EXHIBIT 1

DOCKET NO. DT 10-183

RESPONSE OF NEW ENGLAND CABLE AND TELECOMMUNICATIONS ASSOCIATION, INC., TO THE RURAL INCUMBENT LOCAL EXCHANGE CARRIERS FIRST SET OF DATA REQUESTS

Received on November 5, 2010
Responded to on November 19, 2010
Responding witness: Michael Pelcovits

Request No. RLEC-NECTA 1-1

Please provide a list of NECTA member companies that operate in New Hampshire.

Response

NECTA's New Hampshire members are Charter Communications, Comcast, MetroCast Cablevision, Ski Sat, TDS Cable, Time Warner Cable, and White Mountain Cablevision.

EXHIBIT 2

Exhibit RLEC-NECTA 1-4

ΛB
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U.S. Cable & U.S. Telecom: Getting Down to Business...The Battle for Commercial Services and Wireless Backhaul

Ticker	Rating	CUR	9/7/2010 Closing Price	Target Price	TTM Rel. Perf.	EPS 2009A	EPS 2010E	EPS 2011E	P/E 2009A	P/E 2010E	P/E 2011E	Yield
CMCSA	M	USD	17.80	20.00	1.6%	1.26	1.21	1.40	14.1	14.7	12.7	2.1%
TWC	M	USD	53.93	60.00	37.2%	3.05	3.55	4.68	17.7	15.2	11.5	3.0%
CVC	M	USD	26.26	28.00	29.9%	0.95	1.59	1.77	27.6	16.5	14.8	1.9%
T	M	USD	27.27	25.00	-0.5%	2.12	2.25	2.50	12.9	12.1	10.9	6.2%
VZ	M	USD	30.22	25.00	-1.7%	1.29	1.15	2.13	23.4	26.3	14.2	6.3%
SPX			1091.84			61.70	83.68	96.04	17.7	13.0	11.4	2.0%

O – Outperform, M – Market-Perform, U – Underperform, N – Not Rated

Highlights

The Small and Medium-Sized Business (SMB) and Wireless backhaul markets have long been considered the next, and some would argue last, big growth opportunity for the cable industry. But progress in capitalizing on this opportunity has at times, in our view, seemed painfully slow. Conversely, for the TelCos, SMB has been one of the last bastions of a declining regional TelCo. Margins are high and cord-cutting among SMBs is still a non-issue. We believe, the Cable threat is therefore one that must be taken seriously.

Among all the MSOs, Cox Communications has been – by a huge margin – the standout in the SMB segment, and as such, they provide an invaluable roadmap for other operators (and investors). We recently had the opportunity to meet with Phil Meeks, SVP, and Kristine Faulkner, VP Product Development and Management, the top two executives at Cox Business, a unit of privately held Cox Communications.

- The Small and Medium Business market represents a telecommunications opportunity between $50-70B, equaling the size of the entire residential cable video and broadband market today.

- Among all cable operators, Cox has been the most successful. Cox is the country's third largest cable MSO and was the first to enter the market for business services. Today, Cox Business generates revenues on par with Comcast's and equal to Time Warner Cable's commercial revenues... on a footprint just 20% the size of Comcast's and 35% the size of TWC's.

- Cox's SMB revenues hit $100M in 2000, and were just shy of $1B in 2009, for a nine year CAGR of nearly 30%. Growth for the past two years has been in the mid-teens, and should be better in 2010 as the economy recovers. By their own estimates, Cox has achieved an overall 14% market share of a $7B in-footprint wireline commercial services market opportunity in voice, video, and data (including Enterprise, but excluding wireless backhaul). When considering SMB revenues only, we believe Cox's share is likely closer to 25%.

- In spite of a weak economic backdrop, Comcast and TWC have posted sharp gains in commercial revenues, but are at a much earlier stage of development. Comcast actually managed to *increase* its year over year growth rate to nearly 50% in 2009, seven percentage points higher than in 2008 and twelve times that of its residential business. Time Warner Cable expects growth in 2010 to reaccelerate to a rate in excess of 20%. As of mid-year, it appears to be on track to hit this goal.

See Disclosure Appendix of this report for important disclosures and analyst certifications.

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Investment Conclusion

Our long-held positive view of the Cable stocks rests on their advantaged infrastructure; the SMB market is a logical extension for this infrastructure, and can be expected to sustain growth rates for most of the next decade.

Importantly, we do not believe that SMB is entirely incremental to most investor models, however. Instead, we believe SMB should be viewed as a way for Cable MSOs to prop up growth rates as residential growth rates wane or even turn negative, and that most models are built in such a way that they are indifferent to the segment distinctions between SMB and residential. At Cablevision, for example, growth rates have been sustained long after residential-only models would have suggested a flattening or reversal. This almost certainly owes to success in SMB. Models for other MSOs, including Comcast and TWC, already anticipate this hand-off. Certainly, ours already do.

For the TelCos, we believe the loss of share in the SMB segment would be yet another crippling blow to a Wireline business that is already in secular decline. Wireline represents the majority of both revenues and assets at AT&T and Verizon (adjusted for its 55% ownership of Verizon Wireless).

Our current hesitance in recommending the Cable stocks rests on regulatory uncertainty. We believe investors are underestimating the potential impact of current broadband "reclassification" efforts at the FCC. We rate Comcast, Cablevision, and Time Warner Cable market-perform, with target prices of $20, $28, and $60, respectively.

We rate Verizon and AT&T market -perform with a target price of $25 for each.

Details

The Small and Medium-Sized Business (SMB) market has long been considered the next, and some would argue last, big growth opportunity for the cable industry. The SMB opportunity is an obvious next application for an advantaged infrastructure that has already translated into huge market share gains in residential voice and residential broadband. But progress in capitalizing on this opportunity has at times seemed painfully slow.

Conversely, for the TelCos, SMB has been one of the last bastions of a declining regional TelCo. Margins are high and cord-cutting among SMBs is still a non-issue. The Cable threat is therefore one that must be taken seriously.

The halting progress of the MSOs in serving SMBs has raised as many questions as it has answered. The SMB segment is generally considered underserviced and overcharged by the incumbent telecom providers, making it appear highly susceptible to share shifts. And because the Cable operators already have a high capacity physical plant passing many business locations, the segment appears to offer exceptionally attractive incremental returns. Moreover, Cable offers a better broadband product than TelCo DSL, and it can even be argued that Cable can offer a VoIP service with more sophisticated voice options than POTS, the primary competition. In short, even acknowledging the demanding nature of the segment for network reliability and service levels – the Achilles Heel for many Cable MSOs – Cable would *appear* to be well positioned to break into this market.

But while some operators have had good success – Cablevision comes to mind – for others, the business has fallen short of once high expectations.

Among all the MSOs, Cox Communications has been – by a huge margin – the standout in the SMB segment. We recently had the opportunity to meet with Phil Meeks, SVP, and Kristine Faulkner, VP

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Product Development and Management, the top two executives at Cox Business, a unit of privately held Cox Communications.[1]

Background: The Road to a Billion Dollars... and 25% SMB Market Share

Cox is the country's third largest cable operator and was the first to enter the market for business services. Cox Business has experienced terrific growth, and the company generates revenues that are on par with Comcast's and equal to Time Warner Cable's commercial revenues on a footprint just 20% the size of Comcast's and 35% the size of TWC's (**Exhibit 1**; Cox full year 2009, Comcast and TWC at their Q2 run rates). They serve as a model for what other cable operators can hope to achieve as they focus their efforts on penetrating the commercial space.

Cox Business began offering carrier access in 1993 and broadband by 1997. In 1998 they introduced circuit switched telephone service and between 2005 and 2007 VoIP. Revenues hit $100M in 2000, and were just shy of $1B in 2009, for a nine year CAGR of nearly 30% (**Exhibit 2**). Growth for the past two years has been in the mid-teens, and should be better in 2010 as the economy recovers somewhat (over 40% of Cox's footprint is in particularly hard hit Arizona, Southern California, and Las Vegas). And it has achieved this in a market that, even before the recession, was growing, at best, in the low- to mid-single digit range. Cox has been taking tremendous share from incumbent service providers.

Exhibit 1
Commercial Revenues Relative to Footprint Size (Comcast = 1.0)

Exhibit 2
Cox's Commercial Revenues (Millions)
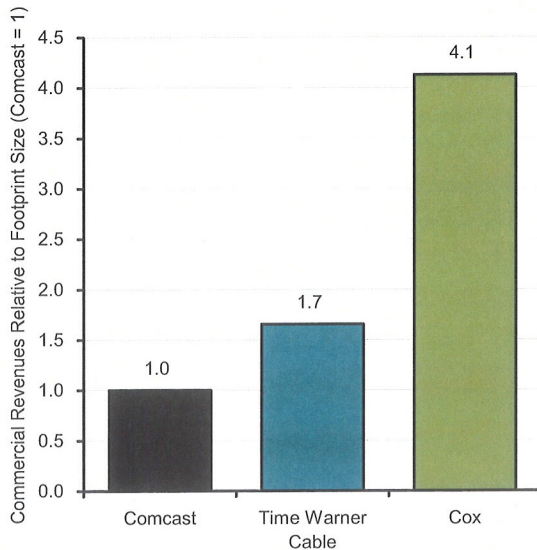
Note: Comcast and TWC are Q2 10 revs annualized, Cox is FY 2009
Source: Company reports, Bernstein estimates and analysis
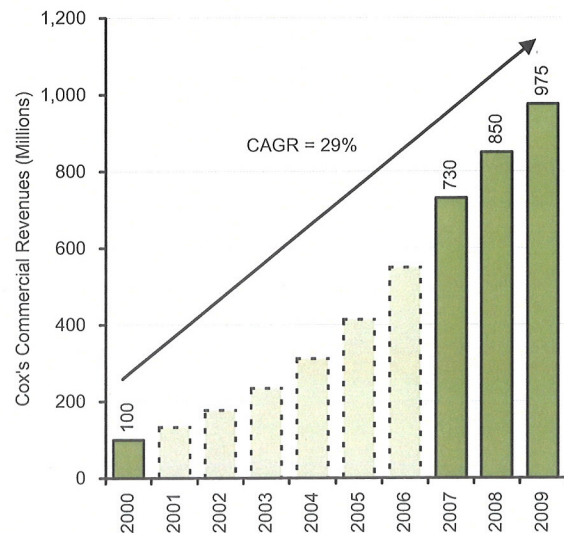
Note: Revenue figures are approximate
Source: Company reports, Bernstein estimates and analysis

To put this into context, Cox believes that the addressable wireline market within its franchise areas is approximately $7.0B – the sum of SMB, Enterprise and wholesale revenues for voice, data, and video, but

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[1] Note that since Cox is private, many of the figures in this piece are either approximate figures disclosed by the company or our estimates.

U.S. Cable & Satellite Broadcasting

excluding cell backhaul. By this metric Cox has achieved an overall 14% market share. When considering SMB revenues only, we believe its share is likely closer to 25%.

Cox's revenue mix is skewed toward smaller businesses and data services, as one would expect. Roughly 60% of revenue comes from small businesses, or those with fewer than 20 employees (**Exhibit 3**). Approximately 30% is generated by larger medium and Enterprise customers. In terms of product mix, almost a third of revenues are from voice services (circuit switched and VoIP) and the balance predominantly from data services, with about half of data revenues from cable modem (non-optical) broadband (**Exhibit 4**). Cox expects voice to account for half of growth between now and 2014, reaching 40% of revenue by that time. The company believes it can sustain mid-teens growth and double its revenues over the next six years by further penetrating the core wireline market, significantly expanding its cell backhaul portfolio, and by growing in adjacent areas like managed services and wireless.

Exhibit 3
Cox Business: Estimated Revenue Mix by Customer
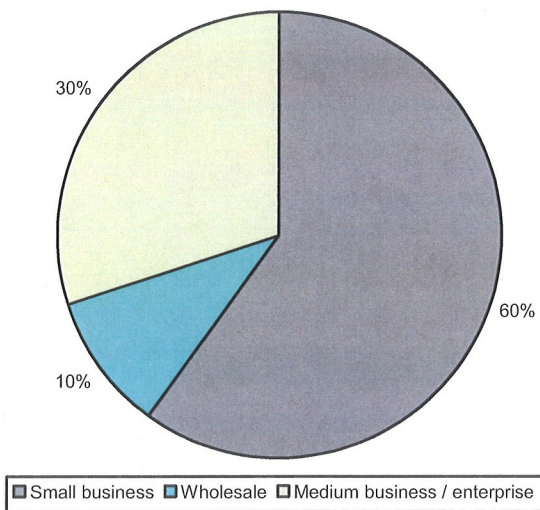
Exhibit 4
Cox Business: Estimated Revenue Mix by Product

Source: Company reports, Bernstein estimates and analysis
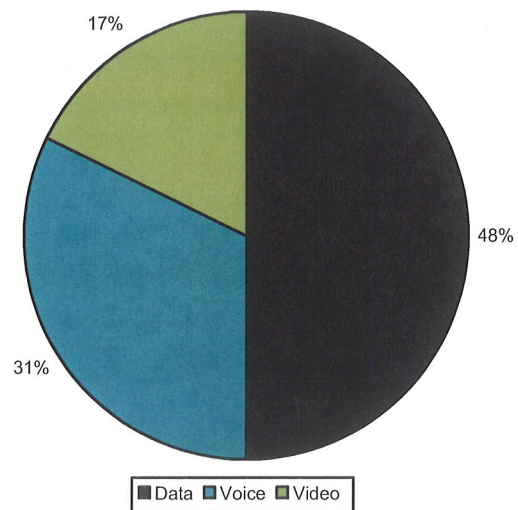
Source: Company reports, Bernstein estimates and analysis

Why SMB?

Small and medium-sized businesses comprise a large share of all U.S. businesses (**Exhibit 5**). The Boston Consulting Group estimates that SMBs spend an amount equal to approximately two thirds what Enterprise-size companies do on telecommunications services. But SMB carries *substantially* higher margins.

Exhibit 5
Number of U.S. Business Enterprises and Establishments
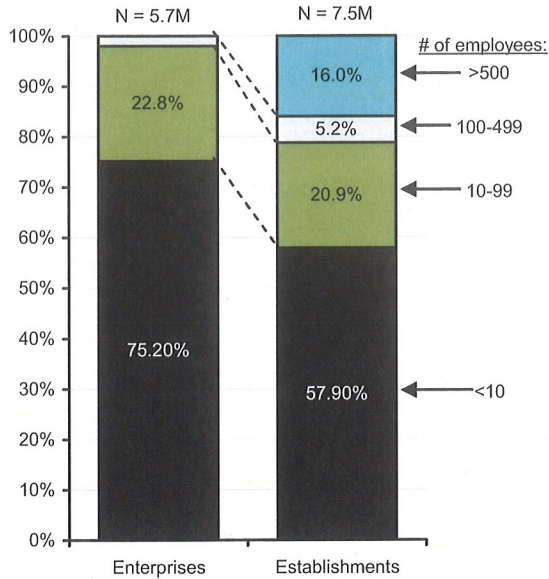

Source: U.S. Census Bureau

In many ways, the market is structurally more attractive than the residential market. Unlike the residential market, for example, the risk of customers going wireless-only is virtually zero. In the residential market, roughly 25% of U.S. households have cut the cord – it is phenomenon we expect to continue and something which will eventually pressure the cable operators' results over time, just as it has the TelCos'. But the idea of a law office, pizza parlor, hospital, or university going wireless-only is still a long ways off. The market for commercial voice services is therefore far more sheltered than residential. Commercial initiatives can help support a Cable MSO's overall voice franchise over time, and the Cable industry's commercial voice penetration rates could actually end up much *higher* than in residential.

The seeds of the profitability of the SMB segment can be found in the TelCos' legacy of rate-of-return regulation. Historically, it never mattered *where* a telephone company made money, only that the return on assets for the *whole company* was in line with regulated levels. At one end of the market, returns in the huge residential segment were held down by regulation (price caps), while at the other end of the market returns in the Enterprise segment were held down by competition. Like squeezing a balloon, when the ends were pressed down, it was the middle that popped up (**Exhibit 6**).

Exhibit 6
TelCo ROIC by Market Segment (Schematic)
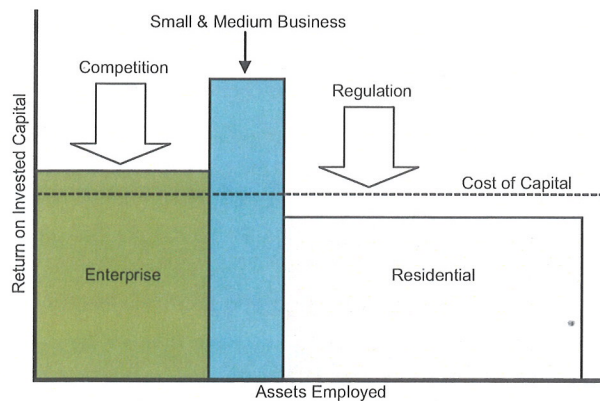
Source: Bernstein analysis

This was largely a principle of regulatory design; it has long been considered a desirable public policy outcome for businesses to subsidize consumers. Prices – often for the exact same services offered to residential customers – were often double, triple, or more what residential customers would pay. Similarly, prices were kept high in cities (where density meant costs were low) in order to keep prices the same for rural customers (where low density meant costs were high).

The T-1 market – a 1.544Mbps symmetrical connection – is illustrative of the TelCos' pricing vulnerability. At a price that is often as high as $400 - $500 per month for a small business, a T-1 connection delivers only a fraction of the downstream speed of a typical residential cable modem connection, but sells for 8-10x the residential monthly price. It is among the most profitable markets in all of telecommunications.

The bulk of the SMB segment's revenues still come from plain vanilla voice services. Here too, prices are far higher than in the residential segment, for what is essentially an identical service.

Of course, the inevitable outcome of such a regime is competitive imbalance. Once a market is deregulated, competitors have a strong incentive to target high return/low investment opportunities, and to ignore low return/high investment opportunities. During the late 1990s, competitive local exchange carriers (CLECs) predictably targeted medium business customers in urban areas. But this endeavor proved unsustainable. The costs of building and supporting a network were simply too high.

The cable operators are unique. They already have facilities that are fully built and economically supported by an existing business (residential video, data, and voice). The *marginal* investment required to compete in the SMB segment is small relative to that of a greenfield build. At the same time, the potential margins are very high, as a consequence of three generations of legacy pricing decisions at the TelCos (and their regulators). Once the Cable MSOs had entered the data services business for consumers, and later the voice business for consumers, it became an obvious next step to target the more lucrative business services market.

Cox's Strategy

Cox was the first MSO to seize upon the commercial services opportunity in a meaningful way. Aside from the high profitability of the SMB market, they also believed that the market was underserved by the incumbent telecom providers. AT&T and Verizon had been focusing on improving share and margins in

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their Enterprise segments as this market has stabilized into what is essentially a duopoly between the two.[2] In the regional business, the focus had been cost reduction, to keep pace with sustained line loss. SMB does not appear to have been a primary area of focus.

This provided an opportunity for Cox to differentiate itself based on product superiority and service quality, historically strong points relative to competitors and peers. Cox has a reputation for good service on the residential side of their business, which helps them attract SMB business since many of these customers are already familiar with Cox (**Exhibit 7**).

Exhibit 7
American Consumer Satisfaction Index Scores, 2009

Cable & Satellite TV		Fixed Line Telephone Service	
DirecTV	71	Cox	74
Cox	66	Qwest	71
Dish Network	64	Verizon	71
Comcast	59	AT&T	71
Time Warner	59	Embarq	68
Charter	51	Comcast	67

Source: American Consumer Satisfaction Index, 2009

Cox's strength in customer service, and customer satisfaction, is a key point of difference relative to other MSOs like Comcast. Small business owners are, after all, members of a local community where a cable operator already carries a well-entrenched reputation, be it for good or poor service. An entrepreneur is unlikely to grant a mission critical commercial services contract to an operator perceived to be unreliable in the residential market. For Cox, this has been a generation-long priority that is unlike any of its cable peers, and Cox has always maintained higher spending on customer satisfaction initiatives than any other cable operator (accepting lower margins in the process). This is perhaps the most significant point of caution for investors to consider as other cable operators attempt to replicate Cox's success.

Like Cox, however, *all* cable operators will claim localism as an advantage. Since cable companies have significant local resources to bring to bear, they believe they can offer better service to SMBs than can the TelCos, which may rely more on centralized call centers. In part because of this customer-oriented focus, Cox Business's churn is low. We believe it to be somewhere in the 1% to 1.5% range (they do not disclose exact figures).

Cox's network, like that of any other cable operator, was originally built to serve residential customers. As such, the company initially targeted the 40% to 60% of the SMB opportunity set that was already connected to their network and most capex was success-based. The company generally waited for a customer win to justify extending the plant to an unserved area. Given their track record, Cox is now being more aggressive in proactively building out its infrastructure to areas like business parks, downtowns, and commercial strips. Within 2 to 4 years of entering an area, Cox believes it can capture a 20-40% share of smaller customers. By modeling what types of businesses are within a prospective area and forecasting market share, Cox can effectively allocate its dedicated growth capex.

As mentioned above, a meaningful portion of Cox Business's revenues come from larger entities. Drilling down further, these customers tend to be in industry verticals whose operations are located entirely *within* one of Cox's franchise areas (**Exhibit 8**). Healthcare (hospitals), education (both local school districts and

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[2] See "*U.S. Telecom: Enterprise Services… Time for a Star Turn?*" March 25, 2008

universities), and government are verticals where Cox has had significant success. Similarly, we have heard that Cox serves approximately two thirds of casinos on the Las Vegas Strip.

Exhibit 8
Cox Franchise Areas and Relative Sizes
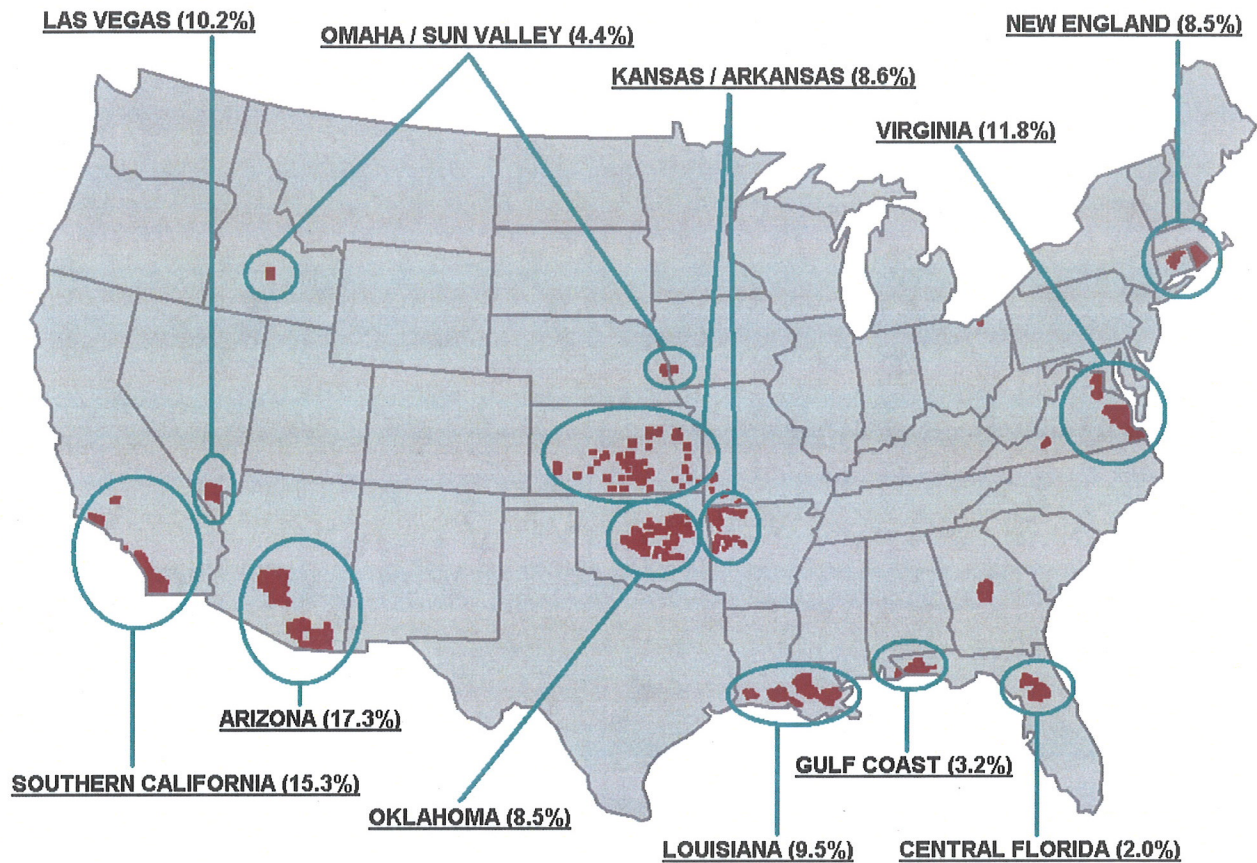
Source: Multichannel News, Bernstein analysis

Localism can be a disadvantage as well, however. The local franchise model naturally limits Cox's ability to offer service to entities with locations both inside and outside their footprint. For example, a California-based company with offices in San Diego (a Cox market) and San Francisco (a Comcast market) would be unable to buy one-stop shopping communications services from Cox. Naturally, this advantages a competitor like AT&T that can. Over time, we expect cable operators to increasingly address this shortcoming by creating SMB "interconnects," along the model of advertising interconnects that operate today (and that allow advertisers and agencies to buy ad time across multiple operators). But the technological hurdles, revenue sharing complexities, and service level agreements common in this segment all make this a significant challenge. We therefore do *not* expect the multi-regional SMB segment to be a significant opportunity for cable for the foreseeable future.

Interestingly, Cox has not needed to be aggressive in terms of pricing to drive its huge share gains. It is difficult to generalize pricing relative to the TelCos because of the large number of service combinations that are possible. Nevertheless, the company tends to charge a premium for broadband based on the quality of the product. AT&T's and Verizon's fiber deployments have been residential in nature, which means that the TelCo broadband offering against which Cox most often competes is legacy DSL.

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On the voice side, Cox tends to price at about a 15% discount. Overall bundled prices for voice and data are therefore roughly comparable with those of the incumbents.

Incremental margins are very attractive. Recall that residential service, which is sold for a fraction of the price of business services, already carries 95% margins for broadband and ~80% for voice, according to trending schedules published by both Comcast and Time Warner Cable. For smaller businesses, the cost of providing service is essentially the same as for a residential customer, but the ARPUs are two to three times greater. Data and voice carry much higher gross margins than video.

Video has proven to be a surprisingly good commercial business as well, with roughly 30% of commercial customers taking video service. Many customers like to put a television in a waiting area (for example, at an auto repair shop) or in their offices. Cox has started to tailor specific video packages to appeal to particular segments to take advantage of this opportunity (as an aside, we believe it is this phenomenon that has helped explain the strong video retention numbers at Cablevision in the face of Verizon FiOS over the past few years).

Cox notes that the TelCos' reaction to their share gains to date has largely been limited to increased marketing. They outspend Cox within their franchise footprints, and increasingly mention Cox by name in their ads. Cox views this almost as a plus, as it is a confirmation of the threat they pose to the TelCos and expands customer awareness that an alternative provider exists. In Cox's opinion, the incumbents are still executing poorly and offer mediocre service, suggesting that effecting change in organizations as large and entrenched as the TelCos is no easy task (turning the proverbial battleship).

How Are the Other MSOs Doing?

All of the other cable operators have identified SMB as their primary growth initiatives.

Comcast, Time Warner Cable, and Cablevision have all sized the total commercial telecommunications markets within their footprints as being roughly the size of their existing cable businesses (based on their own estimates; **Exhibit 9**).[3]

For reasons discussed later, however, we believe the true size of the addressable market is smaller than this.

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[3] Note that disclosures regarding the cable companies' commercial businesses are somewhat limited and not uniform, hence the uneven nature of data available to derive the exhibits and figures in this section of this report. Time Warner Cable reports the most information, followed by Comcast. Cox is private, so all data was either gleaned from interviews with management or represents our estimates. Cablevision occasionally reports snippets of data in its earnings calls, but does not break out SMB/Enterprise as a segment. Cablevision's results are further complicated by the existence of its Optimum Lightpath subsidiary, which serves some, but not all, commercial accounts.

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Exhibit 9
Company Estimates of Size of Commercial Market Within Their Footprints

| Operator	Commercial Segment	Company Estimates of In-Footprint Commercial Market Sizes	2009 Cable Revenues
Comcast	<20 employees	$12B to $15B	
	20 to 250 employees	$10B to $15B	
	Cell backhaul	$1B over time	
	Total	$23B to $31B	$33.9B
Time Warner Cable	1 to 99 employees	$10B	
	100 to 999 employees	$6B to $7B	
	>999 employees	$3B to $4B	
	Total	$20B	$17.9B
Cablevision	Optimum Business	$3.4B	
	Optimum Lightpath	$2.4B	
	Total	$5.8B	$5.4B (a)
Cox Communications	Wireline, ex-cell backhaul	$7B	$8.6B (b)
	Cell backhaul	$0.5B in a couple years	
	Total wireline	$7.5B	
	Wireless	$4B	

(a) Cable plus Lightpath
(b) estimated assuming 5.3M subscribers, a $120 ARPU, and $975M in commercial revenues

Source: Company reports

So far, the impact of commercial services on the industry has been relatively small, with Cox and Cablevision leading the pack by a fairly wide margin. We estimate that approximately 11% of Cox's revenues are from commercial services, compared to 5.9% for Time Warner Cable and just 3.6% for Comcast (**Exhibit 10**). Cablevision is likely somewhere around 10%, including Lightpath.

In practically all areas they have a lot of catching up to do relative to Cox – for example, TWC's revenue per salesperson is roughly two thirds that of Cox (**Exhibit 11**). Over time, however, we believe Comcast and TWC can make progress in closing the performance gap (revenue per salesperson, for example, would be expected to rise over time as the installed base of customers grows relative to the number of new customers acquired).

Exhibit 10
Comcast, Time Warner Cable, Cablevision, and Cox: Portion of Cable Revenues from Commercial Services
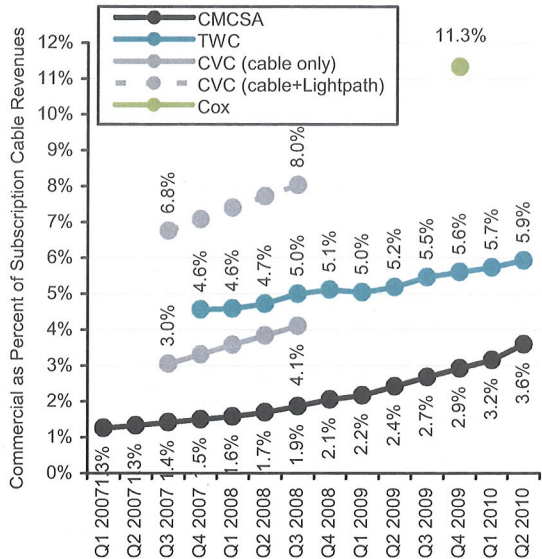
Note: Cox estimated with 5.3M subs, $120 ARPU, ~$1B commercial
Source: Company reports, Bernstein estimates and analysis

Exhibit 11
**Time Warner Cable and Cox: Revenue per Salesperson (Millions)**
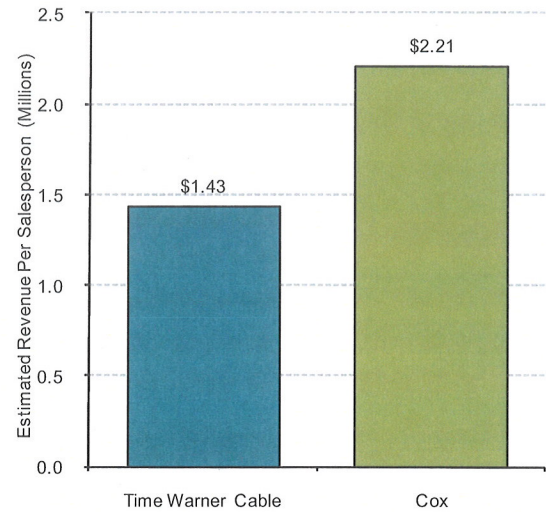
Note: TWC is Q2 10 commercial revenues annualized and assumes company has 750 salespeople, Cox is estimated FY 2009
Source: Company reports, Bernstein estimates and analysis

The relative immaturity of the commercial services businesses at Comcast and Time Warner Cable can be clearly seen in their relatively weak presence in the voice market, still the largest part of the commercial services opportunity. Compared to Cox, Time Warner Cable's business mix is much more heavily skewed towards video and much less towards voice (**Exhibit 12** and **Exhibit 13**). Comcast's business mix is likely very similar to TWC's. Recall from **Exhibit 4** earlier in this report that almost one third of Cox's commercial revenues are from voice services.
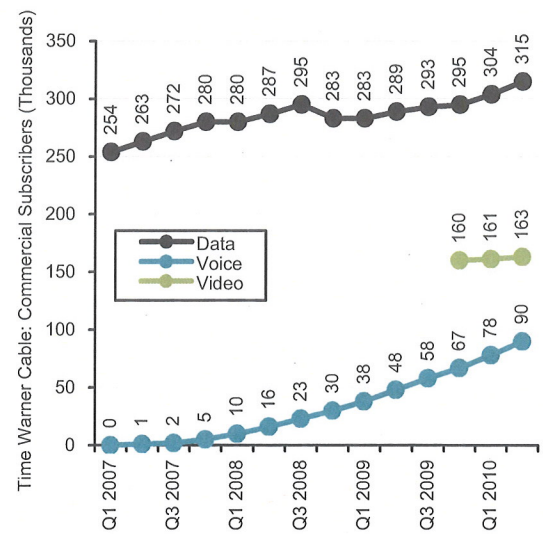
Exhibit 12
Time Warner Cable: Commercial Revenue Mix
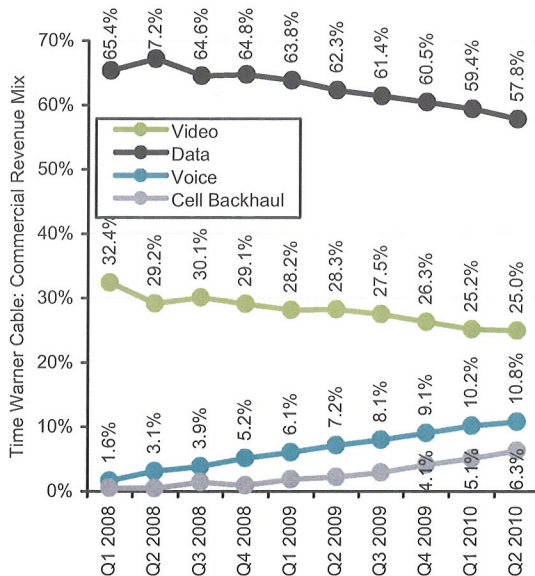
Source: Company reports, Bernstein estimates and analysis

Exhibit 13
Time Warner Cable: Commercial Subscribers by Product

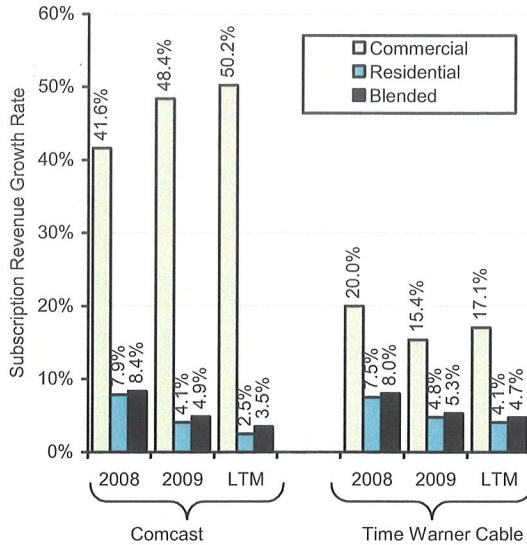Note: Data subscribers include adjustments of -7 in Q1 2008, -15K in Q4 2008, and -3K in Q1 2009
Source: Company reports, Bernstein estimates and analysis

The reason for this difference lies in the fact that TWC and Comcast only started selling voice services to commercial subscribers in 2007 (it was around this time that multi-line VoIP terminals suitable for the SMB market were first introduced). Cox, in contrast, sold circuit switched access leased from incumbent providers for years (although they have since transitioned most of their base to their own VoIP product). Since rolling out the service, however, subscriber gains in voice have been strongest among all categories at TWC, and presumably at Comcast as well (**Exhibit 14**; Comcast's LTM growth modestly inflated by M&A activity).

In spite of a weak economic backdrop, Comcast and TWC have posted sharp gains in commercial revenues. Comcast actually managed to *increase* its year over year growth rate to nearly 50% in 2009, seven percentage points higher than in 2008 and twelve times that of its residential business. Time Warner Cable posted slower growth, partially because of its business being relatively more mature than Comcast's. The company also dealt with some "growing pains" and stumbled with execution, perhaps not to be unexpected in a fast growing, new line of business. By hiring more salespeople and restructuring the organization, it expects growth in 2010 to reaccelerate to a rate in excess of 20%. As of mid-year, it appears to be on track to hit this goal.

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Exhibit 14
Comcast and Time Warner Cable: Commercial, Residential, and Blended Growth Rates

Source: Company reports, Bernstein estimates and analysis

Cablevision does not disclose what portion of its subscriber base is attributable to commercial subscribers, but we can use crumbs of information dropped by management to illustrate just how important the commercial business is to growth. In their Q4 2009 conference call, the company disclosed that they had 2.4M voice lines (lines, not subscribers), a gain of 250K during the year. As of Q4 2009, they had approximately 250K commercial lines in service, and in Q3 2008, they disclosed that each commercial voice subscriber had 2.66 lines on average. Since then, they have indicated that the number of lines per commercial subscriber has increased.

If we assume lines per subscriber are now 3.0, we can use algebra to solve for the mix between commercial and residential voice subscribers. We estimate that 82K of Cablevision's 174K voice subscriber net additions in 2009, or 47%, were commercial subscribers (**Exhibit 15**; assuming 2.75 voice lines per commercial subscriber as of Q4 2009 yields a 106K/68K commercial/residential net adds split, assuming 3.25 yields a 65K/109K split). In contrast, just 37K of TWC's 443K total voice net additions, or 8%, were commercial subscribers. Cablevision's residential voice product is more mature than TWC's and has a far higher penetration rate (38.9% of total homes passed for Cablevision, 15.3% for TWC), so a slower subscriber growth rate is to be expected (5.1% year over year for Cablevision, 10.8% for TWC). But the company also has a far larger number of commercial voice subscribers relative to footprint size – nearly *fifteen times* that of Time Warner Cable.

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Exhibit 15
Cablevision: Estimated Voice Subscriber Mix

	Q3 2008	Q4 2008	Q1 2009	Q2 2009	Q3 2009	Q4 2009
Total voice lines		2,150				2,400
Commercial voice lines		250				522
Lines per commercial voice sub	2.66	2.73	2.80	2.86	2.93	3.00
Commercial voice subs		92				174
Residential voice subs		1,786				1,878
Total voice customers		1,878				2,052

2009 voice net additions:	
Commercial	82
Residential	92
Total	174

Bold = reported or disclosed
Shaded blue = estimated

(thousands, except per subscriber)

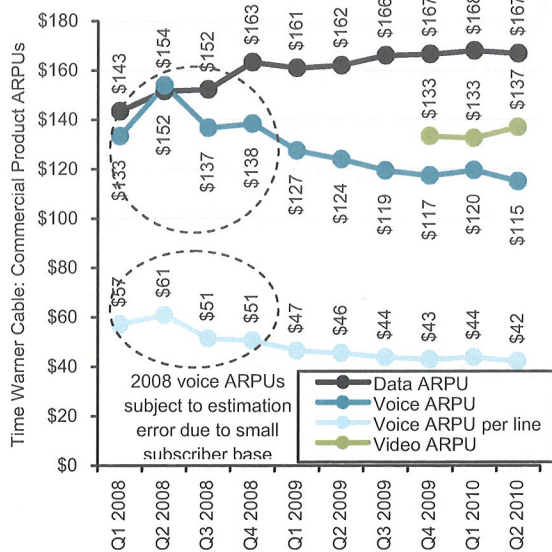Source: Company reports, Bernstein estimates and analysis

Despite being relatively small pieces of their businesses, growth in commercial services has materially boosted the companies' overall growth rates. Time Warner Cable discloses sufficient information to calculate ARPUs by product within their commercial segment (**Exhibit 16**). In Q2, data subscribers carried an ARPU of $167, video an ARPU of $137, and voice an ARPU of $115. The company had approximately 2.7 lines per voice subscriber, with each line carrying an ARPU of about $42. Regardless of the number of lines, however, each account counts as just one subscriber, thus boosting the ARPU.

These commercial product ARPUs are significantly higher than their analogous residential ARPUs (**Exhibit 17**). The contribution from commercial data was sufficient to boost TWC's Q2 overall data ARPU to $42.97, more than $4 higher than it would have been had TWC been a residential-only provider. Commercial voice and video are much smaller than commercial data, so their impacts on blended ARPUs are much lower, but still meaningful. Both blended ARPUs are roughly $1 higher than the residential figures.
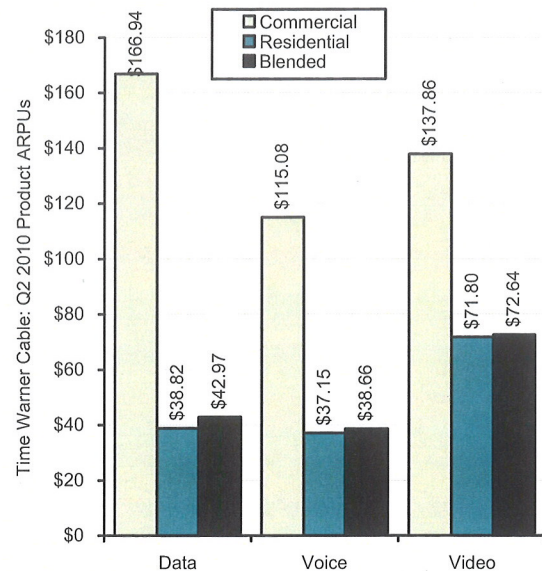
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Exhibit 16
Time Warner Cable: Commercial Product ARPUs

Exhibit 17
Time Warner Cable: Commercial, Residential, and Blended Product ARPUs

Source: Company reports, Bernstein estimates and analysis

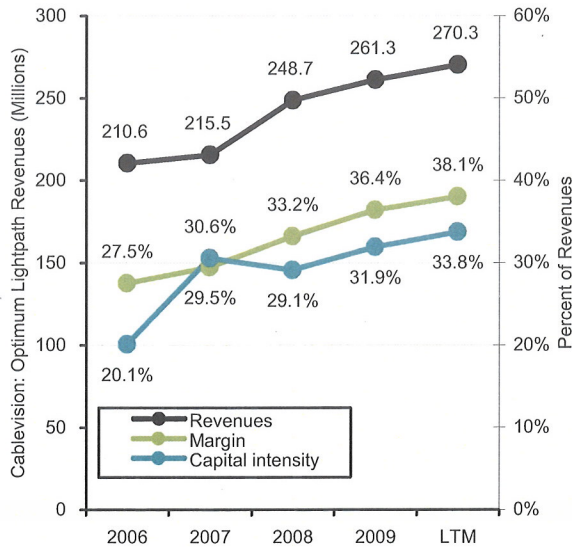Source: Company reports, Bernstein estimates and analysis

Comcast's and TWC's approach to the market has been fairly similar to Cox's in terms of pricing data at a premium to the TelCos and voice at a slight discount.

Cablevision, as is often the case, marches to the beat of its own drummer. Cablevision COO Tom Rutledge has said that they "*are a market share oriented company*", a strategy which we believe makes sense given the high fixed cost / low variable cost nature of the business. In contrast, TWC CFO Rob Marcus has said that they "*lean towards profitability over share gains.*"

Both approaches have their merits, but Cablevision's make it an especially fearsome competitor for the incumbent TelCos, inasmuch as it tends to depress prevailing prices in addition to taking market share (and it tends to take market share at a faster rate, provided the operator has sufficient resources to handle in influx of customers). Cablevision tends to price its SMB services at levels similar to residential. For commercial voice, it gets roughly $30 per line, about the same as residential and a $10 discount to TWC. Overall, it claims to be priced at a 50% discount to the incumbents in the SMB space, and boasts that the market within its footprint would shrink to half its current size if it had 100% share.

Cablevision discloses a fair amount of information regarding Optimum Lightpath, the all-optical CLEC it uses to compete at the high end of the commercial services market in the New York Metro area. Lightpath's growth rate slowed in 2009, which was largely attributable to declines in traditional data services as it migrates to an all-Ethernet strategy, as well as reduced intercompany revenues from Optimum Voice (Cablevision realigned its service model around its infrastructure; small businesses that could be served with the hybrid fiber coax network of the core cable business were moved from Lightpath to the cable group, leaving Lightpath to focus on customers for whom fiber is required). Margins have improved, but capital intensity has risen as well (**Exhibit 18**). While the number of buildings Lightpath has connected to its network has steadily increased at a rate of about 600 per year, revenue per building has steadily fallen (**Exhibit 19**). Management sizes Lighpath's market at $2.3B in total, but $1.7B at its pricing, suggesting a 25% discount to competitors.

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Exhibit 18
Cablevision: Optimum Lightpath Revenue, EBITDA Margin, and Capital Intensity

Source: Company reports, Bernstein estimates and analysis

Exhibit 19
Cablevision: Optimum Lightpath Buildings On-Net and Revenue per Building
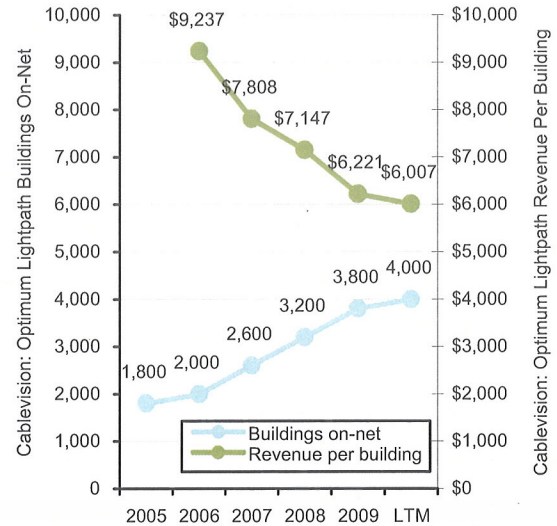
Source: Company reports, Bernstein estimates and analysis

Cell Backhaul

A massive increase in the use of wireless data has left wireless carriers rushing to improve backhaul connections to better serve smartphone subscribers and prepare for 4G, making cell backhaul a hot growth area for the commercial services units of the MSOs.[4] The fiber-rich cores of Cable's networks are well-suited to provide such services. Moreover, while the regional wireline segments of AT&T and Verizon compete directly with the cable operators, their national wireless operations compete directly with *each other,* and are much more likely to view a cable company as being a somewhat neutral party when seeking improved backhaul out of region. For example, if AT&T Mobility were looking for fiber backhaul to a site in Philadelphia, its primary wired options would be Verizon or Comcast (and perhaps an independent provider). Pick your poison.

Hard data regarding the opportunity is somewhat limited. Time Warner Cable's cell backhaul revenues in Q2 were 3.5 times greater than a year ago, but still totaled just $17M. The company had 4,600 towers in service in Q2 compared to 2,000 a year earlier, and was contracted to add another 1,200. Comcast sizes its backhaul opportunity at $1B "over time." Cox has signed contracts with a value of over $100M over the last year (average term of 5 to 7 years), and expects half of its wholesale revenues (presently ~$100M per year) to be cell backhaul in the near future. Revenue per tower at TWC works out to be about $1,200 per month, a figure which Cox indicates is in the right ballpark for them as well.

Based on estimates from The Boston Consulting Group, we believe the overall market for cell backhaul is set to grow at a mid-20% rate over the next two years (**Exhibit 20**). The fiber backhaul sub-segment, that

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[4] See "*U.S. Telecommunications and Global Telecom Equipment: The Wireless Data Exaflood*", June 14, 2010

which is relevant for the cable operators, could grow in excess of 40% over the same timeframe, reaching $2.6B in 2011.

BCG estimates that there were approximately 208K cell sites in the U.S. as of 2007, reaching 234K by the end of 2009 and growing to 264K by 2011. The mix of cell sites is shifting away from low traffic 2G sites and towards higher traffic 3G and 4G sites (**Exhibit 21**; note that this mix analysis excludes Clearwire, which is expected to do the bulk of its backhaul via microwave). And since 3G and 4G sites carry far more traffic, their share of total traffic is increasing even faster than their share of total cell sites (**Exhibit 22**). For example, BCG estimates that in 2011 the average 2G site will be served by 2.4 T-1s, compared to 7.0 for a light traffic 3G site, 14.0 for a heavy traffic 3G site, and 16.0 for a 4G site.

The growth in cell sites and the mix change towards higher volume sites is driving rapid growth in the number of T-1 equivalents needed to serve them (**Exhibit 23**). Even after assuming that the price per T-1 equivalent falls meaningfully one gets to 20% plus growth for the segment as a whole, with higher growth for the those economically served by fiber.

Exhibit 20
Estimated Cell Backhaul Market Size
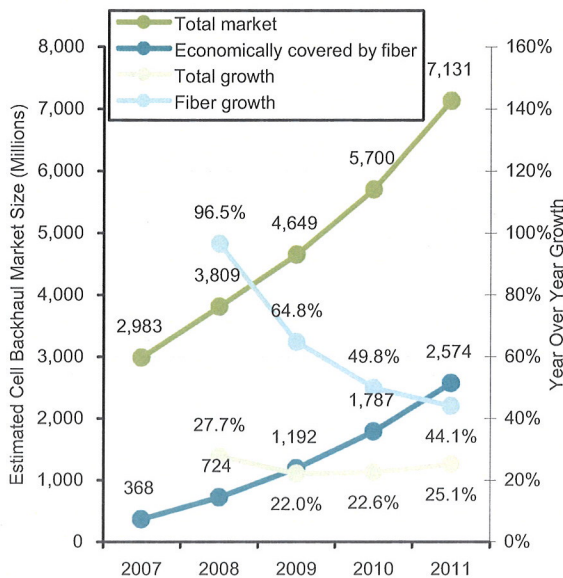
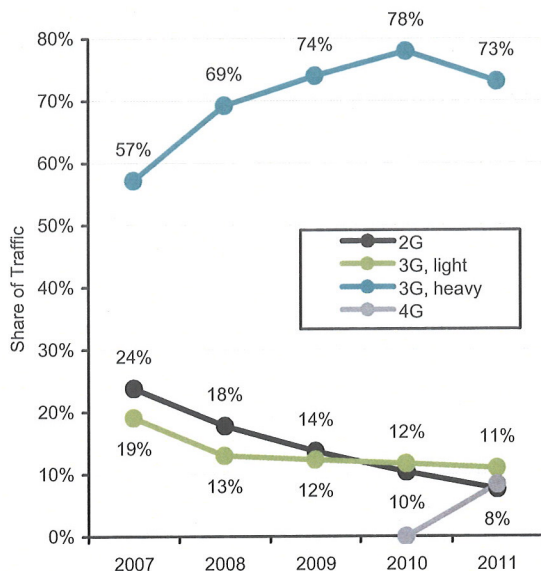Source: Boston Consulting Group, Bernstein analysis

Exhibit 21
Estimated Share of Cell Sites by Site Type
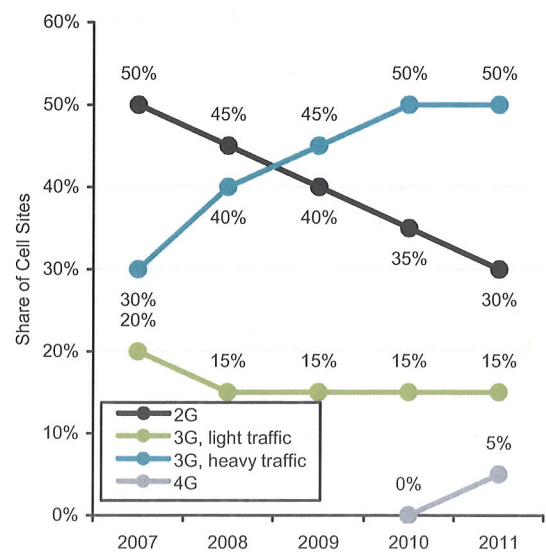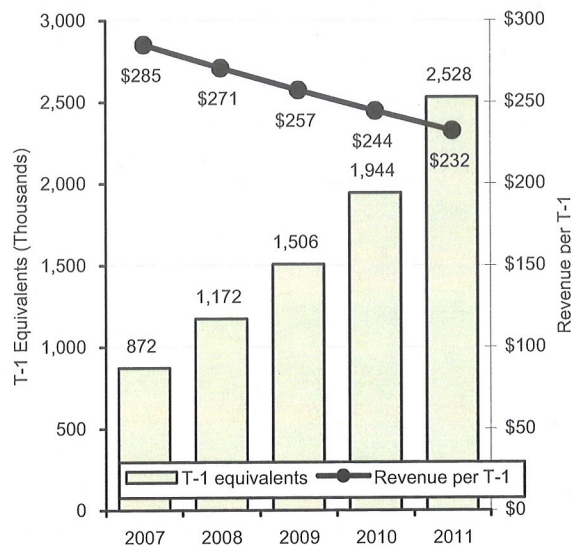

Source: Boston Consulting Group, Bernstein analysis

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Exhibit 22
Estimated Share of Traffic by Cell Site Type

Source: Boston Consulting Group, Bernstein analysis

Exhibit 23
Estimated T-1 Equivalents and Revenue per T-1

Source: Boston Consulting Group, Bernstein analysis

If we assume that the MSOs have to price at a 25% discount relative to the ILECs, by virtue of their lack of a long track record and because adding a competitor to a market lowers the price, and that the cell backhaul market size is directly proportional to their overall footprint size (**Exhibit 24**), then Comcast's $1B "over time" market size estimate seems perfectly reasonable (**Exhibit 25**). Indeed, since backhaul upgrades are more likely to take place in urban and suburban areas than rural areas, and these operators' footprints are skewed towards urban and suburban, it is likely that their overall market opportunities are somewhat larger then even these estimates would suggest. However, if they are smart about capital allocation, they will limit themselves to only considering towers that are close to their existing infrastructures. This would reduce the portion of the market that is truly available to them.

Interestingly, Cox says that it does not price at a discount for backhaul deals. Instead, they argue that they compete on the basis of responding to a carrier's request quickly, executing efficiently, and properly supporting the infrastructure after it is in place. They believe they have built credibility in the market, obviating the need to cut price as the basis for competition. This suggests that the market available to the cable operators may be larger than these estimates.

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Exhibit 24
Major Cable Operator Footprint Sizes

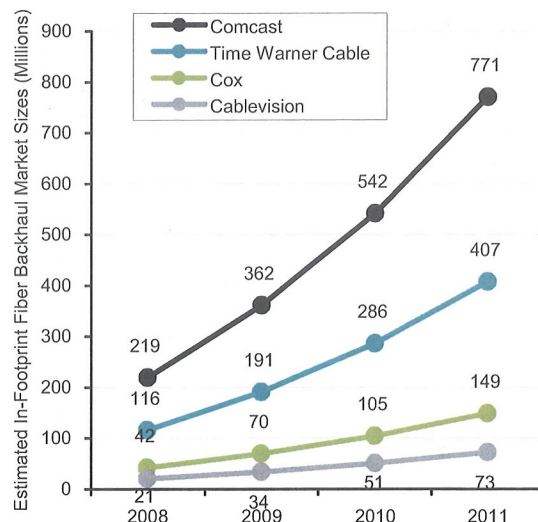|	Homes passed	Share
Comcast	51,547	40.4%
Time Warner Cable	27,253	21.4%
Cox (a)	9,960	7.8%
Cablevision	4,853	3.8%
Other	33,887	26.6%
Industry total (b)	127,500	

(a) 2005 total, less divested systems, grown at 1.5%
(b) per NCTA

(thousands)

Source: Company reports, Bernstein estimates and analysis

Exhibit 25
Estimated In-Footprint Fiber Backhaul Market Sizes

Note: assumes a 25% pricing discount by cable operators

Source: Boston Consulting Group, Bernstein estimates and analysis

Commercial Services Capital Intensity

Capital intensity levels for the commercial segments have been greater than for the residential businesses, although current levels are overstated due to the start-up nature of the business. For both Comcast and TWC, commercial capex as a percent of commercial revenue over the last 12 months was in the 40% range (**Exhibit 26**). In contrast, capital intensity for the residential businesses was 13.1% at Comcast and 15.7% at TWC. Commercial capex was sufficient to meaningfully raise overall capital intensity at both.

Exhibit 26
Comcast and Time Warner Cable: Commercial, Residential, and Blended Capital Intensities
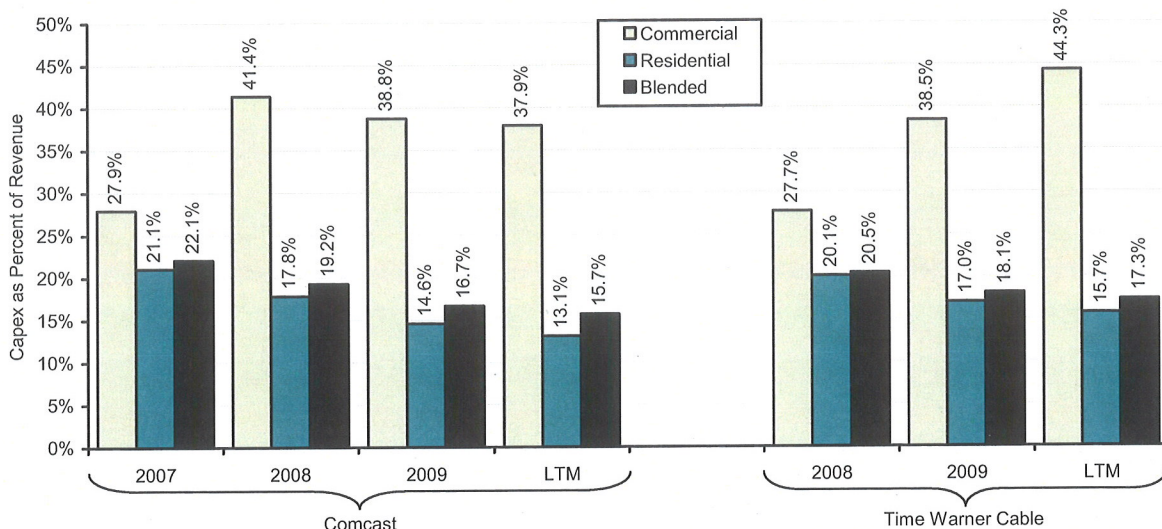
Note: Comcast capex includes additions to intangibles
Source: Company reports, Bernstein estimates and analysis

At first, the high current capital intensity of the business is somewhat surprising. After all, the whole idea behind entering the commercial services space is to leverage existing infrastructure, thus minimizing the required capex and improving total ROIC. The relatively high level of observed capital intensity can be explained by a number of factors.

First is the cost to deploy significant amounts of new equipment to the edge of the network. New customers signing up for voice service need VoIP terminals, data customers need modems, etc. Moreover, this figure would also include labor costs associated with the installation, essentially all of which is capitalized since it represents the first such installation at the vast majority of locations.

Second is the cost of installing the coax or fiber to connect the customer location to the actual network. Because the cable network was constructed to serve residential customers, it passed close to, but was not actually connected to, many of the small and medium sized businesses they are currently targeting. As a result, many installations require a line extension to reach the premises. In early 2008, TWC indicated that 35% of its total line extension capex was to serve commercial customers. Assuming a 1.25% commercial churn rate, this suggests line extension capex of roughly $2,000 per commercial gross addition, but this can vary widely by market (aerial vs. buried plant, zoning restrictions, etc.). Cox generally considers customers within 200 feet of a tap point on their network to be serviceable, and has automated the process of making that determination to reduce truck rolls.

Third are the costs of serving the upper end of the target market – enterprise-type customers and cell sites. These typically require extensions to connect to the fiber portion of the HFC network, and the upfront costs can be significant.

Fourth, the residential network typically requires incremental capacity in order to serve the high speed data needs of the commercial market. A residential cable network is generally engineered to a 750MHz specification, meaning that the services it provides to residences operate between the frequencies of zero and 750 MHz, and the amplifiers along the network's route pass (and amplify) signals between zero and 750

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MHz. But all of the capacity in the residential market is spoken for with a mix of cable channels, video on demand, and broadband. Providing T-1 equivalent or faster services to businesses therefore requires *additional* capacity, generally meaning that it has to operate at higher frequencies than 750 MHz. A 1GHz upgrade, for example, adds 250 MHz of capacity (between 750 MHz and 1 GHz), or an additional 33% incremental capacity over and above what is offered to residential customers. Using higher frequencies means new amplifiers. This kind of upgrade can be highly targeted – it need only be implemented along specific routes where there are business customers needing the capacity – and it is therefore relatively inexpensive. And, unlike the system-wide upgrades of the late 1990s, it does not require new set top boxes or any other changes in the residential plant, since the new frequencies are not used for residential services. But it does mean that upgrades are required *ahead* of incremental revenues, making the first commercial customers more costly to serve than later ones (and thereby inflating capital intensity in the early stages of deployment).

Returns on the capital being invested should prove to be attractive. For example, Cox pegs the targeted ROI on cell backhaul deals in the high teens. Indeed, it would be impossible to post these growth rates without deploying significant sums of capital (a company's reinvestment rate being a key determinant of its growth rate). All of the operators perform a return on investment analysis before extending a line to an unserved location. Historically, a new customer would need to generate incremental profits sufficient to justify the investment on a standalone basis. With more experience and capabilities in the segment, the companies are beginning to use a risk-based approach to consider what additional business they could leverage from line extensions (for example, other stores in a strip mall) and factoring that into their analyses. When pulling fiber to a cell site, Cox considers not only the initial contract with the service provider, but also other tenants at the location, whether the new fiber rings can be used to attract nearby offices as new fiber-based customers, and if they can leverage the backhaul connection for their own nascent wireless service. The national wireless companies are subsidizing a direct competitor in Cox Wireless and, depending on the territory, may be subsidizing a direct competitor in the wireline space as well.

This is capex that hurts in a good way. Relative to a greenfield build, the capital requirements are far, far lower. Capex as a percent of revenues for Verizon's FiOS project, for example, was probably about 75% in 2009, and well in excess of 100% in years prior (admittedly a flawed metric for a new service). Commercial capex for the cable operators doesn't approach these levels, and the risk profile is far lower.

As the businesses mature, capital intensity should fall (just like on the residential side). In essence, the industry has been able to effectively redeploy some of the free cash flow being generated by their residential businesses into their commercial services ventures. The two segments are at different points in the long-term capex cycle.

Past Challenges

One does not build up a billion dollar business from scratch without experiencing some bumps along the way. Cox fingered building an effective sales force and adopting a business focus as two of their initial challenges.

Selling SMB services is much different than selling residential services. A direct sales force is required to identify prospects, pitch a relatively sophisticated suite of products, and close the sale. Cox necessarily hired a large number of people from outside of the organization to meet its staffing needs. It takes about four to six months for a salesperson to ramp to full productivity, with it being more difficult to achieve proficiency in selling voice as opposed to data. We suspect that in the bumpier initial years this maturation curve may have been even longer.

Cox now organizes its salesforce into four groups. Inside sales representatives typically take incoming calls from potential customers that have responded to Cox's advertising. Success is usually achieved on the first call, since these customers are a self-selected group of businesses that are interested in taking Cox's service. This is the largest channel for acquiring customers. Outside salespeople are split into three groups. The first engages in door to door type sales and cold calls. The second are classic account managers charged with retaining particular customers and growing the account. The third are wholesale representatives that sell to carriers. Outside salespeople may take three contacts with a prospect to successfully make a sale. Cox is taking steps to streamline processes so that outside sales representatives can spend more time selling and less time on administrative function, boosting their productivity.

At present, virtually all sales are direct sales, as opposed to through an agent. Over time, Cox believes it would be more balanced to have outside agents, such as IT consultants, sell their services as well. Time Warner Cable has moved down this path. However, the company needs to have the necessary systems in place to be able to support such a sales channel.

Historically, sales incentives were based on volume, but are moving towards a quota system. Cox is also focusing on upselling to existing customers, since half of customers are data-only and their churn is low. Incentives are provided to sell to new customers, but salespeople are benchmarked against overall sell-in rates within their market as so not to lose focus on upselling.

Changing the company culture to understand the needs of business rather than just residential was another major challenge. If a residential customer's television service goes out for some reason, it is not really a big deal in the grand scheme of things so long as it is repaired within a reasonable time frame. Conversely, a business that loses phone service mid-day faces a major problem if it is not immediately restored. Even within an organization like Cox, which might be relatively small and nimble compared to an RBOC, changing a long-held mindset regarding what defines adequate service takes time. The firm has moved in that direction; for example, many business customers actually have their service technician's cell phone number, which is unique in this marketplace.

Other cable operators are at various points in the ramp up of their sales forces. Comcast had 1,000 salespeople two years ago and that number has likely doubled since then, and Time Warner Cable has over 700.

Future Opportunities

Moving up-market will be key to sustaining growth, but comes with its own set of challenges. Addressing the next big customer opportunity, mid-sized businesses (those with 20 to 100 employees), and fully embracing and maximizing the potential of their suite of products are two of the new hurdles Cox faces. 80% of Cox's 250K customers have fewer than 20 employees, and half of its customers take only one service, most often broadband.

With its Hybrid Fiber Coax (HFC) infrastructure, Cox is easily able to address the needs of smaller business with products like a cable modem, and larger entities with optical Internet. Serving the middle ground has been a bit trickier. The challenge for Cox has been using the HFC plant to be able to offer PRI, T-1, Ethernet, and committed information rates to these clients, since the shared nature of cable broadband means performance can vary based on the number of users online at a given time. In terms of broadband, most of these customers are looking for sub-10Mb/s symmetrical data rates, which is not impossible to offer using coax. As technologies like DOCSIS 3.0 are rolled out, meeting the needs of these customers will be facilitated. Cox plans to offer DOCSIS 3.0 services to over two thirds of its footprint by the end of 2010.

Cox's strengths to date have been broadband, optical Internet, and phone – in other words, transport products. Cox believes the trend going forward will be towards convergence, for example voice as an

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application and managed services. Changes enabled by VoIP (unified messaging, click to dial, locating/forwarding features) mean customers can rethink how they can more effectively utilize voice service. This also differentiates their service from POTS offered by the incumbents. Current TDM customers are evolving to VoIP, and Cox already has a SIP platform in place. To successfully make this transition changes will also have to be made in how the sales force is incentivized, namely by focusing on product *components*. This is also part of getting the sales force to upsell voice services to existing data customers. According to Cox, the TelCos are making significant strides in offering converged and managed services to their Enterprise customers, but are not yet successfully executing in the SMB space. Cox has started pushing managed services, such as a data backup service, to foster growth in this area. SMBs typically lack an in-house IT expert, so by demystifying the technology and designing it to appeal to its customer base the company believes it can grow significantly in this area.

Whither Wireless?

There remains little evidence of synergy in bundled wireless and wireline service offerings in the residential market. But the business market is different. Wireless is much more likely to be integrated into a wired service offering, giving a significant advantage to AT&T and Verizon. Cox is unique among the cable operators in that it is building its own cellular network. The company intends to leverage this infrastructure to offer wireless services to the SMB market. It sizes the market for wireless service to all businesses within its franchise areas at about $4B. Cox's edge in wireline is a product of a built-out, advantaged infrastructure and customer service focus. While we would argue that these advantages do not necessarily translate over to wireless as they have in wireline, Cox argues otherwise. They believe SMBs are even more poorly served in wireless than they are in wireline, with lower satisfaction rates. For example, unlimited nights and weekends features have essentially no utility for a businessperson that talks almost exclusively during the day. By crafting products that are specifically designed with SMBs in mind, Cox believes they can successfully sell more services into their base, boost ARPU, improve customer satisfaction, and reduce churn.

If Cox's facilities-based wireless strategy works, it could still provide a template for Comcast and Time Warner Cable to use with their Clearwire reseller strategy. The companies would have leeway to create plans with alternative product characteristics that appeal to SMB customers, without any legacy constraints the major incumbent providers may have.

Can Cox's Success be Replicated?

An important question to consider is whether Cox is an outlier in the group, or if other players can emulate what they have accomplished over time.

Comcast, TWC, and Cablevision do have certain advantages over Cox, namely that they have been able to offer a digital phone product throughout their entire footprint right out of the gate. This provides a huge advantage over being able to offer just data or relying on leased circuit switched access. Multi-line VoIP terminals now exist that were in part responsible for thwarting their entries to date.

Comcast's and TWC's larger footprints mean that the absolute size of the SMB opportunities available to each is proportionately larger than Cox's (with larger footprints the number of regional or national customers located *entirely* within their franchise areas is likely more than proportionately greater). Similarly, TWC's significant degree of clustering, Comcast's sheer size, and Cablevision's concentration in one market expands the opportunity set of serviceable customers.

Finally, being able to follow Cox's winning gameplan is certainly helpful. In the case of Comcast, they actually hired William Stemper to lead their commercial services effort in 2006. Stemper had headed Cox Business up until that point.

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But they also possess certain disadvantages. Perhaps at the forefront is their reputation for poor customer service. Whereas Cox was able to leverage its relatively good reputation to attract residential customers to their SMB offerings, the other MSOs have likely tainted a large chunk of their potential SMB customers. This disadvantage is real, and may require that they offer more attractive pricing relative to the incumbent providers to make an equivalent impact. It also suggests that instituting the necessary cultural changes Cox spoke of could be that much more difficult, making it tougher to retain customers. Fortunately for the MSOs, the TelCos have yet to make meaningful strides in improving their SMB customer service (according to Cox), so the relative hurdle to cross may be low. But as Cable makes further inroads there will likely be a point where TelCo management's attention is sharpened and they better adapt to the evolving competitive landscape.

Additionally, as each of the major TelCos overlaps with Cox in some portion of their footprints, they can use what they have learned from their experiences with Cox to better compete with the newer entrants. Comcast and TWC can expect to face a more knowledgeable and sophisticated set of competitors than did Cox when it first started to break into this market.

Despite these factors, there is every reason to believe that Comcast, TWC, and Cablevision can continue to gain significant share in the SMB market. Their relative cost advantage, diverse product portfolio, and determination to crack this market are evidence of this, as are recent results. They are all clearly gaining traction.

We expect the MSOs, especially Comcast given their relative late entry, to initially focus the bulk of their efforts on the 20 employee and under category. This makes sense because a large portion of these potential customers are very close to or already connected to the existing physical plant, minimizing capital outlays and generating attractive ROICs. As Cox said, pitching data services to this group is a relatively easy sale since the primary competition is DSL and the cable modem product is much faster. The current challenges Cox faces in addressing the 20 to 100 employee category will likely carry over to the other MSOs, meaning gaining share in this segment might be a bit slower.

Players like Comcast and Time Warner Cable may view targeted acquisitions as a way to catch up. Comcast has acquired CIMCO, a small Chicago-area CLEC, for example. By purchasing CIMCO, Comcast gains a small number of accounts (about 2,300 has been reported in the press), but more importantly marketing and customer service know-how, as well as systems and processes for serving the market. TWC CFO Rob Marcus recently said that their "*primary focus right now in growing [their] commercial business is really on doing it organically*", but said that hypothetically they could "*acquire additional customers through an acquisition*" or "*acquire some expertise on the sales and customer care side*".

Acquisitions are problematic in a number of ways, however, especially when dealing with CLECs. First is their focus on mid-size and larger customers, as opposed to the bread and butter small businesses that are the core of the cable companies' opportunities in this segment. Second is the difficulty in finding one with an area of operations that overlaps with or complements the acquirer's franchise areas. Given the size of its footprint (41% of industry homes passed), Comcast would be least limited by this factor. Third is the fact that CLECs generally don't control the last mile connection to the customer, while owning the wire is a major reason why the SMB opportunity is so attractive for the incumbent MSOs (over time service may be transitioned to the cable plant). And fourth, the Communications Act prohibits cable companies from owning more than 10% of any local exchange company that provides service within their franchise areas. The FCC granted a waiver in the case of the CIMCO acquisition, enabling Comcast to close the deal.[5] If it

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[5] A waiver for section 652(b) of the Communications Act requires that the FCC deem such a transaction in the public interest, and no local franchising authority objects. Comcast argued that the companies served different markets, so the public would not be harmed. Regarding the second condition, CIMCO provided service in 298 local service areas

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chooses to apply relatively lenient standards to future deals, this regulatory roadblock would obviously be less of a hurdle to completing other CLEC deals.

How the TelCos Can Defend Themselves

Neither AT&T nor Verizon disclose what their SMB revenues are. AT&T came closest in its old wireline reporting format, used through the end of 2008, which included a value for "business in-region". Business in-region accounted for 18.3% of AT&T's wireline revenues in 2008. Beginning in 2009, AT&T rearranged its reported categories and started reporting "small business and alternate channels" (SBAC), which deducted government, education, and medical revenues (GEM) from business in-region, but added certain smaller categories. SBAC was 13.5% of AT&T's LTM wireline revenues. GEM is an area where Cox and Cablevision have been quite successful. We estimate that about 20% of the TelCos' wireline revenues are SMB, which would put AT&T's trailing SMB revenues at $13.1B, and Verizon's at $8.3B (**Exhibit 27**; Verizon ex-Frontier spin properties).

Historically SMB was among the best performing sub-segments within wireline (**Exhibit 28**). Revenue growth for business in-region at AT&T was as high as 6.8% in late 2006. Performance through the recession has been very weak, as one would expect, with SBAC revenues shrinking -4.4% in Q2.

Exhibit 27
AT&T and Verizon: Estimated SMB Revenues (Billions)
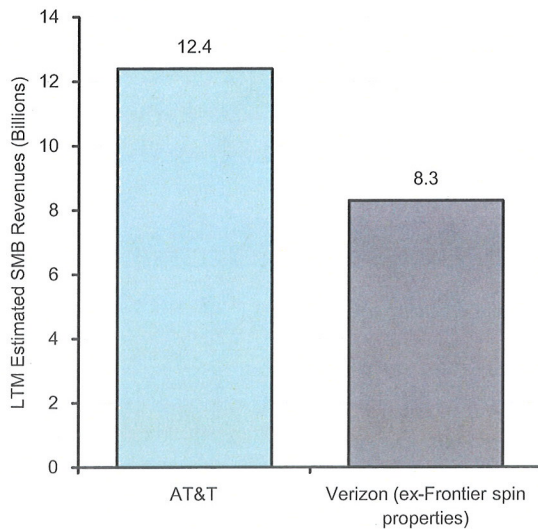
Source: Company reports, Bernstein estimates and analysis

Exhibit 28
AT&T: Small Business Revenue Growth
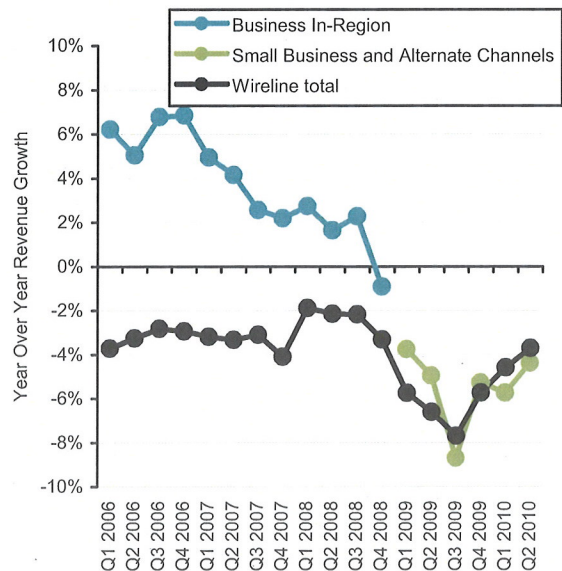
Source: Company reports, Bernstein estimates and analysis

Additionally, SMB has been an important driver of TelCo broadband subscriptions. AT&T discloses sufficient information to break out commercial broadband subscribers from residential. At the end of Q2, AT&T had just over 2M commercial broadband subs, or 12.7% of their base (**Exhibit 29**). Commercial

where Comcast has franchises to sell cable video service. Rather than actively seek approval from each franchise area, the FCC set up a process by which each was informed that they had 60 days to oppose the deal, and easier way to fulfill the second criteria. Only Detroit objected, so CIMCO will not be able to continue offering services in the Motor City.

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broadband subs declined -3.2% year over year in Q2, in part attributable to the weak economy, but also attributable to cable broadband taking share. During the same timeframe, for example, TWC grew its commercial broadband base 9.0%. The trends for Verizon are likely similar, or perhaps even worse, due to its significant overlap with hyper-aggressive Cablevision (we estimate that about 13% of Verizon's pre-Frontier spin footprint overlapped with Cablevision, or 15% post-spin).

Exhibit 29
AT&T and Time Warner Cable: Commercial Broadband Growth Rates and Subscribers (AT&T)
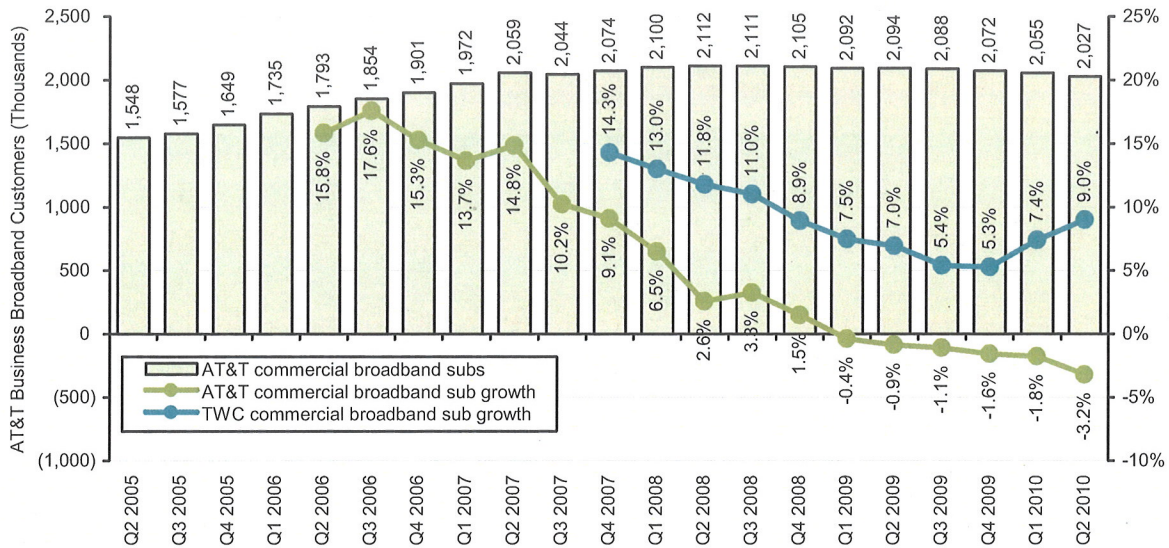
Source: Company reports, Bernstein estimates and analysis

While it's impossible to dimension exactly what the impact of Cable's commercial services initiatives may be on the TelCos, we can at least dimension the risk. Assume that over the next several years Cable takes 15% of the TelCos' SMB revenues, and that the SMB market does not grow. Also assume that the incremental margin on those services is 50%. That would represent a revenue impact of $1.9B for AT&T and $1.2B for Verizon, and EBITDA hits of $0.9B and $0.6B, respectively. Were the market to simply assign a multiple of 5.0x to that lost EBITDA, the value destruction over time for AT&T would amount to $0.80 per share, and for Verizon $1.10 per share.

In anticipation of the threat, AT&T has indicated that they have started to price down in selected markets, and are moving as many customers to longer term contracts as possible. Cox indicates that Verizon is generally more aggressive in pricing than is AT&T. And TWC has stated that the TelCos are offering customers discounts of 15% to 40% in exchange for entering into long-term contracts. Nevertheless, defending the SMB segment for the TelCos will be challenging, since dramatically reducing prices to limit exposure really isn't an option – repricing the entire customer base may do more harm than good. AT&T has indicated that they can be quite granular in anticipating which customers will be targeted based on cable marketing patterns. But all too often, the TelCos find out about cable's competitive offers only *after* a customer calls to announce that they have already switched. By that point, many have signed contracts that make winback difficult or impossible, at least for a number of years.

There are certain important factors working in the TelCos' favor in defending the SMB market, however. The growing mission-criticality of data services for businesses of all stripes puts a premium on the TelCos' advantaged network reliability (whether real or perceived) and Quality of Service (QoS) guarantees, and

their ability to bundle wireless. Similarly, SMBs that are particularly reliant on voice communications may be reluctant to change providers to save a few dollars a month. For example, from the perspective of a pizza parlor owner with a lot of take-out business, that old landline has been a reliable cash generator for years. Would moderate discounts be sufficient to get them to switch?

Over time, the TelCos may also benefit from the growing complexity of managed services. Cox has identified this as a top growth priority over the next several years. AT&T and Verizon have done a good job making progress with managed services on the Enterprise sides of their businesses. If they can effectively leverage the know-how and vendor relationships they have garnered in the SMB space, it could make them more formidable competitors in SMB. However, it would still require meaningful product redesign as the needs and internal IT capabilities of SMBs are quite different from those of Fortune 1000 companies.

The crown jewels of AT&T's and Verizon's Wireline franchises, their Enterprise businesses, are largely protected from Cable competition. Remember that the MSOs can only offer service within their franchise areas, not on a truly nationwide or global basis, which limits their ability to serve many larger customers. Any sort of "synthetic" national service the cable companies could offer through reciprocal service agreements or other arrangements would prove problematic on several levels. Service would be terribly difficult to coordinate, levels of service quality could differ meaningfully by provider, and they still wouldn't have the ability to offer global connectivity (acquiring or constructing assets overseas would stray far from the core idea behind the SMB initiatives – leverage existing physical plant). The TelCos look fairly solid in this area, and the cable companies are likely smart enough not to allocate misallocate resources in an attempt to crack it open. But that is not to say the TelCos are 100% safe – Cox has done well in regional verticals like healthcare, government, and education, which often fall under the Enterprise umbrella.

Just as the MSOs are leveraging their existing networks to serve commercial customers, the TelCos may try to leverage their FiOS and U-Verse networks. FiOS and U-Verse are being built as residential services, but also like cable certainly pass a large number of SMBs. Their reach is not as extensive as Cable's, however. Both AT&T and Verizon currently offer fiber-based services to SMBs on a limited basis. Over time, however, if Cable's impact is meaningful it is possible that they will take steps to use their upgraded networks in an attempt to blunt the incursion.

Finally, the TelCos can use their wireless offerings as a selling point. Virtually all wireline Enterprise deals are now bundled with wireless service. Depending on the nature of their business, wireless can also be a critical service for SMBs. Since they operate on different networks, however, the performance benefits offered by purchasing bundled wireless and DSL are probably zero, whereas buying broadband and VoIP offers some degree of integration. The cable operators may blunt this impact somewhat through either their own wireless networks (like Cox) or by reselling Clearwire service (like Comcast and TWC). Nevertheless, AT&T's and Verizon's wireless franchises are likely strong enough to weather such a storm.

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Disclosure Appendix

Valuation Methodology

We value Comcast on a sum-of-the-parts basis. Our target is based on a forward 12 month EV/forecast EBITDA multiple of 5.75x for the core business. We value other consolidated and non-consolidated operations (including entertainment and sports cable networks) and non-public equity investments on various bases as appropriate, generally based on their own industry norms, primarily including EV/EBITDA multiples and value per subscriber. Publicly traded investments are carried at current market value.

In order to derive our price target for Time Warner Cable we use a target multiple of 5.75x forward 12 month forecast EBITDA, and add back the NPV of Time Warner Cable's deferred tax asset. We estimate that Time Warner Cable will realize approximately $330 million in tax savings per year for fifteen consecutive years from the 2006 acquisition of Adelphia as a result of its step-up in basis. When calculating the net present value of these tax shields, we apply an 8.25% discount rate, which corresponds to Time Warner Cable's estimated weighted average cost of capital.

We value Cablevision on a sum-of-the-parts basis. Our target is based on a forward 12 month EV/forecast EBITDA multiple of 6.5x for the core cable business. We value other consolidated and non-consolidated operations (including entertainment networks) and non-public equity investments on various bases as appropriate, generally based on their own industry norms, primarily including EV/EBITDA multiples and value per subscriber.

We value AT&T and Verizon on a combination of P/FE and a sum of the parts analysis. Assigned multiples are based on historical performance, colored by the company's current allocation of capital.

We value AT&T on a combination of a target P/FE multiple of 11.0x applied to our estimated forward adjusted earnings, and a sum of the parts analysis which yields a warranted blended EV/EBITDA multiple of 5.0x after adjusting for postretirement liabilities.

We value Verizon on a combination of a target P/FE multiple of 11.0x applied to our estimated forward adjusted earnings, and a sum of the parts analysis which yields a warranted blended EV/EBITDA multiple of 5.2x after adjusting for postretirement liabilities.

Risks

Risks to our price targets for the Cable operators include the risk that the competitive pricing environment will be more aggressive than we expect. Notwithstanding our analysis of rational pricing strategies, players may adopt irrational pricing behavior. Alternatively, mere *expectations* of a more challenging pricing environment, even in the absence of evidence of price competition, may continue to weigh on the stocks for some time.

New pathways to the home for video or other entertainment could also reduce the value of cable's video distribution bottleneck. Deep fiber deployment by the RBOCs will impact cable subscriber and revenue growth rates, and could occur more quickly, or have amore significant pricing impact, than we have forecast.

Comcast

If the Comcast NBCU deal is not consummated, the expectation that Comcast will try again would likely depress valuations indefinitely.

Regulatory conditions on a Comcast NBCU deal could materially impair future growth, and the uncertainty arising during a protracted regulatory review could itself weigh on shares.

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Video pricing could come under pressure as growth for the satellite operators and TelCos slows.

The fear of disintermediation (video over the internet) may continue to depress terminal values indefinitely

Longer term, cable's advantaged position in broadband could result in regulation.

Time Warner Cable

Video pricing could come under pressure as growth for the satellite operators and TelCos slows.

The fear of disintermediation (video over the internet) may continue to depress terminal values indefinitely

Longer term, cable's advantaged position in broadband could result in regulation.

Cablevision

Cablevision has a history of erratic corporate governance. A return of cash to shareholders cannot be assured.

Cablevision faces a very substantial overlap with Verizon's FiOS that could result in greater share loss, or lower prices, than anticipated.

The fear of disintermediation (video over the internet) may continue to depress terminal values indefinitely

Longer term, cable's advantaged position in broadband could result in regulation.

The risks to our target price for AT&T include:

- A steeper, or more sudden, deceleration in wireless subscriber growth – as a consequence of wireless saturation or economic weakness – would lead to sharply slower growth, and would likely be met with severe multiple contraction, in our view.

- Faster-than-anticipated penetration of the Small and Medium Business market by the MSOs would undermine revenue and EBITDA recovery in the Enterprise segment.

- Additional spending on fiber expansion (FTTX) projects, or acquisitions targeting the Consumer Wireline segment (including purchasing a Satellite Pay TV provider) would yield lower ROIC and consequent multiple contraction.

- Overpayment in an acquisition, which could be a variety of potential targets.

Our target price for Verizon is below the current trading range. Upside risks to our target price include:

- Lower-than-expected inflationary pressures in the macro economy, which could result in generally lower interest rate expectations, and consequently, make current dividend yields more attractive relative to investment alternatives.

- Faster growth in wireless subscribers than we anticipate, which could be a result of stronger economic growth, increased market share for Verizon, or higher terminal wireless market penetration than we forecast.

- Slower-than-anticipated penetration of the Small and Medium Business market by the MSOs would help to preserve revenue and foster an EBITDA recovery in the Enterprise segment.

- Subscriber gains as a result of fiber expansion (FTTX) projects could be greater than we forecast, yielding a higher ROIC and possible multiple expansion.

- Access line and DSL losses in the TelCo segment could be less severe than we forecast, leading to better than expected revenues and margins.

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– A faster-than-expected recovery in Enterprise revenues and margins.

– Acquisition of Vodafone's 45% stake in Verizon Wireless at an attractive price would be accretive to value and would remove a significant overhang from the shares.

SRO REQUIRED DISCLOSURES

- References to "Bernstein" relate to Sanford C. Bernstein & Co., LLC, Sanford C. Bernstein Limited, and Sanford C. Bernstein, a unit of AllianceBernstein Hong Kong Limited, collectively.

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- Bernstein rates stocks based on forecasts of relative performance for the next 6-12 months versus the S&P 500 for stocks listed on the U.S. and Canadian exchanges, versus the MSCI Pan Europe Index for stocks listed on the European exchanges (except for Russian companies), versus the MSCI Emerging Markets Index for Russian companies and stocks listed on emerging markets exchanges outside of the Asia Pacific region, and versus the MSCI Asia Pacific ex-Japan Index for stocks listed on the Asian (ex-Japan) exchanges - unless otherwise specified. We have three categories of ratings:

    Outperform: Stock will outpace the market index by more than 15 pp in the year ahead.

    Market-Perform: Stock will perform in line with the market index to within +/-15 pp in the year ahead.

    Underperform: Stock will trail the performance of the market index by more than 15 pp in the year ahead.

    Not Rated: The stock Rating, Target Price and estimates (if any) have been suspended temporarily.

- As of 09/07/2010, Bernstein's ratings were distributed as follows: Outperform - 44.7% (1.7% banking clients) ; Market-Perform - 48.5% (1.0% banking clients); Underperform - 6.8% (0.0% banking clients); Not Rated - 0.0% (0.0% banking clients). The numbers in parentheses represent the percentage of companies in each category to whom Bernstein provided investment banking services within the last twelve (12) months.

- Accounts over which Bernstein and/or their affiliates exercise investment discretion own more than 1% of the outstanding common stock of the following companies CMCSA / Comcast Corp, TWC / Time Warner Cable Inc, CVC / Cablevision Systems Corp, T / AT&T Inc.

- Bernstein currently makes a market in the following companies CMCSA / Comcast Corp.

- The following companies are or during the past twelve (12) months were clients of Bernstein, which provided non-investment banking-securities related services and received compensation for such services TWC / Time Warner Cable Inc, T / AT&T Inc, VZ / Verizon.

- An affiliate of Bernstein received compensation for non-investment banking-securities related services from the following companies TWC / Time Warner Cable Inc, CVC / Cablevision Systems Corp, T / AT&T Inc, VZ / Verizon.

- In the next three (3) months, Bernstein or an affiliate expects to receive or intends to seek compensation for investment banking services from CMCSA / Comcast Corp, TWC / Time Warner Cable Inc, CVC / Cablevision Systems Corp, T / AT&T Inc, VZ / Verizon.

12-Month Rating History as of 09/06/2010

Ticker	Rating Changes	
CMCSA	M (RC) 05/10/10	O (IC) 05/29/03
CVC	M (RC) 05/10/10	O (RC) 03/06/07
T	M (RC) 01/05/09	
TWC	M (RC) 05/10/10	O (IC) 03/13/07
VZ	M (RC) 02/09/10	U (RC) 01/05/09

Rating Guide: O - Outperform, M - Market-Perform, U - Underperform, N - Not Rated
Rating Actions: IC - Initiated Coverage, DC - Dropped Coverage, RC - Rating Change
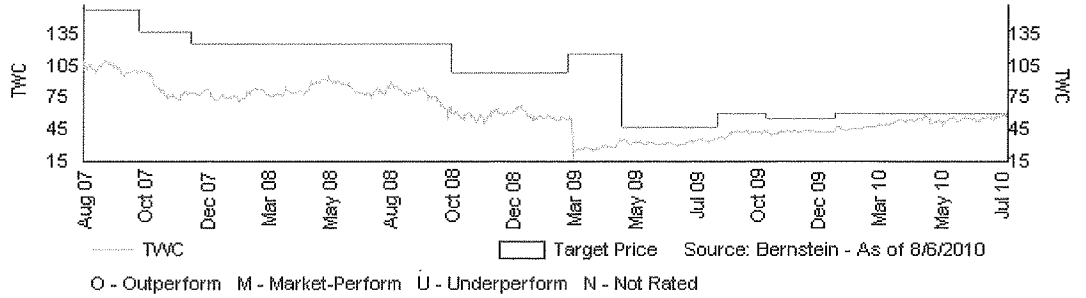
CMCSA / Comcast Corp

Date	Rating	Target(USD)
08/03/07	O	40.00
10/11/07	O	34.00
12/12/07	O	30.00
10/15/08	O	24.00
03/30/09	O	18.00
05/05/09	O	20.00
08/27/09	O	21.00
10/23/09	O	18.00
03/04/10	O	20.00
05/10/10	M	20.00

CMCSA   Target Price   Source: Bernstein - As of 8/6/2010

O - Outperform   M - Market-Perform   U - Underperform   N - Not Rated
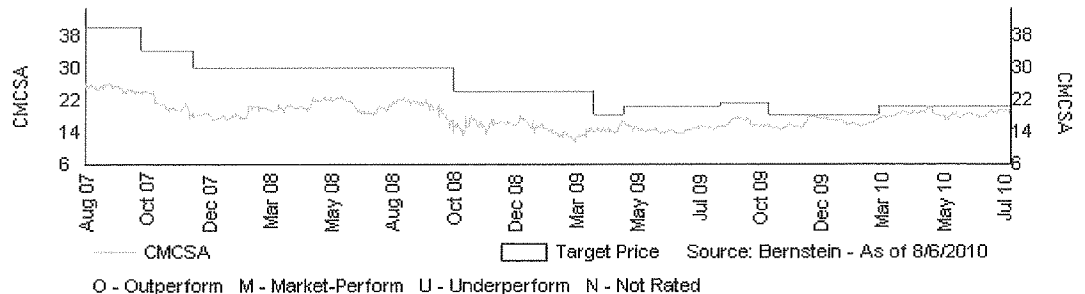
TWC / Time Warner Cable Inc

Date	Rating	Target(USD)
08/03/07	O	159.02
10/11/07	O	138.01
12/12/07	O	126.01
10/15/08	O	99.01
03/03/09	O	117.01
05/05/09	O	47.00
08/27/09	O	60.00
10/23/09	O	55.00
01/13/10	O	60.00
05/10/10	M	60.00

——— TWC   ☐ Target Price   Source: Bernstein - As of 8/6/2010

O - Outperform   M - Market-Perform   U - Underperform   N - Not Rated

CVC / Cablevision Systems Corp

Date	Rating	Target(USD)
08/03/07	O	40.00
01/02/08	O	45.00
10/15/08	O	31.00
04/09/09	O	22.00
05/19/09	O	26.00
09/29/09	O	28.00
01/26/10	O	23.00
04/26/10	O	28.00
05/10/10	M	28.00

——— CVC   ☐ Target Price   Source: Bernstein - As of 8/6/2010

O - Outperform   M - Market-Perform   U - Underperform   N - Not Rated
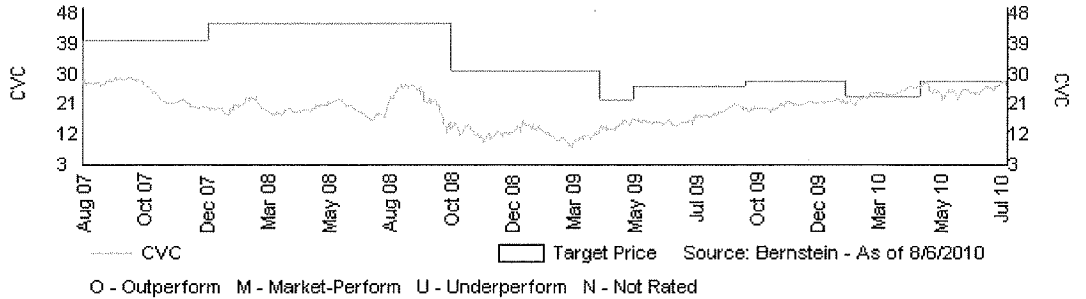
T / AT&T Inc

Date	Rating	Target(USD)
10/17/07	M(IC)	47.00
01/18/08	M	44.00
06/25/08	O	42.00
10/08/08	O	35.00
01/05/09	M	27.00
08/17/09	M	24.00
02/09/10	M	25.00

IC - Initiated Coverage

——— T   ☐ Target Price   Source: Bernstein - As of 8/6/2010

O - Outperform   M - Market-Perform   U - Underperform   N - Not Rated
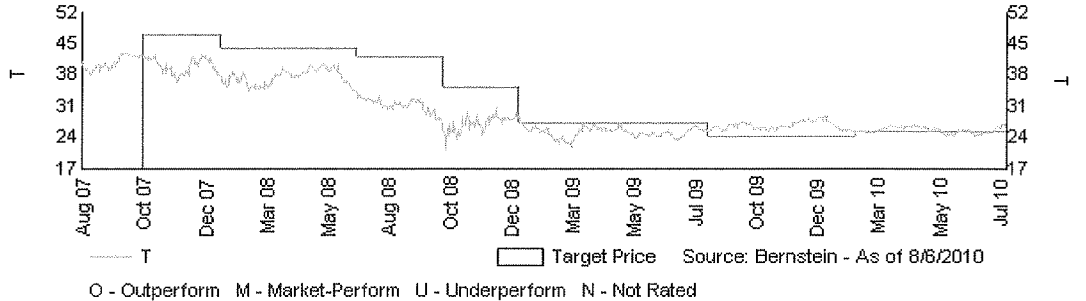
VZ / Verizon

Date	Rating	Target(USD)
10/17/07	M(IC)	44.00
01/18/08	M	41.00
04/04/08	M	37.00
10/08/08	M	32.00
01/05/09	U	27.00
08/17/09	U	25.00
02/09/10	M	27.00
07/06/10	M	25.00

IC - Initiated Coverage

——— VZ   ☐ Target Price   Source: Bernstein - As of 8/6/2010

O - Outperform   M - Market-Perform   U - Underperform   N - Not Rated
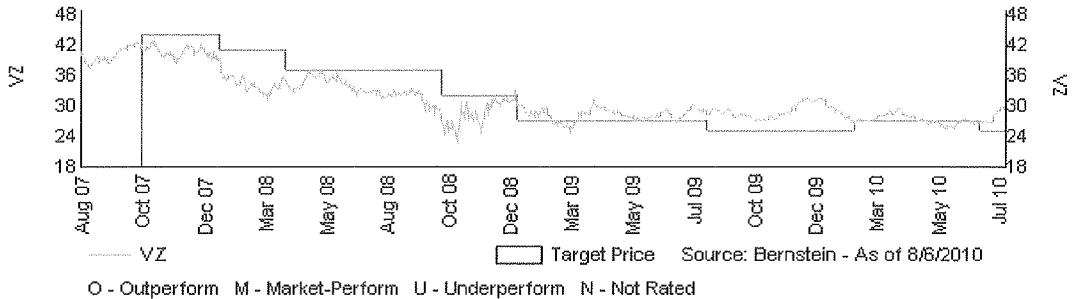
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CERTIFICATIONS

- I/(we), Craig Moffett, Senior Analyst(s), certify that all of the views expressed in this publication accurately reflect my/(our) personal views about any and all of the subject securities or issuers and that no part of my/(our) compensation was, is, or will be, directly or indirectly, related to the specific recommendations or views in this publication.

Approved By: MC

EXHIBIT 3

STATE OF NEW HAMPSHIRE
BEFORE THE
PUBLIC UTILITIES COMMISSION

Joint Petition of Verizon New England Inc., and
FairPoint Communications, Inc.   Docket No. DT 07-011
Transfer of New Hampshire Assets of
Verizon New England, Inc. et al.

DIRECT TESTIMONY OF
MICHAEL D. PELCOVITS

ON BEHALF OF

NEW ENGLAND CABLE & TELECOMMUNICATIONS ASSOCIATION, INC.
AND COMCAST PHONE OF NEW HAMPSHIRE, LLC

August 1, 2007

1   parallel between the proposed transaction and the disastrous situation that

2   occurred in Hawaii following a similar Verizon asset transfer and the acquiring

3   company's cutover to new operating systems. This parallel, also discussed at

4   length below, creates substantial concerns about the impact of the proposed

5   transaction on the public good in general and, in particular, on existing and

6   emerging competition in New Hampshire. Finally, there is reason to doubt

7   FairPoint's technical and managerial ability to offer wholesale services at least as

8   good as Verizon's and its readiness to continue Verizon's existing ILEC service

9   obligations to wholesale competitors.

10   **III.**   **COMPETITIVE LANDSCAPE IN NEW HAMPSHIRE**

11   **A.**   UNDERLYING DIFFICULTIES OF BRINGING COMPETITION TO LOCAL
12   TELEPHONE MARKETS

13   **Q.**   **What is the current state of competition in New Hampshire?**

14   A.   New Hampshire, to date, has experienced a degree of competition in some

15   markets. According to the latest FCC statistics, competitive local exchange

16   carriers ("CLECs") provided approximately 24% of all end-user switched access

17   lines (residential and business) in New Hampshire as of June 30, 2006.[2] The share

18   of residential lines provided by CLECs is much smaller. According to the FCC

19   statistics, as of June 30, 2006 CLECs provided 12.4% of residential lines, which

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[2] Attachment MDP-2 (FCC Local Telephone Competition Report: Status as of June 30, 2006 [January 2007], Table 8) and (FCC Local Competition Report: Status as of December 31, 2005 [July 2006]).

1   is a decline from 15.2% as of December 31, 2005 and 14.9% as of June 30, 2005.[3]

2   This recent decline in residential competition is worrisome and should prompt the

3   Commission to foster a pro-competitive environment in New Hampshire.

4   Q.   **Why has it been difficult to bring competition to local telephone markets?**

5   A.   Competition has been slow to develop in the local residential (and small business)

6   telephone market across the United States, not just in New Hampshire. The main

7   reason for this is that it has been prohibitively expensive for any entrant, such as

8   the CLECs spawned by the Telecommunications Act of 1996, to construct outside

9   telephone wire or fiber optic cable that can come close to matching the ubiquity of

10   the ILECs' plant. Until recently, competitors in this market have relied on one of

11   three ways to avoid having to fully replicate and pay for the cost of building local

12   wireline plant. First, competitors obtained access to the ILECs' local facilities at

13   wholesale rates or at UNE rates and used these facilities (along with some self-

14   provided capabilities) to provide local telephone service. Second, some

15   competitors have offered voice service directly to customers over the public

16   Internet — which is referred to as over-the-top Voice over Internet Protocol

17   ("VoIP"). Customers of over-the-top VOIP providers must obtain a broadband

18   Internet connection from another provider, e.g., the ILEC or the cable company.

19   Third, some customers have "cut the cord" and rely exclusively on wireless

20   telephone service for their local phone service.

---

[3] Attachment MDP-3, at Tables 7 and 12. (The total number of switched access lines for New Hampshire was taken from Table 7. The split between business and residential lines for the ILECs and the CLECs was obtained from Table 12.)

1   **Q.   Has competition from these three sources been sufficient to obviate any**

2   **reason for concern over the existing and future state of competition in the**

3   **local market?**

4   A.   No. Of greatest significance is the fact that all of the competitors in the voice

5   services market must still rely on the incumbent for some vital services in order to

6   serve their customers effectively. I will discuss this issue in greater detail in

7   Sections V and VI of my testimony. It is still vital to facilitate and foster wireline

8   competition in the New Hampshire voice services market. To begin with, the

9   largest source of competition until recently was from the UNE-P (platform)

10   carriers. At their peak, UNE-P providers and other CLECs served 15% of

11   residential lines nationwide.[4]However, not only have the two major UNE-P

12   providers (MCI and AT&T) ceased to exist as independent CLECs, but that mode

13   of competition essentially was eliminated by the FCC in the UNE Remand

14   proceeding in December, 2004.[5]Competition from over-the-top VoIP providers is

15   a limited or imperfect substitute for the ILEC for many customers, who are either

16   not connected to the Internet by broadband facilities or are unwilling to rely on a

17   public Internet connection for voice service. Wireless telephone service has also

18   been an imperfect substitute for most customers, who are unable or unwilling to

19   cut the cord.

---

[4] Attachment MDP-4 (FCC Local Telephone Competition Report: Status as of December 31, 2005 [July 2006], Table 2 [Hereafter: FCC Local Telephone Competition Report])
[5] Federal Communications Commission, *Order on Remand,* WCC Docket No. 04-314, December 15, 2004

1   Q.   **Are there prospects for increased competition in New Hampshire?**

2   A.   Yes. Comcast represents a source of voice services competition on a wider scale

3   than New Hampshire has experienced to date. Comcast has already deployed its

4   Comcast Digital Voice ("CDV") service throughout New Hampshire with the

5   exception of areas served by rural ILECs — where interconnection with rural

6   incumbents has been withheld. By the end of the second quarter of 2007 it had

7   attracted three million customers nationwide. CDV is now marketed to 35 million

8   homes, representing 73% of Comcast's footprint nationwide. Other cable

9   operators in New Hampshire, such as MetroCast, have also taken steps to enter

10   the market to compete with Verizon.

11   Q.   **What services does Comcast now offer in New Hampshire?**

12   A.   Comcast serves 100 communities in the State, providing service to more than

13   290,000 New Hampshire cable customers via 7,000 miles of cable plant.

14   Comcast's upgraded broadband network is capable of providing a rich array of

15   services to its customers, including those in the newly acquired systems in the

16   communities formerly service by Adelphia. Comcast offers its cable customers a

17   wide array of video programming and high-speed Internet at download speeds up

18   to 8 Mbps (which can be doubled for large downloads with Comcast's

19   PowerBoostTM Service). Comcast introduced its CDV service in New Hampshire

20   in 2005. Comcast's ability to grow and expand its voice service in New

21   Hampshire is wholly dependent upon retaining efficient and cost-based access to

1   a limited but critical group of wholesale services from FairPoint should the

2   merger be approved.

3   Q.   What is the potential benefit to consumers from the spread of competition

4   from cable telephony?

5   A.   Last year I conducted a study of these benefits and concluded that the overall

6   benefits over the next five years in the residential and small business market from

7   cable voice service competition were on the order of $100 billion.[6] As shown in

8   the table below, these benefits are derived from a number of sources, including

9   the direct savings to cable voice service customers and the anticipated competitive

10   response by the ILECs.

Total Savings from Cable-Telco Competition (in millions)

Cable, Residential Market	$11,221
Cable, Small Business Market	$526
OTP VoIP	$6,755
ILEC Competitive Response, Residential Market	$69,593
ILEC Competitive Response, Small Business Market	$13,440
Total	$101,534

12   Consumers in all markets will benefit from facilities-based voice services

13   competition by the cable companies. In particular, as cable companies are able to

14   justify upgrades and system expansions, they hold the promise of offering digital

15   television, high-speed Internet access, as well as competitive voice service to a

16   wider range of consumers.

---

[6] Attachment MDP-5 (MiCRA, "Consumer Benefits from Cable-Telco Competition, 2006")

EXHIBIT 4

THE BROADBAND AVAILABILITY GAP

OBI TECHNICAL PAPER NO. 1

TABLE OF CONTENTS

LIST OF EXHIBITS

LIST OF ASSUMPTIONS

This table provides important information about the different assumptions used in the creation of charts throughout this document. The assumptions implicit in each chart are appropriate for the context in which the chart appears. However, it may be the case that assumptions vary between similar charts, leading to what appear to be different results. This table synthesizes the different assumptions to allow the reader to interpret and compare charts in this document.

			Key assumptions	
Chart	Description	Technology	4G Areas	Non-4G areas
1-A	Base-case Broadband Availability Gap Profitable counties are excluded.	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
1-B	Breakout of Ongoing Costs by Category Profitable counties are excluded.	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
1-C	Gap by Census Blocks Ordered by Population density The second lowest cost technology is determined at the county level and assigned to the census blocks. All unserved census blocks then are sorted into centiles by their gap.	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
1-D	Broadband Investment Gap per County	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
1-E	Broadband Investment Gap per Housing Unit in Each County	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
1-G	Broadband Investment Gap, by County Profitable counties are excluded.	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
1-H	Ongoing Support for Each Housing Unit per Month	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
1-I	Investment Gap per Housing Unit by Lowest-Cost Technology for Each County	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.

Chart	Description	Technology	Key assumptions	
			4G Areas	Non-4G areas
1-J	Lowest Cost Technology All unserved areas are included.	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
3-A	Impact of Discount Rate on Investment Gap Profitable counties are excluded.	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
3-D	Gap for Funding One Wired and One Wireless Network Profitable counties for each technology are excluded.	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
3-E	The Cost of Funding Two Wired Networks Profitable counties for each technology are excluded.	12,000-foot DSL	Assumes one competitor.	Assumes one competitor.
		FTTP	Assumes one competitor.	Assumes one competitor.
3-G	Quantifying the Impact of Competition: Investment Gap by Number of Providers Profitable counties are excluded.	12,000-foot DSL	Assumes 0-3 competitors as indicated by label.	Assumes 0-3 competitors as indicated by label.
		Fixed Wireless	Assumes 0-3 competitors as indicated by label. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes 0-3 competitors as indicated by label. Recognizes only Fixed revenue as incremental.
3-H	Broadband Investment Gap by Percent of Unserved Housing Units The second-lowest-cost technology is determined at the county level and assigned to the census blocks. All unserved census blocks then are sorted into centiles by their gap.	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
3-I	Total Investment Cost for Various Upgrade Paths	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network.	Assumes no competitors.
		5,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		3,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		FTTP	Assumes one competitor.	Assumes no competitors.
3-M	Dependence of the Broadband Investment Gap on Speed of Broadband Considered Profitable counties are excluded.	15,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
		5,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		3,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		FTTP	Assumes one competitor.	Assumes no competitors.
		HFC	Assumes one competitor.	Assumes no competitors.

Chart	Description	Technology	Key assumptions	
			4G Areas	Non-4G areas
3-U	Sensitivity of Gap to Take Rate Profitable counties are excluded.	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
3-W	ARPU Sensitivity Profitable counties are excluded.	12,000-foot DSL	Assumes one competitor.	Assumes no competitors
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
3-Z	Sensitivity of Build-Out Cost and Investment Gap to Terrain Classification Parameters Profitable counties are excluded.	Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
4-C	Present Value of Total Costs for All Technologies in Unserved Areas The second lowest cost technology is determined at the county level and assigned to the census blocks. All unserved census blocks then are sorted into centiles by their gap.	12,000-foot DSL	Assumes no competitors.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network.	Assumes no competitors.
		5,000-foot DSL	Assumes no competitors.	Assumes no competitors.
		3,000-foot DSL	Assumes no competitors.	Assumes no competitors.
		FTTP	Assumes no competitors.	Assumes no competitors.
		Cable	Assumes no competitors.	Assumes no competitors.
4-W	Investment Gap for Wireless networks Profitable counties are excluded.	Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
4-Y	Sensitivity of Investment Gap to Terrain Classification Profitable counties are excluded.	Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
4-Z	Sensitivity of Costs and Investment Gap to Subscriber Capacity Assumptions Profitable counties are excluded.	Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
4-AA	Impact of Spectrum Availability on FWA Economics Considers all unserved areas for first column of data; profitable counties are excluded in the other columns.	Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
4-AB	Cost Breakdown of Wireless Network Over 20 Years Considers all unserved areas (including profitable counties).	Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network.	Assumes no competitors.
4-AC	Cost of Deploying a Wireless Network in Unserved Areas Considers all unserved areas (including profitable counties).	Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network.	Assumes no competitors.

Chart	Description	Technology	Key assumptions	
			4G Areas	Non-4G areas
4-AD	Cost of an HFM Second Mile Backhaul Architecture	Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network.	Assumes no competitors.
4-AK	Economic Breakdown of 12,000-foot DSL Profitable counties are excluded.	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
4-AP	Economics of Terrestrially Served if Most Expensive Housing Units are Served with Satellite Includes all unserved areas (including profitable counties).	12,000-foot DSL	Assumes one competitor.	Assumes no competitors.
		Fixed Wireless	Assumes no competitors. Applies a 73.13% cost allocation to the fixed network. Recognizes only Fixed revenue as incremental.	Assumes no competitors. Recognizes Fixed and Mobile revenue as incremental.
4-AV	Breakout of FTTP Gap Profitable counties are excluded.	FTTP	Assumes no competitors.	Assumes no competitors.
4-BE	Breakout of 3,000-Foot DSL Gap Profitable counties are excluded.	3,000-foot DSL	Assumes no competitors.	Assumes no competitors.
4-BF	Breakout of 5,000-Foot DSL Gap Profitable counties are excluded.	5,000-foot DSL	Assumes no competitors.	Assumes no competitors.
4-BG	Breakout of 15,000-Foot DSL Gap Profitable counties are excluded.	15,000-foot DSL	Assumes one competitor.	Assumes no competitors.

INTRODUCTION

The American Recovery and Reinvestment Act directed the Federal Communications Commission (FCC) to include, as part of the National Broadband Plan (NBP), "an analysis of the most effective and efficient mechanisms for ensuring broadband access by all people of the United States."[1] As the NBP indicated, the level of additional funding to extend broadband to those who do not have access today is $23.5 billion; more detail about the gap and results of this analysis are presented in Chapter 2. This document details the underlying analyses, assumptions and calculations that support the $23.5 billion funding gap.[2]

The question implicit in the Congressional mandate is deceptively simple: What is the minimum level of public support necessary to ensure that all Americans have access to broadband? In fact, there are multiple layers of complexity: The analysis must account for existing deployments, both to the extent that they enable current service and can be used to extend service to currently unserved areas; and it must include an analysis of the capabilities and economics of different,

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The Broadband Availability Gap Model

Models are one tool to analyze complex problems such as the Broadband Availability Gap. It is important to recognize, however, that models have limits. An engineering-based, multi-technology economic model of broadband deployment, like the one created as part of the National Broadband Plan (NBP) effort, requires a multitude of inputs and can be used to answer many different questions. The types of inputs range from simple point estimates, such as the cost of a piece of hardware—a Digital Subscriber Line Access Multiplexer (DSLAM) card or chassis, for example— estimates of per-product revenue, assumptions about the evolution of competitive dynamics in different market segments and the likely behavior of service providers. We form hypotheses about all of these types of inputs to calculate the Broadband Availability Gap; of necessity, some of these hypotheses are more speculative than others.

This paper describes the design and use of this model in providing input into the NBP, as well as the underlying views about the relevant technologies. Others may make different assumptions or test different hypotheses or seek to answer somewhat different questions. The model and its associated documentation provide an unprecedented level of transparency and should spur debate. The intent is for this debate to ultimately improve our understanding of the economics related to offering broadband service so that public policy can be made in a data-driven manner.

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competing technologies that can provide service. The analysis therefore comprises two main components: The first focuses on *Availability*, or understanding the state of existing network deployments and services; the second focuses on the *Funding Shortfall*, the capabilities and economics associated with different broadband networks.[3] See Exhibit A.

The *Availability* analysis focuses on determining the state of existing deployments: who has access, and of greater concern, who lacks access to broadband consistent with the National Broadband Availability Target. In addition, this analysis must develop a key input to the Funding Shortfall analysis: data regarding the location of existing network infrastructure to facilitate determining the cost of extending service into unserved areas. Developing this detailed baseline requires a very granular geographic view of the capabilities of all the major types of broadband infrastructure as they are deployed today, and as they will likely evolve over the next three to five years without public support.

Unfortunately, there is a lack of data at the required level of granularity, both in terms of availability—which people have access to what services—and of infrastructure—which people are passed by what types of network hardware. To solve the problem, we combine several data sets for availability and infrastructure, supplementing nationwide data with the output of a large multivariate regression model. We use this regression model to predict availability by speed tier and to fill in gaps, especially last-mile gaps, in our infrastructure data. The approach to developing this baseline is described in Chapter 2.

The second major component focuses on the *Funding Shortfall* by examining the capabilities and economics of different network technologies. To facilitate this analysis, we built a robust economic model that calculates the amount of support necessary to upgrade or extend existing infrastructure to the unserved to provide service consistent with the target. The economic analysis builds on the infrastructure data—known and inferred—from the first step, calculating the cost to augment existing infrastructure to provide broadband service consistent with the target for multiple technologies.

This calculation ultimately provides the gap between likely commercial deployments and the funding needed to extend universal broadband access to the unserved. Underlying the model's construction are a number of principles that guided its design.

➤ **Only profitable business cases will induce incremental network investments.** Private capital will only be available to fund investments in broadband networks where it is possible to earn returns in excess of the cost of capital. In short, only profitable networks will attract the investment required. Cost, while a significant

driver of profitability, is not sufficient to measure the attractiveness of a given build; rather, the best measure of profitability is the net present value (NPV) of a build. This gap to profitability in unserved areas is called the Broadband Availability Gap in the NBP; throughout this paper, we will refer to this financial measure as the Investment Gap.

➤ **Investment decisions are made on the incremental value they generate.** While firms seek to maximize their overall profitability, investment decisions are evaluated based on the incremental value they provide. In some instances, existing assets reduce the costs of deployment in a given area. The profitability of any build needs to reflect these potential savings, while including only incremental revenue associated with the new network build-out.

➤ **Capturing the local (dis-)economies of scale that drive local profitability requires granular calculations of costs and revenues.** Multiple effects, dependent on local conditions, drive up the cost of providing service in areas that currently lack broadband: Lower (linear) densities and longer distances drive up the cost of construction, while providing fewer customers over whom to amortize costs. At the same time, lower-port-count electronics have higher costs per port. In addition, these lower

densities also mean there is less revenue available per mile of outside plant or per covered area.

➤ **Network-deployment decisions reflect service-area economies of scale.** Telecom networks are designed to provide service over significant distances, often larger than five miles. In addition, carriers need to have sufficient scale, in network operations and support, to provide service efficiently in that local area or market. Given the importance of reach and the value of efficient operations, it can be difficult to evaluate the profitability of an area that is smaller than a local service area.

➤ **Technologies must be commercially deployable to be considered part of the solution set.** Though the economic model is forward-looking and technologies continue to evolve, the model only includes technologies that have been shown to be capable of providing carrier-class broadband. While some wireless 4G technologies arguably have not yet met this threshold, successful market tests and public commitments from carriers to their deployment provide some assurance that they will be capable of providing service.

Implicit within the $23.5 billion gap are a number of key decisions about how to use the model. These decisions reflect

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Exhibit A:

Approach to Determining the Availability Gap[4]

Availability	Funding shortfall
Number of unserved and their proximity to current broadband infrastructure	**Funding required to induce operators to deploy ubiquitous broadband**
Current state •HFC, telco and wireless availability calculated independently •Used best available data from commercial and government sources •Filled data gaps with a statistical model **Future state** •Based on public announcements	**Key principles** •NPV analysis •Incremental economics •Sufficiently granular •Economies of scale •Technologically conservative **Key decisions** •Fund only one network •Market based disbursement •Terrestrial coverage for all •Account for 4G build out •Proven use cases
7.0 million unserved homes	**$23.5 billion availability gap**

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beliefs about the role of government support and the evolution of service in markets that currently lack broadband. In short, these decisions, along with the assumptions that follow, describe how we used the model to create the $23.5 billion base case.

➤ **Fund only one network in each currently unserved geographic area.** The focus of this analysis is on areas where not even one network can operate profitably. In order to limit the amount of public funds being provided to private network operators, the base case includes the gap for funding only one network.

➤ **Capture likely effects of disbursement mechanisms on support levels.** Decisions about how to disburse broadband-support funds will affect the size of the gap. Market-based mechanisms, which may help limit the level of government support in competitive markets, may not lead to the lowest possible Investment Gap in areas currently unserved by broadband—areas where it is difficult for even one service provider to operate profitably.

➤ **Focus on terrestrial solutions, but not to the exclusion of satellite-based service.** Satellite-based service has some clear advantages relative to terrestrial service for the most remote, highest-gap homes: near-ubiquity in service footprint and a cost structure not influenced by low densities. However, satellite service has limited capacity that may be inadequate to serve all consumers in areas where it is the lowest-cost technology. Uncertainty about the number of unserved who can receive satellite-based broadband, and about the impact of the disbursement mechanisms both on where satellite ultimately provides service and the size of the Investment Gap, all lead us to not explicitly include satellite in the base-case calculation.

➤ **Support any technology that meets the network requirements.** Broadband technologies are evolving rapidly, and where service providers are able to operate networks profitably, the market determines which technologies "win." Given that, there appears to be little-to-no benefit to pick technology winners and losers in areas that currently lack broadband. Therefore, the base case includes any technology capable of providing service that meets the National Broadband Availability Target to a significant fraction of the unserved.

➤ **Provide support for networks that deliver proven use cases, not for future-proof build-outs.** While end-users are likely to demand more speed over time, the evolution of that demand is uncertain. Given current trends, building a future-proof network immediately is likely more expensive than paying for future upgrades.

Also implicit in the $23.5 billion gap are a number of major assumptions. In some sense, every input for the costs of network hardware or for the lifetime of each piece of electronics is an assumption that can drive the size of the Investment Gap. The focus here is on those selected assumptions that may have a disproportionately large impact on the gap or may be particularly controversial. By their nature, assumptions are subject to disagreement; Chapter 3 includes an estimate of the impact on the gap for different assumptions in each case.

➤ Broadband service requires 4 Mbps downstream and 1 Mbps upstream access-network service.

➤ The take rate for broadband in unserved areas will be comparable to the take rate in served areas with similar demographics.

➤ The average revenue per product or bundle will evolve slowly over time.

➤ In wireless networks, propagation loss due to terrain is a major driver of cost that can be estimated by choosing appropriate cell sizes for different types of terrain and different frequency bands.

➤ The cost of providing fixed wireless broadband service is directly proportional to the fraction of traffic on the wireless network from fixed service.

➤ Disbursements will be taxed as regular income just as current USF disbursements are taxed.

➤ Large service providers' current operating expenses provide a proxy for the operating expenses associated with providing broadband service in currently unserved areas.

These principles, decisions and assumptions are discussed in detail in Chapter 3.

In addition to the key assumptions above, there are numerous other assumptions that we made for each broadband technology we examined. In order to accurately model each technology, we had to understand both the technical capabilities and the economic drivers; a description of our treatment of each technology is provided in Chapter 4.

In addition to this technical paper, there is supplementary documentation describing our analysis and methods including CostQuest Model Documentation: Technical documentation of how the model is constructed, including more detail about the statistical model used to estimate availability and network infrastructure in areas where no data are available.

ENDNOTES

1   American Recovery and Reinvestment Act of 2009, Pub.L. No. 111-5, § 6001(k)(2)(D), 123 Stat. 115, 516 (2009) (Recovery Act).

2   Note the figure differs slightly from Exhibit 8-B of the first printing of the National Broadband Plan (NBP). While the gap remains $24 billion, the data in this paper are updated since the release of the NBP; future releases of the NBP will include these updated data.

3   As a threshold matter, the level of service to be supported must be set. This service is the National Broadband Availability Target which specifies downstream speeds of at least 4 Mbps and upstream speeds of at least 1 Mbps. Support for this target is discussed briefly in Section 4 and in detail in the Omnibus Broadband Initiative's (OBI) technical paper entitled Broadband Performance (forthcoming).

4   Homes are technically housing units. Housing units are distinct from households. "A housing unit is a house, an apartment, a mobile home, a group of rooms, or a single room that is occupied (or if vacant, is intended for occupancy) as separate living quarters." In contrast, "A household includes all the persons who occupy a housing unit. . . . The occupants may be a single family, one person living alone, two or more families living together, or any other group of related or unrelated persons who share living arrangements." There are 130.1 million housing units and 118.0 million households in the United States. U.S. Census Bureau, Households, Persons Per Household, and Households with Individuals Under 18 Years, 2000, http://quickfacts.census.gov/qfd/meta/long_71061. htm (last visited Mar. 7, 2010).

I. THE INVESTMENT GAP

Our analysis indicates that there are 7 million housing units (HUs) without access to terrestrial broadband infrastructure capable of meeting the National Broadband Availability Target of 4 Mbps download and 1 Mbps upload. Because the total costs of providing broadband service to those 7 million HUs exceed the revenues expected from providing service, it is unlikely that private capital will fund infrastructure capable of delivering broadband that meets the target.

We calculate the amount of support required to provide 100% coverage to the unserved consistent with the availability target to be $23.5 billion. As shown in Exhibit 1-A, the $23.5 billion gap is the net shortfall, including initial capital expenditures (capex), ongoing costs and revenue associated with providing service across the life of the asset.

Ongoing costs comprise ongoing capex, network operating expenses and selling, general and administrative expenses; the present values of these costs are shown in Exhibit 1-B.

Costs and the gap vary dramatically with population density, with the least densely populated areas accounting for a disproportionate share of the gap (see Exhibit 1-C). As noted in the NBP, and discussed more fully in the *Satellite* portion of Chapter 4, the highest-gap 250,000 housing units account for $13.4 billion of the total $23.5 billion investment gap.

In fact, deployment costs and the gap are driven largely by the density of the unserved, as will be discussed here and in Chapter 2 (see, for example, Exhibits 1-F and 2-D). Therefore, satellite-based broadband, which can provide service to almost any subscriber regardless of location and at roughly the same cost, could be an attractive part of the overall solution.

We rely on these results to represent an aggregate, nationwide figure. We are more cautious with results in specific geographies because the estimates of the availability of broadband capable networks are in part based on a statistical model (see Chapter 2 for more detail). When examined at a very granular level, the availability model will sometimes overestimate and sometimes underestimate service levels, but should tend to balance out when aggregated to larger geographic areas. In the maps throughout this section we aggregate outputs to the county, but data should still be considered only directionally accurate. Further analysis and improved source data would be required to refine estimates for particular geographies.

The map in Exhibit 1-D presents the Investment Gap for each county in the country. The gap in each county is calculated by adding the gap of all census blocks in that county. Since most counties have at least some census blocks with a net present value (NPV) gap, most counties have an NPV gap. Census blocks with a positive NPV (i.e., blocks where the gap is negative) offset losses in census blocks that are NPV negative. Thus, counties can have no gap if they are currently fully served (i.e., have no unserved), or if the total NPV in the county is positive. Note that dark blue counties have a gap at least 20 times higher than the gap in the light green counties.

Exhibit 1-A:
Base-case Broadband Availability Gap—Cash Flows Associated With Investment Gap to Universal Broadband Availability[1]

15.3	17.1	32.4	8.9	23.5
Initial capex	Ongoing costs	Total cost	Revenue	Investment gap

(in billions of USD, present value)
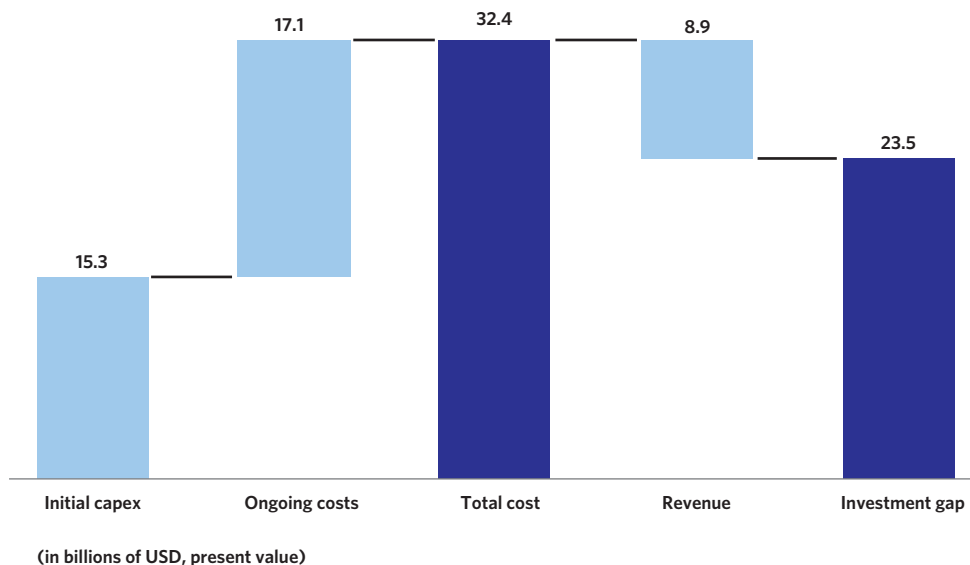
Exhibit 1-B:
Breakout of
Ongoing Costs by
Category

2.8　　　　　　11.8　　　　　　2.5　　　　　　17.1

Ongoing Capex　　　Network OpEx　　　SG&A　　　Total
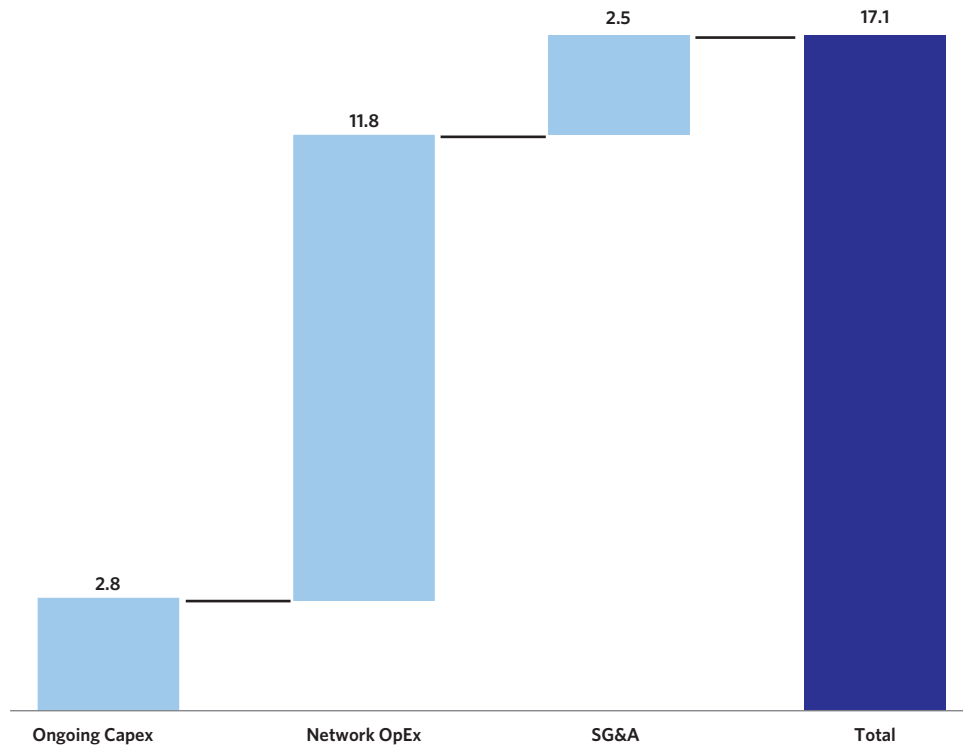
(in billions of USD, present value)
Numbers do not sum due to rounding.

Exhibit 1-C:
Gap by Census
Blocks Ordered by
Population density

Density
HU/Mi²

— Density (left axis)
▮ Investment gap (right axis)

Gap
($ Millions)

13,000

12,000

11,000

10,000

9,000

8,000

7,000

6,000

5,000

4,000

3,000

2,000

1,000

0

6,500

6,000

5,500

5,000

4,500

4,000

3,500

3,000

2,500

2,000

1,500

1,000

500

0

Most Dense

Percentiles of Unserved Census Blocks

Least Dense
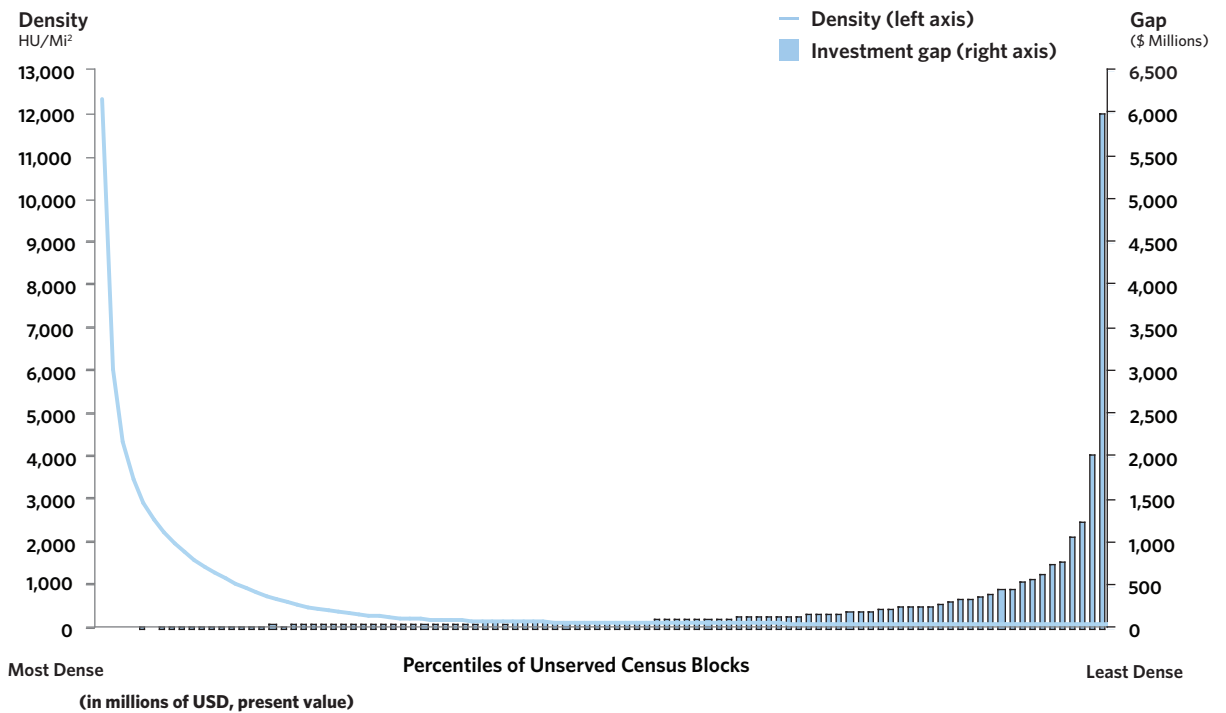
(in millions of USD, present value)

However, the total gap per county tells only part of the story. High county-level gaps can be driven by large numbers of relatively low-gap housing units and/or by small numbers of very high-gap housing units. Examining the gap per housing unit, as shown in Exhibit 1-E, highlights counties where the average gap per home is particularly high. This calculation simply takes the total gap in each county as described above, and divides by the number of unserved housing units in that county. The dark blue counties have a gap per home at least 10 times higher than the gap per home in the green counties.

Exhibit 1-D:
Broadband Investment Gap per County

Conterminous United States

Legend
- No gap
- <$1 million gap
- $1–5 million gap
- $5–20 million gap
- >$20 million gap

Alaska

Hawaii
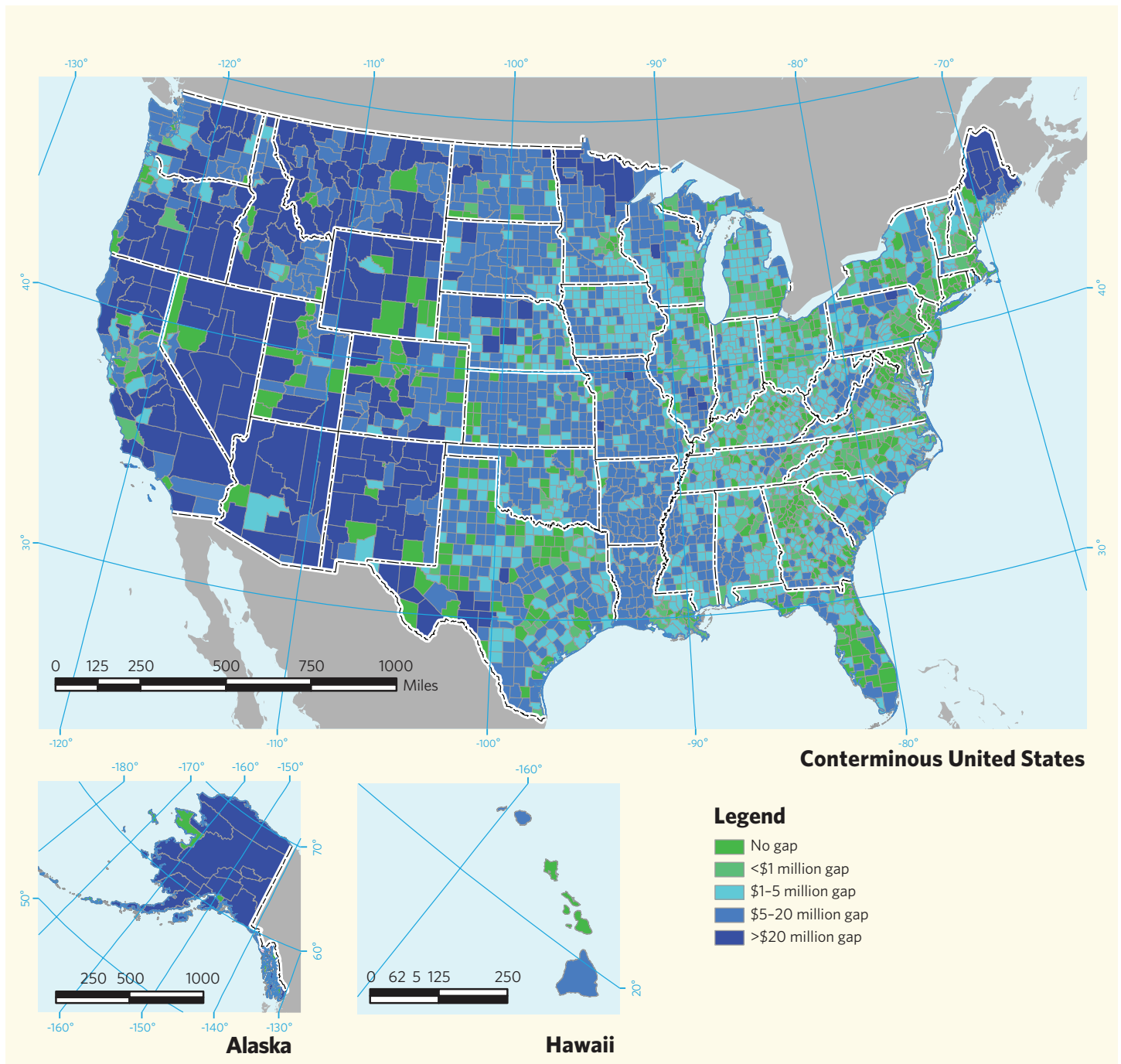
As one might expect, one of the major drivers of cost, and consequently the gap, is the density of unserved housing units (i.e., the number of unserved housing units per square mile, averaged across each county). Areas with higher density as shown in Exhibit 1-F generally have lower gaps per housing unit; note the correlation between low densities in Exhibit 1-F with higher gap per housing unit in Exhibit 1-E. Although density is not the only driver of gap, it is a significant one.

Exhibit 1-E:
Broadband Investment Gap per Housing Unit in Each County

Conterminous United States

Alaska

Hawaii

Legend
- No gap
- <$2,500
- $2,500–$10,000
- $10,000–$25,000
- >$25,000

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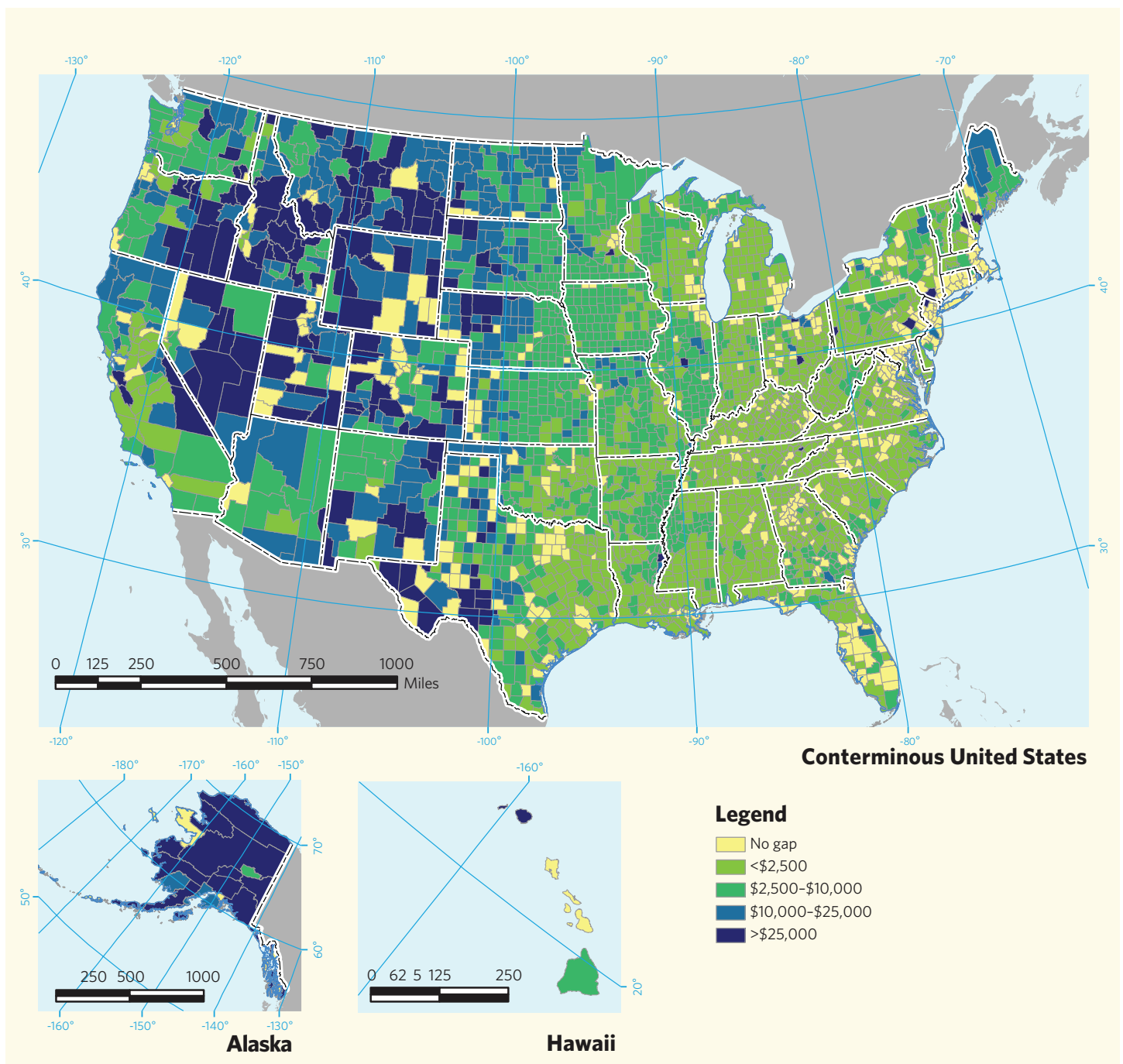
In some areas, the gap exceeds the initial capex required to build out the area. These areas have ongoing costs that are in excess of their revenue—meaning even a network with construction fully subsidized by public funds will not be able to operate profitably. Exhibit 1-G shows the gap for each county, highlighting those where the gap is larger than the initial capex (i.e., markets that require ongoing support), colored in light blue. Areas that require ongoing support generally have larger gaps.

Exhibit 1-F:
Density of Unserved Housing Units per Square Mile

Conterminous United States

Legend
- Up to 1 unserved/sq mile
- 1–5 unserved/sq mile
- 5–10 unserved/sq mile
- more than 10 unserved/sq mile

Alaska

Hawaii

The map in Exhibit 1-H shows the distribution of counties requiring ongoing support across the country. Ongoing support is the monthly annuity required per unserved housing unit to offset ongoing losses (i.e., the amount by which ongoing costs exceed revenues, assuming the network build out is fully subsidized). The darkest colors indicate areas where the highest levels of ongoing support are needed; counties shaded in pink will not need ongoing support.

In Exhibit 1-I, areas in blue are more economic to serve with wireless, and areas in red are cheaper to serve with DSL. For each, darker colors indicate counties with a higher gap per unserved housing unit. This technology comparison is made at the county level, not at a more granular level (See Chapter 3).

Wireline tends to be cheaper in low-density areas (compare Exhibit 1-I with Exhibit 1-F), particularly where terrain drives the need for smaller cell sites that drive up the cost of wireless (see Chapter 4 on wireless technology).

To establish the $23.5 billion gap, it is necessary to make a determination as to which last mile technology is likely to be least expensive given existing infrastructure, density, terrain and other factors. These estimates notwithstanding, this approach and the NBP are technologically neutral: These estimates do **not** reflect choices **or** recommendations that a particular last mile technology be utilized in any given area. Note, that as described later in this section in "**Creating the base-case scenario and output**," the focus in this analysis is on 12,000-foot-loop DSL and fixed wireless.

The map is somewhat misleading about the number of unserved housing units where wireline service is cheaper. In fact, while 42% of the geographic area is covered by counties where wired service has a lower gap, only 15% of counties with only 10% of the unserved housing units are in these areas; see Exhibit 1-J. Over time, these figures, which are based on the calculation of the investment gap for different technologies, may over- or under-estimate the role of any technology for a number of reasons. End-user behavior, specifically take rates or revenue per user, could differ from assumptions made in the model (see Chapter 3). In addition, the capabilities of different technologies could improve more or less quickly than assumed, or their costs could differ from what is modeled (see Chapter 4 for detail about capabilities and costs of different technologies). Finally, the impact of the disbursement mechanisms on individual service providers is impossible to include in these calculations.

The assumptions that underlie each of these calculations, and the method by which these technologies' costs are combined to reach the $23.5 billion gap, are discussed across the remainder of this document.

CREATING THE BASE-CASE SCENARIO AND OUTPUT

The base-case outputs, including the $23.5 billion gap, represent the shortfall of a particular combination of technologies across all unserved geographies. Since a single model run provides information about a single technology with a single set of assumptions, combining calculations for different technologies

Exhibit 1-G:
Broadband Investment Gap, by County

Legend:
- ■ Gap < Initial Capex
- ■ Gap > Initial Capex

Y-axis values:
$1,000,000,000
$100,000,000
$10,000,000
$1,000,000
$100,000
$10,000
$1,000
$100
$10
$1

X-axis labels: **Lowest-gap county** ... **Highest-gap county**

(USD, present value)
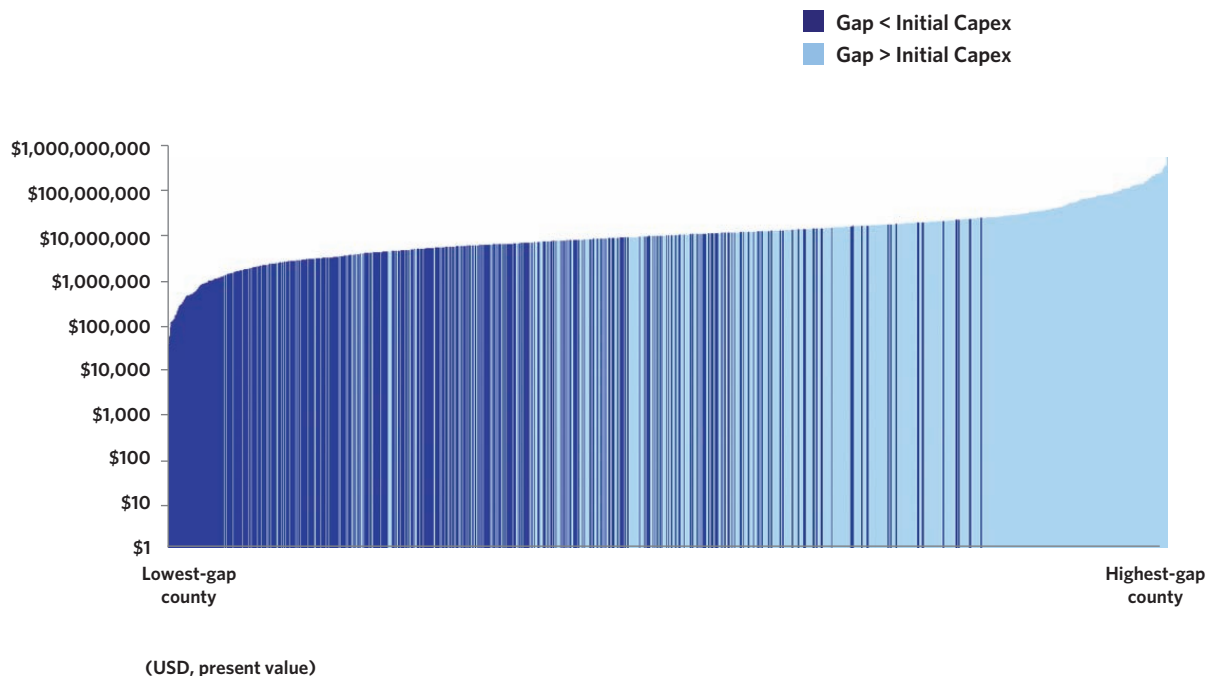
requires multiple model runs. This section describes the various models run as well as the manual post-processing required to create the single base case of $23.5 billion. Post processing of this type is required for each of the different scenarios and sensitivities shown in this document.

To create the base case, we calculate the gap for each of the two lowest-cost technologies: fixed wireless and 12,000-foot DSL (see Exhibit 4-C). Calculating the fixed wireless gap is quite complex, and requires eight different sets of model output. DSL is less complex, and requires only two sets of model

Exhibit 1-H:
Ongoing Support for Each Housing Unit per Month

Conterminous United States

Alaska

Hawaii

Legend
- No ongoing support needed
- <$10
- $10–$50
- $50–$100
- >$100
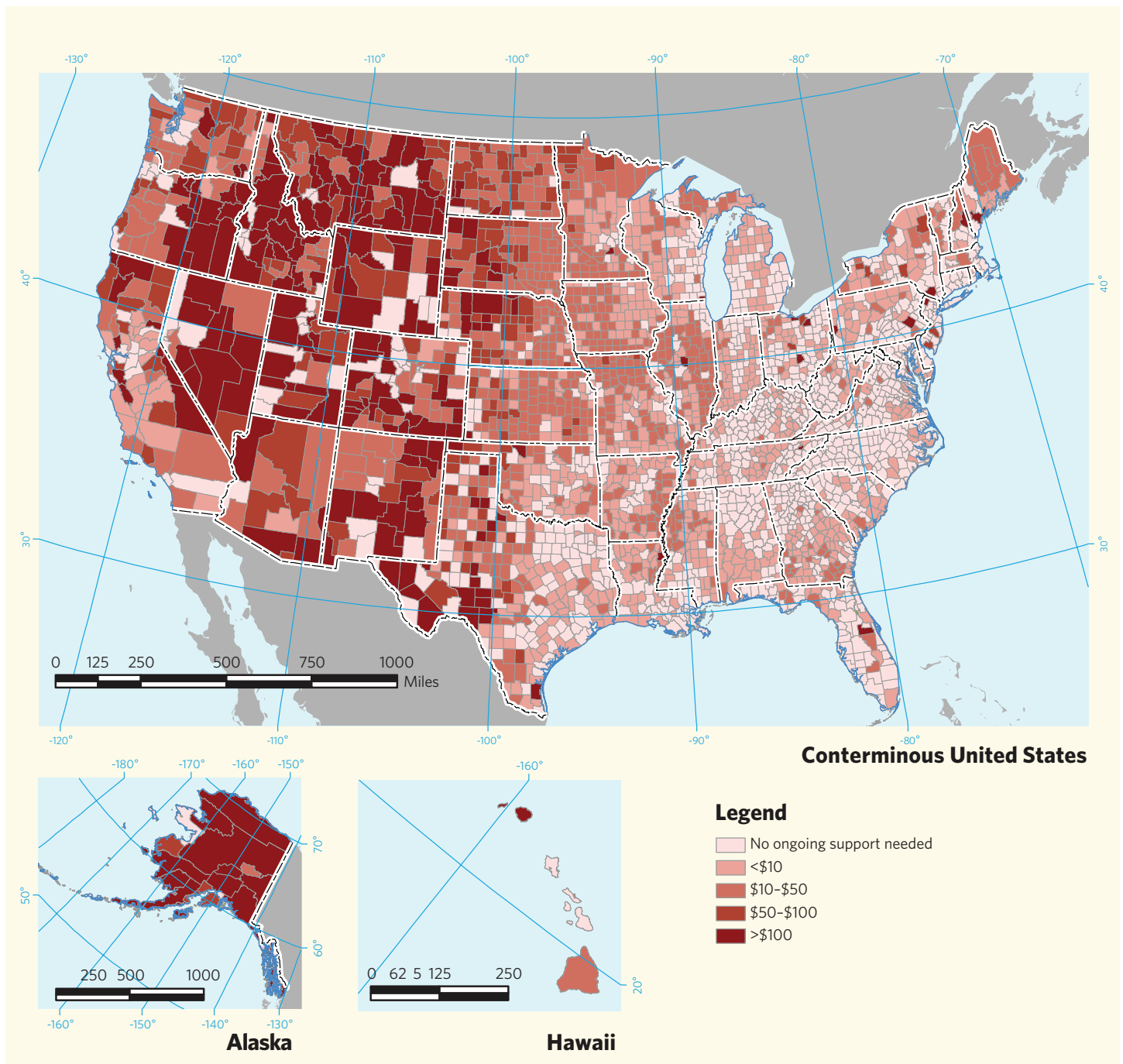
output. Of course, we also calculate the gap for other technologies, which will be discussed in Chapter 4.

For wireless, we require a total of eight different runs to generate the output data and account for two different kinds of information: 1) the presence of planned commercial 4G deployments and 2) which of four different cell radii is required for each census block to provide adequate signal density given terrain-driven attenuation. The base case requires output for each combination.

Exhibit 1-I:
Investment Gap per Housing Unit by Lowest-Cost Technology for Each County

Conterminous United States

Alaska

Hawaii

Legend

12k DSL has lower gap	4G has lower gap
No gap	No gap
<$2,500	<$2,500
$2,500–$10,000	$2,500–$10,000
$10,000–$25,000	$10,000–$25,000
>$25,000	>$25,000
Fully served	
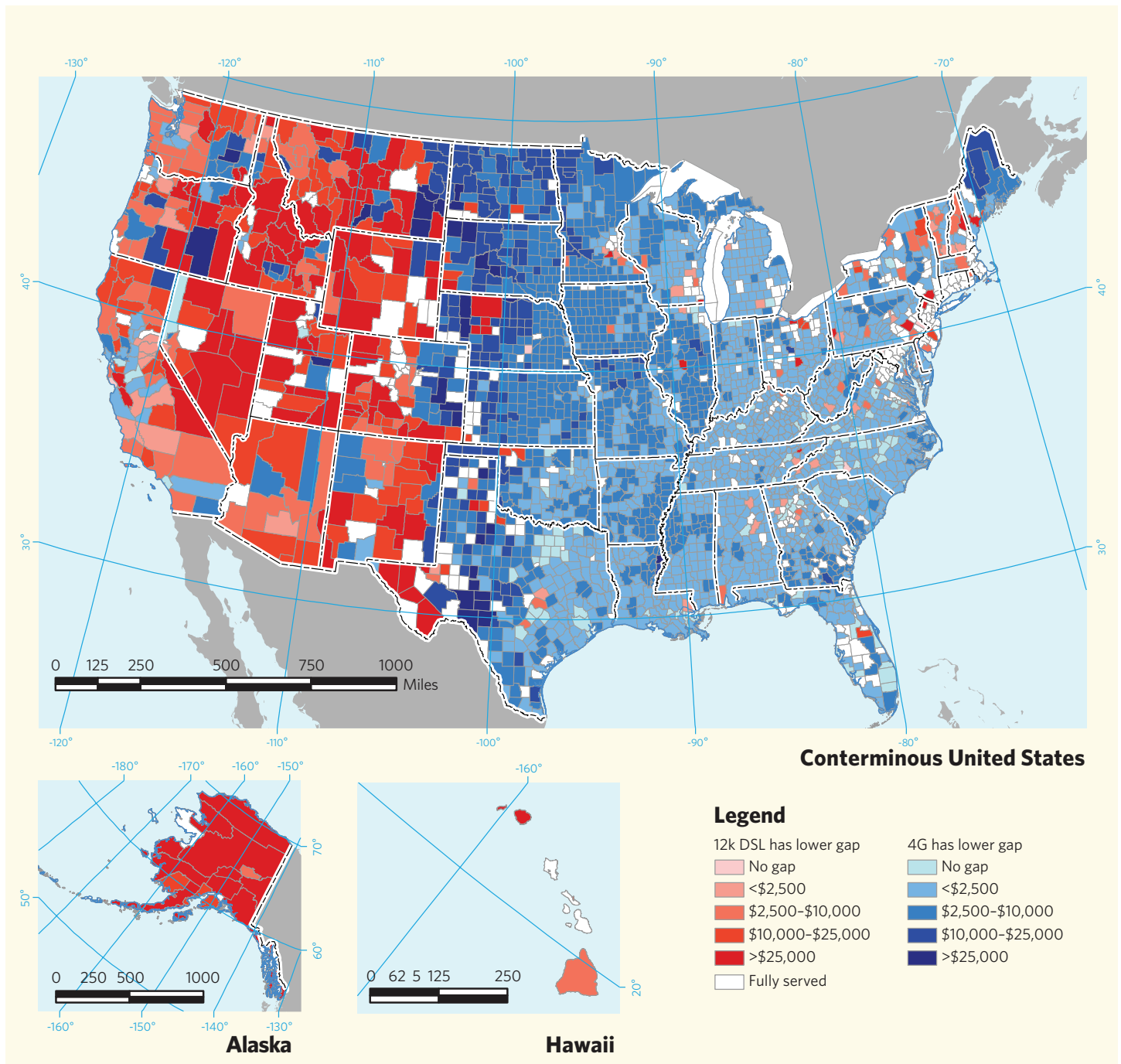
The first issue is the presence of commercial 4G deployments. A substantial fraction of the unserved are in areas we expect will be covered by commercial 4G build-outs. We treat these 4G and non-4G areas differently in our analysis to account for the costs and revenues associated with each and, consequently, need one run for each area. In 4G areas, as noted in the NBP, it is not clear whether these commercial build-outs will provide adequate service without incremental investments. The gap in these 4G areas needs to account for the fact that costs associated with the incremental investments are lower than they would be for a greenfield build. In non-4G areas, we calculate the costs for a greenfield build (note that, as will be discussed in the wireless portion of Chapter 3, we capture the cost savings available from existing cell sites, as appropriate).

Another key driver of the wireless gap is the cell radius in each area. Rather than assume a uniform cell radius across the entire country, the approach is to calculate the cost associated with different cell radii (two, three, five and eight-mile radii) and chose an "optimized" radius, which accounts for topology, for each area.

In total, then, there are eight wireless model runs: four runs (one for each radius) for the costs and gap associated with 4G areas; and four runs for the costs and gap associated with non-4G areas. For each geography (census block), we select the costs, revenues and gap from the appropriate run for each census block, depending on whether the area is in a 4G or non-4G area and what the optimized cell radius is.

The wired, 12,000-foot DSL solution is more straightforward and requires only two runs, which are required to account for the potential competitive impact of commercial 4G overlap on end-user revenue for the wired provider. While it is clear

that a wireless carrier would need to make incremental investments to serve every unserved housing unit, wireless carriers will be able to serve some potentially large fraction of those within the commercial 4G footprint. Therefore, we assume that within the expected 4G footprint, DSL providers will face one fixed-broadband competitor (i.e., will split the end-user revenue with another carrier); in non-4G areas, we assume that DSL providers will not face any competition. The result is that the wired base case requires two model runs: one for 4G areas (with competition) and one for non-4G areas (without competition). The base case assumes wired solutions are all brownfield deployments where the incumbent builds out DSL service using existing twisted-pair copper.

The base case then involves calculating the lowest-cost and second-lowest-cost technology in each area. To make these comparisons at the service-area level (county level), we roll census blocks up into counties. These geographic roll-ups are made with Structured Query Language or SQL queries of the large, census-block-level output of the model and provide the essential outputs including costs, revenues and the gap for each model run or combination of model runs.

The model uses levelized costs and revenues. Levelization, often used in regulatory proceedings, calculates the annuitized equivalent—i.e., the effective annual value of cash flows—of the costs and revenues associated with building and operating a network. A levelized calculation provides a steady cash-flow stream, rather than trying to model or guess the timing of largely unpredictable yet sizable real-world payouts like those for upgrading and repairing equipment. The net present value (NPV) of a levelized cash flow is equal to the NPV of actual cash flows.

Exhibit 1-J.
Lowest Cost
Technology
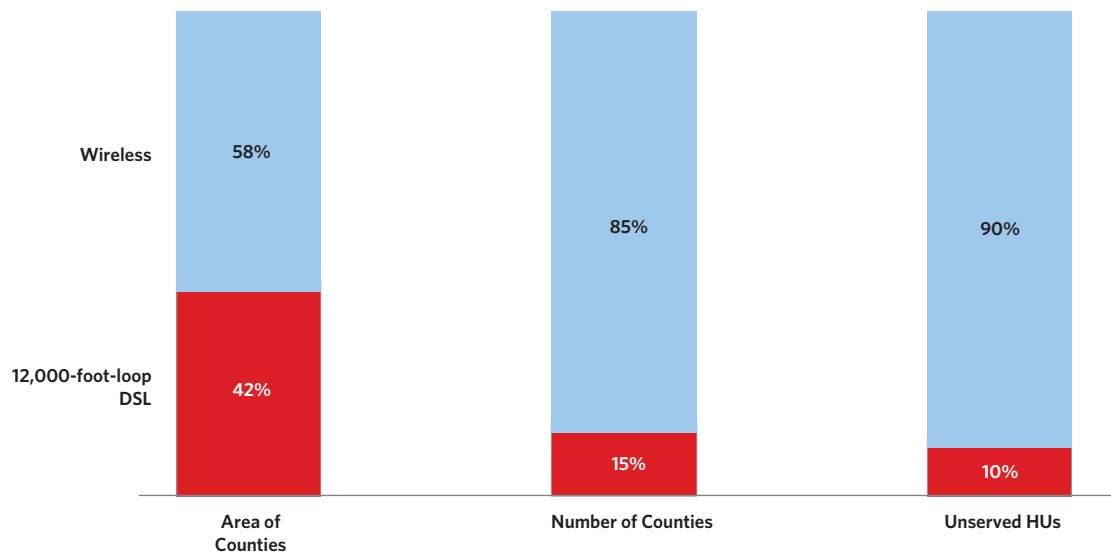
In order to calculate the Investment Gap as laid out in Exhibit 1-A, one need only make calculations from these market-level outputs. The three most important fields for this calculation are "contribution margin" (actually the levelized monthly gap, noting that a negative contribution margin represents a shortfall or positive gap), revenue (levelized monthly revenue) and initial capital investment.

First, determine the Investment Gap and total revenue by calculating the present value of the levelized contribution margin and revenue respectively. Second, calculate total cost by summing the present values for the investment gap and total revenue (moving from right to left in Exhibit 1-A). Third, the initial capital investment is provided in present value terms and can be taken directly from the query output. Finally, ongoing costs, which include all incremental capital expenses, operating expenses and any network residual value, are simply the difference between total cost and initial capital investment. These calculations are the same at any level of geographic aggregation, whether for the entire country or for any county.

CHAPTER 1 ENDNOTES

[1]   Note that this exhibit differs slightly from Exhibit 8-B
      of the first printing of the NBP. While the gap remains
      at $24 billion, the data in this paper are updated since
      the release of the NBP; future revisions of the NBP will
      include these updated data.

II. BROADBAND AVAILABILITY

Before determining the size of the Investment Gap, it is necessary to determine the current state of broadband deployment. This includes the level of service currently supported (or which will be in the near-term without government support) as well as the proximity of unserved areas to broadband infrastructure that can be leveraged to serve the area.

The complexity of this analysis is driven by the need for a very granular geographic view of the capabilities of all the major types of broadband infrastructure as they are deployed today, and as they will likely evolve over the next three to five years without additional public support.

These data are not available: There is a lack of data at the required level of granularity, both in terms of which people have access to which services, and of which people are passed by different types of physical infrastructure. To solve this problem, we combine commercial and public data on availability and infrastructure with statistical techniques to predict or infer the data needed to complete our data set.

In some cases we use broadband availability data to predict the location of broadband infrastructure, and in some cases we use the location of broadband infrastructure to predict the availability of broadband capable networks. In areas where we do not have data, we combine data from other geographies with limited physical infrastructure data in a large multi-variant regression model. We use this regression model to predict availability by speed tier and to fill in gaps, especially last mile gaps, in our infrastructure data.

Once current availability is determined, we forecast the future state by relying on recent publicly announced network build-out plans.

Where the quality of data is limited, broadband-gap calculations will be affected. For example, there are 12 wire centers in Alaska that show no population within their boundaries and an additional 18 wire centers that have no paved public-use roads (i.e., no roads other than 4-wheel-drive or forest-service roads). All 30 of these wire centers were excluded from wired broadband-gap calculations; however, all areas with population were covered by the wireless calculations. In addition, due to insufficient demographic and infrastructure data to calculate baseline availability for Puerto Rico and the U.S. Virgin Islands in the Caribbean, and Guam, American Samoa and the Northern Marianas in the Pacific, these areas are excluded from further analysis.

CURRENT STATE

Although 123 million housing units already have broadband networks available that are capable of providing service that meets the National Broadband Availability Target of at least 4 Mbps download and 1 Mbps upload, many Americans do not. Currently, 7 million housing units representing 14 million people are left without broadband that meets the National Broadband Availability Target. See Exhibit 2-A.

Exhibit 2-A:
Highest Speed Capability of Available Wired Broadband Networks in the United States[1]

Considered "unserved" for the purposes of this paper

116,095 — 10+ Mbps
6,886 — 6 Mbps
126 — 4 Mbps
138 — 3 Mbps
597 — 1.5 Mbps
303 — 768 Kbps
1,783 — 384 Kbps
4,217 — No capability
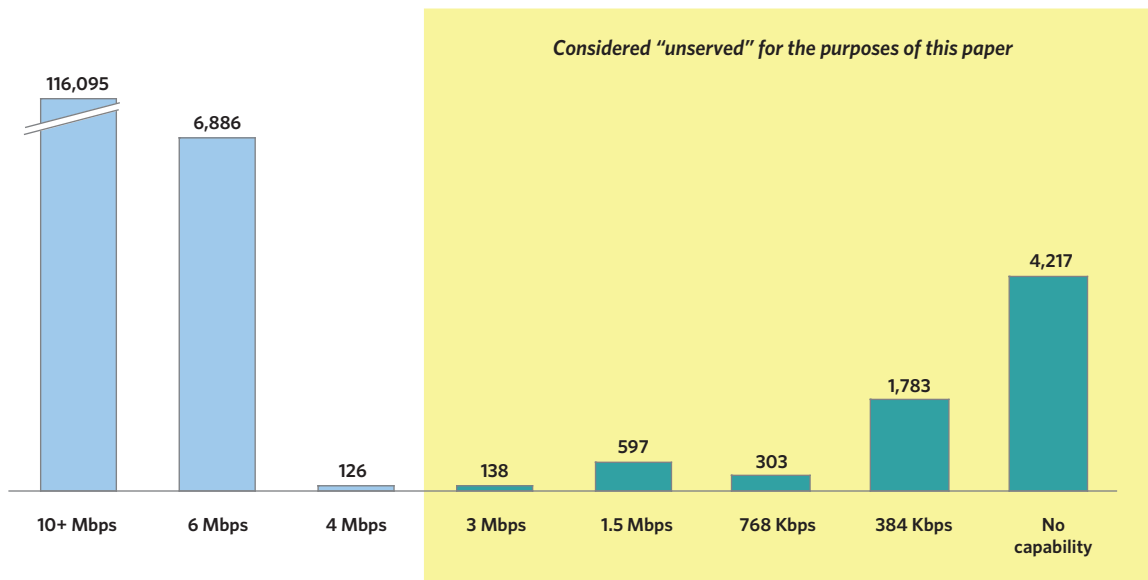
Housing units in thousands, downlink bit rate capability

Exhibit 2-B presents the distribution of these 7 million housing units across the United States. The number of unserved housing units in each county is calculated based on the methodology described below. That number is then divided by the total number of housing units in the county to get the percentage of homes served.

Exhibit 2-B:
Availability of Broadband Networks Capable of Meeting the National Broadband Target

Conterminous United States

Alaska

Hawaii

Legend

🟥	0%-5%	🟩	51%-60%
🟧	6%-10%	🟦	61%-70%
🟧	11%-20%	🟦	71%-80%
🟨	21%-30%	🟦	81%-90%
🟨	31%-40%	🟦	91%-95%
🟩	41%-50%	🟦	96%-100%

0094
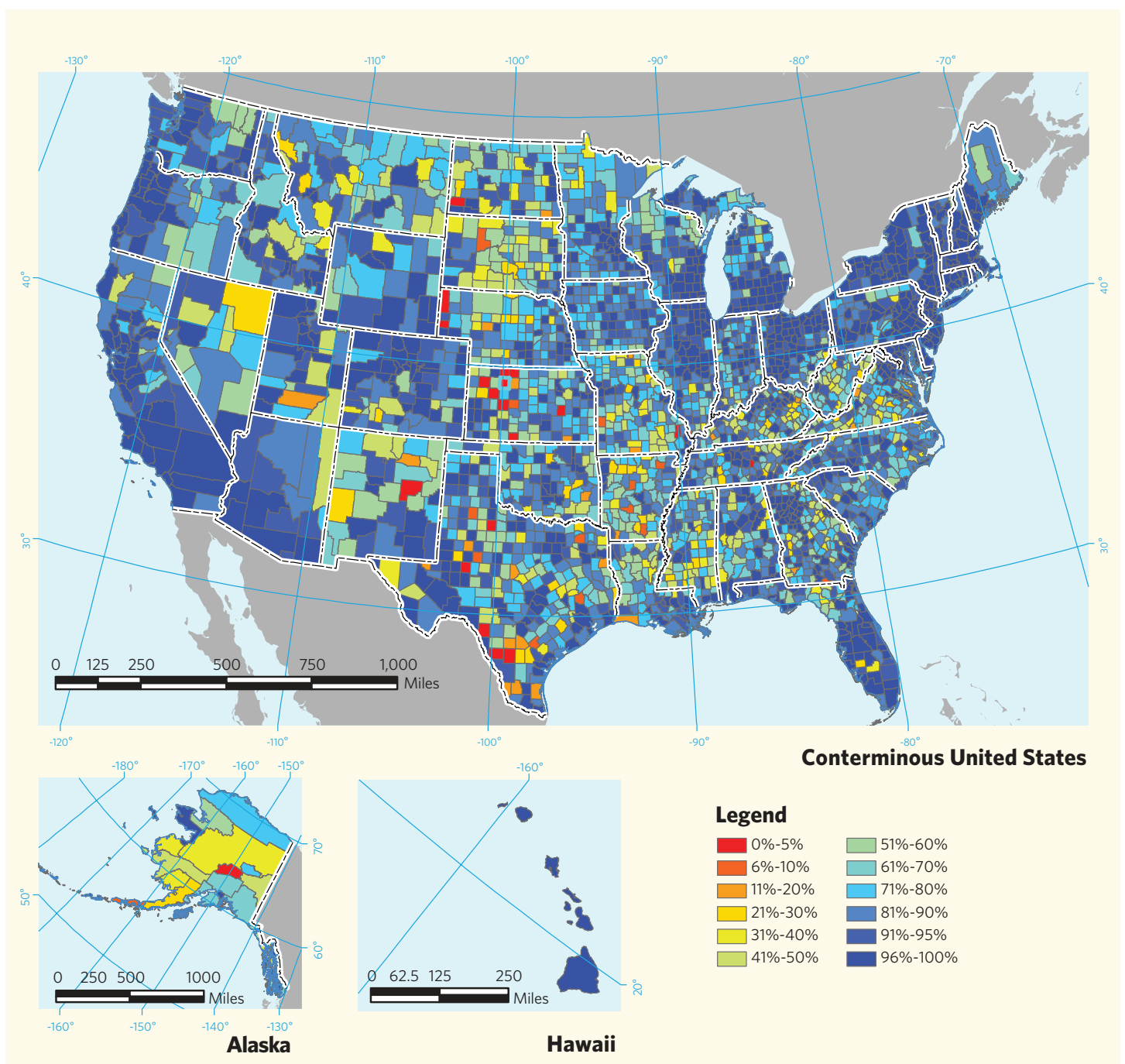
Purpose of the Analysis

Before determining the size of the Investment Gap, it is necessary to determine who is unserved as well as the adjacent broadband infrastructure that could be leveraged to serve them. The distance and density dependencies of both current availability and the cost of providing service to those who do not currently have it required that we take into account the geography of each unserved area at a very granular level. That, in turn, requires that we create a geographically based view of current networks and broadband capabilities in order to calculate the Investment Gap.

Our current-state model calculates the likely broadband performance from multiple technologies at the census-block level to determine the highest level of broadband service available for each census block nationwide.

This model serves two main purposes:

➤ It determines the number and location of housing units and businesses that do not have broadband infrastructure available that meets our performance target.
➤ It provides the location of network infrastructure that can be used as the foundation for building out broadband networks to these unserved housing units; these infrastructure data provide an essential input into the economic model.

Number and location of the unserved

Once the availability of each network technology is determined at the census block level, we determine the highest speed broadband service available for each census block nationwide. Using this speed availability data and the national broadband target, we are able to determine what census blocks are currently "unserved." Then using census data for each block, we are able to determine the number of unserved housing units along with the demographic characteristics of the unserved.

Due to higher network costs per home passed, most of the unserved are located in less dense and/or rural areas. Although more sparsely populated states tend to have a larger portion of residents that are unserved, nearly every state has unserved areas. When examining the population density of the entire United States as in Exhibit 2-C, not just the unserved, one can see that a large portion of the population lives in areas of relatively low population density.

The average population density of populated census blocks in the United States is 153.6 people per square mile, though approximately three quarters of the population lives in areas of lower density. Unserved census blocks have a much lower density, with an average of only 13.8 people per square mile. The population density of the unserved follows a similar pattern to that of the country, with some areas being far more rural than others (see Exhibit 2-D). These areas of extremely low

Exhibit 2-C:
Population Density of the United States, Per Square Mile of Inhabited Census Block

U.S. Average 153.6

Percent of Population
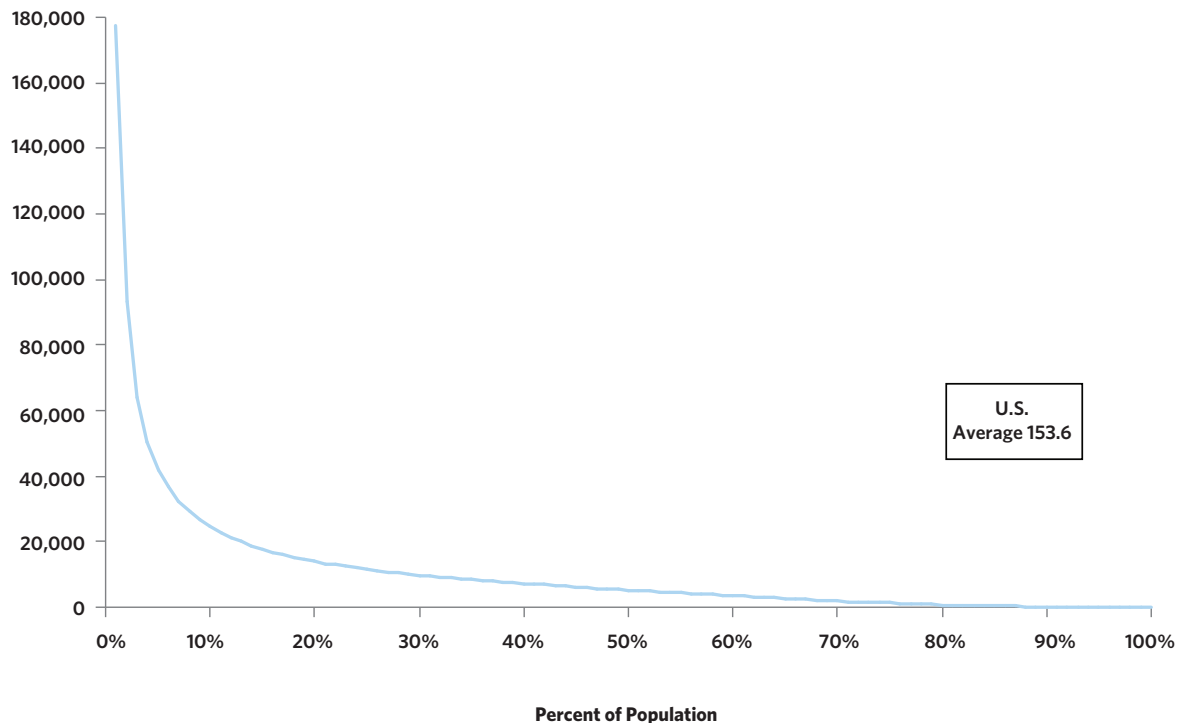
population density are some of the most difficult and expensive areas to serve.

The U.S. Census Bureau has categorized areas as urban areas, urban clusters and all other areas. Exhibit 2-E shows statistics of the unserved in terms of these definitions. As we can see, the deployment problem is one that predominantly exists outside of urban areas.

Since fixed broadband connects homes, not people, and most broadband networks are built along roads, either buried or on telephone/electric poles, an even more important driver of the cost to serve rural areas than population density is the number of road miles per housing unit of an area. Areas with more road miles per housing unit are even more likely to be unserved than areas of low population density. This is because the few homes in a rural area are sometimes clustered, which would decrease the number of road miles as well as the cost to serve.

The average number of road miles per housing unit in the United States is 0.07, which is much lower than the average unserved area of 0.41. But the average does not tell the whole story. A small portion of the population lives in areas with very high road-mile-to-housing-unit ratio, which tend to be the areas of the country that are unserved. Even within those unserved areas, there are portions that have an extremely high number of road miles per housing unit, which will be far more costly to serve than others. See Exhibits 2-F and 2-G.

Given the fact that the unserved are overwhelmingly in rural areas, one might expect that the unserved are in the territories of rural telecom companies. In fact, this is not the case: 52% of unserved housing units are in census blocks where one of the three Regional Bell Operating Companies, or RBOCs, (AT&T, Qwest or Verizon) is the dominant local exchange carrier; an additional 15% of unserved housing units are in census blocks

Exhibit 2-D:
Population Density
of the Unserved,
Per Square Mile of
Inhabited Census Block
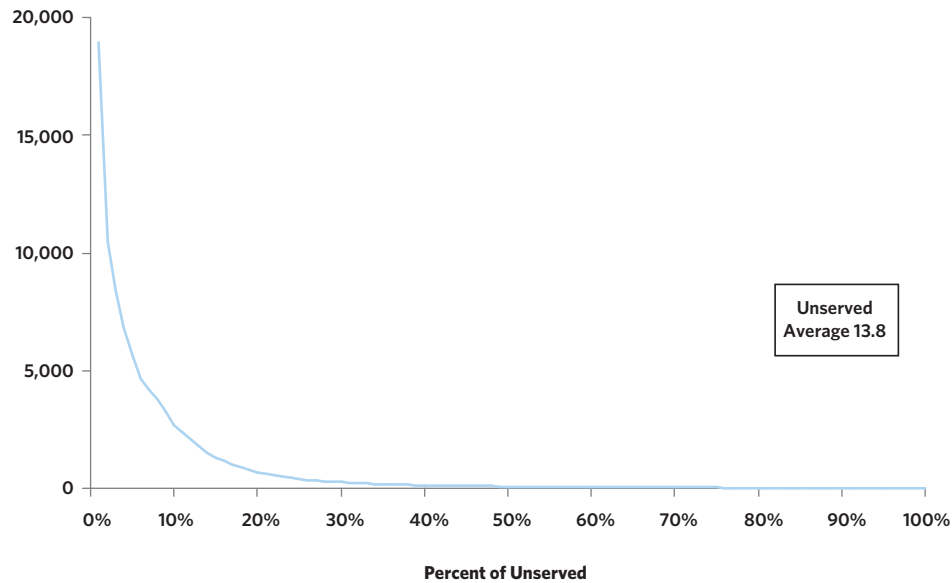
Exhibit 2-E:
Statistics of Urban
Areas/Clusters,
and All Other Areas

Categories	AveragePeople/Sq. Mile	% of Population Unserved	# of Unserved Housing Units	Total Housing Units
Urban Areas/Clusters	2,900	1%	.7M	100M
All other areas	19	20%	6.3M	30M
Total	153.6	5%	7.0M	130M

Numbers do not sum due to rounding.

0096

where a mid-size price-cap carrier is the dominant provider.[2] Only one-third of housing units are in census blocks where a rate-of-return carrier is the dominant provider.

Location of network infrastructure

We model each broadband network type independently to ensure a comprehensive view of infrastructure availability. Knowing where each type of network is currently deployed gives us the ability to calculate the incremental costs to upgrade the performance of an existing network as well as determine the likely location of middle and second mile fiber[3] that could be used to calculate the costs of deploying a new network.

There is a lack of comprehensive and reliable data sufficiently granular for the analysis we have described. To estimate the current state of broadband capable networks, we use the best available commercial and public data sources that meet our granularity, budget and timing requirements. We use infrastructure and speed availability data from a handful of states that were collected prior to the National Telecommunications and Information Administration (NTIA) mapping effort that is currently underway.[4] After evaluating numerous commercial data sets, we license the subset that best meets our needs.[5] We also examine Form 477 data and Form 325 data collected by the FCC but ultimately determine that these data are insufficiently granular.

The NTIA mapping effort will be complete in early 2011, and along with further revisions of the Form 477 data, they may be useful in refining our models in the future, but this will depend on the granularity of the data collected.

Network technologies modeled

The following sections include a description of our approach, data sources used, assumptions and risks for each of the three network technologies we modeled: cable, telco and wireless.

Cable

In order to determine broadband performance availability and infrastructure locations for cable networks, we use network availability data and estimated infrastructure locations based on cable engineering principles.

Data sources

In order to identify areas where cable broadband networks are located we license availability data from a commercial source[6] and collect publicly available infrastructure data from the state of Massachusetts.

We license a commercial data set from Warren Media called MediaPrints that provides data about nationwide availability of cable networks.[7] This data set includes geographic franchise boundaries as well as network capability information for cable

Exhibit 2-F:
Linear Density of the United States, Ratio of Road Mile to Housing Units

Road miles per housing unit of inhabited census blocks
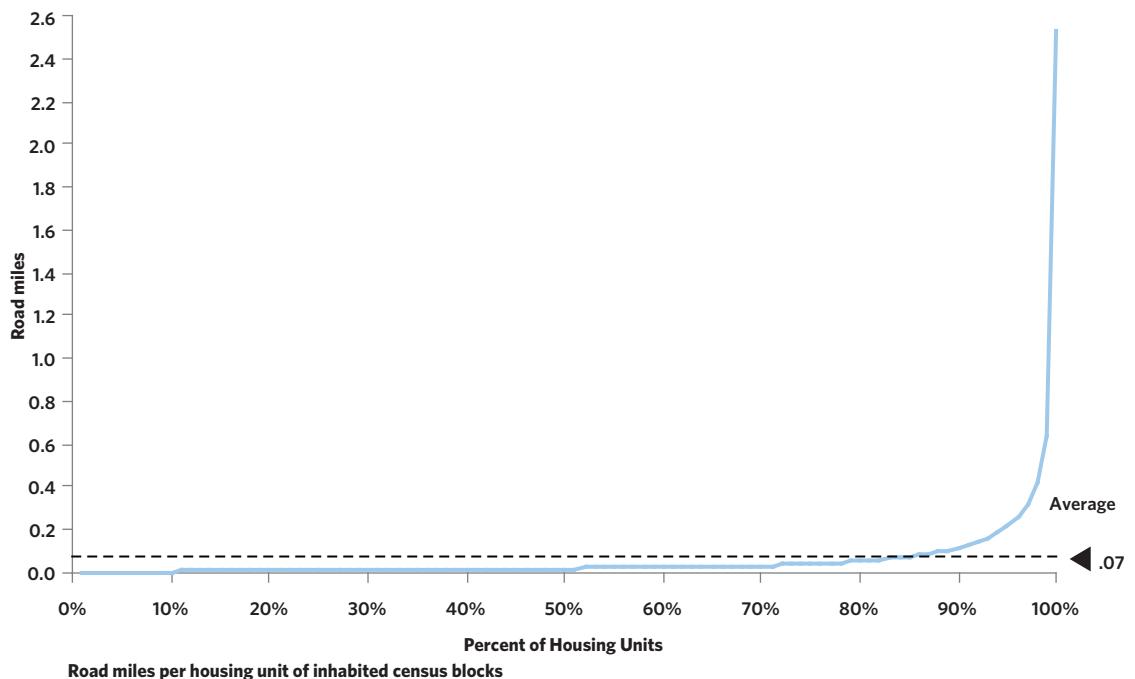
operators nationwide. We use network capability information to exclude franchise areas where operators are still operating networks that have not been upgraded to provide two-way broadband access— i.e., we rely on a field indicating that the cable operator provides Internet services. Without detailed data on the specific services offered by each cable system, we have to make assumptions about one-way and two-way cable plant. We assume that all two-way cable plant is DOCSIS-enabled since we estimate the incremental revenue of providing broadband would likely exceed the DOCSIS upgrade costs once a cable network has been upgraded to two-way plant. We assume that the cost of upgrading areas with one-way cable to a network that supports broadband is equal to a greenfield build (i.e., we treat areas with one-way cable plant the same way we treat areas unserved by cable). We are also aware that MediaPrints may not include every cable network, but we believe the ones it excludes are smaller and are more likely to be one-way plants.

Another limitation is that the MediaPrints data do not allow us to distinguish between areas that have been upgraded from DOCSIS 2.0 to DOCSIS 3.0. In the absence of a data source that identifies the areas where DOCSIS 3.0 has been rolled out, we resort to mapping only the markets where we were able to find public announcements about DOCSIS 3.0 deployments at the time of analysis. This method understates the number of homes passed by DOCSIS 3.0 especially since the DOCSIS 3.0 rollouts proceeded quickly even as the analysis continued. But given that DOCSIS 2.0 areas exceed the broadband target speed of 4 Mbps download and 1Mbps upload, this underestimation does not affect the number of unserved or, therefore, the Investment Gap.

We are not able to acquire cable infrastructure data aggregated by any commercial or public source other than in the state of Massachusetts. These data are of limited use in the state of Massachusetts and, as we explain below, are of limited value for our nationwide analysis.

Risks

As stated previously, we may underestimate the number of housing units served in some areas since MediaPrints does not have data for every cable system, but we believe this number is small. This underestimation may be balanced by the fact that broadband availability is likely slightly overstated in the areas where MediaPrints has franchise data; this is due to the fact that cable operators do not typically build out service to every housing unit in their franchise area. We do not believe this overestimation to be significant because even large cable operators with large franchise areas tend to build out broadband to the vast majority of homes passed.[8] See Exhibit 2-H.

Exhibit 2-G:
Linear Density of the Unserved, Ratio of Road Miles to Housing Units

Road-miles-per-housing-unit of uninhabited census blocks
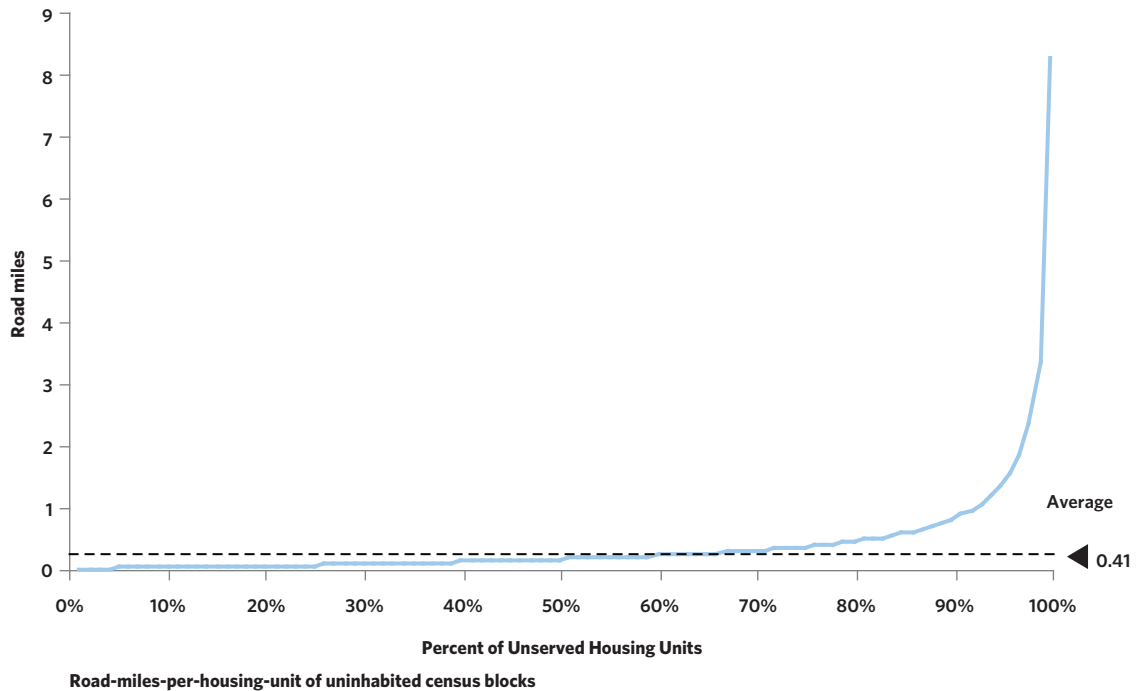
We attempt to correct for this overestimation by comparing the MediaPrints franchise boundaries with actual cable strand maps from the state of Massachusetts.[9] In Massachusetts, operators must provide strand maps to the franchise board, which then publishes them into the public record. Unfortunately, with limited actual information available, we are unable to do a comprehensive comparison. As a result, there is not a pattern to the overestimation that could be applied nationwide.

Capabilities

As discussed in the section on hybrid fiber-coaxial (HFC) technology later in this document, we assume broadband-enabled cable networks are capable of delivering at least 10 Mbps actual download speeds, and those that have been upgraded to DOCSIS 3.0 are assumed to deliver 50 Mbps actual download.

Telco

Since we are not able to acquire a nationwide data set of either availability as a functon of broadband speed or telco infrastructure, we have to take a different approach to model telco. For telco networks we take a five-step approach to calculating availability nationwide:

1. Map availability data in areas where these data are available
2. Use telco infrastructure and engineering assumptions to estimate availability in areas where infrastructure data are available
3. Create a multivariable regression equation using demographic data (the independent variables) to predict broadband availability (the dependent variable), using states where availability data are available as sources for the regression
4. Apply regression equation to areas of the country where only demographic data exist to estimate speed availability
5. Use engineering principals and assumptions to infer infrastructure for estimated speed availability

Data sources

Although a nationwide data set of broadband availability consistent with the 4 Mbps download target is not available, there are a few states that have published availability data at different performance levels. The analysis relies on availability data from the states of California, Minnesota and Pennsylvania, and a combination of availability and infrastructure data is used from the states of Alabama and Wyoming.[10]

Some nationwide telco infrastructure data are used in conjunction with engineering principles and performance availability to more accurately estimate infrastructure locations. These data include locations of telco network nodes, such as central offices and regional tandems, from the Telcordia's LERG database, wire center boundaries from TeleAtlas and location of fiber infrastructure from GeoTel and GeoResults.

In addition to performance availability data and infrastructure data, demographic data are in the regression. These data are based on census forecasts from Geolytics for consumers and GeoResults for businesses.

We are forced to use a statistical model for telco plant because we are not able to acquire a nationwide data source of availability or telco infrastructure locations. An ideal data set for these purposes would focus on actual speed available (not on demand or subscribership), would be geographically granular (to distinguish among service speeds at longer loop lengths) and would provide information about the location of infrastructure (to feed into the economic model).

Unfortunately, no available data source meets all these requirements. Telcordia states that the CLONES database has the locations of all relevant telco infrastructure nationwide, but the FCC was not able to negotiate mutually agreeable license terms.

Data from the FCC's Form 477 are useful for many types of analysis; but, given that Form 477 data are collected at the census tract level, they are not granular enough to accurately estimate service availability and speed as noted in the September 2009 Open Commission Meeting. In the upper left

Exhibit 2-H:
Cable Broadband Deployment for a Few Large MSOs as a Percentage of Homes Passed

Company	Cable Broadband Deployment (as of March 31, 2009)	Homes Passed (Millions)	Percent of Cable Homes Passed
Cablevision	100.0%	4.8	4%
Charter	94.9%	11.3	9%
Comcast	99.4%	50.6	40%
Mediacom	100.0%	2.8	2%
TWC	99.5%	26.8	21%

of Exhibit 2-I, we create an example of what perfect information on availability might look like. However, as noted in the lower left, Form 477 data provide information about the number of subscribers at a given speed, not the availability of service. Therefore, using Form 477 data to estimate availability requires making several assumptions as noted in the upper right of the exhibit. The result of these assumptions, as noted in the lower right, is that we are likely to overestimate the availability of service by relying on data collected at the census-tract level.

The ongoing efforts by states to map broadband availability, as coordinated by the NTIA as part of the Broadband Data Improvement Act[11] and funded by the Recovery Act,[12] may lead to a nationwide availability map that will be useful in this type of analysis, but the map will not be available until early 2011.

Statistical modeling where data did not exist

To estimate availability where no actual performance availability or infrastructure data exist, we create a regression equation that represents the relationship between demographic data and broadband availability data. The multivariable regression is based on more than 100 variables from population density to income levels to education levels. After determining how best to express the variables (in many cases by using their logarithms), initial models are estimated at all target speeds (ranging from 768 kbps to 6.0 Mbps) for each census block, using both forward and backward stepwise logistic regression. We use a logit regression rather than continuous so that we could use different variables and different weightings for each of

the target speeds. Separate regressions are made for different speeds (768 kbps, 1.5 Mbps, 3.0 Mbps, 4.0 Mbps and 6.0 Mbps) inside and outside the cable franchise boundaries, for a total of 10 logit regressions. Accuracy rates among the 10 models were typically between 80% and 90%. Additional information on development of these statistical equations can be found in Attachment 4 of CostQuest Model Documentation.

We then use that series of statistical equations to predict broadband availability (from telco networks) at different speeds in each census block based on their demographics. This availability estimate is used to help determine what census blocks are unserved. Next, we estimate the location of network infrastructure necessary to provide that predicted level of service according to the approach outlined below. The network infrastructure location information generated by this current state model is fed into the economic model so the costs of upgrading and extending networks can be estimated accurately.

Risks

As with any statistical method, there will be errors (either over- or under-predicting the availability at a given speed) in any single, particular, small geography. However, we believe the results should be correct in aggregate. Even though we are able to achieve accuracy rates between 80% and 90% when we apply the regression to areas of known performance, the main risk in this approach is the possibility of systematic differences between the states for which we have data and the states for which we do not.

Since the statistical regression relies on a small number of states, to the extent that the tie between demographics and

---

Exhibit 2-I:

Assumptions Required to Use Tract-Level Data Likely Overestimate Availability

It is unlikely that service is evenly distributed throughout a given census tract

- No DSL
- 768 kbps DSL
- 1.5 Mbps DSL
- 3-5 Mbps DSL
- 10 Mbps DSL
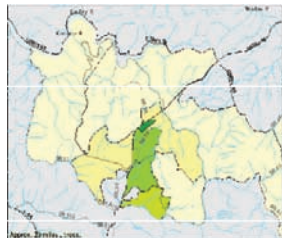
As a result, minimal assumptions are necessary in order to make any estimate

1. Service available anywhere in a tract is available to every housing unit (HU) in that tract

2. The speed provided to the highest-speed HU in each tract is available to every HU in that tract

Form 477 was not designed to address this distribution question

Census tract	Housing Units	Total ADSL subs	ADSL: 768k–1.5Mbps	ADSL: 1.5–3.0Mbps	...
3749265	1,229	208	6	97	

These necessary assumptions probably overstate availability

- No DSL
- 768 kbps DSL
- 1.5 Mbps DSL
- 3-5 Mbps DSL
- 10 Mbps DSL
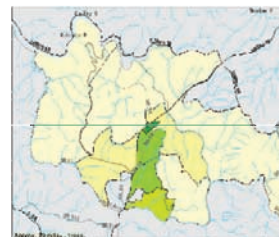
Sources: Census Bureau; March 2009 Form 477 data; OBI analysis

network availability in the rest of the country is not the same as these states, the regression will not be accurate. The states we used in our analysis have a wide variety of rural and urban areas and have varied geographic challenges which are advantageous, but there is no way to verify our outputs without additional data.

Aligning infrastructure with availability data

We estimate the current state of broadband-capable networks using speed availability data and infrastructure data. In the areas where we have infrastructure data we use engineering assumptions to estimate speed availability. In areas where we have availability by speed we use engineering assumptions to estimate the likely location of infrastructure. In this way we are able to estimate both availability by speed and infrastructure locations nationwide.

Exhibit 2-J illustrates these two approaches. On the right-hand side is an illustration of determining speed availability from infrastructure. Imagine that data indicate the presence of a Digital Subscriber Line Access Multiplexer (DSLAM) at No. 1. Using the location of the DSLAM as a starting point, we can trace out a distance along road segments that corresponds to availability for a given speed; for 4 Mbps service, that distance is approximately 12,000 feet.

On the left-hand side is an illustration of determining infrastructure from speed availability. Imagine that we have data for the area shaded in blue that indicates it has 4 Mbps DSL. We know then that homes can be a maximum of 12,000 feet from a DSLAM. Standard engineering rules, combined with clustering

and routing algorithms, allow the model to calculate the likely location of efficiently placed infrastructure. See CostQuest Model Documentation for more information.

Wireless

We rely on a nationwide data set of performance availability for wireless networks as well as infrastructure data in the form of tower site locations. With these two data sets we are able to estimate current availability as well as potential infrastructure locations that could be used to deploy into unserved areas. We do not create a full propagation model but rather, rely on coverage data to determine availability.

Data sources

In order to identify areas where wireless networks are located, we license a commercial data set from American Roamer. This data set provides wireless coverage by operator and by network technology deployed. The wireless technology deployed allows us to estimate the speeds available. As noted in the National Broadband Plan, American Roamer data may overstate coverage actually experienced by consumers as they rely on advertised coverage as provided by many carriers, who may all use different definitions of coverage. These definitions may differ on signal strength, bitrate or in-building coverage.

American Roamer only recently started mapping Wireless Internet Service Providers (WISP) coverage and estimates it has mapped only 20% of WISPs. We do not include WISP coverage in our model due to the current scarcity and reliability of the data.

Exhibit 2-J:

Aligning Infrastructure with Availability

1. Show availability
2. Determine infrastructure required to service

1. Plot known infrastructure
2. Determine availability from infrastructure
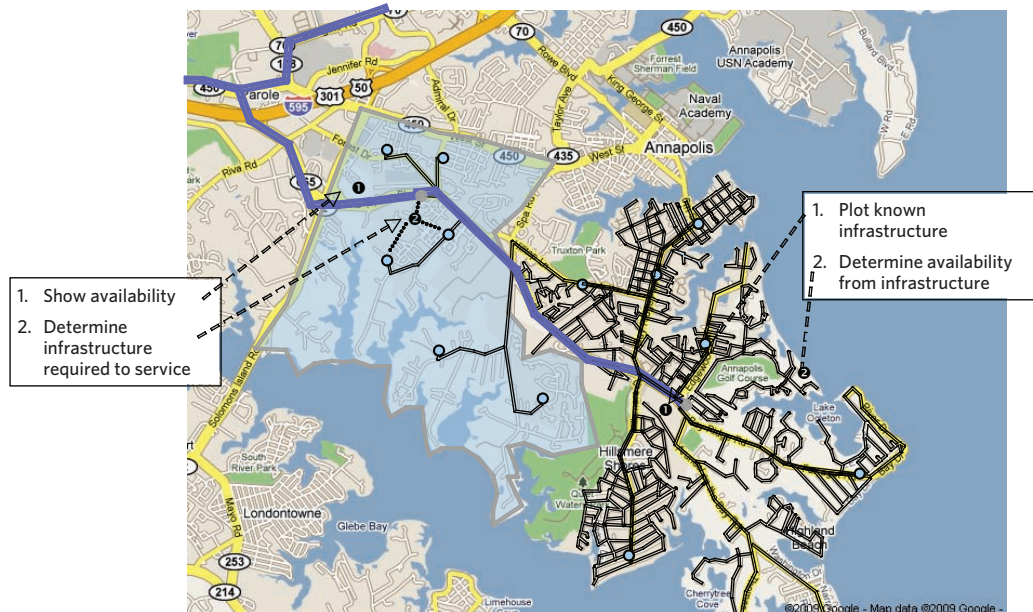
Like telco infrastructure, wireless infrastructure location information (typically towers) is fed into the economic model so the costs of upgrading and extending networks can be calculated accurately. We used Tower Maps data to identify the location of wireless towers in unserved areas that could be used for fixed wireless deployments.

Risks

We potentially overstate the current footprint because what is commercially available is typically based on carrier reported data, perhaps at relatively low signal strength. Overstating the current footprint could lead us to underestimate the cost of future wireless build outs to provide service to the areas currently unserved.

FUTURE STATE

We do not expect the number of unserved housing units to decline materially between now and 2013. Our analysis indicates that most unserved areas are NPV negative to serve with broadband, and so we have made the conservative assumption that there will be few new or upgrade builds in these areas. While significant investments are being made to upgrade the speed and capacity of broadband networks, those investments tend to be made in areas that are already well served. Moreover, those network upgrades are not ubiquitous throughout currently served areas. Therefore, as applications become more advanced and higher performance networks are required—i.e., if the broadband target grows significantly over time—the number of people with insufficient broadband access may actually increase.

Wired network upgrades

Both telephone and cable companies are upgrading their networks to offer higher speeds and greater-capacity networks.

Cable companies are upgrading to DOCSIS 3.0, which will allow them to transfer to broadband some of the network capacity that is currently used for video. Telephone companies are extending fiber closer to end-users, in some cases all the way to the home, in order to improve the capacity and speed of the network. Besides providing a faster, higher-capacity broadband network, once fiber is within approximately 5,000 feet of the home, the network has the ability to offer multi-channel video services in addition to broadband and voice.

The Columbia Institute for Tele-Information recently released a report called "Broadband in America" in which it tried to identify as many of the major publically announced network upgrades as possible. Verizon has announced that it plans to pass 17 million homes by 2010 with its fiber-to-the-premises (FTTP) service called FiOS.[13] Many other small incumbent local exchange carriers (ILECs) also plan to aggressively build FTTP networks where it makes financial sense.[14] AT&T has announced that it will build out FTTN to 30 million homes by 2011.[15] This means that at least 50 million homes will be able to receive 20 Mbps+ broadband from their local telco within the next two years. The cable companies have also announced upgrades to DOCSIS 3.0 over the next few years with analysts predicting cable operators will have DOCSIS 3.0 covering 100% of homes passed by the end of 2013.[16] Exhibit 2-K highlights some of the major publicly announced upgrades to wired broadband networks.

As shown in Exhibit 2-L, for proven technologies, when operators publically announce plans to upgrade their network, they tend to complete those builds on time.

Using these public announcements and our current availability assessment, we create a forecast of wired broadband availability in 2013. We assume that FTTP and upgrades will take place in markets with cable that will be upgraded

Exhibit 2-K:
Publicly Announced
Wired Broadband
Upgrades

Technology	Companies	2009	2010	2011
FTTP	• Verizon • Cincinnati Bell • Tier 3 ILECs	• All providers (17.2MM—as of Sept) • Verizon FiOS (14.5MM– as of June)	• Verizon FiOS (17MM)	
FTTN	• AT&T • Qwest	• Qwest (3MM)	• Qwest (5MM)	• AT&T U-verse (30MM)
DOCSIS 3.0	• Comcast • Cablevision • Cox • Knology • Time Warner • Charter • Mediacom • RCN	• Comcast (40MM) • Charter (St. Louis) • Mediacom (50% of footprint) • Knology (50% of footprint) • RCN (begin deployment)	• Comcast (50MM) • Cablevision (entire footprint) • Cox (entire footprint) • Time Warner (New York City) • Knology (entire footprint)	

Exhibit 2-L:
With the Exception of Satellite, Most Announced Broadband Deployments are Completed on Schedule
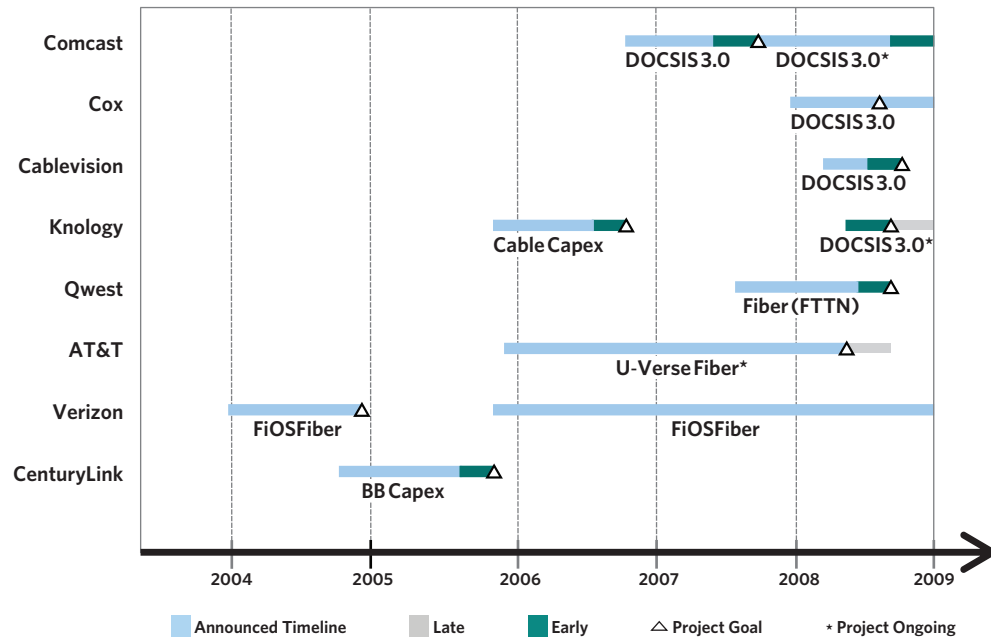
Exhibit 2-M:
Projected 2013 Availability of Broadband Capable Networks
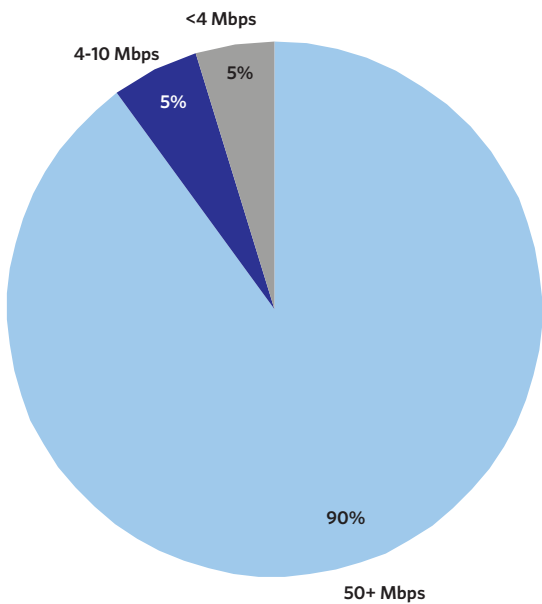
Fastest downlink speed capability of broadband networks

Percent of U.S. population with network availability, Mbps

to DOCSIS 3.0. Therefore, as Exhibit 2-M shows, all of the announced upgrades will likely take place in areas that were already served. Without government investment, the difficult-to-reach areas will remain unserved while the rest of the country receives better broadband availability.

Wireless network upgrades

The wireless broadband networks are still in the nascent stages of development and continue to evolve rapidly with new technologies, applications and competitors.

Many operators still have significant areas covered by 2G technologies but have already announced upgrades to 4G data networks. Mobile operators are investing heavily in network upgrades in order to keep pace with exploding demand for mobile data services.

By 2013, Verizon plans to roll out Long Term Evolution (LTE) technology to its entire footprint, which covered 288 million people at the end of 2008.[17] AT&T has announced that it will undertake trials in 2010 and begin its LTE rollout in 2011. Through its partnership with Clearwire, Sprint plans to use WiMAX as its 4G technology. WiMAX has been rolled out in few markets already and Clearwire announced that it plans to cover 120 million people by the end of 2010.

For well-known technologies, when operators publically announce plans to upgrade their network, they tend to complete

those builds on time. However, as was the case with WiMAX, when a technology is still being developed, technological issues can significantly delay planned deployments. LTE is an example of a new wireless technology that has not been deployed yet commercially on a wide scale so we must be cautious about planned deployment schedules.

As we discuss later in this document these commercial 4G build outs may not fully meet the National Broadband Availability Target without incremental investment; but the commercial investments in these deployments will certainly improve the incremental economics of 4G fixed wireless networks in those areas.

Due to the lack of geographic specificity and overlapping coverage areas we were not able to precisely forecast future wireless coverage speeds that will be available in years to come based on public announcements.

Satellite network upgrades

The capacity of a single satellite will increase dramatically with

the next generation of high throughput satellites (HTS) expected to be launched in the next few years. ViaSat Inc., which acquired[18] WildBlue Communications in December 2009, and Hughes Communications Inc. plan to launch HTS in 2011 and 2012, respectively.[19][20] These satellites each will have a total capacity of more than 100 Gbps, with some designated for upstream and some for downstream. After the launch of the new satellites, ViaSat expects to offer 2-10 Mbps downstream while Hughes suggests it will offer advertised download speeds in the 5-25 Mbps range.[21] Despite this additional capacity, our analysis suggests it will be insufficient to address more than 3.5% of the unserved. See Chapter 4 on satellite.

Conclusion

While such investments in technology and broadband networks may help bring faster speeds to those who are already served, and could potentially reduce the average cost per subscriber, it is far from certain that they will decrease the number of unserved.

Exhibit 2-N:
Publicly Announced 4G Wireless Deployments

Technology	Companies	2009	2010	2011	By 2013
LTE	• Verizon • AT&T • MetroPCS • Cox		• Verizon (100MM) • AT&T (Trials)	• AT&T (start deployment) • Cox (start deployment) • MetroPCS (start deployment)	• Verizon (entire network)
WiMAX	• Clearwire • Open Range • Small WISPs	• Clearwire (30MM) • WISPs (2MM)	• Clearwire (120MM)		• Open Range (6MM)

Exhibit 2-O:
Specific Company Historical Performance Against Announced Completion Dates
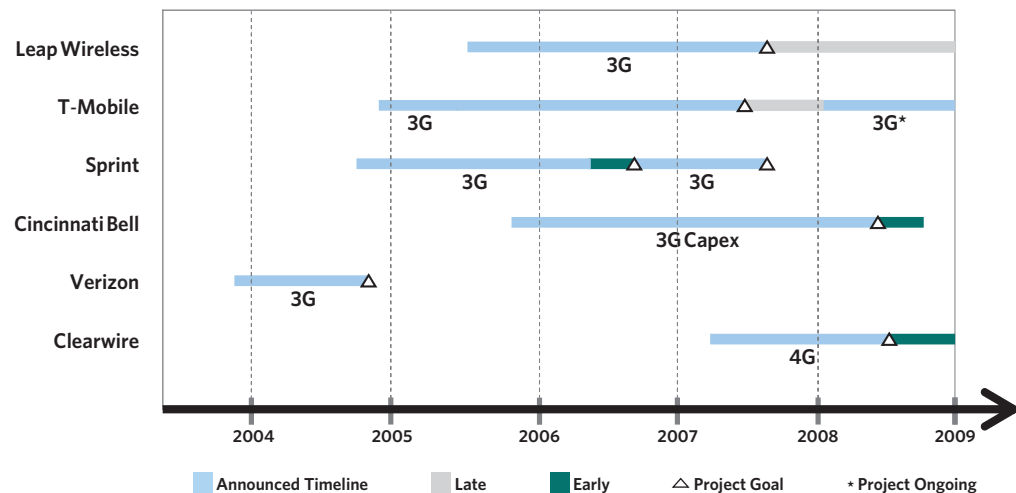
Exhibit 2-P:
Publicly Announced
Total Near Term
Satellite Broadband
Capacity[22]
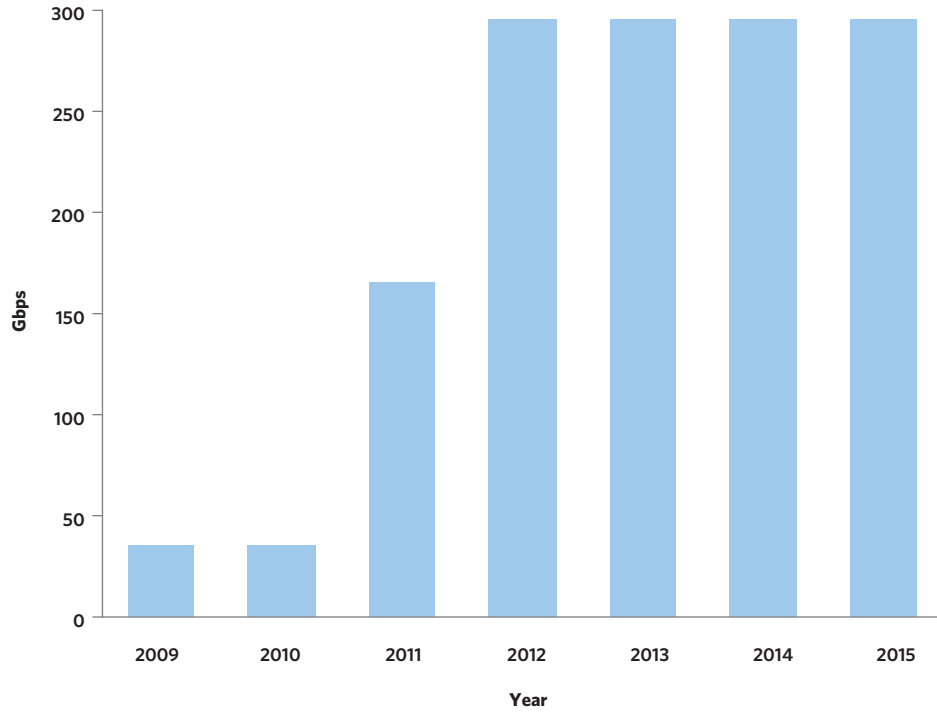
Exhibit 2-Q:
Commercial Data
Sources Used to
Calculate Availability

Vendor	Database	Use
American Roamer	Advanced Services	Wireless service footprint
Geolytics	2009 block estimates	Block level census estimates
	Estimates professional	Block group level estimates
GeoResults	National Business Database	Fiber served building (flag); business locations and demographics
GeoTel(imap)	MetroFiber	Metro Fiber Routes (GDT and Navteq)
	LATA Boundaries	Used for middle mile map to group switches into latas
	Fiber Lit Buildings (point)	Used to flag wire center boundaries as likely having fiber infrastructure
Telcordia	LERG	Switch office locations
TeleAtlas	Wire center boundaries	Wire center boundaries, domswitch, OCN, carrier name
	Zip code boundaries	Zip code boundaries
Tower Maps		Location of towers and sites
Warren Media	Warren Media	Cable-franchise boundary (by block group)

Exhibit 2-R:
Public Data Sources Used to Calculate Availability

Data Source	Database	Location
Alabama	State broadband availability	http://www.connectingalabama.com/ca/maps.aspx <http://www.connectingalabama.com/ca/maps/CBResults072909.zip>
California	State broadband availability	ftp://ftp.cpuc.ca.gov/Telco/Existing_Broadband_Service_Aggregated_072409.zip
Pennsylvania	State broadband availability	Available from Technology Investment Office
Minnesota	State broadband availability	Available from Technology Investment Office
Wyoming	State broadband availability	Available from State CIO
US Census	Tiger 2008	Blocks, Counties, Roads, Block Group Boundaries
	SF1	Summary File 1, US Census 2000
	SF3	Summary File 3, US Census 2000
FCC	Varies	Market Data Boundaries (adjusted for Census County Updates)
NECA	Tariff 4	PDF as filed 9/2009
Congressional Districts	110 Congress	http://www.nationalatlas.gov/atlasftp.html?openChapters=chpbound#chpbound

CHAPTER 2 ENDNOTES

1   DOCSIS 2.0 is capable of delivering ~10 Mbps, while DOCSIS 3.0 is capable of delivering ~50 Mbps. FTTN and FTTP can offer speeds well over 6 Mbps; however, the statistical-regression methodology used to estimate availability as a function of speed, combined with the source data for that regression, do not allow us to make estimates for telco-based service above 6 Mbps. *See* the Telco portion of this section for more detail.

2   Mid-size carriers include Alaska Communications Systems, CenturyLink, Cincinnati Bell, Citizens Communications, Consolidated Communications, FairPoint Communications, Hawaiian Telecom, Iowa Telecom and Windstream.

3   *See* Exhibit 4-BT for a description of middle versus second mile.

4   The Broadband Data Improvement Act (BDIA), Pub. L. No. 110-385, 122 Stat. 4096 (2008).

5   *See* Exhibits 2-Q and 2-R for a complete list of licensed data that we used.

6   *See* Warren Media MediaPrints database, http://www.mediaprints.com/index.htm (accessed Aug. 2009) (on file with the FCC) (Warren Media database).

7   *See* Warren Media MediaPrints database

8   ROBERT C. ATKINSON & IVY E. SCHULTZ, CO-LUMBIA INSTITUTE FOR TELE-INFORMATION, BROADBAND IN AMERICA: WHERE IT IS AND WHERE IT IS GOING (ACCORDING TO BROAD-BAND SERVICE PROVIDERS) at 57 (2009) ("CITI BROADBAND REPORT"), available at http://www4.gsb.columbia.edu/citi/.

9   Massachusetts General Laws Chapter 166A § 4 states, in part: "each applicant shall set forth as completely as possible the equipment to be employed, the routes of the wires and cables, the area or areas to be served." Upon its own investigation (Investigation of the Cable Television Division of the Department of Telecommunications and Energy on its Own Motion to Review the Form 100, CTV 03-3, November 30, 2004), the department (which became known as the "Department of Telecommunications and Cable" in April 2007) found, in part, at pages 18-19, that the statutory requirement referred to above is meant to promote "general use," and finds that "a strand map identifying the presence and location of the cable system within a specific community is sufficient to satisfy the statutory requirement." This order also finds that an issuing authority (a municipality) may request more detailed, technical information about a cable system than the cable plant map is required for general use, provided it is willing to enter into a non-disclosure agreement with the cable operator if requested.

10   Infrastructure data were not accessed by the FCC directly but were analyzed for the FCC by a contractor with access to these data.

11   The Broadband Data Improvement Act (BDIA), Pub. L. No. 110-385, 122 Stat. 4096 (2008).

12   American Recovery and Reinvestment Act of 2009, Pub.L. No. 111-5, § 6001(k)(2)(D), 123 Stat. 115, 516 (2009) (Recovery Act).

13   CITI BROADBAND REPORT AT 7.

14   CITI BROADBAND REPORT AT 7.

15   CITI BROADBAND REPORT AT 7.

16   T. McElgunn, "DOCSIS 3.0 Deployment Forecast," Pike & Fischer, 2009.

17   CITI BROADBAND REPORT AT 8.

18   On October 1, 2009, ViaSat announced it had signed a definitive agreement to acquire privately held WildBlue. On December 15, 2009, ViaSat announced the completion of the announced acquisition; see ViaSat, WildBlue Communications Acquisition Closes, http://www.viasat.com/news/wildblue-communications-acquisition-closes (last visited Feb. 12, 2010).

19   Letter from Mark Dankberg, Chairman & CEO, ViaSat, to Blair Levin, Executive Director of OBI, FCC, GN Docket Nos. 09-47, 09-51, 09-137 (Jan. 5, 2010) ("ViaSat Jan. 5, 2010 Ex Parte") at 2.

20   Letter from Stephen D. Baruch, Counsel for Hughes Communications, Inc., to Marlene H. Dortch, Secretary, FCC (Oct. 26, 2009) ("Hughes Oct. 26, 2009 Ex Parte") at 6.

21   CITI BROADBAND REPORT AT 57.

22   Note that this forecast only includes publicly announced launches and not additional, planned launches that are likely. *See* Northern Sky Research, How Much HTS Capacity is Enough? (2009), http://www.nsr.com/AboutUs/PressRoom.html (last visited Jan. 20, 2010).

III. CALCULATING THE INVESTMENT GAP

To calculate the amount of money required to offer service in areas that would otherwise remain unserved, we must make a number of decisions about how to approach the problem, design an analysis that accurately models the problem and make a number of assumptions to conduct the analysis. To this end, we created an economic model to calculate the lowest amount of external support needed to induce operators to deploy broadband networks that meet the National Broadband Availability Target in all unserved areas of the country.

KEY PRINCIPLES
The FCC developed its broadband economic model to calculate the gap between likely commercial deployments and the funding needed to ensure universal broadband access. Underlying the model's construction are a number of principles that guided its design.

➤ **Only profitable business cases will induce incremental network investments.**
➤ **Investment decisions are made on the incremental value they generate.**
➤ **Capturing the local (dis-)economies of scale that drive local profitability requires granular calculations of costs and revenues.**
➤ **Network-deployment decisions reflect service-area economies of scale.**
➤ **Technologies must be commercially deployable to be considered part of the solution set.**

Only profitable business cases will induce incremental network investments. *Private capital will only be available to fund investments in broadband networks where it is possible to earn returns in excess of the cost of capital. In short, only profitable networks will attract the investment required. Cost, while a significant driver of profitability, is not sufficient to measure the attractiveness of a given build; rather, the best measure of profitability is the net present value (NPV) of a build. This gap to profitability in unserved areas is called the Broadband Availability Gap in the NBP; throughout this paper, we will refer to this financial measure as the Investment Gap.*

The calculation of the $23.5 billion Investment Gap is based on the assumption that the government will not own or operate the network itself, but rather will provide funding to induce private firms to invest in deploying broadband. This is primarily because private firms can provide broadband access more efficiently and effectively due to their ownership of complementary assets and experience in operating networks. By subsidizing only a portion of the costs, the government provides the markets with the incentive to continue to innovate and improve the efficiency of buildouts and operations. In addition, since private firms will be investing a significant portion of the costs, the amount of public money required is greatly reduced.

Simply calculating the incremental costs of deploying broadband is not enough to determine the Broadband Investment Gap necessary to encourage operators to deploy. To ensure that firms seeking an adequate return on their invested capital will build broadband networks in unprofitable areas, we solve for the amount of support necessary to cause the networks' economics to not only be positive, but to be sufficiently positive to motivate investment given capital scarcity and returns offered by alternative investments.

The model assumes an 11.25% discount rate; by calculating the NPV gap as the point where NPV = 0, we equivalently set the internal rate of return (IRR) of these incremental broadband buildouts to 11.25%. This rate is the same one determined by the FCC in 1990 to be an appropriate rate for telecom carriers earning a rate of return on interstate operations.[1]

In order to determine the level of support needed to encourage operators to build broadband networks, we identify the expected cash flows associated with building and operating a network over the project's lifetime of 20 years. Next, we compute the NPV of those cash flows to arrive at the Investment Gap. In other words, the gap is the present value of the amount by which operators fail to produce an 11.25% IRR. It is important to note that ongoing expenses include incremental deployment and operational costs (initial capex, ongoing and replacement capex, opex, SG&A) as well as depreciation, cost of money and tax components for an incremental broadband investment; revenues include all incremental revenue from the modeled network with average revenue per user (ARPU) and take rates calculated as discussed below. As a result, when the NPV analysis yields a value of zero, it means that the project's revenues are sufficient to cover all expenses while providing a rate of return on invested capital of 11.25%.

In fact, if a carrier has a weighted-average cost of capital (WACC) above the 11.25% rate, even a guarantee to reach the 11.25% IRR would not cause it to build.

In contrast, if a carrier has a WACC lower than 11.25%, it will earn profits above the 11.25% IRR proportional to the size of the spread between WACC and discount rate. Having the IRR above WACC does not necessarily mean that operators are earning outsize returns, however. Since the support level is based on forecasts of both revenue and cost across the lifetime of the asset, carriers are taking on significant risk by investing

or committing to invest in network maintenance and operations. The extent to which IRR provides returns in excess of WACC reflects the operational risk of providing service in unserved areas, where the economics are generally unfavorable. Service providers are likely to have other investment opportunities with strong risk-return profiles at their WACCs.

One result of this execution risk is that carriers with WACC below the 11.25% discount rate might tend to favor a guaranteed annuity over time that would lock in the 11.25% return. Receiving support as an upfront payment, either in whole or in part, would require the operator to take on this higher execution risk, making the investment potentially less attractive.

After receiving the one-time payment, the telecom operators can reinvest the funds in their operations. Investments that yield a return above 11.25% will result in an economic benefit to the telecom provider.

Since the operators in any specific area, their associated WACCs and the disbursement mechanism are all unknown at this point, we make the simplifying assumption that carriers will be indifferent to receiving an upfront one-time payment, a series of payments over time or a combination of the two.

While the discount rate typically has significant impact on the NPV of a project, in this case the impact is mitigated for two main reasons. First, initial capital expenditures, which take place at the start of the project and, therefore, are not discounted, account for 65.1% of the Broadband Investment Gap. Second, because revenue and ongoing costs offset one another to a large extent (see Exhibit 1-A), the impact of changes in the discount rate is small. As shown in Exhibit 3-A, even significant changes in the discount rate (of up to 300 basis points) yield modest changes in the base-case Investment Gap of less than $1 billion.

Exhibit 3-A:
Impact of Discount Rate on Investment Gap

+ 3% (discount rate 14.25%)	23.1
Base case (discount rate 11.25%)	23.5
-3% (discount rate 8.25%)	24.2
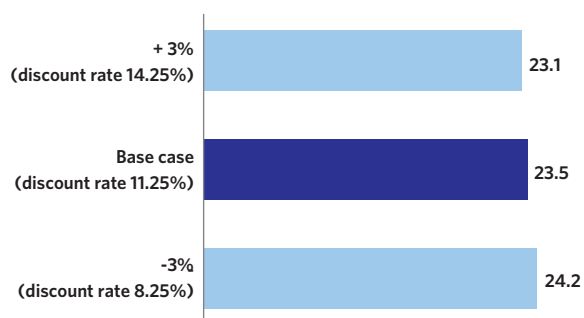
Time horizon for calculations

Calculating the value of long-life investments such as fiber builds or cell-site construction requires taking one of two approaches: explicitly forecasting and modeling over the entire useful life of the asset, or calculating either the salvage value of remaining assets or the terminal value of operations. Although neither choice is optimal, we use a 20-year explicit model period, which corresponds to the long-life assets in broadband networks. We do not include any terminal or salvage value at the end of a shorter explicit forecast period.

Calculating the ongoing terminal value of operations in this context is challenging at best since the modeled cash flows never reach a steady state. As we note below, when describing key assumptions, the take rate grows across the entire calculation period, and levelized take rate for a five- or 10-year forecast dramatically understates the final take rate. The result is that a terminal value calculation will not accurately reflect the ongoing value generated by the investment. Consequently, we must explicitly model over the full 20-year life of the network assets. Although utilizing a 20-year forecast is not atypical for businesses making capital planning decisions, such forecasts obviously require making speculative long-range assumptions about the evolution of costs and revenues.

It is also worth noting that the calculation models the value of an incremental broadband network investment, not the value of the company. Consequently, we assume that at the end of the 20-year explicit period there is no substantial value remaining for two reasons. First, from the accounting perspective—and based on an estimate of actual useful life[2]—most of the assets have been fully depreciated, and those that have some value remaining only have value in a fully operating network. Second, from a technological perspective, it is unclear that there will be any incremental value from the existing 20-year-old network relative to a greenfield build.

Investment decisions are made on the incremental value they generate. *While firms seek to maximize their overall profitability, investment decisions are evaluated based on the incremental value they provide. In some instances, existing assets reduce the costs of deployment in a given area. The profitability of any build needs to reflect these potential savings, while including only incremental revenue associated with the new network buildout.*

The model takes existing infrastructure into account and only calculates the incremental costs and incremental revenues of deploying broadband. This means that in most areas the costs of offering broadband are the costs associated with upgrading the existing telco, cable or wireless network to offer broadband. Exhibit 3-B illustrates the incremental buildout for a telco network. This minimizes support and is consistent

with how firms typically view the sunk costs of existing infrastructure.

The full cost of the network is necessary only in areas that require a greenfield build, i.e. in areas with a complete lack of infrastructure or when the greenfield build of one technology has a lower investment gap than upgrading an existing network. Revenues are treated the same way as costs. Only the incremental revenues associated with new services are used to offset costs in the calculation of the gap.

For example, millions of homes are already "wired" by a telephone network with twisted pair copper lines that provide voice telephony service. These telephone networks require only incremental investments to handle digital communications signals capable of providing broadcast video, broadband data services and advanced telephony. Incremental costs of upgrading these networks include investments in: fiber optic cable and optic/electronics in large portions of the copper plant, the replacement and redesign of copper distribution architecture within communities to shorten the copper loops between homes and telephone exchanges, the deployment of new equipment in the exchanges and homes to support high capacity demands of broadband, and sophisticated network management and control systems. The incremental revenues are the revenues associated with the newly enabled broadband and video services.

One issue with this approach is that it assumes that existing networks will be available on an ongoing basis. To the extent that existing networks depend on public support, such as USF disbursements, the total gap for providing service in unserved areas could be significantly higher than the incremental calculation indicates.

For the purposes of the financial model, we consider only incremental revenue, which is the product of two main components: the number of incremental customers and ARPU.

The number of incremental customers is based on the technology that is ultimately implemented. Throughout the modeling process, we take care to not "double-count" revenues for operators who upgrade their existing networks with broadband data or video capabilities. For example, if an incumbent telco decides to shorten loop lengths in order to deliver data and video services, only incremental data and video-related revenue should be considered. Incremental revenues from voice products will not be considered since those products are already being offered. Exhibit 3-C shows which products are considered to be incremental for each technology.

Capturing the local (dis-)economies of scale that drive local profitability requires granular calculations of costs and revenues. *Multiple effects, dependent on local conditions, drive up the cost of providing service in areas that*

Exhibit 3-B:

Incremental Network Elements Necessary to Upgrade a Telephone Network to Offer Broadband
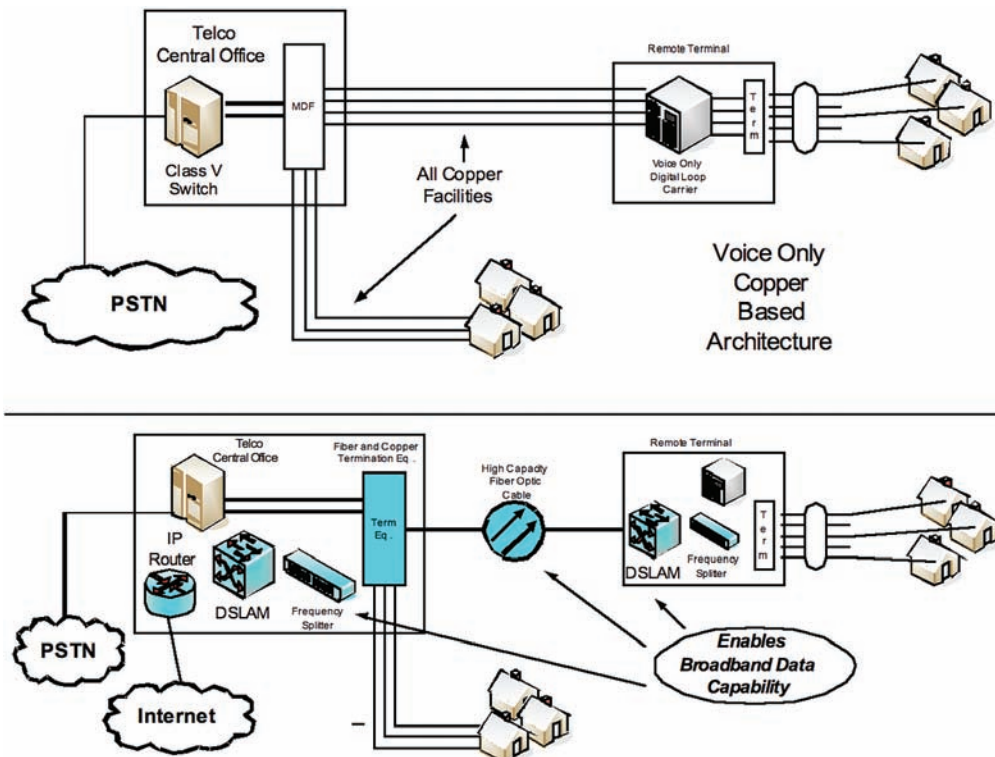
0111

currently lack broadband: Lower (linear) densities and longer distances drive up the cost of construction while providing fewer customers over whom to amortize costs. At the same time, lower-port-count electronics have higher costs per port. In addition, these lower densities also mean there is less revenue available per mile of outside plant or per covered area.

Using the average cost per household of existing deployments, even when adjusted for differences in population density, presents a risk that costs may be underestimated in rural areas. Even when considering local population and linear densities, costs in many rural markets will be subscale, rendering inaccurate a top-down analysis of average costs. Attempting to calculate profitability without taking these variations into account—for example by extrapolating from cost curves in other areas—would necessarily lead to questionable, or even misleading, conclusions. Therefore, we take a bottom-up approach that provides sufficient geographic and cost-component granularity to accurately capture the true costs of subscale markets.

An example of this is evident when we consider the cost allocation of a digital subscriber line access multiplexer (DSLAM) chassis in an area with very low population density. If only one home is connected to the DSLAM, the entire cost of that DSLAM should be allocated to the home rather than a fraction based on the DSLAM capacity. In order to calculate the costs with this level of accuracy, we need geographic and cost-component granularity throughout. Accounting for granularity with respect to geography is particularly important because so many network costs are distance dependent. Calculations are needed at a fine geographic level; therefore, we model the census block as the basic geographic unit of calculation.[3]

Capturing cost-component granularity is important due to the fixed-cost nature of network deployments. For example, one must capture the costs associated with trenching fiber facilities, which are shared among many end-users, differently than the cost associated with line cards and installation, which may be directly attributed to a given customer. We provide more details about the cost calculations of each technology in Chapter 4.

Network-deployment decisions reflect service-area economies of scale. *Telecom networks are designed to provide service over significant distances, often larger than 5 miles. In addition, carriers need to have sufficient scale, in network operations and support, to provide service efficiently in that local area or market. Given the importance of reach and the value of efficient operations, it can be difficult to evaluate the profitability of an area that is smaller than a local service area.*

Though geographic granularity is important in capturing the real costs associated with providing broadband service in rural and remote areas, it does not make sense to evaluate whether to build a network at the census block level. Rather, the modeling needs to capture deployment decisions made at a larger, aggregated "service area" level.

Using the census blocks as a market is problematic for several reasons. First, telecom infrastructure typically has some efficient scale length associated with it. For wireless, that distance is the cell-site radius; for FTTN or DSL the distance is the maximum loop length.[5] These lengths are typically 1 to 3 miles for twisted pair copper and 2 to 5 miles for wireless towers, and span multiple census blocks. As a result, carriers will make deployment decisions based on larger areas.

From a modeling perspective, evaluation at the census block level is problematic as well. Evaluations of which technology has the lowest investment gap done at the census block level could lead to contiguous census blocks with a patchwork of different technologies that no company would actually build.

Even more problematic is that the cost in any one area is driven in part by the costs of shared infrastructure. For example, the cost of a fiber connecting several new DSLAMs to the local central office is shared among all the census blocks served by those DSLAMs. If wireless were found to be cheaper in one of those census blocks and one, therefore, assumed that one of those DSLAMs would not be deployed, the (allocated) cost of the fiber would increase for all remaining DSLAMs. That could lead to another block where wireless is made cheaper, again increasing the cost of the remaining DSLAMs.

Exhibit 3-C:
Incremental Revenue by Product and Network Type

	Data	Voice	Video
Telco 12k	Yes	No	N/A
Telco 5k/3k/FTTP	Yes	No	Yes
Cable[4]	Yes	Yes	Yes
Wireless-Fixed	Yes	Yes	N/A
Wireless-Mobile (Non-4G)	Yes	Yes	N/A
Wireless-Mobile (4G)	No	No	N/A

There is no perfect solution to this problem. If the geography is too big there will be portions that would be more efficiently served by an alternate technology, but if the geography is too small it will be subscale, thereby driving up costs. Although the model is capable of evaluating at any aggregation of census blocks, in order to avoid a patchwork of technologies that are all subscale, we have evaluated the cost of technologies at the county level. Counties appear large enough in most cases to provide the scale benefits but not so large as to inhibit the deployment of the most cost-effective technology.

Note that this geography is also technology neutral since it is not aligned with any network technology's current footprint. No network technology boundaries line up exactly with those of counties. Cable networks are defined by their franchise area; wireless spectrum is auctioned in several different geographies, for example, by cellular market areas; and telco networks operate in study areas, LATAs or wire centers. Since the model is capable of evaluating at any aggregation of census blocks, it is possible to evaluate at more granular levels (where the patchwork problems become more likely) or at more aggregated levels.

Technologies must be commercially deployable to be considered part of the solution set. *Though the economic model is forward looking and technologies continue to evolve, the model only includes technologies that have been shown to be capable of providing carrier-class broadband. While some wireless 4G technologies arguably have not yet met this threshold, successful market tests and public commitments from carriers to their deployment provide some assurance that they will be capable of providing service.*

With the exception of 4G wireless, we only include technologies that are widely deployed and have proven they can deliver broadband. Although network technologies continue to advance, enabling operators to provide more bandwidth over existing infrastructure or to provide new services ever-more-cheaply, the promise surrounding technological innovation often outstrips reality.

To avoid a situation where we assume uncertain, future technological advances are essential to a particular solution— where the solution with the lowest investment gap is reliant on unproven technologies—this analysis focuses on technologies which have been substantially proven in commercial deployments. Over long periods, this may tend to overestimate some costs; however, a significant fraction of deployment costs are insensitive to technology (for example, the cost of trenching) while other costs are technology independent (for example, the cost of a DSLAM chassis would be independent of what type of DSL is being used), meaning that overall impact should be minimal.

One notable exception is our treatment of wireless. Our focus on wireless, whether for fixed or mobile, is on 4G technologies that have only just begun to be deployed commercially. Initial trials and our research with service providers and equipment vendors give us confidence in 4G's ability to provide the stated performance at the stated costs—enough confidence to warrant including 4G in our analysis.[6] In addition, because of the significant advancements of 4G relative to current capabilities and the widespread 4G deployment forecasts, we would run the risk of overstating the Investment Gap significantly if we were to exclude it from our analysis.

As noted in the CITI report[7], a significant fraction of areas served by wireless today are likely to be upgraded to 4G service by wireless operators without external (public) support.

Only one U.S. carrier, Clearwire, has deployed a mobile 4G (WiMAX) network commercially, making it difficult to know how much of the unserved population will be covered by 4G. For our model, we take Verizon's announced build-out as the 4G footprint because Verizon is the only operator that has announced precisely where its 4G builds will take place. Verizon has committed to rolling out 4G to its entire 3G service footprint (including those areas acquired with Alltel). The net result is that we assume 5 million of the 7 million unserved housing units will have access to 4G service (i.e., 5 million housing units are within Verizon Wireless's current 3G footprint, which the company has committed to upgrading to 4G).

No wireless carrier, including Verizon Wireless, has committed to offering service consistent with the National Broadband Availability Target. This uncertainty in the ability of wireless-network deployments to deliver fixed-replacement service points to the need for incremental investment by wireless carriers. Simply put, networks designed for relatively low-bandwidth (typically mobile) applications, potentially lack the cell-site density or network capacity to deliver 4 Mbps downstream, 1 Mbps upstream service.

Our calculations for 4G fixed wireless includes incremental investments sufficient to ensure networks capable of delivery consistent with the National Broadband Availability Target. See the section on wireless in Chapter 4 and the Assumptions discussion later in this chapter for more details.

KEY DECISIONS

Implicit within the $23.5 billion gap are a number of key decisions about how to use the model. These decisions reflect beliefs about the role of government support and the evolution of service in markets that currently lack broadband. In short, these decisions, along with the assumptions that follow, describe how we used the model to create the $23.5 billion base case.

➤ Fund only one network in each currently unserved geography.

➤ Capture likely effects of disbursement mechanisms on support levels.

➤ Focus on terrestrial solutions, but not to the exclusion of satellite-based service.

➤ Support any technology that meets the network requirements.

➤ Provide support for networks that deliver proven use cases, not for future-proof buildouts.

Fund only one network in each currently unserved geography. *The focus of this analysis is on areas where not even one network can operate profitably. In order to limit the amount of public funds being provided to private network operators, the base case includes the gap for funding only one network.*

The $23.5 billion Investment Gap is based on the decision, for modeling purposes, that only one network will be funded in each unserved area. The reason for funding only one network is to keep the amount of public money required to a minimum.

Alternative approaches that would fund more than one network per area—for example, funding one wireline and one fixed-wireless network—would increase the total gap significantly for several reasons. First, the gap must include the costs associated with building and operating both networks. Second, because the two providers are competing for the same

customers, each will have a lower take rate and, therefore, lower revenue.[8] While this lower revenue will be partially offset by lower variable costs—stemming from savings tied to costs like customer support and CPE—the net effect will be much higher costs per subscriber. For example, having both one wireline and fixed-wireless provider moves the Investment Gap up 45%, from $23.5 billion to $34.2 billion.

Funding two wireline competitors (instead of one wireline and one wireless) in these unserved areas has an even larger impact. Since only the first facilities-based service provider can make use of the existing twisted-pair copper network, the second facilities-based provider must deploy a more expensive, greenfield FTTP network (whether telco based or cable-based RFOG; see Chapter 4 discussion of FTTP and HFC). As shown in Exhibit 3-E, having two wireline providers in unserved areas shifts the investment gap to $87.2 billion.

While funding only one broadband provider in each currently unserved market leads to the lowest gap, this choice may carry costs of a different sort. In areas where a wireless provider receives support to provide both voice and broadband service, the incumbent wireline voice provider may need to be relieved of any carrier-of-last-resort obligations to serve customers in that area. In such a circumstance, it may be that only wireless operators will provide service in these areas. If, at some point in the future, the National Broadband Availability Target is revised in such a way that a wireless carrier can no longer economically provide service, a wireline provider may need to build a new, higher-speed network.

As noted above, competition impacts the take rate for each operator. In addition, we assume that competition leads to lower average revenue per user (ARPU). See Exhibit 3-F.

Exhibit 3-D:
Gap for Funding One Wired and One Wireless Network

19.2   11.0

26.0

34.2

| Cost of Wireline | Cost of Wireless | Revenue | Total |

(in billions of USD)
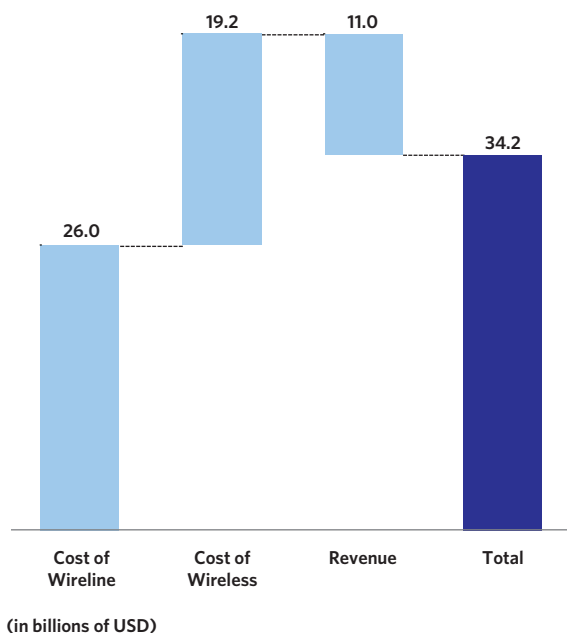
Exhibit 3-E:
The Cost of Funding Two Wired Networks

67.5   87.2

19.7

| 12k Gap | FTTP Gap | Total |

(in billions of USD, present value)
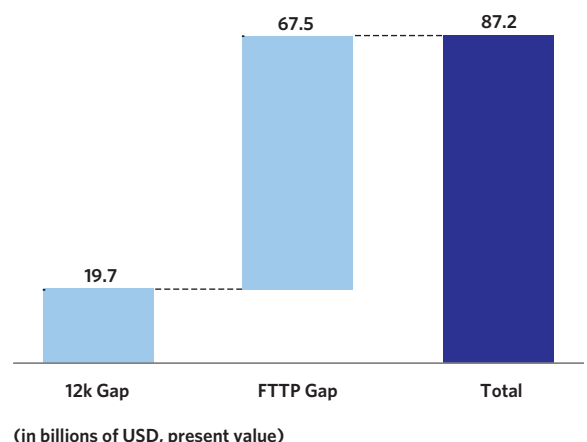
Since costs are calculated based on demand, reducing take rate will also reduce some costs. In particular, CPE costs are driven directly by the number of competitors. In addition, the cost of some network equipment, including last-mile equipment like DSLAMs, is sized according to the number of customers. This calculation will capture both the reduction in total cost and the increase in cost per user that comes from having fewer customers.

Exhibit 3-G shows the impact of competition on the investment gap for both 12,000-foot FTTN and wireless solutions. Remember that the base-case Investment Gap is calculated from a mix of technologies in markets across the country.[9]

Capture likely effects of disbursement mechanisms on support levels. *Decisions about how to disburse broadband-support funds will affect the size of the gap. Market-based mechanisms, which may help limit the level of government support in competitive markets, may not lead to the lowest possible Investment Gap in areas currently unserved by broadband—areas where it is difficult for even one service provider to operate profitably.*

A mechanism that selects the most profitable (or least un-profitable) technology in each area would minimize the overall size of the NPV gap. In highly competitive markets, market-based mechanisms, including reverse auctions, can play that role.[10] However, in unserved areas, where the economics of

providing service are challenging, the impact of market-based mechanisms is less clear.[11]

Since the incremental economics of deploying broadband for each technology depend on the infrastructure that is already deployed, there may only be a single operator capable of profitably deploying a given technology in a given area. In these cases where there are no competing bidders with similar economics, the bidder with the lowest investment gap may not bid based on its economics but rather the economics of the next-lowest-gap technology. In other words, the lowest-gap provider may be in a position to set its bid to be almost as high as the next lowest-gap competitor. Due to this reality, we have calculated the gap based on the second-lowest gap technology, so that we do not grossly underestimate the gap in these areas.

The lowest-gap provider may not always be able to extract the highest level of support because it may have imperfect information about its competitor's economics, or fear that it does. However, we believe calculating the gap based on the second-lowest gap technology is conservative and will be closer to reality in these markets.

A calculation of the gap, assuming the lowest-cost operator provides service to all currently unserved areas, is $8.0 billion. The gap assuming the second-lowest-cost-gap provider in unserved areas is $23.5 billion. Since wireless appears to be the lowest gap technology in most unserved markets, and there is

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Exhibit 3-F:
Quantifying the Treatment of Competition

	Reduction in ARPU*	Reduction in Take Rate
0 Competitors	0.0%	0.0%
1 Competitor	4.3%	50.0%
2 Competitors	14.8%	66.7%
3 Competitors	28.2%	75.0%

* average revenue per user

Exhibit 3-G:
Quantifying the Impact of Competition: Investment Gap by Number of Providers

12,000-foot loop

0 Competitors	16.3
1 Competitor	19.7
2 Competitors	21.2
3 Competitors	22.0

Wireless

0 Competitors	12.9
1 Competitor	14.5
2 Competitors	15.7
3 Competitors	16.5
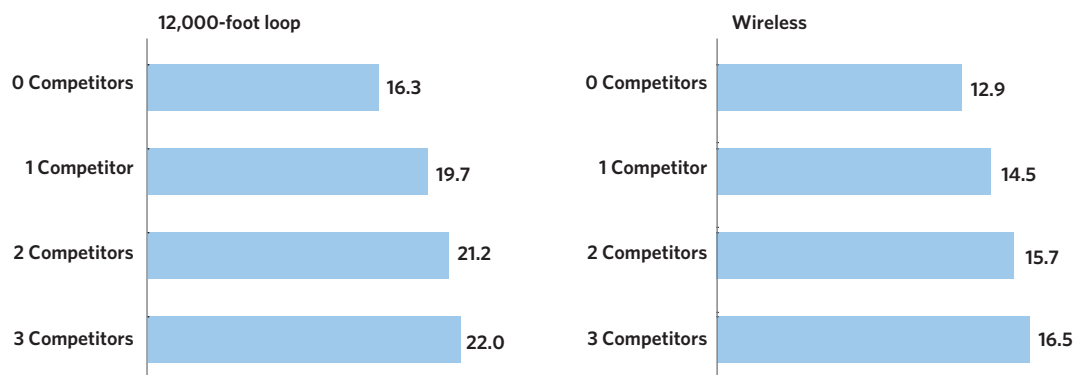
(in billions of USD, present value)

a large disparity in cost between the first and second wireline competitor, excluding wireless from the analysis has a disproportionately large effect on the gap. As noted previously, the second wireline competitor in an area will not be able to take advantage of existing last-mile infrastructure and will, therefore, need to deploy a network connection all the way to the home. As such, the second wireline competitor has much higher costs than the first. If wireless is not part of the analysis and the second-lowest-gap provider uses wired technology, the gap moves up to $62 billion.

Focus on terrestrial solutions, but not to the exclusion of satellite-based service. *Satellite-based service has some clear advantages relative to terrestrial service for the most remote, highest-gap homes: near-ubiquity in service footprint and a cost structure not influenced by low densities. However, satellite service has limited capacity that may be inadequate to serve all consumers in areas where it is the lowest-cost technology. Uncertainty about the number of unserved who can receive satellite-based broadband, and about the impact of the disbursement mechanisms both on where satellite ultimately provides service and the size of the investment gap, all lead us to not explicitly include satellite in the base-case calculation.*

The $23.5 billion Investment Gap calculation estimates the gap to providing service to all housing units in the country with terrestrial service, either wired or wireless. While it seems

likely that satellite will be an important part of the solution to the problem of serving the high-cost unserved, the current analysis includes only terrestrial solutions. Satellite has the advantage of being both ubiquitous and having a cost structure that does not vary with geography, making it particularly well suited to serve high-cost, low-density areas. Nevertheless, the focus of the model analysis remains on terrestrial providers.

While satellite is nearly universally available and can serve any given household, satellite capacity does not appear sufficient to serve every unserved household. In addition, the exact role of satellite-based broadband, and its ultimate impact on the total cost of universalizing access to broadband, depends on the specific disbursement mechanism used to close the broadband gap. The optimal role could be in serving housing units that have the highest per-home gap, or in ensuring that satellite can function as a ubiquitous bidder in a range of auctions. Moreover, while satellite firms can increase their capacity through incremental launches—noting that the current analysis includes all known future launches—the timing for bringing this capacity on-line may be problematic for closing the broadband gap, given the time required to design, build and launch a new satellite.

As noted in Exhibit 1-C, the most expensive counties have a disproportionately large investment gap. That same pattern—the most expensive areas drive a very high fraction of the gap—is repeated at smaller and smaller geographies. Exhibit 3-H shows the gap for all the unserved. The most expensive

Exhibit 3-H.
Broadband Investment Gap, by Percent of Unserved Housing Units Served

Percentile of U.S. housing units by gap
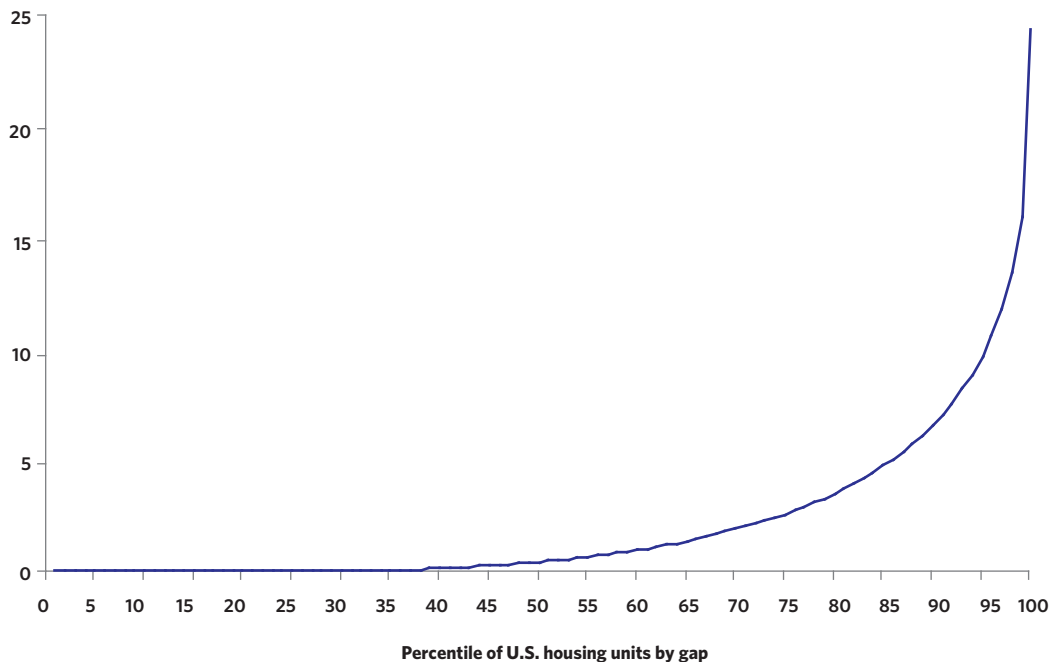
(Billions of USD, present value)

3.5% of the unserved (250,000 housing units, representing < 0.2% of all U.S. housing units) account for 57% or $13.4 billion of the total gap. Were that group served by, for example, satellite broadband, even with a potential buy-down of retail prices, the gap could be reduced to $10.1 billion.[12]

Increasing the number of homes not served by terrestrial broadband leads to diminishing benefit, however. Moving the most expensive 15% of the unserved off of terrestrial options yields a gap of $3.8 billion. In other words, the savings from moving the first 3.5% off of terrestrial options ($13.4 billion) is more than twice the savings from moving the next roughly 12%.[13]

Support any technology that meets the network requirements. *Broadband technologies are evolving rapidly, and where service providers are able to operate networks profitably, the market determines which technologies "win." Given that, there appears to be little-to-no benefit to pick technology winners and losers in areas that currently lack broadband. Therefore, the base case includes any technology capable of providing service that meets the National Broadband Availability Target to a significant fraction of the unserved.*

The purpose of the Investment Gap calculation is not to pick technology winners and losers, but to calculate the minimum gap between likely private investment and the amount required for universal broadband. Therefore, the model is designed to calculate the profitability of multiple technologies to understand the cost and profitability of each.

The focus on profitability—on minimizing an area's investment gap—will lead to calculating the gap based on the least unprofitable mix of technologies. However, this is not an endorsement of any technology over another, or a recommendation for serving demand in any given area with a specific technology.

Over time, it may be the case that several technologies' capabilities improve, or their costs fall, more quickly than has been calculated—in which case, multiple competing technologies could profitably serve demand with a subsidy smaller than the one we calculate. Also, individual providers may have, or believe they have, the ability to provide service more cheaply.

Ultimately, the model assumes that any technology that meets the National Broadband Availability Target will be eligible to provide service.

Provide support for networks that deliver proven use cases, not for future-proof buildouts. *While end-users are likely to demand more speed over time, the evolution of that demand is uncertain. Given current trends, building a future-proof network immediately is likely more expensive than paying for future upgrades.*

The calculation of the $23.5 billion Investment Gap is focused on ensuring universal delivery of broadband over the next decade. However, given historical growth rates, it may eventually be the case that networks designed to deliver 4 Mbps downstream/1 Mbps upstream will be incapable of meeting future demand. In such a case, additional investments

Exhibit 3-I:
Total Investment Cost for Various Upgrade Paths

12k - FTTP	FW - FTTP	12k - 5k - FTTP	12k - 3k - FTTP	5k - FTTP	FTTP
55.8	55.9	53.7	54.6	72.7	86.5

(in billions of USD, present value)
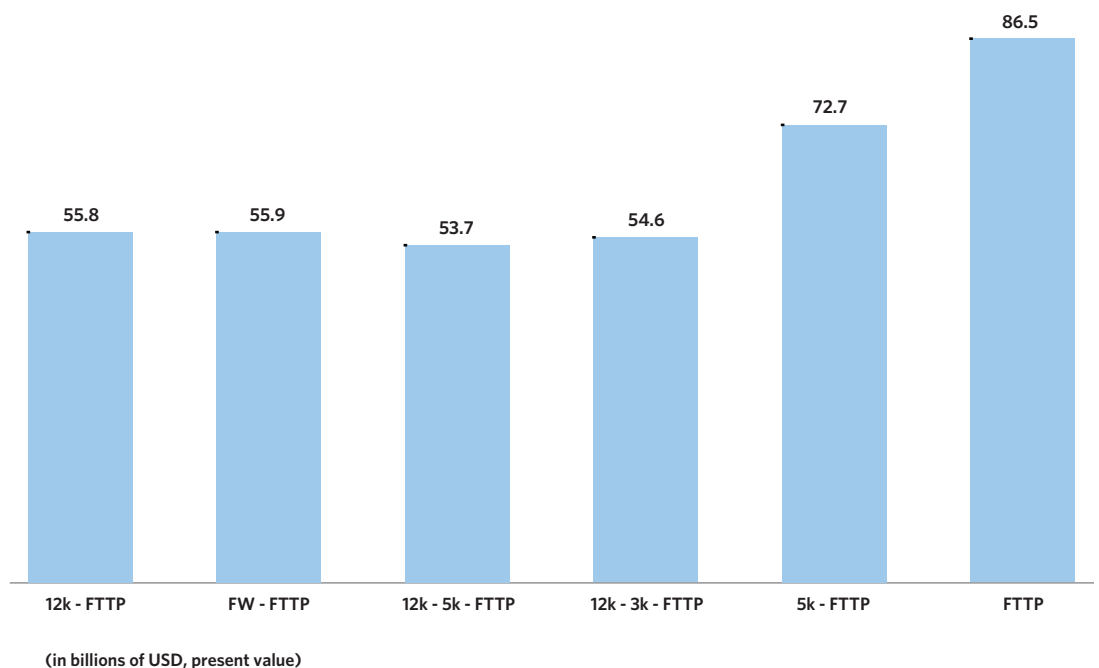
beyond those included in the $23.5 billion gap calculation might be required. Whether historical growth rates continue is dependent on a variety of factors that cannot be predicted. If, however, we make assumptions about growth over time, we can estimate the impact on deployment economics.[14]

For example, the growth rate in the speed of broadband in recent years of approximately 20% suggests that broadband networks might be called upon to deliver speeds higher than 4 Mbps (downstream) and 1 Mbps (upstream) across the next decade or more. Simply put: if required speeds continue to double roughly every three years, demand will outstrip the capabilities of 4G and 12,000-foot-loop DSL.

To account for the current investments as well as these potential future investments, we calculated the lifetime cost of different technology upgrade paths. We evaluate the cost of deploying different technologies including the cost of future upgrades driven by the evolution in network demand, discounted to today. Although the lowest lifetime-cost technology will differ by market, it is possible to calculate the costs associated with various upgrade paths for the unserved areas as a whole, as shown in Exhibit 3-I.

To calculate the total cost for potential upgrade paths, a number of assumptions are necessary. The most important assumptions are the growth rate in broadband speed and the amount of salvage value remaining in a network when it is upgraded. For this calculation, the broadband speed is set to 1 Mbps (downstream) in 2010 and is grown at a rate of approximately 26% per year. When a network is upgraded, the capex required for the upgrade is reduced by the salvage value of the existing network – an upgrade that makes use of many of the assets of the original build will be cheaper. For example, fiber runs used to shorten loops to 12,000 feet will defray the cost of further loop shortening.

In this lifetime-cost calculation, an initial FTTP build-out is the most expensive because none of the initial capex is discounted. Regardless of which path is chosen, deferring the FTTP build-out lessens the total cost burden due to the time value of money. A number of the wireline upgrade paths have similar results. Again, the main differences between these options are salvage value and time value of money, given the assumed broadband growth rate.

This approach disadvantages fixed wireless relative to the other technology paths. Since the calculation only takes into account the ability to provide fixed broadband service, when the requirements for bandwidth outstrip the wireless networks' capability to provide economical fixed service, this calculation assumes that there is no value in wireless networks once they are overbuilt. In reality, and not captured in the calculation, wireless networks would have substantial salvage value in providing mobile service; i.e., once wireless networks can no longer meet the demands of fixed broadband, they can continue

to generate value by delivering mobile services. This is in contrast to investments made in second-mile FTTN fiber that reduce the costs of future FTTP buildouts. However, despite this disadvantage, the fixed-wireless-to-FTTP upgrade path has the same total cost as the 12-kft-DSL-to-FTTP upgrade. Fixed wireless has lower initial capex; this lower capex offsets both higher opex for the wireless network and the cost savings from re-using fiber deployments made for a 12,000-foot-loop deployment. See, for example, Exhibits 4-W and 4-AK.

Note that this calculation is very sensitive to the growth rate assumed in required service speeds. If demand for speed grows only at 15% annually, the cost of the second upgrade path (fixed wireless upgraded to FTTP) drops by 23% as future upgrades are pushed out into the future and discounted further; these cost savings are partially offset by the higher opex of the fixed wireless network remaining in operation for more years. The cost of the first upgrade path (12,000-foot-loops upgraded to FTTP) drops even more, by 26%, as the FTTP investment is delayed.

KEY ASSUMPTIONS

Also implicit in the $23.5 billion gap are a number of major assumptions. In some sense, every input for the costs of network hardware or for the lifetime of each piece of electronics is an assumption that can drive the size of the Investment Gap. The focus here is on those select assumptions that may have a disproportionately large impact on the gap or may be particularly controversial. By their nature, assumptions are subject to disagreement; the section includes an estimate of the impact on the gap for different assumptions in each case.

➤ Broadband service requires 4 Mbps downstream and 1 Mbps upstream access-network service.
➤ The take rate for broadband in unserved areas will be comparable to the take rate in served areas with similar demographics.
➤ The average revenue per product or bundle will evolve slowly over time.
➤ In wireless networks, propagation loss due to terrain is a major driver of cost that can be estimated by choosing appropriate cell sizes for different types of terrain and different frequency bands.
➤ The cost of providing fixed wireless broadband service is directly proportional to the fraction of traffic on the wireless network from fixed service.
➤ Disbursements will be taxed as regular income just as current USF disbursements are taxed.
➤ Large service providers' current operating expenses provide a proxy for the operating expenses associated with providing broadband service in currently unserved areas.

Assumption: Broadband service requires 4 Mbps downstream and 1 Mbps upstream access-network service.[15]

This analysis takes the speed requirements of the National Broadband Availability Target as a given. That is to say that while there are ample analyses to support the target,[16] for the purposes of this analysis the required speed is an input. Below are some brief highlights from the research about speeds available and the impact of different assumptions about speed on the size of the financial gap.

Briefly, there are two independent but complementary approaches to setting the speed target for this analysis. The first approach examines the typical (median) user's actual speed delivered. As shown in Exhibit 3-J, median users receive 3.1 Mbps. In other words, half of all broadband subscribers currently receive less than 3.1 Mbps. These data are from the first half of 2009; based on growth rates (as described elsewhere), the median will likely be higher than 4 Mbps by end of 2010. Updated data from a smaller sample show a median of 3.6 Mbps in January of 2010.

The second approach is to examine the use of applications by end-users to determine what level of broadband speed is required to support that level of use. Typical usage patterns today correspond to the "emerging multimedia" tier shown in Exhibit 3-K, with a growing portion of subscribers being represented best by the "full media" tier. Advanced Telecommunications Capability, including high-speed video, would seem to require at least the 4 Mbps "full media" tier.

While this suggests that speeds as low as 1 Mbps might be sufficient, it is worth noting that demand for broadband speeds has grown quickly, as shown in Exhibit 3-L. In fact, broadband speeds have grown approximately 20% annually since 1997.

Taken together, the median actual speed subscribed (3.1 Mbps, approaching 4 Mbps by year end) and the applications usage (1 Mbps but doubling every three-to-four years) suggest that a download speed of 4 Mbps will provide an adequate target with headroom for growth for universalizing purposes. Although not "future proof," this headroom provides some protection against rapid obsolescence of a high sunk-cost investment.

The calculations in this document focus on the National Broadband Availability Target. However, we built the tool with sufficient flexibility to calculate the gap across a range of target performance levels.

For example, if consumers demand only 1.5 Mbps, fewer housing units would be considered unserved (i.e., those with service above 1.5 Mbps but below 4 Mbps would be considered to have service). In addition, at the lower speed a lower-cost technology, DSL with 15,000 foot loops, becomes viable.

Should consumers demand higher speeds, in contrast, more people would be considered unserved. At the same time, only technologies capable of delivering higher speeds will be part of the solution set (e.g., 3,000-or 5,000-foot-loop FTTN, or FTTP).[17] See Exhibit 3-M.

Exhibit 3-J:
Distribution of Users by Actual Maximum Download Speeds (Mbps)[18]
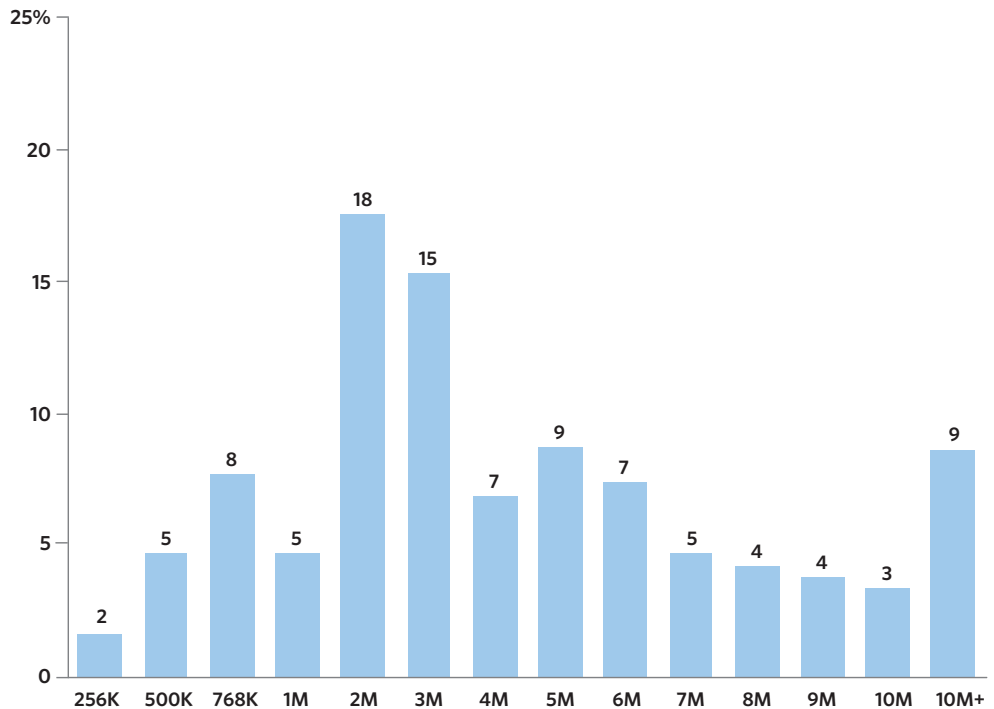
Exhibit 3-K:

Actual Download Speeds Necessary to Run Concurrent Applications (Mbps)
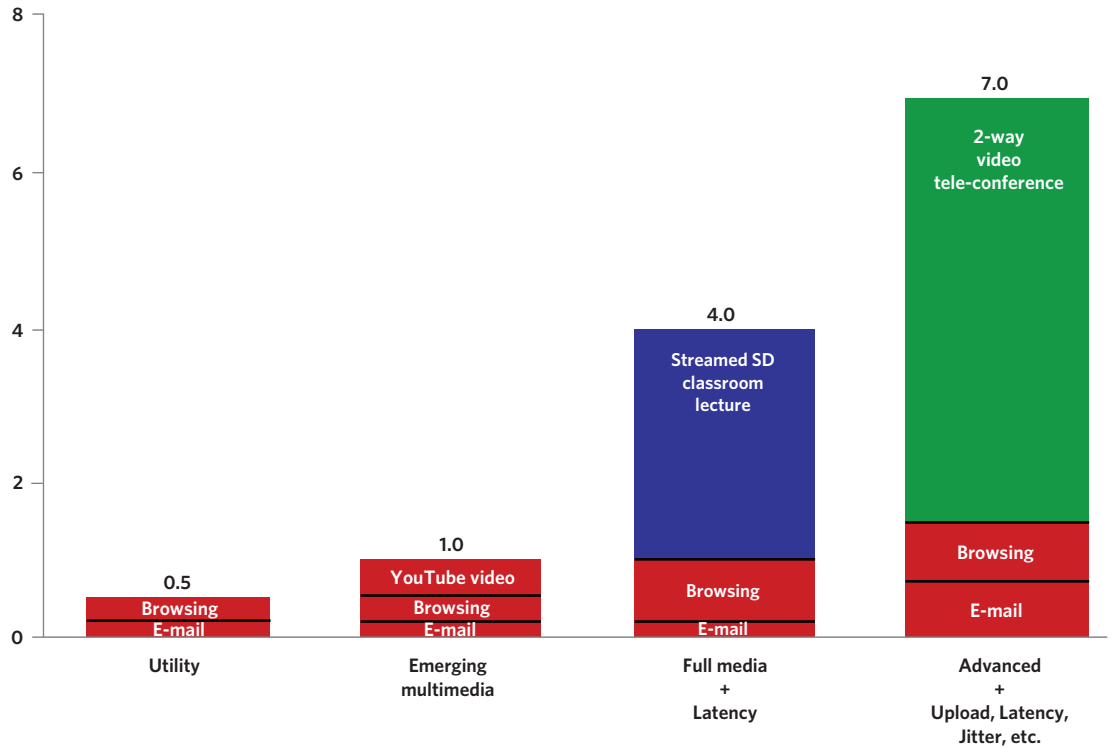
Exhibit 3-L:

Typical (Median) "Up To" Advertised Download Speeds of Most Commonly Deployed and Chosen Consumer Household Broadband (Mbps)

0120
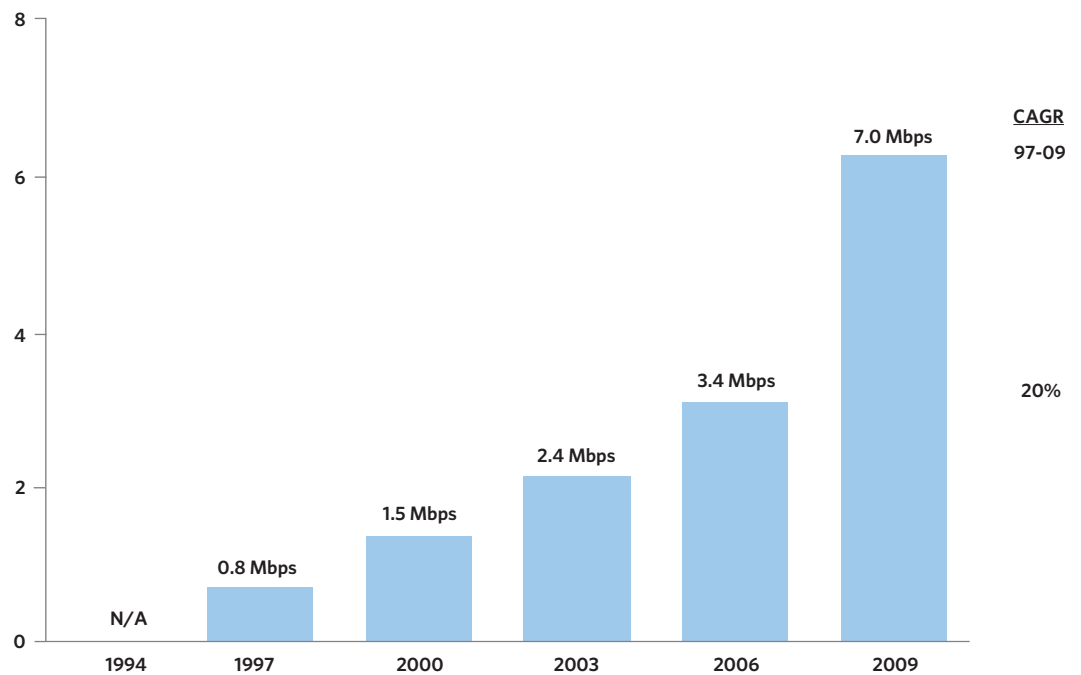
Assumption: The take rate for broadband in unserved areas will be comparable to the take rate in served areas with similar demographics.

We need a measure of adoption over time to understand how quickly operators would attract customers—and accordingly revenue—to offset costs. Moreover, to be consistent with the granularity we have built into the model, it is necessary to make adoption sensitive to demographics.

In order to determine penetration rates of new broadband deployments in unserved areas, we choose to perform a combination of several statistical and regression analyses. Our primary data source is a table of home broadband adoption metrics from the Pew Internet & American Life Project. Since 2001, the Pew Research Center has conducted extensive, anonymous phone surveys on broadband adoption in the United States, breaking out responses by various demographics. Its surveys reveal positive and negative correlation factors between certain demographic characteristics and broadband adoption.[19] The Pew study noted the most significant factors, which are shown in Exhibit 3-N, in order of importance.

We obtained the results of the Pew study on broadband adoption covering 19 survey periods from October 2001 to November 2009. These data aggregate adoption percentages in each period by race, income, education level, rural/non-rural and overall.

Preliminary findings of the data revealed that the trends in broadband adoption matched those of standard technology adoption lifecycles. Our approach to this analysis is to understand the shape and characteristics of the Pew adoption curves in an attempt to incorporate the results into a mathematical model, by which future broadband adoption, or adoption in currently unserved areas, could then be forecast. We begin by examining a popular mathematical model used to forecast technology adoption: the Gompertz model.[20] Exhibit 3-O explains the highlights of the Gompertz model.

Exhibit 3-P illustrates the cumulative characteristics of the Gompertz model as a percentage of the installed base:

From an *incremental* standpoint, the period-to-period technology adoption unfolds as shown in 3-Q.

Note the characteristic "inflection point"—that is, the point at which the incremental curve is maximized and the cumulative curve flips over.[21] The inflection point should be considered the point where technology adoption reaches its maximum growth rate.

Our analysis of the Pew data consists of fitting each demographic data breakout (overall, race, income, age, education Level, rural/non-rural) into a Gompertz curve using a least

Exhibit 3-M:

Dependence of the Broadband Investment Gap on Speed of Broadband Considered [22]

Broadband Speed (downstream)	Number of unserved HUs (millions)	Technology	Total cost ($ billions)	Investment gap per technology ($ billions)
1.5 Mbps	6.3	15,000-foot DSL	21.9	15.3
4 Mbps (base-case)	7.0	12,000-foot DSL	26.2	18.6
		4G wireless	18.3	12.9
6 Mbps	7.1	5,000-foot DSL	62.8	43.4
		3,000-foot DSL	76.9	57.3
50 Mbps	13.7	HFC/RFoG	124.9	85.0
100 Mbps [23]	130.0	FTTP	669.6	321.8

Exhibit 3-N:
Broadband Take-Rate Drivers

Positively Correlated	Negatively Correlated
Income greater than $100K	Less than high school education
Income between $75K–$100K	Senior citizen (65+)
College degree or greater eduction	Rural
	High school degree only

Exhibit 3-O:
Model for Technology
Adoption

Model	Equation	When Used	Examples
Gompertz	$y=e^{-e^{-b(t-a)}}$	When substitution is driven by superior technology, but purchase depends on consumer choice.	Digital television, mobile phones

Exhibit 3-P:
Modeled Cumulative
Adoption
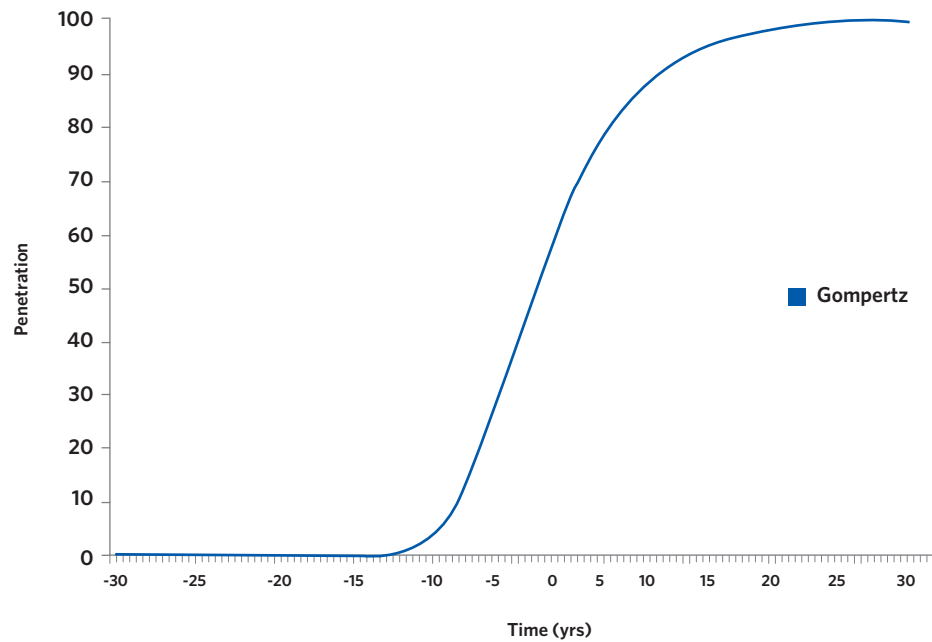
Exhibit 3-Q:
Incremental
Adoption

0122
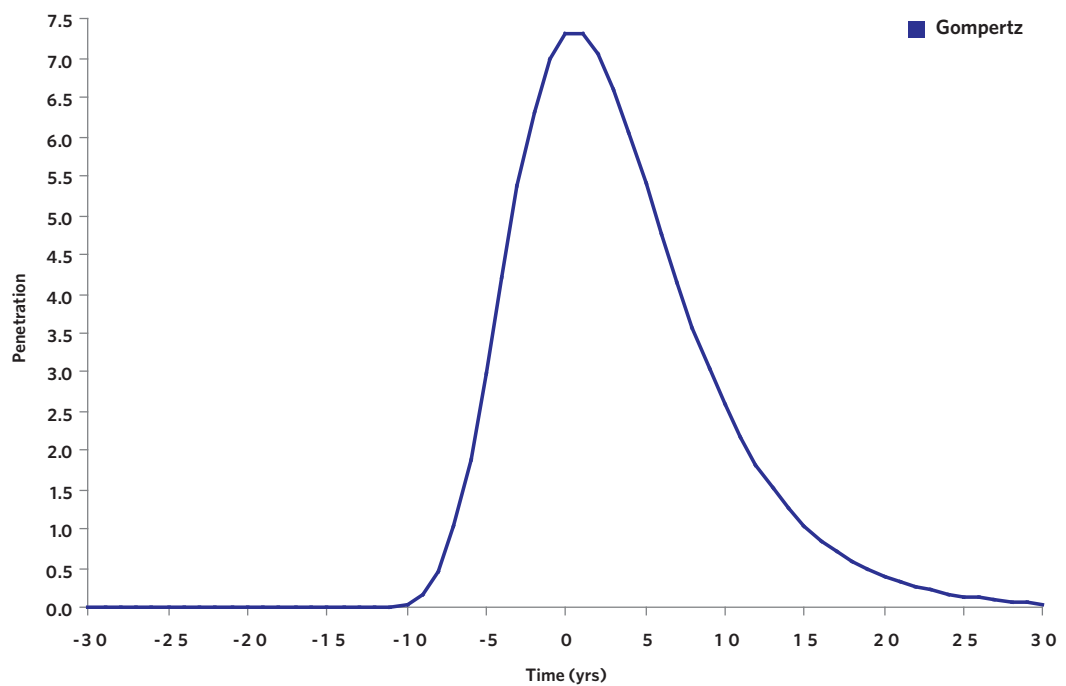
squares approach.[24] With a semiannual time period adjustment, the results indicated the Pew data segments can be fit on a corresponding Gompertz cumulative curve with very reasonable least squares accuracy. One such curve fit for a particular demographic (college graduates) is shown in Exhibit 3-R.

Our analysis provides us with Gompertz curves by each demographic in the Pew survey. However, consider that the Pew research starts with an arbitrary date of October 2001. This date does not presume the "start" of broadband in each surveyed area; it only represents the date at which surveys began. Therefore we must provide a time-based adjustment for every demographic curve. The solution we determine as most appropriate is to develop a series of demographic adoption curves relative to the overall adoption curve. Exhibit 3-S illustrates the relative Gompertz curve fits for every demographic segment. Here, the overall adoption curve inflects at zero on an adjusted time scale.[25]

Reinforcing the conclusions of the Pew study, the Income over $75K and College or Greater Education curves are farthest to the left (representing more rapid adoption relative to the mean), while the High School or Less, Rural and 65+ curves are farthest to the right (representing slower adoption relative to the mean).

It is worth noting that the Gompertz curves are based on adoption in areas across time, largely when broadband was first introduced—i.e., in greenfield areas. In brownfield deployments, however, builders are leveraging previous deployments to capture consumers who have already been educated on the benefits of broadband. We therefore allow for an additional time adjustment where brownfield builds are taking place.

These results provide relative Gompertz curves by every demographic measured in the Pew study; however for a number of reasons, we chose to limit the prediction model to only the demographic factors with the largest positive and negative correlation to broadband adoption. While it would technically be possible to measure adoption changes across all the available demographics on the Pew study, it does not improve results meaningfully to do so—either the remaining demographics had minimal influence on broadband adoption, or the demographic data in question were not readily available at the appropriate demographic level.

The demographic variables we chose to predict broadband adoption are the following:

➤ Income greater than $100K
➤ Income between $75K – $100K
➤ College degree or greater education
➤ Senior citizen (65+)
➤ Less than high school education
➤ Rural
➤ High school degree only

Using the Gompertz coefficients for each demographic, combined with demographic data at the census block level,[26] we can build Gompertz curves for every census block in the nation. To build these custom curves, we weight the demographic Gompertz

Exhibit 3-R:
Broadband Adoption Curve
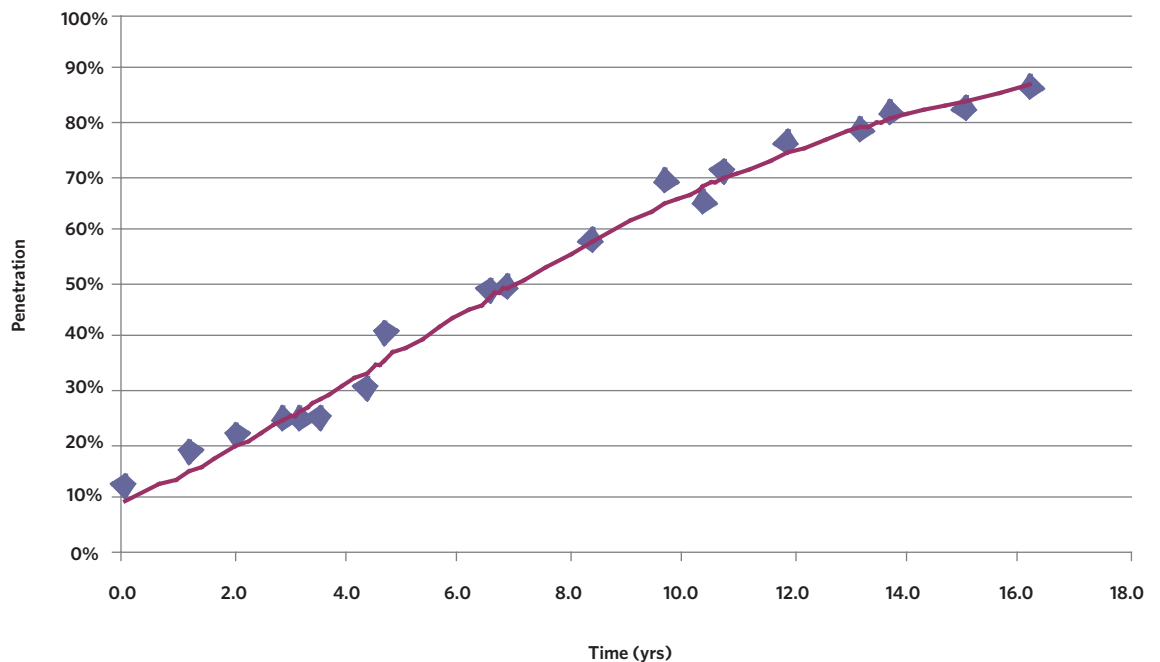
coefficients (a and b) by the incremental demographics prevalent in the area. For example, if the demographics within the overall curve show 18.5% of households have incomes above $100K, but a particular census block contains 20% of households with over $100K income, each "Over $100K" Gompertz coefficient would be weighted by the incremental difference (20% – 18.5% = 1.5%) and added to the overall Gompertz coefficient. By summing up the weightings off each significant variable, our Gompertz equation for each census block would take shape.

The additional step in forecasting broadband penetration rate is to determine how to factor in a brownfield effect, if any, into the census block time coefficient (a). If the census block is revealed to have a prior broadband deployment, the census block curve would be shifted left a designated number of periods. The number of periods to shift is held constant across all brownfield deployments.

The final step of developing the census block curve is to determine where to set the inflection point. The zero point on the horizontal axis scale is intended to represent the point at which the overall curve inflects, but the time at which the scale hits zero must be determined. We initially chose this scale to be two years from the start of deployment; essentially, the overall broadband adoption would reach its maximum growth rate in 24 months. To account for the initial mass influx of customers

in the first 24 months, we chose to start with zero subscribers at initial deployment, then trend towards the number of subscribers at 24 months by dividing them into four equal 6-month periods of subscriber adoption. After 24 months, the penetration rates reflected in the Gompertz curve would be in effect. The selection of an inflection point, while initially set at 24 months, is one that can potentially be re-examined and adjusted as needed.

Additional factors

The resulting census block penetration rate determines the standard broadband adoption rate for that census block. It does not, however, factor in the subscribers of related incremental services (e.g., voice, video), the effect of bundled services or the stratification of tiering (basic vs. premium). To account for each of these, we developed factors from which we could adjust the baseline number of expected broadband adopters in every census block. Each factor is discussed below.

Scaling factor

A scaling factor, in this instance, refers to a multiplying factor developed to predict voice and video subscribers by technology (DOCSIS, FTTP, FTTN and Fixed Wireless) based on the number of broadband subscribers.[27] The presumption is that

Exhibit 3-S:
Gompertz Curves for Broadband Take Rate With Demographics
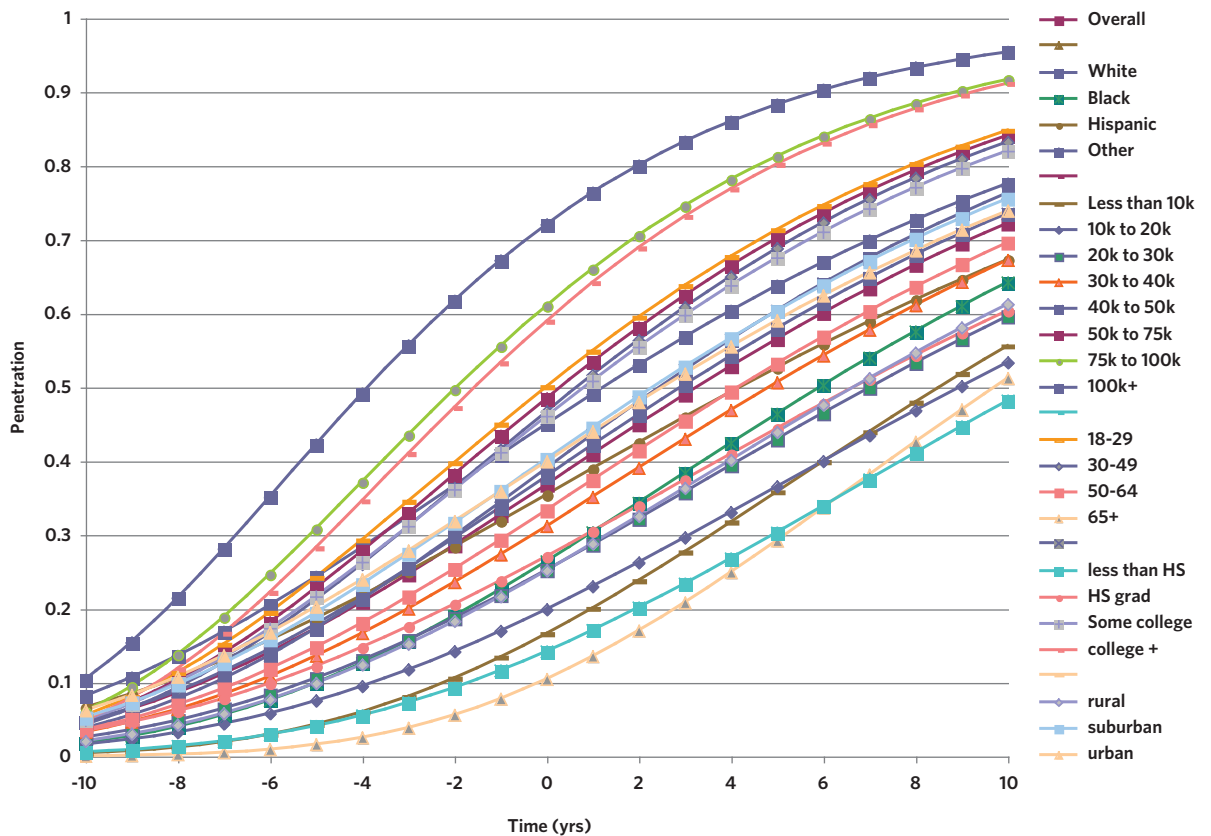
each technology exhibits a constant and unique relationship between broadband subscribers and subscribers to other services like voice and video. In other words, if one knows the number of broadband subscribers for a particular technology, one can predict the number of voice or video subscribers as well.

Bundling percentages

Customers who subscribe to broadband services belong to one of two groups: those that purchase a la carte, or those that purchase as a bundle. Industry analysis confirmed that the relationship between the two subscriber bases is relatively constant for each technology.[28] Using these data, we developed a "bundling" percentage based on the broadband subscribers, in order to arrive at the number of bundled subscribers. The number of bundled customers can then be subtracted from the total number of voice and video subscribers to arrive at the number of a la carte subscribers for each. The percent of users who take bundles for each technology is shown in Exhibit 3-T.

Tiering percentages

Tiering, in this case, refers to the tiered services offered by carriers. To limit unneeded complexity, we limit the number of tiers in the model to two levels: a basic introductory level of service and a "top-shelf" premium service. These low/high tiers are applicable to video (for example, basic vs. premium cable), data (entry-level vs. top speed) and even bundles. Using industry data we are able to develop percentages by technology that break out the respective service subscribers into low-end and high-end tiers.[29] These "tiering" percentages are then applied to the number of broadband, video and bundled subscribers to arrive at low-tier subscribers and high-tier subscribers for each.

Take-rate sensitivities

The Gompertz curve for data product penetration is driven by the demographics at the census block group level and is independent of changes in price. Treating broadband data products as relatively demand inelastic is consistent with the

recent findings by Dutz et al (2009), who estimated own-price elasticity for broadband in 2008 to be -0.69.[30] Despite these findings, it is important to understand the impact of adjusting the market penetration levels up and down to show the sensitivity of take rate on costs and revenues. Exhibit 3-U illustrates the impact on the overall private investment gap at different market penetration levels. Note that the bulk of the difference in the gap comes from changes in revenues rather than changes in costs.

Assumption: The average revenue per product or bundle will evolve slowly over time.

ARPU forecast

In order to develop a close approximation for ARPU, two main issues must be resolved. First, each product category (data, voice, and video) must have an individual ARPU value and the product bundle must also have an ARPU value. An additional level of sophistication, customer segmentation, is added by including a low and high version of the data, voice, video, and bundle product categories. Second, the current disparity in pricing between telco and cable voice products must be resolved.

The complexities of the market create additional challenges. Using estimates of current revenue streams may overestimate, perhaps significantly, the revenue available in the future. Both voice ARPU and the number of residential lines are under pressure from a confluence of technical evolution and new competitive models.[31]

In real terms, the average price of a residential access line has fallen since 1940 by about 50%.[32] Simultaneously, interstate and international per minute revenues have

Exhibit 3-T:
Assumed Percentage of Customers with Bundles

Data	Percent with Bundles
FTTN	65% (data, voice and video where appropriate)
Wireless	98% (data and voice)
Cable	40% (data, voice and video)
FTTP	67% (data, voice and video)

Exhibit 3-U:
Sensitivity of Gap to Take Rate

Take Rate +15%	22.9
Take Rate Base Case	23.5
Take Rate -15%	24.2

(in billions of USD, present value)
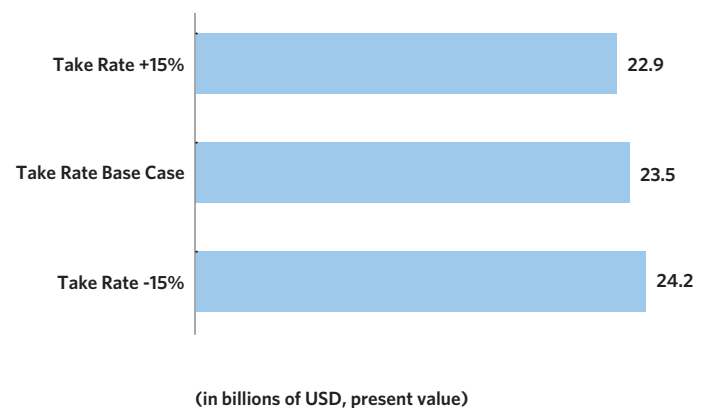
dropped steadily since 1985, even in nominal dollars.[33] These trends are the result of competition from wireless and cable, capacity expansion and the advent of Voice-over-IP (VoIP). As these drivers (especially VoIP growth) accelerate, voice ARPU is expected to continue to decline. To account for this market price shift, revenue attributed to incremental voice customers for telcos is set equal to the ARPU for a similar cable VOIP product.

Video ARPU may also be challenged in the years to come. The FCC's cable pricing survey indicates video ARPU has increased year-over-year since 1995 with 55-60% of that increase attributable to programming cost.[34] Cable's video business was protected from competitive threats for much of this historical period, which may change with the recent rise of telco, satellite and "over-the-top" (OTT) or Internet video offerings like Hulu and Netflix. Just as wireline telephone revenues and margins began to shrink after Congress mandated competition in the local telephone market in 1996, it is possible that video ARPU will come under pressure going forward.

Despite these downward trends in per-product ARPUs, annual spending on voice and video services has remained nearly constant as a percentage of total household spending. The annual Consumer Expenditure Survey by the Bureau of Labor Statistics and the FCC's Cable Industry Prices report shows that aggregate annual household expenditure for telephone (wired and wireless) and video has remained between 3.0% and 3.4% of total expenditures between 1995 and 2007.[35]

It is unclear how these trends will play out over time and whether a rise in data-services ARPU will offset expected erosion in voice and video ARPU. The ARPU assumptions in the model are based on a moderate view, where ARPUs evolve slowly over time. Model ARPUs are shown in Exhibit 3-V; note that these ARPUs are the levelized figures across the study time period.

Finally, a number of products either do not yet exist or do not have a long pricing history (e.g. fixed wireless LTE data services). While the average price per minute for a mobile voice call continues to fall or be replaced by unlimited plans, industry forecasts show continued growth in mobile data revenue.

As more and more consumers begin using mobile devices as broadband connections, the pricing dynamic between voice and data may shift. While this shift may take place, ultimately we believe the total ARPU per customer as noted above will remain relatively flat.

Drawing on the data and forecast methodology described above, we assume the ARPUs described in Exhibit 3-V.

ARPU sensitivity

Given the product dynamics and uncertainty around the evolution of ARPU in the future discussed above, we conducted a number of sensitivities for overall revenue to estimate the impact of a change in ARPU on the investment gap. Exhibit 3-W shows the change in the amount of support required when the ARPU is scaled up and down by a number of percentages.

Assumption: In wireless networks, propagation loss due to terrain is a major driver of cost that can be estimated by choosing appropriate cell sizes for different types of terrain and different frequency bands.

The cost of wireless deployment varies greatly based on terrain due to reduced propagation in areas with significant elevation change. Simply put: more mountainous areas are harder and more expensive to serve, a fact reflected in the existing wireless coverage of mountainous areas.

General principles for the design of a wireless network (discussed further in the wireless section of Chapter 4) can be used to calculate cell size in areas without geographic interference for a given frequency and required bandwidth. Determining the actual cost of a wireless deployment would require a tuned propagation model.[36] We take an approach somewhere between applying the general principles of wireless network design and a tuned propagation model to take into account the impact of terrain on cell sizes and therefore costs.

To try to capture some of these terrain dependencies, the model adjusts the cell size based on the ruggedness of the terrain. Flat areas are assigned larger cell radii, and therefore lower costs, while hilly and mountainous areas have smaller cell radii and higher costs.

Exhibit 3-V:
Summary of
Modeled ARPUs

	Voice	Data		Video		Bundle	
		Low	High	Low	High	Low	High
Telco	33.46	36.00	44.00	50.00	80.00	95.57	130.00
Cable	33.46	36.00	44.00	50.00	80.00	95.57	130.00
Wireless (4G footprint)	33.46	36.00	36.00	-	-	56.00	56.00
Wireless (non-4G footprint)	51.96	43.00	43.00	-	-	80.00	80.00

We are able to take into account the different costs across a variety of terrains by first calculating the cost associated with serving each populated census block in the country with two-, three-, five- and eight-mile cell radii—in other words, the total cost of a nationwide network build is calculated for each cell radius, with costs allocated down to census blocks. Census blocks are then aggregated into census tracts.

We then calculate the standard deviation of elevation in each census tract. See Exhibit 3-X to see the variation of elevation across the country.

Areas with high standard deviations have large elevation variability and require smaller two-mile cell sizes; flatter areas have lower standard deviations and are assigned larger cell sizes. See Exhibit 3-Y, which shows cell-size overlaid on the terrain map. The areas with largest cell sizes, indicated in dark blue, are primarily along the coasts and the Mississippi plain. Smaller cell sizes, in green and yellow, are in mountainous areas of the East (along the Appalachians and Berkshires) and in the West.

More detail about cell radii and the impact of wireless model assumptions can be found below in the section on wireless technology.

Exhibit 3-Z illustrates the results of making different assumptions about what cell sizes are appropriate in what kinds of terrain. The graph includes the cost of the wireless build; the gap associated with that build; and the overall gap, which because it is driven by the second-lowest-cost technology,

varies by less than 10%. In fact, we find that the percentage of unserved housing units served by wireless drops very little (to 89.1% from 89.9% in the most extreme case tested), thus explaining the relatively small impact terrain classification has on the overall investment gap. The analysis and assumptions that led to Exhibit 3-Z are discussed more fully in Chapter 4 (leading up to Exhibit 4-Y).

Assumption: The cost of providing fixed wireless broadband service is directly proportional to the fraction of traffic on the wireless network from fixed service.

The presence of commercial wireless 4G buildouts in areas unserved by terrestrial broadband today can have a major impact on cost and the investment gap. Such commercial buildouts are driven by each company's strategic plans, meaning that the builds could be profitable on their own (i.e., that mobile revenue tied to that location exceeds the cost of deployment), or could be important for other reasons (e.g., to differentiate based on network coverage or to reduce dependence on roaming partners).

Regardless of why such networks are built, their presence has a dramatic impact on local wireless-network economics, since the costs of providing fixed-broadband service will be lower for a service provider that already operates a network that provides mobile services. At issue is the fraction of the total cost required to upgrade commercial buildouts designed

Exhibit 3-W:
ARPU Sensitivity

(in billions of USD, present value)
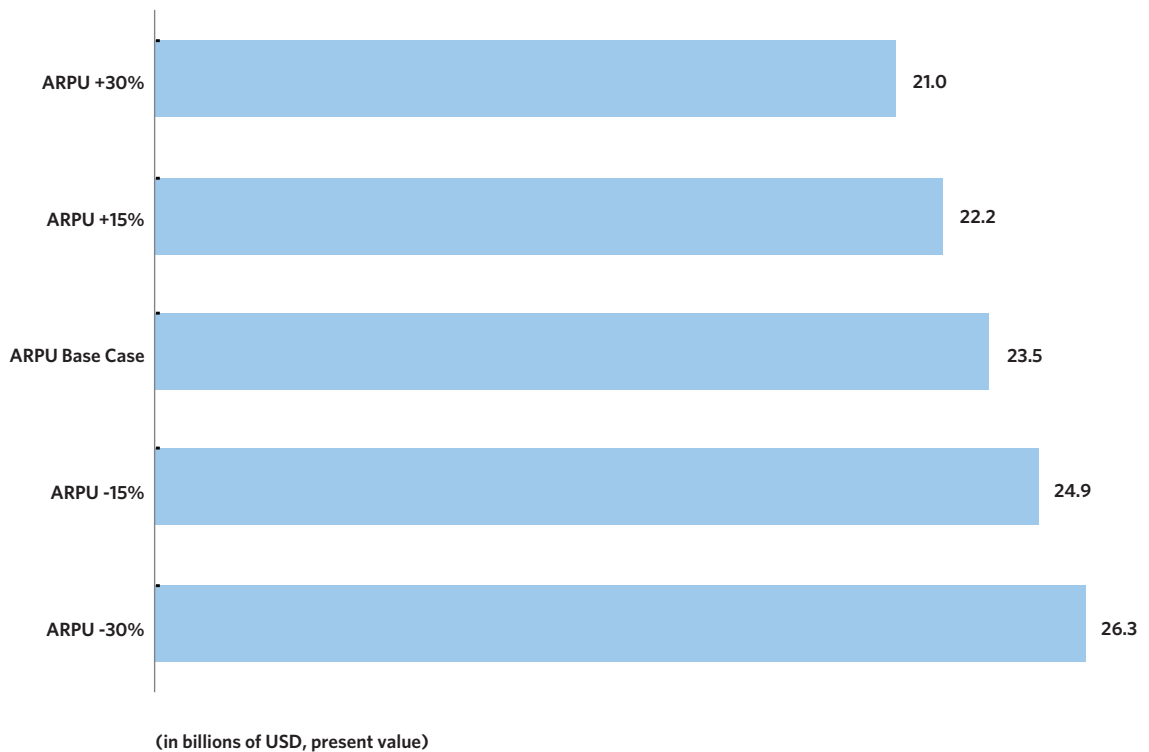
to provide 4G mobile service to the signal density required to provide fixed service at 4 Mbps downstream/1 Mbps upstream. In addition, the operator would have some amount of revenue even without the fixed-network upgrade. Consequently, we estimated both incremental cost and revenue.

To estimate incremental costs, we allocate costs between the fixed and mobile businesses. While both fixed and mobile businesses benefit from improvements to their shared infrastructure, the fixed business drives many of the costs. Fixed service drives more traffic per connection and, as will be

Exhibit 3-X:
Elevation Across the U.S.

Conterminous United States

Alaska

Hawaii

Legend

High elevation

Low elevation
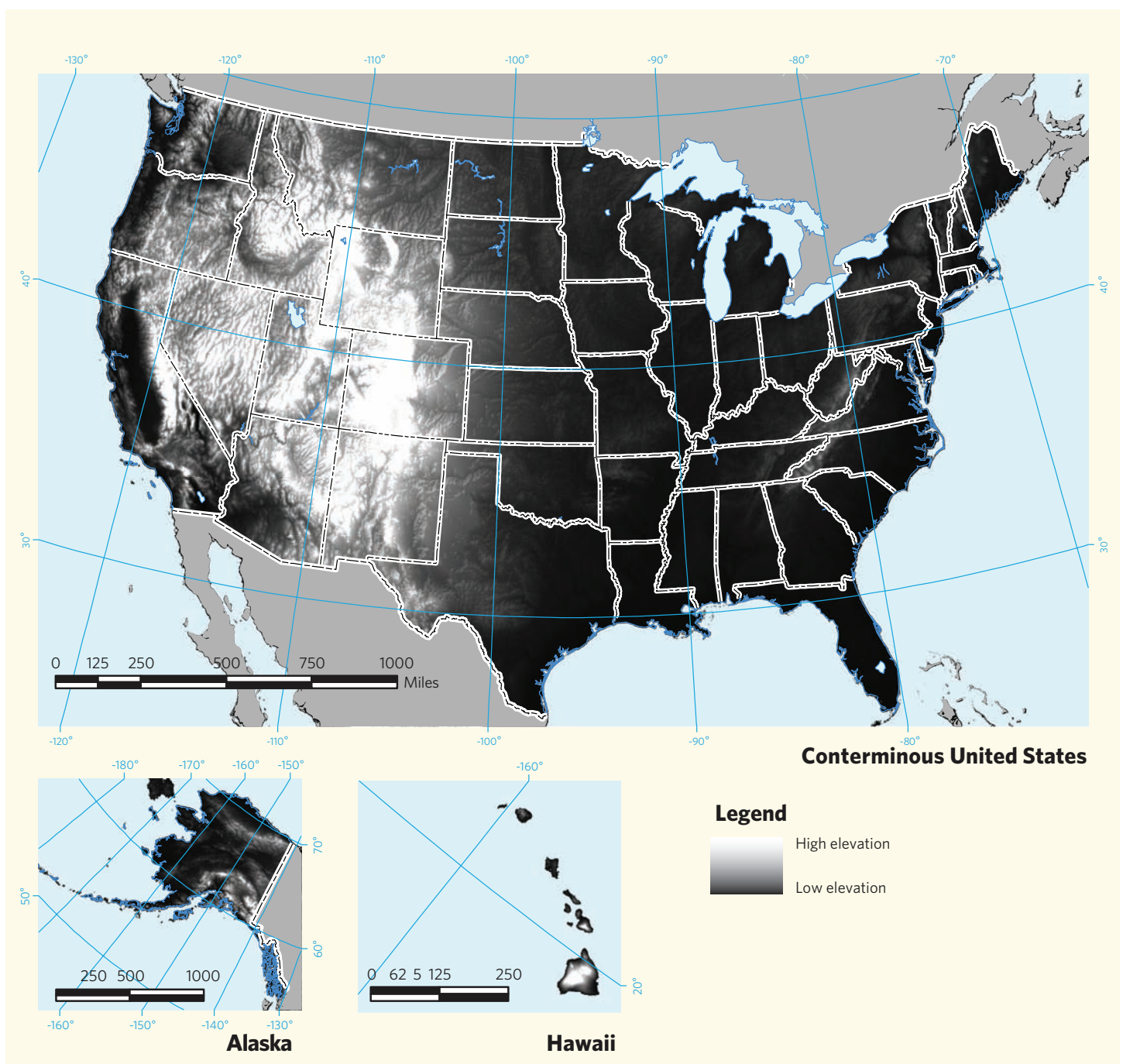
discussed later in the wireless portion of Chapter 4, network requirements for fixed broadband service lead to the need for more and smaller cells.

Therefore, the model allocates costs by the amount of traffic driven by fixed and mobile service. The average mobile user with a broadband handset used 65 MB[37] of capacity per month in 2009, while the average fixed user consumed 9.2 GB;[38] however, mobile data usage per user is currently growing at 84%,[39] while fixed usage per user is growing at "only" about 30%.[40] Assuming that there are two mobile users for every fixed

Exhibit 3-Y:
Estimated Average Cell Size in Each County and Terrain

Conterminous United States

Alaska

Hawaii

Legend

Elevation

High elevation

Low elevation

Average Cell Size (in miles)

	2.0 - 2.5
	2.6 - 4.5
	4.6 - 6. 5
	6.6 - 8.0
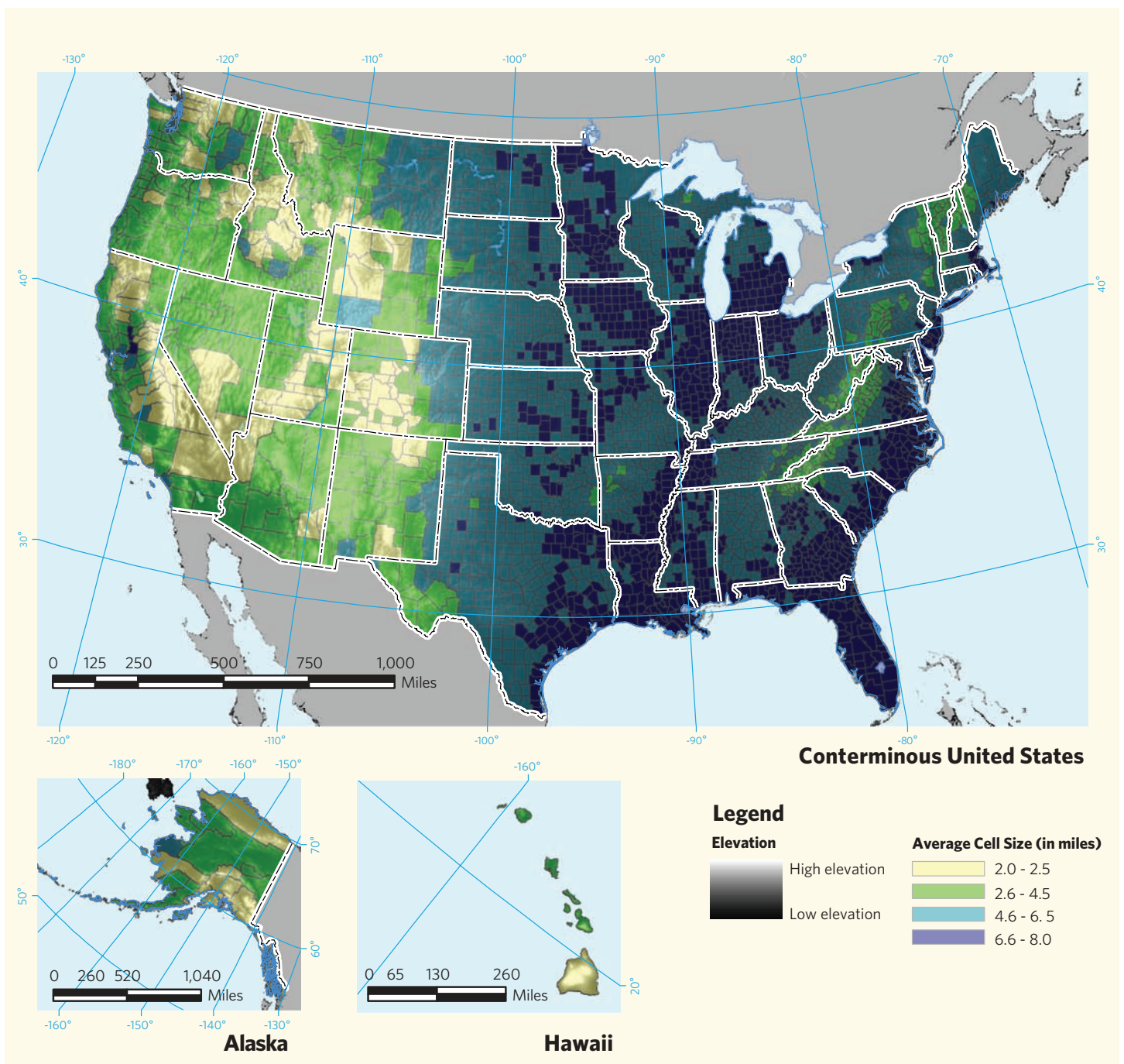
user,[41] and that growth in mobile bandwidth slows to match the growth rate in fixed after five years, fixed service will account for 73% of traffic across the modeled period. Based on these assumptions for traffic allocation, the model allocates 73% of cost to fixed traffic. In other words, the model assumes that mobile carriers can allocate 27% of the build out and operations cost to mobile products, reducing the cost of providing fixed service. If the costs were evenly divided such that 50% of the cost is allocated to fixed and 50% to mobile, the Investment Gap for wireless would decrease to $10.8 billion. If 100% of the cost were allocated to fixed, the Investment Gap for wireless would increase to $15.8 billion.

Offsetting these cost savings is the fact that existing operators may not have significant incremental mobile revenue. The assumption in the model is that there is no incremental mobile revenue within the assumed 4G footprints as defined above (i.e., the carrier does not gain new mobile revenue by building out a network capable of providing 4/1 Mbps fixed service). In other words, the model (conservatively) assumes that a wireless carrier will not increase its share of mobile revenue by adding fixed service.

Outside the assumed 4G footprint, there is no allocation issue: all revenue (fixed and mobile) and all costs are incremental in these areas. The model calculations, therefore, include both fixed and mobile revenue, and 100% of the cost of building and operating the network in those areas outside the 4G footprint.

If one does not allocate some fraction of cost to mobile traffic—if, in other words, one requires the fixed network to provide

returns without the benefit of mobile revenue—the Investment Gap for wireless grows to $16.5 billion. On the other hand, the overall Investment Gap, which is set by the second-least-expensive technology, moves very little, to $25.6 billion.

A new entrant would not have the same starting point. All revenue and all cost would be incremental for a new operator. However, within the 4G footprint, a new operator would face competition in both fixed and mobile markets—and would, therefore, have lower take rate and/or ARPU (as noted above).

Outside the 4G footprint, the Investment Gap calculation is relatively straightforward. Whoever provides broadband service will need to assume all deployment costs and will benefit from both fixed and mobile revenues—though carriers are likely to face some amount of (at least 2G) competition for mobile revenue.[42] Inside the 4G footprint, the gap calculation is more complex. For a major wireless company, likely to build out some amount of 4G commercially, the calculation needs to focus on incremental revenue—revenue for fixed service;[43] and incremental cost—the cost for upgrading to offer 4 Mbps downstream, 1 Mbps upstream service.

Assumption: Disbursements will be taxed as regular income just as current USF disbursements are taxed.

Generally, gross income means all income from whatever source derived.[44] Therefore, taxpayers other than nonprofit or governmental entities must include governmental grants in gross income absent a specific exclusion. In certain circumstances, governmental grants to a corporation[45] may qualify for

Exhibit 3-Z:
Sensitivity of Build-Out Cost and Investment Gap to Terrain Classification Parameters [46]

Legend:
- Parameter set A: "More flat"
- Baseline
- Parameter set B: "More mountainous"
- Parameter set C: "Very mountainous"

Fixed Wireless Access (FWA) cost: 17.8, 18.3, 19.3, 20.3

FWA Investment Gap: 12.8, 12.9, 14.0, 14.9

Overall Investment Gap: 23.5, 23.5, 24.5, 24.5

(in billions of USD, present value)
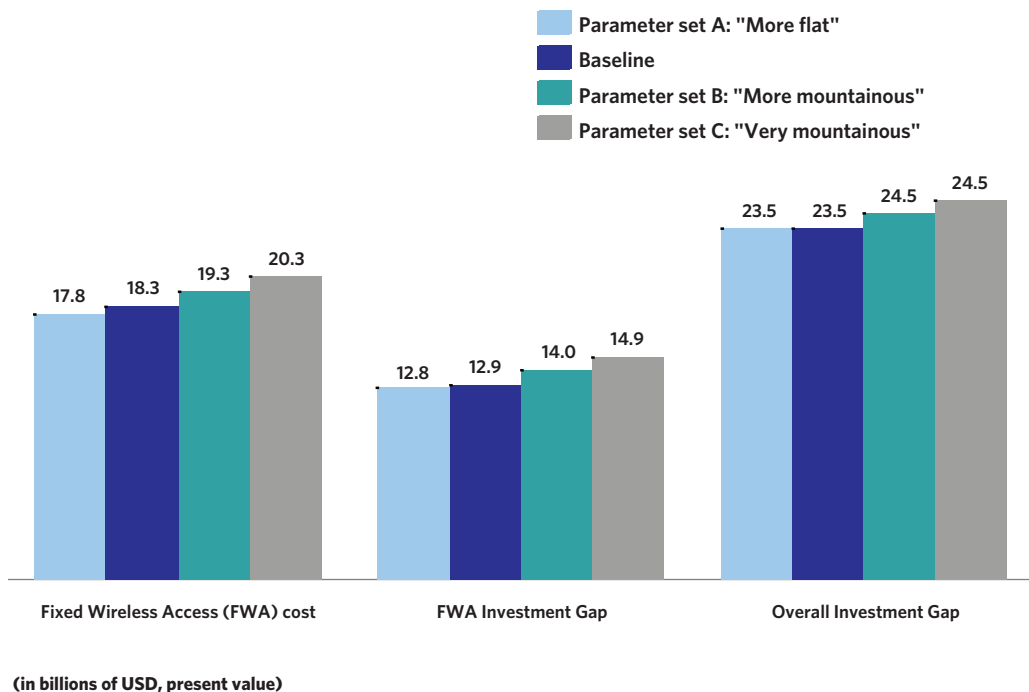
exclusion from gross income as a non-shareholder contribution to capital under section 118 of the Internal Revenue Code. In United States v. Chicago, Burlington & Quincy Railroad Co., 412 U.S. 401 (1973), the Supreme Court adopted a two part inquiry to identify a non-shareholder contribution to capital: (1) the contributor motivation test and (2) the economic effect of the transferee test. The transferor's intent must be to enlarge the transferee corporation's capital to expand its trade or business for the benefit of the community at large and not to receive a direct or specific benefit for the transferor. For the requisite economic effect on the transferee corporation, the following five factors must be present:

➤ The contribution becomes a permanent part of taxpayer's working capital structure
➤ The contribution may not be compensation, such as direct payment for specific, quantifiable service provided for transferor by transferee
➤ The contribution must be bargained for
➤ The contributed asset must foreseeably result in benefit to the transferee in an amount commensurate with its value
➤ The contributed asset ordinarily, if not always, will be employed in or contribute to the production of additional income[47]

The U.S. Treasury has stated that disbursements that may be used for operating expenses will not qualify as a non-shareholder contribution to capital, while disbursements that are made to a corporation, restricted solely to the acquisition of capital assets to be used to expand the recipient's business—and satisfying the five factors—could be exempt from federal income tax. Such a favorable tax treatment on disbursements could reduce the broadband investment gap by up to $2.2 billion. Ultimately, the impact of taxes incurred will depend on the disbursement mechanism, as well as the tax situation of the service providers receiving support.

Assumption: Large service providers' current operating expenses provide a proxy for the operating expenses associated with providing broadband service in currently unserved areas.

As seen in Exhibits 1-A and 1-B, operating expenses (opex) make up a significant fraction of total costs. Complicating matters is that opex comprises many disparate cost elements: everything from the cost of operating the network (network opex) to the cost of sales and marketing, business support services, power, leases and property taxes (collectively overhead or SG&A). And because each service provider operates differently—there are no standards for how many lawyers,

administrative-support staff or network technicians a company needs to hire per mile of plant or number of customers—it is not possible to calculate opex in a "bottom-up" approach.

To find a reasonable approximation of the opex associated with these networks, the team compiled publicly available data sources and ran a series of regressions. These regressions calculate the relationship between opex and already-calculated quantities like revenue or network capex (see CostQuest documentation for more information). Separate regressions are run for cable, telco and wireless companies; for each network type, opex is broken out according to the categories available in the data sources.

For each opex category, the analysis calculates the primary driver (i.e., the known quantity that most strongly correlates with the opex category). Thus some opex categories, like telco network opex, are driven off of network investments; wireless tower operations costs are driven off site counts; while other costs, such as marketing or bad debt, are calculated as a function of revenue. The ratio between the driver and the opex category (the coefficient of the regression) is calculated for different size operators in different geographies, though in some cases the impact of these factors is negligible.

Using this approach to estimate the real-world opex of actual companies (the same opex and companies that formed the source data) suggests that the approach is reasonable. Variations between the calculated and actual values of opex ranged from less than 1% to roughly 10%, depending on the cases studied.

Throughout the calculations described above, we assume that the opex associated with large telco and wireless providers is appropriate. If one instead assumed that a small telco and small wireless operator provided service, the gap would grow to $26.4 billion.[48][49]

CHAPTER 3 ENDNOTES

1   *In the Matter of Represcribing the Authorized Rate of Return for Interstate Services of Local Exchange Carriers*, CC Docket No. 89-624, Order, 5 FCC Rcd 7507 (1990).

2   Note that model runs completed with a shorter time horizon (*see* User Guide for more information) will not include a terminal value. They will, instead, accelerate the depreciation and replacement of longer-lived assets, effectively requiring returns on those long-life assets in a shorter period of time.

3   Note that for census blocks with the largest area (likely the lowest-density census blocks); even census blocks may be too aggregated. *See*, for example, "State Broadband Data and Development Grant Program; Notice of Funds Availability, Clarification," 74 Federal Register 154 (12 Aug. 2009), pp. 40569 -40570.

4   Cable deployments are all new deployments that expand the cable plant; therefore all revenue is incremental.

5   HFC and FTTP networks also have scale lengths associated with them related to the distances of signal propagation in coaxial cable and fiber.

6   Verizon's LTE field trials in Boston and Seattle have shown average downlink rates of 5Mbps to 12Mbps and average uplink speeds of 2Mbps to 5Mbps at the time of this writing. *See* http://www.computerworld.com/s/article/9167258/LTE_speeds_faster_than_expected_in_Verizon_trials.

7   CITI BROADBAND REPORT AT 57.

8   In this example, we assume that the two networks are owned and operated by different entities. The cost impact of supporting two networks may be less severe in cases in which one company owns both networks.

9   The gap, specifically, is built from the *second*-least-expensive technology in each county across the country. Wireless with no competitors is used in all geographies; 12,000-foot-loop FTTN with one competitor is used in areas assumed to have 4G service, and with no competitors in other areas. *See* "Creating the base-case scenario and output" at the end of Chapter 1.

10 *High-Cost Universal Service Support; Federal-State Joint Board on Universal Service*, WC Docket No. 05-337, CC Docket No. 96-45, Notice of Proposed Rulemaking, 23 FCC Rcd 1495, para. 11 (2008).

11 The National Broadband Plan recommends identifying "ways to drive funding to efficient levels, including market-based mechanisms where appropriate."

12 The retail price of satellite service could exceed the price of terrestrial broadband. A "buy down" would ensure that those receiving satellite-based services would not face higher monthly rates than those served by terrestrial providers in other geographies. There is a sample buy-down calculation in Satellite portion of Chapter 4.

13 Satellite broadband and its ability and capacity to provide terrestrial-replacement service are discussed in Chapter 4.

14 *See* broadband-speed assumption section. *See also* Omnibus Broadband Initiative, *Broadband Performance* (OBI Working Paper, forthcoming) (Bowen, *Broadband Performance*).

15 All speeds throughout this paper are "actual" speeds. As with the National Broadband Plan itself, "actual speed" refers to the data throughput delivered between the

network interface unit (NIU) located at the end-user's premises and the service provider Internet gateway that is the shortest administrative distance from that NIU.

16 *See* OBI, Broadband Performance.

17 Note that there were not enough data to complete an accurate predictive model of DSL actual speeds above 6 Mbps; therefore for speeds above 6 Mbps, the cable footprint is taken as the footprint of served housing units without augmentation from telco plant.

18 comScore, Inc., Jan.–June 2009 Consumer Usage database (sampling 200,000 machines for user Web surfing habits) (on file with the FCC) (comScore database).

19 Horrigan, John. <u>Home Broadband Adoption 2009</u>. Pew Internet & American Life Project: June 2009. *See* http://www.pewinternet.org/~/media/Files/Reports/2009/Home-Broadband-Adoption-2009.pdf.

20 Vanston, Lawrence K. and Vanston, John H. <u>Introduction to Technology Market Forecasting</u>. Austin, TX: Technology Futures, Inc, 1996. Note that we considered the Fisher-Pry model but ultimately concluded that, since it is geared toward modeling the substitution of a superior technology for an inferior one, it was not appropriate to use in this instance.

21 Geometrically speaking, the inflection point on the cumulative curve is the point at which the curve moves from convex to concave. The slope of the tangential line along the cumulative curve is highest at the inflection point, indicating maximum acceleration of adoption. Mathematically, the incremental curve is the first derivative of the cumulative, and the inflection point is at the maximum slope of the cumulative or maximum of the incremental curve.

22 Note that these calculations represent the investment gap for each individual technology; the $23.5 billion base case takes the second-lowest-gap technology in each county as described above, not the gap for any one technology.

23 Because we lacked precise data on the location of existing FTTP deployments, the figures for FTTP cost and investment gap are for a run that covers the entire country. Actual costs and gap would be reduced by the roughly 17 million HUs that are already passed by FTTP facilities.

24 The best fit, between modeled data (Gompertz) and observed data (Pew), in its least-squares sense, is an instance of the model for which the sum of squared residuals has its least value, where a residual is the difference between an observed value and the value provided by the model.

25 Each period on the x-axis represents one year, with the inflection point at zero.

26 Note that some demographic data, such as income, are calculated only at the census block group level; these geographically coarser data are applied "down" to the subordinate census blocks.

27 For Telco: 1) Proprietary CostQuest information and industry data/ financials (publically available) 2) Table 5 from FCC's June 30, 2008 Broadband Report For Wireless: 1) http://wirelessfederation.com/news/17341-att-adds-1.4mn-mobile-subscribers-in-q2-usa/ (last accessed Mar. 24, 2010) 2) *See* SNL Kagan (a division of SNL Financial LC), "U.S. 10 year mobile

wireless projections" 3) FCC "High Speed lines by Information Transfer Rates" as of June 30, 2008.
For Cable: 1) *See* SNL Kagan (a division of SNL Financial LC), http://www.snl.com/interactivex/CableMSOOperatingMetrics.aspx (Login required) templates that contained Q1 2004 – Q2 2009 data for: Basic Penetration; Basic Subscribers; Basic Homes Passed; Video Penetration Rates; Video Subscribers; Video Homes Passed; HSD Penetration Rates; HSD Subscribers; HSD Homes Passed; Voice Penetration Rate; Voice Subscribers; Voice Home Passed 2) *See* SNL Kagan (a division of SNL Financial LC), "Cable TV Projections, 2008-2019" 3) Publically available financials for the cable companies, including RCN; Knology; and General.

28 For Telco: Data were obtained from publicly available AT&T investor reports on U-VERSE (http://www.att.com/Common/merger/files/pdf/3Q09_U-verse-Update_10.22.pdf) as well as proprietary CostQuest information.
For Cable: Data were obtained from Forester: Williams, Douglas, et al. "MULTI-PLAY SERVICES: Driving Subscriptions in a Maturing Market and Down Economy", Volume 2, 2008.
For Wireless: Data were obtained from the Wireless Federation article, http://wirelessfederation.com/news/17341-att-adds-1.4mn-mobile-subscribers-in-q2-usa/ (last accessed Mar. 24, 2010).

29 *See*, for example, SNL Kagan (a division of SNL Financial LC), "Cable TV Projections, 2008-2019".

30 Dutz, Mark, Jonathan Orszag, and Robert Willig, "The Substantial Consumer Benefits of Broadband Connectivity for US Households," (July 14, 2009). *See* http://internetinnovation.org/files/special-reports/CONSUMER_BENEFITS_OF_BROADBAND.pdf.

31 *See* FCC, lndustry Analysis and Technology Division, Wireline Competition Bureau, *Trends in Telephone Service Report* ("Trends in Telephone* Service Report, Table 3.2 & 7.1 (August 2008), available online at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-284932A1.pdf.

32 *See* FCC, lndustry Analysis and Technology Division, Wireline Competition Bureau, *Trends in Telephone Service Report* ("Trends in Telephone* Service Report, Table 13.3 (August 2008), available online at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-284932A1.pdf.

33 *See* FCC, lndustry Analysis and Technology Division, Wireline Competition Bureau, *Trends in Telephone Service Report* ("Trends in Telephone* Service Report, Table 1.2 (August 2008), available online at http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-284932A1.pdf.

34 In the Matter of Implementation of Section 3 of the Cable Television Consumer Protection and Competition Act of 1992 Statistical Report on Average Rates for Basic Service, Cable Programming Service, and Equipment, MM Docket No. 92-266, 21 FCC Rcd 2503 (December 2006) *available online at* http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-06-179A1.pdf.

35 *See* FCC, lndustry Analysis and Technology Division, Wireline Competition Bureau, *Trends in Telephone Service Report* ("Trends in Telephone* Service Report, Table 3.1 (August 2008), available online at http://hraunfoss.

CHAPTER 3 ENDNOTES

fcc.gov/edocs_public/attachmatch/DOC-284932A1. pdf; *See also* In the Matter of Implementation of Section 3 of the Cable Television Consumer Protection and Competition Act of 1992 Statistical Report on Average Rates for Basic Service, Cable Programming Service, and Equipment, MM Docket No. 92-266, 21 FCC Rcd 2503 (December 2006) *available online at* http://hraunfoss. fcc.gov/edocs_public/attachmatch/FCC-06-179A1.pdf.

36 Tuning a propagation model involves significant drive testing to ensure simulated signal density correctly accounts for foliage, buildings, terrain and other factors which result in attenuation.

37 Cisco Ex-Parte Filing; A National Broadband Plan for Our Future, GN Docket No. 09-51, Cisco VNI Mobile Data (FCC filed 25 March, 2010).

38 ComScore 200,000 panel of machine survey (Jan-Jun 2009).

39 Cisco Ex-Parte Filing; A National Broadband Plan for Our Future, GN Docket No. 09-51, Cisco VNI Mobile Data (FCC filed 25 March, 2010).

40 *See* OBI, Broadband Performance.

41 2:1 assumption based on the average number of people per household and wireless penetration.

42 While the mobile voice ARPU of a user is $37 per month in model calculations, assuming one competitor on average in non-4G areas leads to a weighted-average mobile voice ARPU of $18.50.

43 Assuming, in other words, that a national carrier will not gain incremental revenue from deploying a fixed-broadband network.

44 26 U.S.C. § 61(a).

45 Includes Limited Liability Companies (LLCs) treated as a corporation for federal income tax purposes. This tax treatment would not apply to noncorporate entities such as partnerships, including LLCs treated as a partnership for federal income tax purposes.

46 The baseline classification is based on parameters in Exhibit 4-K in the following section. The remaining parameter sets alter the classification of flat and hilly terrains, as shown in Exhibit 4-Y. We highlight the changes in the parameters from the baseline for convenience.

47 Letter from William J. Wilkins, Chief Counsel, U.S. Department of Treasury, to Cameron K. Kerry, General Counsel, U.S. Department of Commerce (Mar.4, 2010).

48 The model attempts to capture the scale effects of operations by examining publicly available data. It is possible that there are additional scale effects not captured in this calculation; or that smaller companies could face costs even higher than in the source data.

49 This gap value is different from Exhibit 3-G. In this example, since we are comparing against the base case, the telco faces one competitor in 4G areas and zero in non-4G areas. Exhibit 3-G assumes the telco faces zero competitors in all areas.

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IV. NETWORK ECONOMICS

The United States has a diversity of both wired and wireless broadband networks which provides the vast majority of Americans with choices as to their broadband providers: most homes have a choice between wired broadband provided by a telephone network or a cable network. Telephone and cable networks were originally built for and funded by voice and video services respectively; but now, through upgrades, both are able to provide high-speed broadband to much of the country. Large investments in these networks are being made to further increase speed and capacity in the most profitable areas of the country. In addition to wired networks, there have been significant investments in wireless networks to provide broadband terrestrially via mobile and fixed wireless networks or via satellite. Like wired broadband, mobile broadband is likely to be provided over a network originally built for a different purpose—in this case mobile voice. Strong 3G mobile broadband adoption from smartphones, data cards and netbooks has driven operators to commit to large-scale upgrades to their wireless data networks using new 4G technologies. These new 4G technologies (WiMAX and LTE) can be used to provide broadband in higher speed mobile networks, fixed wireless networks and even hybrid fixed/mobile networks. Due to high costs and low capacity, satellites have primarily targeted customers in remote areas without other broadband options, but recently developed high-throughput satellites may change this.

BASIC NETWORK STRUCTURE

Exhibit 4-A is a diagram of the different portions of a broadband network that connect end-users to the public Internet. Starting at the public Internet, (1) content is sourced from various geographies and providers, data flow through the first peering point of the broadband provider (2), through the "middle mile" aggregation point (3) and "second mile" aggregation point (4), before being transported over either a wired or wireless "last mile" connection to the customer modem (5), which can either be embedded in a mobile device or standalone customer premise equipment (CPE), in the case of a fixed network. Once inside the premises broadband is connected to a device (6) through either wired or wireless connections (e.g. WiFi).

LAST-MILE TECHNOLOGY COMPARISON

We model the deployment economics of DSL/FTTN, FTTP, HFC, Satellite and 4G fixed wireless technologies. Each technology is modeled separately using detailed data and assumptions. Our model shows that fixed wireless and 12,000-foot-loop DSL have the best economics in delivering 4 Mbps down- and 1 Mbps up-stream to the unserved areas of the country.

Fixed wireless networks have favorable economics in most unserved areas, as the high fixed costs of wireless towers are amortized over many customers. In the least dense areas, particularly in mountainous terrain, however, there are few customers per tower and wired technologies are more economically efficient. Among wired networks, 12 kilofeet (kft) DSL has the best economics while still meeting the National Broadband Availability Target because it requires the least amount of network replacement/building. Although satellite capacity is

Exhibit 4-A:
Basic Network Structure
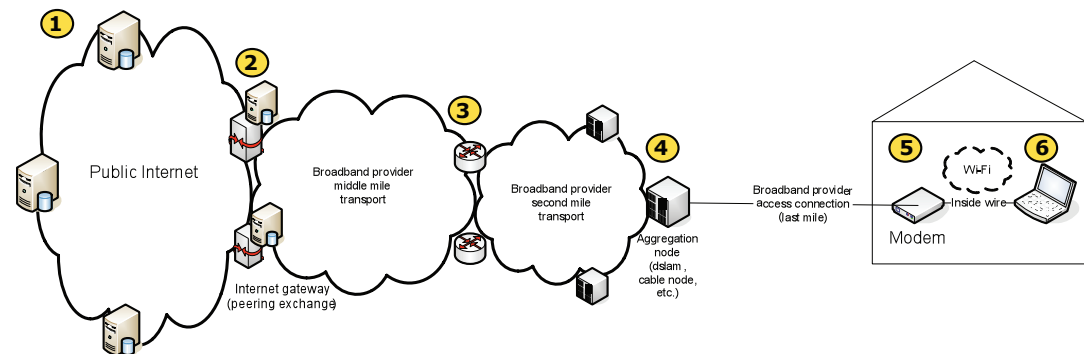
DEFINITIONS

1. **Public Internet content:** Public Internet content that is hosted by multiple service providers, content providers and other entities in a geographically diverse (worldwide) manner
2. **Internet gateway:** Closest peering point between broadband provider and public Internet for a given consumer connection
3. **Link between second mile and middle mile:** Broadband provider managed interconnection between middle and last mile
4. **Aggregation node:** First aggregation point for broadband provider (e.g. DSLAM, cable node, satellite, etc.)
5. **Modem:** Customer premise equipment (CPE) typically managed by a broadband provider as the last connection point to the managed network (e.g. DSL modem, cable modem, satellite modem, optical networking terminal (ONT), etc.)
6. **Consumer device:** Consumer device connected to modem through internal wire or Wi-Fi (home networking), including hardware and software used to access the Internet and process content (customer-managed)

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limited by the number of satellites, and latency can be an issue for some applications, the fact that costs are not dependent on population density makes it an attractive option for serving the most remote areas of the country. We model FTTP, HFC and 3-5 kft DSL as well, and even though the performance and revenue opportunities are better with these technologies, they have unfavorable economics in areas with low population density relative to the other technologies mentioned, due to the high fixed costs of building or replacing large parts of the network.

In order to accurately model each technology, we need to understand both the technical capabilities as well as the economic drivers. First, we determine which of the network technologies could meet end-user speed requirements. Then, we collect detailed cost data required to accurately model the build of a network with the required network capacity. Finally, we determine the incremental revenues that could be generated from each technology.

Network Capabilities

The National Broadband Availability Target is download speeds of 4 Mbps and upload speeds of 1 Mbps. As we shall see in later sections, we dimension the DSL/FTTN, HFC, FTTP, fixed wireless and satellite networks in our network model to meet the National Broadband Availability Target. Further, the sustained data rate capabilities of the networks are comparable.

For example, we compare the streaming capacities of the DSL, wireless, HFC and satellite networks as modeled in our analysis in Exhibit 4-B. For each of the cases, we consider a fully subscribed network, i.e., a network with the maximum

prescribed subscriber capacity at the aggregation point nearest the end-users (a cell site in the case of wireless, a DSLAM/backhaul for DSL and a spot-beam for satellite). The details for each technology will be presented in following sections. For this analysis we assume the following: for wireless, a network of cell sites with 2x20MHz of spectrum, each with 650 subscribers;[1] for DSL, a network with about 550 subscribers[2] being served by a Fast-E second-mile backhaul link.

The exhibit shows the percentage of subscribers in each network that can simultaneously experience video streams of various rates. Thus, for example, we estimate that 29-37% of the wireless subscribers in the cell site can simultaneously enjoy a 480 kbps video stream.[3] For DSL and next-generation satellites, those numbers are 37% and 35%, respectively. So, each of the networks as dimensioned has comparable capabilities. We note that the capacity of an under-subscribed or under-utilized network will, of course, be higher. Thus, for example, if we used a Fast-E backhaul to serve a single 384-port DSLAM, then nearly 55% of subscribers can simultaneously enjoy a 480 kbps video stream.

However, the methods by which each technology can expand to meet growing capacity demand in the last mile differ. For example, with DSL, increased demand can necessitate two types of capacity upgrades that have very different remedies. First, when speed needs for a given user exceed the loop length capabilities on a DSLAM port (unshared network portion), the DSLAM is extended closer to the user so that the shortened copper loop can provide higher speed. This will involve fiber extension, electronics upgrades and significant outside plant reconstruction and rearrangement. This can be a very costly

Exhibit 4-B:
Streaming Capacity
of Modeled
Broadband
Networks [4]

Simultaneous streams in a fully subscribed network
Percent of subscribers of second aggregation point
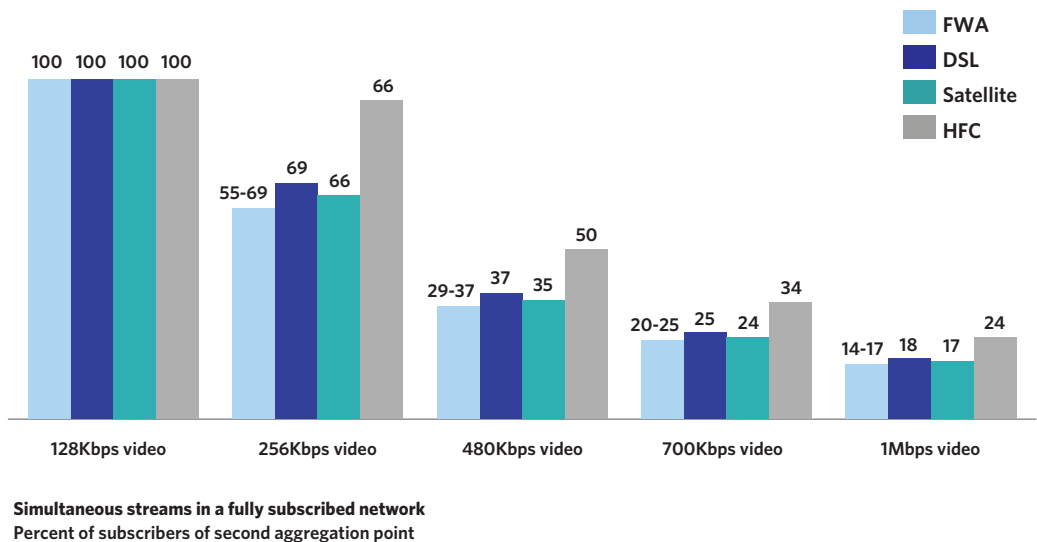
process that involves many aspects of "new" construction, such as pole transfers/make-ready costs, fiber trenching and general overbuild of portions of the outside plant. And second, if the capacity expansion is a result of aggregate demand growth among the users sharing the second-mile backhaul of the network, and not the last mile, one only needs to upgrade DSLAM ports and increase backhaul capacity. Undoubtedly, this carries significant cost, but is relatively straightforward as it primarily involves electronics upgrades.

In the case of HFC, RF signals for data transmission are modulated onto coaxial cables and shared among all of the subscribers who are connected and active on the coaxial portion of the HFC network. Therefore, the last mile is a shared resource. One process for capacity expansion is cable node splitting, which involves electronics upgrades similar to DSL but often also requires significant outside plant reconstruction and rearrangement. Thus, it involves many aspects of "new" cable construction, such as pole transfers/make ready costs, fiber trenching and general overbuild of portions of the outside plant. While this process is not without significant cost and lead time, it is well understood and has been practiced for several years. In addition, there are a number of other often-used methods for increasing capacity as will be discussed in the HFC section.

Similarly, the last mile is shared in FTTP/PON networks. More precisely, optical signals are modulated onto fiber optic cables, which are then distributed to individual homes between the PON splitter and the home. Capacity expansion is again a matter of upgrading electronics either at the headend, home or both, and certainly requires rearrangement of PON splitters and other passive outside plant equipment but does not require a fundamental design and architecture change.

In the case of wireless communications, the primary shared resource in the last mile is the RF spectrum. Multiple wireless devices, such as mobile phones and wireless data cards, simultaneously transmit/receive over the same shared spectrum. In fact, an average cell site covers more than 4,000 people, often referred to as POPs or population.[5] As we will see later, the wireless networks that we model to deliver broadband will be capable of serving up to 650 homes per cell tower using a paired 2x20 MHz[6] of spectrum. Capacity expansion in the last mile typically involves using more spectrum or adding more cell sites or both.[7] Since wireless spectrum is a scarce resource, wireless capacity expansion can be expensive, involving many of the high costs of outside plant/tower construction, etc. (similar to wired technologies discussed above), unless the provider has adequate spectrum holdings. With adequate spectrum, however, capacity expansion is straightforward and relatively inexpensive. Spectrum needs in *unserved rural areas*—with low population densities—are expected to be limited. Given the amount of spectrum currently available and the additional

spectrum likely to become available in the next several years,[8] we expect that capacity expansion in wireless should be relatively inexpensive in *these* areas.

Capacity expansion with satellites will ultimately involve launching additional satellites which are capable of providing more total bandwidth and higher spatial reuse of the available spectrum. New launches, however can cost up to $400 million and require potentially long lead times, as will be discussed later in this chapter.

All of the technology comparisons in this chapter are based on network builds that can meet the target, with an effective busy hour load assumption of 160 kbps (see later section on Network Dimensioning). A fundamental tenet is that the networks have been modeled such that users will receive an equivalent level of service and performance whether they are serviced by the fixed wireless 4G access network or a 12 kft DSL architecture.

Cost Comparison

Our model allows us to calculate the relative cost structure of different last mile technologies as a function of population density in unserved areas. As shown in Exhibit 4-C, the costs associated with all technologies are competitive in the highest densities and diverge as we move toward lower population densities. Note that Exhibit 4-C represents the present value of costs, not the gap associated with each technology.

HFC and FTTP costs are comparable and both are among the most costly in all densities. As one might expect, the cost of running a new connection to every home in low-density areas is very high. In effect, carriers face the cost of deploying a greenfield network in these areas.

Short-loop FTTN deployments (3,000- and 5,000-foot loops) realize some cost savings relative to FTTP from being able to avoid the last few thousand feet of buildout. These savings are particularly valuable in denser areas where operators are more likely to find more homes within 3,000 or 5,000 feet of a given DSLAM location. At the other extreme, in the least-dense areas, where a carrier might have only one customer within 3,000 feet of a DSLAM location, 3,000-foot FTTN is actually more expensive than FTTP; a fiber drop is less costly than a DSLAM. Longer-loop (12,000-foot) DSL is particularly low cost in higher-density areas, where the cost of a DSLAM can be amortized over more customers.

Wireless solutions are among the lowest cost solutions and wireless costs grow less quickly as density falls. As discussed in Chapter 3, and in more detail below, a major driver of wireless cost is cell size. The assumptions made about cell size in hillier terrain are larger drivers of cost than density; however, when ordering census blocks by density, as in Exhibit 4-C, this effect is averaged away and lost. More detail about the impact of cell

size on cost is included later in this chapter.

Exhibit 4-C includes only costs, both capex and ongoing costs, and does not include revenue. Technologies that enable higher revenue could have lower investment gaps than costlier alternatives. Thus, it is possible that FTTP deployment could have a lower investment gap in some census blocks than FTTN or wireless. In addition, given the assumptions made about take rate and ARPU, wireless often will have a lower investment gap than a less-costly 12,000-foot-DSL solution.

However, as noted in Chapter 3, evaluating the economics of technologies over areas as small as a census block makes little sense. Counties or other service areas draw census blocks from across multiple densities. Therefore this revenue-driven advantage is muted when census blocks are aggregated into counties or other service areas and wireless and 12,000-foot-loop DSL are the lowest investment-gap terrestrial solutions overall.

TECHNOLOGIES INCLUDED IN THE BASE CASE

As seen in Exhibit 4-C, our model indicates fixed wireless and 12 kft DSL are the low-cost terrestrial solutions that are capable of delivering speeds consistent with the Broadband Availability Target in unserved areas. We will focus on those technologies and satellite across the next three sections, before returning to those technologies with higher deployment costs.

Wireless Technology

The first mobile networks were built when the FCC approved commercial car-phone service in 1946 but the first commercial cellular telephony service in the United States came in 1983 using AMPS technology. AMPS was an analog phone service that was still in use in some regions of the United States as recently

as 2008. As wired communications started going digital in the 1980s, so did wireless telephony. In the 1990s there were four different 2G digital wireless technologies used in the United States: CDMA-based IS-95, TDMA-based IS-54 (often called Digital AMPS or D-AMPS), GSM and iDEN. Initially, these technologies provided voice services and some limited circuit-switched data services like SMS with peak data rates of 9.6 kbps.

CDMA and GSM became the predominant technologies in the United States, with more than 71% of subscribers in 2004.[9] For GSM, the first real step towards packet-based data services was GPRS, which was later replaced by EDGE. Even with EDGE, the average data rates were still only 100-130 kbps. The big step towards mobile broadband for GSM providers came with UMTS or WCDMA, a CDMA-based air interface standard; average user data rates were 220-320 kbps. Over time, the standards bodies created HSDPA for the downlink and HSUPA for the uplink, collectively referred to as HSPA today. User data rates of up to several Mbps became possible,[10] allowing GSM-family providers to offer true 3G service. See Exhibit 4-D.

Like GSM, CDMA rapidly evolved, first into CDMA2000 1xRTT which delivered peak data rates of 307 kbps and later into CDMA2000 EV-DO that is capable of delivering data rates of up to 3.1 Mbps.

There are two competing 4G standards that can be used in wireless broadband networks:[11] LTE, which is an evolution of the GSM family of standards, and WiMAX. Both of these technologies use OFDMA modulation instead of CDMA and, as such, are not backward compatible with either HSPA or EV-DO. The 4G technologies are only beginning to be deployed and adopted. In fact, LTE, one of the most anticipated

Exhibit 4-C:

Present Value of Total Costs for All Technologies in Unserved Areas [12]

Deciles of Census Blocks
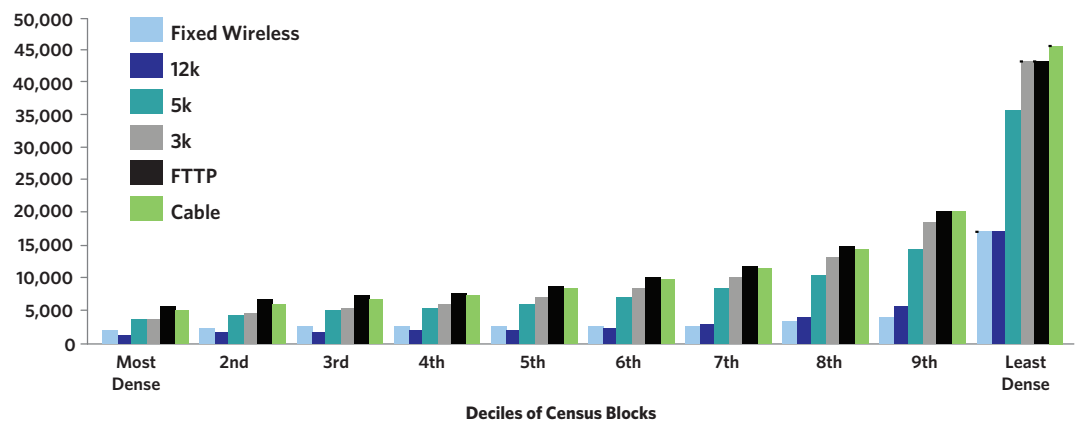
Ordered by unserved housing-unit density

4G technologies, has yet to be commercially deployed in the United States as of the time of this writing, while WiMAX covers less than 3% of the population.[13]

Evolution of the Performance of Wireless Technologies

As wireless technologies have evolved, so have their performances. In a broad sense, with every evolution the industry has achieved higher peak throughputs, improved spectral efficiencies and lower latencies. Additionally, with 4G the wireless signal can be transmitted over wider bandwidths of up to 20MHz,[14] which further increases spectral efficiency and network capacity, while letting the user experience higher data rates. Additionally, 4G uses a native, all-IP architecture, thus benefitting from the technology and economic efficiencies of IP networks.

The most important dimension of performance—at least as far as capacity of the wireless network is concerned—is spectral efficiency, which is the number of bits/second that a sector can

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BOX 4-A

Wireless Multiple Access 101

In any wireless network with multiple users, those users must share the wireless communication channel. Different technologies use different schemes for sharing the channel; these schemes are commonly referred to as multiple access schemes. One such scheme is Time Division Multiple Access, or TDMA, which divides the channel into multiple time slots, allocating each to one of many users. The users then communicate with the base station by transmitting and receiving on their respective time slots. TDMA is used in GSM/GPRS/EDGE as well as the eponymous TDMA IS-54 standard.

Another scheme is Code Division Multiple Access or CDMA. It uses *spread-spectrum* technology for sharing the physical communication channel between the users. More precisely, in CDMA, the signal to and from each user is modulated using a uniquely assigned code. This modulated signal on the assigned code is spread across far more bandwidth than the bandwidth of the data being transmitted. This allows multiple users to simultaneously transmit or receive communication signals on the channel, which are then separated at the base station using the codes. CDMA allows for greater spectral efficiency than TDMA where communication to each user takes place in a uniquely assigned time slot. All 3G technologies, EV-DO and UMTS/HSPA, use CDMA, as does IS-95 and CDMA 1xRTT.

Finally, in Orthogonal Frequency Division Multiplex Access or OFDMA, data transmission occurs on a set of orthogonal *sub-carriers* assigned to each user; the sub-carriers are then modulated and transmitted using conventional modulation techniques. OFDMA has emerged as the multiple access technique for 4G technologies.[15]

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transmit per hertz of spectrum. As such, spectral efficiency drives average downlink data capacity of a cell site linearly. Exhibit 4-E shows the evolution of the average downlink and uplink data capacities of a single sector in a three-sector cell site for the GSM family of standards.[16]

Note that there is no known analytic form for Shannon capacity for a multi-user, multi-site wireless network today. However, one can estimate the Shannon limit for a single user on a single cell site. Further, scheduling efficiency gains from multi-user scheduling are well understood.[17] One can therefore estimate the capacity of a multi-user, multi-site network.[18] But, this estimate does not take into account potential future gains in wireless technology and networks from, for example, coordinated transmission of data to users from multiple cell sites. Nonetheless, this estimated limit suggests that gains in spectral efficiency—and the ability of networks to cheaply improve performance or capacity—will likely be limited in the future.

In fact, as illustrated in Exhibit 4-E, we estimate that the latest release of the LTE standard brings us to within 25% to 30% of the maximum spectral efficiency achievable in a mobile network. Going forward, improvements in spectral efficiency are likely to result from techniques that include the use of new network architectures and multiple-antennas.[19] Specifically:

➤ Multiple-antenna techniques, such as spatial multiplexing in the uplink and improved support for beamforming
➤ Network enhancements:
  ➤ Coordinated transmission of data to users from multiple cell sites
  ➤ Relays or repeaters to improve coverage and user experience at cell edges with low additional infrastructure cost
➤ Carrier or spectrum aggregation to achieve higher user burst data rates

The 4G network architecture represents an evolution as well. 3G networks, having evolved from legacy 2G architectures that were primarily designed for circuit-switched traffic, were hierarchical in design and included many more network elements. 4G, on the other hand, optimizes the network for the user plane and chooses IP-based protocols for all interfaces.[20] The result: a much simpler architecture with far fewer network elements. Not only does this reduce capex and opex for 4G networks relative to 3G, but it also means reduced network latencies; see Exhibit 4-F. The performance of TCP/IP, the Internet data transport protocol, is directly impacted by latency,[21] so that reduced latencies translate directly into improved user experiences.

Exhibit 4-D:

Different Wireless Technology Families Have Evolved Over Time [22]

| 1G: Analog voice 1984-2008 | 2G: Digital voice and Packet data 1992+ | 3G: Multimedia 2003+ | 4G: All-IP networks 2007+ |

Legend: TDMA access — CDMA modulation — OFDMA modulation

Exhibit 4-E:

Downlink and Uplink Spectral Efficiencies by Technology [23]

4G Deployment Plans

Exhibit 4-G shows projected 4G deployment plans for major carriers in the United States based on public announcements.[24] Verizon Wireless has the most aggressive deployment schedule for LTE. It plans to build out to 20 to 30 markets in 2010, extending to its entire EV-DO footprint by 2013—thus reaching more than 93% of the U.S. population.[25] AT&T has announced that it will be trialing LTE in 2010, then rolling it out commercially in 2011. Sprint plans to deploy WiMAX through its partnership with Clearwire. WiMAX has been rolled out in a few markets already and Clearwire announced plans to cover 120 million people by the end of 2010. With carriers in the United States and around the world making these commitments to deploy 4G, we expect it to have significant benefits of scale: a robust ecosystem, strong innovation and substantive cost savings.

Given the superior performance of 4G and the likely extensive 4G coverage by 2013, we shall limit our wireless analysis to 4G technologies in the rest of this document. Our goal is certainly not to pick technology winners, and we recognize that other wireless technologies, such as WiFi mesh, cognitive radios and even 3G, will be important parts of the broadband solution. However, these technologies are unlikely to deliver a cost-effective and reliable wide-area broadband experience consistent with the National Broadband Availability Target in unserved communities. To the extent these technologies offer appropriate service at comparable or lower prices, they will certainly play a role.

Fixed Wireless Access (FWA) Networks

By FWA networks, we refer to wireless networks that use fixed CPEs in addition to (or, possibly, even instead of) mobile portable devices. FWA solutions have been deployed as a substitute for wired access technologies. For example, FWA networks are being used commercially in the U.S. by Clearwire with WiMAX and Stelera with HSPA, and globally by Telstra

Exhibit 4-F:

Evolution of Round-Trip Latencies in Wireless Networks, in Milliseconds [26] [27]
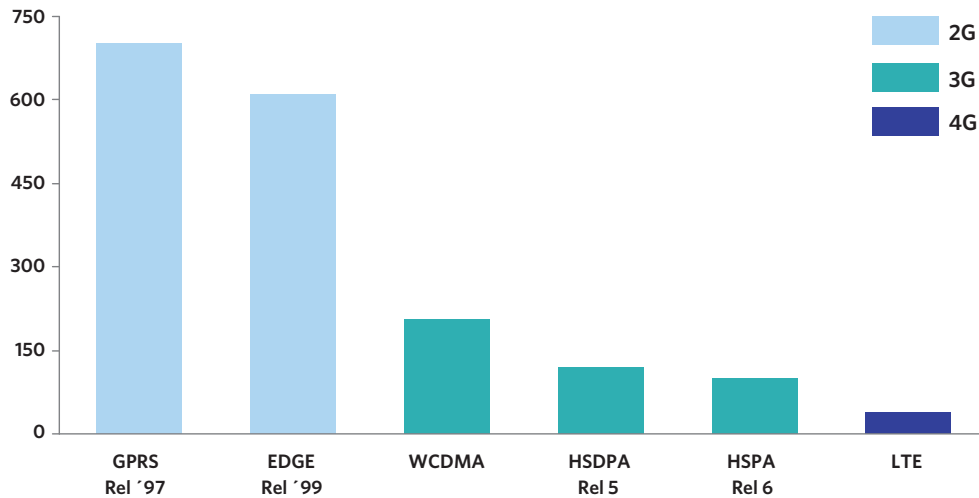
Exhibit 4-G:

Publicly Announced 4G Wireless Deployments

Technology	Companies	2009	2010	2011	By 2013
LTE	• Verizon • AT&T • MetroPCS • Cox		• Verizon (100MM) • AT&T (Trials)	• AT&T (start deployment) • Cox (start deployment) • MetroPCS (start deployment)	• Verizon (entire network)
WiMAX	• Clearwire/Sprint • Open Range • Small WISPs	• Clearwire (30MM) • WISPs (2MM)	• Clearwire (120MM)		• Open Range (6MM)

with HSPA. In addition to the larger providers, there are hundreds of entrepreneurial and independent Wireless Internet Service Providers (WISPs) who provide fixed wireless services to at least 2 million customers in rural areas, including many areas not covered by the national wireless companies.[28] Such deployments are particularly attractive in areas where wired competitors do not exist or have inadequate capabilities.

Fundamentally, FWA uses fixed CPE to deliver better performance by improving end-user signal quality. Examples of techniques that allow fixed wireless to provide superior performance compared to mobile broadband include:

➤ CPE techniques:
  ➤ Using a higher power transmitter than would be possible with a battery-powered end-user device in order to improve the upstream data rate and/or increase the coverage area
  ➤ Using large high-gain antennas along with external mounting to decrease building loss and further improve both upstream and downstream data rate and/or increase the coverage area
  ➤ Placing the antenna in a favorable location to achieve line-of-sight or near line-of-sight to reduce path loss
➤ Base Station techniques: using stronger power amplifiers and multiple antenna techniques in order to increase the coverage area and/or capacity

These techniques are broadly applicable to most spectrum bands and to both 3G and 4G technologies. As such, generally speaking, FWA networks can support both fixed and mobile traffic, with fixed CPEs improving the performance of fixed service relative to mobile.

Our objective is to provide fixed broadband service to homes; so, we have used the performance characteristics of a FWA network in our network model. *In what is to follow, unless otherwise mentioned, the term wireless network will refer to a FWA network.*

Complexity of Analyzing Wireless Networks

It is important to recognize that a wireless network has several layers of complexity that are not found in wireline networks, each of which affect the user experience and, therefore, network buildout costs and the investment gap. For example, the location of the user relative to the cell site has a significant impact on data rates. More precisely, those at the cell edge, i.e., farthest from the cell site, will have much lower signal quality than those closer to it. And as signal quality drops, throughput drops as well; thus, at the cell edge a user may experience more than 60% degradation in data rates relative to the average experience within the cell.[29]

Another factor affecting user experience is the fact that

wireless spectrum is shared by all the users in the cell. As a result, a user can experience significant variations at the same position in the cell depending on temporal changes in capacity demand (or loading).

There are other factors that lead to a heterogeneity of user experience. For example, the wireless signal itself undergoes different levels of degradation depending on terrain, user mobility and location (indoors vs. outdoors vs. in-car). Further, there is a wide range of end-user device types, which vary in their peak bandwidth capabilities, have different types of antennas, form factors, etc. Each of these factors can lead to a different user experience under otherwise identical conditions.

Consequently, analysis of the performance of wireless networks requires a statistical approach under a well-defined set of assumptions. We shall describe the assumptions behind the parameters we used in our wireless network model. However, it is possible that the parameters in an actual network deployment are different from those that we estimated. Improving the accuracy of our estimates would require a RF propagation analysis in the field—an extremely time-consuming and expensive proposition that is usually undertaken only at the time of an actual buildout. And even that approach will not always capture some effects, such as seasonal foliage.

Approach

Exhibit 4-H is a schematic that lays out our approach to analyzing the cost of the network buildout. The cost of the network, as shown, is driven by the number of cell sites required to deliver broadband service and the cost of building, operating and maintaining each cell site.

The number of cell sites required to serve an area is fundamentally dependent on capability of the technology. Using the performance of LTE networks, we dimension cell sites to deliver downlink and uplink speeds of 4 Mbps and 1 Mbps, respectively, in two steps:

➤ First, we ensure that the cell sizes are dimensioned to provide *adequate signal coverage*; i.e., absent any capacity limitations, the propagation losses within the coverage area are constrained and, therefore, the received signal strengths are adequate for delivering the target data rates. Our analysis indicates that the uplink requirement is the driver of coverage limitations.
➤ Next, once we have ensured adequate signal coverage, we ensure that each cell site has sufficient *capacity* to meet the traffic demand. We achieve this by constraining the maximum number of subscribers per cell site. As mentioned in Network Dimensioning, we only consider the downlink capacity requirements—and not the uplink—for our analysis.

Following that, we present the economics of a wireless network. In particular, we analyze the influence of factors like spectrum, terrain and downlink capacity on wireless economics. We also discuss in detail the factors that influence the cost of building and operating a cell site, namely tower lease/construction and backhaul for cell sites.

Dimensioning the Network for Coverage

The method of determining the maximum cell radius to ensure sufficient coverage in the modeled network is driven by three key factors (see Exhibit 4-I):

➤ Broadband rate targets and the corresponding link budgets: Link budgets allow us to calculate the Maximum Acceptable Propagation Loss (MAPL) of the transmitted signal such that the received signal quality is adequate for achieving the target data rates.

➤ Spectrum bands: The propagation characteristics of spectrum bands are different, thereby impacting cell radius.

➤ Terrain: It plays an important role in radio propagation. Simply put, mountains and hills block wireless signals; so areas with rougher terrain require smaller cell radii than areas with flat terrain.

Link Budgets

In order to deliver uplink speeds of 1 Mbps within 90% of the cell coverage area in a FWA network, the maximum acceptable propagation loss (MAPL) is 142 to 161 dB; see highlighted text in Exhibit 4-J. By contrast, the MAPL in a mobile environment is 120 to 132 dB. In other words, higher power CPEs with directional antennas placed in favorable locations in a FWA network yield gains of more than 20 dB over mobile devices.[30]

For our target data rates, it is the uplink that drives coverage limitations; i.e., the cell radius limits imposed by the uplink link budget calculation are smaller than the radii required to ensure adequate downlink received signal strengths. A cell radius small enough for a 200 mW handheld device or a 500 mW FWA device to deliver adequate signal strength to the base station is also small enough for a 40 W (macro) base station to deliver more than adequate downlink signal strengths.

Loosely speaking, unless the downlink and uplink requirements are more asymmetric than the power differential, the significantly higher power at the base station implies that adequate uplink coverage should result in adequate downlink coverage.[31]

Impact of spectrum bands

Cellular service today typically operates in one of several bands: from 700 to 900 MHz; from 1.7 to 2.1 GHz; and from 2.5 to 2.7GHz (see Chapter 5 of National Broadband Plan for details). Generally speaking, in this range of frequencies lower frequency signals suffer lower propagation losses and therefore travel farther, allowing larger cell sizes. Lower frequency signals also penetrate into buildings more effectively. Thus, for example, the Okumura-Hata model[32] predicts that the radius of rural cells in the 700MHz band can be as much as 82% greater

Exhibit 4-H:

Approach for Analyzing Cost of FWA Network
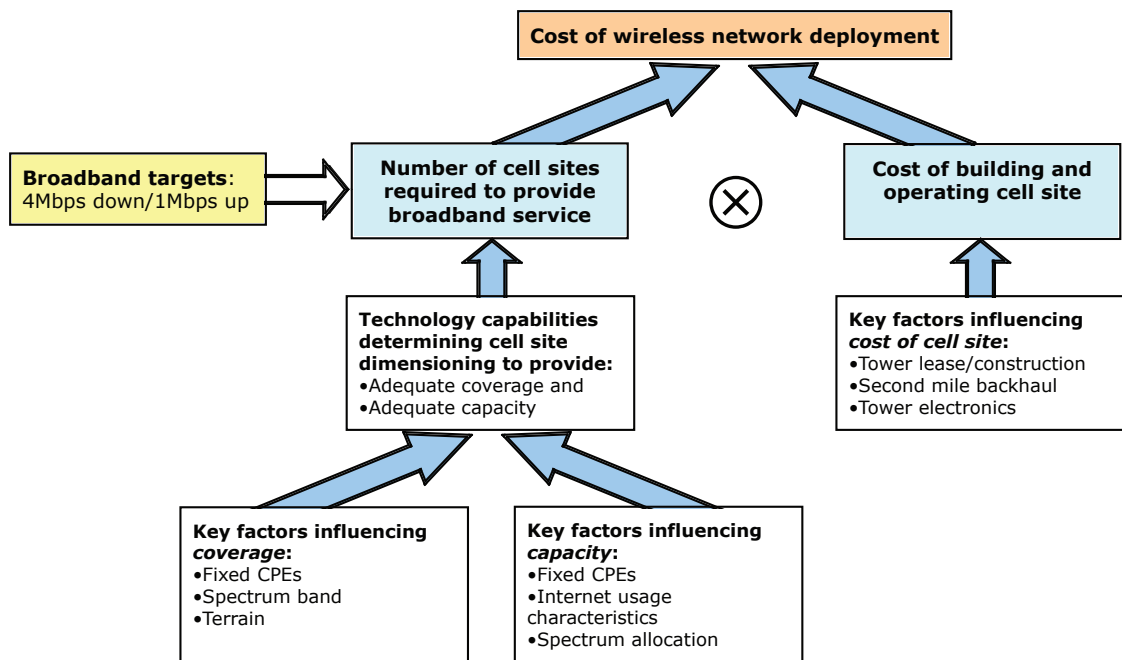
than in the PCS band for comparable coverage. In suburban areas this benefit is 105%, while in urban areas the improvement is greater than 140%. That makes lower frequency bands better suited for coverage and deployments in rural areas.

Terrain classification and maximum cell size

Terrain plays an important role in radio propagation, an effect that cannot be captured using propagation loss models such as

the Okumura-Hata model.[33] Since mountains and hills block wireless signals, areas with rougher terrain require smaller cell radii than areas with flat terrain.

To account for this effect of terrain, we classified terrain into each of the four categories shown in Exhibit 4-K. More precisely, we used GIS data to classify each Census Tract (CT),[34] based on elevation variations across one square Km grids, into one of the four categories.

Exhibit 4-I:

Methodology for Determining Maximum Cell Radius for Coverage
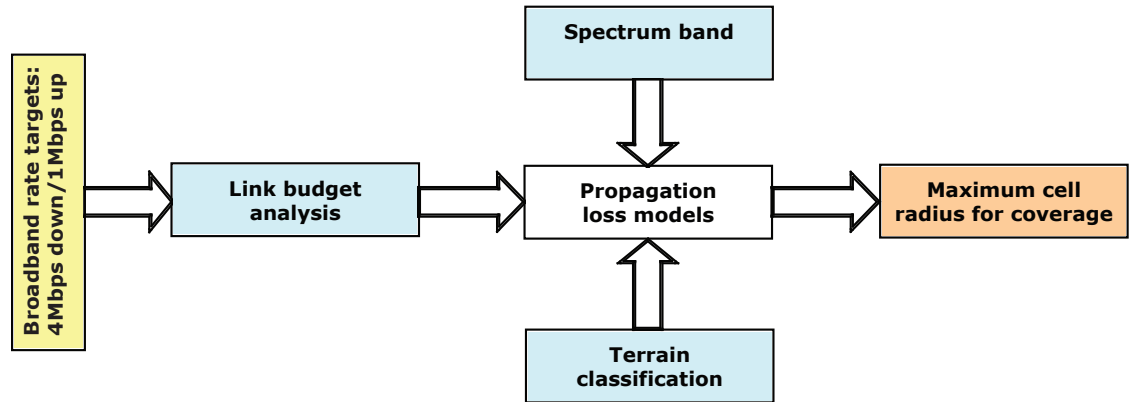
Exhibit 4-J:

Link Budget for Delivering 1.26 Mbps Uplink Speeds at 700MHz [35][36]
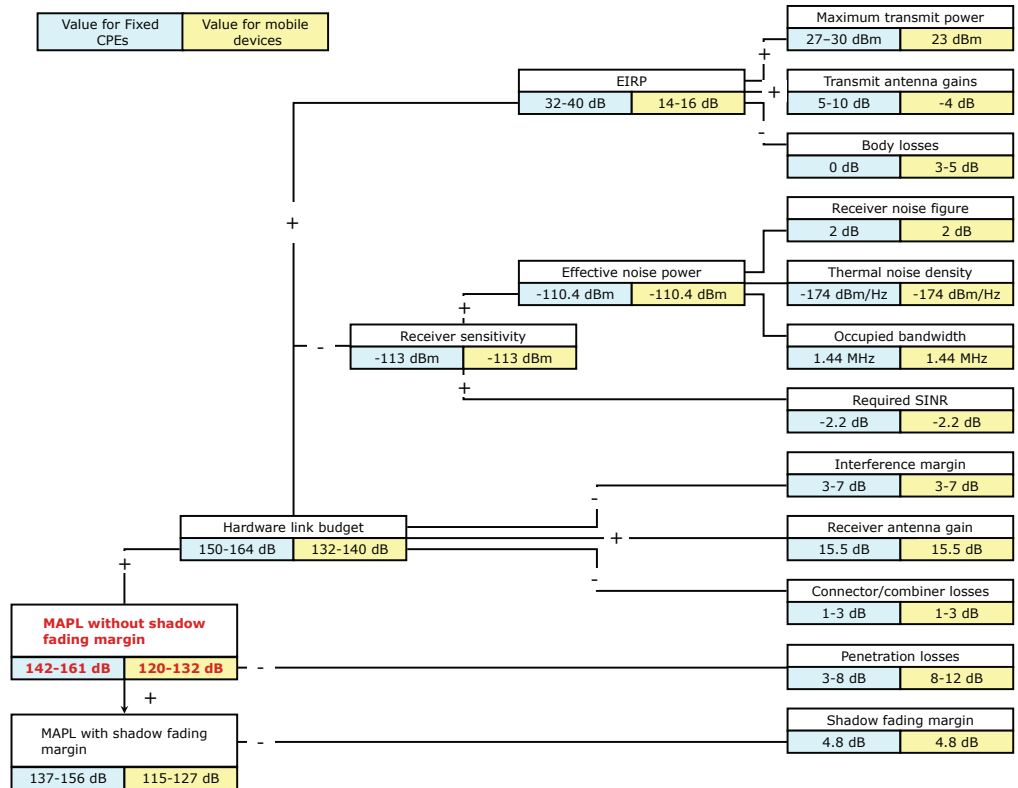
Recall from the discussion of link budgets that the Maximum Allowable Propagation Loss (MAPL) for achieving our target broadband speeds is 142—161 dB. We use RF planning tools[37] (see Exhibit 4-M) to estimate the cell radius for each terrain type that will keep propagation losses within bounds.[38] More specifically, we choose the MAPL to be 140 dB, allowing for possible propagation losses due to foliage.[39] Areas in green in Exhibit 4-M correspond to areas with adequate signal coverage. The results of this analysis are shown in Exhibit 4-L for the 700MHz band.

<table>
<tr><td>

Exhibit 4-K:

Classification of Terrain of Census Tracts

</td><td>

Terrain type	Standard deviation (SD) of elevation (meters)	Examples
Flat	≤ 20	Topeka, Kan.; SD = 12 King City, Mo.; SD = 19
Rolling hills	20 to 125	Manassas, Va.; SD = 41 Lancaster, Pa.; SD = 45
Hilly	125 to 350	Lewisburg, W.V.; SD = 167 Burlington, Vt.; SD = 172
Mountainous	≥ 350	Redwood Valley, Calif.; SD = 350

</td></tr>
</table>

Exhibit 4-L:

Maximum Cell Radius for Adequate Coverage in the 700MHz Band

Terrain type	Examples	Maximum cell radius (miles)
Flat	Topeka, Kan. King City, Mo.	8
Rolling hills	Manassas, Va. Lancaster, Pa.	5
Hilly	Lewisburg, W.V. Burlington, Vt.	3
Mountainous	Redwood Valley, Calif.	2

Exhibit 4-M:

Propagation Loss for Different Terrain Types at 700MHz[40]

■ Excellent signal quality (PL < 140dB)
■ Average signal quality (140dB < PL < 150dB)
■ Poor signal quality (PL > 150dB)

Flat terrain
Cell radius: 8 miles

Rolling hills
Cell radius: 5 miles

Hilly
Cell radius: 3 miles
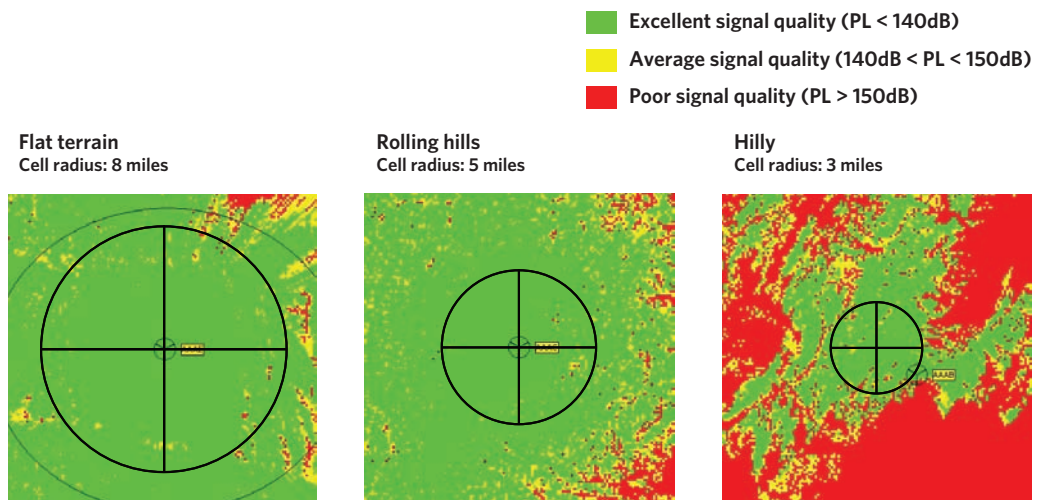
We show a terrain map of the continental United States in Exhibit 3-X; average cell radii for each county based on the classification in Exhibit 4-L for the 700MHz band are shown in Exhibit 4-N. Finally, Exhibit 4-O quantifies the number of households by the cell sizes required to provide adequate coverage to them. Note that only around 13% of housing units (HUs) are in hilly or mountainous areas.

Finally, the propagation characteristics of the spectrum band clearly impact coverage. But, spectrum availability does not play an explicit role in our analysis. Certainly the

Exhibit 4-N:
Average Cell Size in Each County (in miles)

Conterminous United States

Legend

	2.0 - 2.5
	2.6 - 4.5
	4.6 - 6.5
	6.6 - 8.0

Alaska

Hawaii
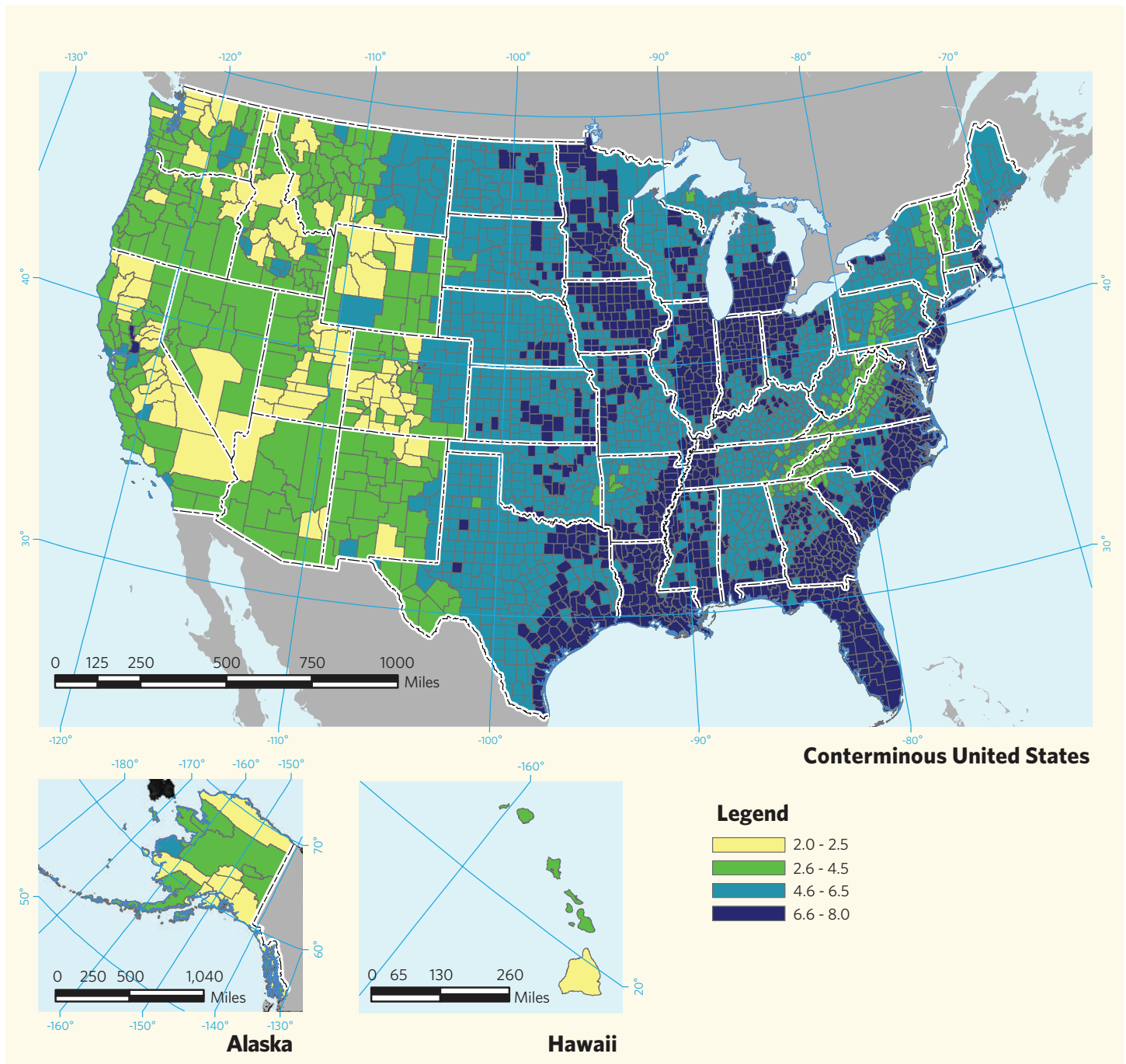
aggregated uplink *capacity* at a cell site improves with spectrum, but the only way to increase the maximum achievable data rate for a *specific user* is to reduce cell size. In other words, site counts will increase if we increase the uplink data rate requirement; adding more spectrum will not alleviate the problem.

Dimensioning the Network for Capacity

Exhibit 4-P shows that subscriber capacity of the wireless network depends primarily on the following:

➤ Broadband requirements and traffic characteristics. The first represents the National Broadband Availability Target of 4 Mbps downlink while the latter is a characterization of the demand for network capacity, generated by the subscribers on the network (see also Network Dimensioning section).

➤ Spectrum allocation. Loosely speaking, if spectral efficiency of the air interface remains unchanged, capacity of the wireless network grows proportionately with spectrum allocation.

➤ Fixed CPE with directional antennas. Specifically, the improvement in signal quality and data rates resulting from using directional antennas at CPE.

We then use the performance of LTE networks to determine the maximum subscriber capacity of the FWA network.

Importantly, signal quality or Signal to Interference and Noise Ratio (SINR)[41] in the downlink is not significantly impacted by increasing the transmission power in cells that are not coverage (i.e., signal strength) limited. This is because signal attenuation depends on the distance from the transmitter, so that SINR depends on the distance of the user from the *serving*[42] cell site relative to the other interfering cell sites. So, if we increase transmission power of all cells similarly, both received signal power and interference power increase proportionately and the net improvement in SINR is small. Correspondingly, reducing the radius of all cell sites proportionately also has a relatively small impact on SINR distribution.

Requirements and Traffic Characteristics

Exhibit 4-Q shows our estimate of the maximum number of subscribers in a FWA cell site for different spectrum allocations.[43] This estimate includes the impact of directional antennas in fixed CPE as discussed below.

As noted in the section on coverage, cell radii are chosen to ensure that the signal quality is adequate for delivering 4 Mbps downlink and 1 Mbps uplink. However, since spectrum is a shared resource, we must ensure that the network is also capable of providing sufficient capacity to deliver these speeds. The approach to sizing the number of subscribers therefore is to first characterize network usage using the Busy Hour Offered Load (BHOL) metric; see Network Dimensioning for details. We assume the BHOL per subscriber is 160 kbps. Then, we use the performance of LTE networks to determine the maximum number of subscribers per cell site for different spectrum allocations such that users achieve the broadband-speed target 95% of the time when the BHOL is 160 kbps.[44]

Note that we achieve our target downlink data rate by limiting the maximum subscribers per cell site, which can be

Exhibit 4-O:
Coverage of
Unserved Housing
Units by Cell Radius

46%

3%

10%

42%

	< 2.5 miles	**Hilly/mountainous terrain**
	2.5 to 4.5 miles	
	4.5 to 6.5 miles	
	6.5 to 8 miles	

Percent of Housing Units
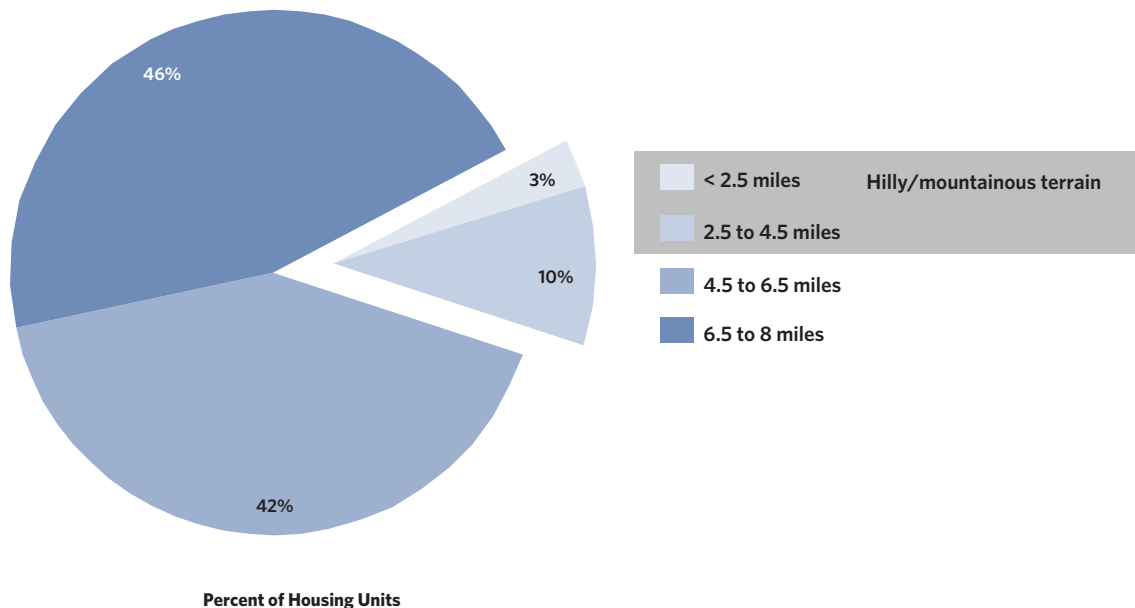
interpreted to be a limit on cell size. But we remarked earlier that we cannot increase data rates by reducing cell size—a seeming contradiction. The resolution is that reducing cell size does not improve signal quality unless it results in a reduction in the number of subscribers per cell site. For example, the user-experience in two cells with 100 subscribers each will not be materially impacted if the cell radius of each is 1/2 km instead of 1 km. Since the load on the network will not change in either case, the utilization is unchanged as well. If we now introduce two additional cells into this hypothetical network, such that each cell has 50 subscribers, then we will see an improved user experience because fewer subscribers in each cell will imply reduced load in each cell. That, in turn, will reduce each cell's utilization and, thereby, improve signal quality and

end-user data rates.

So, we cannot prescribe a maximum cell radius to achieve a target downlink data rate (because population density across geographies is not uniform). But we can limit subscribers per cell to achieve target speeds.

Fixed CPE with directional antennas

Using fixed CPE with directional antennas can result in more than a 75% improvement in spectral efficiency over CPE with omni-directional antennas.[45] More significant is the gain in data rates at the cell edge. We illustrate this in Exhibit 4-R. Specifically, the chart on the left shows the improvement in SINR distribution in the cell site when the network has CPE with directional antennas instead of omni antennas. For

Exhibit 4-P:

Methodology for Dimensioning Wireless Networks to Provide Adequate Capacity
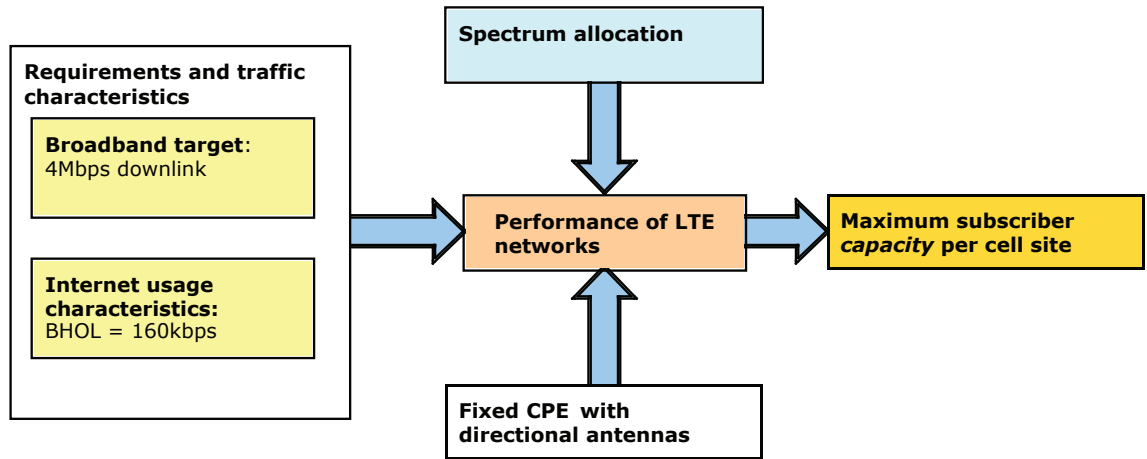
Exhibit 4-Q:

Maximum Number of Subscribers Per Cell Site in an FWA Network with Directional Antennas at the CPE [46]
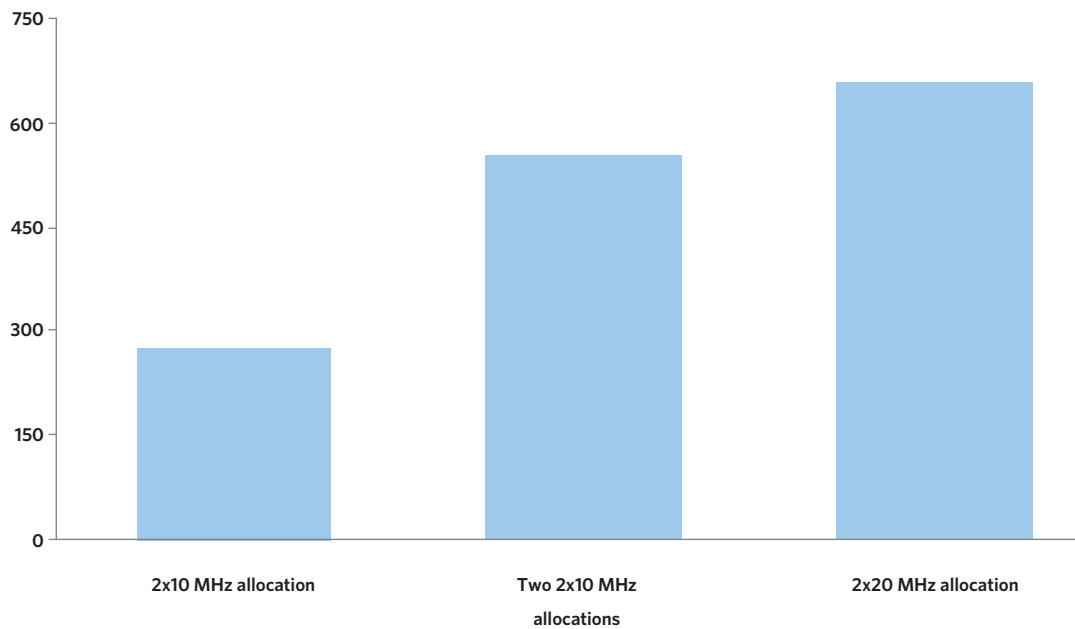
example, nearly 35% of users in a network with omni antennas have a SINR of 0 dB[47] or worse. By contrast, less than 1% of the users in a network with directional antennas have a SINR of 0 dB or worse. The significant boost in signal quality is a result of (a) improved signal reception with the higher antenna gain of a directional antenna and (b) reduced interference due to the increased interference rejection possible with such antennas.

This improvement in SINR directly translates to better data rates. For example, if a CPE with an omnidirectional antenna experiences a data rate of ~3 Mbps, then a CPE with a directional antenna will experience an average of ~9 Mbps under otherwise identical conditions.

Spectrum allocation

We mentioned above that lower spectrum bands are better suited for coverage. Higher frequency spectrum, on the other hand, is better suited for capacity by deploying Multiple Input and Multiple Output, commonly referred to as MIMO,[48] solutions. This is because smaller antennas can be used at higher frequencies and multiple antennas can be more easily integrated into handsets constrained by form factor. As such, deployments in these bands can have higher spectral efficiency. That is not to say that MIMO cannot be deployed in the lower frequency bands; rather, MIMO solutions are more practical and cheaper in the higher bands.

In our model, we assume 2x2 MIMO,[49] which is easily implemented in the 700MHz band in a FWA network.

The importance of spectrum towards ensuring a robust mobile broadband future has been discussed at length in the

Chapter 5 of the NBP. In this section, we discuss how spectrum availability impacts subscriber capacity. For convenience, we shall assume the propagation characteristics of the 700MHz band for this discussion.

In Exhibit 4-Q, we saw that the capacity of a network with two paired 2x10MHz carriers[50] is twice that of a single 2x10MHz carrier. That should not be surprising. Interestingly, however, the capacity with a single 2x20MHz carrier is 20% higher than with two 2x10MHz carriers.[51] This is, in part, due to the better statistical multiplexing possible with the first option (using the wider carrier). Most of these gains will also be achievable with the second option once carrier/spectrum aggregation is introduced in the LTE standard.

Exhibit 4-S shows the spectrum needs in 2020 and 2030 for *coverage* cell sites in the unserved regions of the United States. Recall that coverage cell sites provide adequate downlink and uplink coverage (i.e., 4 Mbps/1 Mbps downlink/uplink speeds at the cell edge); however, depending on the number of households within the cell site, it may not have enough capacity to meet the traffic needs.

For our baseline model, we assume that 2x20MHz of spectrum is available per cell site. So, as the figure shows, in 2020, 94% of the *coverage* cell sites will also have adequate capacity. The remaining cells need techniques such as cell-splitting or 6-sector cell sites to increase capacity.[52] As the uptake continues to increase, the spectrum needs will also increase, as shown by the chart on the right.

This analysis is based on an average BHOL per subscriber of 160 kbps. Higher data usage than that will indeed increase spectrum needs. Still, the analysis shows that spectrum needs are

Exhibit 4-R:

Impact of Directional Antennas at CPE on SINR [53][54]

SINR distribution in a cell with directional antennas compared with omni antennas

Omni antennas
Directional antennas

(Percent of cumulative probability)

SINR at each receive antenna of user device, dB

Gain in data rate achievable with a directional antenna relative to omni antenna

Downlink user data rate with an omni antenna, Mbps

Increasing distance from cell site

relatively modest, due to three reasons. First, we used a FWA network, which has higher capacity than a mobile one. Second, the population density in the unserved regions is very low—less than 10 HUs per square mile. Consequently, the number of subscribers per cell site and the traffic demand per cell site are also relatively modest. Finally, the uplink coverage requirement of 1 Mbps resulted in a much higher cell site density than would otherwise be necessary, which further reduced the number of subscribers per cell site.

We end this discussion on spectrum availability by contrasting the difference in impact spectrum has on uplink and downlink dimensioning:

➤ In order to achieve a target *uplink* user data rate, we limit the maximum cell radius to ensure sufficient *coverage*. And while propagation characteristics of the spectrum band are important for our calculation of maximum cell radius, spectrum availability has little impact—the uplink signal received at the cell tower, not the availability of spectrum, is the limiting factor.

➤ In the *downlink*, on the other hand, we are limited by cell site *capacity*. We can either reduce the cell size to match subscriber demand with capacity, or we can add spectrum to the cell site, because more spectrum implies more capacity. The first option is more expensive, because the incremental cost of using additional spectrum at a cell site is smaller than the construction costs associated with cell-splitting if spectrum is available.

Therefore, the overall impact of spectrum availability on network buildout depends on the evolution of downlink and uplink usage characteristics. Specifically, let us consider two extreme scenarios:

➤ **Extreme uplink usage**: If uplink usage were to evolve disproportionately faster than the downlink, then the only way to dimension the network would be to reduce the cell size. In doing so, we reduce the number of subscribers per cell site. That, in turn, automatically reduces the downlink capacity needs per cell site so that spectrum plays a less critical role in the solution.

➤ **Extreme downlink usage**: If, on the other hand, downlink usage evolves disproportionately faster than the uplink, then availability of spectrum can significantly mitigate the need for additional cell sites. That, in turn, significantly reduces the cost of network capacity expansion.

Second-Mile Backhaul

A key requirement of wireless broadband networks is high-capacity backhaul, a need that will only grow as end-user speed and effective load grow. Today, even though 97.8%[55] of the U.S. population has 3G coverage, most cell sites are still copper fed. For example, Yankee Group estimates that more than 80% of cell sites are copper fed.[56] Further, Sprint Nextel noted that in its network, "most towers carry between one and three

Exhibit 4-S:
Spectrum Needs for Cell Sites in 2020 and 2030, Based on BHOL of 160 kbps

Spectrum needs for cell sites, 2020
Percent of cell sites

Spectrum needs for cell sites, 2030
Percent of cell sites
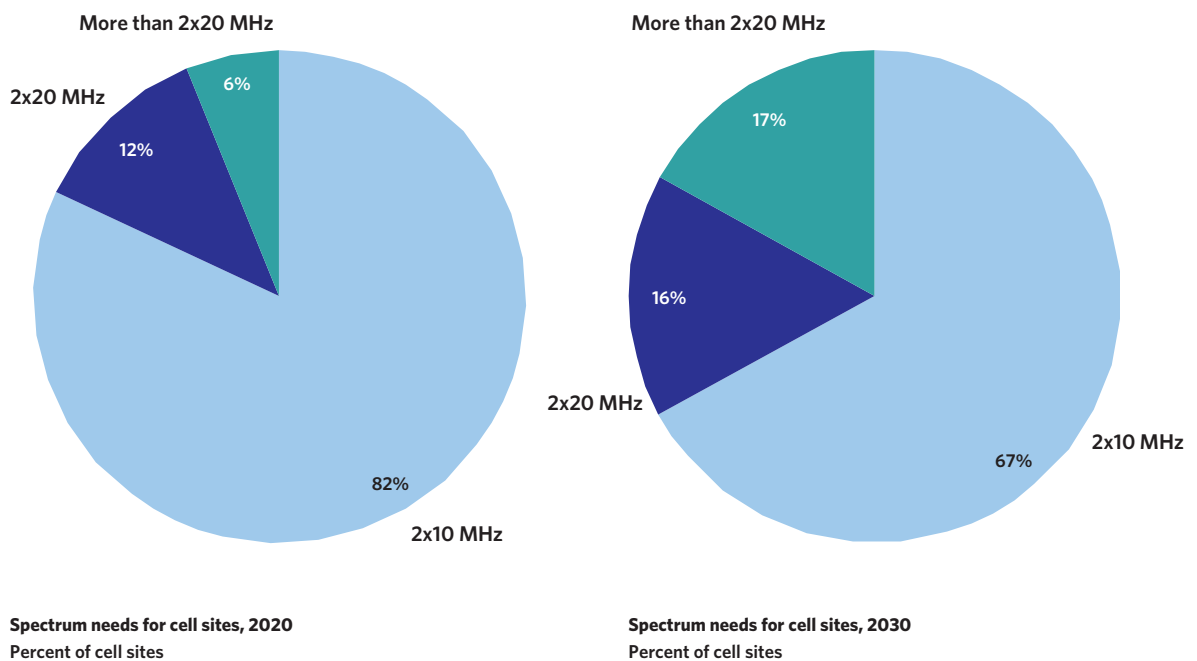
DS-1s" and that "almost no towers have more than five DS-1s."[57] This is important because copper facilities will have inadequate speeds for a well-subscribed 4G cell site; so, without adequate upgrades, backhaul can quickly become the choke point of the network (see Exhibit 4-T). Additionally, both fiber and microwave avoid some of the reliability problems often found in dealing with copper-based backhaul. Said differently, dimensioning adequate backhaul is one of the key drivers for providing wireless broadband. As shown in Exhibit 4-T, for our purposes we need backhaul capacity that can only be provided by fiber and/or microwave.

In unserved areas, microwave point-to-point backhaul is a potentially attractive alternative to fiber for providing second-mile capacity at substantial cost savings relative to fiber. We assume that microwave allows high-capacity connectivity at a lower price by bypassing the need for a direct aerial or trench-based connection. For instance, a microwave link can provide speeds of up to 500 Mbps over a distance of 20 miles[58] at a typical equipment cost of roughly $50,000.[59]

By contrast, costs of new fiber construction depend heavily on the distance to an existing fiber network and whether the area has aerial plant available for connection. Costs can range from approximately $11,000 to $24,000 per mile for aerial construction and roughly $25,000 to $165,000 per mile for buried construction.[60] Many providers may prefer fiber regardless of the cost, especially in denser areas, because of its ability to provide higher capacity per link and its inherent reliability.

Overall, when compared with new fiber construction, and even with leased Ethernet links, microwave links can have a lower total cost for link distances greater than 1-2 miles.[61]

Ethernet over Copper (EoC) may also be part of the 4G-backhaul solution. We did not include EoC in our 4G-backhaul calculations for several reasons: first, as noted above, there is often a limited amount of copper available; second, the quality of that copper over the multi-mile distances in rural areas is unknown; and third, for new cell-site construction, where there are no existing backhaul facilities, carriers are likely to install fiber or rely on microwave.

Hybrid Fiber Microwave (HFM) backhaul architecture

Since microwave can be a cost-effective substitute for fiber, a Hybrid Fiber Microwave (HFM) backhaul architecture would yield significant cost savings in wireless networks relative to an all fiber network (see Exhibit 4-U). Specifically, as illustrated in the exhibit, in an HFM architecture some cell sites rely on microwave for backhaul, and only few cell sites are fiber-fed. The fiber-fed sites serve as backhaul "aggregation points" for the remaining cell sites. These remaining sites connect to the fiber-fed aggregation points using microwave links, sometimes using more than one microwave hop. For example, Cell site 3 is fiber fed, serving as an aggregation point for the backhaul needs of Cell sites 1 and 2. Further, Cell site 2 connects to Cell site 3 using one microwave hop, while Cell site 1 connects using two (via Cell site 2). Such HFM architectures are already being used by wireless service providers such as Clearwire, for example.[62]

Even though the microwave links now have reliability comparable with their wireline counterparts, an HFM network that uses a large number of hops can lead to concerns about

Exhibit 4-T:
Average and Peak Capacity of a 3-Sector Cell Site Relative to Backhaul Speeds, Mbps
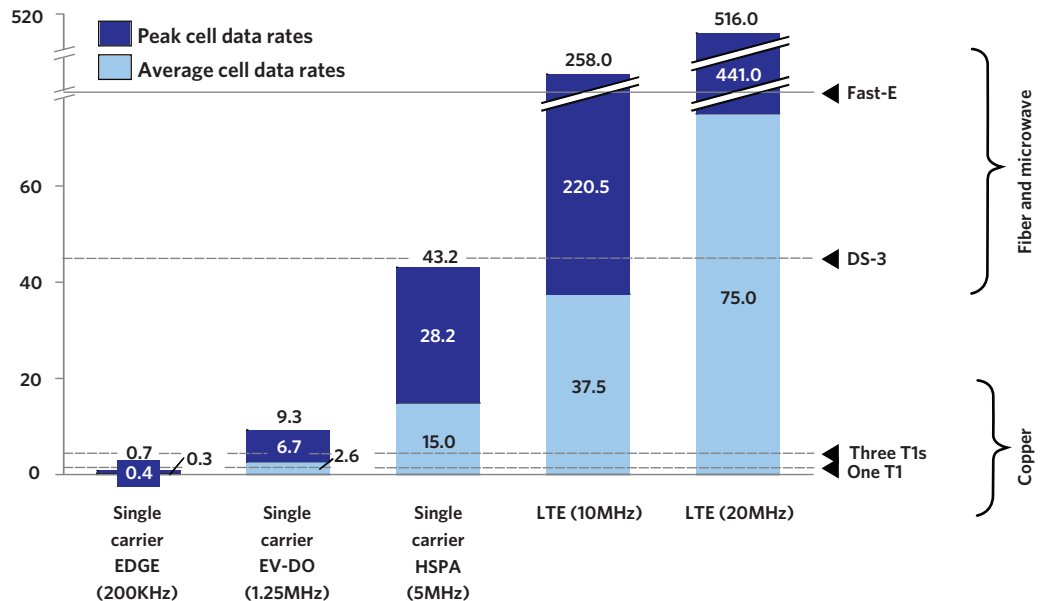
reliability. To see this, observe in Exhibit 4-U that the loss of the microwave link between Cell sites 2 and 3 will also result in the loss of backhaul connectivity for Cell site 1. If each of these cell sites had a radius of 5 miles, then as much as 150 square miles would lose coverage through the loss of the single link. Clearly, then, this cascading effect can become particularly pronounced in a network that has a large number of hops. On the other hand, the more hops, the greater the potential for second-mile cost savings.

Our baseline model for FWA uses an HFM architecture with a maximum of four microwave hops.

In unserved areas, an HFM second-mile network architecture has cost advantages over a fiber-only network architecture. Microwave backhaul has two additional benefits, especially to service providers who do not already own fiber middle-mile backhaul assets. First, microwave can often be deployed faster than fiber. Second, in many territories, the owner of wired backhaul facilities could be a competitor in providing wireless service. In such cases, microwave backhaul offers an effective alternative to paying competitors for backhaul service.

However, microwave backhaul also has two significant limitations. First, as noted earlier, microwave links have capacity limitations and cannot be used for very high-speed backhaul needs. Further, higher data rates require more spectrum. Since there is only a limited amount of spectrum available, carriers can only have a limited number of high-speed microwave links in a geographical area. Note that the NBP had a series of

recommendations related to improving point-to-point backhaul solutions in Chapter 5.

The second limitation is a requirement for line of sight from one microwave tower to the next. In hilly or mountainous terrain, this may mean that a provider needs to add additional microwave relays even beyond the reduction in cell size described above, adding to costs. It may be the case that the same terrain issues drive up fiber costs as well, perhaps even more quickly, so this will not necessarily tip the balance toward fiber. But it will likely drive up backhaul costs overall. Further, in some cases the tower may need structural reinforcements to support a microwave antenna, which will drive up the cost of microwave installation.

So, even though an HFM architecture has significant cost advantages, fiber is expected to be the primary backhaul choice for service providers because it offers a scalable, future-proof backhaul solution.

Finally, a fiber-only architecture has one significant strategic advantage. As broadband needs continue to grow, fiber emerges as the only last-mile technology capable of meeting ultra high-speed needs. So, any solution that brings fiber closer to the home by pushing it deeper into the network puts into place an infrastructure that has long-term strategic benefits. On balance, therefore, we need to weigh this strategic benefit against the higher associated cost to evaluate the value of a fiber-only architecture over an HFM architecture.

Exhibit 4-U:
Hybrid Fiber Microwave Backhaul Architecture for Cellular Networks
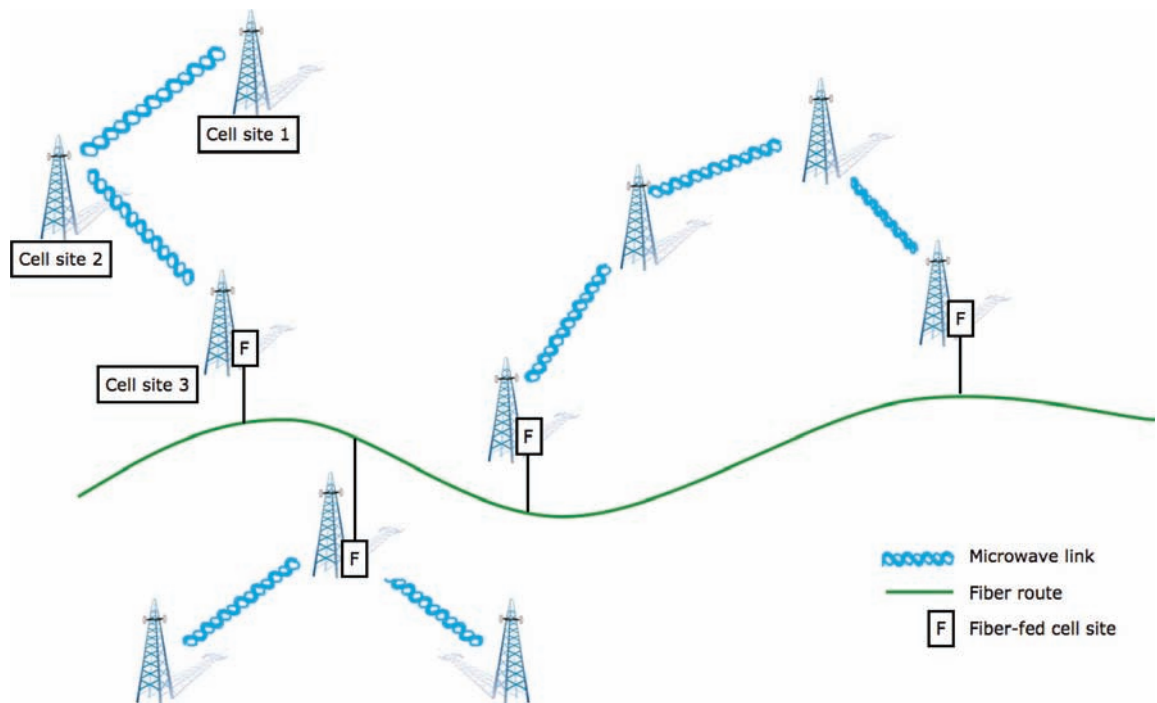
Economics of a Wireless Network

Exhibit 4-V shows the network elements that we modeled for FWA network cost analysis (see also Exhibit 4-A above). Specifically, in the last mile—the link from the cell site to the end-user—we model installation and operations costs, as appropriate, for the tower infrastructure, Radio Access Network (RAN) and other ancillary[63] equipment. We also account for the cost of the end-user CPE. In the second mile, which is the backhaul connection from the cell site to the second point of aggregation in the exhibit, we model the costs of installing microwave equipment and new fiber, as needed; see the Section on Middle Mile for details on backhaul network architecture.

Our network model, as shown in Exhibit 4-V, shows that the Investment Gap when using FWA networks in the 700MHz band for providing broadband to the unserved population in the United States is $12.9 billion (Exhibit 4-W). This funding gap is for the wireless buildout *only* and is not driven by the second least-expensive of a mix of technologies. For more details on our overall network modeling assumptions and principles, see **Creating the Base-case Scenario and Output** above.

Dependence on terrain type

Recall that for our network model, we classify terrain into four types, choosing a different maximum cell radius for each. Exhibit 4-X shows the average investment (i.e. capex) per housing unit (HU) and Investment Gap per HU based on the underlying cell radius required. The smaller cell radii

correspond to counties that are mountainous/hilly.

The exhibit shows that the cost of serving HUs in hilly terrain can be as much as 30 times higher on average than in flatter areas. This is in part due to the fact that smaller cell radii in hilly terrain mean that we need more cell sites, thereby driving up the cost; and, in part due to the fact that HU density is also lower in hilly areas. [64]

Our classification of terrain in Exhibit 4-K is based on a statistical analysis of terrain variation data. It is likely that in some instances our method will misclassify a census tract (CT). The only way to get an extremely accurate estimate of cell radius is to actually do a RF propagation analysis for each CT using tools such as those provided by EDX Wireless. That is extremely time-consuming and expensive. To range the impact of misclassification, we analyze the sensitivity of buildout costs and the investment gap to our terrain classification parameters.

Exhibit 4-Y illustrates the results from our sensitivity analysis. In addition to the FWA buildout costs and the FWA investment gap, we also show the overall investment gap for bringing broadband to the unserved using a mix of technologies. Note that the impact on the overall investment gap is less than 10%. This is because the overall investment gap is driven by the second least-expensive technology. More specifically, we find that the percentage of unserved HUs served by wireless drops from 89.9% in the baseline to 89.1% with the "very mountainous" classification in parameter C, thus explaining the relatively small impact terrain classification has on the overall investment gap.

Exhibit 4-V:
Illustrative
Wireless Network
Architecture
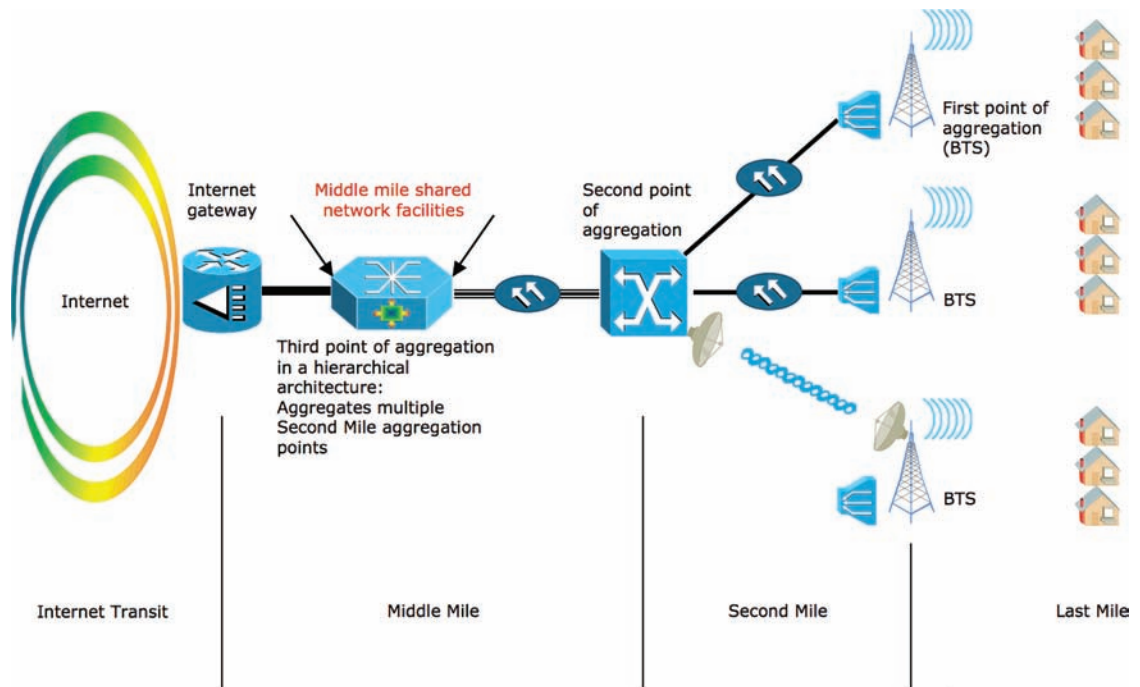
Dependence on downlink capacity

Since LTE is not commercially deployed yet, it is conceivable that actual downlink spectral efficiency and, consequently, subscriber capacity differ from that simulated. So, we analyze the dependence of wireless buildout costs and the investment gap to our subscriber capacity estimates as shown in Exhibit 4-Z. We note that the impact on costs as well as Investment Gap is negligible. Consequently, the impact on the overall Investment Gap—as determined by the cost of the second least-expensive network—is also small (not shown in chart).

Dependence on spectrum

Our baseline model assumes a network deployment in the 700 MHz band. If, instead, we deploy the network in the PCS band, the

Exhibit 4-W:
Investment Gap for
Wireless Networks

6.3	11.0	0.9	18.3	5.3	12.9
Initial CAPEX	OPEX	Ongoing CAPEX	Total Costs	Revenues	Investment Gap
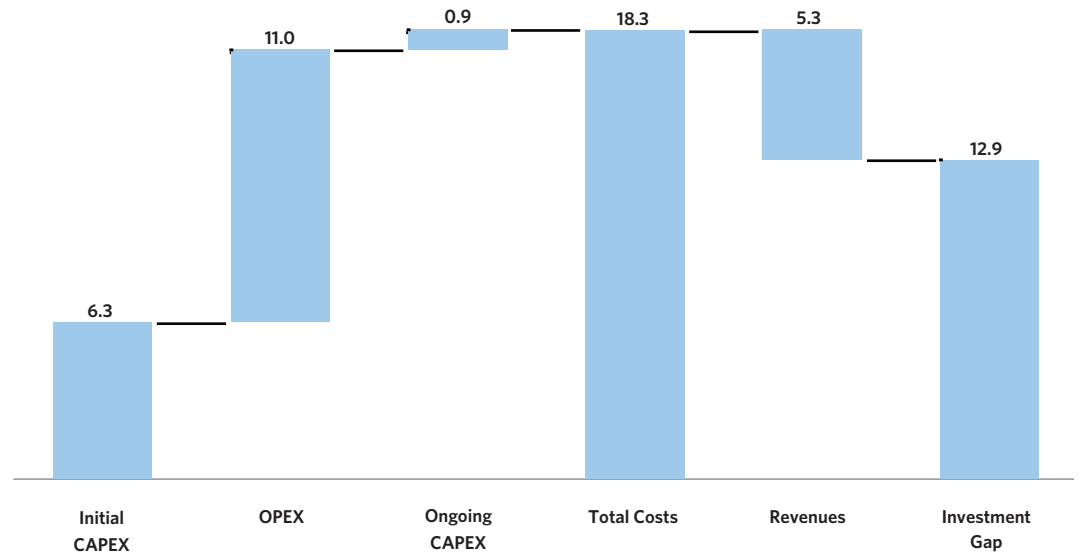
(in billions of USD, present value)

Exhibit 4-X:
Total Investment per
Housing Unit (HU) and
Investment Gap per HU
by Cell Size
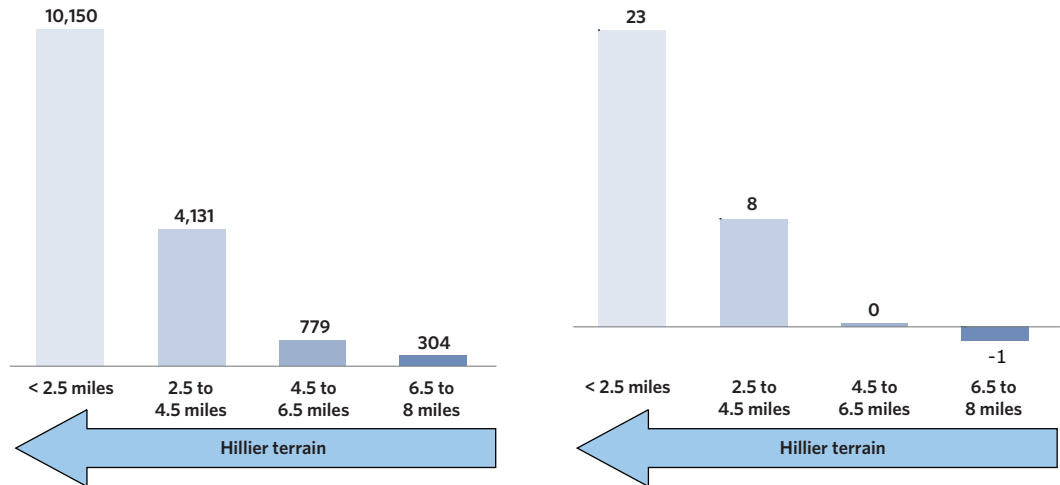
Total initial investment per HU by cell radii

(USD, present value)

Investment Gap per HU by cell radii

(in thousands of USD, present value)

total cost of the FW deployment in counties with negative NPV is 96% greater. Further, the FW investment gap is 90% more. Note that this is a comparison of the FW investment gap only and not that of the overall investment gap. For this analysis, we use the following maximum cell radius for each of the four terrain types.[65]

Terrain classification	Maximum cell radius (miles)
Flat	5
Rolling hills	3
Hilly and Mountainous	2

Exhibit 4-Y:

Sensitivity of Investment Gap to Terrain Classification—Change in Costs and Investment Gap by Changing Terrain Classification [66]

■ **Parameter set A: "More flat"**
■ **Baseline**
■ **Parameter set B: "More mountainous"**
■ **Parameter set C: "Very mountainous"**

(in billions of USD, present value)
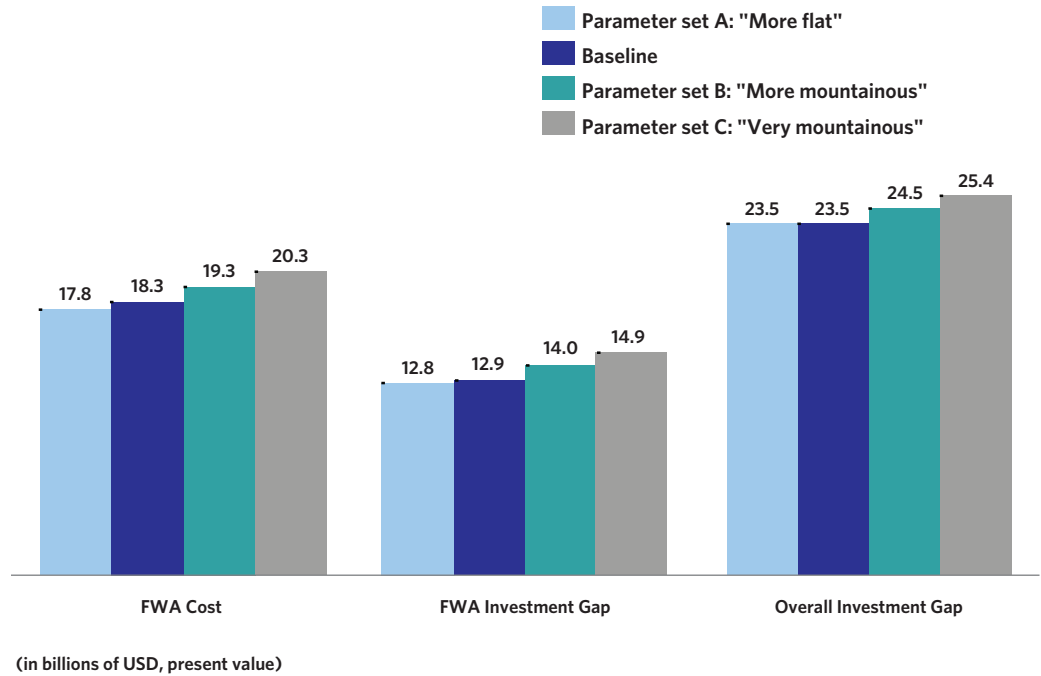
Terrain type	Classification parameters based on Standard Deviation of elevation of CTs			
	Baseline	Parameter set A	Parameter set B	Parameter set C
Flat	≤ 20	≤ 25	≤ 20	≤ 20
Rolling hills	20 to 125	25 to 125	20 to 125	20 to 125
Hilly	125 to 350	125 to 350	125 to 300	125 to 250
Mountainous	≥ 350	≥ 350	≥ 300	≥ 250

Cost and gap shown for counties that have a negative NPV. The baseline classification is based on parameters in Exhibit 4-K. The remaining parameter sets alter the classification of flat and hilly terrains, as shown below. We highlight the changes in the parameters from the baseline for convenience.

Our baseline also assumes 2x20 MHz of spectrum availability. Exhibit 4-AA shows the economic impact of spectrum availability assumptions. Note that the lack of spectrum increases the cost of the buildout in unserved areas by nearly 5%. The cost impact is relatively small because 2x10 MHz of spectrum is sufficient for 82% of the cell sites (see Exhibit 4-S). The cost impact in areas with negative NPV is even smaller (less than 3%). This is because the cell sites in these areas are typically smaller, so that they also have fewer HUs in them (see Exhibit 4-X for the impact of cell radius on the Investment Gap), which reduces the spectrum needs for the cell sites. Consequently, the impact on the Investment Gap in these areas is also small.

We have not yet addressed the fact that no U.S. service provider currently has more than 2x10MHz of contiguous spectrum in the 700MHz band. But both Verizon Wireless and AT&T Wireless do have noncontiguous spectrum holdings of over 2x20MHz of spectrum across different bands. However, these bands will not all have similar propagation characteristics.

A common deployment strategy used in such situations is to use the lower frequency bands with superior propagation characteristics to serve households further away from the cell site. The higher frequency bands, which can have superior capacity through the use of MIMO techniques, are then reserved for serving those closer to the cell site. This ensures that each available spectrum band is efficiently used.

Cost per cell site

Exhibit 4-AB shows a cost breakdown of a wireless network for all unserved areas. Note that the cost of the network is dominated by last-mile and second-mile costs, which we shall refer

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Exhibit 4-Z:

Sensitivity of Costs and Investment Gap to Subscriber Capacity Assumptions— Change in Costs and Investment Gap Under Different Downlink Capacity Assumptions

Legend:
- 20% higher capacity per site
- Baseline
- 20% lower capacity per site

FWA Cost: 18.2 / 18.3 / 18.4

FWA Investment Gap: 12.9 / 12.9 / 13.0

(in billions of USD, present value)
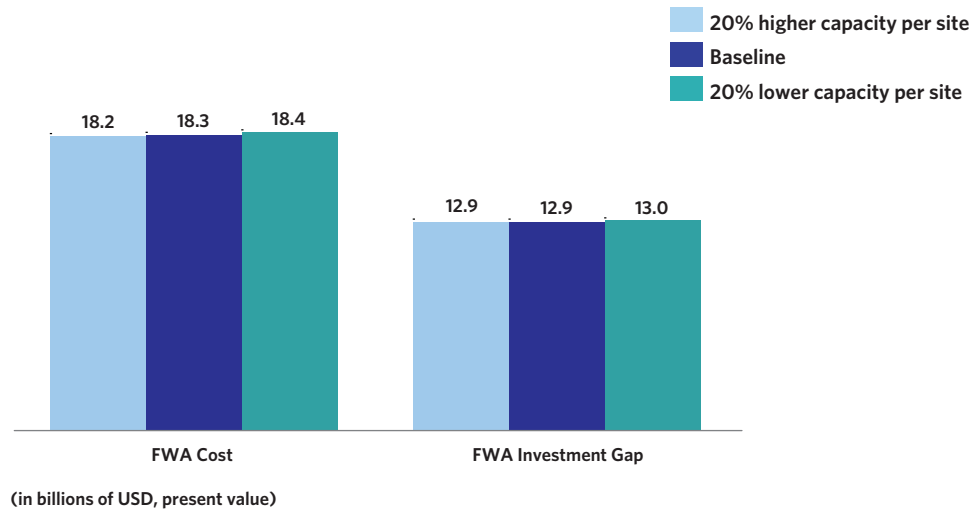
Exhibit 4-AA:

Impact of Spectrum Availability on FWA Economics— Change in FWA Costs and Investment Gap Under Different Spectrum Availability Assumptions

Legend:
- 2x40MHz
- Baseline: 2x20MHz
- 2x10MHz

Total Cost for all unserved areas: 28.7 / 28.8 / 29.8

Total Cost in unserved areas with negative NPV: 18.3 / 18.3 / 18.6

FWA Investment Gap in areas with negative NPV: 12.9 / 12.9 / 13.0

(in billions of USD, present value)

0156
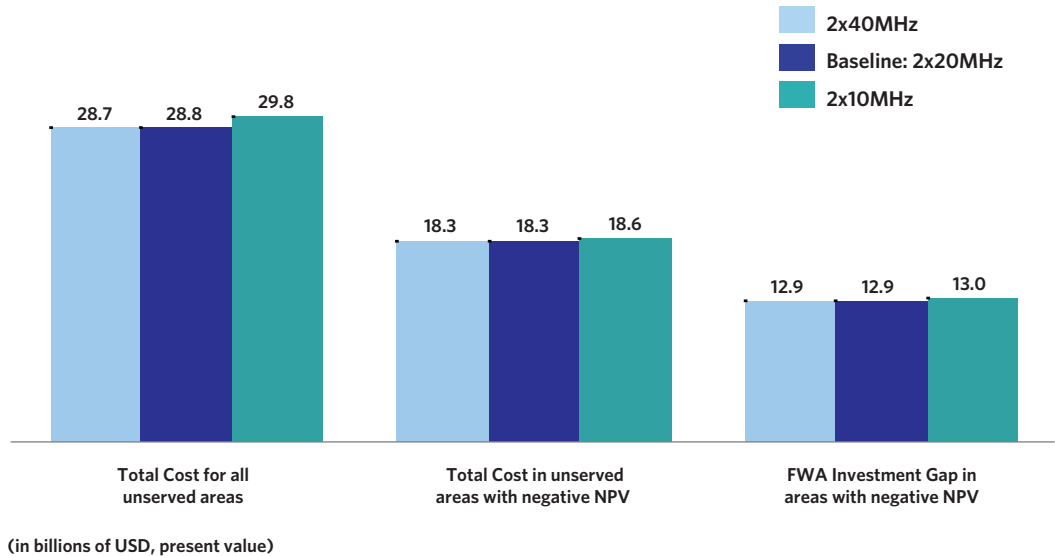
to as simply *site costs*; these account for more than 67% of the total costs. Exhibit 4-AC shows that tower construction/lease and second-mile backhaul costs constitute 68% of the cost of deploying, operating and maintaining a cell site.

Tower construction/lease costs comprise 34% of site costs. To model site costs appropriately, we create one set of hexagonal cells that cover the entire country for each analyzed cell-size (2, 3, 5 and 8 miles). These hexagonal cells represent the wireless cells. Each cell needs to contain at least one tower. To account for the fact that existing services imply existing towers, we turn to several data sources. First, we used the Tower Maps data set of tower locations.[67] For cells that do not include a tower site in that data set, we used 2G and 3G coverage as a likely indicator of cell site availability. Specifically, we assumed that the likelihood of a tower's presence is half the

2G/3G coverage in the hexagonal cell area. For example, a cell that is fully covered by 2G/3G service has only a 50% chance of having a tower site. In areas without a tower, we assume that a new tower needs to be constructed 52.5% of the time;[68] the remainder of the time we assume a cell site can be located on an existing structure (e.g., a grain silo or a church steeple).

In practice, the cost of deploying a wireless network in an area without any wireless coverage today should be higher because of the likely absence of any existing wireless network infrastructure that the provider can leverage. And, with our assumptions above, we capture that effect.

Our cost assumptions in the model indicate that the total 20-year cost of constructing and maintaining a tower is $350K to $450K. By comparison, the total cost of co-locating on an existing structure is only $165K to $250K. Further, our model

Exhibit 4-AB:
Cost Breakdown of Wireless Network Over 20 Years [69]

(in billions of USD, present value)
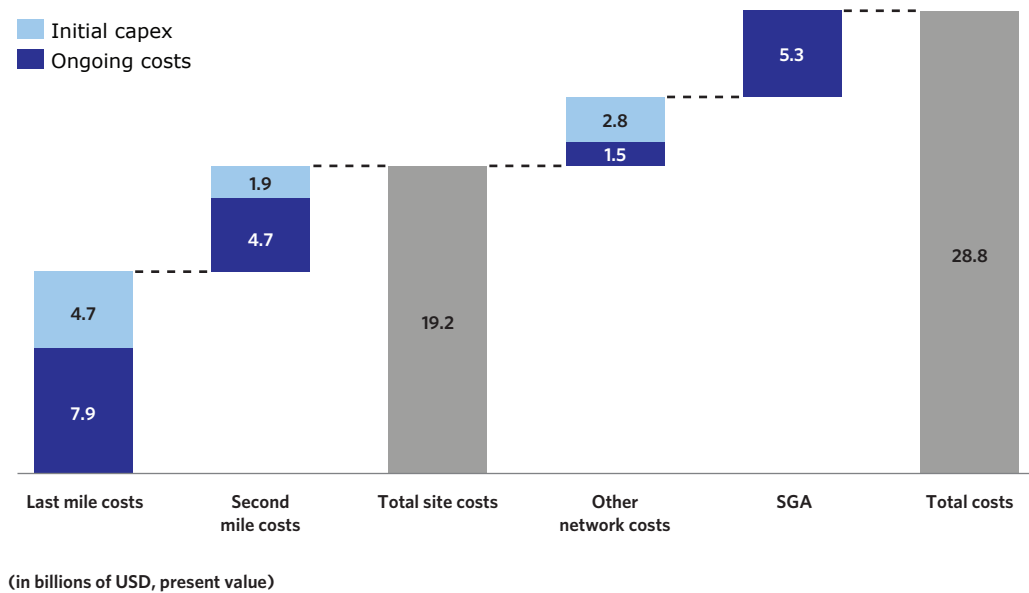
Exhibit 4-AC:
Breakdown of Total Site Costs for Wireless Network in Unserved Areas

(in billions of USD, present value)
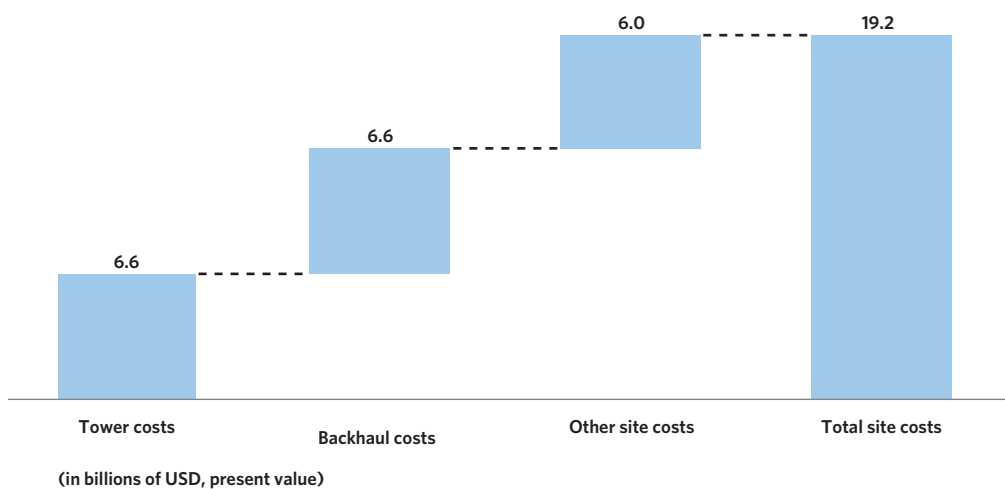
shows that new tower construction is necessary around 15% of the time.

Second-mile backhaul

Our baseline model for the FWA network uses a Hybrid Fiber Microwave (HFM) backhaul architecture with limited microwave penetration. Specifically, we allow a maximum of four hops. Recall that a network architecture that allows a deeper microwave penetration will reduce network costs at the expense of a possible reduction in reliability. Recognizing this trade-off between reliability and cost, we analyze how a restriction on the number of hops affects the cost of the FW buildout and the investment gap. Specifically, we analyze two HFM architectures and compare them with a fiber-only network: (1) Very limited microwave penetration: an HFM network where we allow a maximum of four hops; and (2) Moderate microwave penetration: an HFM network where we allow a maximum of four hops.

In each scenario, we constrained the capacity of the microwave link to 300 Mbps. That limits our ability to daisy-chain microwave links, because the cumulative backhaul needs of all cell sites upstream of a link in the chain cannot exceed the capacity of that link. For example, returning to Exhibit 4-U, the capacity of the link between Cell sites 2 and 3 must be greater than the cumulative backhaul needs of Cell sites 1 and 2; otherwise, one of Cell sites 1 or 2 will require a fiber connection.

Exhibit 4-AD compares the initial investment for the three scenarios. We note that the cost of limiting the number of hops is small—less than 5% when we limit it to two instead of four. This is because most of the unserved regions do not constitute large contiguous areas and can, therefore, be served using a small cluster of cell sites. As a result, the limitation does not severely impact cost. In fact, in the scenario where we allow deep microwave penetration, more than 85% of the cell sites using microwave backhaul connect to a fiber-fed cell site in two or fewer hops.

Exhibit 4-AD:

Cost of an HFM Second-Mile Backhaul Architecture— Initial Investment with Different Second-Mile Backhaul Network Architectures

	8.2	8.5	10.8
	HFM: moderate microwave penetration	HFM: limited microwave penetration	Fiber-only network

(in billions of USD, present value)
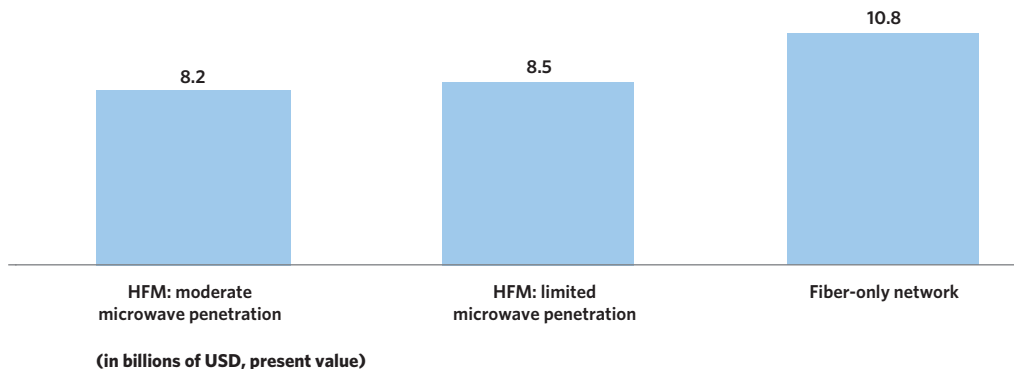
Exhibit 4-AE:

Cost Assumptions and Data Sources for Wireless Modeling

Parameter	Source and comments
Tower construction	Mobile Satellite Ventures filing under Protective Order
BTS	Mobile Satellite Ventures filing under Protective Order
Ancillary Radio Access Network	Mobile Satellite Ventures filing under Protective Order
Core network equipment	Mobile Satellite Ventures filing under Protective Order
Site operations	Mobile Satellite Ventures filing under Protective Order
Land Cover	http://www.landcover.org/data/landcover/ (last accessed Feb. 2010) Summary File 1, US Census 2000
Elevation	NOAA GLOBE system http://www.ngdc.noaa.gov/mgg/topo/gltiles.html (last accessed Feb. 2010)
Microwave radio	Dragonwave
Microwave operations	Level-(3) filing under Protective Order
Fiber installation, equipment, operations and maintenance	See cost assumptions for FTTP
Wireless CPE	Based on online price information available for different manufacturers

Conclusions

In order to engineer a wireless network to provide a service consistent with the National Broadband Availability Target, we use the uplink speed target and supplement it with terrain data to compute a maximum cell radius for four different terrain types. In the downlink, we calculate a maximum subscriber capacity per cell site.

A significant driver of variation in per site costs is tower availability and backhaul costs. For backhaul, a Hybrid Fiber Microwave (HFM) architecture results in a lower cost; but a fiber-only network does have the benefit of deeper fiber penetration.

Next, we conduct a sensitivity analysis of our model parameters and assumptions. Not surprisingly, spectrum availability and spectrum bands can have a significant impact on the cost the FWA network as well as the investment gap.

12,000-foot-loop DSL (Digital Subscriber Line)

Telephone networks have traditionally been two-way (or duplex) networks, arranged in a hub-and-spoke architecture and designed to let users make and receive telephone calls. Telephone networks are ubiquitous in rural areas, in part because local carriers have had the obligation to serve all households in their geographic area; this is known as the carrier-of-last-resort obligation. In addition, some telephone companies have historically relied upon implicit subsidies at both the federal and state levels to provide phone service. More recently, they have received explicit financial support through the federal Universal Service Fund (USF). The USF was designed to ensure that all households have access to telephone service at rates that are reasonably comparable to urban rates.

Thousands of independent telephone companies provided service in local markets. But when the telephone network was originally constructed, a single operator, AT&T, dominated it. In 1984, AT&T divested its access network into seven Regional Bell Operating Companies (RBOCs). Over time, the original seven RBOCs have consolidated into three: AT&T (formerly Southwestern Bell, Pacific Telesis, Ameritech, BellSouth and non-RBOC SNET), Verizon (formerly NYNEX, Bell Atlantic and non-RBOC GTE) and Qwest (formerly US WEST).

Exhibit 4-AF:

Breakout of Voice Line Ownership — Telco Consumer Telephone Access Lines Market Share (3Q 2009)[70]

Percent of United States lines

Numbers do not sum to 100% due to rounding.
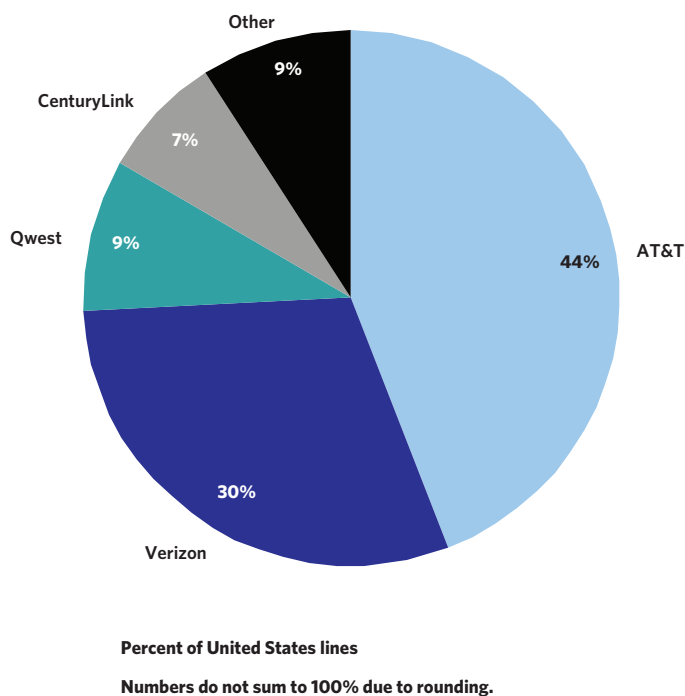
Consolidation has occurred among smaller Incumbent Local Exchange Carriers (ILECs) as well, with many of them consolidating into CenturyLink, Windstream, Frontier and Fairpoint. Yet well over a thousand small ILECs remain. Today, there are more than 1,311 Telco operators,[71] but the three RBOCs own 83% of voice lines.[72] See Exhibit 4-AF.

The evolution of modern telephone company networks has required significant investments in network capabilities in order to offer broadband access. In the late 19th and early 20th centuries, these networks were built for plain old telephone service (POTS), which provides basic voice service between users over twisted-pair copper wires. These wires, or "loops," were installed between the home and the telephone exchange office via an underground conduit or telephone poles. The basic telephone network architecture and service, originally designed for two-way, low frequency (~4 kilohertz, or kHz), all-analog transmissions with just enough capacity to carry a single voice conversation, are still used today by most homes and businesses. In fact, this network is the basis for the high-speed broadband service known as Digital Subscriber Line (DSL) offered by telecommunications companies.

With the advent of the modem, telephone networks were the first networks to provide Internet access. After all, millions of homes were already "wired" with twisted-pair copper lines that provided POTS. Initially, dial-up Internet used the same analog network designed for voice to deliver Internet access at speeds of up to 56 kilobits-per-second (kbps). To offer high-speed access, the network needed to be reengineered to handle digital communications signals and upgraded to handle the tremendous capacity needed for broadband data and broadcast transmissions. Although twisted-pair copper cables are capable of carrying high-capacity digital signals, the network was not optimized to do so. The large distance between a typical home and telephone exchange offices, as well as the lack of high-speed digital electronics, stood in the way of broadband deployments.

Steps to upgrade telephone networks for broadband:

➤ Invest in fiber optic cable and optic/electronics to replace and upgrade large portions of the copper facilities for capacity purposes
➤ Replace and redesign copper distribution architecture within communities to "shorten" the copper loops between homes and telephone exchanges
➤ Deploy new equipment in the exchanges as well as the homes (DSL equipment) to support the high capacity demands of DSL and broadband
➤ Develop the technology and equipment necessary for sophisticated network management and control systems

➤ Implement back-office, billing and customer service platforms necessary to provide the services common among telephone operators today

DSL provided over loops of 12,000 feet (12 kft) is a cost-effective solution for providing broadband services in low-density areas. In fact, it is the lowest cost solution for 10% of the unserved housing units. DSL over 12 kft loops meets the broadband target of a minimum speed threshold of 4 Mbps downstream and 1 Mbps upstream, and the backhaul can easily be dimensioned to meet the BHOL per user of 160 kbps.[73] Since DSL is deployed over the same existing twisted-pair copper network used to deliver telephone service, it benefits from sunk costs incurred when first deploying the telephone network.

Capabilities

DSL over loops of 12,000 feet typically uses ADSL2/ADSL2+ technology, which was first standardized in 2005 and which uses frequencies up to 2.2 MHz. As ADSL2+ over 24AWG gauge wire provides rates of 6 Mbps downstream and 1 Mbps upstream, the technology meets the speed requirements for broadband service of 4 Mbps down and 1 Mbps up. Figure 4-AH illustrates how loop length affects speed for ADSL2+.

The technology can perform 1 Mbps upstream on 12 kft of 24 AWG twisted-pair copper loops.[74] In this case, 24 AWG wire is assumed with no bridged taps. Performance with 22 AWG wire, which is often used in rural areas, would yield higher bitrates, while use of 26 AWG wire would yield lower rates.

In order to provide faster speeds than those listed above, DSL operators can bond loops and continue to shorten loop lengths. The bonding of loops can be used to multiply the speeds by the number of loops to deliver rates over 30 Mbps if sufficient numbers of copper loops are available. [75] The performance improvements that can be achieved by shortening loops from 12 kft to 5,000 feet or 3,000 feet and replacing existing technology with VDSL2 are discussed in the DSL 3-5 kft section below. Shortening loops requires driving fiber closer to the end-user; while costly, it could provide much faster speeds that could serve as an interim step for future fiber-to-the-premises (FTTP) deployments. Investment in 12 kft DSL, therefore, provides a path to future upgrades, whether the upgrade is to 5 kft or 3 kft loops or FTTP.

For the small-to-medium enterprise business community, copper remains a critical component in the delivery of broadband. Ethernet over Copper (EoC), often based on the G.SHDL standard, is a technology that makes use of existing copper facilities by bonding multiple copper pairs electronically. EoC can provide speeds between 5.7 Mbps on a single copper pair

Exhibit 4-AG:

Telco-Plant Upgrades to Support Broadband
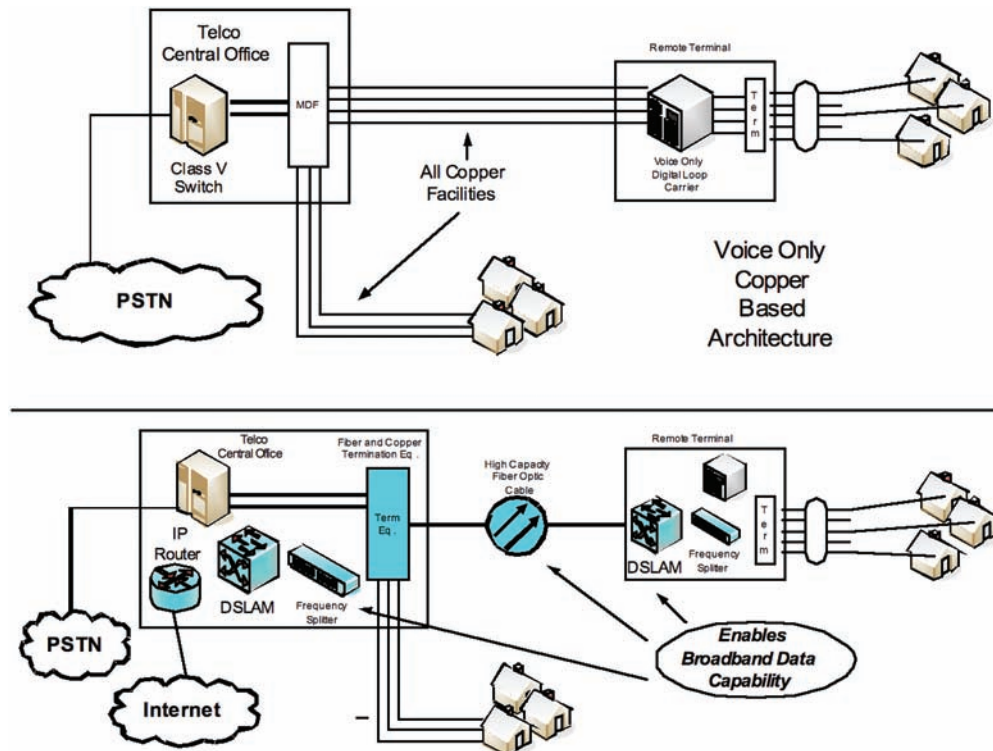
and scale up to 45 Mbps, or potentially higher, by bonding multiple copper pairs. Though middle and second mile connectivity of 100 Mbps is likely necessary, bonded EoC technology can serve as a useful and cost-effective bridge in many areas. Moreover, the embedded base of copper plant is vast—one market study shows that more than 86% of businesses today are still served by copper.[76] Although service providers may prefer to deploy fiber for new builds, existing copper likely will be part of the overall broadband solution, particularly for last- and second-mile applications, for the next several years.

In addition to bonding and loop shortening, marginal speed improvements and increased stability of service levels with ADSL2+ can be achieved through the use of Level 1 dynamic spectrum management (DSM-1).[77] DSM-1 is physical layer network management software that enables reliable fault diagnosis on DSL service. This advancement is available today and may increase bit-rates by up to 10% on ADSL2+.[78] Additionally, DSM-1 helps to ensure stability and consistency of service such that carriers can reach the theoretical 4 Mbps even at high take rates within a copper-wire binder.

We model a 12 kft DSL network that meets the speed and capacity requirements defined in the discussion of 4Mbps downstream requirement in Chapter 3. As outlined in the network design considerations below, we note network sharing in DSL networks does not start until the second mile. The modeled ADSL2+ technology exceeds the speed requirement and includes costs associated with loop conditioning when appropriate. In addition, the modeled build ensures that second and middle-mile aggregation points are connected to the Internet backbone with fiber that can support capacity requirements.

A fundamental operational principle for DSL is that all of the bandwidth provisioned on the last-mile connection for a given end-user is dedicated to that end-user. Unlike HFC, Fixed Wireless, and PON, where the RF spectrum is shared among multiple users of that spectrum and thus subject to contention among them, the last-mile DSL frequency modulated onto the dedicated copper loop and associated bandwidth are dedicated. Sharing or contention with other users on the network does not occur until closer toward the core of the network, in the second and middle mile, where traffic is aggregated (see Exhibit 4-AI). This second- and middle-mile network sharing still occurs in all other access network technologies as well. The "sharing" concept is introduced in detail in the capacity planning discussion in the Network Dimensioning section below.

The ADSL 2+ standard is widely deployed today in telco DSL networks and is assumed to be the minimum required to achieve 4 Mbps downstream and 1 Mbps upstream. The last mile access network ADSL2+ is defined in ITU-T Recommendation G.992.5[11]. The technology provides rates of 6 Mbps downstream and 1 Mbps upstream on the longest loops of a Carrier Serving Area (CSA) (3.7 km or 12 kft of 24 AWG twisted-pair copper loop), with much higher rates attainable on shorter loops.[79]

We perform our analysis and cost calculations based upon a maximum 12 kft properly conditioned copper loop. Loop conditioning costs are applied to those loops that have never been conditioned to offer DSL. For example, if the statistical model showed any DSL speeds for a given census block, we do not apply the loop-conditioning cost since we assume it had already occurred. We believe that only about 1 million homes nationwide have DSL available at a speed below the 4 Mbps

Exhibit 4-AH:

Downstream Speed of a Single ADSL2+ Line as a Function of Loop Length[80] (24 AWG)
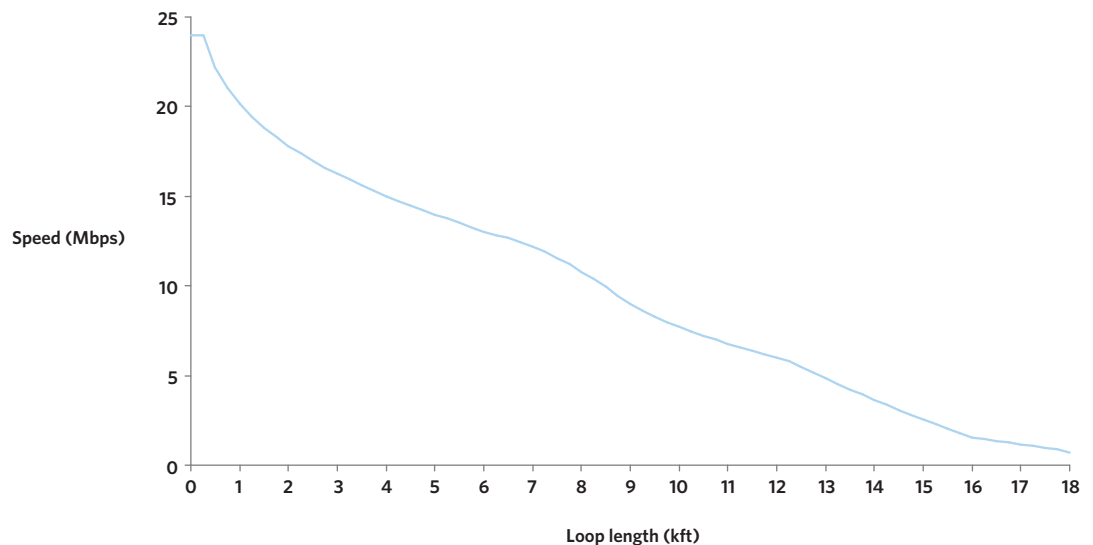
Exhibit 4-AI:
DSL Network
Diagram
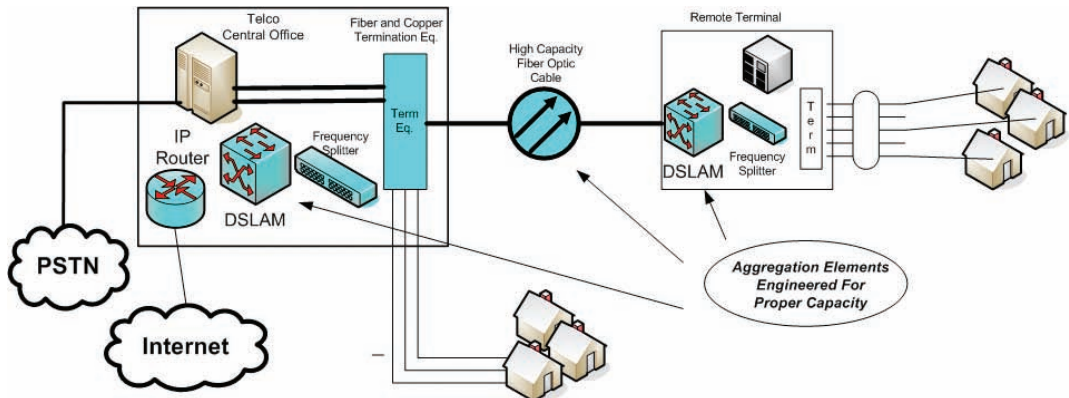
Exhibit 4-AJ:
Capacity of a
DSL Network—
Simultaneous
Streams of Video in
a DSL Network[81][82]

Percent of subscribers, 100% = 384
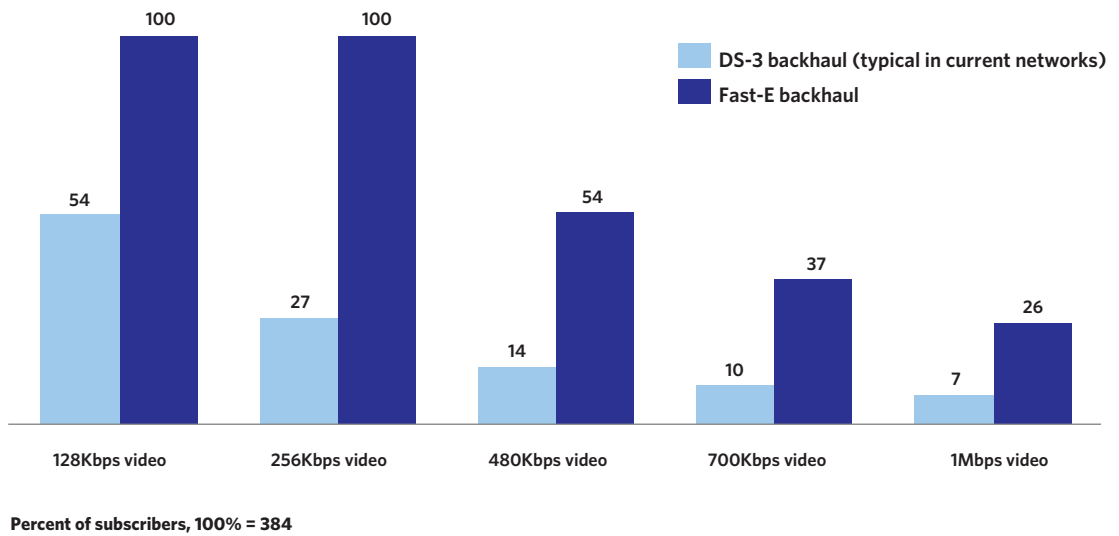
Exhibit 4-AK:
Economic
Breakdown of
12,000-foot DSL

(in billions of USD, present value)
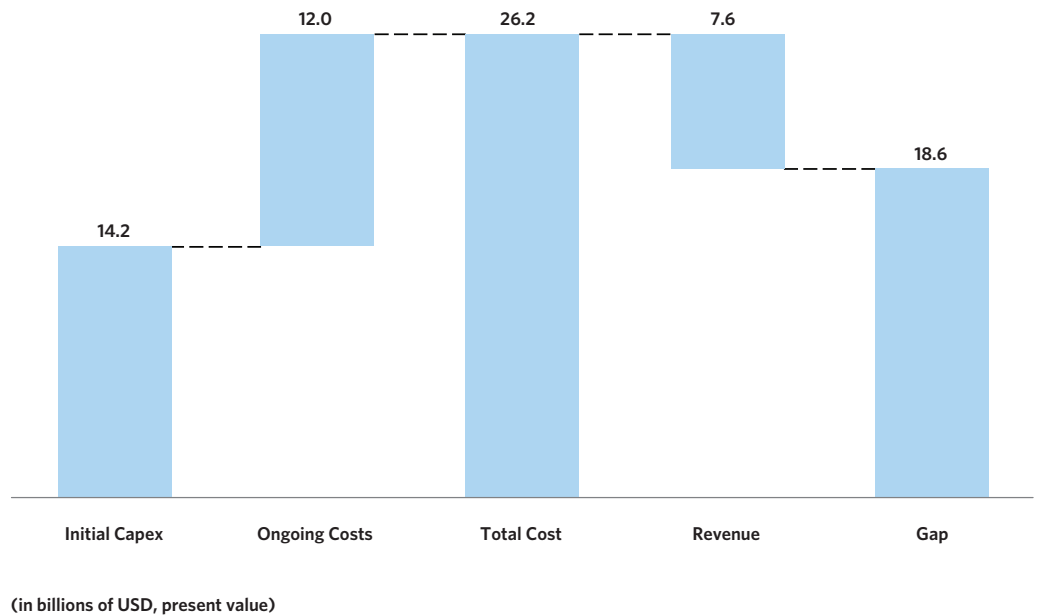
target speed. In the remaining areas, comprising about 6 million housing units, the model includes loop-conditioning costs.

We model the ADSL2+ access network such that DSLAMs are connected to the central office and other middle- and second-mile aggregation points using fiber optic-based Ethernet technology that provides backhaul capacities more than sufficient to meet a 4 Mbps down and 1 Mbps up end-user requirement. Moreover, we calculate the estimated average BHOL per user to be 160 kbps. A typical DSLAM serves between 24-384 subscribers. Since Ethernet-based backhaul provides a minimum of 100 Mbps (a.k.a. Fast-E) bandwidth, scaling to as much as 1 Gbps (a.k.a. Gig-E), the middle- or second-mile aggregation point has sufficient backhaul capacity required to support 4 Mbps down and 1 Mbps up. The resulting capacity of such a DSL network dimensioned with a Fast-E backhaul is shown in Exhibit 4-AJ.

In a DSL network with fewer subscribers, as will be the case in rural areas with low population density, the fraction of users who could simultaneously enjoy video streams of a given data rate would go up proportionately. The dimensioning discussed above is in contrast to the capacity of the network with conventional backhaul provisioning of ~1 Mbps in the shared portions of the network for every 14.5 users.[83]

Economics
The economics of the DSL network depend on revenues, operating costs and capital expenditures. Using granular cost data from DSL operators and vendors, the model calculates the gap to deploy 12 kft DSL to unserved markets as $18.6 billion. Exhibit 4-AK shows the breakout among initial capital expenditure, ongoing costs and revenue.

Initial Capex
Initial capital expenditures include material and installation costs for the following: telco modem, NID, protection, aerial or buried copper drop, DSLAM, cabinet, ADSL2+ line card,

Exhibit 4-AL:
Data Sources for
DSL Modeling

Material Costs	Source
Telco Modem	Windstream filing under Protective Order
For port sizes of 24 - 1,008:	
DSLAM Unit	Windstream filing under Protective Order
Cabinet	Windstream filing under Protective Order
Allocated Aggregation Cost (CO Ear)	Windstream filing under Protective Order
ADSL2+ line cards	Windstream filing under Protective Order
Fiber optic cabling	FTTH Council
Aerial Drop	Windstream filing under Protective Order
Buried Drop	Windstream filing under Protective Order
NID	Windstream filing under Protective Order
Protection	Windstream filing under Protective Order
Copper cable (24 and 22 AWG)	Windstream filing under Protective Order
Drop terminal/ building terminal (DTBT)	Windstream filing under Protective Order
Feeder distribution interface (FDI)	Windstream filing under Protective Order
Material Labor Costs	
FDI Splicing and Placing labor cost	Windstream filing under Protective Order
DTBT Splicing and Placing labor cost	Windstream filing under Protective Order
Telco Drop and NID labor cost	Windstream filing under Protective Order
Structure Labor Costs	
Duct, Innerduct and Manhole labor cost	Windstream filing under Protective Order
Loop Conditioning cost	Windstream filing under Protective Order
Poles. Anchor and Guy labor cost	Windstream filing under Protective Order
Buried Excavation labor cost under various types of terrain- normal, hardrock and softrock	Windstream filing under Protective Order

allocated aggregation cost, fiber cable up to 12 kft from the end-user, feeder distribution interface and drop terminal/building terminal, as well as the engineering costs for planning the network and the conditioning required on loops (i.e., the removal of load coils[84] and bridged taps[85]). For a detailed list of inputs into our model and the source for each, please refer to Exhibit 4-AL.

Ongoing Costs

Ongoing costs include: replacement capital expenditures required to replace network components at the end of their useful lives, network administration, network operations center support, service provisioning, field support, marketing and SG&A.

Revenues

Revenues are calculated by taking the Average Revenue Per User (ARPU)—which varies according to the level of broadband service/speed provided as well as whether the bundle of services provided includes voice, data and video—and multiplying it by the average number of users. For 12 kft DSL, only data ARPUs are used as incremental to voice, which is assumed present due to the fact that DSL technology utilizes twisted-pair copper wires originally installed and used for POTS.

Satellite

Broadband-over-satellite is a cost-effective solution for providing broadband services in low-density areas. In fact, it could reduce by $14 billion the gap to deploy to the unserved if the 250,000 most-expensive-to-reach housing units were served by satellite broadband. Satellite broadband, as provided by next generation satellites that will be launched as early as 2011, meets our Broadband Availability Target requirements by offering a minimum speed threshold of 4 Mbps downstream and 1 Mbps upstream and BHOL per user of 160 kbps.

Capabilities

Satellite operators are in the midst of building high capacity satellites that will dramatically augment the capacity available for subscribers in the next two years. ViaSat and Hughes, for example, plan to launch high-throughput satellites in 2011 and 2012, and offer 2-10 Mbps and 5-25 Mbps download-speed services, respectively. Upload speeds will likely be greater than the 256 kbps offered today, but no specific upload speeds have been announced. Since satellites are technically constrained by the total capacity of the satellite (>100Gbps), operators could change plans to offer customers at least 1 Mbps upstream even if it is not currently planned. Since the next-generation satellites will be able to offer 4 Mbps downstream and 1 Mbps upstream, satellite broadband meets the technological requirements for inclusion in the National Broadband Plan.

Technical limitations

Over the last decade, satellite technology has advanced to overcome some of the common drawbacks previously associated with it. Due to the properties of the spectrum band used for this service (Ku band downlink 11.7-12.7 GHz, uplink 14-14.5 GHz; Ka band downlink 18.3- 20.2 GHz; uplink 27.5-31 GHz), inclement weather can have an effect on service. However, the ability to dynamically adjust signal power, modulation techniques and forward error correction have all reduced degradation of service except in the most severe of weather conditions.

Since the satellites are in geosynchronous orbit nearly 22,300 miles above the earth, there is a round-trip propagation delay of 560 milliseconds associated with a typical PING (user to ISP and back to user). Recently, integrated application acceleration techniques, including TCP acceleration, fast-start and pre-fetch, have helped mitigate satellite latency for some Web-browsing experiences.[86]

Despite these technological advancements to improve the Web-browsing experience, the latency associated with satellite would affect the perceived performance of applications requiring real-time user input, such as VoIP and interactive gaming. Not only does this delay have a potentially noticeable effect on applications like VoIP, but it would also be doubled in cases where both users were using satellite broadband (e.g., if two neighbors, both served by satellite VOIP, talked on the telephone). Given that most voice calls are local, this could become a significant issue for rural areas if all calls must be completed over satellite broadband.

Spot beams

Broadband satellites use multiple spot beams to provide nationwide coverage. Spot beams use the same spectrum over and over in different geographies, providing more total throughput for a given amount of spectrum. The multiple re-use of frequencies across the coverage area for a satellite provider is similar to a cellular system that reuses frequencies in a "cell." Furthermore, because a spot beam focuses all its energy on a very specific area, it makes more efficient use of the available satellite power.

Nevertheless, a satellite's bandwidth to an end user is provided by and limited to the bandwidth of the spot beam covering that geographic area as well as the total satellite capacity. Therefore, potential network chokepoints for a satellite broadband network include total satellite capacity and spot beam bandwidth.[87] Each spot beam is designated over a section of the United States; once a spot beam is assigned to a certain geographic area, it generally cannot be re-allocated, shifted or moved to cover another area.

With its first leased satellite in 2005 and again with its own satellite in 2007, WildBlue found itself running out of capacity in high-demand regions.[88] In fact, ViaSat plans to aim bandwidth at exactly the same regions where WildBlue's capacity has run out.[89] Many unserved do not live in high-demand areas. These are among the factors that play a role in the capacity assumed available for broadband as discussed below.

Capacity

Providing sufficient capacity for a large number of broadband subscribers, e.g. all of the unserved, may prove challenging with satellite broadband. ViaSat and Hughes believe these next generation satellites have the capacity to serve as many as 2 million homes each;[90] ViaSat has stated on the record that its ViaSat-1 satellite will be capable of providing approximately 1 million households with Internet access service at download speeds of 4 Mbps and upload speeds of 1 Mbps.[91]

Treating satellite as a substitute for terrestrial service, however, requires that satellite be able to deliver service comparable to terrestrial options. Practically speaking, that means that satellite needs to support an equivalent BHOL per user.[92] We believe that the satellite industry could support more than 1.4 million subscribers in 2011 (note that this combines existing capacity with what is planned on being launched) and a total of more than 2.0 million subscribers in 2012 (after the launch of Hughes's next generation satellite, Jupiter). The picture becomes less clear, however, as we look to 2015, when the number of subscribers that current and planned satellites can support would decrease as demand per user grows. End-user demand has been growing at rates as high as 30% annually.[93]

We make certain assumptions in quantifying the number of subscribers that the entire U.S. satellite broadband industry could support with the launch of ViaSat-1 in 2011 and Jupiter in 2012. As there have been no commitments to launch new broadband satellites after 2012, we create a five-year outlook on satellite broadband capacity based on the following assumptions (see Exhibit 4-AM):

➤ ViaSat will launch a 130 Gbps satellite in early 2011.[94] A comparable satellite, Jupiter, will be launched by Hughes in 2012.[95]

➤ "Total Downstream Capacity" is 60% of "Total Capacity."
➤ "Total Usable Downstream Capacity" factors in 10% loss, which includes factors such as utilization and a potential loss of capacity from geographic clustering in which a non-uniform distribution of subscribers would engender certain spot beams to not be fully utilized.

Busy hour offered load (BHOL) assumption

Busy hour offered load, or BHOL, is the average demand for network capacity across all subscribers on the network during the busiest hours of the network. Understanding BHOL is critical for dimensioning the network to reduce network congestion. A more detailed discussion on BHOL can be found later in the Network Requirements section, but the basis for our assumption in satellite is explained here.

Suppose we want to dimension a network that will continue to deliver 4 Mbps. In order to estimate the BHOL for such a network in the future, we first note that average monthly usage is doubling roughly every three years, based on historical growth.[96] There is a significant difference between average usage and the typical user's usage with average usage heavily influenced by extremely high bandwidth users. Next, it becomes crucial to pick the right starting point (i.e., today's BHOL). As the mean user on terrestrial based services is downloading roughly 10 GB of data per month, busy hour loads per user for terrestrial networks translate to 111 kbps busy hour load, assuming that 15% of traffic is downloaded during the busy hour. Terrestrial-based services like cable and DSL experiencing busy hour loads of close to 111 kbps today form the "high usage" case in Exhibit 4-AN.

If we exclude the extremely high-bandwidth users, the average user downloads about 3.5 GB/month, which under the same assumptions for the busy hour would translate to 39 kbps busy hour load. The "medium usage" case in Exhibit 4-AN takes the 39 kbps as a starting point and grows to 160 kbps in 2015; it is this case that we use for our analysis of satellite as well as other networks. The "low usage" case assumes a user downloads 1 GB/month, which translates to 11 kbps; that is roughly what level of service satellite providers offer today of 5-10 kbps.[97] Using 11 kbps as a starting point, the "low usage" case applies the same growth rate as the medium and high usage cases. Exhibit 4-AN summarizes the three usage cases.

Year	2009	2010	2011	2012	2013	2014	2015
Total Capacity (Gbps)	35	35	165	295	295	295	295
Total Downstream Capacity (Gbps)	21	21	99	177	177	177	177
Total Usable Downstream Capacity (Gbps)	19	19	89	159	159	159	159

Exhibit 4-AM:
Available Satellite Capacity Through 2015

One reason why the BHOL-per-user might be lower for satellite: satellite operators' fair access policies, which are essentially usage caps, and a degree of self-selection in those who choose satellite-based broadband. However, in a world where users do not self-select into satellite, it is far from certain the extent to which these reasons will still be valid.

Using the above-mentioned assumptions under the "medium usage" case, the satellite industry could support nearly 1 million subscribers by 2015 (see Exhibit 4-AO). Note that each successive year, the satellites can support fewer subscribers due to the doubling of the BHOL every few years noted above. Each next-generation satellite can support approximately 440,000 subscribers using the usage forecast for 2015. Given that the satellite industry in the United States currently supports roughly 900,000 subscribers, this presents a potential

difficulty in meeting the needs of the industry's current subscriber base, plus new net additions. If satellite broadband is offered at a level of service comparable to that of terrestrial broadband under the "medium usage" case and BHOL growth continues, satellite providers will need to devote significant incremental capacity to their existing customer base. Since satellite providers today offer BHOL of between 5 kbps and 10 kbps,[98] our terrestrial-based BHOL assumptions would represent a marked increase in the service level of satellite providers. ViaSat has said on the record that its ViaSat-1 will support a "provisioned bandwidth" (a concept very similar to busy hour load) of 30-50 kbps.[99] However, satellite operators may not be planning for yearly growth comparable to historical terrestrial rates. Thus, despite the growth in satellite capacity between 2010 and 2012, the number of subscribers capable

Exhibit 4-AN:
Satellite Usage
Scenarios[100]

Year	2009	2010	2011	2012	2013	2014	2015
Busy Hour Load (Kbps) @ 27% growth y-o-y							
Low usage	11	14	18	22	28	36	46
Medium usage	39	49	62	79	100	126	160
High usage	111	141	178	225	285	360	455

Exhibit 4-AO:
Satellite Capacity
Based on Low,
Medium and High
Usage Scenarios

(in Gbps)
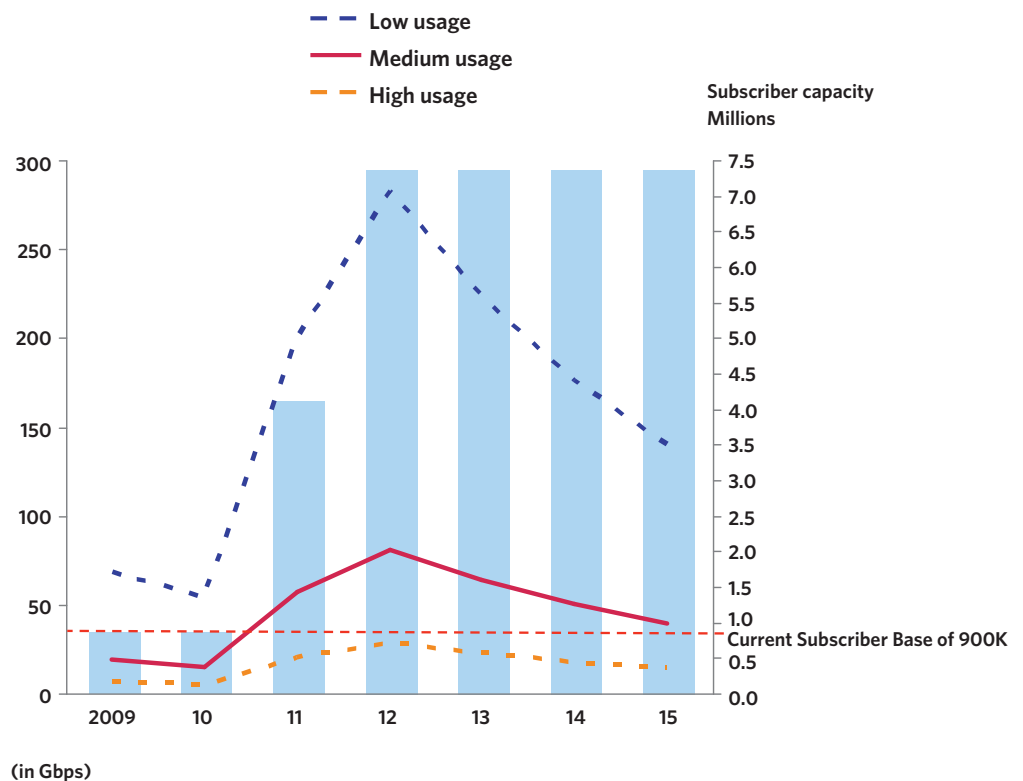
of being supported with our assumptions starts to fall quickly after 2012, absent additional satellite launches. Due to the limited capacity, we do not assume satellite in the calculation of the gap figure of $23.5 billion, but we have contemplated a case in which 250,000 of today's unserved subscribe to broadband over satellite.[101]

If satellite is used to serve the most expensive 250,000 of the unserved housing units, it will reduce the gap. Some 250,000 housing units represent 3.5% of all unserved, <0.2% of all U.S. households, and account for 57%, or $13.4 billion, of the total gap. Exhibit 4-AP shows the remaining gap if satellite is used to serve the most expensive census blocks containing a total of 250,000 subscribers.

The map in Exhibit 4-AQ identifies the location of the highest gap census blocks with a total of 250,000 housing units that we assume are served by satellite in Exhibit 4-AP.

Economics

Nearly all of the costs for satellite broadband are fixed and upfront with the development, construction and launch of the satellite. Each next-generation satellite costs approximately $400 million, which includes satellite construction, launch insurance and related gateway infrastructure.[102] Operating costs for a satellite broadband operator are typically lower than for a wired network provider. Because a single satellite can provide coverage for the entire country with the exception of homes on the north face of mountains or with dense tree cover, the cost of satellite broadband remains constant regardless of household density, which makes it a great option for remote areas.

However, due to the capacity constraints of each satellite, and the growth in use discussed above, satellite operators likely need to continue adding new satellites over time. Estimates of the initial capital expenditure to provide all 7 million of the unserved housing units using satellite broadband service are

near $10 billion, including the cost of up to 16 next-generation satellites as well as the CPE and installation for each end-user, assuming the "medium usage" scenario. Timing may be an issue if satellite broadband were deployed as the only means of reaching the unserved, as a next-generation satellite takes approximately three years to build.[103]

Additionally, with each satellite capable of supporting roughly 440,000 subscribers using our assumptions, satellite operators could be forced to potentially more than double their current monthly subscriber fees, which today range from $60-80 per month, in order to maintain the same return on investment as today.

The cost-per-subscriber is driven by the high up-front costs associated with building and launching a satellite. As capacity required per-subscriber increases, the number of subscribers that each satellite can support drops. That drop, in turn, means that there are fewer subscribers over whom to amortize high fixed costs. Thus the average cost-per-subscriber increases, creating less favorable economics over time or requiring higher monthly fees to be charged to the end-user as described above.

Even with greater efficiency of planned satellites like ViaSat-1 or Jupiter, which provide more capacity per launch, the average capex-per-subscriber will only grow with the increase in effective load-per-user. See Exhibit 4-AR, which shows the average capex per subscriber at various levels of monthly usage. The levels of usage correspond to the low, medium and high usage cases described above.

In Exhibit 4-AR, the capex of a satellite (including build, launch and insurance), the associated gateway infrastructure and the CPE is divided by the number of subscribers, depending on the usage characteristics. Note that the average cost calculation may in fact overstate the true cost of a given subscriber over the lifetime of the satellite.

Exhibit 4-AP:
Economics of Terrestrially Served if Most Expensive Housing Units are Served with Satellite [104]

Initial Capex	Ongoing Costs	Total Cost	Revenue	Gap
9.2	10.0	19.3	9.1	10.1
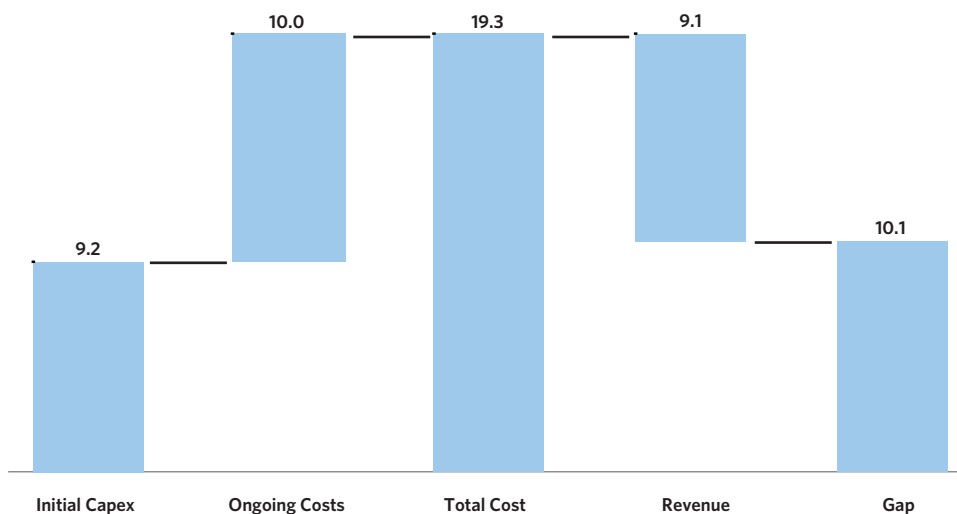
Buy down

Due to the relatively high price of satellite broadband service, there may be a need for a subsidy of the monthly ARPU for those served by satellite broadband. Current ARPU for satellite broadband is generally $60-80 per month depending on speed tier, service provider and choice of whether to purchase CPE upfront or pay a monthly fee for it.[105] For illustrative purposes, assuming a starting point of $70 per month, end-user support to reduce the price to $35 monthly would cost $105 million annually (250,000 people x $35 difference in ARPU x 12 months).

Exhibit 4-AQ:
Location of Highest-Gap Housing Units

Conterminous United States

Legend

🟨 Highest-gap housing units

Number of HUs without 4 Mbps broadband

▢ 0–2,000
▢ 2,001–5,000
▢ 5,001–15,000
▢ 15,001–25,000
▢ >25,001

Alaska

Hawaii
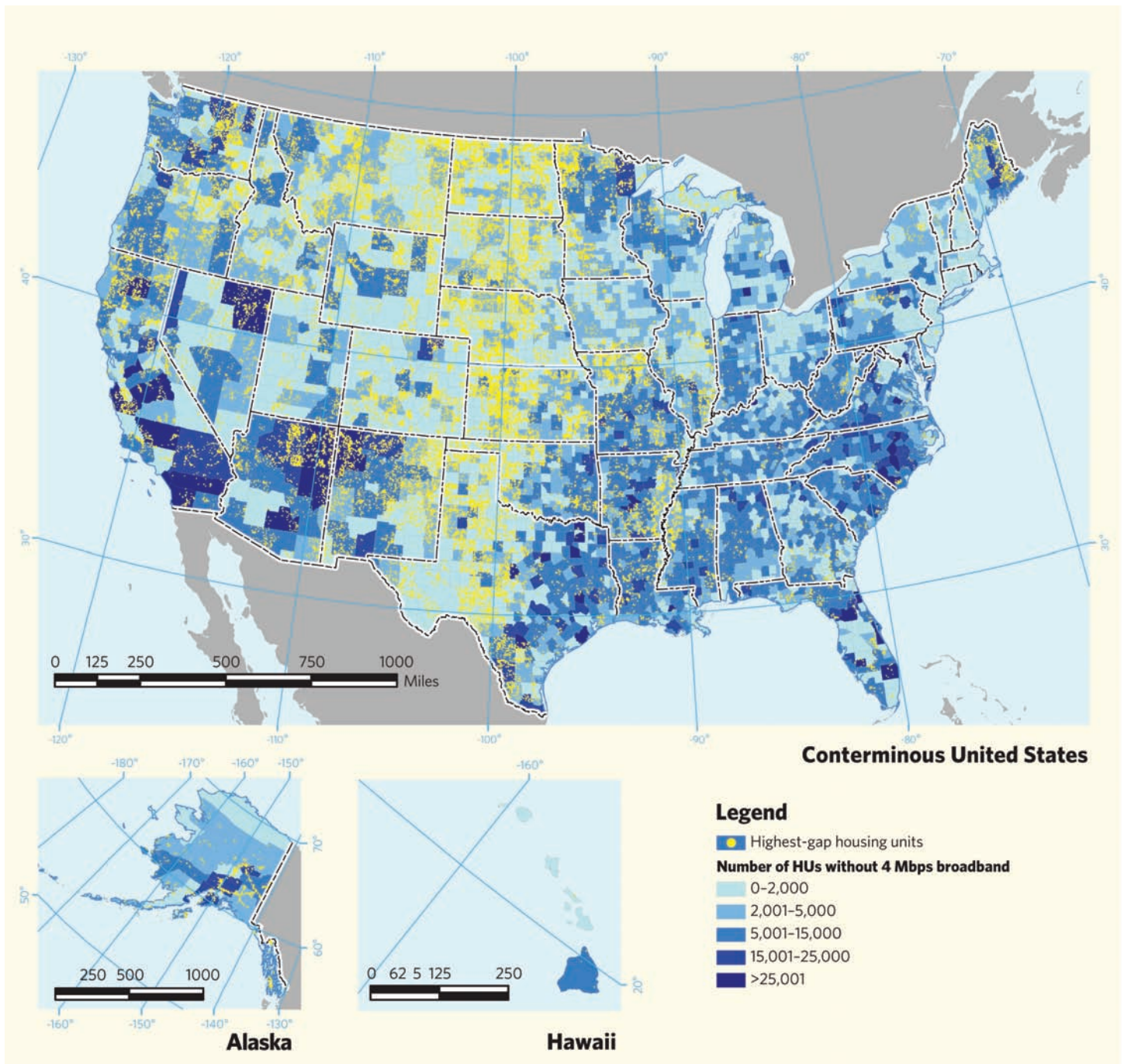
Over 20 years, discounting at 11.25% , the present value of this annual amount is over $800 million.

As discussed above, if satellite operators were to assume a higher use case to provide a level of service comparable to terrestrial providers and to double their price to ensure consistent return on investment (note that the ability to generate enough cash flow affects their ability to finance future satellites), the required subsidy would grow proportionately. Assuming a contemplated starting price of $120, the subsidy required would be $255 million annually (250,000 people x $85 difference in ARPU x 12 months) to yield an end-user price of $35. Over 20 years, the present value of this annual expenditure is roughly $2 billion.

Despite these challenges, we believe that satellite can still provide an economically attractive service for some, and that satellite providers can be an alternative to terrestrial providers, both wired and wireless. However, as we explain further in Chapter 3, uncertainty—principally about the optimal role satellite might play in the disbursement process—has led us to not explicitly include satellite in the base-case calculation.

Exhibit 4-AR:
Satellite Capex per Subscriber— Average cost/POP at Scale
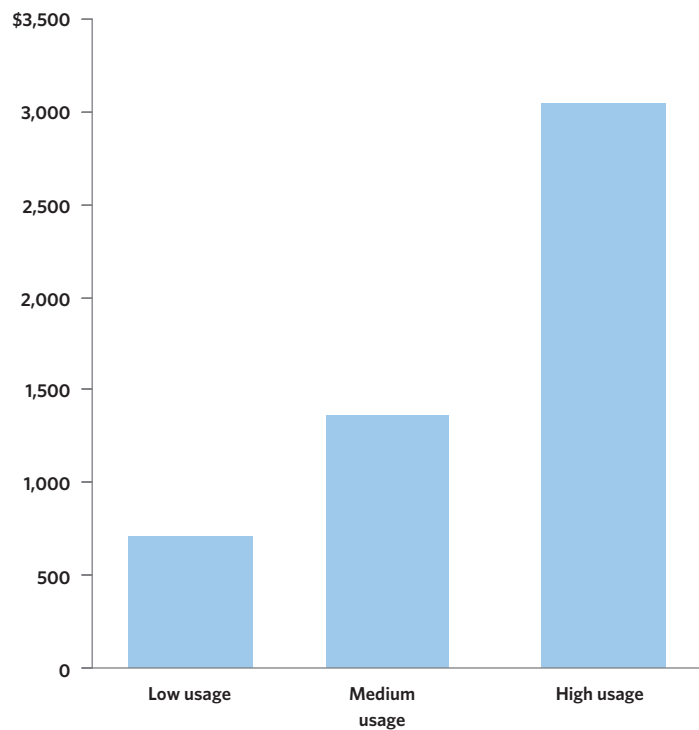
TECHNOLOGIES NOT INCLUDED IN THE BASE CASE

Fiber-to-the-premises (FTTP)

Fiber-to-the-premises (FTTP) offers the greatest potential capacity of any of the technologies considered, making it the most future-proof alternative. The tradeoff for this is the additional construction cost incurred to extend fiber all the way to the premises, making FTTP the most capital-intensive solution considered. On the operational side, the extension of fiber enables the removal of all active components in the outside plant, providing FTTP with a substantial operational savings over competing technologies with active electronics in the outside plant.[106] However, in unserved areas in particular, these savings are insufficient to overcome the initial capital expenditure burden, making FTTP the solution with the highest lifetime cost and the highest investment gap.

Capabilities

There are three basic types of FTTP deployments: point-to-point (P2P) networks, active Ethernet networks and passive optical networks (PON). PON makes up more than 94% of the current residential FTTP deployments in the United States.[107] PON has the advantage of offering lower initial capital expenditure requirements and lower operating expenditures relative to P2P and Active Ethernet deployments, respectively. As such, our analysis utilized PON as the modeled FTTP network.

Exhibit 4-AS shows the capabilities of the varieties of PON currently in use in the United States.[108]

While the majority of homes currently passed by FTTP deployments in the United States are passed by BPON networks, more new deployments are utilizing GPON.[109] PON is a shared medium, meaning that a portion of the access network running between the headend and the passive optical splitter is shared among multiple end-users.

Typical PON deployments share a single fiber in the feeder portion of the access network among 32 end-users. See Exhibit 4-AT. For BPON, this yields a fully distributed downstream capacity of 19.4 Mbps and upstream capacity of 4.8 Mbps per end-user. For GPON, these capacities increase to 78 Mbps downstream and 39 Mbps upstream. As these speeds do not factor in any oversubscription, with a reasonable oversubscription of 15:1,[110] an operator with either a BPON or GPON deployment could easily offer its customers a product with download speeds exceeding 100 Mbps, far exceeding what we anticipate being required in the foreseeable future.[111] As such, FTTP clearly is a candidate from a capability standpoint for delivering broadband to the unserved.

Future PON architectures

PON architectures continue to evolve. The full standard for the next evolution of GPON is expected to be completed in June

2010, with deployments starting in 2012. It will offer download speeds of 10 Gbps and upload speeds of 2.5 Gbps and 10 Gbps, and it will be able to coexist on the same fiber as GPON. Deployments of the next evolution of EPON could even predate those of GPON, offering download speeds of 10 Gbps and upload speeds of 1 Gbps and 10 Gbps.[112] See Exhibit 4-AU.

Beyond these near-term standards, numerous long-term ideas are being presented. For example, Wave Division Multiplexing PON would replace the splitter with an arrayed wave guide and utilize a different wavelength for each end-user. This would effectively eliminate the sharing of the fiber in the second mile that takes place with existing PON varieties, enabling dedicated end-user capacities of 10 Gbps or more.

Exhibit 4-AS:
Capabilities of
Passive Optical
Networks (PON)

	BPON	EPON	GPON
Standard	ITU-T G.983	IEEE 802.3ah	ITU-T G.984
Bandwidth	Downstream up to 622 Mbps	Downstream up to 1.25 Gbps	Downstream up to 2.5 Gbps
	Upstream up to 155 Mbps	Upstream up to 1.25 Gbps	Upstream up to 1.25 Gbps
Downstream wavelength(s)	1490 and 1550 nm	1550 nm	1490 and 1550 nm
Upstream wavelength	1310 nm	1310 nm	1310 nm
Transmission	ATM	Ethernet	Ethernet, ATM, TDM

Exhibit 4-AT:
Passive Optical
Network (PON)
FTTP Deployment

Cost to Pass   Cost to Connect
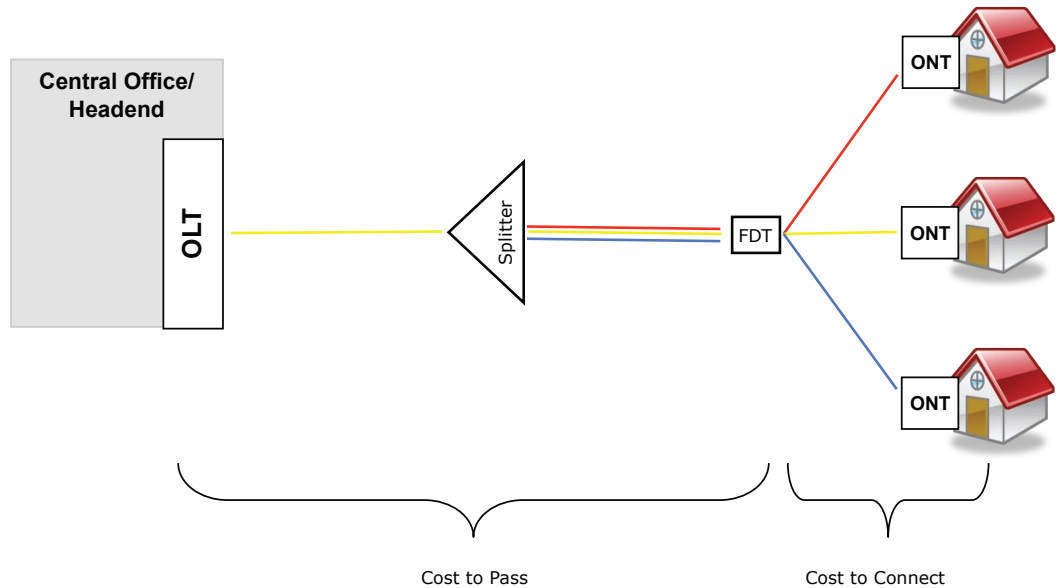
Exhibit 4-AU:
Future PON
Architectures

	10G GPON	10G EPON
Bandwidth (upstream/downstream)	10/2.5 Gbps or 10/10 Gbps shared	10/1 Gbps or 10/10 Gbps shared
Positives	Compatible with existing GPON	First completed
Key challenges	10 Gbps upstream not viable for single-family units	10 Gbps upstream not viable for single-family homes; 1 Gbps upstream too little bandwidth

FTTP economics

To build FTTP to deliver broadband to the 7 million housing units that are classified as unserved (at a broadband definition of 4 Mbps download and 1 Mbps upload) would lead to an investment gap of $62.1 billion.

The initial capital expenditure averages out to be slightly more than $5,000 per premises. This initial capex value comprises two pieces: the cost to pass a premises and the cost to connect a premises. (These costs are detailed in Exhibit 4-AV.)

The cost to connect a premises is the smaller of the two charges, typically averaging about $650-$750/premises.[113] The cost to connect is entirely success-driven and consists of the installation of the fiber drop and equipment at the customer premises. Making up the bulk of the $5,000 initial capex cost of a FTTP deployment is the cost to pass a premises; this is the cost to build the fiber network distributed over the premises capable of being serviced by the network. Cost-to-pass is typically spoken of in terms of all premises passed by a FTTP deployment, but the more meaningful number is cost-to-pass per subscriber, which takes into account penetration rate. With fiber installation costs ranging between $10,000 and $150,000 per mile, depending on a variety of factors including deployment methodology, terrain and labor factors,[114] the cost to pass is highly sensitive to penetration rate and household density.

Using several data points provided by existing FTTP providers, we are able to establish the following empirical relationship between the cost-to-pass for a FTTP deployment and household density, using standard curve-fitting techniques[115] (see Exhibit 4-AW):

Cost per home passed = $701.59 * e$^{(8.19/\text{Household density})}$

where Household density is in homes per square mile.

As one can see, the unserved segment starts to intersect the cost-to-pass curve just as the curve starts to steepen significantly. At about 10 households per square mile, the cost-per-premises passed is slightly less than $1,600. Halving the density to five housing units per square mile more than doubles the cost-to-pass, to more than $3,600. At this level, factoring in average broadband penetration of roughly 65% and including the cost to connect each premises yields a cost-per-subscriber in excess of $6,000. Due to the low densities of the unserved segment and given the current expectation of bandwidth demand over the coming years, even with an optimistic scenario for increasing broadband adoption, FTTP may be prohibitively expensive when alternative technologies can also meet bandwidth demands.

The final category of costs is one where FTTP holds a significant advantage: the cost-to-serve. By extending fiber all the way from the serving office or headend to the customer premises, an FTTP network eliminates the need for any active components in the outside plant. This can reduce ongoing maintenance and support expenditures by as much as 80% relative to an HFC plant.[116] However, on a monthly basis for a typical scale network deployment, this savings amounts to just a few dollars per subscriber, and as such is generally insufficient to offset the initial capital expenditure burden.

Exhibit 4-AV:
Breakout of FTTP Gap

44.4	49.3	93.7	31.6	62.1
Initial Capex	Ongoing Cost	Total Cost	Revenue	Investment Gap
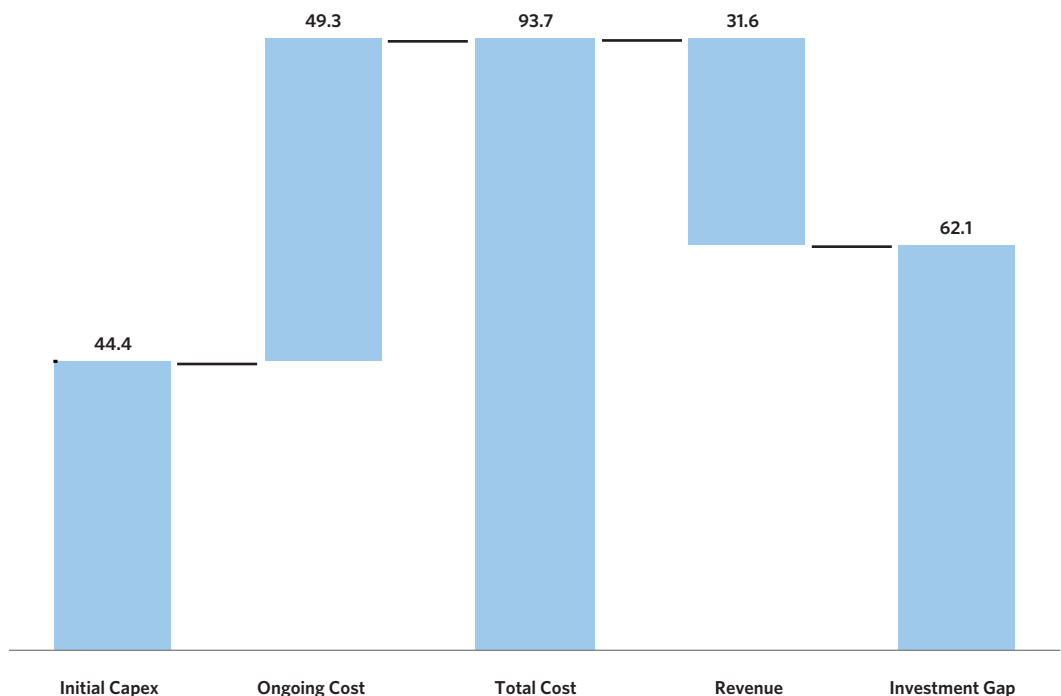
FTTP Deployment

The cost information above can be displayed in a simple financial model that can be used to easily estimate the viability of a FTTP deployment in addition to the model that calculates the cost of the investment gap across the country. See Exhibit 4-AX.

First, consider cost per home passed. In this example, we use $850, a value that would cover roughly 80% of the United States.

Factoring in a 40% penetration rate, a value taken from the high end of Verizon's publicly stated 2010 target rate for its competitive deployments,[117] we get a $2,125 cost-to-pass per subscriber. Adding in the cost-to-connect, inflated to account for churn and equipment replacement over the life of the network, we get a rough estimate of $3,225 total investment per subscriber. At this level, an operator could succeed with a monthly EBITDA of

Exhibit 4-AW:

Cost to Pass with FTTP by Density of Homes[118]

Curve fit to provide cost for any density
$R^2 = 0.992$
R^2 adjusted = 0.990
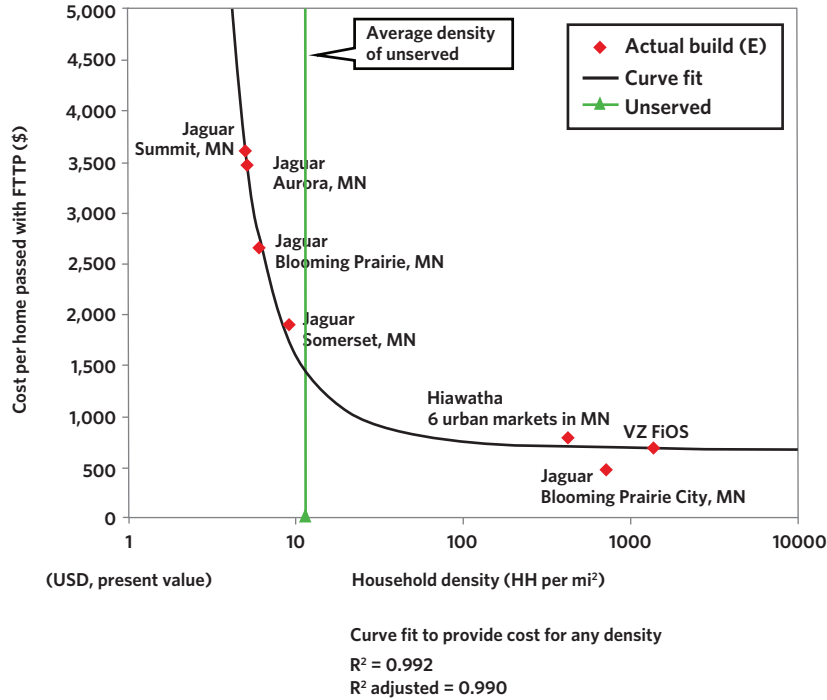
Exhibit 4-AX:

Simple Financial Model to Calculate Breakeven EBITDA for FTTP

Cost per home passed	$850
Take rate	40%
Plant cost per sub	$2,125
Cost to connect/maintain	$1100 — $650 initial cost to connect / $450 CPE/churn replacement
Total capex per sub	$3,225
Profit for NPV = 0 (over 20 years) — Low profit target	$3,225
Taxes (@ 20% effective rate)	$806
PV of EBITDA required	$4,031 — Ignores potentially significant interest payments and impact on required EBITDA
EBITDA per month (@ 10% WACC over 20 years) — Assumes customer lifetime is 5 years	$42.50

Key questions:
- How will EBITDA required for breakeven change as density-driven costs change?
- Is that EBITDA target reasonable?

$42.50/subscriber, a value that is roughly in line with estimates of margins for some of the largest providers in the country.

Next, we calculate the cost to deploy FTTP in each county in the country using the curve fit calculated in Exhibit 4-AW. Applying that cost to the financial model laid out in Exhibit 4-AX, one can calculate the EBITDA required for FTTP to break even in each county; the results are shown in Exhibit 4-AY. Note that a successful FTTP entrant would need to have roughly $38 in monthly EBITDA from each customer at the assumed 40% take rate to provide returns to capital in the denser half of the country.

It is important to note that for an incumbent, much of the revenue associated with a FTTP deployment cannibalizes its existing revenue. As such, an incumbent telco would only want to factor in the incremental revenue offered by a FTTP deployment, namely additional data revenue and video revenue. This has the effect of significantly reducing the viability of FTTP deployments currently for many incumbent providers.

Due largely to this cost structure, there have been few large incumbent providers overbuilding their existing footprints with FTTP. To date, the bulk of FTTP deployments have been driven by a single RBOC, Verizon, which has deployed FTTP in the denser, suburban and urban areas in its footprint, and by Tier 3 ILECs, CLECs, municipalities and other small providers. These providers have deployed FTTP in areas that are less densely populated than those of Verizon, but they have been able to largely replicate the RBOCs' cost structure by achieving an average penetration rate that is nearly double that of the RBOC (54% vs. 30 %).[119]

3,000 – 5,000 foot DSL

Despite providing faster broadband speeds than 12 kft DSL and being capable of delivering video services, DSL over loops of 3,000 (3 kft) feet or 5,000 (5 kft) feet has a higher investment gap when providing broadband services in low-density unserved areas. DSL over 3-5 kft loops delivers broadband speeds well in

Exhibit 4-AY:

Esitmated Monthly EBITDA Required to Break Even on an FTTP Build Across the Country[120]
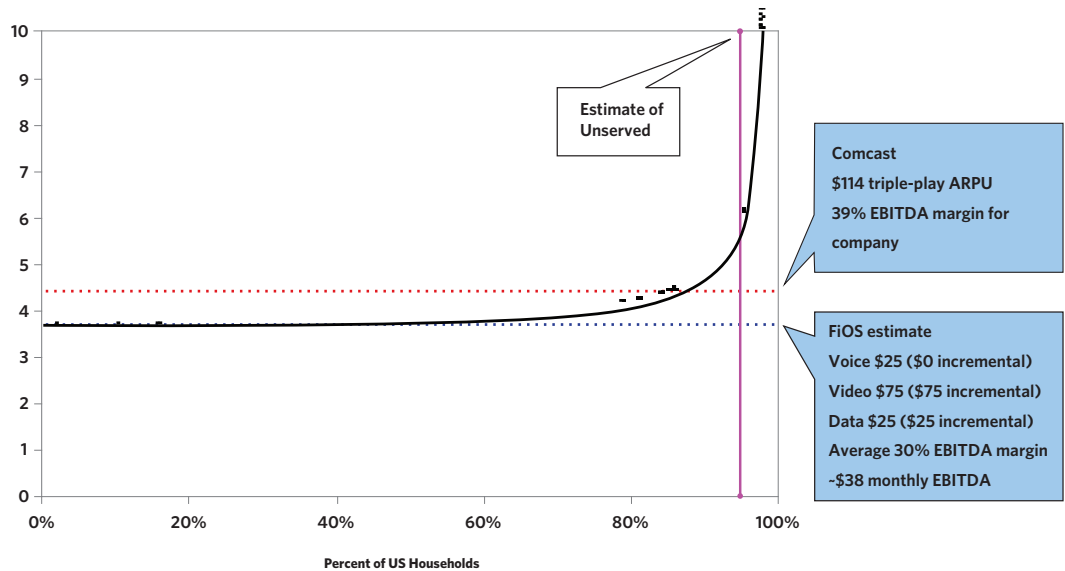
Exhibit 4-AZ:

Data Sources for FTTP Modeling

Item	Source
Optical light terminal (OLT)	Calix protective order filing
Fiber distribution hub (FDH)	FTTH Council
optical splitter	FTTH Council
Fiber drop terminal (FDT)	FTTH Council
Optical network terminal (ONT)	FTTH Council, Calix protective order filing
fiber optic cabling	FTTH Council
aerial placement	FTTH Council
buried placement	FTTH Council
operating/maintenance expenses	Hiawatha Broadband protective order

excess of the 4 Mbps downstream and 1 Mbps upstream target. However, due to the cost of driving fiber an additional 7,000 to 9,000 feet closer to the end user, 3 kft DSL and 5 kft DSL are more costly solutions than 12 kft DSL and, thus, have higher investment gaps than 12 kft DSL in all unserved markets.

Capabilities

DSL over loops of 3 kft or 5 kft typically uses VDSL2 technology, which was first standardized in 2006 and uses frequencies up to 30 MHz. While there may be some VDSL technology still being used

today, many operators are replacing it with VDSL2. Therefore, we will examine the capabilities of VDSL2 technology at 3 kft and 5 kft.

VDSL2 can provide 35 Mbps downstream and 6 Mbps upstream over 3 kft loops, and it can provide 20 Mbps downstream and 2 Mbps upstream over 5 kft loops. As VDSL2 over 24 AWG wire provides rates well above 4 Mbps downstream and 1 Mbps upstream, the technology meets the speed requirements for broadband service. Exhibits 4-BA and 4-BB illustrate how loop length affects speed for VDSL2. Of course, speeds realized in the field are heavily dependent on plant quality, so

Exhibit 4-BA:
Downstream Speed of a Single VDSL2 Line at Various Loop Lengths [121]
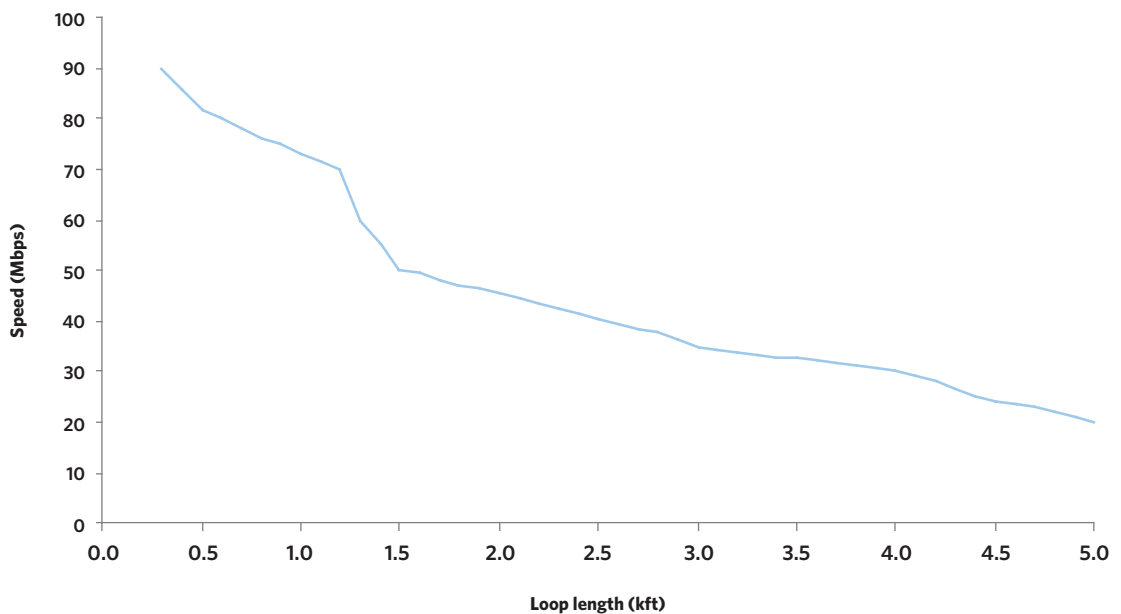
Exhibit 4-BB:
Upstream Speed of a Single VDSL2 Line at Various Loop Lengths [122]
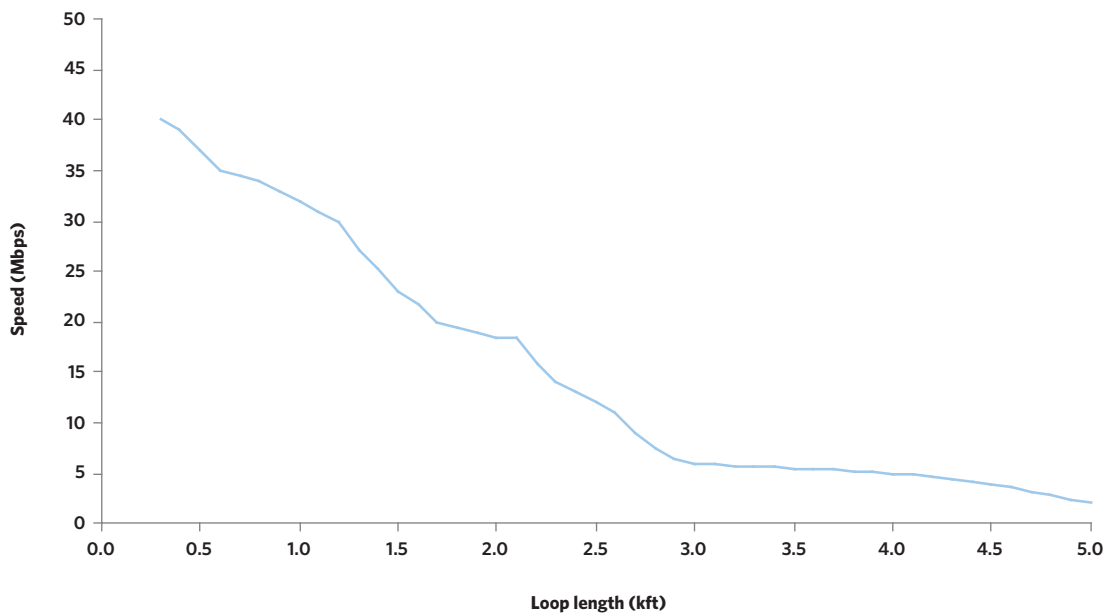
any degradation in the copper plant will lead to lower speeds for a given loop length.

In this case, 24 AWG wire is assumed with no bridged taps. Performance with 22 AWG wire, which is often used in rural areas, would yield higher bitrates, while use of 26 AWG wire would yield lower rates.

For VDSL2, performance can be improved through vectoring, bonding or a combination of the two. Vectoring, or Dynamic Spectrum Management level 3 (DSM-3), has shown improved performance in lab tests by canceling most of the crosstalk

between VDSL2 lines sharing the same binder and is currently being tested in the field. The bonding of loops, assuming there are two copper pairs available, would enable the doubling of the speed achieved to the end-user. A combination of vectoring and bonding could produce downstream speeds over 300 Mbps if lab and field tests prove successful. Exhibits 4-BC and 4-BD illustrate the performance of bonded and vectored VDSL2.

Operators who have shortened loops from 12 kft to 3-5 kft and currently use VDSL2 technology have seen DSL technology offer faster speeds in the past decade.[123] Current and future

Exhibit 4-BC:
Downstream
Speed of VDSL2
Variants[124]
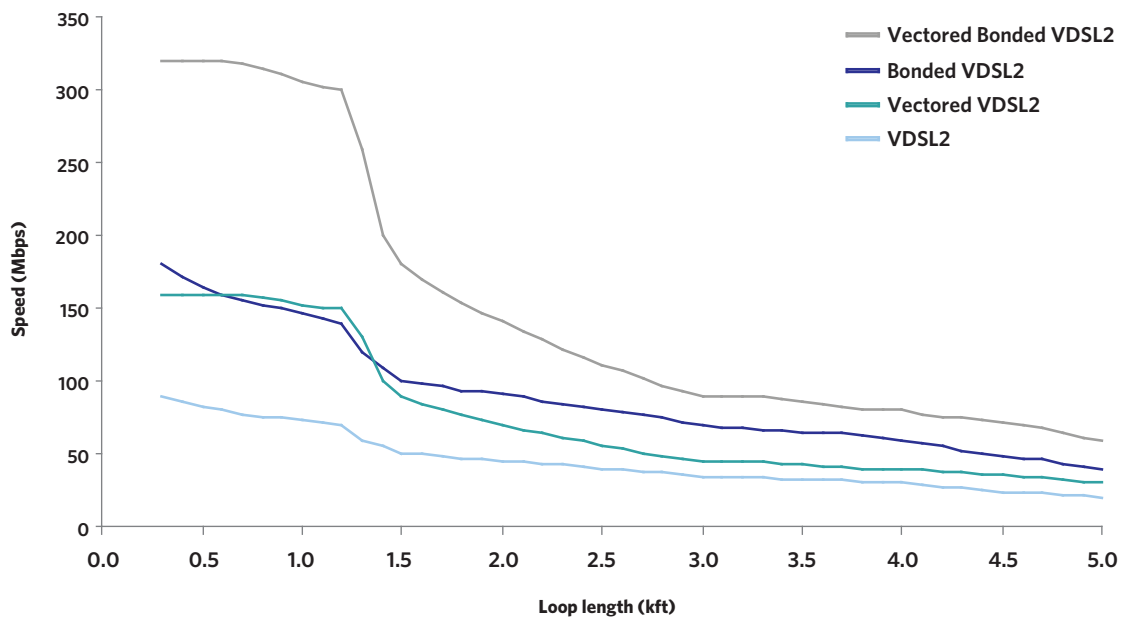
Exhibit 5-BD:
Upstream Speed of
VDSL2 Variants[125]
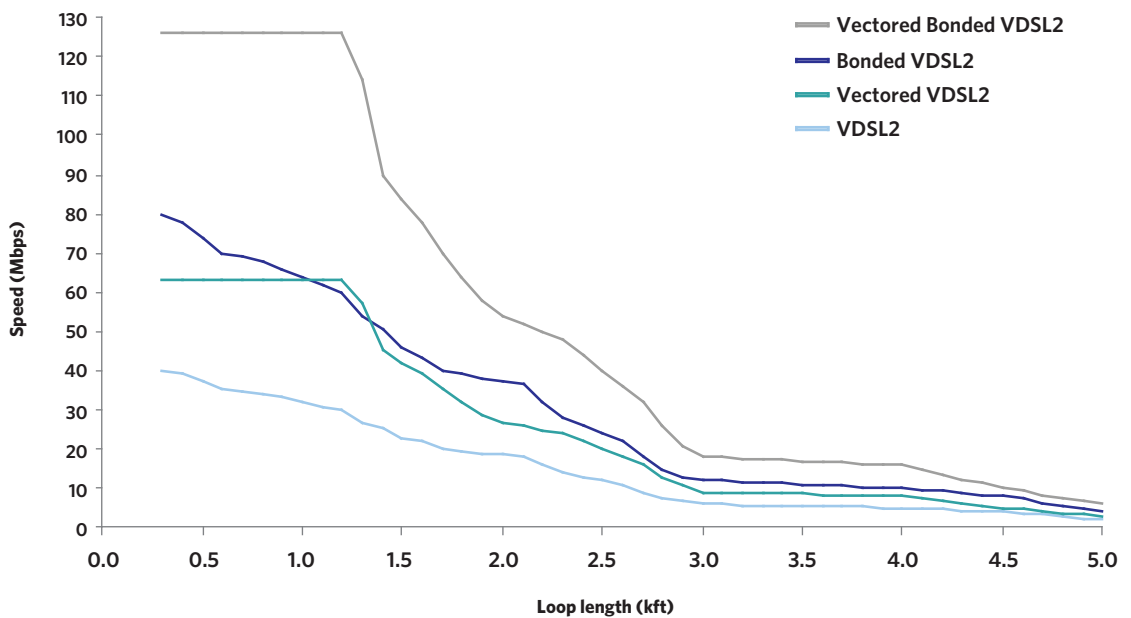
technology improvements, such as the three levels of DSM, are likely to continue to improve speeds as well as the stability of the service provided. Further development of and investment in these improvements, along with bonding, are likely due to DSL's prevalence worldwide.

We model the VDSL2 access network in a similar fashion to the ADSL2+ network described (see above for details). In essence, we assume VDSL2 DSLAMs are connected to central office and other middle- and second-mile aggregation points with fiber-optic-based Ethernet technology providing backhaul capacities that are more than sufficient to meet the end-user requirement. Costs associated with loop conditioning are included when appropriate.

Economics

Like those of the 12 kft DSL network, the economics of the 3 kft DSL and 5 kft DSL networks depend on revenues, operating costs and capital expenditure. Using granular cost data from DSL operators, the model calculates the investment gap to deploy 3 kft DSL to unserved markets as $52.7 billion and the investment gap to deploy 5 kft DSL to unserved markets as $39.2 billion. The total gaps for 3 kft and 5 kft DSL are more than twice as costly as the respective number to deploy 12 kft DSL to the unserved, despite 3-5 kft DSL earning nearly 3x the revenue of 12 kft DSL because their ARPUs include video as well as data. The cost differential is mainly driven by the high cost of driving fiber closer to the end user, less so by the higher cost of VDSL2 technology versus ADSL2+ technology. The following waterfall charts show the breakout among initial capital expenditure, ongoing costs and revenue. See Exhibits 4-BE and 4-BF.

Initial Capex

Initial capital expenditures include material costs and installation for the following: telco modem, NID, protection, aerial or buried copper drop, DSLAM, cabinet, VDSL2 line card, allocated aggregation cost, fiber cable up to 3 kft or 5 kft from the end-user (respectively), feeder distribution interface and drop terminal/building terminal, as well as the engineering costs for planning the network and the conditioning required on loops (i.e., the removal of load coils and bridged taps).

Ongoing Costs

Ongoing costs include replacement capital expenditure required to replace network components at the end of their useful lives, network administration, network operations center support, service provisioning, field support, marketing and SG&A.

Revenues

Revenues are calculated by taking the ARPU—which varies according to the level of broadband service/speed provided as well as whether the bundle of services provided includes voice, data and video—and multiplying it by the average number of users. For 3 kft and 5 kft DSL, data and video ARPUs are used as the incremental services to voice, which is assumed present due to the fact that DSL technology utilizes the twisted pair of copper wires originally installed and used for POTS. VDSL2's higher speeds at 3 kft and 5 kft could support both video and data, although not all real-world operators of VDSL2 choose to offer both services today. The addition of video revenue is not enough to compensate for the incremental investment required to drive fiber within 3 kft and 5 kft of the end user for the unserved.

Exhibit 4-BE:
Breakout of 3,000-Foot DSL Gap
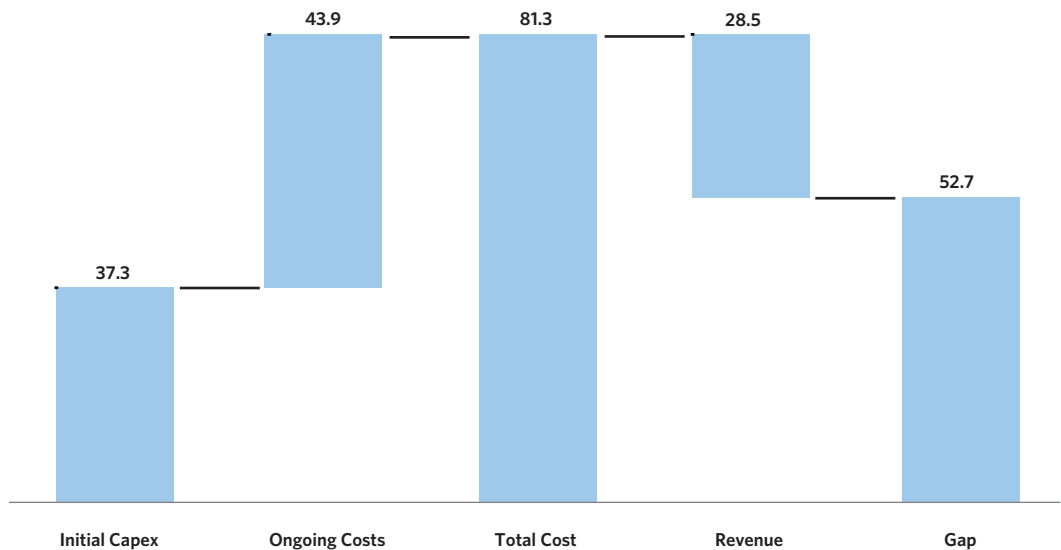
Material and labor costs for 3 kft and 5 kft DSL are the same as for 12 kft DSL except for VDSL2 line cards, which are sourced from a Qwest filing under Protective Order.

15,000 foot DSL

DSL over loops of 15,000 feet (15 kft) is a very cost-effective solution for providing Internet access in low-density areas but fails to meet the Broadband Availability Target.

Capabilities

DSL over 15 kft loops typically uses ADSL2/ADSL2+ technology. ADSL2+ over 24 AWG wire provides rates of 2.5 Mbps downstream and 600 kbps upstream; therefore, the technology

does not meet the speed requirements for broadband service under the Broadband Availability Target. Refer to Exhibit 4-AH in the 12 kft DSL section for a further understanding of how downstream speed varies with loop-length distance.

Hybrid Fiber-Coax Networks

The focus in this section will be on high-speed data connectivity provided by hybrid-fiber-coax (HFC), or cable, networks. We'll look first at the capabilities of HFC networks, then at the economics of these services.

Our analysis indicates that the capabilities of HFC networks far exceed end-user speed and network capacity requirements, as shown above and in the National Broadband Plan. Therefore, by

Exhibit 4-BF:
Breakout of 5,000-Foot DSL Gap

Initial Capex	Ongoing Costs	Total Cost	Revenue	Gap
29.1	37.3	66.5	27.3	39.2
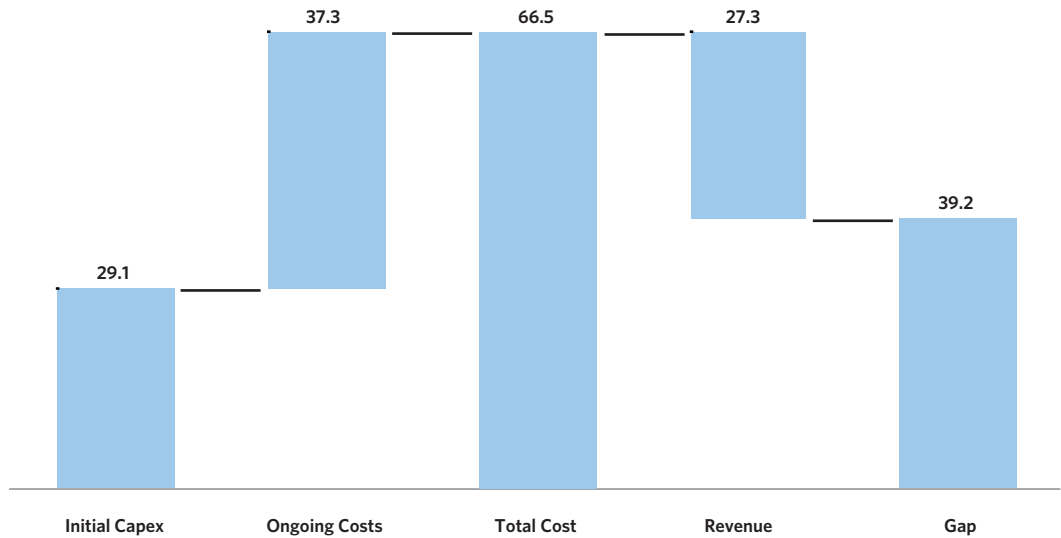
Exhibit 4-BG:
Breakout of 15,000-Foot DSL Gap

Initial Capex	Ongoing Costs	Total Cost	Revenue	Gap
11.8	10.1	21.9	6.6	15.3

0178

definition, homes within the HFC footprint are considered served. However, the investment gap to deploy HFC networks in unserved areas is larger than that of DSL or fixed wireless as noted above.

The near-ubiquity of HFC networks that can provide high-speed broadband access is a tremendous asset that puts the United States in a unique position among other countries. HFC networks were initially designed to deliver one-way video, but have evolved over time to allow two-way transmission of data and voice in addition to video. Today, cable systems pass roughly 90% of U.S. households with high-speed data services; in addition, more than 90% of homes are passed by cable plant, with 50% of those homes taking at least basic cable video service, thereby amounting to 63 million subscribers.[126] Some 52% of broadband subscribers in the United States subscribe to cable-based service, the second highest rate among OECD countries.[127]

History

When cable systems were initially constructed, the industry was highly fragmented, with many small firms operating networks in local markets. Today, there is very little overlap in cable networks because, in most markets, cable operators received exclusive rights to operate in their geography in the form of a franchise agreement granted by local franchising authorities. It is important to note that cable companies have not been subjected to the same network-sharing or carrier-of-last-resort obligations as the telephone companies; however, cable companies do not receive Universal Service Fund (USF) monies to offset the costs of constructing and maintaining

Exhibit 4-BH:
Breakout of Cable Coverage— Share of Homes Passed by Cable Companies

Numbers do not sum to 100% due to rounding.

their networks. Maintaining one network per geographic area greatly reduced the network cost-per-subscriber, which, along with having monopoly or near-monopoly control over the video market, has allowed these networks to be successful in the face of large up-front capex requirements.

Due to the complementary nature of footprints and scale advantages in content acquisition, the cable industry has experienced significant consolidation over the years. Today, there are almost 1,200 cable system operators but, as shown in Exhibit 4-BH, the top five companies pass 82% of homes passed by cable video service.[128]

Cable MSOs have spent $161 billon from 1996-2009 on capital expenditures; in part, this was used to enable broad-band capabilities.[129] Cable systems were originally constructed to provide one-way video signals, so customers initially could not send information back through the network. In the early deployment of cable (1950s-1970s), the networks were known as CATV (Community Antenna Television) and were built to provide TV and radio services. The network was designed to support all-analog, one-way transmissions from the community satellite antennas (cable headends) to end-user televisions over coaxial cable.

In the 1990s with the advent of the Internet and passage of the 1996 Telecommunications Act, cable companies began upgrading their networks to provide the two-way transmission capabilities required for Internet data traffic and telephony in addition to TV/radio signals. The network needed to be reengineered to handle two-way transmissions of digital communication signals and upgraded to handle higher capacity demands. The original "tree and branch" architecture of cable systems was ideal for transmitting TV signals from the head-end to the home television. However, video transmission over coaxial cable was still susceptible to noise and interference and required amplifiers, line extenders and other active electronics to ensure that the signal would reach end-user TV sets with acceptable quality. Unfortunately, these active electronics a) were not capable of passing signals in the upstream direction and b) were often not spaced properly within the cable plant for upstream transmission. As a result cable companies invested in HFC upgrades throughout the 1990s to overcome these problems. Such upgrades were seen as attractive since millions of homes were already "wired" with high capacity coaxial cable and the revenue potential of triple play services created a compelling business case. Exhibit 4-BI illustrates some examples of the infrastructure upgrades required for HFC networks.

Steps to upgrade cable networks for broadband:

➤ Invest in fiber optic cable and optic/electronics to replace and upgrade coaxial cable for capacity purposes

0179
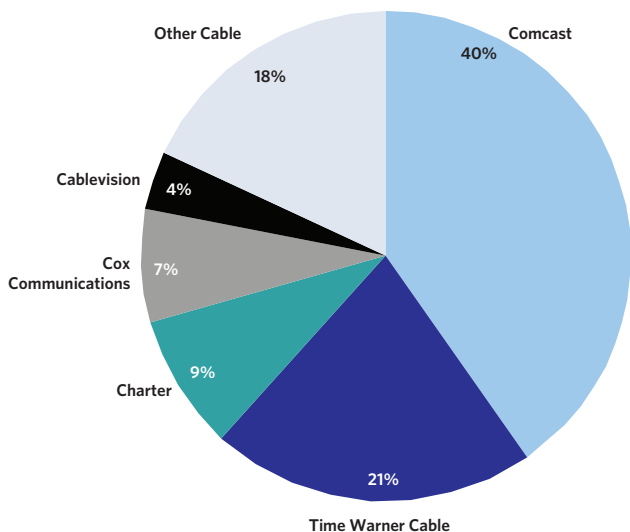
➤ Replace and redesign headend equipment, line transmission equipment, set top boxes to allow for two-way data transmission, and add DOCSIS modems

➤ Deploy telephone switching equipment and interconnection facilities to provide VoIP services

➤ Develop the technology and equipment necessary for more sophisticated network management and control systems

➤ Implement the back-office, billing and customer service platforms necessary to provide the standard triple play services common among cable operators today

Capabilities

Cable companies coupled their investments in two-way upgrades with a standardization effort. Cable-based broadband relies on Data Over Cable Service Interface Specification (DOSCIS). The first release of DOCSIS was in 1997, with DOCSIS 2.0 released in 2001 and the third-generation standard (DOCSIS 3.0) now being deployed widely. DOCSIS 2.0, currently the most widely deployed, provides up to 36 Mbps of downstream bandwidth and up to 20 Mbps upstream, while DOCSIS 3.0 provides up to 152 Mbps of downstream bandwidth and up to 108 Mbps of upstream (with four bonded channels).[130]

As noted above, cable systems provide shared bandwidth in the last mile, with multiple homes sharing a fixed amount of bandwidth at a single node. Ultimately, bandwidth-per-customer is driven both by the number of customers (and their usage) per node and the total bandwidth available per node. Given typical busy-hour usage rates (see Network Dimensioning section), users on a DOCSIS 2.0 system can receive up to 10 Mbps;[131] under DOCSIS 3.0, that number will increase substantially, to 50 Mbps.[132] Actual figures, however, depend on a large number of variables, including not only the DOCSIS specification, but also spectrum allocation and use and the number of homes per node.

Impact of cable-system spectrum

Spectrum in cable plants, as in over-the-air broadcasting, is a measure of how much "real estate" is devoted to transmitting signals. Most two-way cable plants use 450 MHz or more of spectrum, with many having been upgraded to provide 750 MHz or more. Each analog television channel requires 6 MHz of spectrum. Exhibit 4-BJ shows the spectrum allocation for a typical 750 MHz, DOCSIS 2.0 deployment.

Note that all upstream communications take place in low-frequency spectrum, below 52 MHz. FCC rules requiring that broadcast Channel 2 be carried on Channel 2 of the analog spectrum (54 – 60 MHz) established the low end of downstream spectrum.[133] Cable companies' outside plant equipment is tuned for this: band-pass filters allow upstream traffic only below 52 MHz. In addition, band-pass filters in consumer electronics are tuned to block potentially large amplitude upstream signals only below 52 MHz.

The 52-MHz upper bound on upstream spectrum places limits on upstream bandwidth. First, because it would require

Exhibit 4-BI:
Upgrades to Enable
Broadband Services
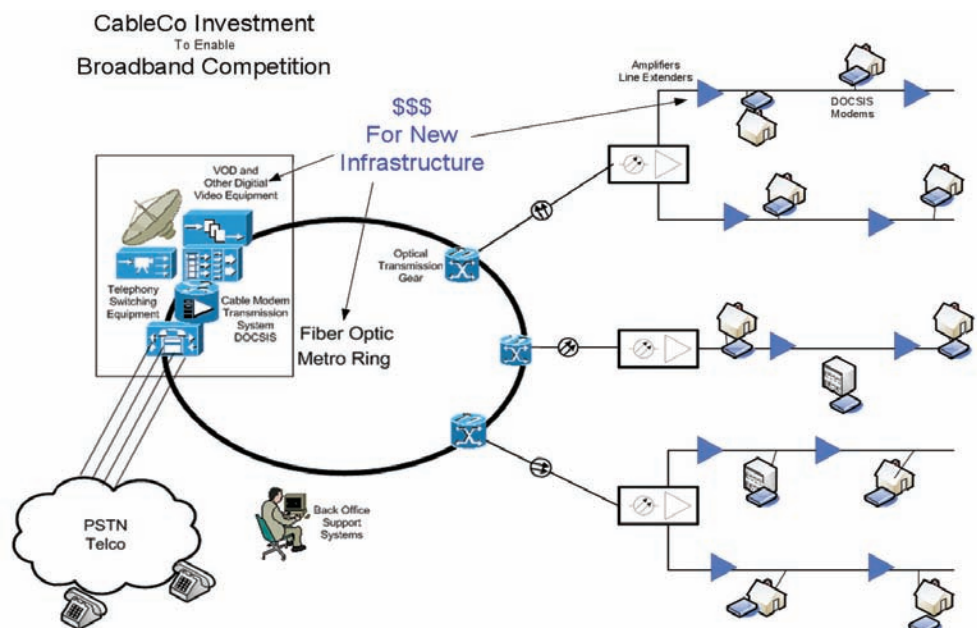
changes to cable plant and consumer electronics, adding spectrum for upstream use above the 52 MHz would be difficult and costly. In addition, interference at low frequencies (e.g., from motor noise, ham and CB radio, walkie-talkies) could reduce usable upstream spectrum significantly.[134] While DOCSIS 3.0 allows for the bonding of multiple channels to increase upstream capacity, these other spectrum issues will likely provide real-world limits to upstream capacity.

Downstream bandwidth faces fewer constraints; cable companies can devote higher-frequency 6 MHz channels to downstream capacity. In addition, DOCSIS 3.0 allows carriers to devote four or even eight channels to downstream data communications.

Cable companies use Quadrature Amplitude Modulation ("QAM") to increase the bandwidth transmitted over a given amount of spectrum (the Mbps-per-MHz), with typical deployments featuring 16, 64 or 256 QAM. In typical DOCSIS 2.0 deployments, the downstream direction is 64 or 256 QAM and the upstream is 16 QAM. As an example, consider a typical DOCSIS 2.0 deployment with one 6 MHz downstream channel at 64 QAM which delivers approximately 36 Mbps.

Cable companies can create additional capacity for downstream bandwidth (or for additional broadcast video channels, or other services like video-on-demand) through a number of means. The most obvious may be to increase the frequency of the cable plant, but this requires extensive upgrades in outside plant and is often very expensive.

There are a number of less expensive options available.

As discussed above, going from DOCSIS 2.0 to DOCSIS 3.0 allows the cable system to devote more frequency, assuming it can be made available, to data while keeping the plant total unchanged. Cablevision estimated the cost of its DOCSIS 3.0 rollout at about $70 per home passed (there may be additional success-based expense, e.g., CPE). Scale economies may bring that number 10-20% lower for larger MSOs.[135]

Another option is Switched Digital Video (SDV). In the current HFC architecture, all video channels are sent to all subscribers with filtering of channels for different subscription services made by the set-top box. SDV transmits only those channels to a given node when those channels are in use by a subscriber. This means that the majority of channels are not transmitted most of the time, thereby using fewer channels in aggregate. SDV is therefore a relatively inexpensive technique to reclaim on the HFC network bandwidth to be used for other purposes. Cisco Systems estimates the cost of SDV at $12-$16 per home passed.[136] A number of MSOs are moving forward with SDV,[137] although concerns exist for third party providers of DVRs like TiVo.[138]

Another approach is analog reclamation. In analog reclamation, often termed "going all digital," cable companies move away from transmitting analog signals entirely. A single analog channel takes up 6 MHz (the equivalent of more than 30 Mbps as noted above); the same spectrum (or bandwidth) can carry 10 digital standard-definition channels or three high-definition channels. Analog reclamation can therefore "add" a substantial number of channels to a typical system. For example, by

Exhibit 4-BJ:
Spectrum Allocation in Cable Plant
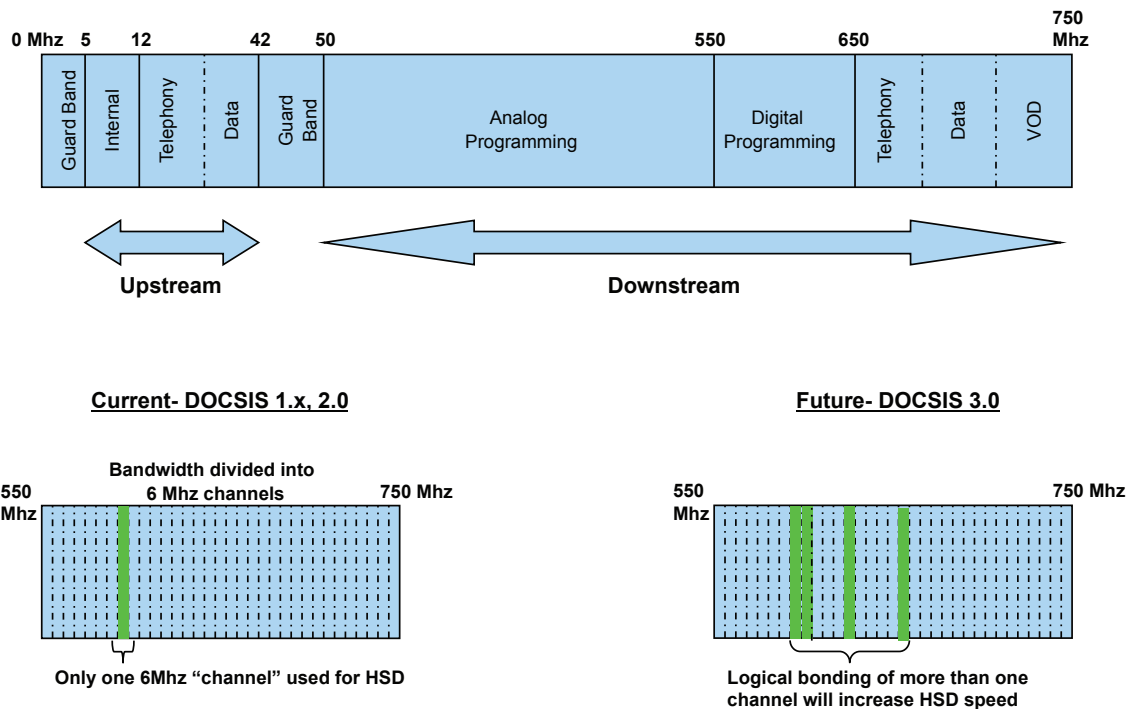
moving a fairly typical 85 analog channels to digital, a cable company can free up over 500 MHz of spectrum, providing enough capacity to carry well over 200 digital HD channels. The cost of analog reclamation is estimated at approximately $30 per home passed.[139]

Finally, cable companies could go all-IP, moving away from the current spectrum allocation entirely. A 750-MHz system could provide 4.5 Gbps[140] of all-IP bandwidth, to be shared among all users and all applications. This would require a significant change not only in network architecture for cable companies, but also significant business-process redesign to figure out how to capture revenue from an all-IP network.

Impact of homes per shared node

As noted above, cable capacity is shared among all users on a given node. Where there are more users, bandwidth is shared more widely and individual users will, on average, have less capacity. By splitting nodes, cable companies can reduce the user-load per node and increase the capacity per user. Some cable companies have been splitting nodes aggressively, moving from 1,000 homes per node to 100 homes per node or fewer.[141] Cisco estimates the cost of splitting a node at approximately $1,500.[142] Assuming 300-400 homes per node puts the cost at approximately $50 per home passed.

As node-splitting continues, HFC networks will reach the point where the run of coaxial cable is quite short—short enough that there is no need for active electronics in the coaxial part of the network. These so-called passive nodes often have roughly 60 homes per node,[143] but the driver is the linear distance covered by the coaxial cable, not the number of homes. Removing active electronics from the field, however, will yield a network that is more robust and that requires less maintenance.

Economics

The economics of providing broadband service over cable plant are driven largely by the presence of existing network. Where networks exist, and costs are sunk, broadband economics are very attractive. In other areas, where one examines greenfield builds, the economics can be far more challenging. Since the network capabilities of an HFC network far exceed the target speed set forth in the plan, the unserved are all in greenfield areas where the investment gap of HFC is much larger than that of DSL or fixed wireless.

Existing cable deployments were funded by video

As noted earlier, cable networks were originally designed to offer video service. And, in many markets, cable companies were granted exclusive franchise agreements. As a result, the video business over

Exhibit 4-BK: Cable Video ARPU Over Time[144]—Cable Pricing

(in USD, present value)
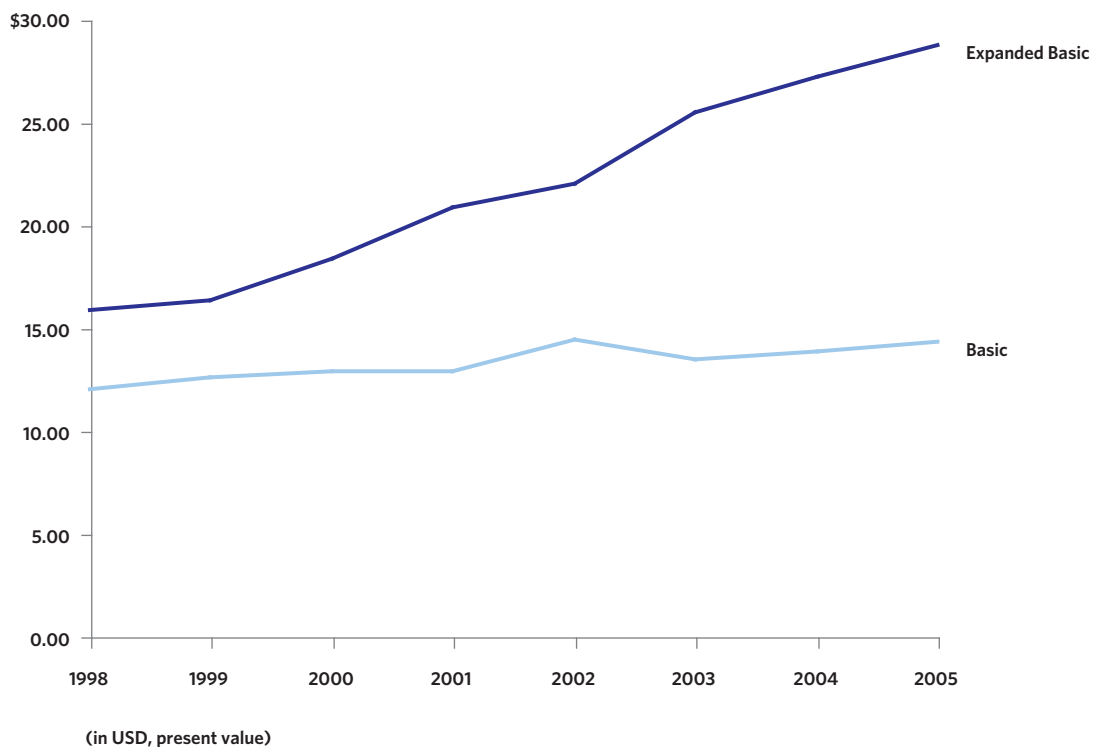
time has accounted for a large portion of cable-company revenue, providing a network on which to build the incremental broadband business. The video business, in fact, has enjoyed increasing ARPU over a long period of time (see Exhibit 4-BK), providing much of the capital for HFC investment in infrastructure. Of all subscribers who have access to these services, 88% subscribe to expanded basic and 55% subscribe to digital programming.[145]

Incremental broadband upgrades

As noted above, large investments have been made in cable systems already, principally funded by the video business. Further, as shown in Exhibit 4-BL, the incremental expense for upgrades—each aspect of which has been discussed previously—is low given the significant sunk investment already in the cable plant. As a consequence, cable systems are relatively well positioned to meet

Exhibit 4-BL:
Upgrade Costs for Cable Plant
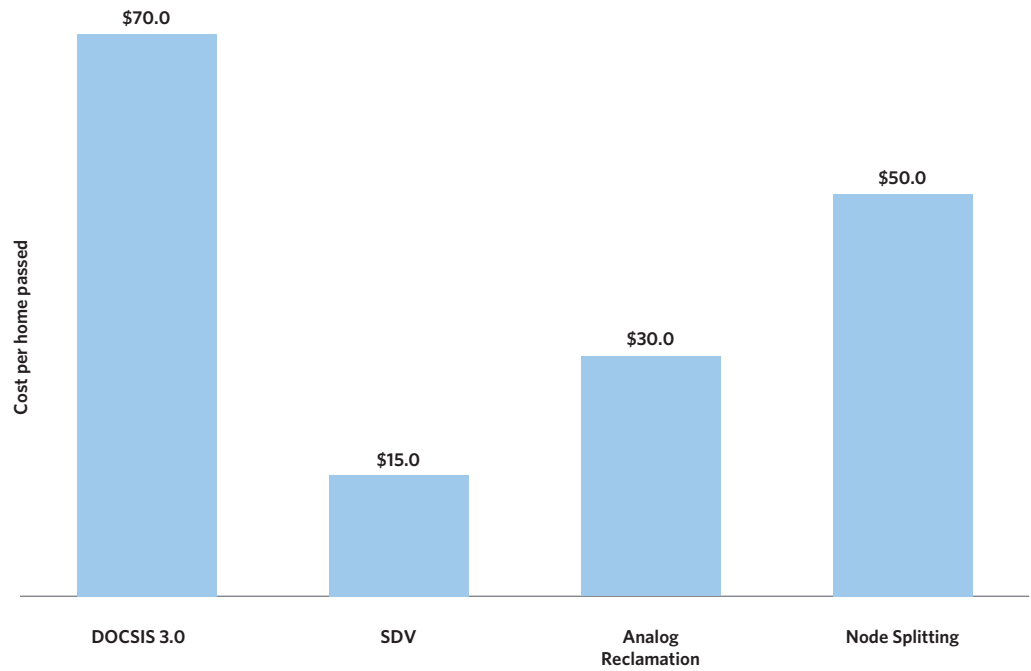
Exhibit 4-BM:
Outside Plant Cost, FTTP or RFoG vs. HFC—Relative Capex Costs of Cable and Fiber, Excluding Headend Equipment [146] [147]
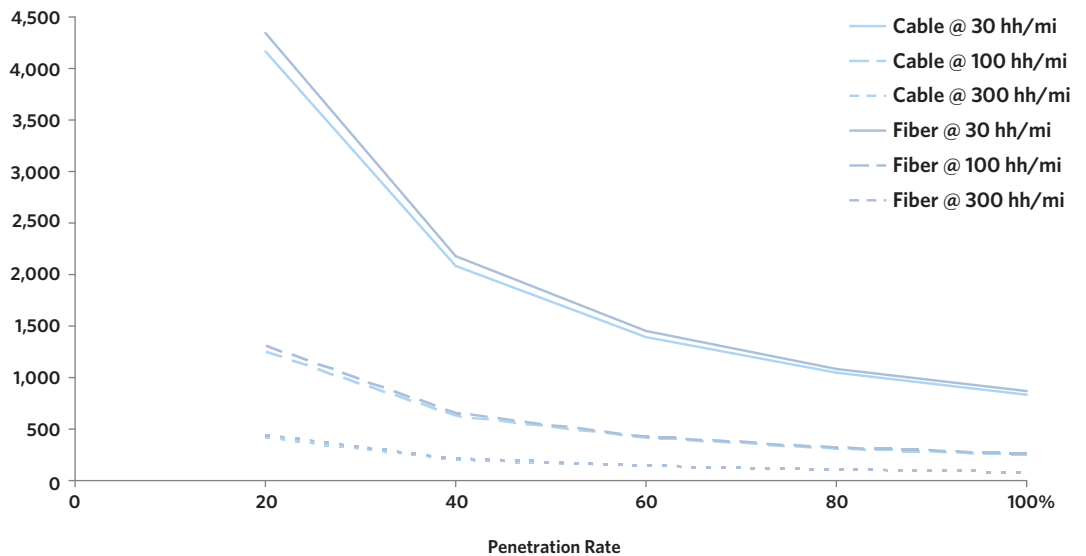
Dollars of capex/sub/mile; penetration rate

future growth in bandwidth demand.

In summary, where existing two-way cable plant exists, up-grade costs to provide high-speed service of up to 50 Mbps are low: roughly $165 per home passed.

Greenfield deployments

Building a new cable plant requires deploying a new outside plant and some form of headend to aggregate and distribute video and data content. The choice of technology for the out-side plant is not an obvious one: providers can deploy a network that is a traditional hybrid fiber-coax plant, or one that is all fiber, a so-called RF over Glass (RFoG) plant.

When connecting a home for the first time—effectively adding a completely new last-mile connection—providers are likely to use the most future-proof technology possible. It would make little sense to deploy, for example, a brand-new long-loop twisted-pair network. The choice is less clear when comparing HFC and RFoG (or any other FTTP deployment). As Exhibit 4-BM shows, HFC and fiber networks have similar outside plant costs, which are mostly a function of labor costs. However, RFoG and FTTP deployments, by removing all active electronics from the outside plant, have lower ongoing expenses.

Estimates suggest these opex savings are approximately $20 per home passed per year.[148] While this may not sound large at

Exhibit 4-BN:
HFC Plant
Diagram—CableCo
HFC Architecture
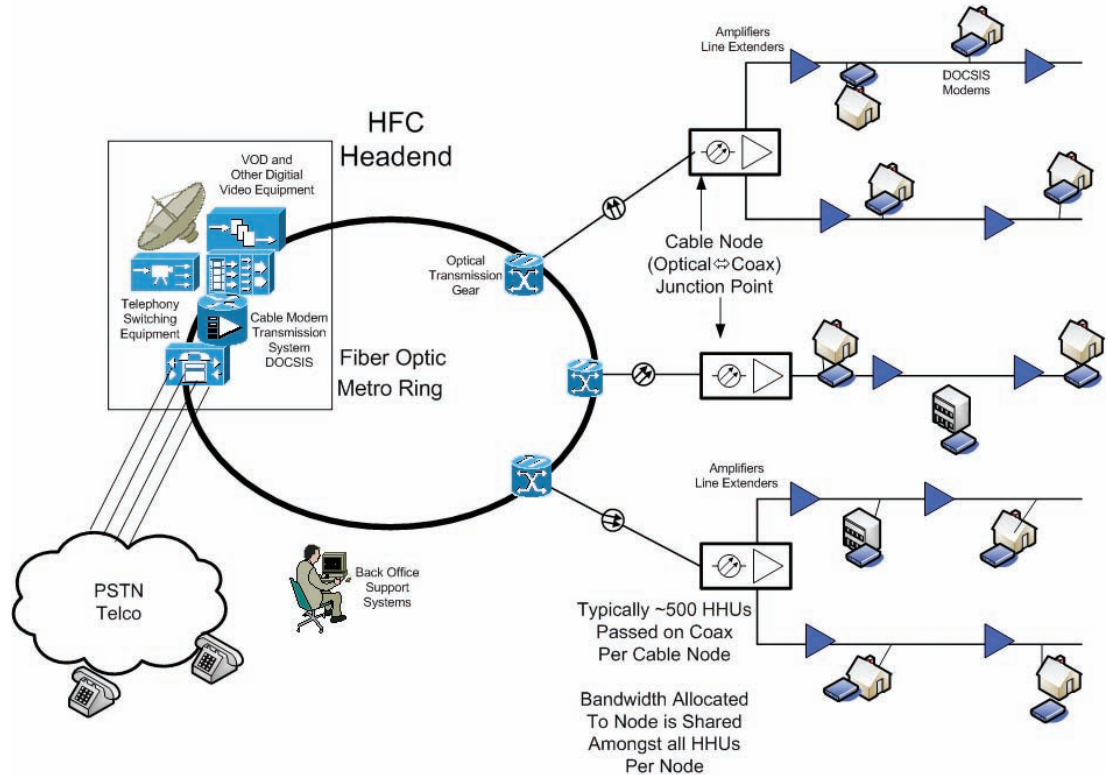
Exhibit 4-BO:
Data Sources for HFC
Modeling

Material Costs	Source
Splitter	Cable ONE (filed under protective order)
Fiber Node	Cable ONE (filed under protective order)
CMTS	Hiawatha (filed under protective order)
Up Stream Reciever	Hiawatha (filed under protective order)
Cable Modem	Hiawatha (filed under protective order)
Drop	Hiawatha (filed under protective order)
Tap	Cable ONE (filed under protective order)
Coaxial Cable	Cable ONE (filed under protective order)

the outset, it adds up over the life of the network. A majority of these savings come from power required for active components, system balancing and sweeping, and reverse maintenance.

The other major expense for a new network, whether HFC or RFoG, is the cost of a drop per subscriber. RFoG drops are approximately $175 more expensive than HFC drops.[149] As a consequence, the initial cost of connecting a subscriber is higher for RFoG relative to HFC.

However, the aggregate cost of a typical HFC customer will exceed, in less than 10 years, the aggregate cost of serving the same customer using RFoG. In other words, the operational savings from having an all-passive plant outstrip the initial cost savings from deploying an HFC system. It is reasonable to expect RFoG and FTTP drop costs will decline over time as deployments become increasingly mainstream and the industry attains greater scale. Accordingly, it is likely that as RFoG and FTTP deployments become cheaper, this break-even period will become even shorter. As a consequence, a greenfield developer of wireline infrastructure is more likely to choose RFoG or FTTP over HFC going forward, given both lifecycle cost and future-proofing benefits of an all-fiber network.

Modeled cost assumptions

We modeled the incremental costs of extending HFC networks into unserved areas with a high degree of granularity. Exhibit 4-BN shows the basic network elements of an HFC network and Exhibit 4-BO lists the sources for assumptions used in the model.

NETWORK DIMENSIONING

In order to ensure that the investment gap is reflective of the full costs of deployment, it is important to dimension the network to be able to deliver target broadband speeds during times of peak network demand. In particular, we need to determine that we properly model the capacity of every shared link or aggregation point in order to ensure that the network is capable of delivering required broadband speeds.

However, data flows are far more complex to characterize than voice traffic, making relatively straightforward analytical solutions of aggregated data traffic demand very challenging; this will be discussed ahead in **Complexities of data-network dimensioning**. Our approach is to describe typical usage patterns during times of peak demand, which we then use to estimate the network capacity needed to ensure a high probability of meeting end-user demand; this is discussed at the end of this chapter in **Capacity considerations in a backhaul network**.

Complexities of data-network dimensioning

Network dimensioning will not guarantee that users will always experience the advertised data rates. Note that even traditional voice networks are designed for a certain probability of being able

to originate a phone call (e.g. 99% of the time in the busy hour for wireline, 95% for cellular) and a certain average sound quality. For dimensioning IP data networks, it may be useful to point out the difficulty of applying traditional voice traffic engineering principles to IP data-traffic flow. Dimensioning IP data networks is intrinsically more complex than dimensioning voice networks.

To properly dimension a traditional circuit switched voice network, it is typical to use the Erlang B formula that allows an operator to provision the number of circuits or lines needed to carry a given quantity of voice traffic. This is a fairly straightforward process mainly because the bandwidth consumed for each call is effectively static for a given voice codec in the busy hour. In fact, technology has enabled carriers to encode speech more efficiently so a voice conversation today may actually consume much less bandwidth than a voice conversation did 20 years ago. Nonetheless, the three basic variables involved are:

➤ Busy Hour Traffic, which specifies the number of hours of call traffic there are during the busiest hour[150]
➤ Blocking, or the failure of calls due to an insufficient number of lines being available and
➤ The number of lines or call-bearing TDM circuits needed in a trunk group

As long as the average call hold time is known and the operator specifies the percentage of call blocks it is willing to accept in the busy hour, the number of trunks is easily calculated using the Erlang B formula.

For broadband Internet access, however, there is much more uncertainty. Unlike voice telephony, Internet traffic is quite complex, multi-dimensional, and dynamic in the minute-to-minute and even millisecond-to-millisecond changes in its characteristics. Network planning and engineering for broadband Internet are more difficult with higher degrees of uncertainty because of the following principal factors:

➤ Each application used during an Internet access session, such as video streaming, interactive applications, voice, Web browsing, etc., has very different traffic characteristics and bandwidth requirements.
➤ End-user devices and applications are evolving continuously at the rate of silicon electronics, as opposed to voice (we continue to speak at the same rate of speech).
➤ Broadband Internet access supports many different user applications and devices, from streaming high definition video (unidirectional, very high bandwidth), to short messaging (bidirectional, very low bandwidth).
➤ The scientific community has not yet developed and agreed upon the best mathematical representations for modeling Internet traffic.

Exhibit 4-BP illustrates the additional complexities of multi-dimensional data traffic verses traditional circuit switched voice traffic. These differences introduce chaotic variables not present in the Erlang traffic model used to dimension voice networks.

Many individual Internet applications are "bursty" in nature. Consider a typical Web-surfing session, in which a user will "click" on an object, which results in a burst of information painting the computer screen followed by a lengthy period of minimal data transmission, followed by another burst of information. The instantaneous burst may occur at several Mbps to paint the screen, followed by many seconds or even many minutes with essentially no traffic, so the average transmission rate during a session may only be a small percentage of the peak rate. This type of traffic does not lend itself to modeling by the traditional mathematical models such as the Erlang formulas used for voice traffic; it can be considered fractal and chaotic in nature, as shown in Exhibit 4-BP. By contrast, the viewing of a high-definition video involves streaming content in one direction steadily at several Mbps. And a typical Skype video conference may involve a two-way continuous streaming of information but at only at around 384 kbps in each direction.[151]

Computer processing keeps improving at the rate set forth by "Moore's Law," as does the price/performance of storage.

This doubling every two years enables much better performance of existing applications (e.g., very refined graphics instead of simple pictures, high definition and now even 3D-HD instead of NTSC video or standard-definition TV), as well as new applications that could not have existed several years earlier. So as long as silicon chips and electronics continue to improve, network providers may see more and more demands placed on the network by individual user applications. Moreover, behind an individual network interface, the subscriber is likely to have a local area network with several users running various applications for which traffic characteristics vary widely and with variable timescales such that the cumulative effect is a highly variable and unpredictable traffic flow into the network.

To conclude this discussion, we note that traffic engineering is based on mathematical models involving probabilities and statistics. As noted earlier, modeling voice traffic makes use of the simple inputs of average duration of call, bits-per-second used by the voice encoding scheme and number of call originations per hour. This has enabled scientists and engineers over the years to develop reliable mathematical models that correlate well with real-world experience. However, for Internet traffic, the number of variables, the magnitude of variation of these variables and the statistical nature of the variables have made it difficult for the scientific community to develop

Exhibit 4-BP:
Differences Between
Voice and Data
Networks
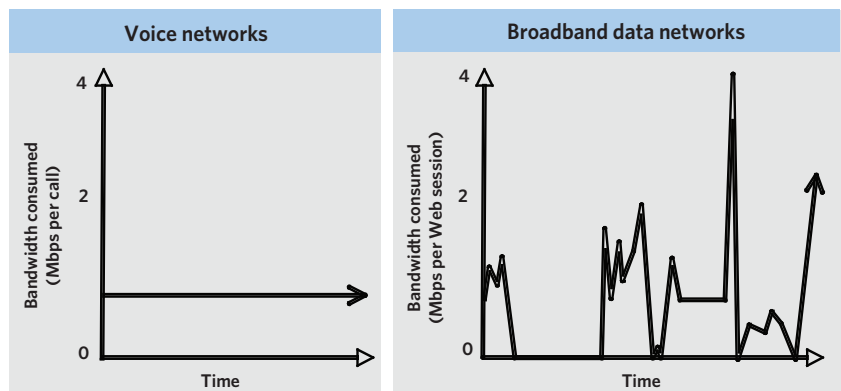
Factor	Relevance to voice network dimensioning	Relevance to data network dimensioning
Number calls/data sessions	Number of calls generated in the busy hour	Number of sessions invoked by user or users during busy hour
Average call/session duration	Average duration of each call (usually in minutes)	Duration of application session (range from hours to milliseconds)
Variation in call/session duration	Almost all calls measured in minutes with little deviation	Variable session duration between applications ranging from minutes to seconds to milliseconds
Bandwidth intensity (amplitude)	N/A- bandwidth consumed for each call is static at 64 kbps	Bandwidth consumed per application session (Variable based upon active application)
Variation in bandwidth intensity	N/A (see previous)	Wide variation of bandwidth consumption for different applications
Calls Blocked / Congestion threshold during busy hour	"blocked" calls tolerated in the busy hour (typically one call block per 100 call attempts)	Minimum bandwidth at which packets are lost

a well-accepted mathematical model that can predict network traffic based on end-user demand. In fact, the underlying behavior of the traffic is still the subject of research and debate.

Consequently, it is very difficult to statistically characterize the traffic per subscriber or the aggregated traffic at each node in the network. And without such a characterization, we cannot dimension the network, *ex ante*, with the level of precision necessary to ensure subscribers will always experience the advertised data rates.

Generally speaking, Internet traffic engineers do not drive the expansion of network capacity from end-user demand models. Rather, they measure traffic on network nodes and set thresholds to increase capacity and preempt exhaust for each critical network element. Adtran remarks in its filing: "While sustainable speed can be measured in existing networks, it is nearly impossible to predict in the planning stages due to its sensitivity to traffic demand parameters."[152]

Still, we need to engineer our network model to deliver a robust broadband experience, capable of delivering burst rates of 4 Mbps in the download and 1 Mbps in the upload even without being able to measure traffic on actual network elements. The approach to do this is to provide sufficient capacity to provide a high probability of a robust user experience (as discussed in the next section). For this, we need a metric that characterizes traffic demand. One such metric that measures traffic demand is the Busy Hour Offered Load (BHOL) per subscriber.[153]

Capacity per user: busy hour offered load (BHOL)

The data received/transmitted by a subscriber during an hour represent the network capacity demanded by the subscriber during that hour. This can be expressed as a data rate when the volume of data received/transmitted is divided by the time duration. BHOL per subscriber is the network capacity demand or offered load, averaged across all subscribers on the network, during the peak utilization hours of the network.

In general, the total BHOL at each aggregation point or node of the network must be smaller than the capacity of that node in order to prevent network congestion. Alternately, the number of subscribers per aggregation node of the network must be smaller than the ratio of the capacity of the node to the average BHOL. This is the general principle we use to dimension the maximum number of subscribers at each aggregation point of the network model.

The BHOL-per-subscriber depends on a subscriber's Internet usage pattern and, as such, is a complicated overlay of the mix of Internet applications in use, the bandwidth intensity of each application and the duration of usage. But, for practical engineering purposes, the average BHOL-per-subscriber can be derived from monthly subscriber usage. Typically, 12.5% to 15% of daily usage happens during the busy hour.[154] We recognize that very high monthly usage on the same connection speeds usually results from increased hours spent online, outside of the busy hours, rather than an increased intensity of usage during the busy hours. As such, very heavy usage may not quite lead to the same proportionate increase in BHOL. However, for the purposes of our network dimensioning, we shall make the simplifying (and conservative) assumption that the effect is proportionate.

Current usage levels and corresponding BHOLs for different speed tiers are shown in Exhibit 4-BQ. Observe that the mean usage is more than five times that of the usage by the median or typical user. In fact, a small percentage of users generate an overwhelming fraction of the network traffic as shown in Exhibit 4-BR. This phenomenon is well known and is discussed in more detail in Omnibus Broadband Initiative, Broadband Performance.[155] For example, the heaviest 10% of the users generate 65% of the network traffic. So, if we were to exclude the capacity demand of these heaviest users, the BHOL of the remaining users would be far lower. For example, by excluding the heaviest 10% of the users, the BHOL by the remaining 90% is only 36-43 kbps. In Exhibit 4-BS, we show the impact on the BHOL by excluding different fractions of the heaviest users. For comparison, we also show the BHOL for the median or typical user.

Suppose we want to dimension a network that will continue to deliver 4 Mbps to all users even after the next several years of BHOL growth. In order to estimate the future BHOL, we first note that average monthly usage is doubling roughly every three years as discussed in Omnibus Broadband Initiative, Broadband Performance.[156] Next, given the significant difference between mean usage and the typical or median user's usage, it is likely that the service provider will seek to limit the BHOL on the network using reasonable network management techniques to mitigate the impact of the heaviest users on the network. For example, an Internet service provider might limit the bandwidth available to an individual consumer who is using a substantially disproportionate share of bandwidth and causing network congestion. Exhibit 4-BS shows the BHOL for possible scenarios, ranging from dimensioning for the typical user to mean usage. For our network dimensioning purposes, we shall use a BHOL of 160 kbps to represent usage in the future. Thus, this network will not only support the traffic of the typical user, but it will also support the traffic of the overwhelming majority of all user types, including the effect of demand growth over time. It is also worth noting that the additional cost of adding capacity on shared links, as described throughout this paper, is low.

Capacity considerations in a backhaul network

Operators of IP broadband networks must provide a consistent, reliable broadband experience to consumers in the most cost-effective way that meets the consumer broadband requirements set forth in the Broadband Plan: 4 Mbps downstream and 1 Mbps upstream of actual speed.

An important consideration for an economical deployment of affordable broadband networks is proper sizing and

dimensioning of the middle- and second-mile links. A fundamental element in the design of all modern packet-switched networks is "sharing" or "multiplexing" of traffic in some portions of the network to spread costs over as many users as possible.[157] In other words, network operators can take advantage of the network capacity unutilized by inactive applications and/or users by dynamically interleaving packets from active users and applications thus leading to a better shared utilization of the network. This is commonly known as statistical multiplexing.

This ability to dynamically multiplex data packets from multiple sources contributes to packet-switched networks being more

Exhibit 4-BQ:
Monthly Usage and BHOLs by Speed Tier

Median monthly usage in GB by speed tier in Mbps, 1H 2009

Mean monthly usage in GB by speed tier in Mbps, 1H 2009

Median BHOL in Kbps by speed tier in Mbps, 1H 2009

Mean BHOL in Kbps by speed tier in Mbps, 1H 2009
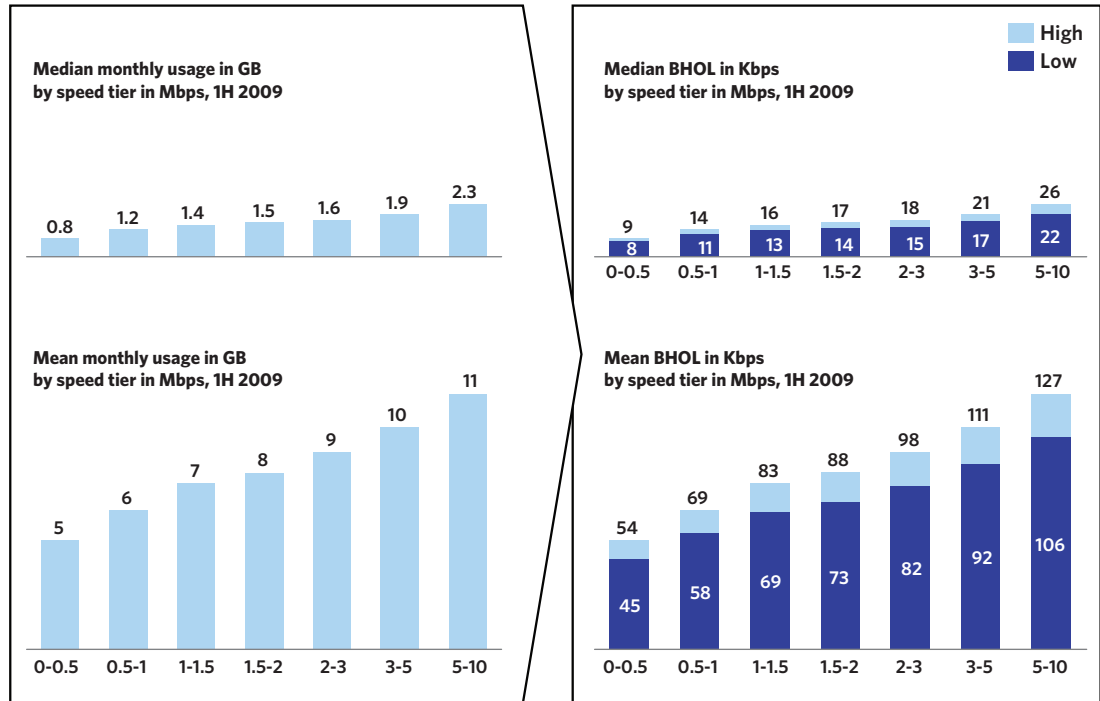
Exhibit 4-BR:
Usage by Tier and BHOL

Usage by the heaviest users
Percent, 1H2009

BHOL by usage type for the 3-5 Mbps speed tier in 1H2009
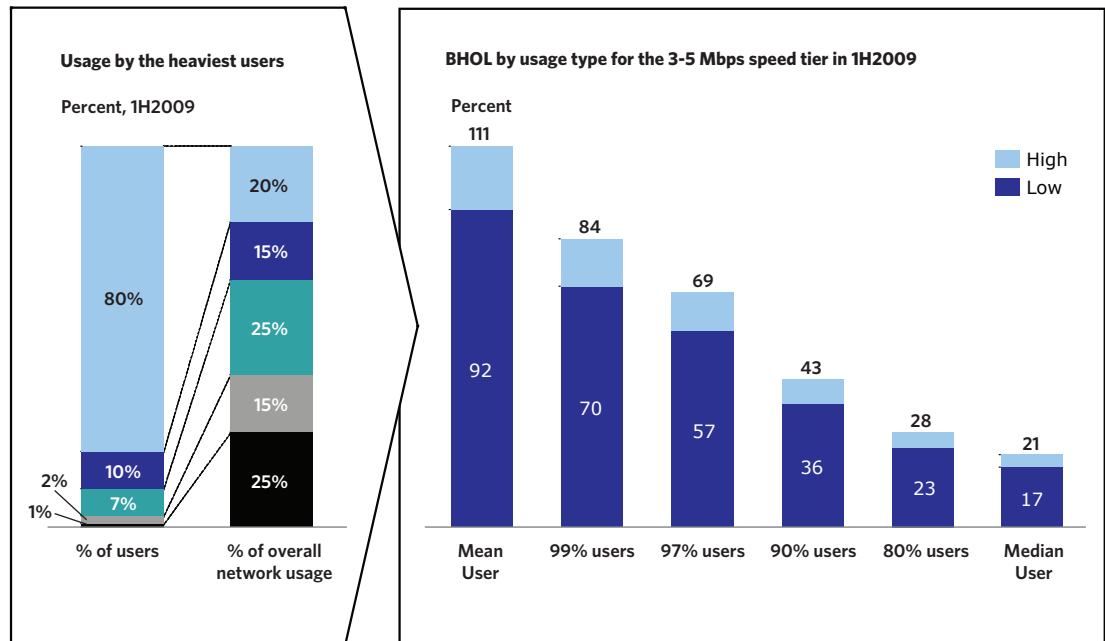
efficient and economical than circuit-switched networks. Shared network resources are the principle of network "convergence" in practice. Voice, video and data applications like Web browsing and other applications noted above are now all packetized and transmitted using the same network transmission facilities.

Of course there is a downside to shared networks, which are typically oversubscribed in order to exploit the benefits of statistical multiplexing. Oversubscription refers to the fact that the maximum aggregate demand for capacity at a shared link or

node in the network can exceed the link or node capacity. Thus, there is a risk, however small, that the total traffic presented at a given time might exceed transport resources in a way that will, in turn, result in congestion, delay and packet loss.

Even though it is challenging, *a priori*, to accurately characterize the user experience on a network because of the complexity of characterizing the traffic per subscriber, we used some available analytical tools to validate the network dimensioning assumptions in our model. Specifically, in Exhibit 4-BT,

Exhibit 4-BS:
Expected Future BHOL in Broadband Network Dimensioned to Deliver 4 Mbps—Expected BHOL in kbps for Different Usage Types in 2015
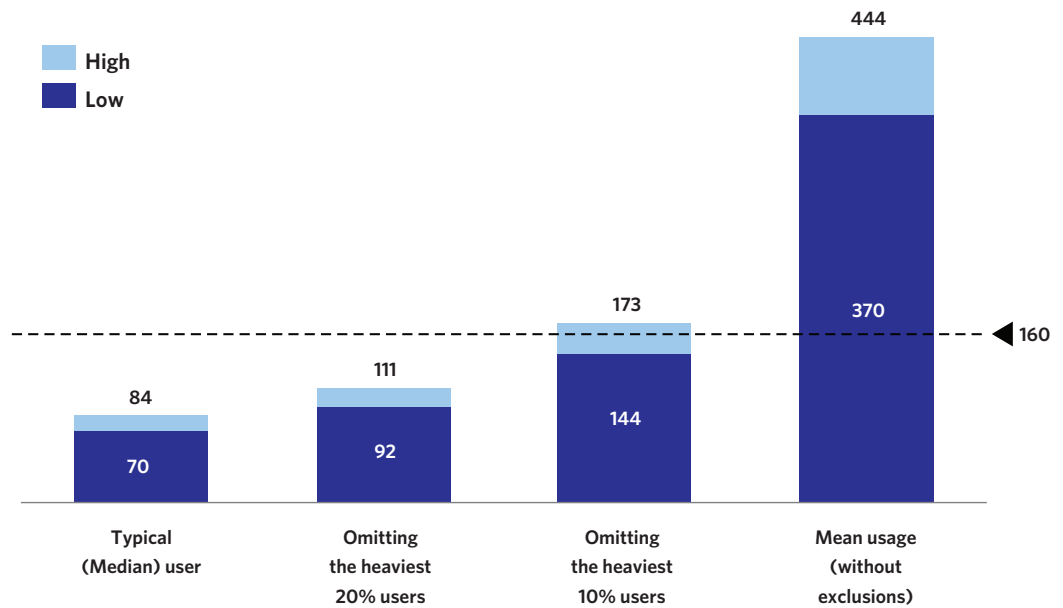
Exhibit 4-BT
Likelihood of Achieving a Burst Rate Greater Than 4 Mbps at Different Oversubscription Ratios with a Varying Number of Subscribers[158]
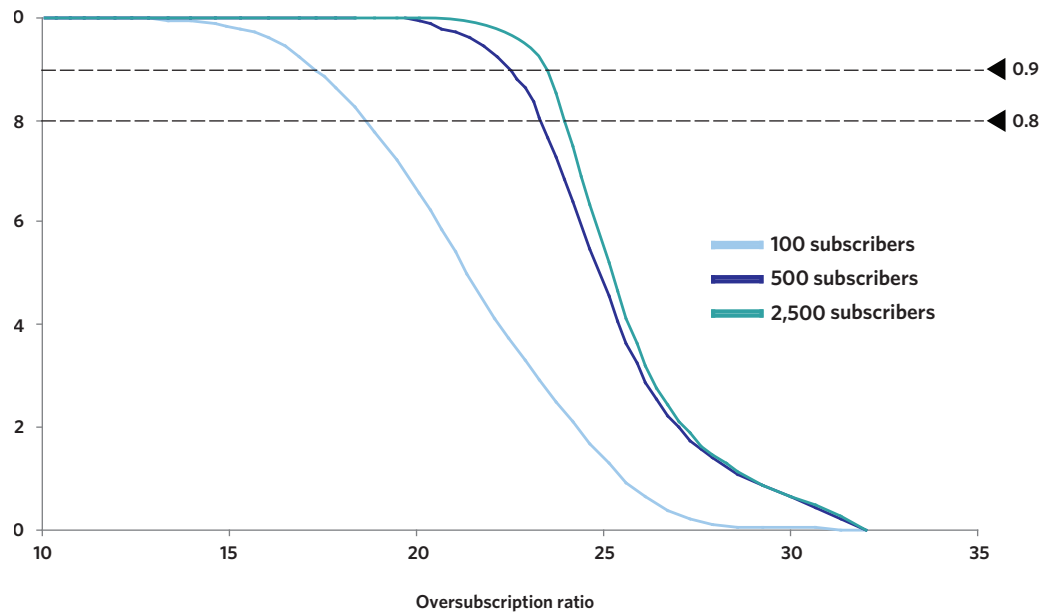
we show the likelihood of being able to burst at rates greater than 4 Mbps on a shared *wired* or *satellite* link at different oversubscription ratios. For convenience, we shall refer to this likelihood as simply "burst likelihood."

In Exhibit 4-BT, the case with 100 subscribers is meant to represent a typical HFC node with ~100 subscribers; the 500 and 2,500 subscriber curves, on the other hand, represent a DSLAM with ~500[159] and a satellite beam with ~2,500 subscribers, respectively.

We use this chart to validate the network dimensioning assumptions in our model. For example, the chart shows that for a burst likelihood of 90%, the maximum oversubscription ratio on a link with 100 subscribers is approximately 17. Recall that oversubscription ratio of a link of capacity C Mbps with N subscribers who have an actual data rate of R Mbps is:

$$\text{Oversubscription ratio} = \frac{(\text{Number of subscribers}) \times (\text{Actual Speed})}{(\text{Link Capacity})} = \frac{N \times R}{C}$$

That implies that the link capacity must be greater than approximately 23.5 Mbps. Since the capacity of a DOCSIS 2.0 HFC node is about 36 Mbps, we conclude that a single DOCSIS 2.0 node, which serves about 100 subscribers can deliver our target broadband speeds with high likelihood. We can use the same approach to validate the dimensioning of shared links and aggregation points in other networks like DSL, Satellite and FTTP.[160]

We recognize that the results shown in the chart are based on certain traffic demand assumptions,[161] and that these assumptions may not hold in practice. Still, given our conservative choice of parameters in our network models, these results indicate that the network will support the required broadband speeds with very high probability. In reality, network operators may monitor traffic levels at different links within their networks and engineer their respective oversubscription ratios to ensure that capacity in the shared portions of the network is available to support offered service levels; in this case, 4 Mbps download and 1 Mbps upload in the busiest hours of the network.

One very interesting implication of the traffic simulation represented in Exhibit 4-BT is that higher oversubscription rates for the larger number of subscribers mean that capacity can grow more slowly than the number of subscribers. This is due to improved statistical multiplexing with increased number of users. For example, adding five times more subscribers, moving from 100 to 500 or from 500 to 2,500 subscribers, requires adding only roughly four times as much capacity to provide the same probability of end-user service. Thus, adding capacity linearly with the number of subscribers, as we assume in our analysis, is a conservative approach that does not account for the full benefits of statistical multiplexing.

MIDDLE-MILE ANALYSIS

Middle-mile facilities are shared assets for all types of last-mile access. As such, the cost analysis is very similar regardless of last-mile infrastructure. The local aggregation point can vary based on technology (e.g., a cable headend, LEC central office or a wireless mobile switching center (MSC)) while the Internet gateway is a common asset. Middle-mile facilities are widely deployed but can be expensive in rural areas because of the difficulties of achieving local scale, thereby increasing the investment gap. On a per-unit basis, middle-mile costs are high in rural areas due to long distances and low aggregate demand when compared to middle-mile cost economics in urban areas.

While there may be a significant affordability problem with regard to middle-mile access, it is not clear that there is a middle-mile fiber *deployment* gap. The majority of telecom central offices (approximately 95%)[162][163] and nearly all cable nodes (by definition, in a true HFC network) are fed by fiber.

Please note: terms like "backhaul," "transport," "special access" and "middle-mile" are sometimes used interchangeably, but each is distinct. To avoid confusion, "middle-mile transport" refers generally to the transport and transmission of data communications from the central office, cable headend or wireless switching station to an Internet point of presence or Internet gateway as shown in Exhibit 4-BU.

Middle-Mile Costs

The middle-mile cost analysis concludes that the initial capex contribution to serve the unserved is 4.9% of the total initial capex for the base case. That is, the modeled cost for the incumbent or lowest cost provider to build these facilities incrementally is estimated at approximately $747 million.

In order to accurately model the costs of middle-mile transport, particularly in rural, unserved areas, we examined all available data about the presence of reasonably priced and efficiently provided, middle-mile transport services. However, we recognize that broadband operators who rely on leased facilities for middle-mile transport may pay more for middle-mile than broadband providers who self-provision. This is discussed further within the subsection titled **Sensitivity: Lease vs. Build**. Thus, in a hypothetical case in which leasing facilities turns out to be four times the modeled incumbent build cost, the resulting middle-mile contribution could be estimated as high as 9.8% of the total initial capex for the base case, or approximately $1.6 billion. The following discusses the analysis done to ensure our model accurately captures the appropriate costs.

Broadband networks require high-capacity backhaul, a need that will only grow as end-user speed and effective load grow. Given the total amount of data to be transmitted, optical fiber backhaul is the required middle-mile technology in most

instances. Once the transport requirement reaches 155 Mbps and above, the only effective transport mode is at optical wavelengths on a fiber optic-based transmission backbone. Plus, while the initial capital requirements of fiber optic systems are substantial, the resulting infrastructure provides long-term economies relative to other options and is easily scalable.[164] Microwave and other terrestrial wireless technologies are well suited in only some situations such as relatively short middle-mile runs of 5-25 miles. However, microwave backhaul may be a critical transport component in the second mile, primarily for wireless backhaul as discussed in detail in the wireless section.

Approach to Modeling Middle-Mile

The costs associated with providing middle-mile services are heavily dependent on the physical distances between network locations. Therefore, the approach to modeling middle-mile costs revolves around calculating realistic distance-dependent costs.

Our focus is on ILEC central offices given the availability of information on their locations. Starting with the location of ILEC central offices and the network homing topology, we estimated the distances and costs associated with providing middle-mile service. Since the cost estimate is distance-dependent, calculating the cost requires making an assumption about the routing used to connect LEC offices as will be discussed

below. This same approach—mapping known fiber locations and their logical hierarchy to calculate the distances and costs for providing middle-mile service—could apply equally well to cable headends, or CAP, or IXC POPs given thorough information on their locations. However, publically available information on exact locations of cable headends, private IXC fiber POPs and other entity fiber node locations is limited; thus, the focus exclusively on ILEC fiber suggests that this analysis will significantly underestimate the presence of fiber around the country.

The following sections describe the process of collecting and processing data, along with the cost inputs and assumptions used in the model. The gap calculation assumes internal transfer pricing: i.e., the incremental cost the owner of a fiber facility would assign to the use of the fiber in order to fully cover both the cash cost and opportunity cost of capital. Importantly, as discussed below, this cost may be substantially lower than the price a competitor or other new entrant, like a wireless provider, may be charged for the same facility.

Middle-Mile Data Collection

➤ Identify all ILEC Central Offices (CO) and obtain each Vertical and Horizontal coordinates (analogous to latitude and longitude)

Exhibit 4-BU:
Breakout of Middle,
Second & Last Mile
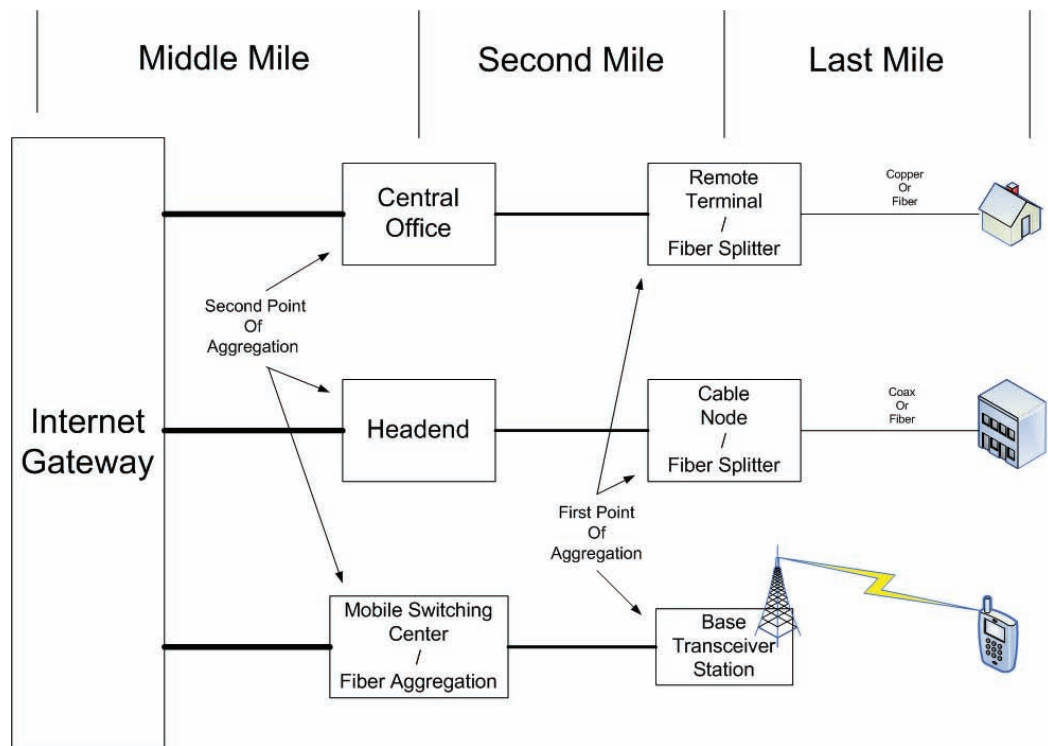
➤ Identify all Regional Tandems (RT) within their respective LATA locations and determine which Central Office subtends which RT

After the middle-mile anchor node locations and hierarchical relationships between the nodes are captured, the distances between these nodes must be calculated so that the distance-dependent cost elements can be applied appropriately.

Middle-Mile Processing Steps

➤ Each subtending CO is assigned to its nearest RT to create the initial relation of COs to RTs.
➤ COs are then routed to other COs that subtend the same RT using shortest distance routing back to their respective RTs (i.e., we calculate a shortest-distance route to connect the COs to their respective RTs). To achieve this route, the process starts at the CO coordinate farthest from the appropriate RT and selects the shortest CO-to-tandem distance based on airline mileage. The CO starting point is prohibited from routing back to itself and must route toward the tandem. This approach minimizes the amount of fiber needed.

➤ The RTs within a given LATA are routed together in a ring.
  ➤ The shortest ring is chosen by comparing the distances between RTs and selecting the shortest ring distance within each LATA; this distance is then used for the middle-mile feeder calculations.
  ➤ It is assumed that the Internet gateway peering point is located on the RT ring. In this manner, all COs that are connected to the RT ring have access to the Internet.
  ➤ Internet gateway sites are assumed to be located in regional carrier collocation facilities (known commonly as "carrier hotels"). We estimate there are some 200 of these located regionally throughout the United States.
➤ The middle-mile calculation is run state-by-state and stored in one central distribution and feeder table.

Tree vs. Ring architecture

➤ The design depicted in Exhibit 4-BV represents a hub-and-spoke hierarchy interconnected via closed rings. The model contemplates that a typical ILEC would likely interconnect end office, tandems and regional tandems in redundant-path "ring architecture."

Exhibit 4-BV:
Topology Used for
Middle-Mile Cost
Modeling
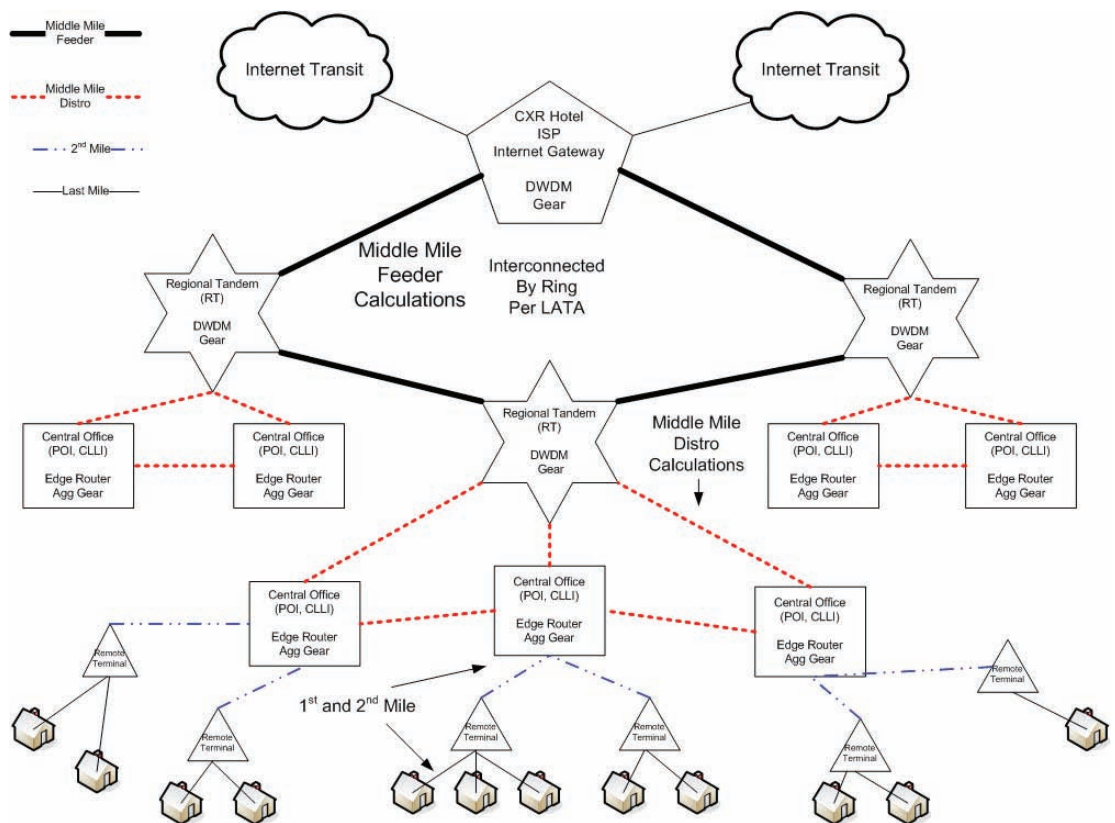
➤ By assumption, the fiber link and distance calculations between COs and RTs are increased by a factor of 1.8 to account for the redundant, geographically diverse, fiber spans that would be required in ring architecture as opposed to a hub-and-spoke architecture. Note that this assumption could be fairly conservative (i.e., assuming higher than necessary costs) given degree of interconnection among the COs.

Cost Allocations on Facility

These middle-mile facilities by nature and design are engineered as shared infrastructure facilities that aggregate end-user traffic and transport traffic to regional Internet gateways. The cost of a particular middle-mile facility cannot be allocated solely to the consumer broadband users of that facility. Since that facility is shared with other provider services such as residential and enterprise voice, wholesale carrier services, enterprise data services and other management services utilized by the provider, the cost needs to be allocated appropriately.

➤ The model assumes that the total cost of the facility is allocated thus: 1/3 for service provider voice service, 1/3 wholesale and enterprise carrier services and 1/3 consumer broadband services. This is an estimation of the allocation of traffic within a typical ILEC transport environment, but the allocation of cost to any single product or customer group is speculative at this point.

➤ The model only calculates the consumer broadband services portion of the facility and assumes that BHOL doubles roughly every three years.

Nationwide Middle-Mile Fiber Estimation

Data sources about fiber routes or even the presence of fiber in a given LEC office are extremely limited. Consequently, we created our best approximation of fiber facilities available for middle-mile service; detail on that process is provided below. The overwhelming majority of telecom central offices (approximately 95%)[165][166] and nearly all cable nodes (by HFC definition) are fed by fiber.

The map shown in Exhibit 4-BW is an illustration of the paths of fiber used in our calculation to connect ILEC offices (and only ILEC offices). While it is based on as much real and calculated data as are available, we had to make a number of assumptions about the specific routes. Therefore, while we believe this map represents an accurate, if conservative, estimate of middle-mile fiber, it is not appropriate for network-planning purposes.

The diagram in Exhibit 4-BW is an estimation based on:

➤ Known locations of ILEC CO
➤ Topology based on a Gabriel Network[167] topology was considered but likely overestimated the number of links of fiber distribution. Thus, a Relative Network

Neighborhood[168] distribution was chosen given the set of points representing the CO locations.
➤ Approximately 90% ILEC Fiber CO deployment, which is significantly lower (i.e., more conservative) than most estimates. Exhibit 4-BX, which shows the distribution of fiber-fed CO based on known services available per CO.

Exhibit 4-BW contemplates ILEC fiber only. Estimating the presence of middle-mile fiber based only on the fiber that connects LEC central offices, while excluding the fiber networks of cable companies, CAPs, CLECs and other facilities-based providers, systematically underestimates the presence of fiber. If one imagines overlaying the fiber optic facilities that have been deployed by other entities—such as Tier One IXCs/ISPs (ATT, Sprint, GX, Verizon Business, Level 3, XO, TWTC, etc.); Nationwide and regional Cable Operators (Comcast, Cox, Time Warner, Charter etc); Competitive Fiber Providers (Abovenet, Zayo, Deltacom, 360 Networks, Fiberlight, Alpheus etc.); private fiber deployments (hospitals and institutional); municipal fiber; and utility fiber—it becomes clear that the United States is generally well connected coast-to-coast.

In the limited instances where LEC fiber is not available, Windstream[169] has found that the exchanges typically have the following reasons for lack of deployment:

➤ The exchange is an island exchange (i.e., isolated from other exchanges in the LECs footprint) or part of a small, isolated grouping of exchanges;
➤ Fewer than 1,000 access lines fall within the exchange; and
➤ The closest point of traffic aggregation is more than 50 miles away from the CO.

The combination of a small customer base and long transport distances can make it impossible to build an economic case for fiber deployment.

However, recognizing that fiber-based middle-mile services are physically deployed does not necessarily mean that they are always economically viable in every rural area. The challenge is that access to such fiber may not be available at prices that result in affordable broadband for businesses, residents and anchor institutions, as discussed in the following section.

Costs Drivers for Middle-Mile Transport

Transporting data 50 miles or more from a local CO or other access point to the nearest Internet point of presence is a costly endeavor.

The costs of these facilities are proportional to their lengths. In urban or suburban areas, the cost of new fiber network construction varies widely, roughly from $4 to $35 per foot where the largest cost component is installation. The cost range

depends on whether the fiber is suspended from utility poles or buried, the number of fiber strands in the cable, right-of-way costs, terrain, soil density and many other factors.[170] In the model, we assume that in rural settings, even for inter-CO transport facilities, 75% would be aerial construction. Of the 25% buried

construction, the model calculates fiber burial costs that take into account local terrain, including soil composition.

Providing fiber-based service to low-density areas carries with it higher per-user costs. These costs are driven by larger distances which, even when offset by lower per-foot costs, lead

Exhibit 4-BW:
Calculated Telco Fiber Routes

Conterminous United States

Alaska

Hawaii

Legend

Calculated fiber routes

• CO locations

0194
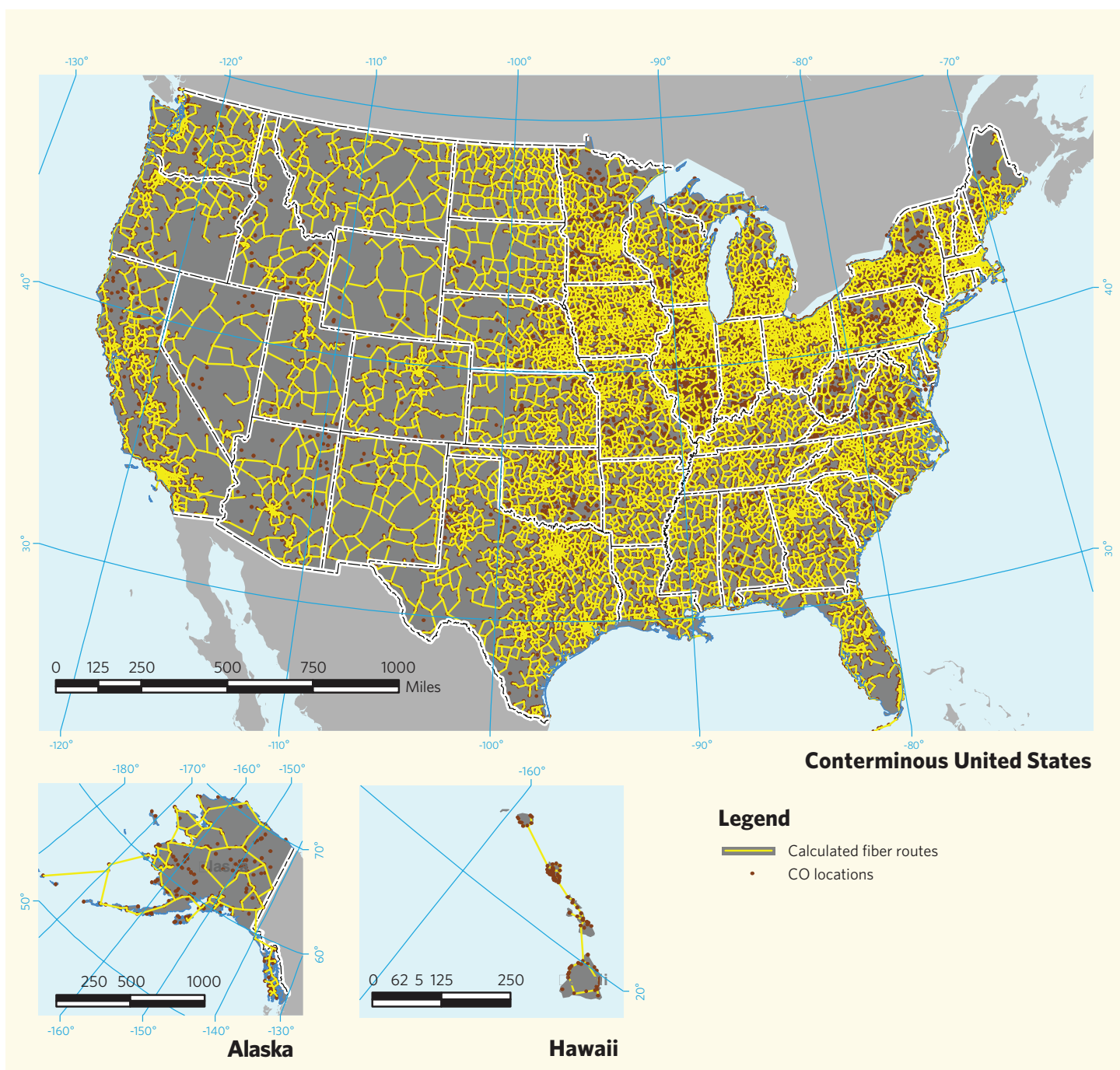
to higher total cost per link. In addition, there are simply fewer users per link. Given that middle-mile links have very high fixed costs yet low costs associated with adding capacity, larger connections are more cost-effective per bit than smaller links. This is reflected in the prices shown in Exhibit 4-BY.

The low density and demand in rural areas, coupled with the volume-dependent middle-mile cost structure, mean that rural broadband operators do not benefit from the same economies of scale common among providers in denser areas. The distances at issue in unserved areas are much longer than typical

Exhibit 4-BX:
Classification of Central Offices for Creating Fiber Map

Conterminous United States

Alaska

Hawaii

Legend
- Fiber services offered from CO
- DS1 service offered from CO
- DSL service offered from CO
- No definitive data
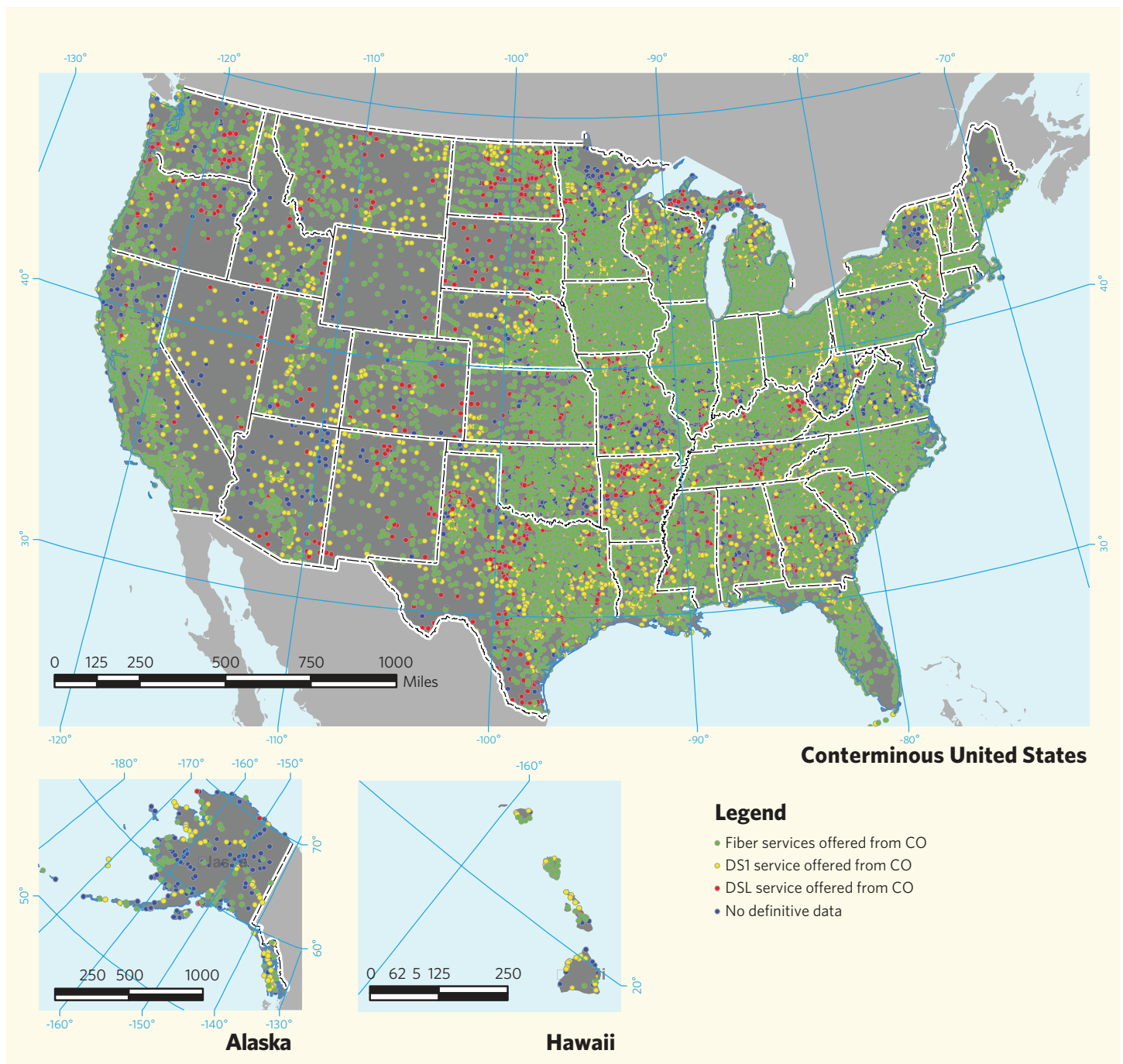
special access connections. Moreover, low population density prevents the aggregation of demand that would allow rural carriers to use lower-cost, high-capacity links.[171]

Pricing data are difficult to obtain. Tariffs are widely available but "street prices," including all contract savings and contract-term penalties, are not as readily available. Different discount structures, terms and agreements can cause great variability in middle-mile rates. As part of its COMMENTS ON NBP NOTICE #11, the NTCA provided Exhibit 4-BY that shows that while prices of middle-mile connections are indeed dependent on volume, they also vary widely across providers and geographies.[172] The highest and lowest prices vary by more than an order of magnitude for services below about 100 Mbps.

Exhibit 4-BY illustrates that on a per-unit basis, higher capacity middle-mile facilities are more economical than low-capacity facilities. According to NTCA and NECA filings, the average middle-mile cost contribution per subscriber per month is approximately $2.00 in study areas using middle-mile Ethernet connections of higher than 1,000 Mbps.[173] This can be compared to areas using middle-mile Ethernet connections of less than 10 Mbps, that resulted in monthly middle-mile costs per user of approximately $5.00 or more.[174] Again, these data are consistent with the premise that larger pipes carry lower costs per bit, suggesting the benefit for communities in smaller and less-dense areas to aggregate demand for homes and businesses as much as possible and that long-term commitments to utilize these facilities be in place.

Sensitivity: Lease vs. Build
The base case assumes that operators in unserved areas have access to middle-mile transport at economic pricing—cost plus a

rate of return. To the extent that middle-mile transport prices exceed this cost-plus pricing model, middle-mile costs can be higher for carriers leasing capacity. The broadband team models the cost to incrementally build middle-mile fiber facilities from scratch to a) understand the overall middle-mile cost contribution for the unserved and b) to establish a baseline middle-mile cost with which to compare to leased middle-mile costs.

The analysis in Exhibit 4-BZ compares middle-mile facility connections of different distances, connection sizes and methods to highlight the lease vs. build decision. Leasing facilities from an incumbent carrier, when properly sized for capacity demand, carries higher costs than the modeled cost for the incumbent provider to build these facilities incrementally. Thus broadband operators who rely on leased facilities for middle-mile may pay more for middle-mile costs than incumbent broadband providers.

To arrive at these estimates, we examine randomly chosen regional routes as shown in Exhibit 4-BZ. Separate "city-pair" routes were selected specifically in rural areas that are homed back to regional carrier collocation facilities (CCF) or "carrier hotels." These particular towns and CCF pairs were selected based upon known locations of CCFs to avoid Tier One MSA access points to best represent rural middle-mile connections. For each route, we calculate the applied tariff rate for the appropriate connection, applying a 30% discount rate for each connection. We recognize, however, that discount levels can range from 10-70% from "rack rates" and that a particular provider in an area may pay more or less than modeled.

NECA Tariff #5 was used as these tariffs are published, and we believe NECA carriers are likely to provide these rural

Exhibit 4-BY:
Middle-Mile Cost
Dependency on
Capacity

Cost per Mbps by Guaranteed Mbps per Connection
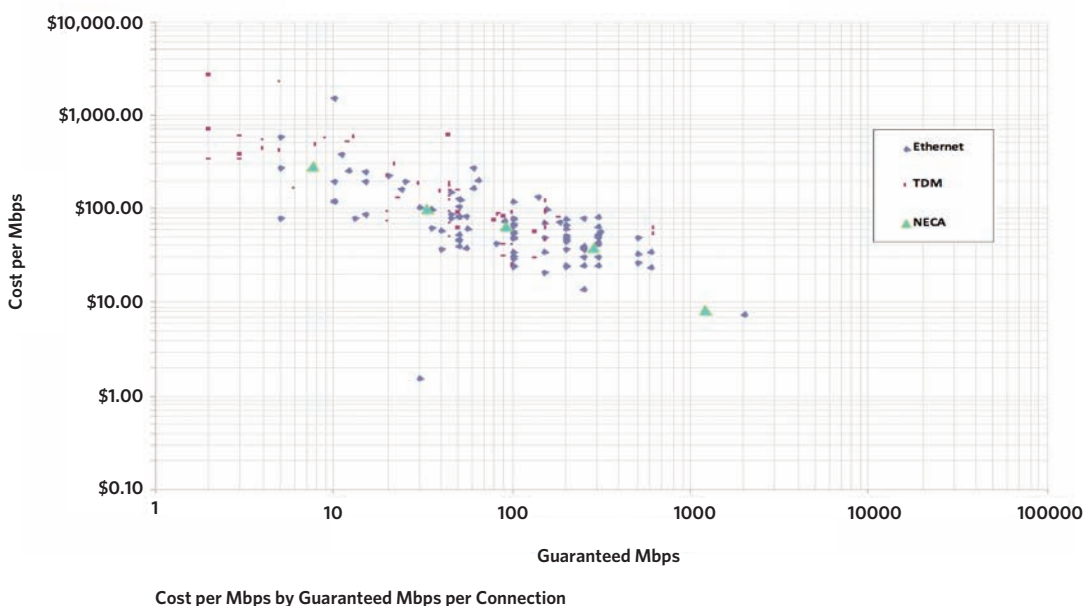
middle-mile connections. The towns were selected such that they are likely to be in the high-cost study group in accordance with NECA rate band blends.[175] In its comments, NECA suggests that on average, 1 Mbps is required in the shared portions of the network for every 14.5 users for a typical consumer best-effort DSL service.[176] We use this ratio in the analysis and size middle-mile capacity to provide 1 Mbps for every 14.5 users. For example, in the Exhibit 4-BZ for Flasher, ND, the middle-mile capacity required to support 351 HUs is 24 Mbps. In order to provide middle-mile support in Flasher ND, the lowest-cost facility likely available for lease large enough to carry the required 24 Mbps is a DS-3, which has a capacity of 45 Mbps. This need to "overbuy" capacity is repeated as demand requires the lease of larger facility tiers from DS3 to OC3 to OC12, etc. This illustrates the importance of demand aggregation and capacity utilization in the middle mile.

We also estimate the incremental cost that the owner of existing fiber facilities would assign to the use of these facilities in order to fully cover both the cash cost and opportunity cost of capital along these routes. The cost of the build includes the fiber deployment costs (labor, plowing, trenching, pole attachments, ROW, etc.) and the fiber optic electronics (DWDM transport nodes, regenerators, aggregation electronics, etc.). The capacity of the middle-mile network was modeled as 40 Gbps between interoffice nodes. While we believe that the modeled electronics

are very high capacity and represent future scalability, it should be understood that included in this cost model is the fiber itself, which is virtually unlimited in capacity as electronics are upgraded. While we make assumptions about the allocation of cost to the modeled services as discussed in the previous section entitled "Approach to Middle-Mile Model," we also estimate the full cost of providing service along these routes as a price ceiling. The results of the analysis are summarized in Exhibit 4-BZ.

Exhibit 4-BZ suggests that on a per-unit basis, it is cheaper to build than to lease. However, that does not necessarily imply that for a given (small) user base and limited capacity demand that the lowest cost option is to build. Cost-per-unit for fiber builds is highly sensitive to scale and utilization. Consequently, it is possible that cost-per-unit for a build is actually higher than lease when demand and utilization are subscale. There is still a question regarding the extent to which leased facility pricing in rural areas is reflective of high deployment costs—long distances driving high-cost deployments that can be amortized over only a small base of end users—or of rent-seeking by facilities owners. The Federal Communications Commission is currently undertaking a proceeding to address special access pricing generally, not only with regard to interoffice transport in rural areas.[177] That proceeding will delve in greater depth into the question of costs and pricing.

In order to connect some rural areas, providers must deploy

Exhibit 4-BZ:

Middle-Mile Build vs. Lease Comparison

From City	To City	# of unserved HU	Airline miles between	Circuit size	Build cost per HU per month	Lease cost per HU per month	Lease Premium
Nenana, Alaska	Juneau, Alaska	315	648.96	DS3	$26.99	$302.44	1020%
Bagdad, Ariz.	Phoenix, Ariz.	206	100.32	DS3	$36.49	$93.34	156%
Irwinton, Ga.	Macon, Ga.	934	26.95	OC3	$3.46	$10.10	192%
Libby, Mont.	Missoula, Mont.	2,372	127.95	OC12	$10.89	$12.93	19%
Fort Sumner, N.M.	Ruidoso, N.M.	701	113.87	OC3	$28.22	$31.86	13%
Flasher, N.D.	Bismark, N.D.	351	32.66	DS3	$16.73	$28.06	68%
Lindsay, Okla.	New Castle, Okla.	834	29.46	OC3	$4.87	$11.76	141%
Glide, Ore.	Eugene, Ore.	759	51.76	OC3	$11.19	$17.28	54%
Denver City, Texas	Brownfield, Texas	455	35.24	DS3	$17.98	$22.44	25%
Eureka, Utah	Provo, Utah	578	31.02	DS3	$3.61	$16.65	361%
Rock River, Wyo.	Cheyenne, Wyo.	30	73.32	DS3	$155.63	$516.23	232%
Sheffield, Ala.	Huntsville, Ala.	3,570	58.88	OC12	$1.93	$5.00	159%
Hope, Ark.	Fouke, Ark.	3,465	32.65	OC12	$2.40	$3.75	56%
Buena Vista, Colo.	Colorado Springs, Colo.	2,592	70.96	OC12	$5.29	$7.75	47%
Ketchum, Idaho	Boise, Idaho	1,532	92.00	OC3	$2.92	$12.46	326%
Monticello, Miss.	Hattiesburg, Miss.	2,746	50.59	OC12	$2.09	$5.94	184%
Winchester, Tenn.	Chattanooga, Tenn.	5,145	46.77	OC12	$1.46	$3.03	107%
Pomeroy, Wash.	Walla Walla, Wash.	893	45.15	OC3	$9.99	$13.59	36%
Fayetteville, W. Va.	Beckley, W. Va.	2,780	24.30	OC12	$0.86	$4.11	381%

middle-mile facilities over considerable distances at significant cost. These challenges are further compounded by the fact that these areas often do not have the population density necessary to generate the type of demand that justifies the large investment needed to construct these facilities.[178] The list below summarizes the basic conclusions based upon the middle-mile analysis:

➤ The distances at issue in unserved areas are much longer than typical special access connections and the low housing-unit or population density results in demand that is insufficient for lower cost high-capacity links.[179]

➤ As Internet demand increases, the total middle-mile cost for all providers will rise.

➤ Rural broadband operators do not benefit from the economies of scale on middle-mile facility cost in comparison to urban providers.

CHAPTER 4 ENDNOTES

[1] See Section 5, Wireless Technology, for a discussion of wireless second mile backhaul.

[2] While we realize that a typical fully configured DSLAM would likely support no more than ~350 subscribers, we used 550 to show maximum subscribers that can be achieved at a DSLAM aggregation point (RT or CO) using Fast Ethernet backhaul.

[3] Note that the number of simultaneous video streams is driven by capacity of the cell site, not the coverage which is limited by upstream signal strength as discussed below.

[4] Simultaneous streams assume non-real-time streams/ videos with sufficient buffers at the receiver. Capacity with real-time traffic requirements, such as is required with video-conferencing applications, will be lower. The 480Kbps and 700Kbps video streams here are typical Hulu video streams. See Hulu typical video streaming requirements, http://www.hulu.com/support/technical_faq, February 2010. The 1Mbps video stream corresponds to a high-def Skype video conference.

[5] UBS Investment Research, "US Wireless 411," August 14, 2009.

[6] A paired 2x20MHz of spectrum refers to a spectrum allocation where downlink and uplink transmissions occur on two separate 20MHz bands.

[7] Enhanced technologies, such as multiple antenna technologies (aka MIMO), can also help. See Wireless Technology section below for more detail.

[8] In the bands below 3.7GHz, 547MHz is currently licensed as flexible use spectrum that can be used for mobile broadband. The NBP recommends an additional 300MHz be made available within the next five years.

[9] Yankee Group, "North America Mobile Carrier Monitor," December, 2009.

[10] Theoretical peak rate inside a cell, does not take into account many real world deployment issues or cell-edge average rate.

[11] The CDMA family of standards has its own 4G evolution called UMB. However, UMB is no longer in development and most worldwide CDMA operators have already announced plans to adopt either WiMAX or LTE for when they upgrade to 4G. In the United States, for example, Verizon has chosen LTE while Sprint is planning to deploy WiMAX.

[12] Includes total cost of network plus success based capital for subscribers.

[13] Based on American Roamer mobile coverage data, August 2009.

[14] In 2G systems, by contrast, the signals were transmitted over 200kHz and 1.25MHz.

[15] For a more detailed exposition on these multiple access techniques, see, for example, "Fundamentals of Wireless Communication," David Tse and Pramod Viswanath, as well as references therein.

[16] Letter from Dean R. Brenner, Vice Pres., Gov't Aff., Qualcomm Inc., to Marlene H. Dortch, Secretary, FCC, GN Docket No. 09-51 (Dec. 9, 2009) Attach. A at 2. Figure shows downlink capacities calculated for 2x10MHz spectrum availability. Estimates of spectral efficiency calculated for each technology with the following antenna configuration: WCDMA, 1x1 and 1x2; HSPDA, Rel.5, 1x1; HSPA Rel. 6, 1x2; HSPA, Rel. 7, 1x1 and 1x2; LTE, 1x1 and 1x2.

[17] See, for example, "Fundamentals of Wireless Communications," David Tse and Pramod Viswanath, for details on Shannon theory as well as multi-user scheduling.

[18] Our estimate of the limit is based on a simplified evaluation of the "single-user" Shannon capacity of a cell site using the signal quality distribution for a cell site provided in Alcatel Lucent's Ex Parte Presentation, GN Docket 09-51, February 23, 2010, and then adjusting for multi-user scheduling gains. Our analysis also assumes 43% loss in capacity due to overhead; see, for example, "LTE for UMTS - OFDMA and SC-FDMA Based Radio Access," Harri Holma and Antti Toskala (Eds). See, for example, "Fundamentals of Wireless Communications." See, for example, Section 7.7 in "The Mobile Broadband Evolution: 3G Release 8 and Beyond, HSPA+, SAE/LTE and LTE-Advanced," 3G Americas.

[19] See, for example, Section 7.7 in "The Mobile Broadband Evolution: 3G Release 8 and Beyond, HSPA+, SAE/LTE and LTE-Advanced," 3G Americas.

[20] See, for example, "LTE for UMTS - OFDMA and SC-FDMA Based Radio Access," Harri Holma and Antti Toskala (Eds).

[21] See, for example, "The performance of TCP/IP for networks with high bandwidth-delay products and random loss," T. V. Lakshman and U. Madhow, IEEE/ACM Transactions on Networking, June 1997.

[22] CDMA operators can choose either LTE or WiMAX for their 4G evolution. LTE currently supports handoffs from CDMA systems.

[23] Spectral efficiencies calculated for a (paired) 2x10MHz spectrum allocation for all technologies. Downlink spectral efficiency for WCDMA performance based on 1x1 and 1x2 antenna configurations; HSDPA Rel 5 and HSPA Rel 6 results based on 1x1 and 1x2 configurations, respectively; HSPA Rel 7 performance assumes 1x2 and 2x2 configurations while LTE result assumes 2x2. Uplink spectral efficiencies for WCDMA, HSPA and LTE capacities evaluated for 1x2 antenna configurations. Performance of (3G) EV-DO, which is not shown in the chart, is comparable to (3G) HSPA.

[24] CITI BROADBAND REPORT AT 25-28.

[25] CITI BROADBAND REPORT AT 8.

[26] "HSPA to LTE-Advanced: 3GPP Broadband Evolution to IMT-Advanced (4G)," Rysavy Research/3G Americas, September 2009.

[27] Round-trip latencies do not include public Internet latencies. Illustrative latencies for 2G/3G/4G networks; latencies for two networks using the same technology can vary depending on network configuration, infrastructure vendor optimizations, etc.

[28] CITI BROADBAND REPORT AT 8.

[29] See, for example, Figure 9.12 in "LTE for UMTS - OFDMA and SC-FDMA Based Radio Access," Harri Holma and Antti Toskala (Eds); and "LS on LTE performance verification work" at http://www.3gpp.org/FTP/tsg_ran/WG1_RL1/TSGR1_49/Docs/ R1-072580.zip.

[30] In terms of cell radius, this gain translates to nearly a three-fold improvement in coverage.

[31] See also Clearwire Ex-Parte filing, "Mobile broadband link budget example – for FCC", GN Docket No. 09-51 (Nov. 13, 2009) and link budget templates in http://www.3gpp.org/ftp/tsg_ran/TSG-RAN/TSGR_45/Documents/RP-090740.zip. Both documents perform downlink and uplink link budget analyses for a number of data rates and show that the limiting link budget in each scenario is the uplink.

[32] Okumura-Hata is a RF propagation model. See, for example, "Introduction to RF propagation," by John Seybold.

[33] Using the Okumura-Hata model, we obtain the maximum cell-size at 700MHz to be 12 miles or higher.

[34] We chose to classify CTs instead of counties or Census Block Groups (CBG) because counties can be very large and CBGs too small—especially when compared with a typical cell size. Studying the variation over too large an area can lead to picking up terrain effects that are well outside of the cell-coverage area. On the other hand, looking at variations over an area that is too small compared with the desired cell size can lead us to overlooking significant terrain variations that are within the cell coverage area.

[35] Based on data provided in Qualcomm Ex-Parte filing, "Mobile broadband Coverage by Technology," GN Docket No. 09-51 (Feb. 22, 2010); Clearwire Ex-Parte filing, "Mobile broadband link budget example – for FCC," GN Docket No. 09-51 (Nov. 13, 2009); "LTE for UMTS - OFDMA and SC-FDMA Based Radio Access," Harri Holma and Antti Toskala (Eds); and link budget templates in http://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_45/Documents/RP-090740.zip.

[36] Maximum transmit power: fixed CPEs can have higher transmit powers and higher antenna gains through the use of directional antennas and can avoid body losses. Receiver noise figure assumes the use of low-noise amplifiers. Effective noise power is calculated as: Total noise density + 10log10 (Occupied bandwidth), where total noise density = thermal noise density +receiver noise figure = -172dBm/Hz. Required SINR assumes the use of two receive antennas at the base station. Penetration losses can be reduced by fixed CPEs by placing the antennas in ideal locations within the house or outside. MAPL without shadow fading margin is appropriate when using RF planning tools because these tools enable shadowing and diffraction losses due to terrain. Shadow fading margin is required for 90% coverage reliability. MAPL with shadow fading margin is appropriate when using propagation loss models, such as the Okumura-Hata model.

[37] RF planning tools by EDX Wireless; see http://www.edx.com/index.html.

[38] Propagation loss analysis using RF planning tools takes into account shadowing and diffraction effects due to terrain. So, it is not necessary to include a shadowing margin in the MAPL.

[39] Propagation losses due to foliage are ~2-7dB at 700MHz.

[40] "PL" denotes propagation loss.

[41] Signal quality is the ratio of the received signal strength to the sum of the aggregated interference from other cell sites and thermal noise. This ratio is often called SINR or Signal to Interference and Noise Ratio.

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42 A *serving* cell site is the cell site that is transmitting the desired data to the end-user. All other cell sites are, then, interfering cell sites.

43 Based on data and analysis provided in: Alcatel Lucent in Ex Parte Presentation, GN Docket 09-51, February 23, 2010; Ericsson in Ex Parte filing, GN Docket 09-51, February 17, 2010; "*The LTE Radio Interface - Key Characteristics and Performance*," Anders Furuskar, Tomas Jonsson, and Magnus Lundevall, Ericsson Research; "LTE-Advanced – Evolving LTE towards IMT-Advanced," Stefan Parkvall, et al, Ericsson Research; "LTE and HSPA+: Revolutionary and Evolutionary Solutions for Global Mobile Broadband," Anil Rao, et al, in Bell Labs Technical Journal 13(4), (2009); "LS on LTE performance verification work," at http://www.3gpp.org/FTP/tsg_ran/WG1_RL1/TSGR1_49/Docs/ R1-072580.zip; 3GPP RAN-1 submission by QUALCOMM Europe, Ericsson, Nokia and Nokia Siemens Networks in 3GPP TSG-RAN WG1 in "Text proposal for TR on system simulation results," http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_53/Docs/R1-082141.zip.

44 *See*, for example: Ericsson in Ex Parte filing, GN Docket 09-51, February 17, 2010; 3GPP RAN-1 submission by QUALCOMM Europe, Ericsson, Nokia and Nokia Siemens Networks in 3GPP TSG-RAN WG1 in "Text proposal for TR on system simulation results," http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_53/Docs/R1-082141.zip; "The LTE Radio Interface - Key Characteristics and Performance," Anders Furuskar, Tomas Jonsson, and Magnus Lundevall, Ericsson Research; "LTE-Advanced – Evolving LTE towards IMT-Advanced," Stefan Parkvall, et al, Ericsson Research; "LS on LTE performance verification work," at http://www.3gpp.org/FTP/tsg_ran/WG1_RL1/TSGR1_49/Docs/ R1-072580.zip.

45 Based on signal quality distribution data provided by Alcatel Lucent in Ex Parte Presentation, GN Docket 09-51, February 23, 2010. We then determine spectral efficiency for mobile and FWA networks by mapping signal quality to data rates using the method and results published in "LTE Capacity compared to the Shannon Bound," by *Morgensen, et al*, in IEEE 65th Vehicular Technology Conference, 2007.

46 A paired 2x20MHz of spectrum refers to a spectrum allocation where downlink and uplink transmissions occur on two separate 20MHz bands. This is also referred to as Frequency Division Duplex, or FDD, allocation. Note that the total spectrum allocation in this example is 40MHz. Similarly, the total allocation in a paired 2x10MHz of spectrum is 20MHz.

47 When SINR is 0 dB, the power of the signal is equal to the sum of the powers of the interfering signals and noise.

48 MIMO techniques use multiple antennas at the transmitter and receiver to improve spectral efficiency of communication. *See*, for example, "Fundamentals of Wireless Communications," David Tse and Pramod Viswanath, for a detailed exposition.

49 In a system with 2x2 MIMO downlink, both the transmitter (base station) and the receiver (CPE) are equipped with two antennas.

50 For the rest of this section, we shall refer to a "paired 2x10MHz" carrier as simply a 2x10MHz carrier. Thus, for example, a 2x20MHz carrier will imply a "paired 2x20MHz" carrier.

51 Based on results published by QUALCOMM Europe, Ericsson, Nokia and Nokia Siemens Networks in 3GPP TSG-RAN WG1 in "*Text proposal for TR on system simulation results*," http://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_53/Docs/R1-082141.zip.

52 *See* "WCDMA 6-sector Deployment - Case Study of a Real Installed UMTS-FDD Network," by Ericsson Research and Vodafone Group R&D, in IEEE Vehicular Technology Conference, Spring 2006; "LTE for UMTS - OFDMA and SC-FDMA Based Radio Access," Harri Holma and Antti Toskala (Eds); "Higher Capacity through Multiple Beams using Asymmetric Azimuth Array," by TenXc wireless, April 2006. The last two references show that 6-sector cells result in an 80% to 90% capacity improvement per cell site.

53 Based on signal quality distribution data provided by Alcatel Lucent in Ex Parte Presentation, GN Docket 09-51, February 23, 2010, and "LTE Capacity compared to the Shannon Bound," by *Morgensen, et al*, in IEEE 65th Vehicular Technology Conference, 2007.

54 "Downlink user data rate" refers to burst rate in a fully utilized network.

55 *See* American Roamer Advanced Services database (accessed Aug. 2009) (aggregating service coverage boundaries provided by mobile network operators) (on file with the FCC) (American Roamer database); see also Geolytics Block Estimates and Block Estimates Professional databases (2009) (accessed Nov. 2009) (projecting census populations by year to 2014 by census block) (on file with the FCC) (Geolytics databases).

56 "Mobile Backhaul: Will the Levees Hold?", Yankee Group, June 2009.

57 Sprint Nextel in Ex Parte Presentation, GN Docket 09-51, January 13, 2010.

58 Level(3) Communications, Notice of Ex Parte Presentation, GN Docket 09-51, November 19, 2009; the filing notes that gigabit links are also available, albeit with limited range; see also "Microwave, Leased Lines, and Fiber Backhaul Deployments: Business Case Analysis."

59 Dragonwave, "Achieving the Lowest Total Cost of Ownership for 4G Backhaul," and "Microwave, Leased Lines, and Fiber Backhaul Deployments: Business Case Analysis."

60 Fiber-to-the-Home Council (FTTH Council), Notice of Ex Parte Presentation, GN Docket 09-51,October 14, 2009, Response to September 22, 2009, FCC Inquiry regarding Broadband Deployment Costs.

61 Dragonwave, "Achieving the Lowest Total Cost of Ownership for 4G Backhaul."

62 Clearwire Ex Parte Presentation, GN Docket 09-51, November 12, 2009 at 12.

63 Ancillary equipment here refers to communication cables, antennas, etc.

64 Average HU density in mountainous and hilly areas is 3 POPs/square mile and 7.4 POPs/square mile, respectively, while in flat areas it is 308 POPs/square mile.

65 Cost and gap shown for counties that have a negative

NPV. Recall that the rural cell radius in the 700MHz band can be as much as 57% greater than that at 1900MHz. We chose the cell radius in mountainous areas to be 2 miles as well. In these areas, terrain rather than propagation losses dominate the determination of cell radius; so, it is unlikely that cell sizes will get much smaller than 2 miles.

66 This exhibit supports information and conclusions found in Exhibit 4-Z: Sensitivity of Buildout Cost and Investment Gap to Terrain Classifications.

67 *See* Tower Maps database (Accessed August, 2009) (on file with the Commission).

68 Mobile Satellite Ventures Subsidiary, LLC, Comments, in PS Docket 06-229 at 50 (June 20, 2008). They show that 30% of the sites required to cover 95th percentile of the population in the rural United States are "greenfield;" that number grows to 75% for the 99th percentile. We assume in our model that the number of greenfield sites required is 52.5%, which is the average of those two numbers.

69 Other network costs include those incurred in the Core (Node-0) network as well as on CPE (Node-4) subsidies

70 IDC, United States Consumer Communications Services QView Update, 3Q09, pg. 5, December 2009.

71 United States Telecom Association, Telecom statistics, http://www.ustelecom.org/Learn/TelecomStatistics. html (last visited Feb. 3, 2010). It should be noted that these 1,311 operating companies comprise fewer than 850 holding companies.

72 IDC, United States Consumer Communications Services QView Update, 3Q09, pg. 5, December 2009.

73 *See* Network Dimensioning section below.

74 Adtran -"Defining Broadband Speeds: Estimating Capacity in Access Network Architectures." Submissions for the Record -- GN Docket No. 09-51, (January 4, 2010) at 8.

75 Adtran -"Defining Broadband Speeds: Estimating Capacity in Access Network Architectures." Submissions for the Record -- GN Docket No. 09-51, (January 4, 2010) at 8.

76 Zhone Applications, http://www.zhone.com/solutions/ethernet/, (last visited Nov. 17, 2009).

77 Level 2 Dynamic Spectrum Management (DSM-2) is currently available and aids in the management of power and begins to cancel some crosstalk. Level 3 Dynamic Spectrum Management (DSM-3), also known as vectoring, is currently being tested in the laboratory and in field trials. Vectoring is discussed in greater detail in the 3-5 kft section of the appendix because, although possible on ADSL2+, the technique is most beneficial on line lengths below 4,000 feet; Broadband Forum Jan. 19, 2010 Notice of *Ex Parte* Communication – Addendum at 5.

78 Letter from Robin Mersh, Chief Operating Officer, Broadband Forum, to Marlene H. Dortch, Secretary, FCC (Jan. 19, 2010) ("Broadband Forum Jan. 19, 2010 Notice of *Ex Parte* Communication – Addendum") at 4.

79 Adtran -"Defining Broadband Speeds: Estimating Capacity in Access Network Architectures." Submissions for the Record -- GN Docket No. 09-51 (January 4, 2010).

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80 Broadband Forum Jan. 19, 2010 Notice of *Ex Parte* Communication – Addendum at 10.

81 Comments of National Exchange Carrier Association (NECA) at Table 1, Impact of Middle and Second Mile Access on Broadband Availability and Deployment, GN Docket #s 09-47,09-51,09-137 (filed November 4, 2009).

82 "Current backhaul dimensioning" is based on comments from NECA that on average ~1Mbps is required in the shared portions of the network for every 14.5 users.

83 Comments of National Exchange Carrier Association (NECA) at Table 1, Impact of Middle and Second Mile Access on Broadband Availability and Deployment, GN Docket #s 09-47,09-51,09-137 (filed November 4, 2009).

84 Load coils, which are in-line inductors used as low-pass filters to balance response for voice frequency transmission, effectively block xDSL signals. Load coils generally exist on loops exceeding 18,000 feet.

85 Bridged taps, lengths of unterminated wire typically formed when changes are made to the loop and unneeded cable is left attached to the loop, can cause some service degradation, especially for data services.

86 TCP acceleration is the consolidation of requests for and acknowledgement of data to minimize the number of serial transmissions over communications links. TCP fast-start is the disabling of slow-start, which entails error checking before the link is brought to full speed, in order to provide full link bandwidth from the outset of the session. TCP pre-fetch is the use of the predictive caching of Web content and DNS look-ups.

87 Letter from John P. Janka on behalf of ViaSat, Inc. to Marlene H. Dortch, Secretary, FCC (Jun. 24, 2009) ("ViaSat Jun 24, 2009 *Ex Parte*") at 6.

88 Max Engel, Satellite Today, http://www.satellitetoday.com/via/satellitegetspersonal/Why-ViaSat-Acquired-WildBlue-and-Why-WildBlue-Needed-It_32911.html (last visited Jan. 12, 2010).

89 Peter B. de Selding, Space News, http://www.spacenews.com/satellite_telecom/with-wildblue-acquisition-viasat-doubles-bet-satellite-broadband.html (last visited Jan.12, 2010).

90 CITI BROADBAND REPORT AT 57.

91 ViaSat Comments at 3.

92 BHOL is the average demand for network capacity across all subscribers on the network during the busiest hours of the network. BHOL is discussed later in the Network Dimensioning section.

93 *See* OBI, Broadband Performance.

94 ViaSat Jan. 5, 2010 *Ex Parte* at 2.

95 Hughes Oct. 26, 2009 *Ex Parte* at 6.

96 See OBI, Broadband Performance.

97 ViaSat Comments in re A National Broadband Plan for Our Future, GN Docket No. 09-51, Notice of Inquiry, 24 FCC Rcd 4342, (2009) at 13.

98 ViaSat Comments in re National Broadband Plan NOI, at 13.

99 ViaSat Comments in re National Broadband Plan NOI, at 3.

100 We assume a growth rate that doubles exactly every three years, i.e. 26.5%, for this analysis.

101 It is unclear what the effect of the Plan will be for satellite broadband providers' subscriber churn due to

the buildouts in areas that are currently served only by satellite.

102 ViaSat 2009 Annual Report at 17.

103 ViaSat 2009 Annual Report at 4.

104 Note that the investment gap calculation does *not* exclude NPV-positive counties as the base case does, which explains why the revenue number differs from the $8.9 billion in the base case.

105 Hughes, High-speed Internet Service Plans and Pricing, http://consumer.hughesnet.com/plans.cfm (last visited Mar. 8, 2010).

106 Operational savings are offered by the Point to Point (P2P) and Passive Optical Network (PON) varieties of FTTP, not by the Active Ethernet variety.

107 RVA LLC, FIBER TO THE HOME: NORTH AMERICAN HISTORY (2001-2008) AND FIVE YEAR FORECAST (2009-2013), 7 (2009), *available* at http://www.rvallc.com/FTTP_subpage7.aspx.

108 CISCO SYSTEMS, FIBER TO THE HOME ARCHITECTURES, 4 (2007), *available* at http://www.ist-bread.org/pdf/FTTP%20Architectures.pdf.

109 Dave Russell, Solutions Marketing Director, CALIX, Remarks at FCC Future Fiber Architectures and Local Deployment Choices Workshop 31 (Nov. 19, 2009).

110 National Exchange Carrier Association Comments in re PN#11 filed (Nov. 4, 2009) at 10.

111 See OBI, Broadband Performance.

112 Dave Russell, Solutions Marketing Director, CALIX, Remarks at FCC Future Fiber Architectures and Local Deployment Choices Workshop 31 (Nov. 19, 2009).

113 Letter from Thomas Cohen, Counsel for Hiawatha Broadband Communications, to Marlene H. Dortch, Secretary, FCC (November 10, 2009) ("Hiawatha Broadband November 10, 2009 *Ex Parte*") at 7.

114 Letter from Thomas Cohen, Counsel for the Fiber to the Home Council, to Marlene H. Dortch, Secretary, FCC (October 14, 2009) ("Fiber to the Home Council October 14, 2009 *Ex Parte*") at 9-10.

115 This equation was derived from fitting a curve to the data, and as such averages over the type of outside plant (aerial or buried). This curve fit may underestimate costs in very high-density areas or other areas with a greater mix of buried infrastructure. The r2 for the curve fit is 0.992 and the R2 adjusted is 0.990.

116 JOHN A. BROUSE, JR., FIBER ACCESS NETWORK A CABLE OPERATOR'S PERSPECTIVE, 3 (2006), http://www.itu.int/ITU-T/worksem/asna/presentations/Session_2/asna_0604_whitepaper_brouse.doc.

117 DOREEN TOBEN, FIBER ECONOMICS AND DELIVERING VALUE, 34 (2006) *available* at http://investor.verizon.com/news/20060927/20060927.pdf.

118 Letter from Thomas J. Navin, Counsel for Corning, to Marlene H. Dortch, Secretary, FCC (October 13, 2009) ("Corning October 13, 2009 *Ex Parte*") at 17.

119 RVA LLC, FIBER TO THE HOME: NORTH AMERICAN HISTORY (2001-2008) AND FIVE YEAR FORECAST (2009-2013), 7 (2009), http://www.rvallc.com/FTTP_subpage7.aspx.

120 Data obtained from Comcast SEC Form 10Q dated 11/4/09, Verizon SEC Form 10Q dated 10/29/09, and Verizon Communications, FIOS Briefing Session, 37-41, 2006.

121 Broadband Forum Jan. 19, 2010 Notice of *Ex Parte* Communication – Addendum") at 7.

122 Broadband Forum Jan. 19, 2010 Notice of *Ex Parte* Communication – Addendum") at 8.

123 Qwest, Wireline Network News, http://news.qwest.com/VDSL2 (last visited Jan. 20, 2010).

124 Broadband Forum Jan. 19, 2010 Notice of *Ex Parte* Communication – Addendum") at 7.

125 Broadband Forum Jan. 19, 2010 Notice of *Ex Parte* Communication – Addendum") at 8.

126 NCTA, Industry Data, http://www.ncta.com/Statistics.aspx, (last visited Jan. 13, 2010).

127 OECD, OECD Broadband subscribers per 100 inhabitants, by technology, June 2009, http://www.oecd.org/sti/ict/broadband; (last visited Feb. 10, 2010).

128 National Cable & Telecommunications Association, Industry Data, http://www.ncta.com/StatsGroup/Availability.aspx (last visited Feb. 3, 2009) and ROBERT C. ATKINSON & IVY E. SCHULTZ, COLUMBIA INSTITUTE FOR TELE-INFORMATION, BROADBAND IN AMERICA: WHERE IT IS AND WHERE IT IS GOING (ACCORDING TO BROADBAND SERVICE PROVIDERS) at 20 (2009) ("CITI BROADBAND REPORT"), *available* at http://www4.gsb.columbia.edu/citi/.

129 National Cable & Telecommunications Association, Industry Data, http://www.ncta.com/StatsGroup/Investments.aspx (last visited Feb. 3, 2009).

130 David Reed, Chief Strategy Officer, CableLabs, Remarks at FCC Future Fiber Architectures and Local Deployment Choices Workshop 31 (Nov. 19, 2009).

131 Adtran, Defining Broadband Speeds: Deriving Required Capacity in Access Networks, at 24, GN Docket No. 09-51, January 4, 2010. Assumes 40% penetration of 350 person node so that capacity = 36 Mbps/(40% x 350) = 250 kbps of capacity per subscriber, well in excess of the 160 kbps average usage forecast.

132 This does not mean that every cable operator will offer packages at these speeds, nor that every subscriber will have service at these speeds; instead this is a comment on the capability of the access network for typical user loads. Localized heavy use, e.g., from heavy use of peer-to-peer programs could load the network more than is typical and lead to lower realized speeds.

133 FCC, US spectrum allocation (http://www.fcc.gov/mb/engineering/usallochrt.pdf), (last visited Feb. 19, 2010).

134 ADRIANA COLMENARES et al., DETERMINATION OF THE CAPACITY OF THE UPSTREAM CHANNEL IN CABLE NETWORKS, 3-4, https://drachma.colorado.edu/dspace/bitstream/123456789/74/1/NCS_Spec_031299.pdf, (last visited Feb. 9, 2010).

135 Stacey Higginbotham, DOCSIS 3.0: Coming Soon to a Cableco Near You, http://gigaom.com/2009/04/30/docsis-30-coming-soon-to-an-isp-near-you/, (last visited Feb. 9, 2010).

136 Cisco Systems, The Economics of Switched Digital Video, http://www.lanpbx.net/en/US/solutions/collateral/ns341/ns522/ns457/ns797/white_paper_G1701A.pdf, (last visited Feb. 9, 2010).

137 Zacks Equity Research, Switched Digital Video Thriving, http://www.zacks.com/stock/news/30346/Switched+Digital+Video+Thriving+-+Analyst+Blog,

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138 TiVo Comments in re NBP PN#27 (Video Device Innovation – NBP PN#27, GN Docket Nos. 09-47, 09-51, 09-137; CS Docket No. 97-80, Public Notice, DA 09-2519, rel. Dec. 3, 2009), filed Feb. 17, 2010, at 1.

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140 Assumes 50% of the spectrum operates at 256-QAM and the other 50% at 64-QAM.

141 Cisco Systems, Understanding Data Throughput in a DOCSIS World, https://www.cisco.com/en/US/tech/tk86/tk168/technologies_tech_note09186a0080094545.shtml, (last visited Feb. 9, 2010).

142 Cisco Systems, Unicast Video Without Breaking the Bank: Economics, Strategies, and Architecture, https://www.cisco.com/en/US/solutions/collateral/ns341/ns522/ns457/unicast_video_white_paper.pdf, (last visited Feb. 9, 2010).

143 Cisco Systems, Understanding Data Throughput in a DOCSIS World, https://www.cisco.com/en/US/tech/tk86/tk168/technologies_tech_note09186a0080094545.shtml, (last visited Feb. 9, 2010).

144 Report on Cable Industry Prices, MM Docket No. 92-266, ATTACHMENT 4 (2009).

145 Report on Cable Industry Prices, MM Docket No. 92-266, ATTACHMENT 3-b (2009).

146 Charter Communications, Fiber Access Network: A Cable Operators Perspective, http://www.itu.int/ITU-T/worksem/asna/presentations/Session_2/asna_0604_s2_p4_jb.ppt, (last visited Feb. 19, 2010).

147 Penetration rate denotes attach rate of homes passed for digital TV, high-speed data and voice; cost does not include CPE cost.

148 Charter Communications, Fiber Access Network: A Cable Operators Perspective, http://www.itu.int/ITU-T/worksem/asna/presentations/Session_2/asna_0604_s2_p4_jb.ppt, (last visited Feb. 19, 2010). Assumes 50% penetration of homes passed.

149 Letter from Thomas Cohen, Kelley Drye & Warren LLP, to Marlene H. Dortch, Secretary, FCC (Nov. 10, 2009) at 1.

150 Westbay Engineers - http://www.erlang.com/whatis.htm; February 2010.

151 *See* https://support.skype.com/faq/FA1417/How-do-I-know-if-I-have-sufficient-bandwidth?: For Skype-to-Skype video (both normal and high quality) we recommend: 384 kbps.

152 Adtran, *Defining Broadband Speeds: Deriving Required Capacity in Access Networks*, at 22, GN Docket No. 09-51, January 4, 2010.

153 IEEE: Similarities between voice and high speed Internet traffic provisioning, IEEE CNSR'04, 25 October 2004.

154 "LTE for UMTS - OFDMA and SC-FDMA Based Radio Access", *Harri Holma and Antti Toskala* (Eds).

155 *See* OBI, Broadband Performance.

156 *See* OBI, Broadband Performance.

157 Consumer-oriented broadband today is provided as a best-effort service whereby the transport network ele-

ments are shared among many users. However, business-oriented broadband networks often are sold with service level guarantees that provide performance assurances. As such, last mile as well as the backhaul network elements must be engineered with higher capacity to assure that bandwidth is always available to the subscribers at all times, regardless of network conditions. This adds cost to the transport portions of the networks, which are reflected in much higher prices to the end-users. Business class "dedicated" Internet services have a pricing structure that can be many times more expensive on a cost-per-bit basis.

158 Adtran Ex-Parte Filing; *A National Broadband Plan for Our Future*, GN Docket No. 09-51, (FCC filed 23 February, 2010).

159 While we realize that a typical fully configured DSLAM would likely support no more than ~350 subscribers, we used 500 per the availability of the simulation tool. Assuming that fast Ethernet backhaul is still used for a ~350 subscriber DSLAM would result in an even better oversubscription ratio and even greater probability performance.

160 The results of this analysis do not easily apply to wireless networks. Unlike in other networks, the signal quality or data rate in a wireless network is strongly dependent on the location of the user relative to the cell site. We need to account for this non-uniformity in signal quality to dimension the wireless network [See Wireless Section above.] Still, we note that the spectral efficiency of a Fixed Wireless Access (FWA) network is ~2.35—2.7 b/s/Hz. So, the oversubscription ratio of a 3-sector cell site with 2x20 MHz spectrum allocation and 650 subscribers is ~16—18.5. Therefore, at first blush, this figure indicates that a FWA network should be able to deliver 4 Mbps in the download with high likelihood. And, as we show in more detail in the Wireless Section above, the FWA network can indeed support this subscriber capacity.

161 The analysis is based on a simulation of N subscribers on a link with capacity C. Specifically, the simulation determines the burst likelihood for the Nth subscriber on the link when the remaining subscribers generate traffic according to a Pareto distribution of mean 160 kbps. Note that the mean of this distribution corresponds to our BHOL assumption of 160 kbps. For more details, *see* Adtran, *Defining Broadband Speeds: Deriving Required Capacity in Access Networks*, at 22, GN Docket No. 09-51, January 4, 2010.

162 Centurylink Ex-Parte filing; *A National Broadband Plan for Our Future*, GN Docket No. 09-51; *International Comparison and Consumer Survey Requirements in the Broadband Data Improvement Act*, GN Docket No. 09-47; *Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, as Amended by the Broadband Data Improvement Act*, GN Docket No. 09-137(FCC filed January 22, 2010).

163 Windstream Ex-Parte Filing; *A National Broadband Plan for Our Future*, GN Docket No. 09-51; *International Comparison and Consumer Survey Requirements in*

the Broadband Data Improvement Act, GN Docket No. 09-47; *Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, as Amended by the Broadband Data Improvement Act*, GN Docket No. 09-137 (FCC filed January 13, 2010).

164 Comments of Kodiak-Kenai Cable Company, LLC. at 5, *A National Broadband Plan for Our Future*, GN Docket # 09-51, PN #11 (FCC filed November 4, 2009).

165 Centurylink Ex-Parte filing; *A National Broadband Plan for Our Future*, GN Docket No. 09-51; *International Comparison and Consumer Survey Requirements in the Broadband Data Improvement Act*, GN Docket No. 09-47; *Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, as Amended by the Broadband Data Improvement Act*, GN Docket No. 09-137(FCC filed January 22, 2010).

166 Windstream Ex-Parte Filing; *A National Broadband Plan for Our Future*, GN Docket No. 09-51; *International Comparison and Consumer Survey Requirements in the Broadband Data Improvement Act*, GN Docket No. 09-47; *Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, as Amended by the Broadband Data Improvement Act*, GN Docket No. 09-137 (FCC filed January 13, 2010).

167 The Gabriel network for a point set is created by adding edges between pairs of points in the source set if there are no other points from the set contained within a circle whose diameter passes through the two points, introduced as one means of uniquely defining contiguity for a point set such that no other point could be regarded as lying 'between' connected pairs; *available* at: http://www.spatialanalysisonline.com/output/html/Gabriel-network.html.

168 A subset of the Gabriel network in which the additional constraint is applied that no other points may lie within the area of intersection defined by circles placed at each Gabriel network node with radius equal to the inter-node separation: *available* at: http://www.spatialanalysisonline.com/output/html/Gabrielnetwork.html.

169 Comments of Windstream at16 1, *A National Broadband Plan for Our Future*, GN Docket # 09-51, PN #11 (FCC filed November 4, 2009).

170 Comments of XO Communications at 10, *A National Broadband Plan for Our Future*, GN Docket # 09-51, PN #11 (FCC filed November 4, 2009).

171 Comments of Verizon at 3, *A National Broadband Plan for Our Future*, GN Docket # 09-51, PN #11 (FCC filed November 4, 2009).

172 Comments of National Telecommunications Cooperative Association (NTCA) at 10, *Comment Sought on Impact of Middle and Second Mile Access on Broadband Availability and Deployment*, GN Docket #s 09-47,09-

CHAPTER 4 ENDNOTES

51,09-137 (filed November 19, 2009).

[173] Comments of National Telecommunications Cooperative Association (NTCA) at 8, *Comment Sought on Impact of Middle and Second Mile Access on Broadband Availability and Deployment*, GN Docket #s 09-47,09-51,09-137 (filed November 19, 2009).

[174] Comments of National Exchange Carrier Association (NECA) at 3, *Impact of Middle and Second Mile Access on Broadband Availability and Deployment*, GN Docket #s 09-47,09-51,09-137 (filed November 4, 2009).

[175] High Cost group is the average of special access rate bands 8, 9, 10; Middle Cost group is the average of special access rate bands 4, 5, 6 and 7; Low Cost group is the average of special access rate bands 3 or lower Comments of National Exchange Carrier Association (NECA) at Table 3, *Impact of Middle and Second Mile Access on Broadband Availability and Deployment*, GN Docket #s 09-47,09-51,09-137 (filed November 4, 2009).

[176] Comments of National Exchange Carrier Association (NECA) at Table 1, Impact of Middle and Second Mile Access on Broadband Availability and Deployment, GN Docket #s 09-47,09-51,09-137 (filed November 4, 2009).

[177] See Parties Asked to Comment on Analytical Framework Necessary to Resolve Issues in the Special Access NPRM, WC Docket No. 05-25, Public Notice, 24 FCC Rcd 13638 (WCB 2009).

[178] Comments of Verizon at 1, *A National Broadband Plan for Our Future*, GN Docket # 09-51, PN #11 (FCC filed November 4, 2009).

[179] Comments of Verizon at 1, *A National Broadband Plan for Our Future*, GN Docket # 09-51, PN #11 (FCC filed November 4, 2009).

LIST OF COMMON ABBREVIATIONS

3G .... Third generation

4G .... Fourth generation

ADSL................ Asymmetric Digital Subscriber Line

AMPS................ Advanced Mobile Phone Service

ARPU .... Average Revenue per User

AWG .... American Wire Gauge

BHOL................ Busy Hour Offered Load

BPON................ Broadband Passive Optical Network

CAP .... Competitive Access Provider

Capex .... Capital Expenditures

CDMA............... Code-Division Multiple Access

CLEC .... Competitive Local Exchange Carrier

CO..................... Central Office

CPE .... Customer Premises Equipment

DOCSIS............ Data Over Cable Service Interface Specification

DSL .... Digital Subscriber Line

DSLAM............. Digital Subscriber Line Access Multiplexer

EBITDA............ Earnings Before Interest, Taxes, Depreciation and Amortization

EPON................ Ethernet Passive Optical Network

EV-DO .... Evolution-Data Optimized

FTTN................ Fiber to the Node or Fiber to the Neighborhood

FTTP................. Fiber-to-the-Premise

FW..................... Fixed Wireless

Gbps .... Gigabits per second

GHz .... Gigahertz (1 billion Hertz)

GPON................ Gigabit Passive Optical Network

GSM .... Global System for Mobile communication

HFC................... Hybrid Fiber Coaxial

HFM.................. Hybrid Fiber Microwave

HSDPA .... High Speed Downlink Packet Access

HSUPA .... High Speed Uplink Packet Access

HSPA................. High Speed Packet Access

HU .... Housing Units

Hz .... Hertz

iDEN .... Integrated Digital Enhanced Network

ISP..................... Internet Service Provider

kft .... Kilo-feet (1,000 feet)

ILEC .... Incumbent Local Exchange Carrier

IXC .... Interexchange Carrier

kbps .... Kilobits per second

kHz .... Kilohertz (1 thousand Hertz)

LATA................. Local Access and Transport Area

LTE.................... Long-Term Evolution

Mbps .... Megabits per second (1 million bits per second)

MHz .... Megahertz (1 million Hertz)

MIMO............... Multiple Input, Multiple Output

MSC .... Mobile Switching Center

MSO .... Multiple System Operator

NBP................... National Broadband Plan

NIU .... Network Interface Unit

NPV................... Net Present Value

OECD................ Organization for Economic Co-operation and Development

Opex.................. Operating Expenses

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OTT .... Over-the-top

POP .... Point of Presence

PON................... Passive Optical Network

POTS................ Plain Old Telephone Service

PSTN................ Public Switched Telephone Network

PV .... Present Value

QAM.................. Quadrature Amplitude Modulation

QOS................... Quality of Service

RBOC................ Regional Bell Operation Company

RFoG................. Radio Frequency Over Glass

RT .... Regional Tandem

SG&A .... Selling, General and Administrative expenses

SINR .... Signal to Interference plus Noise Ratio

TDMA............... Time Division Multiple Access

UMTS .... Universal Mobile Telecommunications System

VDSL................. Very high bit rate Digital Subscriber Line

VOIP .... Voice Over Internet Protocol

WCDMA........... Wideband Code Division Multiple Access

WISP................. Wireless ISP

GLOSSARY

4G—Abbreviation for fourth-generation wireless, the stage of broadband mobile communications that will supersede the third generation (3G). Specifies a mobile broadband standard offering both mobility and very high bandwidth. Usually refers to LTE and WiMax technology. For the purposes of analysis in this paper, areas where carriers have announced plans to deliver 4G service are treated as 4G areas; all other areas are treated as non-4G areas.

Access Network—Combination of Last and Second Mile portions of a broadband network. See Last Mile and Second Mile.

Actual Speed—Refers to the data throughput delivered between the network interface unit (NIU) located at the end-user's premises and the service provider Internet gateway that is the shortest administrative distance from that NIU. In the future, the technical definition of "actual speed" should be crafted by the FCC, with input from consumer groups, industry and other technical experts, as is proposed in Chapter 4 of the National Broadband Plan. The technical definition should include precisely defined metrics to promote clarity and shared understanding among stakeholders. For example, "actual download speeds of at least 4 Mbps" may require certain achievable download speeds over a given time period. Acceptable quality of service should be defined by the FCC.

Advanced Mobile Phone Service (AMPS)—A standard system for analog signal cellular telephone service in the United States and elsewhere. It is based on the initial electromagnetic radiation spectrum allocation for cellular service by the FCC in 1970 and first introduced by AT&T in 1983.

American Wire Gauge (AWG)—A U.S. measurement standard of the diameter of non-ferrous wire, which includes copper and aluminum—the smaller the number, the thicker the wire. In general, the thicker the wire, the greater the current-carrying capacity and the longer the distance it can span.

Analog reclamation—In a cable system, refers to repurposing spectrum previously used to carry analog channels for other uses, either digital channels or high-speed data.

Asymmetric Digital Subscriber Line (ADSL)—A technology that transmits a data signal over twisted-pair copper, often over facilities deployed originally to provide voice telephony. Downstream rates are higher than upstream rates—i.e., are asymmetric. ADSL technology enables data transmission over existing copper wiring at data rates several hundred times faster than analog modems using an ANSI standard.

Average Revenue Per User (ARPU)—A metric used by investors and financial analysts to measure the financial performance of telecommunications service providers. ARPU is the average amount of revenue a company collects from each user per month.

Availability Gap—See Broadband Availability Gap and Investment Gap.

Base Case—The basic set of assumptions that leads to the $23.5 billion Investment Gap. The base case in the model compares the most economical technologies: 12,000-foot-loop DSL and Fixed Wireless. For the 12k-foot-loop DSL, the main assumption is that there is one competing provider in areas that are assumed to receive 4G service, and zero competing technologies in non-4G areas. For Fixed Wireless, costs are allocated to mobile infrastructure in 4G areas; in non-4G areas, all costs are allocated to fixed service, but the carrier is assumed to earn incremental revenue from mobile operations.

Broadband—For the purposes of determining the Investment Gap, 4 Mbps actual download and 1 Mbps actual upload; see also the National Broadband Availability Target.

Broadband Availability Gap—The amount of funding necessary to upgrade or extend existing infrastructure up to the level necessary to support the National Broadband Availability Target. Because this is a financial metric, and to avoid confusion with measures of whether local networks are capable of supporting a given level of broadband service, the Broadband Availability Gap is referred to as the *Investment Gap* throughout this paper.

Broadband Passive Optical Network (BPON)—A type of PON standardized by the ITU-T, offering downstream capacities of up to 622 Mbps and upstream capacities of up to 155 Mbps, shared among a limited number of end users.

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[1] The authors provide this glossary as a reader aid. These definitions do not necessarily represent the views of the FCC or the United States Government on past, present or future technology, policy or law and thus have no interpretive or precedential value.

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Brownfield—A network in which a carrier already has infra-structure in the area that can be used to deliver service going forward.

Burst Rate—The maximum rate or "speed" which a network is capable of delivering within a short timeframe, typically seconds or minutes. This is usually expressed as a rate in Mbps.

Busy Hour Offered Load (BHOL)—BHOL (per subscriber) is the network capacity required by each user, averaged across all subscribers on the network, during the peak utilization hours of the network. Network capacity required is the data received/transmitted by a subscriber during an hour; this can be expressed as a data rate (like kbps) when the volume of data received/transmitted is divided by the time duration.

Capacity—Ability of telecommunications infrastructure to carry information. The measurement unit depends on the facility. A data line's capacity might be measured in bits per second, while the capacity of a piece of equipment might be measured in numbers of ports.

Capital Expenditures (Capex)—Business expense to acquire or upgrade physical assets such as buildings, machinery and in this case telecommunications equipment; also called capital spending or capital expense.

Census Block—The smallest level of geography designated by the U.S. Census Bureau, which may approximate actual city street blocks in urban areas. In rural districts, census blocks may span larger geographical areas to cover a more dispersed population.

Central Office (CO)—A telephone company facility in a locality to which subscriber home and business lines are connected on what is called a local loop. The central office has switching equipment that can switch calls locally or to long-distance carrier phone offices. In other countries, the term *public exchange* is often used.

Churn—The number of subscribers who leave a service provider over a given period of time, usually expressed as a percentage of total customers.

Code-Division Multiple Access (CDMA)—Any of several protocols used in so-called second-generation (2G) and third-generation (3G) wireless communications. As the term implies, CDMA is a form of multiplexing, which allows numerous signals to occupy a single transmission channel, optimizing the use of available bandwidth. The technology is used in ultra-high-frequency (UHF) cellular telephone systems in the 800-MHz and 1.9-GHz bands.

Competitive Access Provider (CAP)—Facilities-based competitive local exchange carriers (CLECs).

Competitive Local Exchange Carrier (CLEC)—The term and concept coined by the Telecommunications Act of 1996 for any new local phone company that was formed to compete with the ILEC (Incumbent Local Exchange Carrier).

Coverage—In wireless communications, refers to the geographic area in which one can obtain service.

Customer Premises Equipment (CPE)—Equipment which resides on the customer's premise. Examples include set top boxes, cable modems, wireless routers, optical network terminals, integrated access devices, etc.

Data Over Cable Service Interface Specification (DOCSIS)—A cable modem standard from the CableLabs research consortium (www.cablelabs.com), which provides equipment certification for interoperability. DOCSIS supports IP traffic (Internet traffic) over digital cable TV channels, and most cable modems are DOCSIS compliant. Some cable companies are currently deploying third-generation (DOCSIS 3.0) equipment. Originally formed by four major cable operators and managed by Multimedia Cable Network System, the project was later turned over to CableLabs.

Digital signal 1 (DS-1)—Also known as T1; a T-carrier signaling scheme devised by Bell Labs. DS-1 is a widely used standard in telecommunications in North America and Japan to transmit voice and data between devices. DS-1 is the logical bit pattern used over a physical T1 line; however, the terms DS-1 and T1 are often used interchangeably. Carries approximately 1.544 Mbps.

Digital Subscriber Line (DSL)—A generic name for a group of enhanced speed digital services generally provided by telephone service providers. DSL services run on twisted-pair copper wires, which can carry both voice and data signals.

Digital Subscriber Line Access Multiplexer (DSLAM)— Technology that concentrates or aggregates traffic in DSL networks. Located in the central office or in a remote terminal.

Discount Rate—The annual percentage rate used to determine the current value of future cash flows.

Earnings Before Interest, Taxes, Depreciation and Amortization (EBITDA)—An approximate measure of a company's operating cash flow based on data from the company's income statement. Calculated by looking at earnings, which are calculated by subtracting opex and SG&A from net revenues, before the deduction of interest expenses, taxes, depreciation and amortization. This earnings measure is of particular interest in cases where companies have large amounts of fixed assets which are subject to large depreciation.

Ethernet Passive Optical Network (EPON)—A type of PON standardized by the IEEE, offering downstream capacities of up to 1.25 Gbps and upstream capacities of up to 1.25 Gbps, shared among a limited number of end users.

Evolution-Data Optimized (EV-DO)—A 3G wireless radio broadband data standard that enables faster speeds than are available in existing CDMA networks or other 2G services, such as GPRS or EDGE.

Fast Ethernet (Fast-E)—A network transmission standard that provides a data rate of 100 Mbps.

Fiber—Shorthand for "fiber-optic cable." Fiber-optic cable is the medium associated with the transmission of information as light impulses along a strand of glass.

Fiber to the Node (FTTN)—A high-capacity bandwidth approach that uses both fiber and copper wires. Optical fiber is used from the core of the telco or CATV network to an intelligent node in the neighborhood where copper wire is used for the connection to the end-user, with one node serving perhaps many residences or small businesses. The few 100 meters or so of the local loop from the node to the premises generally is either unshielded twisted pair (UTP) in a telco application or coaxial cable (coax) in an HFC application, although some form of wireless technology is also possible. Known as Fiber to the Neighborhood, or Fiber to the Cabinet (FTTCab), as well.

Fiber-to-the-Premise (FTTP)—A fiber-deployment architecture in which optical fiber extends all the way to the customer's premise. Also known as Fiber to the Home (FTTH) or Fiber to the Building (FTTB). Typically using PON for residential deployments.

Fisher-Pry Model—A mathematical model used to forecast technology adoption when substitution is driven by superior technology where the new product or service presents some technological advantage over the old one.

Fixed Wireless (FW)—Wireless service that uses fixed CPE in addition to (or, possibly, even instead of) mobile portable devices to deliver data services. FW solutions have been deployed as a substitute for wired access technologies. For example, it is being used commercially in the U.S. by Clearwire with WiMAX and Stelera with HSPA, and globally by Telstra with HSPA.

Gabriel Network Topology—An approach to modeling efficient (shortest-route) connections between known network nodes, where the links are determined by making a pairwise comparison of points in the context of the points around them. In a classic Gabriel network, the set of points should not include any co-incident points, that is two points that lie exactly at the same location.

Gigabit Ethernet (Gig-E)—A network transmission standard that provides a data rate of 1,000 megabits per second.

Gigabit Passive Optical Network (GPON)—A type of PON standardized by the ITU-T, offering downstream capacities of up to 2.5 Gbps and upstream capacities of up to 1.25 Gbps, shared among a limited number of end users.

Global System for Mobile communication (GSM)—A second-generation digital mobile cellular technology using a combination of frequency division multiple access (FDMA) and time division multiple access (TDMA). GSM operates in several frequency bands: 400MHz, 900MHz and 1800MHz. On the TDMA side, there are eight timeslots or channels carrying calls, which operate on the same frequency. The standard was jointly developed between European administrations under Groupe Speciale Mobile in the 1980s and introduced commercially in 1991. Unlike other cellular systems, GSM provides a high degree of security by using subscriber identity module (SIM) cards and GSM encryption.

Gompertz Model—A mathematical model used to forecast technology adoption when substitution is driven by superior technology, but purchase depends on consumer choice.

Greenfield—A network in which a carrier has no infrastructure currently (of that technology), and it needs to be built from scratch.

High Speed Packet Access (HSPA)—A family of high-speed 3G digital data services provided by cellular carriers worldwide that uses the GSM technology. HSPA service works with HSPA cell phones as well as laptops and portable devices with HSPA modems. The two established standards of HSPA are HSDPA (Downlink) and HSUPA (Uplink).

Housing Units (HU)—Includes a house, an apartment, a mobile home, a group of rooms or a single room that is occupied (or if vacant, is intended for occupancy) as separate living quarters.

Hybrid Fiber Microwave (HFM)—A network (usually wireless) whereby the backhaul transport elements of the network are a mixture or combination of fiber-optic facilities and wireless microwave transport.

Hybrid Fiber Coaxial (HFC)—Another term for cable systems, which are a combination of fiber (Middle and Second Mile) and coaxial cable (Last Mile).

Incumbent Local Exchange Carrier (ILEC)—The dominant local phone carrier within a geographical area. Section 252 of the Telecommunications Act of 1996 defines Incumbent Local Exchange Carrier as a carrier that, as of the date of enactment of the Act, provided local exchange service to a specific area; for example, Verizon, Windstream and Frontier. In contrast, Competitive Access Providers (CAPs) and competitive local exchange carriers (CLECs) are companies that compete against the ILECs in local service areas.

Integrated Digital Enhanced Network (iDEN)—A wireless technology from Motorola combining the capabilities of a digital cellular telephone, two-way radio, alphanumeric pager and data/fax modem in a single network. iDEN operates in the 800 MHz, 900MHz and 1.5 GHz bands and is based on time division multiple access (TDMA) and GSM architecture. It uses Motorola's Vector Sum Excited Linear Predictors (VSELP) voice encoder for voice compression and QAM modulation to deliver 64 kbps over a 25 KHz channel.

Interexchange Carrier (IXC)—A telecommunications service provider authorized by the FCC to provide interstate, long distance communications services and authorized by the state to provide long distance intrastate communications services. An Interexchange Carrier provides, directly or indirectly, interLATA or intraLATA telephone toll services. May be an individual, partnership, association, joint-stock company, trust, governmental entity or corporation engaged for hire in interstate or foreign communication by wire or radio, and between two or more exchanges. Also known as an Interexchange Common Carrier.

Internet Service Provider (ISP)—A company that provides a connection to the public Internet, often owning and operating the Last-Mile connection to end-user locations.

Investment Gap—The amount of funding necessary to upgrade or extend existing infrastructure up to the level necessary to support the National Broadband Availability Target, which is referred to in the National Broadband Plan as the Broadband Availability Gap.

Last Mile—Refers generally to the transport and transmission of data communications from the demarcation point between the end user's internal network and the carrier's network at the customer premise to the first point of aggregation in the carrier's network (such as a remote terminal, wireless tower location, or HFC node).

Levelized–A method, often used in regulatory proceedings, to calculate the annuitized equivalent—i.e., the effective annual value of cash flows—of the costs and revenues associated with building and operating a network. A "levelized" calculation provides a steady cash-flow stream, rather than trying to model or guess the timing of largely unpredictable yet sizable real-world payouts like those for upgrading and repairing equipment. The (net) present value of a levelized cash flow is equal to the (net) present value of actual cash flows.

Link Budget—A calculation involving the gain and loss factors associated with the antennas, transmitters, transmission lines and propagation environment used to determine the maximum distance at which a transmitter and receiver can successfully operate.

Local Access and Transport Area (LATA)—One of 196 local geographical areas in the U.S. created by the Modified Final Judgment in which a divested Regional Bell operating company (RBOC) was permitted to offer exchange telecommunications and exchange access services.

Long-Term Evolution (LTE)—A high performance air interface for cellular mobile communication systems. LTE technology increases the capacity and speed of wireless networks relative to current 3G deployments.

Microwave—Microwave transmission refers to the technique of transmitting information over microwave frequencies, using various integrated wireless technologies. Microwaves are short-wavelength, high-frequency signals that occupy the electromagnetic spectrum 1 GHz to roughly 300 GHz, (typically within ITU Radio Band Signal EHF) though definitions vary. This is above the radio frequency range and below the infrared range.

Middle Mile—Refers generally to the transport and transmission of data communications from the central office, cable headend or wireless switching station to an Internet point of presence.

Mobile Switching Center (MSC)—The mobile switching center (MSC) connects the landline public switched telephone network (PSTN) system to the wireless communication system. The mobile switching center is typically split into a mobile switching center server and a media gateway, and incorporates the bearer independent call control (BICC). The MSC routes the communications to another subscribing wireless unit via a BSC/base station path or via the PSTN/Internet/other network to terminating destination.

Multiple Input Multiple Output (MIMO)—An antenna technology for wireless communications in which multiple antennas are used at both the source (transmitter) and the destination (receiver). The antennas at each end of the communications circuit are combined to minimize errors and optimize data speed. MIMO is one of several forms of smart antenna technology, the others being MISO (multiple input, single output) and SIMO (single input, multiple output).

Multiple System Operator (MSO)—Typically refers to a firm that owns more than one cable system, but may refer also to an operator of only one system.

National Broadband Availability Target—The level of service set in the National Broadband Plan that should be available to every household and business location in the U.S. The initial target is an actual download speed of at least 4 Mbps and an upload speed of at least 1 Mbps, with a proposed review and update every four years.

Net Present Value (NPV)—A technique used to assess the current worth of future cash flows by discounting those future cash flows at today's cost of capital. The Net Present Value (NPV) of a project is the total discounted value of all revenues and costs; NPVs greater than zero generate value for a company.

Node—An active or passive element in a cable system where Second-Mile fiber connects with coaxial cable.

Node splitting—In a cable system, adding infrastructure so that subscribers previously served by a single node are moved to multiple nodes, reducing the number of subscribers per node.

Operating Expenses (Opex)—An expense a business incurs over the course of its normal operations. Examples include product overhead, employee salaries and electric bill payments. Importantly, operating expenses on a balance sheet reflect only ordinary expenses rather than unexpected, one-time expenses. One subtracts the operating expense from operating revenue to determine the operating profit.

Organization for Economic Co-operation and Development (OECD)—The 30 member countries are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

Over-the-top (OTT)—Carried over an Internet connection. For example, OTT video would include video delivered by YouTube, Hulu and TV Everywhere.

Passive Optical Network (PON)—A type of Fiber To The Premise (FTTP) network in which unpowered optical splitters are utilized to enable a single fiber to be shared by multiple end users. There are several varieties of PON currently in use in the U.S., including BPON, EPON and GPON, each of which has its own set of standards and capabilities.

Plain Old Telephone Service (POTS)—The basic single line switched access service offered by local exchange carriers to residential and business end users, using loop-start signaling.

Point of Presence (POP)—An access point to the Internet. A point of presence is a physical location that houses servers, routers, switches and aggregation equipment.

Point to point (P2P)—A type of fiber to the premise network in which each endpoint is connected to its serving office via a dedicated fiber optic strand.

Present Value (PV)—The value today of a future payment, or stream of payments, discounted at some appropriate compound discount rate. For example, the present value of $100 to be received 10 years from now using a discount rate equal to 10% interest compounded annually is about $38.55.

Public Switched Telephone Network (PSTN)—The worldwide collection of interconnected public telephone networks that was designed primarily for voice traffic. The PSTN is a circuit-switched network, in which a dedicated circuit (also referred to as a channel) is established for the duration of a transmission, such as a telephone call. This contrasts with packet switching networks, in which messages are divided into small segments called packets and each packet is sent individually. Packet switching networks were initially designed primarily for data traffic.

Quadrature Amplitude Modulation (QAM)—A system of modulation in which data is transferred by modulating the amplitude of two separate carrier waves, mostly sinusoidal, which are out of phase by 90 degrees (sine and cosine). Due to their phase difference, they are called quadrature carriers. Used extensively in cable systems.

Quality of Service (QoS)—The ability to provide different priority to different applications, users or data flows, or to guarantee a certain level of performance to a data flow in a broadband network.

Radio Frequency over Glass (RFoG)—An evolutionary technology that allows cable companies to offer an all-fiber architecture (not hybrid-fiber coax) without changing modulation schemes. RFoG is an SCTE Interface Practices Subcomittee standard in development for Point to Multipoint (P2MP) operations that has a proposed wavelength plan compatible with data PON solutions including EPON and 10G-EPON.

Regional Bell Operation Company (RBOC)—Local exchange carriers formed after the breakup of AT&T in 1984. The seven regional holding companies (RHCs) of roughly equal size were formed as a result of the 1982 Consent Decree AT&T signed with the U.S. Department of Justice, stipulating that it would divest itself of its 22 wholly owned telephone operating companies. The seven RHCs were Ameritech, Bell Atlantic, BellSouth, NYNEX, Pacific Telesis, Southwestern Bell and US West. After a series of acquisitions, mergers and name changes (including one in which a combination of several RHCs reclaimed the original AT&T name), only three of the original seven remain. They are AT&T, Qwest and Verizon. The RBOCs are the incumbent local exchange carriers (ILECs) in their local markets.

Regional Tandem (RT)—A tandem switch is an intermediate switch or connection between an originating telephone call or location and the final destination of the call. These are hub facilities that interconnect telephone central office exchanges and are deployed by geographical region within a telco LATA or exchange.

Remote Terminal—Telephone communications equipment that is installed within the service area or "neighborhood" that traditionally aggregates and multiplexes telephone local loops and transmits the aggregated signals from the service area back to the telephone central office switch. This has evolved to become the "Node" within a service area in a fiber-to-the-node architecture.

Second Mile—Refers generally to the transport and transmission of data communications from the first point of aggregation (such as a remote terminal, wireless tower location, or HFC node) to the point of connection with the Middle Mile transport.

Selling, General and Administrative expenses (SG&A)—Corporate overhead costs, including expenses such as marketing, advertising, salaries and rent. SG&A is found on a corporate income statement as a deduction from revenues in calculating operating income.

Signal to Interference plus Noise Ratio (SINR)—For a wireless communications device, the ratio of the received strength of the desired signal to the received strength of undesired signals (noise and interference).

Spectrum Allocation—The amount of spectrum dedicated (or allocated) to a specific use; in wireless, spectrum allocation is typically made in paired bands, with one band for upstream and the other for downstream.

Spectrum Band—The frequency of the carrier wave in wireless communications. Radios can transmit on different frequencies in the same area at the same time without interfering; frequency marks the division of different parts of spectrum for different uses. Frequency is measured in Hertz (Hz); the range of frequency typically used for radio communications is between 10,000 (10 kHZ) and 30,000,000,000 Hz (30 GHz). Different frequencies have different natural properties: Lower frequencies travel farther and penetrate solids better, while higher frequencies can carry more information (faster data rates, etc.) The best balance of these properties for the purpose of cell phones is in the range of roughly 700-2,500 MHz. A specific range of frequencies allocated for a specific purpose is called a "band."

Switched Digital Video (SDV)—A network scheme for distributing digital video via a cable more efficiently to free up bandwidth for other uses. Only channels being watched by end-users in a given node are transmitted to that node.

Take rate—The ratio of the number of premises that elect to take a service divided by the total number of premises in a market area; effectively a penetration rate of homes passed.

Time Division Multiple Access (TDMA)—Technology used in digital cellular telephone communication that divides each cellular channel into three time slots in order to increase the amount of data that can be carried. TDMA is used by Digital-American Mobile Phone Service (D-AMPS), Global System for Mobile communications (GSM), and Personal Digital Cellular (PDC). Each of these systems implements TDMA in somewhat different and potentially incompatible ways. An alternative multiplexing scheme to FDMA with TDMA is CDMA (code division multiple access), which takes the entire allocated frequency range for a given service and multiplexes information for all users across the spectrum range at the same time.

Universal Mobile Telecommunications System (UMTS)—Third-generation (3G) broadband, packet-based transmission of text, digitized voice, video and multimedia at data rates up to and possibly higher than 2 Mbps, offering a consistent set of services to mobile computer and phone users. Based on the Global System for Mobile (GSM) communication standard.

Unserved—Those housing units without access to a broadband network capable of offering service that meets the National Broadband Availability Target.

Very high bit rate Digital Subscriber Line (VDSL)—A form of DSL similar to ADSL but providing higher speeds at shorter loop lengths.

Voice Over Internet Protocol (VOIP)—A family of transmission technologies for delivery of voice communications over IP networks such as the Internet or other packet-switched networks. Other terms frequently encountered and synonymous with VoIP are *IP telephony*, *Internet telephony*, *voice over broadband* (VoBB), *broadband telephony* and *broadband phone*.

Wideband Code Division Multiple Access (WCDMA)—Another name for UMTS. Also see Universal Mobile Telecommunications System.

Wireless ISP (WISP)—An Internet service provider that provides fixed or mobile wireless services to its customers. Using Wi-Fi or proprietary wireless methods, WISPs provide last mile access, often in rural areas and areas in and around smaller cities and towns. The largest provider of wireless broadband in the U.S. is currently Clearwire Corporation, a WISP that uses an early version of WiMAX to deliver the Internet to customers in the U.S., Ireland, Belgium and Denmark (see WiMAX).

WiMax—Worldwide Interoperability for Microwave Access (WiMAX) is a telecommunications technology that uses radio spectrum to transmit bandwidth between digital devices. Similar to WiFi, WiMAX brings with it the ability to transmit over far greater distances and to handle much more data.

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EXHIBIT 5

Local Telephone Competition:
Status as of December 31, 2009

Industry Analysis and Technology Division
Wireline Competition Bureau
January 2011

Contents

TEXT

FIGURES

TABLES

CHARTS

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Local Telephone Competition: Status as of December 31, 2009

Introduction. This is the third of our reports about local telephone service in the United States that includes comprehensive information about subscribership to interconnected Voice over Internet Protocol ("interconnected VoIP") service as well as comprehensive information about the more traditional telephone service lines.[1,2] The report summarizes data collected by FCC Form 477 as of December 31, 2009.

We include certain ZIP Code-based information in the report.[3] At present, there is no Form 477 requirement to report any telephone service information at the census tract level of detail.[4] We also update summary statistics for the mobile telephony subscribership information collected by Form 477.[5]

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[1] The first such comprehensive report, which was released in June 2010, is available at http://www.fcc.gov/wcb/iatd/comp.html. It contains more extensive citations for the Commission's adoption, in 2008, of improvements to the FCC Form 477 data collection program, which made reporting mandatory for providers of retail interconnected VoIP services as well as for local exchange carriers and facilities-based providers of mobile telephony service. Qualifying entities file FCC Form 477 each year on March 1 (reporting data for the preceding December 31) and September 1 (reporting data for June 30 of the same year). The first data collected on Form 477 were for December 31, 1999. Effective with the filing of data as of December 31, 2008, Form 477 is a Web-based electronic filing system. Information about the filing system and the Form 477 program generally is available at http://www.fcc.gov/form477/.

[2] The FCC's rules (at 47 C.F.R. § 9.3) state:
An interconnected Voice over Internet Protocol (VoIP) service is a service that:
  (1) Enables real-time, two-way voice communications;
  (2) Requires a broadband connection from the user's location;
  (3) Requires Internet protocol-compatible customer premises equipment (CPE); and
  (4) Permits users generally to receive calls that originate on the public switched telephone network and to terminate calls to the public switched telephone network.

We note that the current interpretation of element (4) of the definition excludes the VoIP services that Skype offers in the United States, and subscribers to those services are not reported on Form 477. Prior to the December 2008 data, companies such as Vonage that solely provide interconnected VoIP service did not file Form 477. Telephone companies and cable companies that provided local exchange telephone service were required to file Form 477 but were not required to report interconnected VoIP subscriptions. However, some of these companies chose to include interconnected VoIP subscriptions in the number of retail (end-user) switched access lines that they reported.

[3] Wireline service providers report whether they have at least one residential or business customer in each ZIP Code, using either switched access or interconnected VoIP. Because providers may not offer service across an entire ZIP Code and because different providers may target different customer segments in areas where they provide service, we cannot conclude that the number of providers identified as delivering wireline service within a ZIP Code represents the number of options available to any specific customer within that ZIP Code. We further note that these data on the number of providers in a ZIP Code do not indicate whether a particular provider is offering service solely over its own last-mile facilities or is using the facilities of another carrier or entity.

[4] This contrasts with the census tract-based broadband reporting requirements the Commission adopted in 2008, at which time the Commission sought comment about requiring local exchange carriers and interconnected VoIP service providers to report the number of voice telephone service connections, and the percentage of these that are residential, at the 5-digit ZIP Code or census tract level of detail. *See Development of Nationwide Broadband Data to Evaluate Reasonable and Timely Deployment of Advanced Services to All Americans, Improvement of Wireless Broadband Subscribership Data, and Development of Data on Interconnected Voice over Internet Protocol (VoIP) Subscribership*, WC Docket No. 07-38, Further Notice of Proposed Rulemaking, 23 FCC Rcd 9691 (2008) at 9708, para. 33.

Explanation of terminology used in this report.

- We use "Non-ILEC" to refer to any service provider who does not have incumbent local exchange carrier (ILEC) regulatory status, including, for example, competitive local exchange carriers (CLECs), including both those who provide service over their own facilities and those who employ ILEC facilities or services, cable companies without CLEC regulatory status who provide interconnected VoIP service, and over-the-top (OTT) interconnected VoIP providers who neither own nor operate telecommunications facilities.
- All "VoIP subscriptions" discussed in this report are interconnected VoIP subscriptions.
- When referring specifically to ILECs, we use the term "total lines" to mean the sum of ILEC-reported retail (end-user) switched access lines, ILEC interconnected VoIP subscriptions, and ILEC wholesale switched access lines and unbundled network elements (UNEs) provided to CLECs.
- We specify "RBOC" and "Other ILEC" when we wish to distinguish between information reported by the Regional Bell Operating Companies (that is, AT&T, Qwest, and Verizon) operating in their respective ILEC service areas and information reported by all other ILECs as a group.

Data interpretation.

- Lines from CLECs who have ILEC affiliates are handled at the state level in one of several ways. We place the lines into the non-ILEC category if the affiliate is an ILEC other than AT&T or Verizon. Lines from CLEC affiliates of AT&T and Verizon are allocated between the ILEC and non-ILEC categories based on staff estimates if the CLEC operates in the AT&T or Verizon ILEC service area in the state, respectively.
- When counting service providers who have any retail customers in a particular geography (for example, a state or a ZIP Code), we count a holding company or common-control entity no more than once in any specified sub-category of total providers.
- Nationwide counts of providers are unique counts for any specified sub-category of total providers (for example, all non-ILECs or all interconnected VoIP providers); an entity operating in multiple states is counted only once.

Wireline retail local telephone service. Retail local telephone service customers are served by two wireline technologies – "end-user" switched access lines and interconnected VoIP "subscriptions." The Form 477 program counts lines and subscriptions as the maximum number of voice calls that can be active at one time from the retail customer's location (for example, a business customer's premises) under the service plan that the end user has purchased from a local exchange carrier or interconnected VoIP service retailer.[6]

(Continued from previous page)

[5] The presentation of mobile wireless telephone subscriber counts in this report does not constitute, or imply, Commission analysis of the extent to which wireline and mobile wireless telephone services are demand substitutes or complements in general or in any particular situation. In the Form 477 program, commercial mobile radio service (CMRS) carriers who own or operate wireless networks report both their retail telephone service customers and the retail customers of mobile wireless telephone service resellers.

[6] Form 477 data may not count all VoIP phone connections to Internet Protocol Private Branch Exchange (IP PBX) equipment that is owned by business end users because of the variety of ways the IP PBX may connect to the public switched telephone network.

- In December 2009, there were 127 million end-user switched access lines in service and 26 million interconnected VoIP subscriptions in the United States, or 153 million wireline retail local telephone service connections in total. See Figure 1.

- Between December 2008 and December 2009 – the first full year of mandatory interconnected VoIP reporting – interconnected VoIP subscriptions increased by 22% (from 21 million to 26 million) and retail switched access lines decreased by 10% (from 141 million to 127 million). The combined effect was an annual decrease of 6% in wireline retail local telephone service connections (from 162 million to 153 million). See Figure 1.

Figure 1
Interconnected VoIP Subscriptions and Retail Switched Access Lines, 2008 - 2009
(In Thousands)

	Dec 2008	Jun 2009	Dec 2009
■ Interconnected VoIP Subscriptions	21,274	23,462	25,981
□ Retail Switched Access Lines	140,996	133,262	127,136
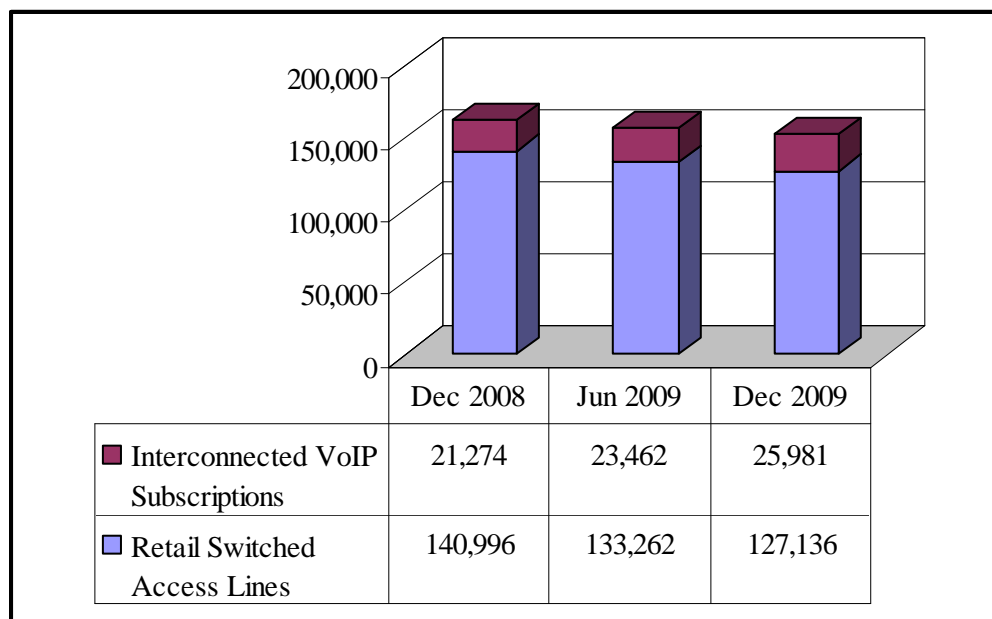
- Of the 153 million wireline retail local telephone service connections in December 2009, 91 million (or 59%) were residential connections and 62 million (or 41%) were business connections. See Figure 2.

- Cross-classified by technology and customer type, the 153 million wireline retail local telephone service connections in December 2009 were: 45% residential switched access lines, 38% business switched access lines, 15% residential interconnected VoIP subscriptions, and 2% business interconnected VoIP subscriptions. See Figure 2.

Figure 2
Wireline Retail Local Telephone Service Connections by Technology and
Customer Type as of December 31, 2009 (In Thousands)

	Switched Access Lines	Interconnected VoIP	Total
Residential	68,646	22,407	91,052
Business	58,490	3,574	62,064
Total	127,136	25,981	153,117

Figures may not add to totals due to rounding.
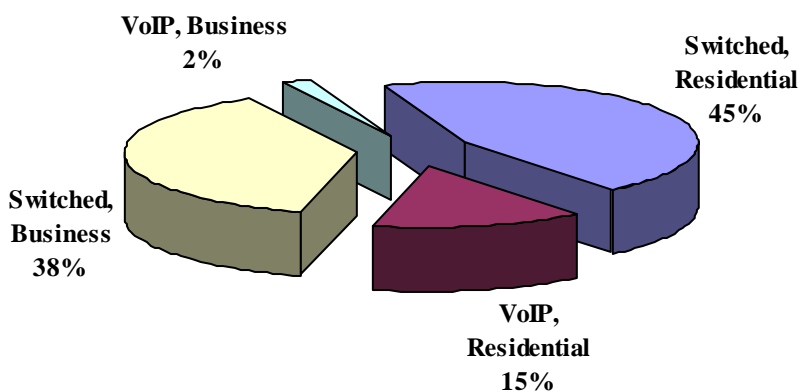
Service providers. The retailers of wireline local telephone service include a variety of entities that are subject to different federal communications regulation. The Form 477 program – and this report – distinguishes ILEC operations from all other operations. Generally, ILEC operations are more closely regulated than non-ILEC operations because they operated as local monopolies for many years. After the Telecommunications Act of 1996 became law, some ILECs established CLEC affiliates (usually within a holding company or common-control structure) that compete against other ILECs. Also, some ILECs have acquired CLECs. In particular, RBOCs AT&T and Verizon have acquired major CLECs that operated within their ILEC service areas and elsewhere.[7] With this overview as background, we report:

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[7] Qwest is the third of the three surviving RBOCs.

- Cross-classified by customer type (residential or business) and the service retailer's regulatory status (ILEC or non-ILEC), the 153 million wireline retail local telephone service connections (including both switched access lines and interconnected VoIP subscriptions) in December 2009 were: 42% ILEC residential service, 28% ILEC business service, 17% non-ILEC residential service, and 13% non-ILEC business service. See Figure 3.

Figure 3
Wireline Retail Local Telephone Service Connections by Customer Type and Regulatory Status as of December 31, 2009 (In Thousands)

	Residential	Business	Total
ILEC	64,615	42,803	107,418
Non-ILEC	26,438	19,261	45,698
Total	91,052	62,064	153,117

Figures may not add to totals due to rounding.
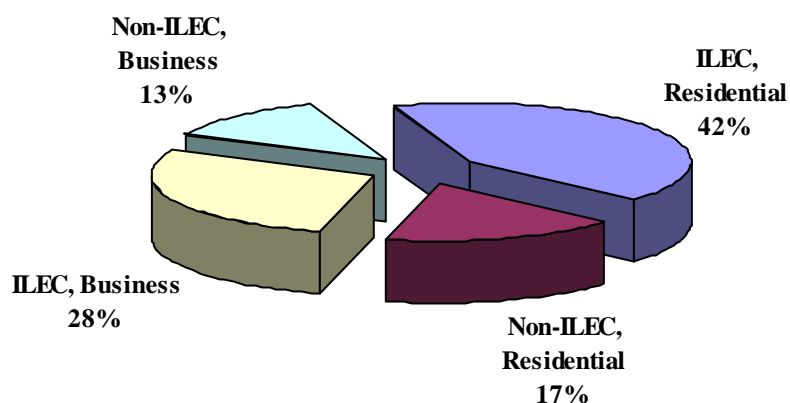
- Additionally cross-classified by technology, the 91 million wireline residential connections in December 2009 were: 69.9% ILEC switched access lines, 23.5% non-ILEC interconnected VoIP subscriptions, 5.5% non-ILEC switched access lines, and 1.1% ILEC interconnected VoIP subscriptions. Similarly, the 62 million wireline business connections were: 68.0% ILEC switched access lines, 26.3% non-ILEC switched access lines, 4.8% non-ILEC interconnected VoIP subscriptions, and 1.0% ILEC interconnected VoIP subscriptions. See Figure 4.

Figure 4
Wireline Retail Local Telephone Service Connections by Technology, Regulatory Status, and Customer Type as of December 31, 2009 (In Thousands)

Total	Switched Access Lines	Interconnected VoIP	Total
ILEC	105,826	1,592	107,418
Non-ILEC	21,310	24,389	45,698
Total	127,136	25,981	153,117
Residential			
ILEC	63,632	983	64,615
Non-ILEC	5,013	21,424	26,438
Residential Total	68,646	22,407	91,053
Business			
ILEC	42,194	610	42,803
Non-ILEC	16,297	2,964	19,261
Business Total	58,490	3,574	62,064

Figures may not add to totals due to rounding.

Residential

ILEC, Switched 69.9%
Non-ILEC, VoIP 23.5%
Non-ILEC, Switched 5.5%
ILEC, VoIP 1.1%

Business

ILEC, Switched 68.0%
Non-ILEC, VoIP 4.8%
Non-ILEC, Switched 26.3%
ILEC, VoIP 1.0%
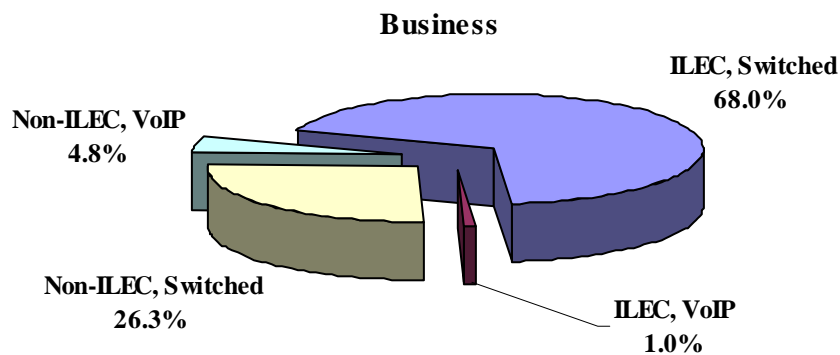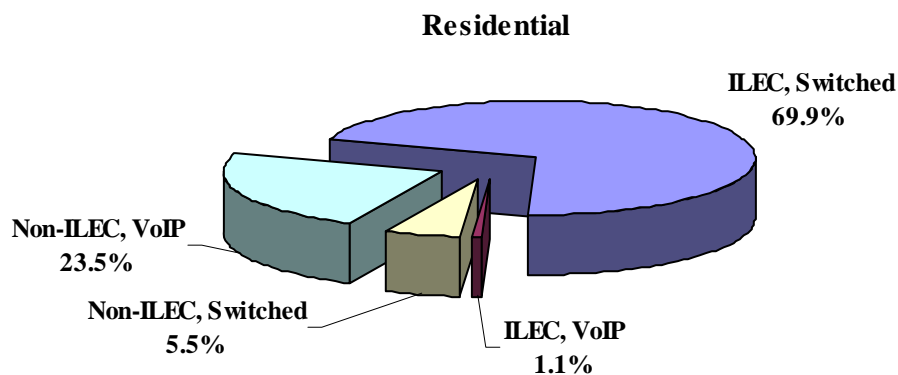
Interconnected VoIP service. Form 477 identifies three types of information about retail interconnected VoIP service.

- First, interconnected VoIP service retailers distinguish between the interconnected VoIP subscriptions they sell to their broadband Internet access service customers ("broadband bundle" subscriptions, in this report)[8] and all the other interconnected VoIP subscriptions that they sell ("standalone" subscriptions).[9]

- Second, filers report whether or not interconnected VoIP subscriptions include, as a service feature, the capability to use the service over any broadband connection to which the customer has access, for example, at a hotel or vacation residence ("nomadic" functionality).

- Third, filers identify the different broadband technologies (for example, cable modem Internet access service) in the broadband bundle.

The Form 477 data cross-classify the first two of these three sets of information. See Figure 5.

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[8] We note that the interconnected VoIP service "broadband bundles" reported on Form 477 do not need to be sold together for a single price, although they may be. The interconnected VoIP service and Internet access service could be marketed and billed by separate retailers, who are affiliated. The retailer of the Internet access service could either own the connection that delivers the service or be reselling Internet access service.

[9] The "standalone" service might be OTT interconnected VoIP. It also might be interconnected VoIP sold by a cable system operator as an individual service or in combination with cable TV service.

Total	Broadband Bundle	Standalone VoIP	Total
Nomadic	580	2,285	2,864
Not nomadic	21,294	1,822	23,116
Total	21,874	4,107	25,981
ILEC			
Nomadic	14	8	22
Not nomadic	1,571	#	1,571
ILEC Total	1,584	8	1,592
Non-ILEC			
Nomadic	566	2,277	2,843
Not nomadic	19,723	1,822	21,546
Non-ILEC Total	20,290	4,099	24,389

= Rounds to zero. Figures may not add to totals due to rounding.

ILEC

Bundle, Not nomadic
98.7%

Standalone, Nomadic
0.5%

Bundle, Nomadic
0.9%

Non-ILEC

Bundle, Not nomadic
80.9%

Standalone, Nomadic
9.3%

Bundle, Nomadic
2.3%

Standalone, Not nomadic
7.5%
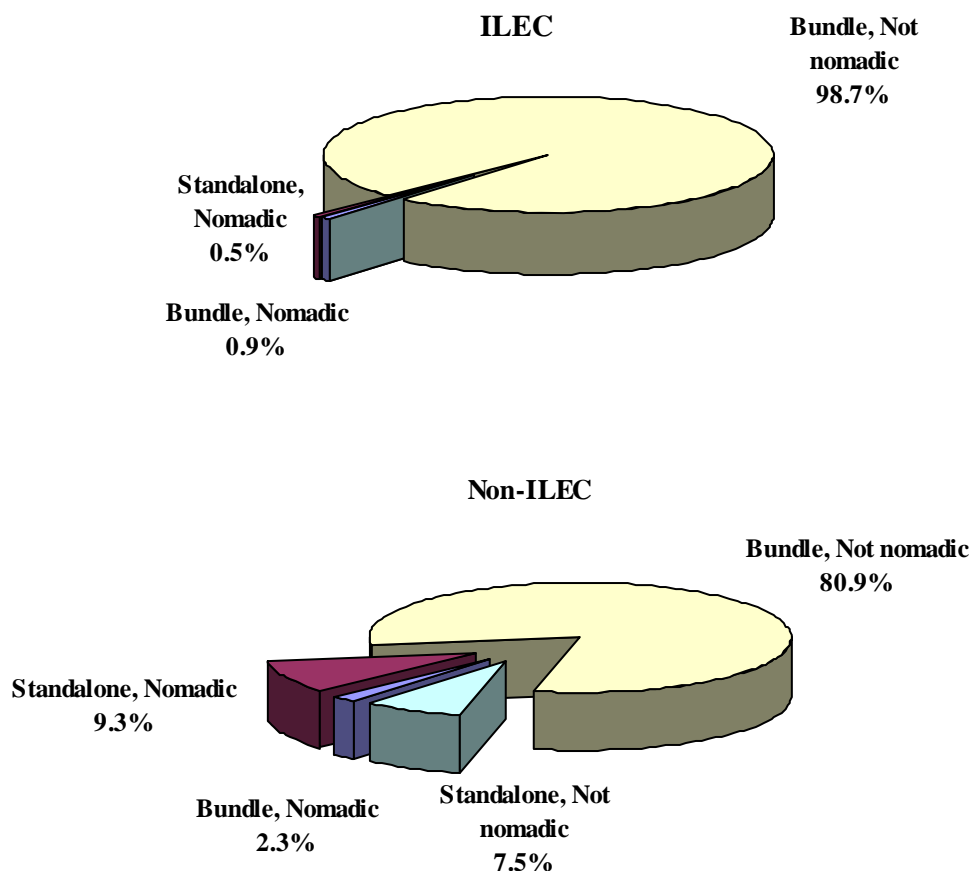
Form 477 collects the third type of information about retail interconnected VoIP service – the technology of the Internet access connection – for broadband bundles but not for standalone interconnected VoIP. See Figure 6.[10]

Figure 6
Technology of Internet Access Connections in Interconnected VoIP
Broadband Bundles as of December 31, 2009 (In Thousands)

Technology	ILEC	Non-ILEC	Total
DSL or Other Wireline	1,531	1,089	2,619
FTTP	53	160	213
Cable Modem	1	18,927	18,928
Terrestrial Fixed Wireless	#	21	21
Other	#	93	93
Total	1,584	20,290	21,874

= Rounds to zero. Figures may not add to totals due to rounding.

ILEC

DSL or Other Wireline 96.6%

Cable Modem 0.1%

FTTP 3.3%

Non-ILEC

Cable Modem 93.3%

FTTP 0.8%

DSL or Other Wireline 5.4%

Other 0.5%

Terrestrial Fixed Wireless 0.1%

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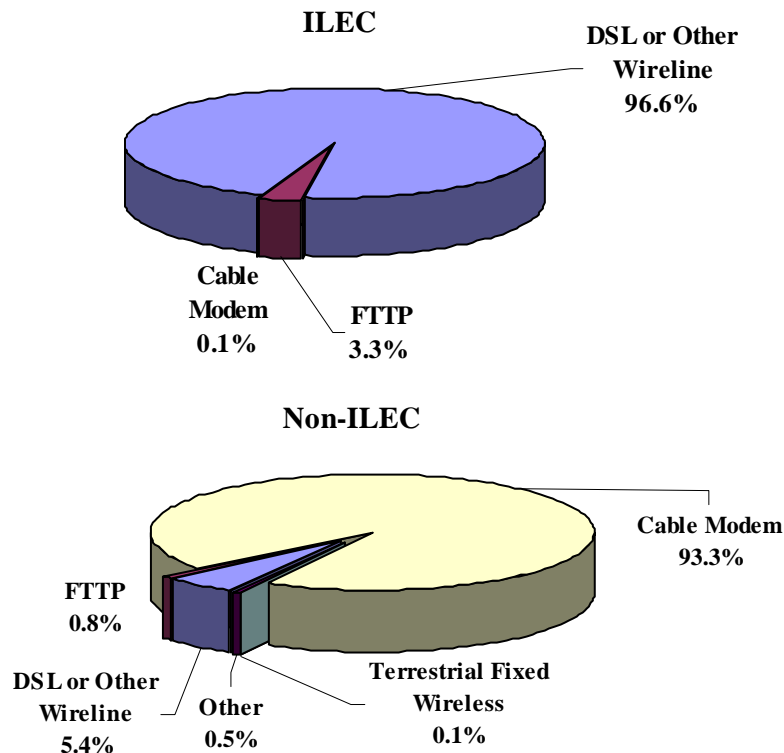
[10] "DSL" is Digital Subscriber Line technology, which typically delivers Internet access service over telephone company "local loops" (pairs of copper wires). The "Other Wireline" component of "DSL or Other Wireline" includes other ways of using telephone company local loops to deliver Internet access services, for example, over "T-1" circuits or Ethernet over copper. "FTTP" is fiber to the premises – optical fiber taken all the way to the end user. "Cable modem" is the cable TV industry's mass-market Internet access service, delivered to the end user over a coaxial cable. Terrestrial fixed wireless service makes a point-to-point connection between the service provider's antenna and an antenna installed at the end user's premises.

Switched access lines. ILECs as a group predominantly deliver retail switched access lines over copper local loops. This appears also to be the case for those non-ILECs who report retail switched access lines. See Figure 7.

Figure 7
Technology of Retail Switched Access Lines
as of December 31, 2009 (In Thousands)

Technology	ILEC	Non-ILEC	Total
FTTP	3,886	1,890	5,777
Coaxial Cable	156	2,482	2,639
Terrestrial Fixed Wireless	2	15	16
Other (copper local loop)	101,781	16,923	118,704
Total	105,826	21,310	127,136

Figures may not add to totals due to rounding.

ILEC

Other
96.2%

FTTP
3.7%

Non-ILEC

Terrestrial Fixed
Wireless
0.1%

Coaxial Cable
11.6%

FTTP
8.9%

Other
79.4%
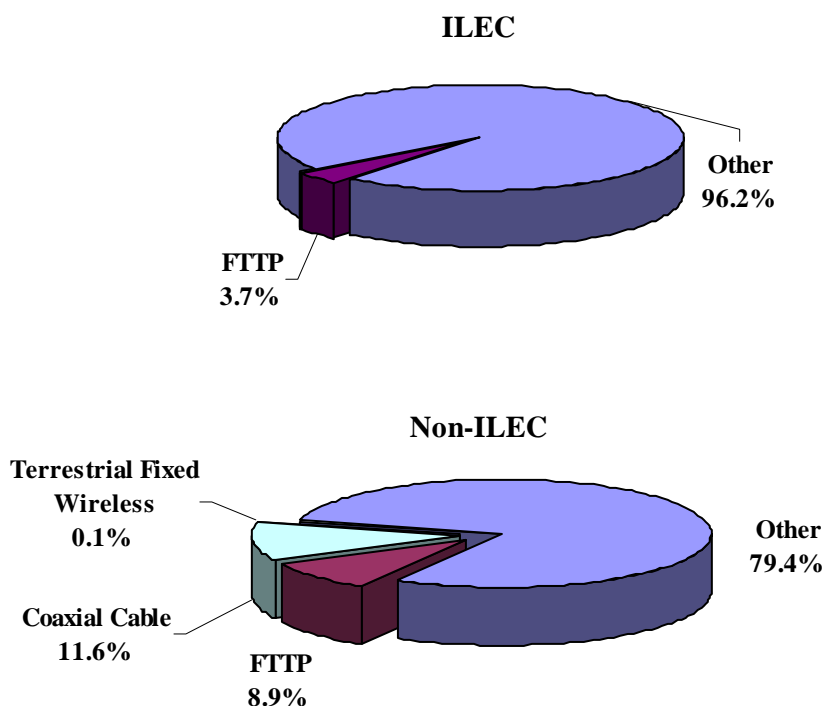
Wholesale relationships for switched access lines. ILECs typically own the communications facilities over which they provide retail services. By contrast, CLECs use a range of methods: equipping ILEC UNE loops ("UNE-L") as CLEC switched access lines,[11] reselling services (for example, reselling ILEC

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[11] CLECs (as opposed to non-ILECs more generally) have certain regulatory rights to obtain ILEC local loops at cost-based UNE rates, which the CLEC may use to provide retail switched access lines or retail broadband Internet access connections. *See* C.F.R. § 51.307.

switched access lines obtained at wholesale rates or reselling ILEC lines obtained under commercial agreements that replaced the UNE-Platform ("UNE-P")), equipping leased ILEC special access circuits as switched access lines, and equipping local loops that the CLEC owns.

- At year-end 2009, CLECs reported using several methods to provide their 21 million retail switched access lines. They reported providing 33% of lines (or about 7.1 million lines) by reselling ILEC wholesale or retail services. They reported providing 38% of lines (or about 8.2 million lines) over ILEC facilities leased at regulated, cost-based rates (that is, as unbundled network elements, or UNEs). And they provided the remaining 28% of lines (or about 6.0 million lines) over local loops that they owned. However, the information about wholesale relationships differs as reported by CLECs and by ILECs, as discussed in Figure 8.

Figure 8
Wholesale Relationships as Reported Respectively by CLECs and ILECs
as of December 31, 2009 (In Thousands)

	CLEC Retail Switched Access Lines provisioned over ILEC Services (reported by CLECs)	ILEC Wholesale Switched Access Lines and UNEs provided to CLECs (reported by ILECs)	Difference
Resold ILEC services[1]	7,101	2,993	4,108
UNE-P[2]	1,446	2,396	(949)
UNE-L[3]	6,752	3,668	3,084
Total ILEC UNEs	8,199	6,063	2,135
Total ILEC services	15,299	9,056	6,243

Figures may not add to totals due to rounding.

[1] Resold ILEC services include switched access lines made available to CLECs at wholesale rates, resold Centrex, Integrated Services Digital Network (ISDN), or other ILEC services, ILEC special access circuits channelized to provide CLEC retail switched access lines, and ILEC switched access lines provided to CLECs under commercial agreements that replaced UNE-P. (*See* note 2, below.) Filers are instructed to count the number of voice-grade channels the retail customer purchased, not the theoretical capacity of the circuit over which the service was delivered. ILECs generally do not know (and do not report) which ILEC leased special access circuits or other high-capacity circuits are being used to provide CLEC retail switched access lines (which the CLECs do report).

[2] UNE-P was the combination of ILEC loop UNE, switching UNE, and transport UNE. The Commission directed CLECs to migrate their retail customers served by UNE-P to an alternative arrangement within 12 months of the effective data of the *Triennial Review Remand Order*, that is, by March 11, 2006. *See* C.F.R. § 51.319(d)(2)(ii).

[3] ILECs report the number of UNE-L they provide to CLECs but do not convert any high-capacity UNE-L, such as DS1 UNE loops, into voice-grade equivalents. By contrast, CLECs report the number of switched access lines their retail customers purchase which the CLEC provisioned over UNE-L obtained from ILECs. Note, however, that a CLEC might use UNE-L only to provide broadband Internet access connections.

Remainder of the report. The remainder of the report consists of tables and charts that update and expand data presented in earlier reports in this series. We present national data first, followed by state-specific data and, finally, summary statistics of the presence of competitors to the incumbent wireline local telephone service providers in individual ZIP Codes.[12]

* * * *

We invite users of this information to provide suggestions for improved analysis of data presented in this report by using the attached customer response form or by e-mailing comments to IATDreports@fcc.gov for subject: December 2009 local telephone data. We encourage users of this information to provide suggestions for improved data collection by participating in any formal proceedings undertaken by the Commission to solicit comments for improvement of FCC Form 477.

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[12] In any individual ZIP Code, the competitors to ILECs may be CLECs or interconnected VoIP providers who are not affiliated with the ILEC, or ILECs, who serve end users in that ZIP Code. Appropriate interpretation of the ZIP Code-based information is discussed in n. 3, above.

Table 1
End-User Switched Access Lines and VoIP Subscriptions[1]
(In Thousands)

Date	Provided by		Total	Non-ILEC Share
	ILEC	Non-ILEC		
Dec 1999	181,203	8,194	189,397	4.3 %
Jun 2000	179,649	11,557	191,206	6.0
Dec 2000	177,561	14,871	192,432	7.7
Jun 2001	174,752	17,275	192,027	9.0
Dec 2001	171,917	19,653	191,571	10.3
Jun 2002	167,330	21,645	188,975	11.5
Dec 2002	164,386	24,864	189,250	13.1
Jun 2003	158,275	26,985	185,260	14.6
Dec 2003	153,158	29,775	182,933	16.3
Jun 2004	147,993	32,034	180,027	17.8
Dec 2004	144,810	32,881	177,691	18.5
Jun 2005	143,758	33,975	177,733	19.1
Dec 2005	143,773	31,388	175,161	17.9
Jun 2006	142,293	29,896	172,189	17.4
Dec 2006	138,834	28,626	167,460	17.1
Jun 2007	134,640	28,729	163,369	17.6
Dec 2007	129,693	28,725	158,418	18.1
Jun 2008	124,606	30,049	154,655	19.4
Dec 2008	118,496	43,774	162,270	27.0
Jun 2009	112,748	43,976	156,724	28.1
Dec 2009	107,418	45,698	153,117	29.8

Some data for December 2008 and June 2009 have been revised.

[1] Incumbent local exchange carriers (ILECs) and competitive local exchange carriers (CLECs) with at least 10,000 switched access lines in service in a state were required to report through December 2004. Thereafter, all were required to report. Mandatory reporting by interconnected VoIP service providers started in December 2008. Previously, individual ILECs and CLECs included VoIP subscribers in reported switched access lines to a varying and largely unknown degree. Interconnected VoIP is distinguished from VoIP service more generally by permitting users to receive calls that originate on the public switched telephone network *and* to terminate calls to the public switched telephone network. *See* 47 C.F.R. § 9.3. Form 477 counts both switched access lines and interconnected VoIP subscriptions as the maximum number of calls that may be active, simultaneously, from the end user's location under the purchased service plan.

Chart 1
End-User Switched Access Lines and VoIP Subscriptions
(In Millions)

	Dec 1999	Jun 2000	Dec 2000	Jun 2001	Dec 2001	Jun 2002	Dec 2002	Jun 2003	Dec 2003	Jun 2004	Dec 2004	Jun 2005	Dec 2005	Jun 2006	Dec 2006	Jun 2007	Dec 2007	Jun 2008	Dec 2008	Jun 2009	Dec 2009
Non-ILEC	8.2	11.6	14.9	17.3	19.7	21.6	24.9	27.0	29.8	32.0	32.9	34.0	31.4	29.9	28.6	28.7	28.7	30.0	43.8	44.0	45.7
ILEC	181.2	179.6	177.6	174.8	171.9	167.3	164.4	158.3	153.2	148.0	144.8	143.8	143.8	142.3	138.8	134.6	129.7	124.6	118.5	112.7	107.4

■ ILEC   ■ Non-ILEC

Table 2

End-User Switched Access Lines and VoIP Subscriptions by Customer Type[1]

(In Thousands)

Date	Reporting ILECs			Reporting Non-ILECs		
	Residential	Business	% Residential	Residential	Business	% Residential
Dec 1999	139,694	41,508	77.1 %	3,369	4,826	41.1 %
Jun 2000	140,566	39,083	78.2	4,580	6,978	39.6
Dec 2000	138,824	38,737	78.2	6,620	8,251	44.5
Jun 2001	134,531	40,221	77.0	7,793	9,482	45.1
Dec 2001	133,320	38,597	77.5	9,489	10,164	48.3
Jun 2002	130,937	36,393	78.3	11,081	10,564	51.2
Dec 2002	127,495	36,892	77.6	14,608	10,255	58.8
Jun 2003	122,574	35,701	77.4	16,771	10,215	62.1
Dec 2003	118,659	34,499	77.5	18,702	11,073	62.8
Jun 2004	114,533	33,460	77.4	20,872	11,162	65.2
Dec 2004	112,054	32,755	77.4	19,812	13,069	60.3
Jun 2005	95,316	48,442	66.3	16,338	17,637	48.1
Dec 2005	94,393	49,381	65.7	13,873	17,515	44.2
Jun 2006	92,453	49,840	65.0	12,474	17,422	41.7
Dec 2006	89,167	49,667	64.2	12,211	16,415	42.7
Jun 2007	85,633	49,007	63.6	12,117	16,612	42.2
Dec 2007	81,798	47,894	63.1	12,051	16,675	42.0
Jun 2008	77,457	47,149	62.2	12,396	17,654	41.3
Dec 2008	72,786	45,711	61.4	24,654	19,120	56.3
Jun 2009	68,582	44,166	60.8	24,382	19,594	55.4
Dec 2009	64,615	42,803	60.2	26,438	19,261	57.9

Some data for December 2008 and June 2009 have been revised.

[1] In 2004, the Commission modified instructions for reporting lines serving small businesses. They were counted with residential lines through December 2004 and with business lines thereafter. This change caused a one-time drop in the percentages of ILEC and CLEC lines reported as residential. The December 2008 data are the first for which comprehensive reporting of interconnected VoIP subscribers was required. See footnote 1, Table 1.

Chart 2

Percent of Lines and VoIP Subscriptions that Serve Residential Customers[1]

	Dec 1999	Jun 2000	Dec 2000	Jun 2001	Dec 2001	Jun 2002	Dec 2002	Jun 2003	Dec 2003	Jun 2004	Dec 2004	Jun 2005	Dec 2005	Jun 2006	Dec 2006	Jun 2007	Dec 2007	Jun 2008	Dec 2008	Jun 2009	Dec 2009
ILECs	77.1%	78.2%	78.2%	77.0%	77.5%	78.3%	77.6%	77.4%	77.5%	77.4%	77.4%	66.3%	65.7%	65.0%	64.2%	63.6%	63.1%	62.2%	61.4%	60.8%	60.2%
Non-ILECs	41.1%	39.6%	44.5%	45.1%	48.3%	51.2%	58.8%	62.1%	62.8%	65.2%	60.3%	48.1%	44.2%	41.7%	42.7%	42.2%	42.0%	41.3%	56.3%	55.4%	57.9%
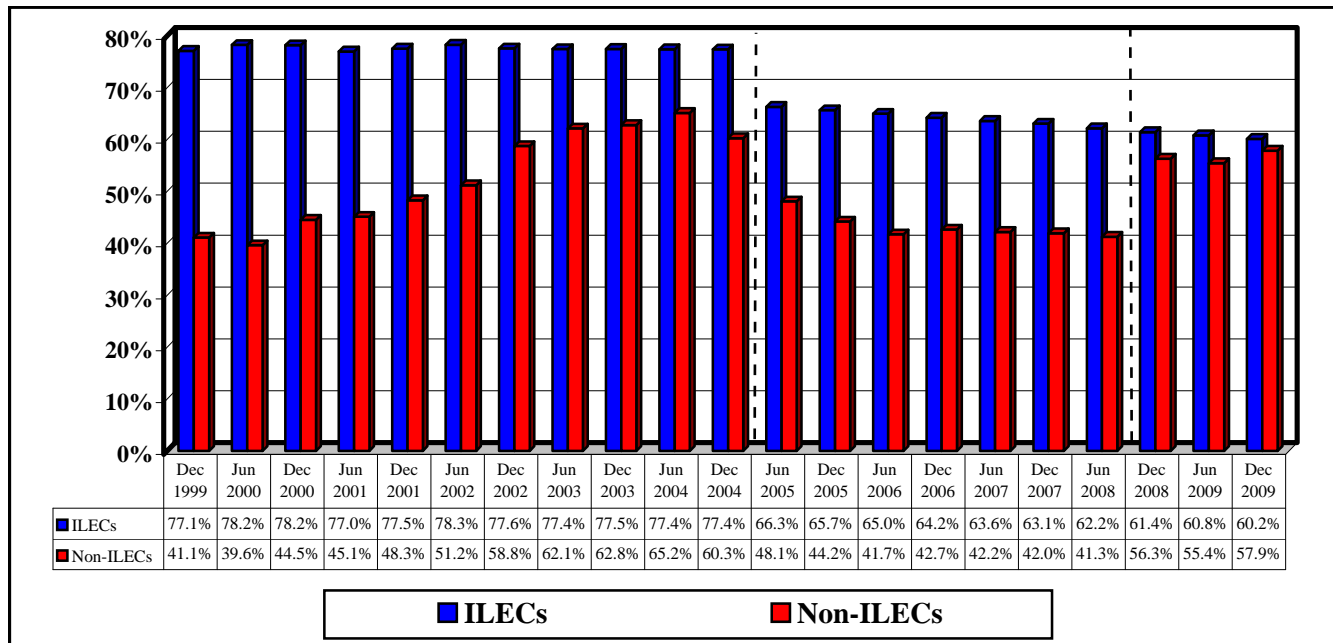
■ ILECs   ■ Non-ILECs

Table 3

End-User Switched Access Lines and VoIP Subscriptions Reported by Non-ILECs[1]

(Lines and Subscriptions in Thousands)

| Date | Reporting Non-ILECs | End-User Switched Access Lines and VoIP Subscriptions | End-User Switched Access Lines | | | VoIP | Percent | | | |
| | | | Acquired from other LECs | | CLEC-owned local loops [3] | | Resold LEC service | ILEC UNEs | CLEC-owned local loops | VoIP |
			Resold LEC service	ILEC UNEs [2]						
Dec 1999	81	8,194	3,513	1,959	2,723	-	42.9%	23.9%	33.2%	-
Jun 2000	78	11,557	4,315	3,201	4,042	-	37.3	27.7	35.0	-
Dec 2000	89	14,871	4,114	5,540	5,217	-	27.7	37.3	35.1	-
Jun 2001	91	17,275	3,919	7,580	5,776	-	22.7	43.9	33.4	-
Dec 2001	94	19,653	4,250	9,332	6,072	-	21.6	47.5	30.9	-
Jun 2002	96	21,645	4,478	10,930	6,236	-	20.7	50.5	28.8	-
Dec 2002	112	24,864	4,677	13,709	6,479	-	18.8	55.1	26.1	-
Jun 2003	125	26,985	4,887	15,728	6,370	-	18.1	58.3	23.6	-
Dec 2003	136	29,775	4,842	17,888	7,045	-	16.3	60.1	23.7	-
Jun 2004	137	32,034	4,927	19,624	7,483	-	15.4	61.3	23.4	-
Dec 2004	149	32,881	5,417	18,961	8,503	-	16.5	57.7	25.9	-
Jun 2005	326	33,975	5,826	19,025	9,124	-	17.1	56.0	26.9	-
Dec 2005	382	31,388	6,704	14,521	10,163	-	21.4	46.3	32.4	-
Jun 2006	400	29,896	6,548	12,547	10,802	-	21.9	42.0	36.1	-
Dec 2006	397	28,626	5,819	11,663	11,144	-	20.3	40.7	38.9	-
Jun 2007	406	28,729	6,193	11,511	11,025	-	21.6	40.1	38.4	-
Dec 2007	443	28,725	6,430	10,582	11,713	-	22.4	36.8	40.8	-
Jun 2008	469	30,049	6,073	10,884	13,093	-	20.2	36.2	43.6	-
Dec 2008	705	43,774	7,066	9,606	6,359	20,745	16.1	21.9	14.5	47.4
Jun 2009	717	43,976	6,840	8,631	6,002	22,504	15.6	19.6	13.6	51.2
Dec 2009	753	45,698	7,101	8,199	6,009	24,389	15.5	17.9	13.1	53.4

Some data for December 2008 and June 2009 have been revised. Figures may not sum to totals due to rounding.

[1] See footnote 1, Table 1.

[2] Includes unbundled network element (UNE) loops leased from an unaffiliated ILEC on a stand-alone basis and also UNE loops leased in combination with UNE switching or any other unbundled network element.

[3] Lines provided over CLEC-owned "last-mile" facilities.

Chart 3

Non-ILEC End-User Switched Access Lines and VoIP Subscriptions as of December 31, 2009

Resold LEC service
15.5%

ILEC UNEs
17.9%

CLEC-owned local loops
13.1%
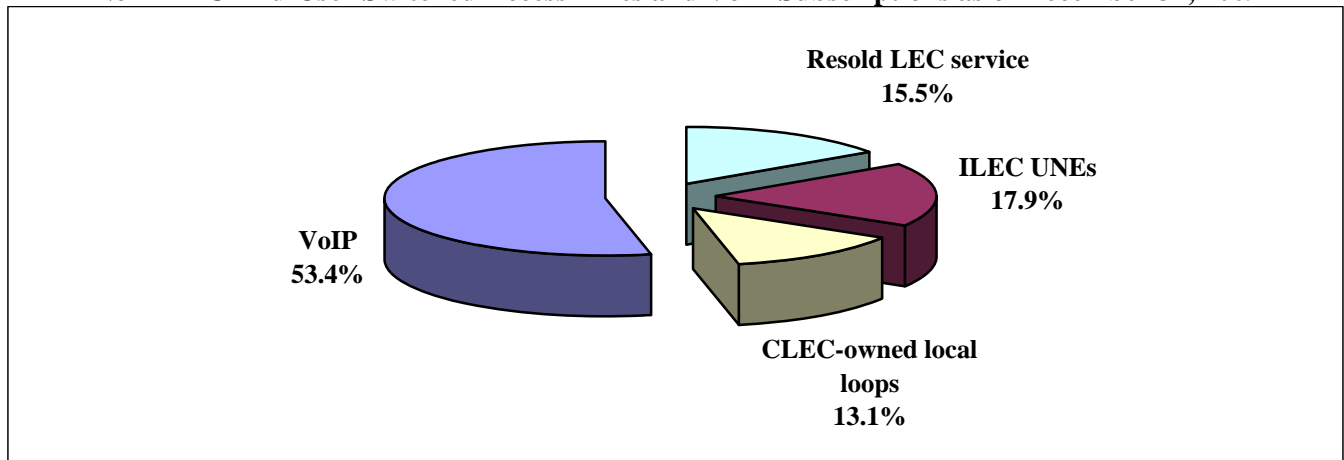
VoIP
53.4%

Table 4

ILEC End-User (Retail) and Wholesale Switched Access Lines, VoIP Subscriptions, and UNEs[1]
(Lines, Subscriptions, and UNEs in Thousands)

Date	Reporting ILECs[2]	ILEC Total Lines[3]	End-User Switched Access Lines	VoIP	Switched Access Lines and UNEs Provided to CLECs					
					Resold Lines	UNEs			Total UNEs & Resold Lines	% of Total Lines
						Without Switching	With Switching[4]	Total UNEs		
Dec 1999	168	187,190	181,203	-	4,494	1,004	489	1,493	5,987	3.2 %
Jun 2000	159	188,058	179,679	-	5,098	1,696	1,616	3,312	8,409	4.5
Dec 2000	166	188,223	177,561	-	5,388	2,436	2,838	5,274	10,662	5.7
Jun 2001	156	187,092	174,752	-	4,417	3,161	4,761	7,922	12,340	6.6
Dec 2001	164	185,391	171,917	-	4,014	3,679	5,781	9,460	13,474	7.3
Jun 2002	166	182,345	167,330	-	3,475	4,061	7,478	11,540	15,015	8.2
Dec 2002	174	181,616	164,386	-	2,743	4,259	10,227	14,487	17,229	9.5
Jun 2003	181	177,770	158,275	-	2,232	4,227	13,036	17,263	19,495	11.0
Dec 2003	185	174,453	153,158	-	1,833	4,287	15,176	19,463	21,296	12.2
Jun 2004	185	171,050	147,993	-	1,600	4,322	17,136	21,458	23,057	13.5
Dec 2004	190	167,063	144,810	-	1,490	4,217	16,546	20,763	22,253	13.3
Jun 2005	757	164,449	143,758	-	1,796	4,300	14,596	18,895	20,691	12.6
Dec 2005	807	160,881	143,773	-	1,793	4,469	10,846	15,315	17,108	10.6
Jun 2006	805	156,872	142,293	-	1,723	4,413	8,443	12,856	14,579	9.3
Dec 2006	814	151,958	138,834	-	1,613	4,408	7,103	11,511	13,124	8.6
Jun 2007	816	146,672	134,640	-	1,517	4,285	6,230	10,515	12,032	8.2
Dec 2007	805	140,808	129,693	-	1,460	4,122	5,534	9,655	11,115	7.9
Jun 2008	800	134,846	124,606	-	1,473	3,827	4,941	8,768	10,241	7.6
Dec 2008	777	128,288	117,968	529	3,209	3,844	2,740	6,583	9,792	7.6
Jun 2009	778	121,884	111,790	958	3,012	3,580	2,543	6,123	9,136	7.5
Dec 2009	768	116,474	105,826	1,592	2,993	3,668	2,396	6,063	9,056	7.8

Some data for December 2008 and June 2009 have been revised. Figures may not sum to totals due to rounding.

[1] See footnote 1, Table 1.

[2] Fewer ILECs were counted after mid-year 2007 primarily because FCC staff identified additional common-control relationships.

[3] Sum of ILEC-reported end-user (retail) switched access lines, ILEC interconnected VoIP subscriptions, and ILEC wholesale switched access lines and UNEs provided to CLECs.

[4] ILEC loops provided with ILEC switching, including the combination of ILEC loop UNE, switching UNE, and transport UNE, collectively referred to as the UNE-Platform ("UNE-P"). In the *Triennial Review Remand Order,* which was adopted on December 15, 2004, the Commission directed CLECs to migrate their retail customers served by these methods to alternative arrangements by March 11, 2006, i.e., within 12 months of the date the order went into effect *See* C.F.R. § 51.319(d)(2)(ii).

Chart 4
ILEC Total Lines and the Percent Provided to CLECs
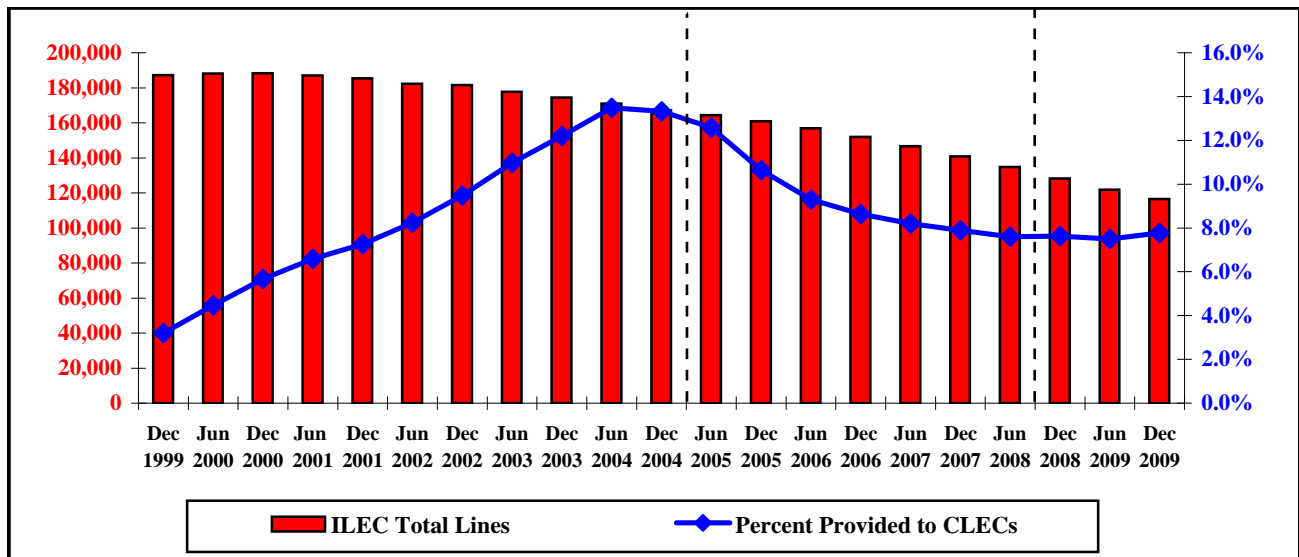
Table 5
End-User Switched Access Lines and VoIP Subscriptions
by Type of Technology for Non-ILEC Providers[1]
(In Thousands)

Date	Coaxial Cable[2]	Other Technology	Total	Percent Coaxial Cable
Dec 1999	308	7,886	8,194	3.8 %
Jun 2000	614	10,943	11,557	5.3
Dec 2000	1,125	13,746	14,871	7.6
Jun 2001	1,876	15,399	17,275	10.9
Dec 2001	2,246	17,408	19,653	11.4
Jun 2002	2,597	19,048	21,645	12.0
Dec 2002	3,071	21,793	24,864	12.4
Jun 2003	3,123	23,863	26,985	11.6
Dec 2003	3,301	26,474	29,775	11.1
Jun 2004	3,338	28,696	32,034	10.4
Dec 2004	3,706	29,175	32,881	11.3
Jun 2005	4,571	29,404	33,975	13.5
Dec 2005	5,100	26,287	31,388	16.2
Jun 2006	6,070	23,826	29,896	20.3
Dec 2006	6,751	21,875	28,626	23.6
Jun 2007	7,730	21,000	28,729	26.9
Dec 2007	8,385	20,340	28,725	29.2
Jun 2008	9,352	20,697	30,049	31.1
Dec 2008	20,114	23,660	43,774	45.9
Jun 2009	21,547	22,429	43,976	49.0
Dec 2009	23,182	22,516	45,698	50.7

Some data for December 2008 and June 2009 have been revised.

[1] See footnote 1, Table 1.

[2] Reported end-user switched access lines and interconnected VoIP connections that terminate on coaxial cable at the end user's premises. Starting, systematically, with the December 2008 data, interconnected VoIP service providers report subscriptions they sold in a bundle with cable modem Internet access service. For December 2008 and later dates, FCC staff used other Form 477 data to estimate the number of standalone VoIP subscriptions that terminated on coaxial cable at the end user's premises.

Chart 5
End-User Switched Access Lines and VoIP Subscriptions
by Type of Technology for Non-ILEC Providers
(In Thousands)
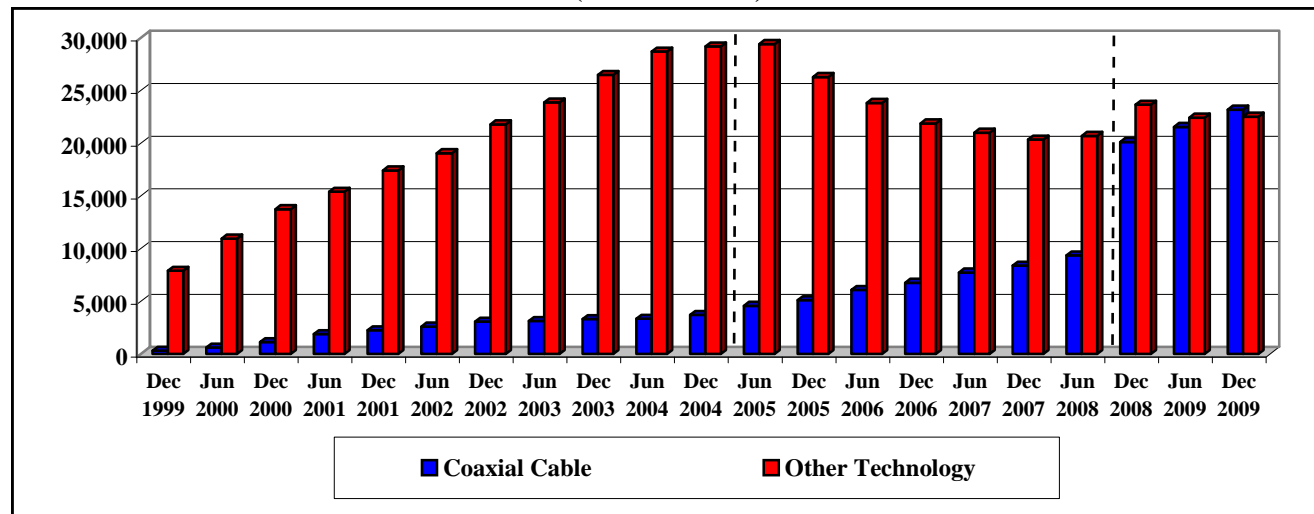
Table 6
Percentage of Switched Access Lines Presubscribed for Long Distance Service

	RBOC	Other ILEC	ILEC Total	CLEC	Total
Residential					
Jun 2005	52%	49%	51%	80%	56%
Dec 2005	56	57	56	88	60
Jun 2006	59	58	59	85	62
Dec 2006	66	60	65	86	68
Jun 2007	66	61	65	86	68
Dec 2007	66	63	65	87	68
Jun 2008	66	64	66	88	69
Dec 2008	69	65	68	80	69
Jun 2009	70	66	69	80	70
Dec 2009	71	68	70	76	71
Business					
Jun 2005	45	30	43	69	50
Dec 2005	34	39	34	71	44
Jun 2006	38	37	38	69	46
Dec 2006	47	39	46	68	51
Jun 2007	49	42	48	72	54
Dec 2007	50	43	49	70	54
Jun 2008	49	44	49	72	55
Dec 2008	44	47	44	70	51
Jun 2009	42	49	43	73	51
Dec 2009	43	48	43	71	51
Total					
Jun 2005	50	44	49	74	54
Dec 2005	48	52	49	79	54
Jun 2006	51	52	51	76	56
Dec 2006	59	54	58	76	61
Jun 2007	59	56	59	78	62
Dec 2007	60	57	59	77	63
Jun 2008	60	58	59	79	63
Dec 2008	59	60	59	73	61
Jun 2009	58	61	59	74	61
Dec 2009	59	62	60	72	62

Some data for December 2008 and June 2009 have been revised.

RBOC is an acronym for Regional Bell Operating Company. They currently are AT&T, Qwest, and Verizon.

Chart 6
Percent Presubscribed Interstate Long Distance Lines for ILECs
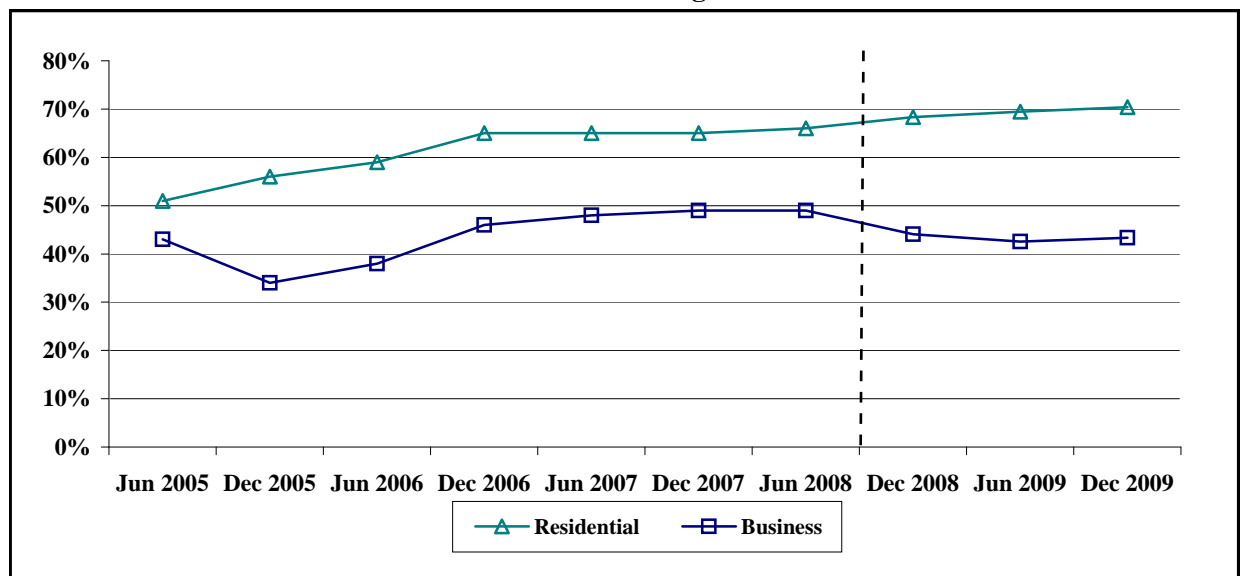
Table 7

Residential and Business Presubscribed Switched Access Lines

(In Thousands)

	December 31, 2009				
	RBOC	**Other ILEC**	**ILEC Total**	**CLEC**	**Total**
Residential					
Presubscribed	35,363	9,415	44,778	3,813	48,591
Not Presubscribed	14,402	4,452	18,854	1,200	20,054
All Lines	49,765	13,868	63,632	5,013	68,646
Percent Presubscribed	71%	68%	70%	76%	71%
Business					
Presubscribed	15,389	2,895	18,283	11,636	29,919
Not Presubscribed	20,757	3,153	23,910	4,661	28,571
All Lines	36,146	6,048	42,194	16,297	58,490
Percent Presubscribed	43%	48%	43%	71%	51%
Total					
Presubscribed	50,752	12,310	63,062	15,449	78,510
Not Presubscribed	35,159	7,605	42,764	5,861	48,625
All Lines	85,910	19,915	105,826	21,310	127,136
Percent Presubscribed	59%	62%	60%	72%	62%
	June 30, 2009				
	RBOC	**Other ILEC**	**ILEC Total**	**CLEC**	**Total**
Residential					
Presubscribed	37,634	9,575	47,209	4,082	51,291
Not Presubscribed	15,856	4,919	20,775	1,026	21,802
All Lines	53,490	14,494	67,984	5,109	73,093
Percent Presubscribed	70%	66%	69%	80%	70%
Business					
Presubscribed	15,595	3,049	18,644	11,889	30,533
Not Presubscribed	21,961	3,201	25,162	4,475	29,636
All Lines	37,557	6,249	43,806	16,363	60,169
Percent Presubscribed	42%	49%	43%	73%	51%
Total					
Presubscribed	53,229	12,624	65,853	15,971	81,824
Not Presubscribed	37,818	8,120	45,937	5,501	51,438
All Lines	91,047	20,743	111,790	21,472	133,262
Percent Presubscribed	58%	61%	59%	74%	61%

Some data for June 2009 have been revised. Figures may not sum to totals due to rounding.

RBOC is an acronym for Regional Bell Operating Company. They currently are AT&T, Qwest, and Verizon.

Table 8
Total End-User Switched Access Lines and VoIP Subscriptions by State as of December 31, 2009
(In Thousands)

State	ILECs				Non-ILECs				Total	Non-ILEC % of Total
	Switched Access Lines	VoIP purchased as		Total	Switched Access Lines	VoIP purchased as		Total		
		Stand-alone	Bundled with Internet			Stand-alone	Bundled with Internet			
Alabama	1,575	#	4	1,579	274	61	167	502	2,081	24%
Alaska	273	0	0	273	*	1	*	*	*	*
American Samoa	10	0	0	10	0	0	0	0	10	0
Arizona	1,649	#	1	1,650	844	80	261	1,184	2,834	40
Arkansas	925	0	16	941	115	21	89	224	1,165	18
California	14,576	1	255	14,832	2,261	368	2,102	4,731	19,564	23
Colorado	1,656	0	0	1,656	366	88	376	830	2,487	32
Connecticut	1,338	#	52	1,390	225	54	399	678	2,068	30
Delaware	343	#	2	345	67	*	*	163	508	31
District of Columbia	695	#	18	713	130	14	48	192	904	20
Florida	6,432	#	98	6,531	1,067	398	1,405	2,869	9,400	28
Georgia	3,135	#	22	3,156	550	159	461	1,169	4,326	25
Guam	49	0	0	49	*	*	*	*	*	*
Hawaii	472	#	#	473	43	*	*	125	597	19
Idaho	514	#	#	515	73	10	39	122	637	17
Illinois	4,684	#	169	4,854	642	233	754	1,629	6,482	24
Indiana	2,242	#	70	2,312	245	85	261	591	2,903	19
Iowa	1,024	#	#	1,024	194	109	26	330	1,354	22
Kansas	841	0	19	860	225	27	156	408	1,268	31
Kentucky	1,350	0	2	1,352	246	25	249	520	1,872	27
Louisiana	1,486	0	3	1,489	284	45	208	538	2,027	24
Maine	482	0	0	482	141	13	119	273	755	30
Maryland	2,398	#	32	2,430	464	99	344	906	3,336	26
Massachusetts	2,231	#	25	2,256	740	139	768	1,646	3,902	40
Michigan	2,981	#	139	3,121	493	206	788	1,487	4,608	30
Minnesota	1,725	0	#	1,725	524	84	296	903	2,628	32
Mississippi	878	0	1	879	125	18	71	213	1,092	17
Missouri	2,215	0	44	2,259	266	72	215	553	2,812	20
Montana	351	0	#	351	42	8	54	104	456	23
Nebraska	543	0	#	543	249	15	68	332	875	38
Nevada	851	#	6	857	138	59	214	411	1,268	32
New Hampshire	385	0	0	385	153	38	182	373	759	49
New Jersey	3,273	1	50	3,324	757	128	1,115	2,000	5,324	38
New Mexico	682	0	0	682	71	15	52	137	819	17
New York	5,887	1	67	5,955	1,981	181	2,600	4,762	10,717	44
North Carolina	3,179	#	18	3,198	440	102	646	1,188	4,385	27
North Dakota	224	0	0	224	80	2	41	123	347	35
Northern Mariana Isl.	16	0	0	16	0	0	0	0	16	0
Ohio	3,839	1	80	3,920	658	82	840	1,579	5,499	29
Oklahoma	1,101	0	16	1,117	313	44	212	569	1,686	34
Oregon	1,139	#	3	1,142	255	54	267	577	1,719	34
Pennsylvania	4,765	1	26	4,792	1,186	210	818	2,213	7,005	32
Puerto Rico	610	0	0	610	*	*	90	170	779	22
Rhode Island	270	#	1	270	234	*	*	310	580	53
South Carolina	1,480	#	10	1,490	267	48	215	530	2,021	26
South Dakota	233	0	0	233	72	*	*	121	354	34
Tennessee	2,053	0	8	2,061	358	68	341	767	2,829	27
Texas	7,787	#	244	8,031	1,121	205	1,028	2,353	10,384	23
Utah	690	0	0	690	186	32	131	349	1,039	34
Vermont	280	0	0	280	51	*	*	101	382	27
Virgin Islands	57	0	0	57	0	*	0	*	*	*
Virginia	3,045	#	31	3,076	1,055	129	369	1,552	4,629	34
Washington	2,069	#	5	2,074	378	111	594	1,083	3,157	34
West Virginia	637	#	1	638	123	16	95	234	871	27
Wisconsin	2,005	#	48	2,054	329	62	376	767	2,821	27
Wyoming	190	0	#	190	12	6	36	54	244	22
Nationwide	105,826	8	1,584	107,418	21,310	4,099	20,290	45,698	153,117	30

= Rounds to zero.   * = Data withheld to maintain firm confidentiality.

Table 9
Residential End-User Switched Access Lines and VoIP Subscriptions by State as of December 31, 2009
(In Thousands)

State	ILECs				Non-ILECs				Total	Non-ILEC % of Total
	Switched Access Lines	VoIP purchased as		Total	Switched Access Lines	VoIP purchased as		Total		
		Stand-alone	Bundled with Internet			Stand-alone	Bundled with Internet			
Alabama	1,045	0	3	1,048	97	58	131	286	1,334	19%
Alaska	138	0	0	138	*	1	*	*	*	*
American Samoa	5	0	0	5	0	0	0	0	5	0
Arizona	1,001	#	0	1,001	483	66	198	748	1,749	41
Arkansas	587	0	16	603	20	18	73	112	715	14
California	8,213	1	178	8,393	657	305	1,613	2,575	10,968	22
Colorado	1,054	0	0	1,054	19	75	307	402	1,455	26
Connecticut	781	#	49	830	56	46	226	327	1,157	34
Delaware	205	#	#	205	8	*	*	100	305	31
District of Columbia	143	#	0	143	15	11	28	55	198	25
Florida	3,949	#	43	3,992	115	346	1,288	1,750	5,742	27
Georgia	1,840	#	10	1,850	122	145	390	657	2,506	24
Guam	27	0	0	27	*	*	*	*	*	*
Hawaii	264	0	0	264	#	*	*	79	343	22
Idaho	329	#	#	329	23	9	32	63	392	14
Illinois	2,531	#	108	2,639	84	214	639	937	3,575	25
Indiana	1,401	#	52	1,454	72	80	244	397	1,851	19
Iowa	688	#	#	688	89	108	6	203	891	21
Kansas	479	0	18	496	107	22	129	259	755	33
Kentucky	844	0	1	846	137	21	241	399	1,245	30
Louisiana	900	0	2	902	122	41	183	346	1,248	25
Maine	355	0	0	355	16	12	114	141	495	26
Maryland	1,352	#	1	1,354	94	89	313	496	1,850	26
Massachusetts	1,273	#	2	1,274	74	125	700	900	2,174	39
Michigan	1,642	#	119	1,761	157	192	726	1,075	2,837	36
Minnesota	1,196	0	#	1,196	103	79	240	423	1,619	24
Mississippi	545	0	#	545	56	16	68	140	685	16
Missouri	1,415	0	40	1,455	45	68	180	293	1,748	17
Montana	227	0	#	227	15	7	47	69	296	23
Nebraska	307	0	0	307	109	12	50	171	478	36
Nevada	490	#	4	495	6	52	181	239	734	33
New Hampshire	265	0	0	265	6	34	170	210	475	44
New Jersey	1,877	1	5	1,883	106	113	1,022	1,241	3,124	40
New Mexico	458	0	0	458	10	13	39	62	520	12
New York	3,414	1	2	3,417	297	148	2,409	2,854	6,271	46
North Carolina	1,995	#	4	1,999	59	90	622	771	2,770	28
North Dakota	151	0	0	151	46	2	35	83	235	35
Northern Mariana Isl.	8	0	0	8	0	0	0	0	8	0
Ohio	2,374	1	61	2,435	226	65	792	1,082	3,518	31
Oklahoma	683	0	15	698	159	37	176	372	1,069	35
Oregon	777	#	0	778	19	48	235	302	1,080	28
Pennsylvania	3,195	1	#	3,197	164	186	745	1,095	4,291	26
Puerto Rico	457	0	0	457	*	*	85	99	556	18
Rhode Island	167	#	#	167	121	*	*	182	349	52
South Carolina	974	#	3	976	73	42	196	312	1,288	24
South Dakota	146	0	0	146	45	*	*	85	231	37
Tennessee	1,348	0	5	1,353	84	62	287	432	1,786	24
Texas	4,602	#	188	4,791	182	175	932	1,289	6,080	21
Utah	440	0	0	440	22	28	111	161	601	27
Vermont	198	0	0	198	9	*	*	57	255	22
Virgin Islands	38	0	0	38	0	*	0	*	*	*
Virginia	1,731	#	#	1,731	266	112	315	693	2,425	29
Washington	1,341	#	0	1,341	37	102	540	679	2,020	34
West Virginia	480	#	0	480	14	14	92	120	599	20
Wisconsin	1,189	#	42	1,231	75	55	344	474	1,705	28
Wyoming	100	0	#	100	4	5	33	43	142	30
Nationwide	63,632	8	975	64,615	5,013	3,618	17,806	26,438	91,052	29

= Rounds to zero.   * = Data withheld to maintain firm confidentiality.

State	ILECs				Non-ILECs				Total	Non-ILEC % of Total
	Switched Access Lines	VoIP purchased as		Total	Switched Access Lines	VoIP purchased as		Total		
		Stand-alone	Bundled with Internet			Stand-alone	Bundled with Internet			
Alabama	530	#	1	531	177	3	36	216	747	26%
Alaska	135	0	0	135	*	#	*	*	*	*
American Samoa	5	0	0	5	0	0	0	0	5	0
Arizona	648	0	1	649	360	14	63	437	1,085	38
Arkansas	338	0	#	339	94	2	15	112	451	26
California	6,363	0	77	6,440	1,603	63	490	2,156	8,596	24
Colorado	602	0	0	602	347	13	69	429	1,031	39
Connecticut	558	0	3	560	169	8	173	351	911	25
Delaware	139	0	2	140	58	*	*	63	204	31
District of Columbia	552	0	18	569	115	3	19	137	706	19
Florida	2,484	0	55	2,538	951	52	116	1,120	3,658	30
Georgia	1,295	0	12	1,307	428	14	70	513	1,819	26
Guam	22	0	0	22	*	0	*	*	*	*
Hawaii	208	#	#	209	43	*	*	45	254	16
Idaho	185	#	#	186	51	2	7	59	245	23
Illinois	2,153	0	62	2,215	558	19	115	692	2,907	22
Indiana	841	#	17	858	173	5	16	194	1,052	18
Iowa	336	#	#	336	105	1	20	126	463	25
Kansas	362	0	1	364	118	5	26	149	513	29
Kentucky	506	0	#	507	109	4	9	121	628	20
Louisiana	586	0	1	587	163	4	25	192	779	24
Maine	127	0	0	127	126	1	5	132	259	41
Maryland	1,046	0	30	1,076	370	10	30	410	1,486	26
Massachusetts	958	0	24	982	665	13	68	746	1,728	42
Michigan	1,339	0	21	1,360	336	14	62	412	1,771	21
Minnesota	529	0	#	529	420	5	55	480	1,009	44
Mississippi	333	0	#	334	69	1	3	73	407	18
Missouri	800	0	3	803	221	4	35	260	1,064	24
Montana	124	0	0	124	28	1	7	35	159	22
Nebraska	237	0	#	237	140	3	18	161	398	41
Nevada	361	0	1	362	132	7	32	172	534	32
New Hampshire	120	0	0	120	147	3	12	163	283	58
New Jersey	1,396	0	45	1,441	651	15	93	758	2,200	34
New Mexico	224	0	0	224	61	1	13	76	299	25
New York	2,473	0	65	2,537	1,684	33	191	1,909	4,446	43
North Carolina	1,185	0	14	1,199	382	11	24	417	1,616	26
North Dakota	73	0	0	73	34	#	6	40	112	35
Northern Mariana Isl.	9	0	0	9	0	0	0	0	9	0
Ohio	1,465	0	19	1,484	432	17	48	497	1,981	25
Oklahoma	418	0	1	419	154	8	36	198	616	32
Oregon	362	0	3	365	237	6	33	275	640	43
Pennsylvania	1,570	0	25	1,595	1,022	24	72	1,118	2,714	41
Puerto Rico	153	0	0	153	*	*	5	70	223	32
Rhode Island	103	0	1	103	113	*	*	128	232	55
South Carolina	507	0	7	514	193	6	19	219	733	30
South Dakota	87	0	0	87	27	*	*	37	123	30
Tennessee	705	0	3	708	275	6	54	335	1,043	32
Texas	3,184	#	55	3,239	938	30	96	1,064	4,303	25
Utah	250	0	0	250	164	4	20	188	438	43
Vermont	82	0	0	82	42	*	*	45	127	35
Virgin Islands	19	0	0	19	0	*	0	*	*	*
Virginia	1,314	0	31	1,345	789	16	54	859	2,204	39
Washington	728	0	5	733	341	10	54	404	1,137	36
West Virginia	157	0	1	158	109	2	3	114	272	42
Wisconsin	817	0	6	823	254	7	32	293	1,116	26
Wyoming	90	0	#	90	8	#	4	12	102	11
Nationwide	42,194	#	610	42,803	16,297	481	2,483	19,261	62,064	31

= Rounds to zero. * = Data withheld to maintain firm confidentiality.

Table 11
Non-ILEC Share of Total End-User Switched Access Lines and VoIP Subscriptions by State[1]

State	2005 Jun	2005 Dec	2006 Jun	2006 Dec	2007 Jun	2007 Dec	2008 Jun	2008 Dec	2009 Jun	2009 Dec
Alabama	16 %	15 %	16 %	13 %	13 %	14 %	16 %	21 %	21 %	24 %
Alaska	*	*	26	*	*	*	*	*	*	*
American Samoa	0	0	0	0	0	0	0	0	0	0
Arizona	27	30	30	32	33	34	37	40	40	40
Arkansas	13	11	12	13	14	14	14	18	18	18
California	18	13	13	14	14	14	15	22	23	23
Colorado	17	20	19	17	17	16	19	31	32	32
Connecticut	14	11	12	12	13	14	15	29	30	30
Delaware	20	20	18	18	19	17	18	30	31	31
District of Columbia	20	17	14	14	14	14	15	20	20	20
Florida	16	17	15	13	13	13	14	27	28	28
Georgia	21	18	19	14	16	16	17	25	25	25
Guam	NA	0	0	0	0	*	*	*	*	*
Hawaii	6	7	9	11	13	16	18	18	19	19
Idaho	10	10	11	10	11	11	11	17	17	17
Illinois	20	15	15	15	14	14	14	24	24	24
Indiana	14	10	10	10	9	9	11	18	19	19
Iowa	14	14	15	16	17	18	19	22	22	22
Kansas	25	21	24	23	25	26	28	31	31	31
Kentucky	14	15	16	15	16	19	18	25	27	27
Louisiana	19	17	18	16	17	18	21	23	24	24
Maine	20	20	16	16	17	20	24	30	32	30
Maryland	18	18	16	15	15	14	15	25	26	26
Massachusetts	25	25	24	24	23	24	25	39	40	40
Michigan	25	19	18	17	18	19	20	29	30	30
Minnesota	21	24	23	22	24	23	22	31	32	32
Mississippi	14	12	13	10	10	10	11	16	17	17
Missouri	14	11	13	13	14	14	15	17	18	20
Montana	8	10	12	14	16	18	19	21	22	23
Nebraska	25	26	27	28	29	30	31	34	35	38
Nevada	13	13	17	15	24	22	26	30	31	32
New Hampshire	25	25	24	23	23	23	25	42	44	49
New Jersey	22	21	17	18	17	17	18	34	36	38
New Mexico	8	7	8	8	8	8	9	14	15	17
New York	30	31	27	27	28	29	31	41	43	44
North Carolina	13	15	16	16	18	19	20	24	25	27
North Dakota	20	19	20	21	21	22	24	32	31	35
Northern Mariana Isl.	NA	0	0	0	0	0	0	0	0	0
Ohio	15	15	15	16	18	20	23	25	26	29
Oklahoma	18	18	20	21	23	25	27	30	30	34
Oregon	13	19	16	17	18	18	18	31	32	34
Pennsylvania	23	23	20	19	20	20	21	29	30	32
Puerto Rico	*	*	*	*	*	*	19	22	25	22
Rhode Island	40	42	43	46	47	48	50	52	52	53
South Carolina	13	13	15	14	16	17	19	22	24	26
South Dakota	30	33	33	30	30	31	32	36	36	34
Tennessee	16	17	18	15	16	17	18	25	25	27
Texas	19	16	16	17	16	17	18	21	22	23
Utah	23	22	24	21	22	20	21	26	32	34
Vermont	14	12	12	12	12	12	13	23	23	27
Virgin Islands	*	*	*	0	0	0	0	*	#	*
Virginia	21	22	21	22	22	23	23	30	32	34
Washington	14	14	14	14	15	14	16	30	31	34
West Virginia	12	12	12	13	13	14	16	21	24	27
Wisconsin	19	18	19	20	21	23	24	25	26	27
Wyoming	11	12	14	15	17	18	19	20	21	22
Nationwide	19 %	18 %	17 %	17 %	18 %	18 %	19 %	27 %	28 %	30 %

\# = Rounds to zero. * = Data withheld to maintain firm confidentiality. NA = Not available. Some data for December 2008 and June 2009 have been revised.

[1] See footnote 1, Table 1.

Table 12
Non-ILEC Total End-User Switched Access Lines and VoIP Subscriptions by State[1]
(In Thousands)

State	2005		2006		2007		2008		2009	
	Jun	Dec	Jun	Dec	Jun	Dec	Jun	Dec	Jun	Dec
Alabama	394	359	366	301	298	315	352	460	449	502
Alaska	*	*	116	*	*	*	*	*	*	*
American Samoa	0	0	0	0	0	0	0	0	0	0
Arizona	865	979	970	1,018	1,043	1,071	1,129	1,218	1,156	1,184
Arkansas	182	152	163	166	178	173	175	223	222	224
California	4,030	3,023	2,900	3,046	2,898	2,984	3,101	4,536	4,674	4,731
Colorado	497	591	529	452	425	395	449	838	815	830
Connecticut	316	251	262	261	261	265	291	625	640	678
Delaware	122	118	102	100	99	85	85	164	164	163
District of Columbia	223	173	145	144	137	131	136	182	181	192
Florida	1,745	1,869	1,618	1,340	1,298	1,265	1,276	2,690	2,680	2,869
Georgia	1,032	886	909	655	730	725	764	1,157	1,109	1,169
Guam	0	0	0	0	0	*	*	*	*	*
Hawaii	38	49	61	74	88	103	115	114	116	125
Idaho	77	76	81	76	78	75	79	122	115	122
Illinois	1,602	1,136	1,139	1,075	950	909	875	1,646	1,590	1,629
Indiana	493	360	338	335	293	284	313	559	557	591
Iowa	216	222	230	238	251	269	273	307	309	330
Kansas	362	301	347	327	349	358	375	417	411	408
Kentucky	302	306	337	313	328	371	331	493	506	520
Louisiana	460	365	394	358	363	383	449	488	503	538
Maine	169	164	135	123	135	150	181	231	248	273
Maryland	717	691	591	552	527	475	479	854	886	906
Massachusetts	1,089	1,037	979	928	865	844	871	1,590	1,593	1,646
Michigan	1,483	1,049	993	883	923	893	927	1,442	1,433	1,487
Minnesota	643	724	676	641	659	613	572	873	858	903
Mississippi	175	156	161	125	125	112	122	182	182	213
Missouri	452	369	426	403	436	448	471	519	514	553
Montana	43	52	62	72	82	93	96	101	102	104
Nebraska	228	237	244	249	258	265	274	298	301	332
Nevada	185	182	246	219	356	307	372	414	405	411
New Hampshire	218	209	196	182	171	165	167	343	347	373
New Jersey	1,389	1,283	994	977	897	859	866	1,925	1,984	2,000
New Mexico	76	65	77	75	77	73	75	121	126	137
New York	3,575	3,553	3,043	2,942	2,868	2,941	3,125	4,511	4,632	4,762
North Carolina	627	749	798	768	846	888	953	1,084	1,122	1,188
North Dakota	69	67	68	70	71	71	76	113	104	123
Northern Mariana Isl.	0	0	0	0	0	0	0	0	0	0
Ohio	981	953	963	962	1,069	1,171	1,365	1,463	1,437	1,579
Oklahoma	329	329	362	387	420	445	474	519	503	569
Oregon	260	375	306	318	325	308	300	571	558	577
Pennsylvania	1,878	1,892	1,572	1,437	1,521	1,407	1,423	2,186	2,172	2,213
Puerto Rico	*	*	*	*	*	*	186	210	234	170
Rhode Island	267	265	276	287	291	290	301	316	310	310
South Carolina	290	292	330	321	349	369	399	472	491	530
South Dakota	128	136	135	119	117	119	124	140	136	121
Tennessee	538	543	576	465	483	510	523	751	720	767
Texas	2,332	1,884	1,906	1,969	1,859	1,944	1,919	2,349	2,316	2,353
Utah	281	260	282	245	242	212	211	269	336	349
Vermont	61	51	49	48	47	47	47	88	90	101
Virgin Islands	*	*	*	0	0	0	0	*	#	*
Virginia	1,058	1,110	1,047	1,032	1,048	1,034	1,043	1,427	1,463	1,552
Washington	505	514	506	479	480	428	471	1,020	1,013	1,083
West Virginia	118	118	117	119	121	132	141	195	213	234
Wisconsin	645	588	612	653	684	709	744	765	750	767
Wyoming	30	34	39	44	46	48	51	54	53	54
Total	33,975	31,388	29,896	28,626	28,729	28,725	30,049	43,774	43,976	45,698

\# = Rounds to zero. * = Data withheld to maintain firm confidentiality. Some data for December 2008 and June 2009 have been revised.

[1] See footnote 1, Table 1.

State	2005		2006		2007		2008		2009	
	Jun	Dec	Jun	Dec	Jun	Dec	Jun	Dec	Jun	Dec
Alabama	2,024	2,024	1,979	2,016	1,982	1,991	1,861	1,746	1,665	1,579
Alaska	328	326	325	321	318	301	294	289	282	273
American Samoa	11	11	11	11	11	10	11	10	10	10
Arizona	2,326	2,295	2,227	2,175	2,109	2,035	1,943	1,847	1,741	1,650
Arkansas	1,216	1,215	1,193	1,164	1,132	1,105	1,069	1,021	982	941
California	18,945	19,631	19,479	18,926	18,485	17,864	17,149	16,345	15,555	14,832
Colorado	2,371	2,338	2,276	2,207	2,133	2,057	1,973	1,873	1,758	1,656
Connecticut	1,985	1,962	1,928	1,849	1,785	1,681	1,632	1,540	1,463	1,390
Delaware	479	467	468	450	432	414	396	380	363	345
District of Columbia	894	872	892	855	832	797	788	737	714	713
Florida	9,345	9,210	9,013	8,975	8,708	8,356	7,932	7,440	6,918	6,531
Georgia	3,972	3,970	3,844	4,045	3,957	3,824	3,675	3,468	3,304	3,156
Guam	0	67	68	68	67	66	62	54	51	49
Hawaii	644	627	608	584	562	541	516	512	489	473
Idaho	682	672	666	664	651	628	609	582	550	515
Illinois	6,214	6,497	6,354	6,154	5,976	5,773	5,562	5,342	5,086	4,854
Indiana	3,070	3,112	3,080	2,971	2,875	2,766	2,665	2,547	2,434	2,312
Iowa	1,356	1,325	1,302	1,273	1,245	1,200	1,162	1,113	1,077	1,024
Kansas	1,110	1,123	1,100	1,074	1,046	1,012	977	939	899	860
Kentucky	1,792	1,768	1,732	1,725	1,684	1,616	1,542	1,458	1,387	1,352
Louisiana	1,954	1,832	1,800	1,825	1,801	1,759	1,710	1,634	1,561	1,489
Maine	688	664	692	669	649	611	579	542	519	482
Maryland	3,173	3,097	3,166	3,079	2,984	2,886	2,792	2,588	2,520	2,430
Massachusetts	3,246	3,102	3,076	2,927	2,830	2,712	2,609	2,493	2,369	2,256
Michigan	4,411	4,609	4,491	4,303	4,118	3,895	3,719	3,514	3,323	3,121
Minnesota	2,385	2,319	2,273	2,210	2,137	2,078	2,006	1,922	1,826	1,725
Mississippi	1,117	1,114	1,089	1,108	1,091	1,035	1,018	963	922	879
Missouri	2,892	2,907	2,842	2,778	2,722	2,650	2,568	2,465	2,367	2,259
Montana	487	473	460	445	435	416	406	387	371	351
Nebraska	692	681	661	644	628	624	606	584	564	543
Nevada	1,252	1,246	1,233	1,200	1,158	1,106	1,042	972	911	857
New Hampshire	646	624	624	598	575	546	507	470	435	385
New Jersey	4,847	4,715	4,784	4,543	4,354	4,137	3,936	3,734	3,519	3,324
New Mexico	902	893	877	860	834	816	783	754	713	682
New York	8,292	8,020	8,297	7,900	7,417	7,068	6,902	6,557	6,234	5,955
North Carolina	4,239	4,142	4,060	4,067	3,973	3,847	3,715	3,519	3,335	3,198
North Dakota	280	279	272	267	261	253	248	241	233	224
Northern Mariana Isl.	0	23	21	21	19	18	18	17	17	16
Ohio	5,505	5,575	5,368	5,168	4,973	4,763	4,537	4,326	4,124	3,920
Oklahoma	1,535	1,521	1,470	1,425	1,375	1,321	1,267	1,215	1,169	1,117
Oregon	1,673	1,643	1,627	1,562	1,502	1,429	1,359	1,286	1,210	1,142
Pennsylvania	6,400	6,300	6,385	6,175	5,953	5,775	5,494	5,243	5,029	4,792
Puerto Rico	1,048	1,021	1,035	994	916	809	786	755	698	610
Rhode Island	394	369	363	340	327	312	302	292	281	270
South Carolina	1,895	1,939	1,908	1,909	1,866	1,798	1,728	1,629	1,561	1,490
South Dakota	297	279	280	278	276	268	261	251	244	233
Tennessee	2,727	2,718	2,676	2,695	2,618	2,537	2,436	2,297	2,170	2,061
Texas	9,730	10,036	9,958	9,738	9,608	9,329	9,020	8,673	8,307	8,031
Utah	917	924	915	894	864	844	811	776	725	690
Vermont	370	364	370	362	355	340	323	289	299	280
Virgin Islands	70	70	69	68	67	64	62	61	59	57
Virginia	3,925	3,834	3,844	3,734	3,642	3,540	3,422	3,265	3,160	3,076
Washington	3,137	3,063	2,994	2,868	2,762	2,643	2,509	2,367	2,211	2,074
West Virginia	891	876	852	828	806	780	752	714	677	638
Wisconsin	2,725	2,739	2,670	2,605	2,516	2,422	2,336	2,246	2,156	2,054
Wyoming	249	252	245	238	233	225	218	209	200	190
Total	143,758	143,773	142,293	138,834	134,640	129,693	124,606	118,496	112,748	107,418

Some data for December 2008 and June 2009 have been revised.

[1] See footnote 1, Table 1.

Table 14
Non-ILEC Methods of Providing Wireline Telephone Services by State
as of December 31, 2009
(In Thousands)

State	Resold LEC service	ILEC UNEs	CLEC-owned local loops	VoIP Subscriptions[1]	Total
Alabama	75	128	71	227	502
Alaska	*	*	*	*	*
American Samoa	0	0	0	0	0
Arizona	156	122	565	341	1,184
Arkansas	13	37	65	109	224
California	903	603	756	2,471	4,731
Colorado	155	161	50	464	830
Connecticut	44	79	103	453	678
Delaware	*	34	*	96	163
District of Columbia	61	31	38	61	192
Florida	403	517	146	1,802	2,869
Georgia	138	300	112	619	1,169
Guam	*	*	*	*	*
Hawaii	24	4	15	82	125
Idaho	20	29	25	49	122
Illinois	208	338	95	987	1,629
Indiana	55	108	82	346	591
Iowa	55	49	91	136	330
Kansas	54	61	109	183	408
Kentucky	63	79	103	274	520
Louisiana	78	100	107	253	538
Maine	26	67	48	132	273
Maryland	282	147	34	443	906
Massachusetts	314	278	148	906	1,646
Michigan	65	381	47	994	1,487
Minnesota	124	264	136	380	903
Mississippi	71	45	9	88	213
Missouri	72	144	50	287	553
Montana	9	10	23	62	104
Nebraska	50	8	191	83	332
Nevada	69	48	21	273	411
New Hampshire	45	82	26	220	373
New Jersey	396	225	136	1,243	2,000
New Mexico	34	18	19	67	137
New York	782	754	444	2,781	4,762
North Carolina	146	188	106	747	1,188
North Dakota	5	9	66	43	123
Northern Mariana Isl.	0	0	0	0	0
Ohio	128	247	283	922	1,579
Oklahoma	90	62	162	256	569
Oregon	75	155	26	322	577
Pennsylvania	380	492	314	1,027	2,213
Puerto Rico	37	*	*	*	170
Rhode Island	34	29	170	76	310
South Carolina	75	126	66	263	530
South Dakota	5	2	65	49	121
Tennessee	139	140	79	409	767
Texas	370	558	193	1,233	2,353
Utah	61	93	32	163	349
Vermont	13	27	10	51	101
Virgin Islands	0	0	0	*	*
Virginia	473	219	363	497	1,552
Washington	114	200	64	705	1,083
West Virginia	27	87	9	110	234
Wisconsin	40	251	38	438	767
Wyoming	4	6	3	42	54
Total	7,101	8,199	6,009	24,389	45,698

= Rounds to zero. * = Data withheld to maintain firm confidentiality. Figures may not sum to totals due to rounding.

[1] See footnote 1, Table 1.

Table 15
Percentage of End-User Switched Access Lines and VoIP Subscriptions
Provided to Residential Customers by State as of December 31, 2009

State	ILECs	Non-ILECs	Total
Alabama	66%	57%	64%
Alaska	51	*	*
American Samoa	50	NA	50
Arizona	61	63	62
Arkansas	64	50	61
California	57	54	56
Colorado	64	48	59
Connecticut	60	48	56
Delaware	59	61	60
District of Columbia	20	29	22
Florida	61	61	61
Georgia	59	56	58
Guam	55	*	*
Hawaii	56	63	57
Idaho	64	52	62
Illinois	54	58	55
Indiana	63	67	64
Iowa	67	62	66
Kansas	58	63	60
Kentucky	63	77	67
Louisiana	61	64	62
Maine	74	52	66
Maryland	56	55	55
Massachusetts	56	55	56
Michigan	56	72	62
Minnesota	69	47	62
Mississippi	62	66	63
Missouri	64	53	62
Montana	65	66	65
Nebraska	57	52	55
Nevada	58	58	58
New Hampshire	69	56	63
New Jersey	57	62	59
New Mexico	67	45	63
New York	57	60	59
North Carolina	63	65	63
North Dakota	67	67	68
Northern Mariana Isl.	50	NA	50
Ohio	62	69	64
Oklahoma	62	65	63
Oregon	68	52	63
Pennsylvania	67	49	61
Puerto Rico	75	58	71
Rhode Island	62	59	60
South Carolina	66	59	64
South Dakota	63	70	65
Tennessee	66	56	63
Texas	60	55	59
Utah	64	46	58
Vermont	71	56	67
Virgin Islands	67	*	*
Virginia	56	45	52
Washington	65	63	64
West Virginia	75	51	69
Wisconsin	60	62	60
Wyoming	53	80	58
Nationwide	60	58	59

* = Data withheld to maintain firm confidentiality. NA = Not applicable.

Table 16
Number of Reporting ILECs, Non-ILECs, and VoIP Providers by State
as of December 31, 2009

State	ILECs	Non-ILECs	Total[1]	VoIP Providers[2]
Alabama	22	102	124	68
Alaska	17	15	32	13
American Samoa	1	0	1	0
Arizona	16	96	112	77
Arkansas	20	68	88	47
California	15	141	156	106
Colorado	26	97	123	77
Connecticut	2	75	77	60
Delaware	1	61	62	44
District of Columbia	1	79	80	58
Florida	11	185	196	114
Georgia	27	143	170	96
Guam	1	4	5	3
Hawaii	2	32	34	29
Idaho	21	59	80	46
Illinois	45	147	192	98
Indiana	30	110	140	68
Iowa	135	96	231	45
Kansas	38	88	126	54
Kentucky	17	114	131	68
Louisiana	11	90	101	54
Maine	7	50	57	33
Maryland	2	103	105	73
Massachusetts	4	97	101	72
Michigan	27	110	137	73
Minnesota	51	105	156	64
Mississippi	13	84	97	54
Missouri	32	94	126	63
Montana	18	52	70	35
Nebraska	32	65	97	45
Nevada	13	77	90	60
New Hampshire	6	72	78	53
New Jersey	3	117	120	81
New Mexico	17	67	84	42
New York	25	141	166	97
North Carolina	17	125	142	84
North Dakota	22	49	71	27
Northern Mariana Isl	1	0	1	0
Ohio	34	126	160	88
Oklahoma	39	84	123	56
Oregon	26	92	118	65
Pennsylvania	22	124	146	88
Puerto Rico	1	13	14	12
Rhode Island	1	55	56	42
South Carolina	17	110	127	67
South Dakota	28	48	76	31
Tennessee	18	112	130	76
Texas	52	164	216	102
Utah	12	69	81	51
Vermont	7	42	49	29
Virgin Islands	1	1	2	1
Virginia	15	112	127	88
Washington	18	105	123	78
West Virginia	7	61	68	47
Wisconsin	41	105	146	65
Wyoming	10	54	64	38
Nationwide	768	753	1,521	421

[1] Holding companies or common-control entities that report both ILEC and non-ILEC operations in a state are counted once in the ILECs column and once in the Non-ILECs column for that state. Either type of operations might report interconnected VoIP subscribers.

[2] The providers reporting interconnected VoIP subscribers in a state are a subset of the ILECs and non-ILECs in that state.

State	Dec 2009 Carriers	Dec 2009 % Resold [1]	2005 Jun	2005 Dec	2006 Jun	2006 Dec	2007 Jun	2007 Dec	2008 Jun	2008 Dec	2009 Jun	2009 Dec
Alabama	13	9 %	2,874	3,105	3,276	3,375	3,605	3,765	3,887	3,960	4,003	4,228
Alaska	11	6	341	377	397	412	432	460	480	383	544	586
American Samoa	*	*	*	*	*	*	*	*	*	*	*	*
Arizona	11	5	3,543	3,844	4,153	4,405	4,637	4,800	4,936	4,983	5,005	5,101
Arkansas	8	10	1,681	1,781	1,924	2,044	2,149	2,288	2,446	2,530	2,576	2,519
California	15	7	24,572	25,537	27,497	29,717	30,204	32,247	31,946	32,177	32,215	32,938
Colorado	11	8	3,041	3,247	3,428	3,608	3,756	3,968	4,066	4,311	4,357	4,503
Connecticut	7	6	2,329	2,463	2,582	2,705	2,787	2,884	2,959	3,030	3,047	3,123
Delaware	8	6	585	618	650	683	724	751	775	778	779	803
District of Columbia	8	7	753	825	879	880	966	936	1,047	1,096	1,116	1,183
Florida	11	10	12,620	12,568	14,177	14,762	15,255	15,605	15,809	16,158	16,425	16,744
Georgia	14	7	6,001	6,079	6,865	7,282	7,598	7,941	8,142	8,322	8,562	8,863
Guam	*	*	*	*	*	*	*	*	*	*	*	*
Hawaii	7	3	934	983	1,010	1,035	1,067	1,096	1,115	1,184	1,196	1,216
Idaho	14	5	774	834	901	973	1,019	1,086	1,125	1,167	1,180	1,221
Illinois	14	7	8,227	8,655	9,148	9,589	9,949	10,330	10,634	10,919	11,070	11,523
Indiana	12	8	3,443	3,716	3,973	4,271	4,448	4,675	4,824	4,956	4,983	5,205
Iowa	71	7	1,634	1,811	1,867	2,010	2,058	2,166	2,245	2,319	2,336	2,432
Kansas	15	11	1,660	1,794	1,905	2,047	2,133	2,261	2,326	2,421	2,430	2,466
Kentucky	12	10	2,508	2,662	2,821	2,966	3,101	3,291	3,343	3,445	3,439	3,631
Louisiana	10	7	2,942	3,192	3,356	3,492	3,612	3,765	3,896	4,012	4,053	3,993
Maine	8	17	711	746	787	845	882	941	972	1,012	1,006	1,065
Maryland	10	5	3,968	4,239	4,471	4,691	4,818	5,024	5,124	5,234	5,260	5,338
Massachusetts	8	9	4,488	4,728	4,917	5,129	5,289	5,470	5,624	5,749	6,027	6,171
Michigan	12	12	6,230	6,604	6,863	7,094	7,333	7,608	7,821	8,027	8,171	8,576
Minnesota	11	6	3,132	3,380	3,543	3,702	3,834	4,048	4,164	4,345	4,254	4,439
Mississippi	10	7	1,631	1,821	1,923	2,030	2,070	2,196	2,252	2,312	2,361	2,345
Missouri	12	8	3,595	3,853	4,068	4,322	4,480	4,674	4,835	4,940	4,985	5,129
Montana	9	8	466	525	575	620	650	694	723	748	707	802
Nebraska	11	5	1,071	1,160	1,199	1,272	1,325	1,387	1,451	1,496	1,508	1,515
Nevada	12	8	1,605	1,777	1,883	1,990	2,093	2,167	2,249	2,268	2,325	2,393
New Hampshire	8	10	791	849	897	943	973	1,022	1,045	1,080	1,075	1,125
New Jersey	8	5	6,234	6,617	6,954	7,207	7,419	7,654	7,834	8,008	8,036	8,158
New Mexico	10	5	1,025	1,170	1,253	1,333	1,416	1,489	1,555	1,536	1,550	1,624
New York	11	10	12,996	13,805	14,574	15,262	15,901	16,395	17,260	16,702	18,193	18,882
North Carolina	12	9	5,503	5,792	6,209	6,627	6,962	7,306	7,428	8,024	8,193	8,108
North Dakota	9	6	368	432	457	473	492	513	541	581	562	618
Northern Mariana Isl.	*	*	*	*	*	*	*	*	*	*	*	*
Ohio	12	10	6,994	7,504	7,939	8,380	8,723	9,099	9,357	9,565	9,456	10,059
Oklahoma	17	6	2,002	2,189	2,317	2,480	2,572	2,723	2,808	2,889	2,988	3,077
Oregon	11	6	2,056	2,339	2,484	2,656	2,781	2,923	3,007	3,084	3,112	3,235
Pennsylvania	14	10	7,397	7,942	8,349	8,831	9,201	9,615	9,895	10,214	10,455	10,867
Puerto Rico	6	2	2,003	2,111	2,171	2,301	2,323	2,411	2,502	2,624	2,706	2,807
Rhode Island	7	6	689	749	765	798	829	848	874	888	880	893
South Carolina	13	8	2,607	2,784	3,001	3,209	3,340	3,500	3,573	3,323	3,374	3,896
South Dakota	8	7	434	481	514	548	570	596	611	631	613	681
Tennessee	13	10	4,066	4,417	4,731	5,127	4,971	5,246	5,791	5,518	5,676	5,914
Texas	26	6	14,424	15,644	16,928	17,822	18,792	19,677	20,390	21,008	21,403	21,849
Utah	13	5	1,414	1,530	1,649	1,775	1,874	1,971	2,046	2,095	2,109	2,166
Vermont	7	15	295	314	334	358	375	402	421	435	398	463
Virgin Islands	*	*	*	*	*	*	*	*	*	*	*	*
Virginia	10	8	4,851	5,073	5,325	5,607	6,148	6,416	6,242	6,856	6,596	7,250
Washington	11	6	4,062	4,249	4,495	4,799	5,035	5,292	5,461	5,624	5,671	5,816
West Virginia	11	16	821	858	965	1,040	1,095	1,173	1,236	1,295	1,315	1,386
Wisconsin	13	9	3,200	3,366	3,517	3,510	3,641	3,842	3,966	4,265	4,317	4,546
Wyoming	13	9	315	342	359	387	410	441	457	484	429	517
Nationwide	180	8 %	192,053	203,667	217,418	229,619	238,316	249,332	255,729	261,284	265,332	274,283

* = Data withheld to maintain firm confidentiality. Some data for December 2008 and June 2009 have been revised.

[1] Percentage of mobile telephony subscribers purchasing their service subscriptions from a mobile wireless reseller.

Table 18

Percentage of ZIP Codes with CLECs or Non-ILEC VoIP Providers[1]

Number of Providers[2]	2005		2006		2007		2008		2009	
	Jun	Dec	Jun	Dec	Jun	Dec	Jun	Dec	Jun	Dec
Zero	17.4 %	18.4 %	17.7 %	17.7 %	17.7 %	19.4 %	18.3 %	7.7 %	8.7 %	9.3 %
One	10.5	11.4	11.3	11.1	11.1	11.7	11.6	9.2	10.1	10.1
Two	7.6	7.6	7.8	8.2	8.3	8.3	8.6	7.8	7.9	7.6
Three	6.0	6.2	6.2	6.7	6.7	6.2	6.3	6.4	6.1	6.2
Four	4.8	4.7	5.0	5.2	5.4	5.0	5.0	5.4	5.4	5.2
Five	4.2	4.1	4.2	4.4	4.4	3.9	4.1	4.8	4.6	4.5
Six	3.4	3.6	3.5	3.8	3.8	3.5	3.5	4.2	4.0	3.8
Seven	3.1	3.3	3.2	3.2	3.4	3.3	3.2	3.6	3.4	3.5
Eight	3.1	2.9	2.9	3.0	2.8	2.9	3.0	3.2	3.1	3.0
Nine	2.8	2.7	2.8	2.7	2.9	2.6	2.7	2.8	2.6	2.7
Ten or More	36.9	35.0	35.3	34.0	33.5	33.1	33.6	44.7	44.0	44.0

Table 19

Percentage of Households in ZIP Codes with CLECs or Non-ILEC VoIP Providers[1]

Number of Providers[2]	2005		2006		2007		2008		2009	
	Jun	Dec	Jun	Dec	Jun	Dec	Jun	Dec	Jun	Dec
Zero	2.2 %	2.4 %	2.3 %	2.4 %	2.4 %	2.8 %	2.6 %	0.4 %	0.5 %	0.6 %
One	2.1	2.3	2.4	2.5	2.4	2.6	2.4	0.9	1.2	1.2
Two	2.3	2.2	2.1	2.2	2.2	2.4	2.4	1.2	1.3	1.3
Three	2.2	2.3	2.2	2.4	2.3	2.5	2.4	1.3	1.4	1.4
Four	2.2	2.1	2.3	2.4	2.4	2.2	2.2	1.3	1.5	1.5
Five	2.2	2.2	2.0	2.4	2.5	2.2	2.2	1.6	1.4	1.5
Six	1.9	2.2	1.9	2.4	2.3	2.2	2.1	1.7	1.5	1.5
Seven	2.0	2.4	2.2	2.4	2.4	2.5	2.3	1.8	1.5	1.6
Eight	2.6	2.5	2.3	2.5	2.4	2.8	2.8	1.7	1.8	1.6
Nine	2.4	2.7	2.7	2.5	2.8	2.8	2.7	1.6	1.6	1.7
Ten or More	77.9	76.8	77.4	76.1	75.8	75.0	75.9	86.6	86.2	86.1

Demographic data were created by geographically merging contemporaneous Tele Atlas ® Dynamap ® ZIP Code Boundary & Inventory Files with census block-level population data from the 2000 Census of Population and Housing. Figures may not add to 100% due to rounding.
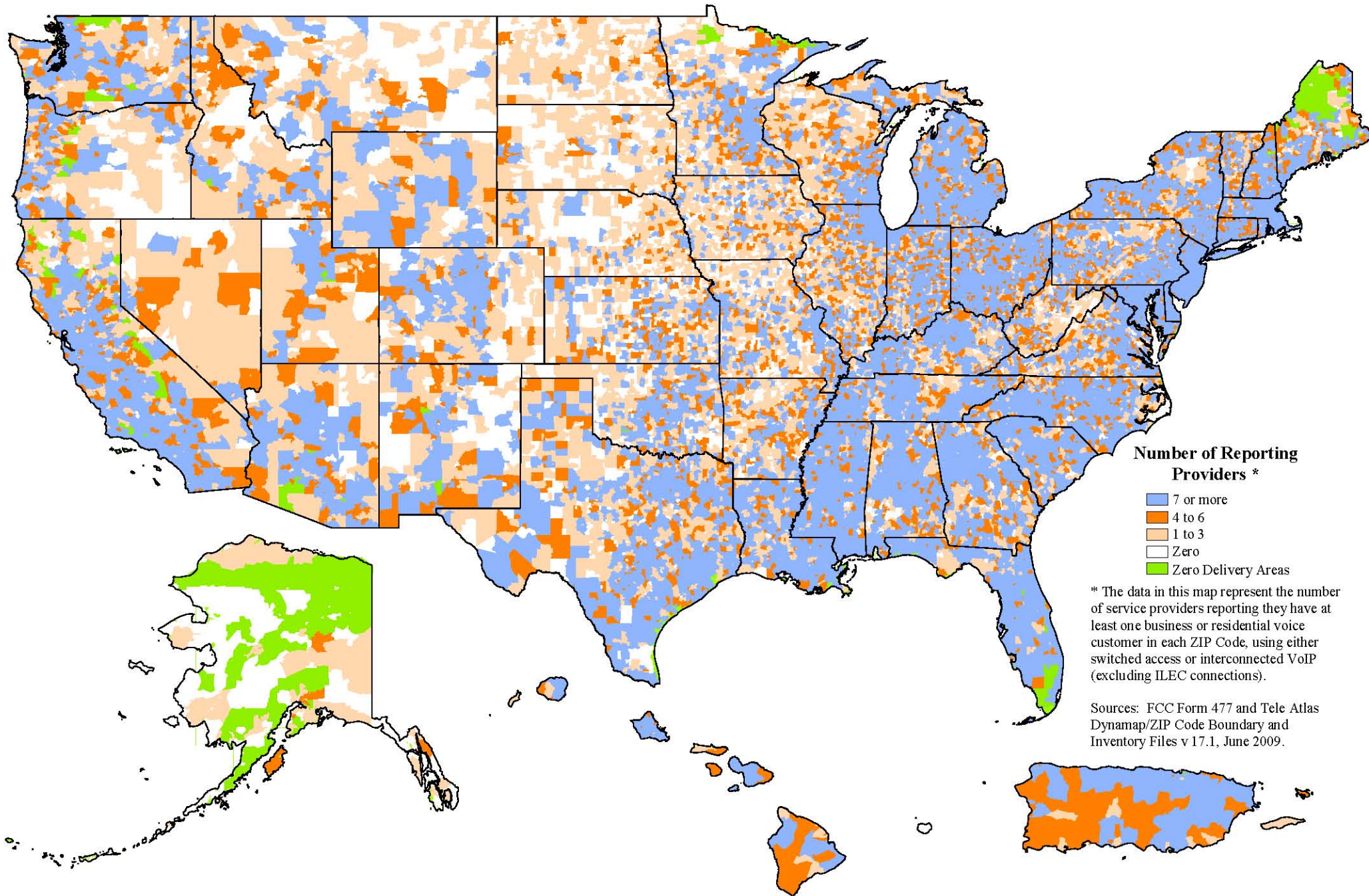
[1] See footnote 1, Table 1.

[2] A holding company or common-control entity that reports both CLEC end-user switched access lines and interconnected VoIP subscribers in a state reports a single list of ZIP Codes in which it has any such customers and is counted once in each listed ZIP Code.

Table 20

Percentage of ZIP Codes with CLECs or Non-ILEC VoIP Providers by State

as of December 31, 2009

State	Number of Providers								
	Zero	**One - Three**	**Four**	**Five**	**Six**	**Seven**	**Eight**	**Nine**	**Ten or More**
Alabama	6 %	16 %	5 %	4 %	4 %	4 %	2 %	1 %	56 %
Alaska	69	19	2	2	4	2	0	0	0
Arizona	6	16	6	4	2	2	3	2	59
Arkansas	18	43	6	5	4	4	2	2	16
California	2	13	3	4	3	3	3	2	66
Colorado	14	24	3	3	2	3	3	2	46
Connecticut	0	6	7	9	7	6	4	7	53
Delaware	0	3	3	3	3	3	2	3	78
District of Columbia	0	12	0	0	0	0	0	0	88
Florida	0	5	1	2	1	2	2	2	85
Georgia	4	19	5	4	3	3	4	2	55
Hawaii	0	22	7	10	10	10	6	1	34
Idaho	15	40	5	8	3	4	2	3	20
Illinois	7	31	8	6	3	3	2	2	37
Indiana	4	24	9	8	5	5	2	2	40
Iowa	23	49	5	4	2	2	1	1	12
Kansas	23	34	6	5	4	3	3	2	21
Kentucky	8	28	6	4	6	5	5	4	35
Louisiana	3	18	4	3	3	3	4	4	56
Maine	5	23	7	9	9	8	9	5	24
Maryland	1	4	4	4	4	4	4	5	69
Massachusetts	0	4	2	2	2	3	2	4	82
Michigan	1	13	5	5	6	5	5	4	56
Minnesota	17	34	4	4	4	3	2	2	30
Mississippi	1	12	4	5	5	4	5	4	60
Missouri	22	36	5	4	2	2	2	2	26
Montana	43	33	3	3	2	3	3	2	9
Nebraska	32	46	2	3	1	2	1	2	10
Nevada	9	21	5	5	2	4	1	3	50
New Hampshire	1	6	8	7	5	6	7	6	54
New Jersey	0	0	0	1	1	2	1	2	92
New Mexico	25	32	9	3	2	3	2	2	22
New York	1	13	5	3	5	4	4	4	61
North Carolina	2	18	6	8	4	4	3	3	53
North Dakota	43	45	3	2	1	0	0	0	5
Ohio	0	12	7	6	7	6	6	4	53
Oklahoma	18	31	5	4	3	2	2	2	34
Oregon	13	30	5	6	4	3	4	3	33
Pennsylvania	3	26	6	5	4	4	4	3	45
Puerto Rico	0	8	9	12	13	10	23	13	12
Rhode Island	1	9	5	4	5	4	8	3	60
South Carolina	2	14	6	2	3	3	3	5	62
South Dakota	40	45	3	3	1	2	1	1	4
Tennessee	5	18	4	4	3	4	2	4	56
Texas	8	22	4	3	3	2	2	2	54
Utah	7	32	7	2	4	4	1	1	41
Vermont	2	36	10	8	6	9	5	7	16
Virginia	9	29	7	6	4	4	3	3	36
Washington	6	28	4	3	3	2	3	3	49
West Virginia	12	38	13	7	6	4	2	3	13
Wisconsin	9	42	6	5	5	3	3	2	26
Wyoming	16	55	4	6	1	1	1	1	16
Nationwide	9 %	24 %	5 %	4 %	4 %	3 %	3 %	3 %	44 %

Reporting Non-ILEC Interconnected VoIP Providers and CLECs by 5-Digit Geographical ZIP Code

(As of December 31, 2009)

Number of Reporting Providers *

- 7 or more
- 4 to 6
- 1 to 3
- Zero
- Zero Delivery Areas

* The data in this map represent the number of service providers reporting they have at least one business or residential voice customer in each ZIP Code, using either switched access or interconnected VoIP (excluding ILEC connections).

Sources: FCC Form 477 and Tele Atlas Dynamap/ZIP Code Boundary and Inventory Files v 17.1, June 2009.

Prepared by the Federal Communications Commission,
Wireline Competition Bureau, Industry Analysis and Technology Division

0249

Customer Response

Publication: *Local Telephone Competition: Status as of December 31, 2009*

You can help us provide the best possible information to the public by completing this form and returning it to the Industry Analysis and Technology Division of the FCC's Wireline Competition Bureau.

1.   Please check the category that best describes you:
　　　　　____   press
　　　　　____   current telecommunications carrier
　　　　　____   potential telecommunications carrier
　　　　　____   business customer evaluating vendors/service options
　　　　　____   consultant, law firm, lobbyist
　　　　　____   other business customer
　　　　　____   academic/student
　　　　　____   residential customer
　　　　　____   FCC employee
　　　　　____   other federal government employee
　　　　　____   state or local government employee
　　　　　____   Other (please specify)

2.   Please rate the report:

	Excellent	Good	Satisfactory	Poor	No opinion
Data accuracy	(_)	(_)	(_)	(_)	(_)
Data presentation	(_)	(_)	(_)	(_)	(_)
Timeliness of data	(_)	(_)	(_)	(_)	(_)
Completeness of data	(_)	(_)	(_)	(_)	(_)
Text clarity	(_)	(_)	(_)	(_)	(_)
Completeness of text	(_)	(_)	(_)	(_)	(_)

3.   Overall, how do you   Excellent   Good   Satisfactory   Poor   No opinion
        rate this report?   (_)   (_)   (_)   (_)   (_)

4.   How can this report be improved?

5.   May we contact you to discuss possible improvements?
        Name:
        Telephone #:

To discuss the information in this report, contact: 202-418-0940		
or for users of TTY equipment, call 202-418-0484		
Fax this response to	or	Mail this response to
202-418-0520		FCC/WCB/IATD, Mail Stop 1600 F Washington, DC 20554

EXHIBIT 6

Study Area Name	Number of ILEC Loops	Unseparated NTS Revenue Requirement	Total High-Cost Support Payments	High-Cost Support per Line	Total ILEC Interstate Access Minutes
Bretton Woods Tel. Co.	965	$311,110	$396,558	$411	1,340,819
Granite State Tel.	9,704	$4,552,486	$2,151,753	$222	25,486,325
Dixville Tel. Co.	470	$255,892	$107,745	$229	510,617
Dunbarton Tel. Co.	1,724	$794,523	$305,274	$177	4,153,524
Kearsarge Tel. Co.	9,176	$3,047,272	$919,740	$100	29,661,608

Study Area Name	Number of ILEC Loops	Net Present Value of Profit	Net Present Value Remaining after $100,000 Application Costs
Bretton Woods Tel. Co.	965	$926,813	$826,813
Granite State Tel.	9,704	$9,319,992	$9,219,992
Dixville Tel. Co.	470	$451,401	$351,401
Dunbarton Tel. Co.	1,724	$1,655,778	$1,555,778
Union Tel Co.	7,263	$6,975,587	$6,875,587
Kearsarge Tel. Co.	9,176	$8,812,886	$8,712,886
Merrimack County Tel.	7,545	$7,246,428	$7,146,428
Wilton Tel Co.	3,185	$3,058,963	$2,958,963
MCTA	11,500	$11,044,920	$10,944,920

Profits per 1,000

960,428

Study Area Name	Number of ILEC Loops	Unseparated NTS Revenue Requirement	Total High-Cost Support Payments	High-Cost Support per Line
Bretton Woods Tel. Co.	965	$311,110	$396,558	$411
Granite State Tel.	9,704	$4,552,486	$2,151,753	$222
Dixville Tel. Co.	470	$255,892	$107,745	$229
Dunbarton Tel. Co.	1,724	$794,523	$305,274	$177
Union Tel Co.	7,263	$1,806,797	$1,246,824	$172
Kearsarge Tel. Co.	9,176	$3,047,272	$919,740	$100
Merrimack County Tel.	7,545	$2,186,344	$1,206,180	$160
Wilton Tel Co.	3,185	$1,066,077	$463,980	$146
MCTA	11,500	$3,513,457	$1,128,258	$98

Total ILEC Interstate Access Minutes
1,340,819
25,486,325
510,617
4,153,524
18,612,909
29,661,608
24,225,540
10,523,696
38,563,972

Year	ILEC Customers		Market Share in 60% of Area		Monthly Revenue per Customer	Operating Margin	Margin per Customer	Net Revenue	Discounted Net Revenue
1	1000	#	6%	#	$115.00	80%	$92.00	$66,240	$59,542
2	1000	#	9%	#	$115.00	80%	$92.00	$99,360	$80,281
3	1000	#	12%	#	$115.00	80%	$92.00	$132,480	$96,217
4	1000	#	15%	#	$115.00	80%	$92.00	$165,600	$108,109
5	1000	#	18%	#	$115.00	80%	$92.00	$198,720	$116,612
6	1000	#	21%	#	$115.00	80%	$92.00	$231,840	$122,289
7	1000	#	21%	#	$115.00	80%	$92.00	$231,840	$109,923
8	1000	#	21%	#	$115.00	80%	$92.00	$231,840	$98,807
9	1000	#	21%	#	$115.00	80%	$92.00	$231,840	$88,815
10	1000	#	21%	#	$115.00	80%	$92.00	$231,840	$79,834
							Present Value		$960,428

Discount Rate   1.1125