



# WHITE PAPER

## **BREAKING THE BACKHAUL BOTTLENECK**

*How to Meet Your Backhaul Capacity Needs  
While Maximizing Revenue*

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## Executive Overview

Operators and network owners everywhere are dealing with the same critical problems:

- 1. Exponentially increasing capacity demand***
- 2. Simultaneous decrease in revenue-per-bit***
- 3. Spectrum crunch***

Across the industry, the quest to find a gigabit-capacity low-cost backhaul solution for mobile network expansion continues at a frantic pace. To truly differentiate from competitors, today's Wireless Network Operators need to deploy a disruptive combination of backhaul technologies. Providers need a solution that can transform their network capacity in a fraction of the time and cost of current solutions, and can completely disarm the threat of the impending bandwidth crunch crisis.

Today's mobility backhaul landscape consists of a handful of technologies that specifically address unique backhaul cost and capacity needs. These include traditional industry solutions such as Fiber, Microwave, and Millimeter Wave, as well as an important new technology called Optical Wireless Broadband.

Each of these four technologies address a key portion of the backhaul puzzle. Fiber is the right choice for high-capacity routes where logistics are manageable, capacity need is high, and the potential revenue gain offsets the expense. Microwave makes sense for lower capacity long-distance runs where fiber is either logistically or economically infeasible. Millimeter wave addresses the subset of short-distance applications where spectrum is available and the deployment environment can handle rain-fade impacts, and data capacity needs are below 500 Mbps full duplex. Optical Wireless Broadband is the technology that rounds out this group, specifically addressing high-density urban backhaul environments where low cost, high capacity, and rapid deployment are critical for success.

In this paper, we will highlight the market conditions driving backhaul requirements, the looming spectrum crisis, and the pros and cons of each of these four technologies. We will look at the conditions in which each flourishes, and where they fall critically short. We will also discuss the relatively unknown but critically important Optical Wireless Broadband technology, and how its unique capabilities bring a critical missing link to the optimal backhaul solution.

*Mobile backhaul demands will increase 9.7 times between 2011 and 2016, fueled by rapidly growing data consumption.*

*Backhaul can account for as much as 30% of a mobile operator's total network operating costs.*

## State of Backhaul and Looming Spectrum Crisis

The wireless industry's capacity crisis is looming, and Mobile Backhaul is a key component in that crisis. Though not always considered the most interesting portion of a successful wireless network, these days Backhaul is becoming arguably the most important. The onslaught of capacity demand being driven by wireless devices and the rollout of 4G/LTE requires Service Providers to deal with a level of capacity demand far greater than could have been imagined in the days of 2G/3G mobility.

### Exponential Increase in Capacity Demand

A recent report from iGR Research Company confirmed that the demand for mobile backhaul in the U.S. market will increase 9.7 times between 2011 and 2016, fueled by rapidly growing data demands.<sup>1</sup> The unavoidable fact

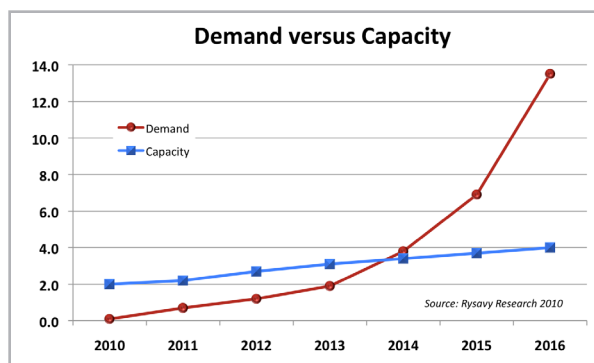


Figure 1: Demand vs Capacity per user

is that demand is increasing far faster than Mobile Network Operators (MNOs) can keep up. And according to Rysavy Research, the crisis is coming fast: demand will definitively exceed capacity by mid-2013,<sup>2</sup> as we can see in Figure 1.

The advent of urban Small Cells, although specifically intended to address this rapid growth, will actually have the effect of accelerating capacity demand, as users explore new capabilities on wireless devices facilitated by faster networks.

### Revenue per Byte is Flat in the Data Era

MNOs face a double-edged dilemma, because at the same time that demand is increasing exponentially, revenue-per-user and revenue-per-bit is flattening out. Global data traffic surpassed global voice traffic in 2007, and established the beginning of the "Data Era."<sup>3</sup> Ever since that crossover, the network operators have faced a major challenge in generating revenue from new higher-capacity services. In the Data Era, a ten-fold increase in data capacity only translates to approximately a 20-30% increase in data service rev-

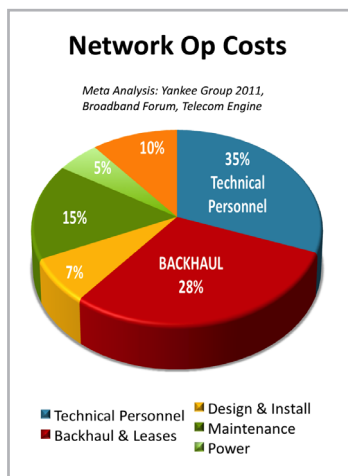


Figure 2: Operating Costs

*Increasing data capacity does not guarantee a proportional increase in revenue for Service Providers.*

enue for a provider. As illustrated in Figure 3, this decoupling of revenues from capacity requires that MNOs find and implement innovative solutions to manage backhaul costs to keep them in lock-step with this constrained revenue growth. As backhaul capacities transform from Megabits-per-second to Gigabits-per-second, the technologies and solutions chosen to provide this capacity must be capable of delivering significant economies of scale.

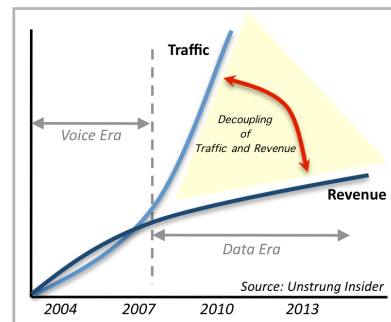


Figure 3: Traffic vs Revenue

## Imminent Spectrum Crunch

The other key challenge impacting Wireless Operators is the rapidly diminishing availability of spectrum. Wireless spectrum is a scarce and precious

*Today, a Wireless Operator's most valuable and non-renewable resource is spectrum.*

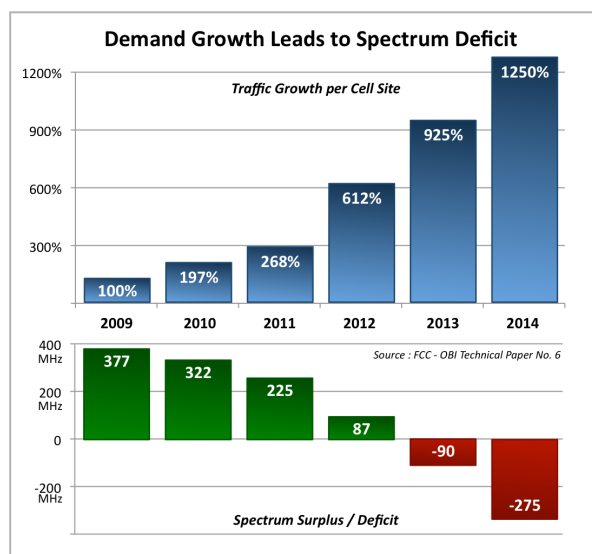


Figure 4: Wireless Data Growth Leads to Spectrum Deficit

*T1/E1 copper circuits and Microwave links previously sufficient for yesterday's 3G backhaul will be forced to transition to fiber or higher-capacity wireless backhaul solutions.*

resource for Service Providers. As can be seen from this FCC graph, the remaining wireless spectrum surplus of 80 MHz will become a deficit of 275 MHz by 2014<sup>4</sup>. Network designers go to great lengths to maximize the aggregate network throughput in their network's limited amount of wireless spectrum. As a result, there is a substantial need for cost-effective non-RF solutions that can move backhaul traffic off

## What 4G Really Means for Backhaul Technology

of overworked wireless frequencies. Each of today's current backhaul solutions have pros and cons in their ability to address this spectrum crunch.

According to the ITU, 4G mobile networks are defined as providing at least 100 Mbps peak capacity for high mobility applications, and 1 Gbps for stationary applications.<sup>5</sup> This massive jump in performance definitions from 3G to 4G is one of the key drivers for backhaul capacity needs, and is the main

*By 2015, 100 Mbps to 500 Mbps is the projected minimum viable capacity per cell site.*

*Fiber installation ranges from \$250K-\$700K per mile in dense urban areas.*

*Leasing high-capacity data capacity can be prohibitively expensive, even the lowest-cost short-range services are typically \$5k-\$15k per month.*

reason that the multiple T1/E1 copper circuits and Microwave links previously sufficient for yesterday's 3G backhaul will be forced to transition to Fiber or higher-capacity wireless backhaul solutions.

In 2009, the average high-density base station capacity was 5-20 Mbps. By 2014, 100 Mbps to 500 Mbps will be the projected minimum viable capacity per urban cell site. Cell site backhaul will inevitably grow to hundreds of megabits per second per cell site, and gigabits per second in the aggregation networks.

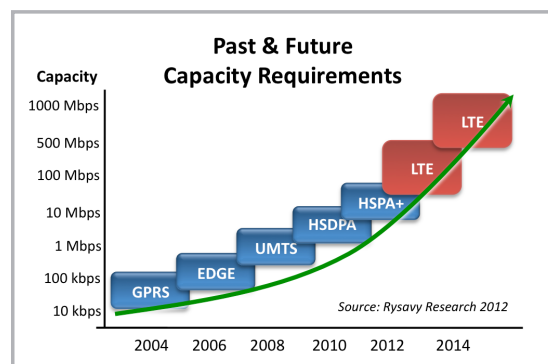


Figure 5: Capacity Requirements for LTE

## Traditional Solutions: Advantages & Challenges

### Fiber and Leased Lines

Fiber continues to hold its place in the hearts and minds of the Telecommunications Industry as the preferred solution for backhaul. It is widely viewed as a time-proven technology that offers almost limitless capacity and scalability. And yet, Fiber is also one of the most expensive, difficult, and time-intensive capital expenditures a carrier can make.

The reality is that pulling Fiber to every cell site is simply not feasible, not only due to cost issues but also due to excessive logistical challenges. Fiber installation ranges from \$250k-\$700k per mile in dense urban areas, making it cost prohibitive especially in the most important and congested subscriber areas. Time delays due to acquiring permits and lengthy construction for trenching also make Fiber installation an unattractive solution.

In most situations, operators do not already have their own Fiber running to a base station cell site, and when the cost of laying new Fiber is too high, the only other Fiber alternative is to lease from another operator. Leasing high-bandwidth data capacity can be prohibitively expensive, even the lowest-cost short-range (GigE or SONET/SDH) services are typically in the \$5k-\$15k per month range, and can run much higher. Additionally, leased Fiber is available only about 30% of the time.<sup>6</sup>



*Although traditional Microwave has played an important role in backhaul for 2G and 3G, the demands of 4G will exceed its capability.*

*Millimeter-Wave can potentially deliver high-capacity links, but with major reliability and spectrum issues.*

*MMW Challenges include compromised reliability due to rain-fade and beam-alignment issues, limited growth capabilities, and the need for large amounts of available spectrum.*

At many points in the backhaul network, the time and high cost of Fiber build-out makes it impractical, and sometimes completely economically non-viable. Service Providers want to spend their resources on improving end-user capacity and functionality, not on overhead-intensive backhaul solutions, and as a result are moving in larger and larger numbers to non-Fiber based backhaul solutions.

### **Microwave (3-30 GHz)**

LTE wireless cell sites will require an aggregate capacity of more than 500 Mbps in less than three years (see Figure 5). Although traditional Microwave (MW) has played an important role in backhaul for 2G and 3G, the demands of 4G will exceed its capability. Microwave capacity taps out around 400 Mbps full-duplex due to the permitted limits placed on RF channel bandwidth. Maximum allowed channel bandwidths are normally no more than 56 MHz, and even using high-order modulation (256-QAM) these links are limited to transmitting around 350 Mbps per channel. <sup>7</sup>

In order to scale beyond this data rate in the traditional Microwave bands, it is necessary to transmit multiple signals using multiple RF channels. Each channel used requires additional electronics and an additional spectrum license, so these links fail to deliver significant economies of scale beyond 350 Mbps. Attempting to deploy multiple dishes to increase capacity leads to major interference issues, in addition to scaling challenges.

### **Millimeter Wave (60/80 GHz)**

The term Millimeter Wave (MMW) applies to any RF technology operation in the 30-300GHz range, but is generally used to discuss 60-80 GHz equipment. Millimeter Wave can potentially deliver high-capacity links, but with major reliability and spectrum issues.

In recent years, some Millimeter Wave suppliers have successfully coaxed the technology to deliver approximately 800 Mbps full-duplex (often marketed as 2 Gbps, however these capacity statements are half-duplex only and include unusable capacity lost to transmission overhead). However, Millimeter Wave technology relies on tightly-focused antenna beamwidths and very large spectrum allocations (10 GHz Tx/Rx) to even approach 1 Gigabit capacities. This results in several major issues for the technology, including compromised reliability due to rain-fade and beam-alignment issues, limited

*Reliability challenges due to rain-fade and beam-alignment issues also continue to plague Millimeter wave.*

*Correcting a loss of alignment for a Millimeter Wave Radio requires a truck-roll to the site.*

*Millimeter Wave cannot reliably maintain beam alignment on 2-degree towers.*

*Millimeter Wave equipment advertised as 800 Mbps can very quickly become a 50 Mbps product in a heavy-rain environment.*

long-term capacity growth capabilities, and the need for large amounts of available spectrum to accommodate high-capacity links.

Like other RF technologies, Millimeter Wave must also contend with spectrum availability issues. Although licensed bandwidth for MMW is less costly than standard Microwave, it still represents a non-negligible cost to the Network Operator, and can be difficult to obtain depending on the particular market's regulatory environment. The alternative of using unlicensed or light-licensed bandwidth involves major investment risk. Once a network is deployed, if another user subsequently installs their own unlicensed Millimeter Wave in the same area, the entire network capacity could be cut in half, effectively doubling the investments costs to achieve the same capacity.

Reliability challenges due to rain-fade and beam-alignment issues also continue to plague Millimeter Wave. The tightly focused beams mean that the deployments are vulnerable to losing link alignment.<sup>8</sup> No Millimeter Wave equipment on the market today has an internal tracking & alignment capability, so correcting a loss of alignment requires a truck-roll to the site. Lack of tracking capabilities also means that Millimeter Wave technology is not conducive for use on towers that have greater than 1-degree of twist and sway (majority of towers deployed today are 2-degrees or greater).

Rain absorption rates peak around the standard frequencies used by Millimeter Wave products, and is a key consideration when deploying the technology. As can be seen in the highlighted area in Figure 6, link attenuation increases sharply as rainfall increases, and in fact the greatest attenuation in the entire 1-100 GHz frequency range occurs precisely in the 60/80 GHz range, the frequencies typically used by Millimeter Wave equipment (see highlighted range). Only a standard heavy rain (25mm/hr) causes a loss of 10 dB/km, and a tropical rain level (100mm/hr) means a loss of 30 dB/km, enough to completely disable most links.<sup>9</sup> A product advertised as 800 Mbps can very quickly become a 50 Mbps product

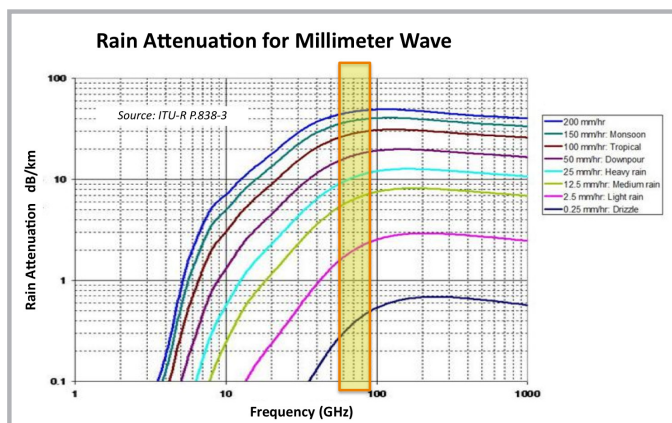


Figure 6: Rain Attenuation - MMW Frequencies Highlighted



*Optical Wireless Broadband (OWB) is a technology that uses infrared light to provide gigabit data capacities.*

*For the vast majority of high-capacity urban backhaul links, OWB has significant cost and reliability advantages over fiber, Microwave, and Millimeter Wave.*

*Optical Wireless Broadband brings key advantages to high-capacity backhaul: High Capacity at Low Cost, Rapid Deployment Speed, No Spectrum, and a Long-term Capacity Roadmap.*

in a heavy-rain environment.

Long-term capacity growth is another challenge for Millimeter Wave. Despite the advances that have allowed the technology to approach the 1-Gbps mark, MMW is now hitting a wall with regards to the amount of spectrum needed to deliver such speeds, and at this time there is no clear roadmap for how the technology will move past its current capacity.

## Optical Wireless Broadband for Backhaul

### Optical Wireless Broadband

Optical Wireless Broadband technology is the next generation of the Free Space Optics (FSO) technology that originated in the 1960's and first commercialized in the late 1990's. Optical Wireless Broadband is a point-to-point, line-of-sight technology that delivers over 1 Gbps of bandwidth across a 1.6 km distance, for a fraction of the cost of traditional solutions. Similar to

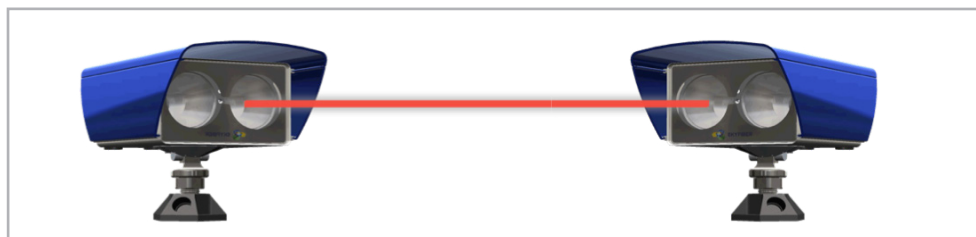


Figure 7: Representation of an Optical Wireless Broadband Link & Infrared Beam

FSO, Optical Wireless Broadband (OWB) is an infrared technology, but unlike FSO, the technology description contains features and capabilities including Forward Error Correction (FEC), Alignment Tracking, Integrated Packet Processing, and advanced optical laser and lensing techniques that make OWB's reliability and capabilities much greater than traditional FSO technology.

### High-Capacity Urban Backhaul

Optical Wireless Broadband addresses a crucial part of the Wireless Backhaul ecosystem, specifically high-capacity aggregation links in urban backhaul scenarios. This is where gigabit capacities are most needed, and where the backhaul distances required are consistent with OWB deployments at 99.995% or better availability (up to 1 mile /1.6 kilometers).

For long-distance backhaul, OWB does not replace Fiber and Microwave,

however for the vast majority of high-capacity urban backhaul links OWB has significant cost, spectrum, and reliability advantages over Fiber, Microwave, and Millimeter Wave technologies. There are four key areas in which Optical Wireless Broadband brings significant advantages to high-capacity urban backhaul:

- **High Capacity at Low Cost**
- **Rapid Deployment Speed**
- **No Spectrum Needed**
- **Long-term Capacity Roadmap**

*OWB's total cost per bit is significantly lower than any other backhaul solution.*

These advantages make Optical Wireless Broadband an important component of the full Mobile Backhaul ecosystem's portfolio.

### Low-Cost, High-Capacity, Rapid Deployment

OWB's total cost per bit is significantly lower than any other solution, as can be seen in Figure 8. This graph shows the total cost-per-bit of Optical Wireless Broadband versus Fiber, Microwave, MillimeterWave, and leased

*OWB Installation takes just days, not weeks or months like other backhaul options.*

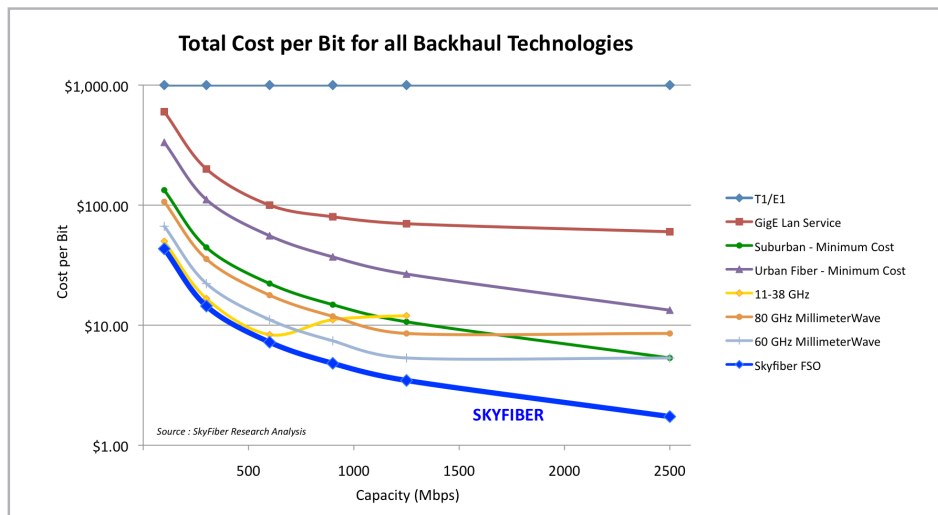


Figure 8: Total Cost per Bit by Technology for 1 mile link

lines for a 1-mile link over a 3-year period. Especially for high-density urban backhaul applications, Optical Wireless Broadband provides significant cost benefits.

Speed of deployment is another critical factor to take into account when designing backhaul networks. Choosing a technology that takes weeks or months to deploy can end up costing network operators greatly in terms

*Optical Wireless Broadband requires absolutely no spectrum.*

*Active Tracking and Forward Error Correction ensure high reliability for OWB.*

*Optical Wireless Broadband delivers full-duplex 1 Gbps.*

*OWB has a clear roadmap to reach future capacities of 2.5 Gbps and 10 Gbps without significant cost increase.*

of lost revenue. Fiber has the biggest challenges in this area, with major difficulties to obtain right-of-way, dig the trenches and install the Fiber cable. This is especially true in urban deployments. Even wireless RF technologies like Millimeter Wave and Microwave have significant issues with extra deployment time overhead. To start, either spectrum must be obtained or RF studies conducted (if attempting to use unlicensed bands) to ensure no interference. Depending on the regulatory requirements of the area, just acquiring permits to mount a RF dish can take weeks to months.

In contrast, OWB uses **no** RF spectrum, so neither licenses nor permits are needed to deploy the technology. Actual deployment of the link equipment itself takes just 1 to 2 days. With Optical Wireless Broadband, customers can have a Gigabit-capacity link in a small fraction of the time that is required for Fiber, Microwave or Millimeter Wave.

### **OWB: Reliable, Spectrum-Free, and Future-Proofed**

Reliability is a key concern for any network operator. Every technology has its unique set of challenges, but one issue in particular is often overlooked when deploying point to point (PTP) solutions like Millimeter Wave, Free Space Optics, and Optical Wireless Broadband: the question of beam alignment. For these PTP links to remain operational, alignment must be maintained at all times. Unlike MMW and FSO, Optical Wireless Broadband technology by definition includes Active-Tracking that ensures that signal strength is maintained at all times on all structures rated for up to 1-degree of sway. One vendor in particular (SkyFiber) takes this part of the technology a step further with a **Rapid** Active-Tracking capability (patent pending held by SkyFiber). With this enhanced Active-Tracking capability, the OWB technology is augmented to accommodate even the twist and sway of a 3-degree tower, and still remain fully operational.

Historically, the primary reliability challenge of the Free Space Optics technology was dense fog. Rain and snow have little effect on FSO technology, but dense fog can cause signal attenuation. In contrast to FSO, Optical Wireless Broadband builds in capabilities to improve link reliability, including additional power margin, forward error correction, and protection-switching capabilities with redundant links. With these features, and careful network design, OWB can achieve carrier grade reliability in most weather conditions.

Network evolution and guarding against obsolescence is another critical consideration when building a backhaul network. Both from a technological per-

*OWB signals are virtually impossible to intercept, and multiple OWB units can be used in the same location with no interference concerns.*

*To meet future demands, Mobile Network Operators must consider the three backhaul options of Fiber, Microwave, Millimeter Wave, and Optical Wireless Broadband as four parts of a complete backhaul solution set.*

***Optical Wireless Broadband is the clear choice for high-capacity urban backhaul.***

spective as well as due to spectrum limitations, Microwave cannot make it much past 500Mbps, and Millimeter Wave will hit a similar limit as future products approach the 1 Gbps and then 1.5 Gbps capacity mark. In contrast, Optical Wireless Broadband currently provides 1 Gbps full-duplex payload capacity (1.25 Gbps including overhead), and the technology has a clear roadmap to reach future capacities of 2.5 Gbps and 10 Gbps without a significant cost increase.

Spectrum is an extremely valuable and limited resource. Optical Wireless Broadband offers a major advantage to wireless carriers because it requires absolutely no RF spectrum. This also means that OWB does not have the interference and security issues that Microwave and Millimeter Wave must contend with. An OWB signal is virtually impossible to intercept, and multiple OWB units can be used in the same location with no concern about side-lobe interference. Aggregating 30 OWB units at a single location is completely feasible; where as even just three MW or MMW units on the same tower can cause major interference issues.

## Cost Effective Backhaul

### Managing Backhaul Successfully

The Wireless Industry is facing a major challenge to determine how to best augment existing network capacity capabilities to accommodate the ever-increasing mobile data demand. As we can see from Figure 9, the “Capacity Gap” that we see today will continue to grow exponentially over the next several years.<sup>10</sup> To meet this demand, Mobile Network Operators must consider the four main backhaul options, Fiber, Microwave, Millimeter Wave, and Optical Wireless Broadband, as four parts of a complete backhaul solution set. No single solution will address all needs, and yet each one has its own particular area of highest value.

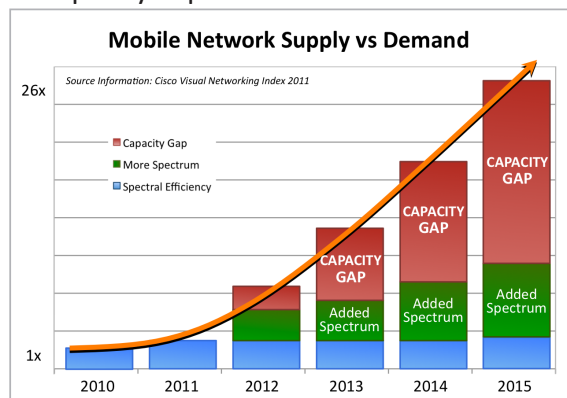


Figure 9: Mobile Network Capacity versus Demand

These four key solutions combine to cover all backhaul deployment needs.

When permission to trench is obtainable and the revenue-to-capacity opportunity is so high that the heavy price tag can be profitably accommodated, Fiber is the correct choice, such as in long-haul urban deployments. Microwave is the go-to option for long-haul links that require lower capacity, and therefore particularly suited to rural backhaul links. And Optical Wireless Broadband is the clear choice for urban backhaul connections that require high-capacity, resilience to rain, particularly in places where spectrum is scarce or oversaturated.

### About SkyFiber

SkyFiber, founded in 1996, is a privately held corporation of 50 employees, headquartered in Bryan, Texas, with additional offices in Dallas, TX and a partner network that spans the globe. SKYFIBER specializes in Optical Wireless Broadband solutions that can economically augment or replace traditional fiber optic and microwave technologies to meet customer needs for wireless backhaul and last-mile extension.

- 1 U.S. Mobile Backhaul Forecast: 2011-2016, iGR Research, 2012.
- 2 Mobile Broadband Capacity Constraints And the Need for Optimization, Rysavy Research, 2010.
- 3 Unstrung Insider Targeted Analysis 2007 and 2011.
- 4 "Mobile Broadband: The Benefits of Additional Spectrum", FCC OBI Technical Paper No.6, October 2010.
- 5 ITU Global Standard for International Mobile Telecommunications (IMT-Advanced) or 4G, 2010.  
"Mobile Broadband Explosion", Rysavy Research/4G Americas, August 2012.
- 6 "Access to Business Fiber", Vertical Systems Group, ENS Research, 2011.
- 7 "Will 4G Networks Break The Bank?", Mobile Dev & Design, Schrami, 2009.
- 8 "On beam alignment for outdoor millimeter wave beamforming", "ITA at USCD, 2011.
- 9 ITU-R P.838-3, "Specific attenuation model for rain for use in prediction methods," 2005.
- 10 Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update (2010-2015), 2011.

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