TELECOM ADVISORY SERVICES

# ASSESSMENT OF THE IMPACT OF THE BROADBAND DATA SERVICES MARKET DYNAMICS ON INNOVATION AND COMPETITION IN THE U.S. WIRELESS MARKET

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## AUTHOR

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## EXECUTIVE SUMMARY

Wireless backhaul is a critical and unique input to competitive wireless services. Some wireless inputs are held by each carrier, such as spectrum licenses (although spectrum can also be shared across operators) and base station electronics. Other inputs are typically purchased from third parties, such as cell towers, end user devices, and, often, backhaul. Wireless backhaul, particularly in the United States, represents a special case from an industrial organization standpoint. Two carriers, AT&T and Verizon, control 66% of total retail wireless connections[1] and can acquire Business Data Services ("BDS") to use as wireless backhaul directly from their wireline incumbent local exchange carrier ("ILEC") affiliates. On the other hand, competitive wireless carriers (such as Sprint, T-Mobile, US Cellular and other Competitive Carriers Association (CCA) members that serve rural and remote parts of the country) can, in some cases, deploy their own or use an affiliate's infrastructure or, in most cases, purchase BDS from third party providers, such as competitive local exchange carriers ("CLECs"), cable companies, or ILECs.[2] Where a competitive wireless carrier must purchase BDS from AT&T or Verizon, the competitive carriers are in the disadvantageous position of having to compete downstream (*i.e.*, in the wireless market) with operators that control a critical input of their production chain (*i.e.*, wireless backhaul).

Evidence has been compiled in numerous comments filed in the FCC BDS proceeding to support the argument that ILECs are exercising market dominance in the BDS market through the following approaches:

- Supra-competitive BDS prices: BDS customers are frequently required to purchase BDS from the ILEC at supra-competitive prices as a result of ILEC market dominance;
- Wholesale rates higher than retail: despite their large volume purchase commitments, wholesale customers are charged higher rates than enterprise customers;
- High month-to-month rates: as a result of stringent loyalty mandates, month-to-month purchasing is subject to much higher rates than long term contracts;
- Loyalty mandates: the purchaser of backhaul servicers has to commit to purchase a set level of links and capacity which restricts the ability of a BDS competitive provider, such as a CLEC, to enter the market;
- Excessive penalties for reduction of the loyalty commitment: ILEC charges "commitment shortfall" penalties that exceed the amount of missed volume; and

[1] Source: GSMA Intelligence database.

[2] Purchasing from an ILEC affiliate is the only option available in approximately 70% of locations around the country. *Bus. Data Services in an Internet Protocol Env't*, Tariff Investigation Order and Further Notice of Proposed Rulemaking, FCC No. 16-54, WC Docket Nos. 16-143, 15-247, 05-25, RM-10593 (rel. May 2, 2016), App. B Rysman, M., "Empirics of Business Data Services" at 224 ("*FNPRM*").

- Unworkable portability restrictions: the backhaul purchaser that needs to shift circuits to respond to demand changes is prevented from doing so by loyalty provisions.

The purpose of this study is to assess the impact of the current BDS (previously known as special access services) market dynamics on backhaul economics as a factor driving innovation and competition in the wireless market. The study examines the following questions:

- How is purchasing BDS for backhaul services from ILEC affiliates of the two largest wireless carriers impacting network deployment of competitive carriers' wireless services?
- Is purchasing BDS for backhaul services from ILEC affiliates of the two largest wireless carriers impacting service quality of competitive wireless carriers?
- How would current BDS market conditions impact the future ability of competitive wireless carriers to migrate to 5G services?
- What is the impact of current BDS market conditions on future wireless competition, particularly in rural areas of the country?

This study is based on interviews of four regional wireless operators, one national wireless carrier, and a Competitive Local Exchange Carrier (CLEC), complemented with the compilation of industry benchmarking and economic wireless engineering data. These information inputs were used to simulate several economic effects of current BDS market dynamics.

***First Conclusion: Competitively-priced backhaul services will increase competitive wireless carriers' capital expenditures, leading to greater funds assigned for network deployment and maintenance, and developing new service offerings.***

Backhaul costs represent almost 6% in some cases of a wireless carrier total operating expenses (OPEX) and 30% of total network costs.[3] The range in the percentage of total OPEX that constitutes backhaul costs is driven by factors such as number of cell sites, build vs. rent of backhaul links, microwave vs. fiber optics in owned links, and leased lines from CLECs or ILEC affiliated carriers. In this context, a potential reduction in backhaul pricing (such as, for example, resulting from reducing the cost of BDS services to reflect competition in the marketplace through BDS rate regulation or reducing wholesale BDS rates to retail BDS rates) could result in an equivalent decrease of the overall cost structure. Subsequently, a wireless carrier could transfer the reduction in OPEX to CAPEX, investing in better network facilities, or could use the reduction to increase its profits. Separately, it could also enable

[3] The main body of this report includes the detailed calculations used to arrive at this range. It has been estimated that backhaul costs represent 33% of a cell site operating cost. *See* Comments of Sprint Nextel Corp., WC Docket No. 05-25, RM-10593 (filed Aug. 8, 2007), Statement of Gary Lindsey (2007). This percentage was estimated by dividing Sprint Nextel's total backhaul costs incurred in 2006 by the total costs of operating its cell sites.

carriers to lower service pricing. Prior research on the impact of regulatory initiated cost reduction initiatives on the economics of telecommunications carriers in the United States (Katz et al, 2012) estimates that carriers transfer approximately 85% of the decrease to CAPEX, while the remaining 15% is transferred to profits. Accordingly, wireless carriers transfer a very significant portion of an OPEX decrease to CAPEX.

Based on these assumptions, a set of sensitivity analyses were developed to determine the range of impact of a potential reduction of BDS pricing, initially assuming a very conservative 50/50 split between owned and leased backhaul links. This split is extremely conservative given that many competitive carriers purchase all their backhaul links, rather than build out their own infrastructure.

**Table A. Sensitivity Scenarios of Reduced BDS Backhaul Prices**

| | | Overall Backhaul Savings | | |
|---|---|---|---|---|
| | | **10%** | **20%** | **30%** |
| **Backhaul as Percentage of OPEX (*)** | **2.25 %** | • BDS pricing declines by 20%<br>• CAPEX increases by 0.91% | • BDS pricing declines by 40%<br>• CAPEX increases by 1.81% | • BDS pricing declines by 60%<br>• CAPEX increases by 2.69% |
| | **4.30 %** | • BDS pricing declines by 20%<br>• CAPEX increases by 1.73% | • BDS pricing declines by 40%<br>• CAPEX increases by 3.40% | • BDS pricing declines by 60%<br>• CAPEX increases by 5.01% |
| | **5.95 %** | • BDS pricing declines by 20%<br>• CAPEX increases by 2.38% | • BDS pricing declines by 40%<br>• CAPEX increases by 4.64% | • BDS pricing declines by 60%<br>• CAPEX increases by 6.81% |

(*) The three estimates of backhaul as percentage of OPEX represent the average ranges of estimates calculated through bottom up benchmarking presented in Column 3 of Table 9 of this report.
*Source: Telecom Advisory Services analysis*

This analysis demonstrates that if, for example, backhaul costs represent 5.95% of carrier OPEX, and assuming that they are split 50/50 between carrier-owned infrastructure on one side and BDS links on the other, a scenario of 30% overall backhaul savings driven by a reduction of 60% in BDS prices would yield an increase in CAPEX of 6.81%. Alternatively, if the competitive carrier does not have any owned infrastructure and relies solely on BDS for backhaul purposes, a 60% reduction in BDS prices would result in 12.75% increase in CAPEX.

The BDS price decline scenarios in Table A are achievable and realistic in a truly competitive BDS marketplace. In fact, it was reported in one carrier interview (identified as Carrier # 6 in the main body of this report) that in areas where an ILEC and at least two CLECs offered BDS services, the carrier saw ILEC prices drop by 50%; however, in areas where there was only the ILEC and 1 CLEC, the carrier saw prices declined only by 10%. In other words, a competitive environment with 3+ players resulted in BDS price declines close to the scenarios outline above. Therefore, if rate regulations were adopted to reflect competitive pricing conditions and ultimately reduced prices by the reductions calculated herein, wireless carriers would likely experience significant CAPEX growth. This increase in capital spending would, in turn, result in improved service quality, better coverage, and lower churn, as well as increased competition against incumbents.

***Second Conclusion: High backhaul costs reduce competitive wireless carrier service quality, increase industry consolidation and exacerbate the digital divide.***

The United States wireless data traffic has been growing annually at rates over 60% and is projected to continue growing at 57% annually through at least 2020. This growth is driven largely by adoption of smart connected devices and usage per terminal. To accommodate this growth in traffic, wireless carriers can acquire more spectrum, migrate to spectrum efficient technologies, where economically available, or increase the number of cell sites (a reconfiguration of the network known as cell splitting[4]).

In general terms, the cost of backhaul (in addition to rent and power costs) doubles when a cell is split. In order to control backhaul costs, a carrier that considers splitting a cell needs to evaluate whether the price of BDS and/or the related contractual obligations impose an economically prohibitive hurdle. For example, as reported in another carrier interview (identified as Carrier #1 in the body of this report), this operator caps BDS backhaul costs for rent in an area where cell splitting might occur at $1,500 per month. If the cost exceeds this threshold, the carrier might opt not to split the overburdened cell. Under this scenario, the carrier's customers experience an increase in blocked and dropped calls, as well as higher latency in data services.

Prior research (Katz et al, 2014) has shown that service quality erosion leads to an increase in churn. For example, according to our analysis based on US data, an increase of 1 millisecond in latency increases churn by 0.00144 percentage points.[5] Unless a competitive wireless carrier can deploy its own infrastructure for backhaul—which might be cost prohibitive for most competitive carriers—or acquire backhaul links at competitive pricing, the possibility of economically achieving cell splitting is limited and, under this scenario, the competitive wireless carrier incurs an increase in churn, a consequent loss of market share, and, ultimately, revenues. In other words, if cell splitting becomes cost prohibitive, the competitive wireless carrier endures a service quality degradation and consequent loss in market position. Econometric analysis of US data (Katz et al, 2014) indicates that an increase of 1

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[4] A cell site is an area within a carrier's wireless network, which is serviced by an antenna array. A carrier's coverage area is dependent upon the capacity of its equipment and the frequency of the signal being transmitted. As data usage increases, it places greater demands on cell sites. As a result, networks become overburdened and carriers must split cell sites to meet subscriber demand.

[5] Similarly, a decrease of 1% in data sessions over 1 Mbps increases churn by 0.0159 percentage points.

millisecond in latency tends to decrease total market share by 0.0058 percentage points.

Alternatively, according to Carrier # 6, under an increase in traffic, a rural carrier might not split cells in order to accommodate traffic growth. This situation may not result in a loss of market share for the rural carrier due to the lack of competitive alternatives for the consumer. However, under this scenario, the rural consumer progressively undergoes an erosion of service quality. In turn, this produces a greater digital divide, where rural areas are left with poorer service quality.

***Third Conclusion: Current BDS market conditions impact the competitive wireless carriers' ability to migrate to 5G services***

5G is generally defined as a technology that provides throughput that will be 10-100x faster than 4G,[6] which could mean real-world speeds of about 4 Gbps or more. Most of the speed increases are due to carriers adding more wireless channels, using millimeter wave technology (which means the signal has to travel shorter distances), installing small cells that dramatically increase the coverage map, and increasing capacity in the wired backhaul locations.

The increase of 15 to 20 times in throughput resulting from the migration from LTE/LTE-A to 5G will change the sizing requirements of the backhaul networks, driving dense 10 Gbps and 100 Gbps requirements close to the cell site.[7] The increase in backhaul costs depends on the 5G migration approach that the wireless carrier takes. In the near future, wireless carriers will face a decision as to whether to deploy 5G in Stand Alone (5G New Radio (NR) to a 5G core) or in Non-Stand Alone (5G NR to a 4G core). Under the first scenario, 5G requires its own backhaul while under non-stand alone, 5G shares the backhaul with 4G for signaling. Even under the non-standalone case, wireless carriers will require additional backhaul capacity as a result of the increased throughput. The standalone option presents competitive wireless carriers with the largest hurdle, entailing a higher barrier to migration. In fact, according to Carrier # 1, ILECs appear to be pushing for a Stand Alone solution in standards, which would not allow new radios to connect to older cores. If this were to happen, a competitive carrier will have to buy a completely new core network in order to migrate to 5G. This will create an additional hurdle and barrier to entry in the next 5 years.

The current BDS regime has a significant impact on the economics of 5G deployment, consequently delaying the migration of competitive wireless carriers to the new technology. In fact, based on information obtained in interviews with Carriers 1, 2, 3 and 6, competitive wireless carriers cannot even consider a 5G migration under

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[6] *See* Tom Wheeler, Chairman, FCC, The Future of Wireless: A Vision for U.S. Leadership in a 5G World," at the Nat'l Press Club at 1 (June 20, 2016).

[7] The increase in backhaul costs resulting from migrating to 5G is not necessarily proportional to the number of new cells, given that many of the small sites would not require their own link.

current BDS backhaul economics. The resulting effect could ultimately be that AT&T and Verizon will more quickly launch 5G, while the rest of the industry (and consumers) is relegated to prior generations of wireless technology. Several studies indicate that carriers that introduce leading edge wireless technologies can build lasting competitive advantage. For example, by rapidly building economies of scale, the first mover can achieve lower unit costs than its competitors, while it can start learning how to optimize production under new technology before its competitors. Furthermore, by being the first to introduce a new technology, the first mover can compete in more favorable market conditions, while the followers need to operate in a more crowded market. These effects could further accentuate market inequities. This has already been the case with 4G. By becoming the leader in LTE deployment, Verizon Wireless profited before its competitors, achieving by 1Q2016 the lowest churn (1.23%), and the highest ARPU ($49.77) in the US wireless industry. In addition, the anticipated investment paid off in terms of customer perception, with the quality gap between Verizon and the other national carriers increasing over time.

***Fourth Conclusion: Current BDS market conditions impede future US economic growth, particularly in rural areas of the country***

The wireless industry is more concentrated in rural areas. The National Broadband Map data reveal that the 3.1% percent of the total US population by county is served by only one or two wireless carriers. However, when analyzing industry structure at the geographically segmented level, wide disparities emerge. We have analyzed wireless service industry structure in the following five states selected for the extent of their rural population: Kentucky, New Hampshire, Oregon, Vermont and West Virginia.[8]

With the exception of urban counties in Kentucky, New Hampshire and Oregon, all other counties in the five selected states exhibit a much higher percentage of the population than the national average served by either one or two wireless operators. For example, in West Virginia, 20.6% of the suburban population and 33.8% of the residents in rural counties can access wireless broadband service from, at best, two operators (see Table B).

[8] We classified all the counties in each of the five states across the urban-rural continuum code provided by the Department of Agriculture. Each county was assigned a code (urban-suburban-rural). Next, all counties in each states were grouped according to the three classifications. Subsequently, using the data in the National Broadband Map, we estimated the population-weighted average of the percent of population being served by one, two or more wireless carriers.

**Table B. Comparative Coverage Metrics by County (Percent of Population)**

| | FCC Claimed Population served by 1 or 2 carriers (%) | | |
|---|---|---|---|
| National | 3.1 | | |
| | **Urban Counties** | **Suburban Counties** | **Rural Counties** |
| Kentucky | 0.7 | 5.3 | 24.7 |
| N. Hampshire | 2.1 | 5.0 | 16.2 |
| Oregon | 0.7 | 4.7 | 6.4 |
| Vermont | 4.8 | 14.1 | 19.7 |
| W. Virginia | 12.9 | 20.6 | 33.8 |

*Source: National Broadband Map; TAS analysis*

The underlying premise of this analysis is widely accepted and supported by economic literature: a market served by only two providers cannot generate sufficient consumer benefits derived from appropriate competitive dynamics.[9] For example, in his research on the risk of collusive behavior, Selten (1973) established through a theoretical model that "four players are few and six are many." Therefore, according to the research on the optimal number of players in a static context, two firms would not be sufficient to obtain effective competition. That has also been supported by Kwoka (1979), Mueller and Greer (1984), and Besen and Mitchell (2016). Additionally, there are several economic studies on the relationship between firm size and market structure on the one hand, and technological innovation on the other (Aghion et al., 2005).

In the context of highly concentrated rural markets, high backhaul costs resulting from the dominance of AT&T and Verizon's ILEC affiliates in the BDS sector could further increase the barriers to entry, thus exacerbating industry concentration. Furthermore**,** if the backhaul economics of 5G implementation were disadvantageous, carriers operating in rural areas would not be able to migrate to the newer technology. This situation could accentuate the digital divide, preventing rural population from obtaining access to the latest wireless technology.

[9] *See .Applications of AT&T Inc. and Deutsche Telekom AG*, Order, 26 FCC Rcd. 16,184, 16,206-07 (2011).

# 1. INTRODUCTION

A value chain framework of the wireless industry comprises a number of inputs including access to radio-frequency spectrum, cell towers, base stations, backhaul links, mobile switching, end-user devices, distribution channels, and customer service. Some of these inputs are owned by each carrier (spectrum licenses, base station electronics, mobile switching infrastructure, direct distribution channels, and customer service facilities), while other ones can be shared across carriers or purchased from an outside party (cell towers, end-user devices, indirect distribution channels). Other inputs can either be provisioned in-house or acquired from a third party (leased lines for backhauling and carrier interconnection).

Wireless backhauling, particularly in the United States, represents a special case. Two carriers, AT&T and Verizon, control 66% of total retail wireless connections[10] and can acquire this input directly from their wireline affiliates. On the other hand, competitive carriers (including Sprint, T-Mobile, and other CCA members) can, in some cases, deploy their own or use an affiliate's infrastructure (microwave links or fiber optics) or, in most cases, purchase BDS services from third party providers (ILECs, CLECs, or cable companies). Therefore, where competitive wireless carriers are forced to purchase backhaul from ILECs due to lack of competitive alternatives, they must compete downstream in the wireless markets with operators that are affiliated with the companies that control the critical backhaul input. This is not a mere theoretical possibility. The ILEC is the only BDS provider in approximately 73 percent of locations nationwide.[11]

The ILECs argue that this situation does not put the competitive carriers at a disadvantage since the BDS market is competitive. If the BDS market were competitive (meaning the ILECs cannot exercise undue dominance), competitive wireless carriers would not be harmed by not being present at that stage of the value chain. They would make decisions, based on economic and strategic considerations, to either deploy their own infrastructure or purchase access from the ILECs or any other provider.

On the other hand, if the BDS market is not competitive—as argued by numerous parties including CCA, other competitive wireless carriers, CLECs, and consumer groups—the ILECs dominance could result in several harmful effects to consumers:

- **Reduced competition**: Under conditions of market dominance, and consistent with the industrial organization literature, the provider of backhaul can raise prices and/or impose onerous contract terms and conditions. These could harm competition by preventing non-vertically integrated operators

10 Source: GSMA Intelligence database.

11 Comments of Sprint Corporation at 2, 22, 87, WC Docket No. 05-25, RM-10593 (filed Jan. 27, 2016) ("Sprint Comments").

(*i.e.*, the competitive carriers) from offering comparable services. If the dominant provider is also present in downstream markets, these could accentuate market imbalances.

- **Limited innovation**: The ever-increasing mobile broadband traffic will push wireless carriers to migrate to a 5G infrastructure. 5G networks require more cell sites than 4G. A larger footprint of cell sites is going to increase demand of backhaul services. If the BDS market is not competitive, this could further impact the value chain imbalance. For example, it could increase backhaul costs as a percentage of total operating costs for competitive carriers. This could affect the economics of 5G services and, ultimately, delay the migration of competitive carriers. The resulting effect could be that AT&T and Verizon, the only ILECs with nationwide wireless networks, would have launched 5G while the rest of the industry is relegated to prior generations of wireless technology. Studies indicate that carriers that introduce leading edge wireless technologies can build lasting competitive advantage. This effect could further exacerbate market inequities and industry concentration.

- **Accentuating the digital divide**: If the backhaul economics of 5G implementation were disadvantageous, carriers operating in rural areas would not be able to migrate to the newer technology. This situation could accentuate the digital divide, limiting the ability of rural populations to gain access to the latest wireless technology. This is an analogue case to the dichotomy of wireline broadband deployment between fiber optic Next Generation Access platforms in urban and suburban areas and slower access infrastructure in rural territories.

In the context of the prior argument, this study tackles four key questions:

- How is purchasing BDS for backhaul services from the ILEC affiliates of the two largest wireless carriers impacting network deployment of competitive carriers' wireless services?
- Is purchasing BDS for backhaul services from the ILEC affiliates of the two largest wireless carriers impacting service quality of competitive carriers?
- How would current BDS market conditions impact the future ability of competitive wireless carriers to migrate to 5G services?
- What is the impact of current BDS market conditions on future economic growth, particularly in rural areas of the country?

This study is based on interviews that Telecom Advisory Services, LLC ("TAS") conducted with four regional wireless carriers, one national wireless carrier, and a CLEC that sells backhaul services to regional wireless carriers.

**Table 1. Carrier Interviews**

| Carrier # | Carrier Description | States Covered |
|---|---|---|
| 1 | Rural carrier | 2 |
| 2 | Regional carrier | 23 |
| 3 | Rural carrier | 2 |
| 4 | National carrier | 50 |
| 5 | CLEC | 3 |
| 6 | Rural carrier | 2 |

The study was complemented with the compilation of industry benchmarking and economic wireless engineering data. These information inputs were used to simulate the economic effect of current BDS market dynamics.

# 2. THE IMPACT OF BACKHAUL COSTS ON WIRELESS NETWORK DEPLOYMENT

An analysis was undertaken to determine the impact of a reduction in backhaul costs driven by rate and conduct regulation on wireless network deployment. This issue is important because an increase in wireless deployment is very likely to enhance competition in the wireless markets and improve consumer welfare.

In order to tackle this question, it was necessary to simulate cost changes in the cost structure of a competitive carrier. For this purpose, one must first understand the portion of a competitive wireless carrier's overall cost structure represented by backhaul costs. Once this amount is estimated, one can determine what portion of a reduction in backhaul prices a carrier would use to increase CAPEX and what portion would translate into higher margins. An increase in CAPEX would accelerate the deployment of wireless networks, with the consequent improvement in coverage and quality of service. The analysis is structured into three steps:

1. Estimate the portion of a wireless carrier total operating costs that is spent on backhaul
2. Determine backhaul access pricing scenarios
3. Simulate impact of changes in backhaul costs on CAPEX

## 2.1. Estimating the portion of total operating costs spent on backhaul:

We estimated the backhaul costs as a percent of total operating expenses through two different analyses. First, by relying on the cost structure based on a previously-performed benchmark study of four carriers (the "Wireless Carriers Benchmarking Study" or the "Benchmark Study"),[12] we drilled down to estimate the portion of total expenses accounted for by backhaul. Second, using secondary and primary sources

[12] The Benchmark Study was separate from the interviews that TAS conducted with six carriers. Accordingly, carriers from the Benchmark Study have been identified with letters rather than numbers to indicate that these are not the same carriers that are identified in Table 1 above.

(*i.e.*, carrier interviews), we built up an estimate of share of backhaul costs of a carrier total operating expenses.

### 2.1.1. "Drill down" of benchmark data

We examined the overall cost structure of a typical wireless carrier based on data presented in the Benchmark Study. As indicated in Table 2, network costs are, on average, the largest component of the operating cost structure of a wireless carrier.

**Table 2. Wireless Operator Cost Breakdown (OPEX and Headcount CAPEX)**

| Cost Categories | Average Percentage of Total Operating Costs |
|---|---|
| General &Administrative | 19% |
| IT | 10% |
| Network | 31% |
| Customer Service | 16 % |
| Sales | 11 % |
| Marketing | 13 % |

*Source: Wireless Carriers Benchmarking Study*

While on average, network costs (which is the category where backhaul costs are included) represent 31% of total operating expenses, they can vary somewhat across carriers (from 23% to 37%) (see Table 3).

**Table 3. Wireless Operator Cost Breakdown (OPEX and Headcount CAPEX)**

| | Percentage of Total Operating Costs | | | | |
|---|---|---|---|---|---|
| **Cost Categories** | **Carrier A** | **Carrier B** | **Carrier C** | **Carrier D** | **Average** |
| G&A | 18% | 21% | 22% | 17% | 19% |
| IT | 11% | 7% | 11% | 11% | 10% |
| Network | 23% | 37% | 29% | 37% | 31% |
| Customer Service | 16 % | 20% | 16% | 14% | 16 % |
| Sales | 15 % | 8% | 12% | 8% | 11 % |
| Marketing | 16 % | 8% | 10% | 13% | 13 % |

*Source: Wireless Carriers Benchmarking Study*

The variance of network costs as a percentage of operating expenses changes according to three drivers or constraints:

- Different network designs and deployment;
- Distinct operations strategies; and
- Variance in costs of maintenance contracts in radio, core and transmission.

The Benchmark Study drilled down on network costs of a wireless carrier, identifying four major cost items:

- Network strategy and support: network applications, operations planning, network monitoring; network quality assurance; strategy and management;

- Network infrastructure rent: sites rentals, backhaul leasing, and frequency fees;
- Core network and transmission: design and planning, deployment, operations and maintenance of the core network; and
- Radio operations and maintenance: design and planning, deployment, operations and maintenance of the radio network.

Network infrastructure rent represents on average 39% of total network costs (see Table 4).

**Table 4. Wireless Network Cost Breakdown (OPEX and Headcount CAPEX)**

| Cost categories | Subcategories | Average Sub-component Breakdown |
|---|---|---|
| Network strategy and support | | 14% |
| Network infrastructure rent | | 39% |
| Core network and transmission | Transmission | 7% |
| | Core Network | 8% |
| Radio operations and maintenance | Radio operations & maintenance | 14 % |
| | Radio deployment | 10 % |
| | Radio design | 8 % |

*Source: Wireless Carriers Benchmarking Study*

Again, network rental costs can be somewhat heterogeneous across carriers, but appear to be fairly consistent (see Table 5),

**Table 5. Wireless Network Cost Breakdown (OPEX and Headcount CAPEX)**

| Subcomponents | Carrier A | Carrier B | Carrier C | Carrier D | Average of All Carriers |
|---|---|---|---|---|---|
| Strategy and Support | 13 | 8 | 10 | 19 | 14% |
| Network infrastructure rent | 36 | 45 | 33 | 37 | 39% |
| Transmission | 6 | 5 | 13 | 8 | 7% |
| Core Network | 10 | 9 | 13 | 3 | 8% |
| Radio ops & maintenance | 11 | 15 | 18 | 14 | 14 % |
| Radio deployment | 13 | 8 | 8 | 10 | 10 % |
| Radio design | 10 | 9 | 5 | 8 | 8 % |

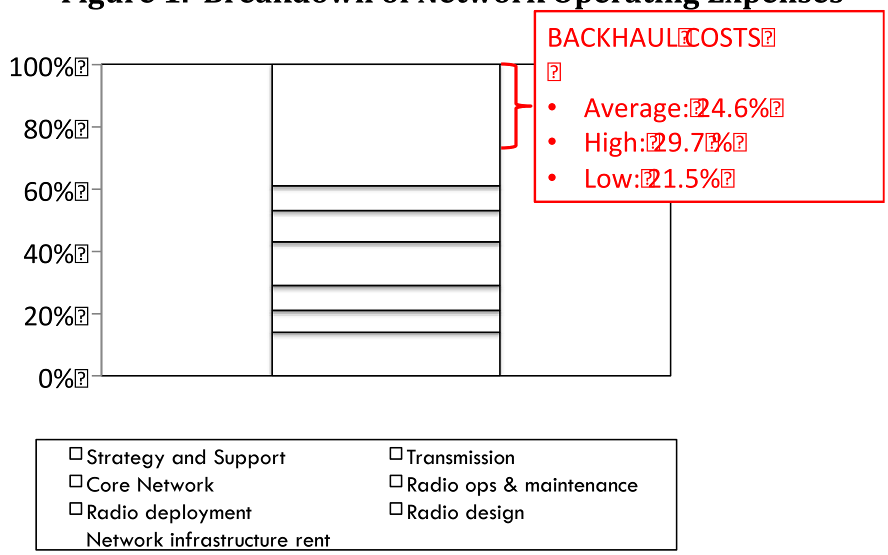
*Source: Wireless Carriers Benchmarking Study*

Network infrastructure rent costs vary according to the following five drivers:

- Number of cell sites;
- Build vs. rent of backhaul links;
- Microwave vs. fiber optics in owned links;
- Leased lines from cable TV or ILEC affiliated carriers; and
- Network sharing approaches.

Proceeding along the drill down to identify backhaul costs, the Benchmark Study indicates that an average 63% of network infrastructure rental costs are non-headcount related (this value ranges between 58% and 66%). Backhaul costs (in terms of purchasing BDS for linking cell sites and interconnection) are included in the network infrastructure rent category, along with tower rental costs. Multiplying the average percentage of network infrastructure rental cost (63%) by network rental costs (39%) yields the proportion that backhaul costs represent of total network-related expenses (24.6%). This value ranges between 24.6% and 21.5% (see Figure 1).

**Figure 1. Breakdown of Network Operating Expenses**




*Source: Wireless Carriers Benchmarking Study; Telecom Advisory Services analysis*

These estimates are consistent with the information collected through interviews in this study. Carrier # 3 reported that interconnection and backhaul costs represent 30% of its total network costs, which comprise (1) Network Service Fees, (2) Cost of In-collect, (3) Cost of Long Distance, (4) Cost of Out-collect, (5) Cell Site Rent and Utilities, (6) BSC/MGW Rent and Utilities, (7) Vendor Support Expenses, (8) Other Network Expenses, and (9) Interconnection/Backhaul.

Additionally, this drill down breakdown allows the calculation of backhaul costs as a percent of total operating expenses. This value is calculated by multiplying average non-headcount network infrastructure rental costs (63%) as a percentage of network costs (39%) by network costs as a percentage of total operating expenses (31%):

63% (non headcount network rental) * 39% (network rental costs) * 31% (network costs) = 7.6%

Based on the different benchmark observations, backhaul costs as a percentage of total operating expenses could range between 6.4 % and 11% depending primarily on number of cell sites and backhaul ownership (lease vs. owned) model (see Table 6).

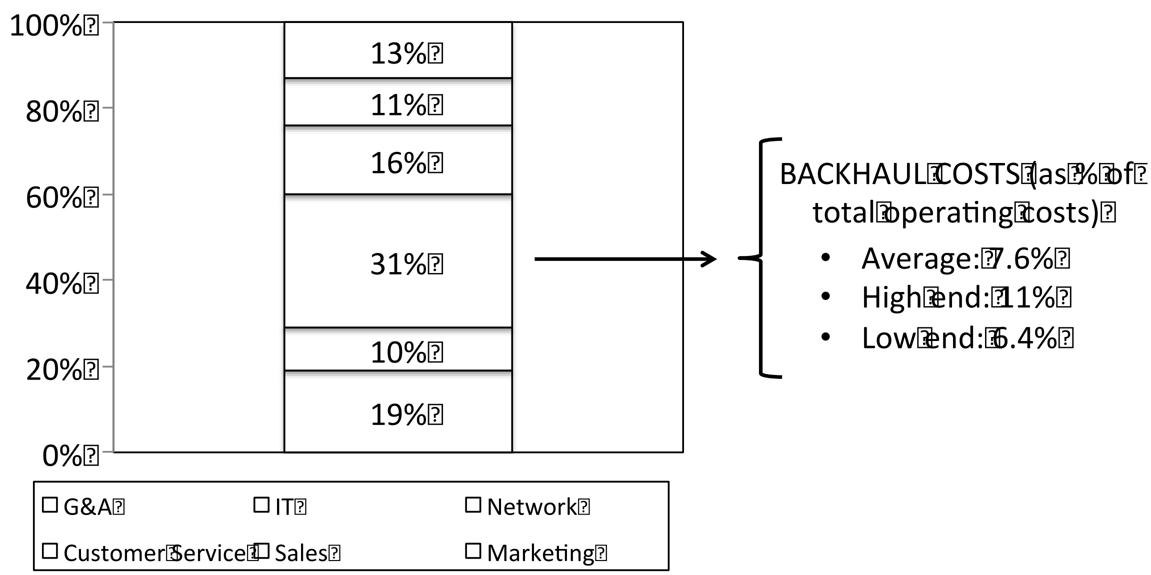
**Table 6. Range of Network rental costs as percentage of operating expenses**

| | Average | Carrier with lowest rental costs | Carrier with highest rental costs |
|---|---|---|---|
| Non headcount network rental costs | 63 % | 58 % | 66 % |
| Network rental costs | 38 % | 37 % | 45 % |
| Network costs | 31 % | 30 % | 37 % |
| Backhaul costs | 7.8 % | 6.4 % | 11 % |

*Source: Wireless Carriers Benchmarking Study; Telecom Advisory Services analysis*

In summary, according to these four benchmarks, rental (including backhaul and towers) costs account, on average, for 7.8 % of total operating expenses of a wireless carrier.

**Figure 2. Network Rental Cost estimate based on benchmark data**




*Source: Wireless Carriers Benchmarking Study; Telecom Advisory Services analysis*

This analysis demonstrates that the benchmarks of four wireless carriers indicate that rental costs represent 24.6% of network costs (ranging between 29.7% and 21.5%) and 7.6% of total operating expenses (ranging between 6.4% and 11%). In order to isolate backhaul from the total rental costs, we perform a bottom-up analysis in the following section.

### 2.1.2. Estimation of backhaul costs through bottom up analysis:

Another way of calculating backhaul costs as a percent of a wireless carrier's total operating expenses is to build up a cost estimate using a variety of data sources on various cost items. This bottom up analysis was conducted using publicly available financial information, as well as through an interview process with the carriers identified in Table 1. It should be mentioned upfront that backhaul costs vary widely by technology and supplier. For clarification purposes, there are potentially three ways to procure wireless backhaul:

- Deploy a fully-owned microwave link or, in case of high volume urban areas, fiber optic
- Lease a line from a carrier that competes with an ILEC affiliates (*e.g.*, a CLEC or cable company)
- Lease a line from an ILEC

The deployment of a microwave link could be a potential approach in case the cell site is projected to handle low volume traffic, but the approach has significant technical and economic limitations. [13] On the technical side, microwave propagation characteristics limit the distance a fixed link can cover. Furthermore, the technology can also be sensitive to adverse weather conditions (rain, snow), which affect the service quality. From an economic side, the costs of deploying microwave links might be too high to justify it for relatively low-capacity connections. The capital required to deploy a microwave link is approximately $ 70,000 (Naveh, 2009), which represents a significant upfront cost, especially for a small wireless operator. Furthermore, if traffic begins to increase as a result of either new customer acquisition or more intense usage, microwave links undergo throughput limitations, resulting in service degradation and potential customer churn. Migrating to fiber would be, in this case, the most suitable technological option. However, deployment costs, particularly in rural areas, would be prohibitive.

The second option – lease a backhaul link from a CLEC or cable company – could be a reasonable option if a carrier wants to avoid spending capital, recognizing however that OPEX of a proprietary link is much lower than leasing. At this point, the wireless operator would deploy a new cell site linked to its MSC via a leased line. While this option might be cost beneficial,[14] it is limited to those few areas where either a CLEC or cable company offers BDS services. Consequently, this option is limited to selected areas, primarily urban and suburban. More importantly, there is evidence that indicates that BDS prices decline significantly only when there are multiple CLECs competing with the ILEC. Carrier # 6 reported that in areas where an ILEC and two CLECs are present, it observed that ILEC prices tend to drop 50%; however, in areas where options were restricted to the ILEC and 1 CLEC, prices declined only by 10%. In other words, it is only within a 3+ player competitive environment that BDS pricing renders this option economically attractive.

The third option is to lease a link from an ILEC. However, the barriers imposed by ILECs in terms of higher prices and contractual limitations greatly limit this option. Engineering staff of Carrier # 1 explained that, according to their experience, leasing

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[13] *See* Reply Comments of Sprint Nextel Corp. at 12-13, WC Docket No. 05-25, RM-10593 (filed Mar. 12, 2013).

[14] The price of a CLEC provisioned 1GB Ethernet link amounts to $900/month, approximately 30% less expensive than one supplied by an ILEC affiliate.

a DS1 line[15] for backhaul purposes costs between $ 1,100 and $1,500 per month and represents between 36% and 50% of total cell site OPEX.[16] As stated by Carrier # 1, the $ 1,500 monthly cost allows purchasing a DS1, or a link of up to 100 Mbps of IP.

While switching from an ILEC contract to a CLEC contract may makes sense where the CLEC is offering the same or suitably similar service at a cheaper rate, loyalty clauses in ILEC contracts raise switching costs, which typically must be incurred by the CLEC who seeks to win the contract or the competitive wireless carrier who seeks to eat the penalty in order to obtain a lower priced option. For example, under a five year contract, a carrier that wants to switch from an ILEC to a cost competitive CLEC has to either assume the term liabilities or shift them to the CLEC, in order to have the switching costs subsidized. Under a cancellation scenario after two years of a five-year contract, the liabilities (equaling to 100% of three year costs) might be cost prohibitive to either party. At any rate, this option is only available in the geographies were a competitor to the ILEC affiliate is present (limited to 31% of locations), and where competitive intensity has driven BDS pricing down (only 3.8% of census blocks have more than one competitive BDS provider).[17]

In terms of other data points to triangulate backhaul costs, an equipment vendor case study [18] explains that a carrier with 1,000 cell sites spends approximately $15,000,000 annually on local access transport services for backhaul from the cell sites to the Mobile Switching Centers (MSCs) and interconnections from the MSCs to the LEC access tandems. This results in a $15,000 cost per cell site, which equals $1,250 per site per month. It is, therefore, fair to conclude that backhaul leasing represents between $1,250 and $ 1,666, amounting to between 36% and 50% of cell site OPEX. Carrier 1 indicated that cell site operating costs could be broken down as follows: site or tower rent (56%), backhaul (27%), utilities (7%), maintenance and other (10%). The 27% estimate of Carrier # 1's backhaul costs is fairly consistent with the amount the bottom up analysis reveals (36%), since the bottom up analysis data point blends leased lines with the costs of running an owned microwave link.

On the other hand, total backhaul operating costs of a wireless carrier amount to expenses required to run a mix of microwave (maybe fiber), leasing from a CLEC or cable company, and leasing from an ILEC.

A blended (that is to say costs to lease lines and operate owned links) backhaul cost estimate was provided by Gary Lindsey in his statement of August 8, 2007 and included as attachment to Sprint Nextel comments in the WC Docket No. 05-25. Mr. Lindsey, Director of Access Solutions for Sprint Nextel Corp. at the time, stated that

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[15] While DS1 is not necessarily a suitable option for all backhaul needs—and certainly not suitable for 5G—this estimate is valid since it is a widely used alternative in the case of many existing rural carrier networks.

[16] This number is supported by the costs of leasing a tower, which is estimated at $1,666 per month, which means the cost of backhaul plus leasing a tower is estimated at $2,766 to $3,166. American Tower, *Introduction to the Tower Industry and American Tower*, Boston: 2011, p. 12.

[17] *FNPRM* at 224.

[18] CFN Services. *Wireless carrier optimizes its backhaul*.

the cost of operating a cell site include items such as rent, utilities (*i.e.* power), maintenance and backhaul. He estimated that this last item made up about 33% of the cell site operating cost, a number that was calculated by dividing Sprint Nextel's total backhaul costs incurred in 2006 by the total costs of operating its cell sites. As stated above, this approach to calculating cell site backhaul costs relied on total backhaul expenses, therefore blending OPEX of owned microwave and fiber links, as well as leased lines. This metric has been quoted often times in BDS related proceedings and reports such as in the FCC Eighteenth Report of Competitive Dynamics in the Wireless Industry.[19]

Multiplying the monthly cost of a DS1 or 100 Mbps Ethernet connection ($ 1,250–$1,666) by the publicly available number of cell sites of selected carriers yields total backhaul costs for a number of US carriers.

**Table 7. United States Carriers: Estimated Backhaul Costs**

| Carrier | Cell Sites | Year | Annual Backhaul Costs (US$ '000) |
|---|---|---|---|
| US Cellular | 6,306 | 2016 | $94,590 - $126,069 |
| nTelos (merged 2Q16) | 1,008 | 2015 | $15,120 - $20,152 |
| T-Mobile | 64,000 | 2015 | $960,000 - $1,279,488 |
| Cincinnati Bell (closed 1Q15) | 480 | 2014 | $7,200 - $9,596 |
| Sprint | 38,000 | 2014 | $570,000 - $759,696 |
| Cricket (merged 1Q14) | 9,500 | 2013 | $142,500 - $189,924 |

Note: Some of these carriers have merged; however, the estimation of backhaul pre-merger remains a viable approach.

*Source: Total number of cell sites is contained in GSMA Intelligence (a database of the GSM Association); Telecom Advisory Services analysis*

By relying on public OPEX data, we have calculated backhaul costs as a percentage of total operating expenses (see Table 8).

[19] It should be noted that this metric is sometimes misstated in some documents as in *Implementation of Section 6002(b) of the Omnibus Budget Reconciliation Act of 1993,* Eighteenth Report, DA 15-1487, WT Docket No. 15-125, ¶ 69 (rel. Dec. 23, 2015) ("Eighteenth Report") ("the cost of backhaul is approximately 30 percent of the operating cost of providing wireless service"). As shown above, 31% of total operating cost of providing wireless service includes all network operations cost categories.

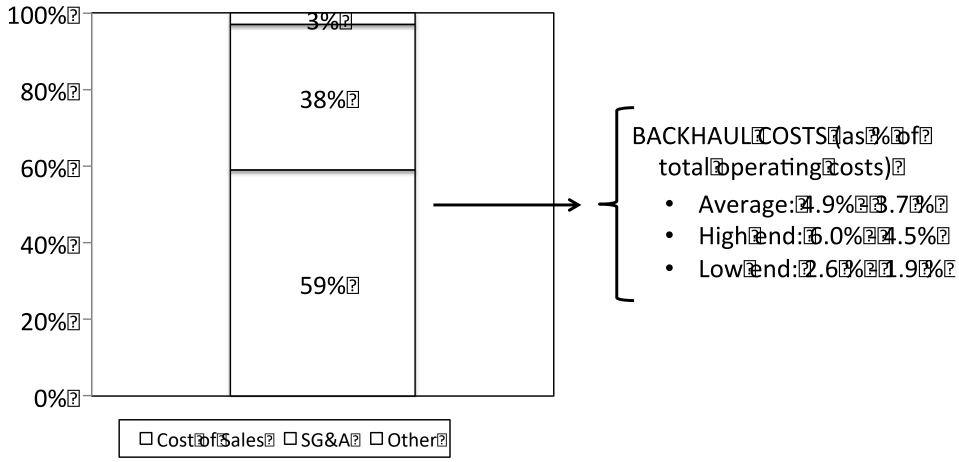
**Table 8. United States: Backhaul Costs as Percentage of OPEX**

| Carrier | Cell Sites | Year | Annual OPEX (US$ '000) | Annual Backhaul Costs (US$ '000) | Backhaul as percentage of OPEX |
|---|---|---|---|---|---|
| US Cellular | 6,306 | 2016 | $ 3,224,636 | $ 94,590 - $ 126,069 | 2.93% - 3.90 % |
| nTelos (merged 2Q16) | 1,008 | 2015 | $ 333,249 | $ 15,120 - $ 20,152 | 4.53% - 6.04 % |
| T-Mobile | 64,000 | 2015 | $ 25,469,000 | $ 960,000 - $ 1,279,488 | 3.76% - 5.02 % |
| Cincinnati Bell (closed 1Q15) | 480 | 2014 | $ 201,999 | $ 7,200 - $ 9,596 | 3.56% - 4.75 % |
| Sprint | 38,000 | 2014 | $ 29,176,000 | $ 570,000 - $ 759,696 | 1.95% - 2.60 % |
| Cricket (merged 1Q14) | 9,500 | 2013 | $ 2,534,074 | $ 142,500 - $ 189,924 | 5.62% - 7.49 % |

Note: While some of these carriers have merged, the estimation of backhaul pre-merger remains a viable approach.
*Source: GSMA Intelligence for total number of cell sites and annual OPEX; Telecom Advisory Services analysis.*

In sum, according to the bottom up analysis, backhaul costs account, on average, between 3.7 % and 4.9% and of total operating expenses of a wireless carrier (see Figure 3).

**Figure 3. Backhaul Cost estimate based on bottom up analysis**




*Source: Telecom Advisory Services analysis*

### 2.1.3. Conclusion

Table 9 summarizes all the estimates presented in this chapter.

**Table 9. Comparative estimates of backhaul costs**

| | Backhaul as percent of total OPEX | | | | Backhaul as percent of network OPEX | | Backhaul as percent of cell site OPEX | | |
|---|---|---|---|---|---|---|---|---|---|
| | Benchmark analysis (*) | Bottom up analysis | Carrier interview 1 | Carrier interview 3 | Benchmark analysis | Carrier interview 2 | Carrier interview 1 | Carrier interview 2 (**) | Sprint Nextel (***) |
| High end | 11 % | 5.9 % - 6.0 % | | | 29.7 % | | | 50 % | |
| Average | 7.8 % | 3.7 % - 4.9 % | 3.0 % | 3.1 % | 24.6 % | 30 % | 27 % | 43 % | 33 % |
| Low end | 6.4 % | 1.9 % - 2.6 % | | | 21.5 % | | | 36 % | |

(*) Includes tower rental costs.
(**) This estimate is for leased backhaul only.
(***) See attachment to comments in the WC Docket No. 05-25. This estimate refers to blended backhaul costs (in other words costs of leasing lines and operating owned links)
*Source: Telecom Advisory Services interviews and analysis*

Data presented in Table 9 allows the validation of the following estimates:

- Backhaul as percent of cell site OPEX: carrier interview data (range from 36% to 50%) appears to be fairly robust since the Sprint Nextel estimate published in the comments to the docket includes owned links, whose OPEX is lower than the cost of leasing (33%), and Carrier # 1 is 30%. Therefore, if all backhaul costs are included (e.g., owned and leased lines), backhaul costs represent between 27% and 33% of a cell site. Alternatively, for a cell site that is linked through a BDS leased line, backhaul costs amount to between 36% and 50% (Carrier # 2).

- Backhaul as percent of network OPEX: the estimate from carrier interview 2 (30%) is fairly close to the benchmark results (range between 21.5% and 29.7%).

- Backhaul as percent of total OPEX: the estimates derived from bottom-up analysis are almost half of the benchmark results. This is because the benchmark estimates include tower rental costs, which the bottom-up calculations estimate to be approximately half of rental costs. However, the two carrier interviews estimate backhaul costs as percent of total OPEX to be at the average point of the bottom up analysis (4.3%).

In sum, in order to assess the impact on BDS backhaul economics on the investment of a competitive wireless carrier, we will rely on the average of the three levels of backhaul costs as a percent of total OPEX.

**Table 10. Backhaul as percentage of OPEX**

| | Bottom up analysis | Mid-point |
|---|---|---|
| High end | 5.9 % - 6.0 % | 5.95 % |
| Average | 3.7 % - 4.9 % | 4.30 % |
| Low end | 1.9 % - 2.6 % | 2.25 % |

*Source: Telecom Advisory Services analysis*

## 2.2. Assessment of impact on CAPEX of changes in backhaul costs and contractual terms

Having formalized the cost structure of a wireless carrier operating in a non-competitive BDS marketplace and estimated the portion of said costs that are represented by backhaul, we can now calculate the impact of a change in BDS pricing to reflect supra-competitive pricing or other non-competitive conditions. The logic underlying this analysis is:

- If backhaul represents an average of 4.3 % of total OPEX, 30 % of network OPEX, and 33% of cell site OPEX, a reduction in BDS pricing (such as, for example, resulting from BDS rate regulation or reducing wholesale BDS rates to retail BDS rates could result in a decrease in the overall cost structure;

- Subsequently, a reduction in OPEX could either be transferred to CAPEX, transferred to profits or some combination of both. This reduction could also eventually enable a reduction in prices.

The first step is to define the potential price reduction scenarios to be tested. For this purpose, we rely on data provided in comments submitted by competitive carriers to the FCC in the BDS proceeding (see Table 10).

**Table 10. Pricing impact of ILEC dominance**

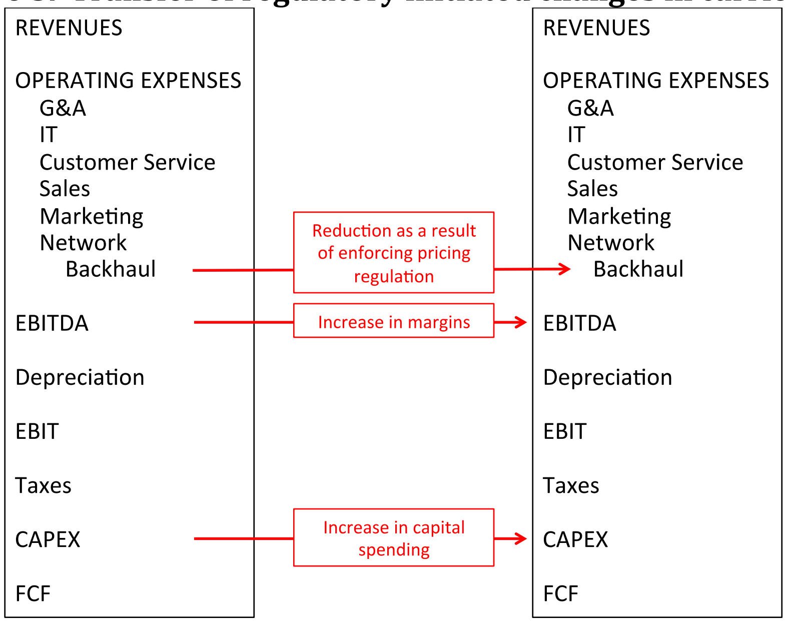
| Source | Pricing Spread |
|---|---|
| XO | • ILEC's discounted prices are higher than similar services offered by competitive providers[20] |
| | • Prices for Ethernet services from facilities-based competitive providers are cheaper than ILEC prices for similar capacity Ethernet[21] |
| | • ILEC wholesale Ethernet prices are priced so that XO must price its retail services 30% higher than the ILEC's[22] |
| Windstream | • A tariffed monthly price of TDM DS1 is $126 under a 36 month commitment plan, while a comparable Ethernet connection is priced at $1,075 on a three-year plan (ATT)[23] |
| Sprint | • ILEC charges "rack rates" for monthly service if carriers do not agree to a loyalty contract[24] |

Given that this information is not entirely consistent, we assume scenarios that allow the calculation of sensitivities regarding backhaul price declines. Carrier # 6 indicated that, considering the level of overpricing that they estimate in backhaul prices (around 50%), it would be reasonable to assume a backhaul cost decline scenario of 30% (considering that owned backhaul facilities would not be affected by such a reduction in leased line prices). Carrier # 2 and Carrier # 4 also indicated that such a scenario is fairly conservative.

Our prior research based on historical data of the impact of regulatory initiated cost reduction (*e.g.*, tax exemptions) on the economics of telecom carriers (Katz et al, 2014) demonstrates that carriers transfer approximately 85% of the OPEX decrease to CAPEX, and transfer the remaining 15% to increase margins. These dynamics are represented conceptually in Figure 5.

[20] Comments of XO Communications, LLC on the Further Notice of Proposed Rulemaking at 34, WC Docket No. 05-25, RM-10593 (filed Jan. 27, 2016)
[21] Id.
[22] Id. at 43.
[23] Comments of Windstream Services, LLC at 52, WC Docket No. 05-25, RM-10593 (filed Jan. 27, 2016).
[24] Sprint Comments at 44.

**Figure 5. Transfer of regulatory initiated changes in carrier economics**




These assumptions were used to develop a scenario of a change in a competitive carrier economic profile as a result of a reduction in BDS pricing. We use a small wireless carrier for this analysis and assume that the carrier generates $26 million in revenues and EBITDA of $ 5.3 million (see Table 11).

**Table 11. Income Statement and Selected Operating metrics (in '000 US except for CAPEX / connection and OPEX / connection)**

| | |
|---|---:|
| Revenues | $26,000 |
| Operating Expenses | $20,700 |
| EBITDA | $5,300 |
| Tax | $43 |
| Net interest expense | ($1,450) |
| CAPEX | $4,300 |
| FCF | ($526) |
| CAPEX / Revenues | 16.53% |
| CAPEX / connection | $92.75 |
| OPEX / connection | $443.69 |

*Source: Telecom Advisory Services analysis*

Based on the cost breakdown presented in Section 2.1, backhaul costs amount to between 2.25% and 5.95% of OPEX (equivalent to a range between $465,700 and $1,231,650). On this basis, the following sensitivity analyses were specified (see Table 12).

**Table 12. Sensitivity Analysis: Reduction in Leased backhaul**

| Backhaul as percentage of CAPEX Scenarios | | 50 % Split between Owned and Leased links | | Reduction in Leased Backhaul Costs | | |
|---|---|---|---|---|---|---|
| Percent | Value | Owned | Leased | 10 % | 20 % | 30 % |
| 2.25 % | $465,750 | $232,875 | $232,875 | $186,300 | $139,725 | $93,150 |
| 4.30 % | $890,100 | $445,050 | $445,050 | $356,040 | $267,030 | $178,020 |
| 5.95 % | $1,231,650 | $615,825 | $615,825 | $492,660 | $369,495 | $246,330 |

**Table 12. Sensitivity Analysis: Contribution to CAPEX**

| Backhaul as percentage of CAPEX | | Backhaul Savings | | | Contribution to CAPEX | | |
|---|---|---|---|---|---|---|---|
| Percent | Value | 10 % | 20 % | 30 % | 10 % | 20 % | 30% |
| 2.25 % | $ 465,750 | $ 46,575 | $ 93,150 | $ 139,725 | $ 39,589 | $ 79,178 | $ 118,766 |
| 4.30 % | $ 890,100 | $ 89,010 | $ 178,020 | $ 267,030 | $ 75,659 | $ 151,317 | $ 226,976 |
| 5.95 % | $ 1,231,650 | $ 123,165 | $ 246,330 | $ 369,495 | $ 104,690 | $ 209,381 | $ 314,071 |

*Source: Telecom Advisory Services analysis*

Data in Table 12 allows estimating the economic impact of several scenarios, of which three are described in detail:

- Minimum scenario: under a total OPEX of $ 20,700,000 and backhaul amounting to 2.25% of OPEX, total backhaul cost is $ 467,750. Assuming that backhaul cost is split 50/50 between operating owned links and site rentals on one side and BDS links on the other, the latter is $ 232,875. A scenario of 10% overall backhaul cost reduction implies that backhaul cost savings would amount to $ 46,575. According to the econometric modeling, 85% of savings are transferred to CAPEX, resulting in an increase in CAPEX from $ 4,300,000 to $ 4,339,589 (0.91% increase).

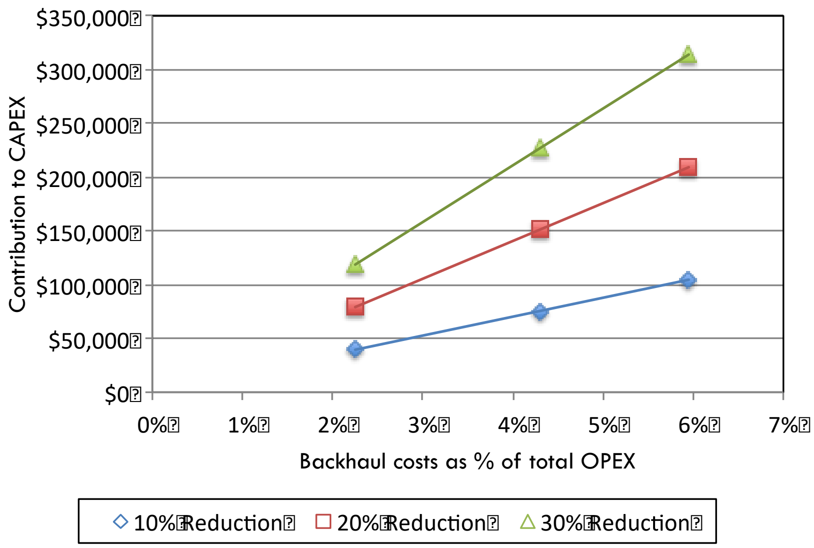
- Medium scenario: under a total OPEX of $ 20,700,000 and backhaul amounting to 4.30% of OPEX, total backhaul cost is $ 890,100. Assuming that backhaul cost is split 50/50 between operating owned links (such as microwave) and site rentals on one side and BDS links on the other, the latter is $ 445,050. A scenario of 20% overall backhaul cost reduction implies that backhaul cost savings would amount to $ 178,020. According to the econometric modeling, 85% of savings are transferred to CAPEX, resulting in an increase in CAPEX from $ 4,300,000 to $ 4,451,317 (3.40% increase).

- Maximum scenario: under a total OPEX of $ 20,700,000 and backhaul amounting to 5.95% of OPEX, total backhaul cost is $ 1,231,650. Assuming that backhaul cost is split 50/50 between operating owned links (such as microwave) and site rentals on one side and BDS links on the other, the latter is $ 615,825. A scenario of 30% overall backhaul cost reduction implies that backhaul cost savings would amount to $ 369,495. According to the econometric modeling, 85% of savings are transferred to CAPEX, resulting in an increase in CAPEX from $ 4,300,000 to $ 4,614,071 (6.81% increase).

All sensitivity scenarios detailed above assume that the competitive carrier has a 50/50 split in its backhaul between owned and leased links. If the competitive carrier does not have any owned infrastructure and relies solely on BDS for backhaul purposes, a 60% reduction in BDS prices would result in 12.75% increase in CAPEX.

Sensitivities of all cases are plotted in Figure 6.

**Figure 6. Sensitivity analysis of a reduction in backhaul costs**




*Source: Telecom Advisory Services analysis*

The increase in capital spending yielded by a reduction in backhaul costs would, in turn, result in improved service quality, better coverage, and lower churn, as well as increased competition against incumbents. Econometric analysis of US wireless data conducted by Katz et al. (2014) indicates that an increase in CAPEX has substantial impact service quality metrics, such as speech call quality, and data latency reduction. Thus, consumers, particularly in rural areas would be benefitting substantially from these network quality improvements.

## 3. THE IMPACT OF CHANGES IN BACKHAUL COSTS ON BROADBAND QUALITY OF SERVICE

Wireless data traffic in the US has been growing at rates over 60% annually and is projected to continue growing at 57% annually through 2020. This growth is driven by the adoption of smart connected devices and usage per terminal. In order to meet the growth in traffic, wireless operators have several choices; they can increase the number of cells, gain access to more spectrum, or migrate their networks to technologies that ensure higher efficiency in spectrum usage. The first and third options imply an increase in backhaul spending to link a larger number of cell sites. This chapter examines the implications of high backhaul prices in constraining the deployment of cell sites to accommodate the growth in traffic, with the consequent erosion in quality of service. The third option, migration to next generation technologies, will be examined in Section 3.

### 3.1. Projected growth in wireless traffic

Wireless data traffic in the United States currently amounts to 7.87 exabytes per month, and is projected to continue growing by 57% through 2020.[25] Growth in traffic is driven by the adoption of smartphones, Tablets and other "connected" devices that, on average, generate significantly more traffic than non-smart devices, such as feature phones. The adoption of usage intensive devices has been increasing exponentially. As of December 2015, approximately 74% of US mobile subscribers owned smartphones[26], while Tablet penetration reached 33% (see Table 13).

**Table 13. United States: Device Penetration (2010-2020)**

| | | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Feature phones | Base | 215.16 | 189.21 | 153.46 | 113.22 | 97.76 | 89.18 | 82.06 | 79.82 | 79.12 | 79.38 | 80.18 |
| | Penetration | 68.15 % | 60.34 % | 48.57 % | 35.57 % | 30.49 % | 27.62 % | 25.23 % | 24.38 % | 23.98% | 23.88 % | 23.96 % |
| Smartphones | Base | 79.40 | 125.27 | 165.06 | 201.79 | 231.65 | 252.18 | 269.86 | 282.03 | 290.39 | 296.20 | 300.46 |
| | Penetration | 26.95 % | 39.83 % | 51.82 % | 64.06 % | 70.32 % | 73.87 % | 76.68 % | 77.94 % | 78.59 % | 78.86 % | 78.93 % |
| Tablets | Base | 26.41 | 35.01 | 46.41 | 61.53 | 81.56 | 108.13 | 121.62 | 136.79 | 153.85 | 173.05 | 194.63 |
| | Penetration | 8.42% | 11.07% | 14.56% | 19.15% | 25.19% | 33.13% | 37.26% | 41.91% | 47.14% | 53.02% | 59.63% |
| PCs | Base | 235.18 | 237.16 | 239,08 | 240.99 | 242.89 | 244.81 | 246.73 | 248.66 | 250.61 | 252.57 | 254.54 |
| | Penetration | 75.00% | 75.00% | 75.00% | 75.00% | 75.00% | 75.00% | 75.00% | 75.00% | 75.00% | 75.00% | 75.00% |

*Sources: GSMA Intelligence (2016); Deloitte (2013). State of the Media democracy; Telecom Advisory Services analysis*

On the other hand, average traffic per device amounts to 2.11 Gb per month. It is projected to continue increasing at a 23.83 % annual rate (see Table 14).

**Table 14. United States: Traffic generated by device (Gb per month)**

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | CAGR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Feature phone | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.03 | 0.04 | 0.04 | 0.05 | 0.06 | 0.07 | 48.87% |
| Smartphone | 0.06 | 0.11 | 0.20 | 0.46 | 1.04 | 1.40 | 1.84 | 2.43 | 3.20 | 4.22 | 5.55 | 57.27% |
| Tablet | 0.17 | 0.25 | 0.37 | 0.80 | 1.74 | 3.77 | 4.50 | 5.36 | 6.39 | 7.62 | 9.09 | 48.87% |
| PC | 1.60 | 1.98 | 2.45 | 2.49 | 2.53 | 2.87 | 3.29 | 3.77 | 4.31 | 4.94 | 5.65 | 13.45% |
| Average | 0.69 | 0.84 | 1.05 | 1.20 | 1.53 | 2.11 | 2.58 | 3.16 | 3.87 | 4.77 | 5.88 | 23.83% |

*Sources: Cisco Visual Network Index; Telecom Advisory Services analysis*

The increase in traffic generation per device is driven by the adoption of mobile cloud-based applications. As such, wireless cloud traffic is expected to increase 12x through 2018. Simultaneously, consumption of mobile video applications represents the most important factor driving traffic growth. Mobile video traffic will be growing at a CAGR of 69 % through 2018.

[25] Source: Telecom Advisory Services analysis.
[26] Source: ComScore.

As a result, overall wireless traffic (of which, in 2015, 75.86 % is routed through carrier-grade Wi-Fi sites) is expected to grow at 57 % annually between 2015 and 2020 (see Table 15).

**Table 15. United States: Total Traffic (Exabytes per month)**

| | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | CAGR | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | 2010-15 | 2015-20 |
| Cellular Traffic | 0.20 | 0.32 | 0.49 | 0.77 | 1.21 | 1.90 | 2.77 | 3.99 | 5.71 | 8.16 | 11.74 | 57% | 44% |
| Wi-Fi Traffic | 0.45 | 0.67 | 1.07 | 1.80 | 3.22 | 5.97 | 9.59 | 15.41 | 24.75 | 39.66 | 63.33 | 68% | 60% |
| Total Traffic | 0.65 | 0.98 | 1.56 | 2.58 | 4.43 | 7.87 | 12.36 | 19.40 | 30.46 | 47.82 | 75.07 | 65% | 57% |

*Sources: Cisco Visual Network Index; Telecom Advisory Services analysis*

In sum, US monthly mobile traffic has increased 12 times between 2010 and 2015, and will grow 10 times through 2020.

## 3.2. Impact of traffic growth on wireless capital spending

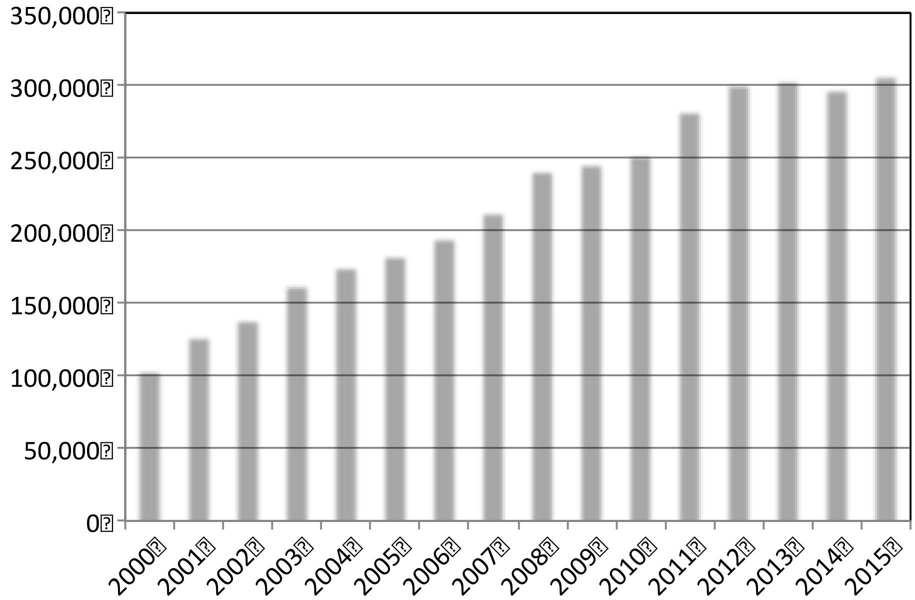
To accommodate such a growth in traffic, wireless carriers can rely on three approaches. One of them is to acquire more spectrum. Since 2010, the FCC has licensed 688 MHz of spectrum to the wireless industry. Going forward it is expected that, to accommodate the exponential growth in traffic, blocks of 200 MHz will be assigned to mobile carriers, complemented with 14 GHz in unlicensed bands[27].

The second approach to handle the growth in traffic is to introduce new technologies that yield higher spectral efficiency. This has been one of the drivers in the migration from 3G to 4G, since the latter platform supports download speeds 10 times faster than 3G. So far, most carriers in the US have launched 4G services and are at various stages of implementation: 62% of total US wireless connections are already 4G.

The third approach that we analyze in this chapter requires a wireless carrier to increase the number of cell sites (a process known as cell splitting). In doing so, carriers can increase the density of their networks in order to accommodate a portion of the traffic growth. By reducing the service radius served by a cell site, a carrier can focus on a smaller set of customers and improve quality. Cell splitting has been one of the most important drivers of cell site growth until now (see Table 16).

[27] Tom Wheeler, Tom (Chairman, Fed. Commc'ns Comm'n, "The Future of Wireless: A Vision for U.S. Leadership in a 5G World," at the Nat'l Press Club at 1 (June 20, 2016).

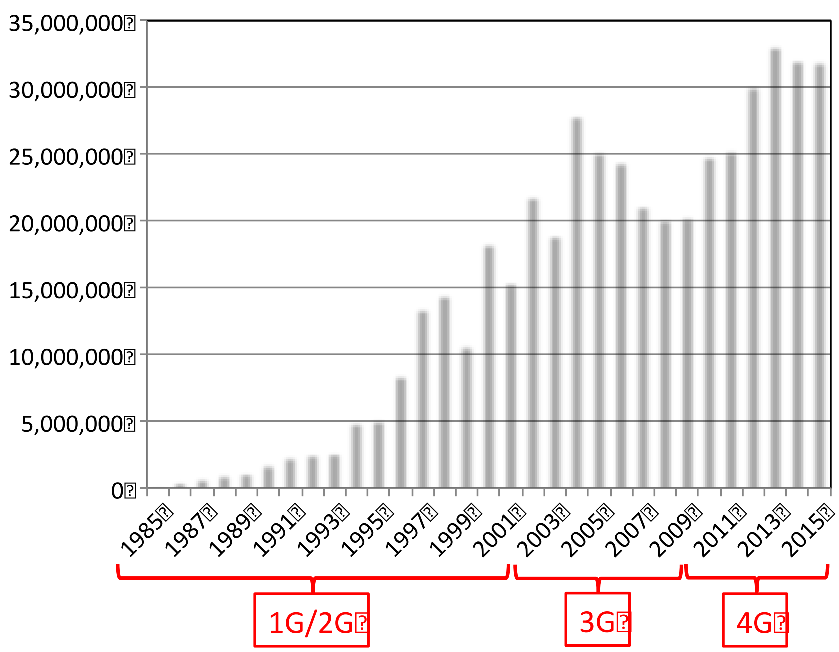
**Figure 7. United States: Number of Cell Sites (2000-15)**




*Sources: CTIA*

Traffic growth, combined with technology migration, has been a primary driver of CAPEX increase since the industry inception (see Figure 8).

**Figure 8. United States: Wireless CAPEX**




*Source: CTIA*

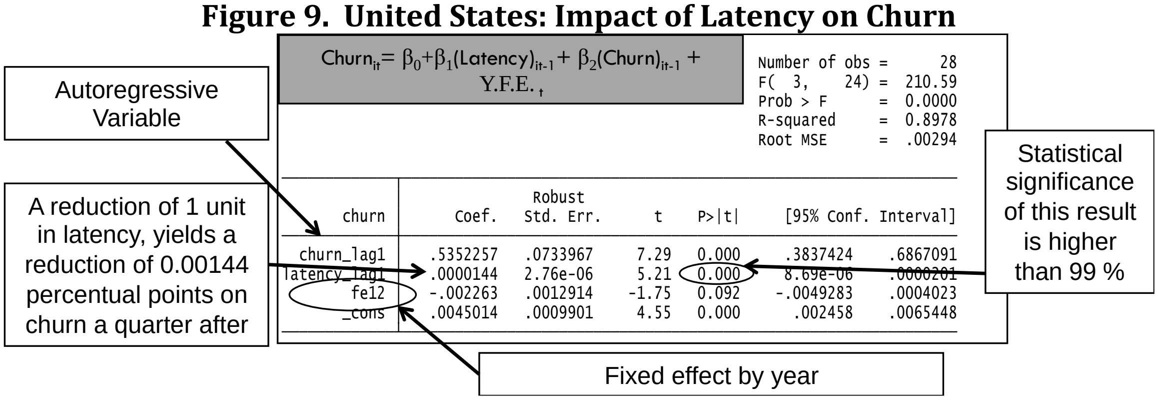
A rule of thumb used in the industry is that a split cell doubles the operating costs comprising backhaul, rent, and power. On the other hand, some efficiency is gained in general maintenance as a result of economies of scale inherent in network growth.

### 3.3. Backhaul pricing constraining cell splitting

A carrier that considers cell-splitting needs to evaluate whether the price of BDS and/or any related contractual obligations impose an economically prohibitive rate. For example, Carrier # 1 caps backhaul costs for rent in an area where cell splitting might occur at $1,500 per month. Carrier # 6 explained that in areas with significant CLEC presence, backhaul costs could be affordable. However, if CLEC activity is not present,[28] then the backhaul cost might exceed the $ 1,500 hurdle, and the carrier may opt not to split the overburdened cell. Under this scenario, the carrier experiences an increase in blocked and dropped calls as well as latency.

Our prior research (Katz et al, 2014) has shown that an erosion of service quality leads to an increase in churn. For example, according to our analysis based on US data, an increase of 1 millisecond in latency increases churn by 0.00144 percentage points.[29] (See Figure 9)

**Figure 9. United States: Impact of Latency on Churn**




*Source: Telecom Advisory Services analysis*

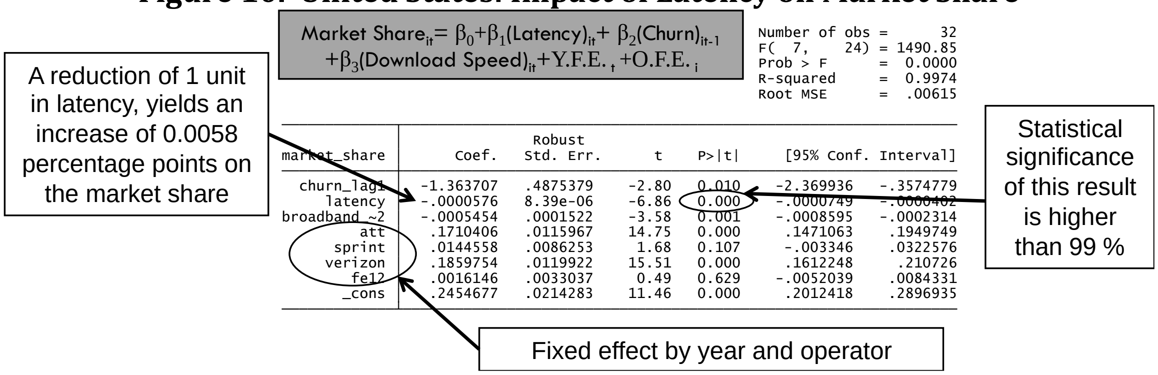
Therefore, unless a competitive wireless carrier can acquire backhaul links from a CLEC or a cable company, the possibility of implementing a cell split has economic limitations. If a traffic-burdened cell is not split, the competitive wireless carrier incurs an increase in churn with a consequent loss of market share and, ultimately revenues. In other words, if cell splitting becomes prohibitive, the competitive carrier

[28] Carrier # 6 stated that for backhaul prices to be low enough to allow for cell-splitting, the cell site has to be served by at least two CLECs. If that is not the case, Carrier # 6 observed that a mere duopoly (ILEC and CLEC) was not enough to drive prices down. Under this scenario, Carrier # 6 reported that the price differential was only 10%. If 2 or more CLECs are present in a market, Carrier # 6 reported that the price differential with the ILEC can reach 50%. Obviously, this has limited applicability due to the fact that, as reported, only 3% of all locations are served by 2 or more BDS providers.

[29] Similarly, a decrease of 1 percentage point in data sessions over 1 Mbps yields an increase of 0.0159 percentage points in churn.

endures a service quality degradation, and consequent loss in market position. For example, econometric analysis of US data indicates that an increase of 1 millisecond in latency tends to decrease total market share by 0.0058 percentage points. (See Figure 10)

**Figure 10. United States: Impact of Latency on Market Share**




*Source: Telecom Advisory Services analysis*

In this context, a competitive wireless carrier has two options, both entailing negative outcomes. If it decides to split a cell and upgrade the leased backhaul link, it will undergo a decrease in margins because the increase in cost of upgrading the backhaul does not yield higher revenues. In other words, with the increase in traffic, profitability decreases in part because of backhaul pricing. To make matters worse, because of the way pricing is formulated by AT&T and Verizon, there is no direct relationship between capacity and BDS pricing. As explained by Carrier #1, the difference in pricing between a 100 Mbps to 150 Mbps Ethernet circuit is significantly greater than the corresponding increase in capacity.

Alternatively, if the competitive wireless carrier decides not to upgrade the capacity, service quality erodes and the carrier undergoes a loss in share. Therefore, the possibility of being able to respond to the increase in traffic has economic limitations. Again, in the words of a Carrier #1, the competitive wireless carrier "is put in a position where it needs to make a call between seeing its margins drop versus incurring an increase in churn."

Carrier #6 explained that where there is an increase in traffic, the carrier may decide not to split cells in order to accommodate the traffic growth. Instead, because there is limited competitive pressure from other wireless carriers in the area, the carrier may decide to forego network upgrades due to cost. Instead, the customer experience suffers. In other words, under an increase in traffic, the rural carrier does not split cells in order to maintain adequate customer experience as a result of backhaul costs. This situation does not result in a loss of market share for the rural carrier because there are not enough competitive alternatives for the consumer to switch to. On the other hand, the rural consumer is progressively undergoing an erosion of service quality. This is another dimension of digital divide, where rural areas are left with poorer service quality as a result of the disadvantaged backhaul market economics.

# 4. THE IMPACT ON THE FUTURE ABILITY OF COMPETITIVE WIRELESS CARRIERS TO MIGRATE TO 5G SERVICES

In a scenario similar to cell splitting, a competitive wireless carrier will experience a significant increase in backhaul costs in order to migrate to 5G technology. 5G is predicated on the deployment of a large number of small cell sites. This change in network architecture will require an increase in backhaul links. The increased BDS costs to a competitive wireless carrier for the needed backhaul could preclude the competitive wireless carriers from migrating to 5G. This creates a further competitive divide vis-à-vis the dominant wireless players. Ultimately, this scenario could lead to additional consolidation of the wireless industry with a negative impact on consumer welfare, particularly in rural areas. This chapter will present the evidence underlying such a scenario.

## 4.1. Technical requirements entailing the migration to 5G

5G technology is generally defined as providing throughput that will be 10-100x faster than 4G, which could mean real-world speeds of about 4Gbps or more. Most of the speed increases are due to how the carriers will be adding more wireless channels, using millimeter wave technology (which means the signal has to travel shorter distances), installing small cells that dramatically increase the coverage map, and in increasing capacity in the wired backhaul locations.

The speed boosts, low latency, and backwards compatibility with existing networks will provide a framework for new network architectures, like Cloud RAN (radio access network) where localized nano-data centers will occur supporting server-based networking functions like Industrial IoT gateways, video caching and transcoding at the edge for UltraHD video, and newer mesh-like topologies supported with more distributed heterogeneous networks ("HetNets"). In short, 5G will lead to a dramatic increase in cell sites (which due to the higher frequency a lot of them will have significantly shorter range) and demand for backhaul.

5G wireless technology has been defined according to eight requirements (GSMA, 2015):

- 1-10 Gbps connections to end points in the field (*i.e.* not theoretical maximum)[30]
- 1 millisecond end-to-end round trip delay (latency)
- 1000x bandwidth per unit area
- 10-100x number of connected devices
- (Perception of) 99.999% availability
- (Perception of) 100% coverage

[30] The maximum theoretical downlink speed for LTE-A is 1 Gbps.

- 90% reduction in network energy usage
- Up to ten year battery life for low power, machine-type devices

Since these requirements are presented from a target perspective as opposed to being formally measured, it is difficult to determine the ultimate network architecture that will emerge in the future. Furthermore, it is conceivable that not all eight requirements would need to be achieved uniformly across a wireless network. However, there is a consensus that requirements 3 (1000x bandwidth per unit area), 4 (10-1000x number of connected devices), 5 (perceived 99.999% availability), and 6 (perceived 100% coverage) will have a significant impact on backhaul OPEX (in addition to power consumption).

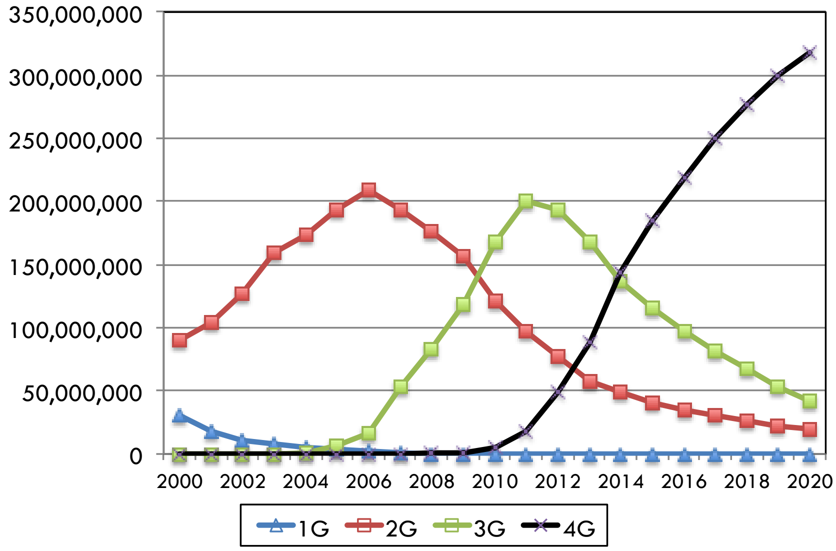
5G networks will require frequencies above 6 GHz potentially reaching as high as 300 GHz. However, as expected, higher frequency bands offer smaller cell radiuses and so achieving widespread coverage would require not only increasing cell sites under current network topology, but also to fulfill the needs of future architectures. For example, the fulfillment of requirement 2 (1 millisecond latency) is estimated to require an exponential increase in cell sites.[31] The increase in the number of cell sites is dependent on the technology and spectrum bands to be utilized. While all frequencies will trigger a radical increase in sites, some might require a smaller number of outdoor cells due to better signal propagation. Further, while the increase in backhaul costs will be significant, it might not be proportional to the number of sites given that many outdoor cells will not require their own links.

In addition, in order to achieve access to content at the expected latency rate, carriers will require backhaul capacity capable of providing high speed interconnectivity among them, as well as accessing other servers containing content.

When do we expect 5G deployment to go commercial? So far, AT&T and Verizon have already launched 5G trials, supported by vendors such as Ericsson, Samsung and Alcatel Lucent. They expect to launch service in 2020 (Follow, 2016; Wheeler, 2016). A forecast of 4G adoption provides some validation to this estimate. The adoption of 4G is proceeding at a faster rate than the prior generations. By 2020, 84 % of US wireless connections will be 4G, which allows us to forecast that, for a generational standpoint, 5G would have already started to deploy. (See Figure 11)

[31] While it is difficult at this point to estimate the growth in cell sites, it is relevant to consider that AT&T announced that as part of its new "Project VIP" network upgrade, the carrier is adding 10,000 new large cells and 40,000 small cells in urban areas. Similarly, Verizon has stated that it set aside $500M of capital budget for densification.

**Figure 11. United States: Total Cellular Connections by Technology Generation**




*Source: GSMA Intelligence; Telecom Advisory Services analysis*

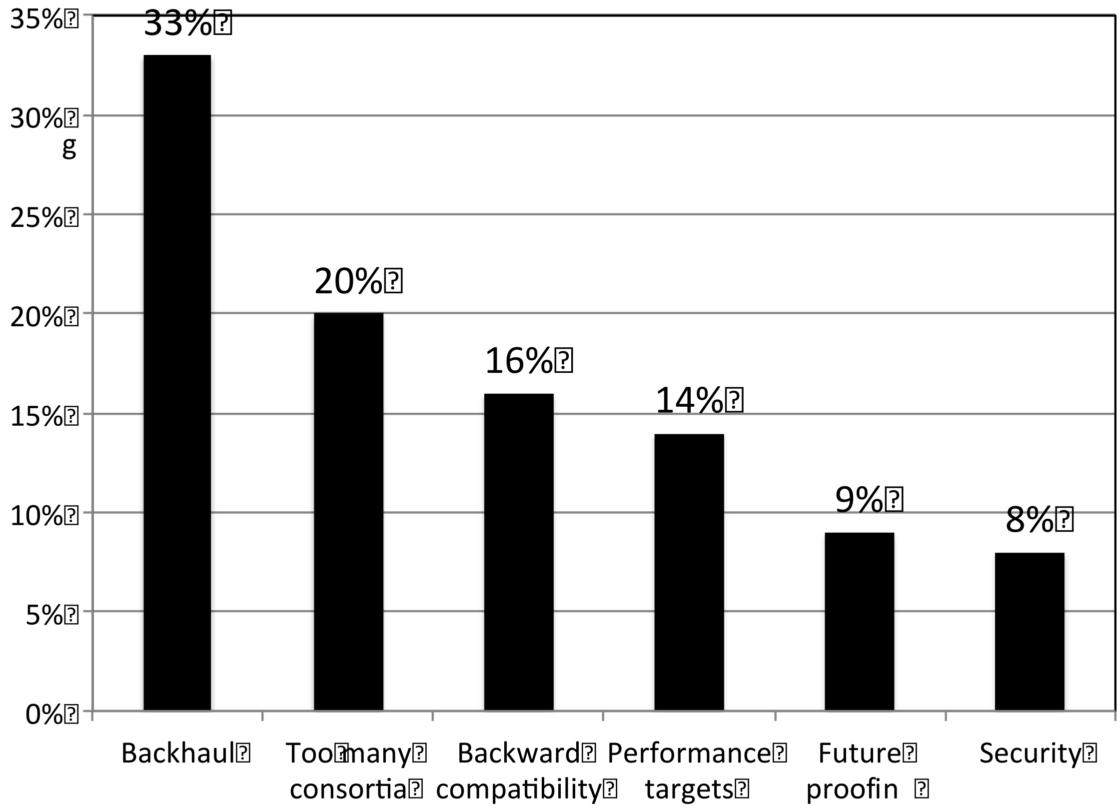
To conclude, it is conceivable that at least the two ILECs will launch 5G services in 2020.

## 4.2. Estimate the impact of 5G cell site deployment on backhaul costs

The increase of 15 to 20 times in throughput resulting from the migration from LTE/LTE-A to 5G (amounting to a growth from ~100 Mbps to ~10 Gbps) will change the sizing requirements of the backhaul networks, driving dense 10 G and 100 G requirements close to the cell site. When small cells are densely deployed, as will be the case in 5G, forwarding massive backhaul traffic into the core network remains a key problem. The main engineering concern is that the large number of small cells will cause the signaling load on the network nodes to increase due to frequent handovers; then, increased handovers coupled with radio link failures will result in degraded mobility (Ge et al, 2014).

It is, therefore not surprising to see that a survey among industry executives indicates that the biggest challenge to 5G will be backhaul costs. (See Figure 12)

**Figure 12. Challenges to 5G Migration**




*Source: Light reading cited in Hannula (2015)*

The exponential increase in backhaul costs is driven by two factors. First, the network engineering literature considers that current backhaul architectures (mostly built around microwave links that are operator owned) and copper based links cannot sustain even the traffic growth of LTE and LTE-A networks beyond 2017-18. The massive migration to fiber backhaul has substantial cost implications for carriers that depend on leased links. In this context, a potential transition to 5G would become cost prohibitive (Jaber et al., 2016).

Second, the approach that a wireless carrier adopts to migrate to 5G could further aggravate the economic hurdle. Carriers will face a decision as to whether they will be deploying 5G in Stand Alone (5G New Radio (NR) to a 5G core) or in Non-Stand Alone (5G NR to a 4G core). In the case of Stand Alone, 5G requires its own backhaul (which means acquiring a completely new core network to support 5G). Under Non-Stand Alone, 5G shares the backhaul with 4G for signaling. Even under the last case, additional backhaul capacity will be required due to increased capacity demands. The Stand Alone option presents competitive wireless carriers with the largest hurdle to 5G migration. In fact, ILECs are pushing for a Stand Alone solution in standards, which does not allow new radios to connect to older cores. If this were to happen, in order to get into the 5G pool, a competitive carrier will have to buy a completely new Core Network to support 5G. That will be the new hurdle and new barrier to entry in the next 5 years, regardless of backhaul.

### 4.3. Impact of economic constraints on competitive wireless carriers to migrate to 5G

The current BDS regime has a significant impact on the economics of 5G deployment and, consequently could delay the ability of competitive wireless carriers to migrate to the new technology. The resulting effect could be that AT&T and Verizon will launch 5G by 2020, while the rest of the industry remains relegated to prior generations of wireless technology. Carriers #1, #2, #3, and #6 indicate that a 5G migration will not take place in the short or long term; nonetheless, early dominance of 5G by two large carriers may prevent those competitive carriers from deploying 5G technologies while 5G is still considered the latest, fastest mobile technology. In sum, AT&T and Verizon will already reap the benefits of being first movers and an unregulated BDS marketplace will ensure other carriers cannot adopt 5G at a competitively meaningful pace.

Studies indicate carriers that introduce leading edge wireless technologies can forge a lasting competitive advantage. This effect could further accentuate market inequities. The mechanisms by which being a first mover translates into competitive advantage that have been identified thus far can be categorized under four domains, namely economic, preemption, technological and behavioral (Kerin et al, 1992). Each of these factors focuses on a different aspect of the market dynamics and/or corporate capabilities, explaining how being the first in the market could build competitive advantage and achieve long-term superior performance. (See Table 16)

**Table 16. Advantages of a First Mover**

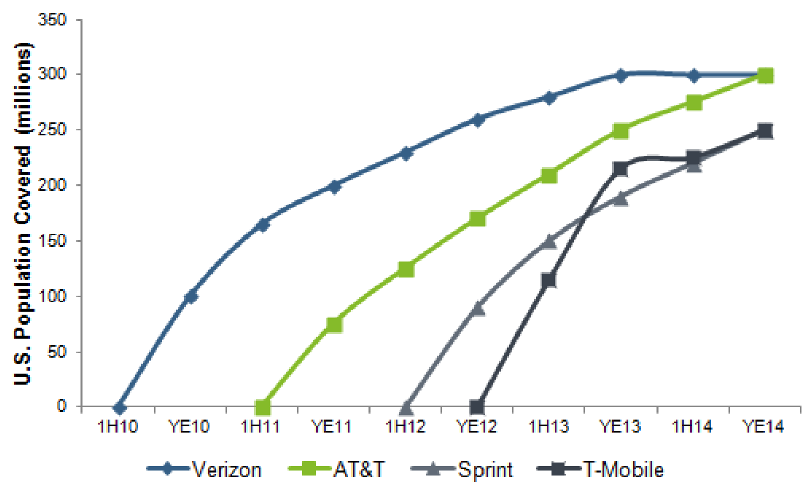
| Domains | Benefits |
|---|---|
| Economic | • By rapidly building economies of scale, the first mover can achieve lower unit costs than its competitors (Krouse, 1994; Makadok, 1998; Jakopin & Klein, 2012)<br>• The first mover is more likely to increase its market share (Bijwaard et al., 2008; Jakopin & Klein, 2012)<br>• The first mover can start learning how to optimize production under new technology before its competitors (Lieberman, 1987; Ruiz-Ortega & Garcia-Villaverde, 2008)<br>• Being the first to introduce a new technology, the first mover can compete in more favorable market conditions, while the followers need to operate in a more crowded market (Bowman et al, 1996, 222-42; Makadok, 1998) |
| Preemption | • The first mover can acquire inputs at prices below those that will prevail in the market later (Lieberman & Montgomery, 1988; Lee et al, 2007)<br>• Similarly, the first entrant can gain better access to distribution channels (Dierickx et al, 1989; Fernandez & Usero, 2007)<br>• The first mover has the ability to identify, assess and nurture resources or capabilities that yield an asymmetry relative to competitors (Hidding, 2001)<br>• The first mover can occupy the most attractive niches in terms of geographic location, product characteristics, distribution channels, and market segments (Kerin et al, 1992; Fernandez & Usero, 2007) |
| Behavioral | • By leveraging switching costs, the first mover can raise barriers to entry for its followers (Klemperer, 1987)<br>• Switching cost is a more compelling barrier in markets where the demand is homogeneous (Capone et al, 2013)<br>• First-movers can have major influence on how attributes are valued and ideally bundled, and can become strongly associated with the product category as a whole, and as a result, attain |

| Domains | Benefits |
|---|---|
| | certain insulation against later entrants that are positioned close to it (Carpenter et al, 1989, 285-298)<br>• In a market where there is asymmetric information about product quality, rational consumers are willing to pay a higher price for a product of known quality (that of the first mover) than for a product of unknown quality (that of new comers) (Conrad, 1983)<br>• A consumer can be incentivized to adopt the product of the first mover if he expects that it represents the dominant offering in the future (Koski et al, 2004) |
| Technological | • The smoother the innovation process and the more stable the customer needs, the more easily the first mover profit from its own innovations (Kerin et al, 1992; Min et al., 2006)<br>• Same as technological innovations, administrative innovations yield opportunities of profit for early adopters and penalize non-adopter with worse performance (Teece, 1980) |

According to this argument, if, by virtue of favorable backhaul economics, the ILECs anticipate their investment in 5G, that would further market concentration and diminish competition. The 4G case amply illustrates these dynamics.

In the US, Verizon anticipated its peers in the deployment of LTE by one to two years. (See Figure 13)

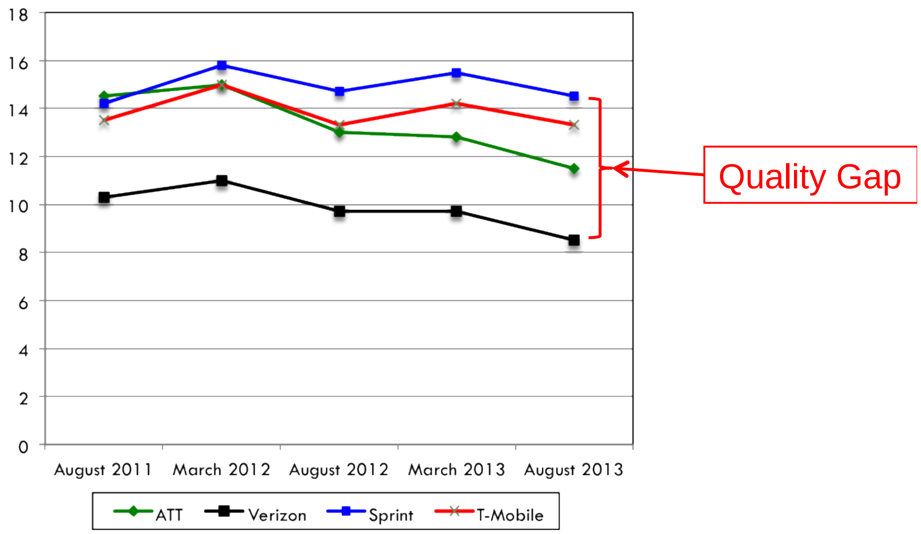
**Figure 13. United States: LTE Coverage**




*Source: Company data; Stifel*

In addition, the anticipated investment paid off in terms of customer perception, with the quality gap between Verizon and the other national carriers increasing over time. (See Figure 14)

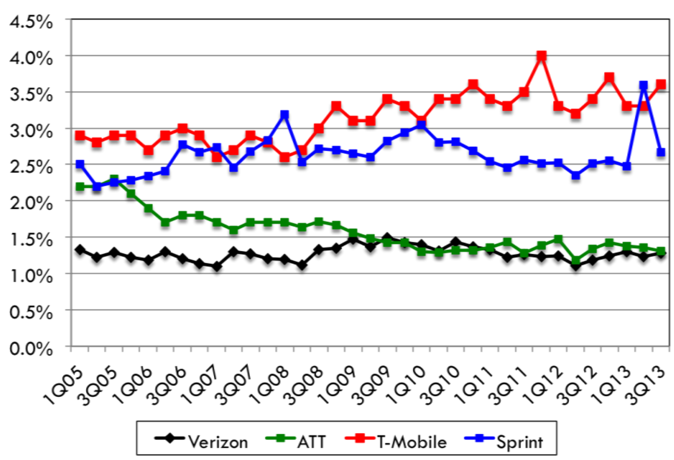
**Figure 14. United States Wireless Carriers: Network Quality Performance Ratings (*)**




(*) The lower the rating, the better is network quality performance
*Source: J.D. Power*

As demonstrated in the quantitative analysis above, Verizon was capable of leveraging its superior network quality to achieve the lowest market churn (although its position is under challenge by AT&T). (See Figure 15)

**Figure 15. United States Wireless Carriers: Quarterly Churn (2005-13)**




*Source: GSMA Intelligence*

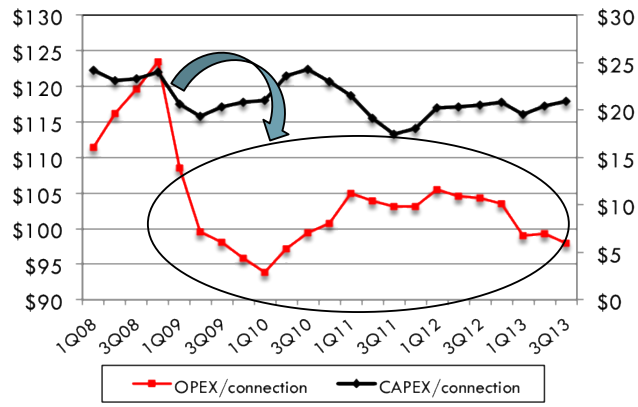
By becoming the leader in LTE deployment, Verizon Wireless profited before its competitors, achieving by 1Q2016:

- The lowest churn (1.23%)
- The carrier with the highest ARPU ($ 49.77)
- The highest volume of smartphone sales since 2013
- Highest revenues (despite the inorganic effect of the Alltel acquisition)

- Superior EBITDA margins since 2007

For example, by leading in LTE deployment (among other factors), Verizon Wireless was able to bring down operating expenses per connection by 12% since 2008. (See Figure 16)

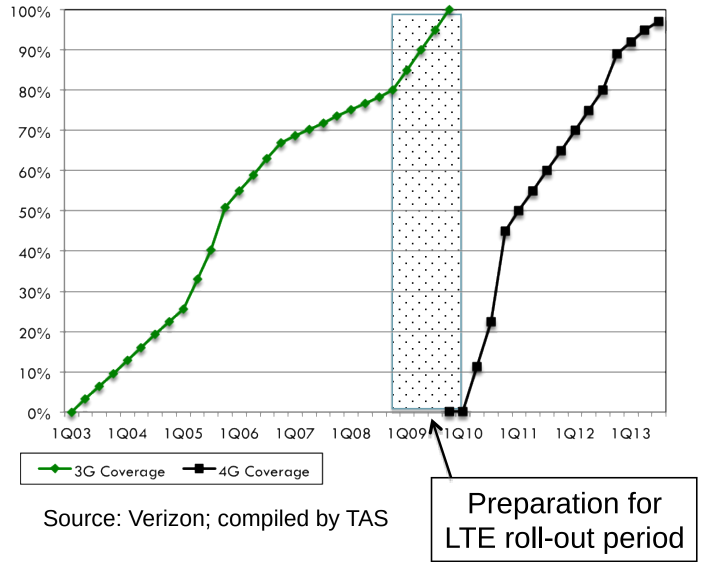
**Figure 16. Verizon Wireless: CAPEX and OPEX per connection (2008-2013)**




*Source: GSMA Intelligence; TAS analysis*

How can we explain the OPEX reduction effect of front-loading the migration to LTE? The research literature points out that, in the presence of potential learning to manage new production infrastructure, the best decision for a first mover is to produce as many units as possible above marginal cost. The final cost is the one achieved after some period of learning in the market, and is usually lower than the cost at the time when the company first enters (Spence, 1981). An analysis of the behavior of Verizon indicates that learning effects are at the core of cost reductions. For example, data would indicate that Verizon has developed a fairly good approach to technology migration strategy. In 2007, while continuing to upgrade its 3G network, the carrier shifted its network strategy to LTE. After purchasing spectrum, the carrier implemented a streamlined approach to network construction and roll-out. The build-up and deployment of LTE infrastructure started in 2009, comprising a modification of antennas at every LTE cell, the upgrading of the cell site backhaul at every LTE cell, and a conversion of the network to MPLS. The net result of a better management of network transition significantly shortened the time to deployment of LTE. (See Figure 17)

**Figure 17. Verizon Wireless: Network Coverage (2005-2013)**




In addition, the LTE migration gave Verizon a capital efficiency advantage.

Extrapolating the 4G experience to 5G deployment leads to a very pessimistic outcome of development of the new platform for competitive carriers. Reduced competition and less innovation could be even more serious in the case of consumers resident in rural and isolated areas.

## 4.4. Rural impact of economic constraints on competitive wireless carriers to migrate to 5G

Wireless industry structure in rural areas is more concentrated. Based on the National Broadband Map data, the percentage of population by county that is served by only one or two carriers is fairly high. Economic literature has long supported the conclusion that a market served by, at best, only two providers cannot generate sufficient consumer benefits derived from appropriate competitive dynamics. This conclusion is supported by the economics literature. For example, in his research on the risk of collusive behavior, Selten (1973) established through a theoretical model that "four players are few and six are many." Therefore, according to the economics literature on the optimal number of players in a static context, two firms would not be sufficient to obtain effective competition. That has also been supported by Kwoka (1979), Mueller and Greer (1984), and Besen and Mitchell (2016). In particular, Kwoka (1979) concluded that price discipline was related to the presence of at least three industry players with strong market shares. This finding seems to be supported by empirical observations in international wireless markets with three equally balanced participants (Katz, 2009). Mueller and Greer (1984) consider, however, that a fourth player or, alternatively, a group of smaller players operating under the umbrella of the large two industry participants could play a role similar to the third player. Besen and Mitchell (2016) consider, rightly so, that "the exact number (of players) may be different in different industries, based on their different cost and demand characteristics", but conclude that in telecommunications it should likely be "four – and certainly more than two providers."

Additionally, there are several economic studies on the relationship between firm size and market structure on the one hand, and technological innovation on the other. According to Aghion et al. (2005), there is an "inverted U" relationship between competition and innovation. While the exact number of firms that is optimal cannot be precisely determined, the dynamic efficiency model establishes that too much competition is not conducive for innovation because then there are little rents to be captured from innovation. On the other hand, too little competition is not optimal either, since firms do not obtain much additional profit from innovation.

At the national level, the FCC claims that only 3.1% of the total US population is served by one or two wireless service providers. The situation in suburban and rural counties in the five states studied is considerably worse. We have analyzed wireless service industry structure in the following five states: Kentucky, New Hampshire, Oregon, Vermont and West Virginia. We started by classifying all the counties in each of the five states across the continuum code provided by the Department of Agriculture. Specifically, the county grouping method utilized was as follows:

**Table 17. County Coding Methodology**

| Code | Category |
|---|---|
| 1,2,3 | Urban |
| 4,5,6 | Suburban |
| 7,8,9 | Rural |

*Source: Telecom Advisory Services LLC*

This method is consistent with the official description of the code (shown below[32]).

[32] Found in the documentation explanation by the Department of Agriculture: http://www.ers.usda.gov/data-products/rural-urban-continuum-codes.aspx#.U8kwwbHCffs

**Table 18. Country-Urban Continuum Code**

| Code | Description |
|---|---|
| **Metropolitan Counties** | |
| 1 | Counties in metro areas of 1 million population or more |
| 2 | Counties in metro areas of 250,000 to 1 million population |
| 3 | Counties in metro areas of fewer than 250,000 population |
| **Nonmetropolitan Counties** | |
| 4 | Urban population of 20,000 or more, adjacent to a metro area |
| 5 | Urban population of 20,000 or more, not adjacent to a metro area |
| 6 | Urban population of 2,500 to 19,999, adjacent to a metro area |
| 7 | Urban population of 2,500 to 19,999, not adjacent to a metro area |
| 8 | Completely rural or less than 2,500 urban population, adjacent to a metro area |
| 9 | Completely rural or less than 2,500 urban population, not adjacent to a metro area |

*Source: US Department of Agriculture*

Once all counties were assigned a code and grouped according to the three classifications, the population-weighted average of the percent of population being served by one, two or more wireless carriers. With the exception of urban counties in Kentucky, New Hampshire and Oregon, all other counties in the 5 surveyed states exhibit a much higher percentage of the population than the national average served by either one or two wireless operators. For example, in West Virginia, 20.6% of the suburban population and 33.8% of the residents in rural counties are able to access wireless broadband service from, at best, two operators (see Table 20).

**Table 19. Comparative Coverage Metrics by County (Percent of Population)**

| | FCC Claimed Population served by 1 or 2 carriers (%) | | |
|---|---|---|---|
| National | 3.1 | | |
| | **Urban Counties** | **Suburban Counties** | **Rural Counties** |
| Kentucky | 0.7 | 5.3 | 24.7 |
| N. Hampshire | 2.1 | 5.0 | 16.2 |
| Oregon | 0.7 | 4.7 | 6.4 |
| Vermont | 4.8 | 14.1 | 19.7 |
| W. Virginia | 12.9 | 20.6 | 33.8 |

| | The percentage of population is lower than the prorated national statistic |
|---|---|

*Source: National Broadband Map; TAS analysis*

In this context, high backhaul costs could further increase the barriers to entry in rural areas, thus exacerbating industry concentration. Furthermore**,** if the backhaul economics of 5G implementation are disadvantageous, carriers operating in rural areas will not be able to migrate to the newer technology. This situation could accentuate the digital divide, according to which rural population would not be able to gain access to the latest wireless technology. 5G is therefore an analogue case to the dichotomy of wireline broadband deployment between fiber optic NGA platforms in urban and suburban areas and slower access infrastructure in rural territories.

# 5. CONCLUSIONS

The purpose of this study was to assess the economic impact resulting from the dominance exercised by the ILEC affiliates of AT&T and Verizon in the BDS market and to evaluate the impact of BDS on the wireless market. Substantial evidence has been documented showing that AT&T and Verizon charge wireless carriers higher rates for backhaul than they charge their own enterprise customers for the same BDS service. Furthermore, the ILEC affiliates providing backhaul links tend to impose unusually high loyalty commitments and penalties for their reduction. The study evaluated three potential negative economic effects of the current market situation.

First, based on benchmark analysis, carrier interviews, and secondary data analysis, the study concluded that backhaul costs represent an average of 4.3% of a wireless carrier total operating expenses, and 30% of its network costs. Based on these estimates, it is estimated that a 30% decrease in backhaul costs that could result from limiting an ILEC affiliate from imposing higher prices or contractual obligations on competitive wireless carriers purchasing BDS, would yield an increase of 5.28 % in CAPEX of competitive wireless carriers. This increase in capital spending would, in turn, yield improved service quality, better coverage, and lower churn, as well as increased competition against incumbents.

Second, facing exponential traffic growth, competitive wireless carriers are confronting an economic constraint in deploying additional cell sites to increase their capacity. If they decide to split a cell or upgrade the leased backhaul link, they will undergo a decrease in margins because the increase in cost of upgrading the backhaul does not yield higher revenues. In other words, with the increase in traffic, profitability decreases in part because of backhaul pricing. Alternatively, if carriers decide not to upgrade their network capacity, service quality erodes and they undergo an increase in churn and consequent loss in share. This situation further aggravates the economic condition of competitive wireless players reinforcing a trend toward industry concentration. In fact, econometric analysis of US data indicates that an increase of 1 millisecond in latency tends to decrease market share by 0.0058 percentage points.

Third, the current BDS market condition becomes an impediment for competitive carriers to even consider their migration to 5G, a goal outlined by the FCC Chairman. The resulting effect could be that the two ILECs would have launched 5G by 2020, while the rest of the industry will be relegated to prior generations of wireless technology. Several studies indicate that carriers that introduce leading edge wireless technologies can build lasting competitive advantage. For example, by rapidly building economies of scale, the first mover can achieve lower unit costs than its competitors, while at the same time learning how to optimize production under new technology before its competitors. Furthermore, by being the first to introduce a new technology, the first mover can compete in more favorable market conditions, while the followers operate in an inevitably more crowded market. These effects could further accentuate market inequities.

The combination of these three effects will be particularly serious for the future of wireless broadband in rural communities of the United States. In numerous counties within the states of Kentucky, New Hampshire, Oregon, Vermont and West Virginia, between 10% and 20% of the population is served by, at best, by two wireless operators. The economics literature has shown that a market served by only two wireless service providers cannot generate sufficient consumer benefits derived from appropriate competitive dynamics. In the context of highly concentrated rural markets, high backhaul costs resulting from the dominance of ILEC affiliates in the BDS sector could further increase the barriers to wireless development in rural areas, thus exacerbating industry concentration. Furthermore, if the backhaul economics of 5G implementation are disadvantageous, carriers operating in rural areas will not be able to migrate to the newer technology. This situation will accentuate the digital divide, under which rural Americans will not be able to gain access to the latest wireless technology. This is an analogue case to the dichotomy of wireline broadband deployment between fiber optic NGA platforms in urban and suburban areas and slower access infrastructure in rural territories.

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