

THE BROADBAND AVAILABILITY GAP

OBI TECHNICAL PAPER NO. 1

TABLE OF CONTENTS

List of Exhibits	III
List of Assumptions	VIII
Introduction	1
I The Investment Gap	5
Creating the Base-Case Scenario and Output	10
II Broadband Availability	17
Current State	17
Future State	26
III Calculating the Investment Gap	33
Key Principles	33
Key Decisions	37
Key Assumptions	42
IV Network Economics	59
Basic Network Structure	59
Last-mile Technology Comparison	59
Technologies Included in the Base Case	62
<i>Wireless Technology</i>	62
<i>12,000-foot-loop DSL (Digital Subscriber Line)</i>	84
<i>Satellite</i>	89
Technologies Not Included in the Base Case	94
<i>Fiber-to-the-premises (FTTP)</i>	94
<i>3,000 – 5,000 foot DSL</i>	98
<i>15,000 foot DSL</i>	102
<i>Hybrid Fiber-Coax Networks</i>	102
Network Dimensioning	109
Middle-Mile Analysis	114
List of Common Abbreviations	128
Glossary	130
List of Technical Paper Contributors	137

LIST OF EXHIBITS

Exhibit A: Approach to Determining the Availability Gap2

Exhibit 1-A: Base-case Broadband Availability Gap5

Exhibit 1-B: Breakout of Ongoing Costs by Category6

Exhibit 1-C: Gap by Census Blocks Ordered by Population density6

Exhibit 1-D: Broadband Investment Gap per County7

Exhibit 1-E: Broadband Investment Gap per Housing Unit in Each County8

Exhibit 1-F: Density of Unserved Housing Units per Square Mile9

Exhibit 1-G: Broadband Investment Gap, by County10

Exhibit 1-H: Ongoing Support for Each Housing Unit per Month 11

Exhibit 1-I: Investment Gap per Housing Unit by Lowest-Cost Technology for Each County12

Exhibit 1-J: Lowest Cost Technology 13

Exhibit 2-A: Highest Speed Capability of Available Wired Broadband Networks in the United States..... 17

Exhibit 2-B: Availability of Broadband Networks Capable of Meeting the National Broadband Target18

Exhibit 2-C: Population Density of the United States, Per Square Mile of Inhabited Census Block.....19

Exhibit 2-D: Population Density of the Unserved, Per Square Mile of Inhabited Census Block 20

Exhibit 2-E: Statistics of Urban Areas/ Clusters, and All Other Areas 20

Exhibit 2-F: Linear Density of the United States, Ratio of Road Mile to Housing Units 21

Exhibit 2-G: Linear Density of the Unserved, Ratio of Road Miles to Housing Units 22

Exhibit 2-H: Cable Broadband Deployment for a Few Large MSOs as a Percentage of Homes Passed 23

Exhibit 2-I: Assumptions Required to Use Tract-Level Data Likely Overestimate Availability..... 24

Exhibit 2-J: Aligning Infrastructure with Availability 25

Exhibit 2-K: Publicly Announced Wired Broadband Upgrades 26

Exhibit 2-L: With the Exception of Satellite, Most Announced Broadband Deployments are Completed on Schedule.....27

Exhibit 2-M: Projected 2013 Availability of Broadband Capable Networks.....27

Exhibit 2-N: Publicly Announced 4G Wireless Deployments 28

Exhibit 2-O: Specific Company Historical Performance Against Announced Completion Dates..... 28

Exhibit 2-P: Publicly Announced Total Near Term Satellite Broadband Capacity..... 29

Exhibit 2-Q: Commercial Data Sources Used to Calculate Availability 29

Exhibit 2-R: Public Data Sources Used to Calculate Availability 30

Exhibit 3-A: Impact of Discount Rate on Investment Gap 34

Exhibit 3-B: Incremental Network Elements Necessary to Upgrade a Telephone Network to Offer Broadband..... 35

Exhibit 3-C: Incremental Revenue by Product and Network Type 36

Exhibit 3-D: Gap for Funding One Wired and One Wireless Network..... 38

Exhibit 3-E: The Cost of Funding Two Wired Networks..... 38

Exhibit 3-F: Quantifying the Treatment of Competition 39

Exhibit 3-G: Quantifying the Impact of Competition: Investment Gap by Number of Providers 39

Exhibit 3-H: Broadband Investment Gap, by Percent of Unserved Housing Units Served 40

Exhibit 3-I: Total Investment Cost for Various Upgrade Paths 41

Exhibit 3-J: Distribution of Users by Actual Maximum Download Speeds (Mbps)..... 43

Exhibit 3-K: Actual Download Speeds Necessary to Run Concurrent Applications (Mbps) 44

Exhibit 3-L: Typical (Median) “Up To” Advertised Download Speeds of Most Commonly Deployed
and Chosen Consumer Household Broadband (Mbps) 44

Exhibit 3-M: Dependence of the Broadband Investment Gap on Speed of Broadband Considered 45

Exhibit 3-N: Broadband Take-Rate Drivers 45

Exhibit 3-O: Model for Technology Adoption 46

Exhibit 3-P: Modeled Cumulative Adoption 46

Exhibit 3-Q: Incremental Adoption..... 46

Exhibit 3-R: Broadband Adoption Curve 47

Exhibit 3-S: Gompertz Curves for Broadband Take Rate With Demographics 48

Exhibit 3-T: Assumed Percentage of Customers with Bundles..... 49

Exhibit 3-U: Sensitivity of Gap to Take Rate 49

Exhibit 3-V: Summary of Modeled ARPUs 50

Exhibit 3-W: ARPU Sensitivity 51

Exhibit 3-X: Elevation Across the U.S..... 52

Exhibit 3-Y: Estimated Average Cell Size in Each County and Terrain 53

Exhibit 3-Z: Sensitivity of Build-Out Cost and Investment Gap to Terrain Classification Parameters 54

Exhibit 4-A: Basic Network Structure 59

Exhibit 4-B: Streaming Capacity of Modeled Broadband Networks..... 60

Exhibit 4-C: Present Value of Total Costs for All Technologies in Unserved Areas 62

Exhibit 4-D: Different Wireless Technology Families Have Evolved Over Time 64

Exhibit 4-E: Downlink and Uplink Spectral Efficiencies by Technology 64

Exhibit 4-F: Evolution of Round-Trip Latencies in Wireless Networks, in Milliseconds..... 65

Exhibit 4-G: Publicly Announced 4G Wireless Deployments 65

Exhibit 4-H: Approach for Analyzing Cost of FWA Network..... 67

Exhibit 4-I: Methodology for Determining Maximum Cell Radius for Coverage..... 68

Exhibit 4-J: Link Budget for Delivering 1.26 Mbps Uplink Speeds at 700MHz..... 68

Exhibit 4-K: Classification of Terrain of Census Tracts 69

Exhibit 4-L: Maximum Cell Radius for Adequate Coverage in the 700MHz Band..... 69

Exhibit 4-M: Propagation Loss for Different Terrain Types at 700MHz..... 69

Exhibit 4-N: Average Cell Size in Each County (in miles)..... 70

Exhibit 4-O: Coverage of Unserved Housing Units by Cell Radius 71

Exhibit 4-P: Methodology for Dimensioning Wireless Networks to Provide Adequate Capacity.....72

Exhibit 4-Q: Maximum Number of Subscribers Per Cell Site in an FWA Network with Directional Antennas at the CPE.....72

Exhibit 4-R: Impact of Directional Antennas at CPE on SINR.....73

Exhibit 4-S: Spectrum Needs for Cell Sites in 2020 and 2030, Based on BHOL of 160 kbps 74

Exhibit 4-T: Average and Peak Capacity of a 3-Sector Cell Site Relative to Backhaul Speeds, Mbps 75

Exhibit 4-U: Hybrid Fiber Microwave Backhaul Architecture for Cellular Networks 76

Exhibit 4-V: Illustrative Wireless Network Architecture 77

Exhibit 4-W: Investment Gap for Wireless Networks..... 78

Exhibit 4-X: Total Investment per Housing Unit (HU) and Investment Gap per HU by Cell Size 78

Exhibit 4-Y: Sensitivity of Investment Gap to Terrain Classification—Change in Costs and Investment Gap by Changing Terrain Classification..... 79

Exhibit 4-Z: Sensitivity of Costs and Investment Gap to Subscriber Capacity Assumptions 80

Exhibit 4-AA: Impact of Spectrum Availability on FWA Economics..... 80

Exhibit 4-AB: Cost Breakdown of Wireless Network Over 20 Years 81

Exhibit 4-AC: Breakdown of Total Site Costs for Wireless Network in Unserved Areas 81

Exhibit 4-AD: Cost of an HFM Second-Mile Backhaul Architecture 82

Exhibit 4-AE: Cost Assumptions and Data Sources for Wireless Modeling..... 82

Exhibit 4-AF: Breakout of Voice Line Ownership..... 84

Exhibit 4-AG: Telco-Plant Upgrades to Support Broadband..... 85

Exhibit 4-AH: Downstream Speed of a Single ADSL2+ Line as a Function of Loop Length (24 AWG)..... 86

Exhibit 4-AI: DSL Network Diagram.....87

Exhibit 4-AJ: Capacity of a DSL Network—Simultaneous Streams of Video in a DSL Network.....87

Exhibit 4-AK: Economic Breakdown of 12,000-foot DSL.....87

Exhibit 4-AL: Data Sources for DSL Modeling..... 88

Exhibit 4-AM: Available Satellite Capacity Through 2015..... 90

Exhibit 4-AN: Satellite Usage Scenarios 91

Exhibit 4-AO: Satellite Capacity Based on Low, Medium and High Usage Scenarios 91

Exhibit 4-AP: Economics of Terrestrially Served if Most Expensive Housing Units are Served with Satellite 92

Exhibit 4-AQ: Location of Highest-Gap Housing Units 93

Exhibit 4-AR: Satellite Capex per Subscriber 94

Exhibit 4-AS: Capabilities of Passive Optical Networks (PON) 95

Exhibit 4-AT: Passive Optical Network (PON) FTTP Deployment..... 95

Exhibit 4-AU: Future PON Architectures 95

Exhibit 4-AV: Breakout of FTTP Gap..... 96

Exhibit 4-AW: Cost to Pass with FTTP by Density of Homes 97

Exhibit 4-AX: Simple Financial Model to Calculate Breakeven EBITDA for FTTP 97

Exhibit 4-AY: Estimated Monthly EBITDA Required to Break Even on an FTTP Build Across the Country 98

Exhibit 4-AZ: Data Sources for FTTP Modeling..... 98

Exhibit 4-BA: Downstream Speed of a Single VDSL2 Line at Various Loop Lengths 99

Exhibit 4-BB: Upstream Speed of a Single VDSL2 Line at Various Loop Lengths..... 99

Exhibit 4-BC: Downstream Speed of VDSL2 Variants 100

Exhibit 5-BD: Upstream Speed of VDSL2 Variants..... 100

Exhibit 4-BE: Breakout of 3,000-Foot DSL Gap 101

Exhibit 4-BF: Breakout of 5,000-Foot DSL Gap 102

Exhibit 4-BG: Breakout of 15,000-Foot DSL Gap..... 102

Exhibit 4-BH: Breakout of Cable Coverage..... 103

Exhibit 4-BI: Upgrades to Enable Broadband Services..... 104

Exhibit 4-BJ: Spectrum Allocation in Cable Plant 105

Exhibit 4-BK: Cable Video ARPU Over Time..... 106

Exhibit 4-BL: Upgrade Costs for Cable Plant107

Exhibit 4-BM: Outside Plant Cost, FTTP or RFoG vs. HFC.....107

Exhibit 4-BN: HFC Plant Diagram 108

Exhibit 4-BO: Data Sources for HFC Modeling 108

Exhibit 4-BP: Differences Between Voice and Data Networks 110

Exhibit 4-BQ: Monthly Usage and BHOLs by Speed Tier 112

Exhibit 4-BR: Usage by Tier and BHOL 112

Exhibit 4-BS: Expected Future BHOL in Broadband Network Dimensioned to Deliver 4 Mbps..... 113

Exhibit 4-BT Likelihood of Achieving a Burst Rate Greater Than 4 Mbps at Different Oversubscription Ratios with a Varying Number of Subscribers 113

Exhibit 4-BU: Breakout of Middle, Second & Last Mile 115

Exhibit 4-BV: Topology Used for Middle-Mile Cost Modeling..... 116

Exhibit 4-BW: Calculated Telco Fiber Routes 118

Exhibit 4-BX: Classification of Central Offices for Creating Fiber Map..... 119

Exhibit 4-BY: Middle-Mile Cost Dependency on Capacity 120

Exhibit 4-BZ: Middle-Mile Build vs. Lease Comparison 121

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.

Chart	Description	Technology	Key assumptions	
			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,

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

BOX A

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.

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.

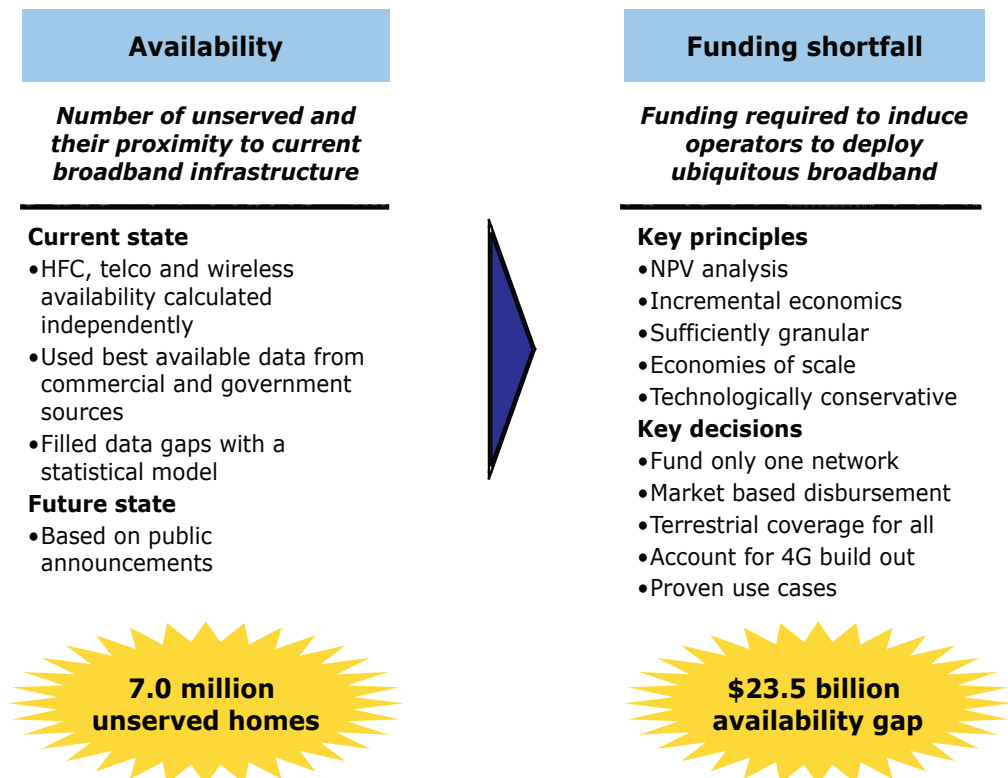
- ▶ **Investment decisions are made on the incremental value they generate.** While firms seek to maximize their overall profitability, investment decisions are evaluated based on the incremental value they provide. In some instances, existing assets reduce the costs of deployment in a given area. The 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

*Exhibit A:
Approach to
Determining the
Availability Gap⁴*



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).