The WiFiber™ Value Proposition versus Other Media (Optical Fiber and Other Radio Technologies)

Introduction

GigaBeam's WiFiber™ digital millimeter-wave radio is the first FCC approved product to exploit the recently released 71 to 76 GHz and 81 to 86 GHz frequency bands. WiFiber offers true full-duplex Gigabit data rates (1.25 Gbps or 1GigE) in a cost effective radio architecture. Transmission distances of over 1 mile can be achieved with carrier-class 99.999% availability under all weather conditions throughout most of the USA.

This white paper demonstrates how GigaBeam's WiFiber technology is the only product family with gigabit bandwidth capacity today plus a near term growth path that provides a viable substitute to fiber optic cable for carriers in the last mile. A combination of GigaBeam WiFiber and terrestrial fiber should become the basic building blocks for network planners to meet the explosive growth in broadband communications capacity demand.

This paper is divided into the following sections:

- Overview: Carriers Confronting Local Access and Backhaul Demand
- High Bandwidth Demand Drivers
- WiFiber Versus Microwave Fixed Wireless for High Bandwidth Local Access and Backhaul
    - Overview of Inherent Limitations Facing Microwave
    - GigaBeam's WiFiber 70/80 GHz Solution
    - Licensing Comparisons
- WiFiber Versus Fiber Optics for High Bandwidth Local Access and Backhaul
- Summary: GigaBeam's Value Proposition to Carriers
- About the Authors
- Appendix A: Decision Tree Diagrams of Why Our Value Proposition Works
- Appendix B: Discussion of Distance and Reliability Tradeoffs

Overview: Carriers Confronting Local Access and Backhaul Demand

Increasing Bandwidth Demand: The accelerating move towards broadband, in the US and abroad, has been documented in countless published sources. We therefore focus on high bandwidth access and backhaul—where we define high bandwidth as 45 Mbps and up. The demand drivers for improved high bandwidth local access and backhaul facilities options are similarly documented in both the US and abroad.

Carrier Options: Carriers today have two options for local access and backhaul: terrestrial and wireless. Both of these options can further be subdivided into lower bandwidth access technologies (not the focus of this paper), and backhaul and higher bandwidth access technologies (i.e., 45 Mbps and up), which are the focus of this paper and discussed immediately below. Subsequently, we will explore the relevant wireless options for 45 Mbps and up services—including fixed microwave—versus GigaBeam's offering, and the terrestrial option—fiber optics—versus GigaBeam's offering. We conclude with a summary as to why WiFiber should be a carrier network planners' primary compliment to, back-up for and competitor to fiber. An appendix is included with a diagrammatic summary of the major points of the paper.

High Bandwidth Demand Drivers

Wireless Drivers: First, on the wireless side, one needs to differentiate between lower and higher bandwidth wireless technologies. Lower bandwidth technologies are usually one-to-many technologies (point-to-multipoint (PTMP)) and they are generally designed for mobility. On the other hand, higher bandwidth wireless options are usually one-to-one (point-to-point (PTP)) and they are generally designed for high bandwidth backhaul to/from stationary locations. The classic lower bandwidth PTMP service is cellular, which not only reaches many locations with very low bandwidth (as low as 8 Kbps), but also adds the crucial dimension of mobility. Cellular is moving towards higher bandwidth, but the range for the next several years will be 256 Kbps to 1 Mbps. This very movement up the bandwidth scale, however, will greatly increase the need for high bandwidth backhaul that plays well into the economics of GigaBeam's completely complimentary high bandwidth backhaul offering. Furthermore, cellular is not the only wireless low bandwidth service that will be driving backhaul demand—WiFi, especially the city wide meshed WiFi services being implemented in Philadelphia, San Francisco, and elsewhere, WiMax, and other services will all drive demand for backhaul. Lastly, large scale roll-outs of medium speed EVDO technologies at 1 to 5 Mbps, initially by Verizon and Sprint, will further drive the need for flexible location of high speed backhaul

Contrasted with mass market access lower speed PTMP technologies, are a class of wireless technologies and services aimed at the backhaul market—principally PTP microwave radio. Free space optics has also been targeted at this market, but various limitations have diminished its success and relegated the technology to very short distance or in-building applications we do not consider here. This paper focuses on the space that GigaBeam is transforming radically: high bandwidth PTP technology and local last mile solutions.

Terrestrial Drivers: On the terrestrial side, the two major options are fiber optics and all other access technologies, which consist overwhelmingly of copper loop plant and Cable TV coaxial plant. Even with advanced DSL and cable modem services, copper and coaxial loop plant top out at 6-24 Mbps, not 45 Mbps. Very importantly however, these access media are strongly driving the demand for very high bandwidth local loop transmission capacity—i.e., both need high bandwidth backhaul, and both need more of it every day. Similar to advances in consumer cellular from 2G to 3G/4G and video services, including HDTV, driving the need for backhaul, advances in wireline consumer based access technologies are completely complimentary with GigaBeam's high bandwidth WiFiber product, and are driving the need for it. Of course, business broadband services are exploding as well. For terrestrial services backhaul, and for access at 45 Mbps and above, until now terrestrial fiber has been the media of choice, and we spend significant time below analyzing its characteristics and its economics, and comparing it to GigaBeam's offering.

The remainder of this paper examines the value proposition of GigaBeam: WiFiber versus microwave fixed wireless and WiFiber versus fiber optics. In Appendix A, we provide a graphical representation of the entire space—fixed and wireless—from the carrier industry's future perspective, which we believe clearly illustrates why our total value proposition is so compelling.

WiFiber versus Microwave Fixed Wireless

Inherent Limitations Facing Microwave

We begin our discussion with microwave fixed wireless. Fixed wireless radios at frequencies below 40 GHz are widely used to distribute data in both point-to-point (PTP) and point-to-multi-point (PTMP) configurations. Many different technologies are currently deployed in these frequency bands:

- Sub 1-GHz bands - long distance broadcast and trunked radio
- 1 to 6 GHz bands - cellular, WiFi, MMDS and future WiMax technologies
- 6 to 40 GHz bands - a variety of access and transmission applications including LMDS and other fixed point-to-point (PTP) microwave radios.

Spectrum and Data Capacity: The data capacity of these technologies depends primarily on the amount of radio spectrum in which these technologies operate. Generally, the higher spectrum bands with greater total frequency allotments, have larger spectrum bandwidth, and can support higher total data rates. The only technology able to support full-duplex data rates of 100 Mbps (true 100BaseT Ethernet) or 155 Mbps (OC-3 or STM-1 SONET) or higher is fixed PTP microwave radio, operating at frequencies of 6 to 40 GHz[1]. SkyLight Research (www.skylightresearch.com) estimates that the 2005 worldwide market for 6 to 40 GHz, short haul, point to point microwave radios is almost 400,000 terminals, amounting to an almost $2B market.

Spectrum Channelization: Because the spectrum at 6 to 40 GHz is considered scarce, spectrum authorities have heavily segmented these bands into narrow channels to ease spectrum coordination and promote spectrum efficiency and frequency reuse. In the United States, the FCC divides the 6 to 40 GHz bands into channels of 1.25, 2.5,

[1] This report uses the term Microwave Radio or Microwave Fixed Wireless to refer to these 6 to 40 GHz point to point radio products.

5, 10, 20, 30, 40, and 50 MHz. In Europe, ETSI employs similar logic, but defines channels slightly differently at 1.75, 3.5, 7, 14, 28 and 56 MHz. Every country in the rest of the world employs some form of channeling that limits available contiguous bandwidth, with most countries following the ETSI or FCC lead. Typically the largest channels generally available to operators are 30 MHz in the USA and 28 MHz in Europe.

Compression and Complexity: To support 100 Mbps+ data rates at frequencies of 6 to 40 GHz, fixed PTP microwave radios have to compress the data into narrow channels of 28 or 30 MHz. As a result, highly complex system architectures must be developed, employing sophisticated modem technology with compression schemes up to 128 QAM[2]. The complexity of 128 QAM modulation is best understood by recognizing that it has a theoretical spectral efficiency of 7 bits/Hz, meaning it can compress 7 bits of information into every 1 Hz of channel bandwidth. To further increase data rates, further signal processing technologies such as Cross Polarization Interference Cancellers (XPIC) are introduced to reuse frequencies for dual data streams. These highly complex systems result in high product costs, yet still limit practical data rates to 311 Mbps. To achieve even higher data rates, fixed PTP microwave systems can be architected with multiple units, multiple antennas, multiple frequencies and multiple paths, resulting in even more complex and costly installations, which are very difficult to install and maintain.

To further complicate matters, the sub-division of frequencies means that the transmit receive frequencies are generally close to one another. This is referred to as the TR spacing and can be as low as 118 MHz for some forms of the 8 GHz band, although typically it is from 500 to around 1,000 MHz. Such tight specifications mean that very high stability and high quality filtering is needed to keep the high powered transmitter signal from leaking into or interfering with the closely situated, very weak receive signal over a wide range of operating frequencies and environmental operating conditions.

A summary of a Fixed Microwave radio's situation is shown pictorially in figure 1.

[2] QAM (quadrature amplitude modulation) is a method of combining two amplitude-modulated (AM) signals into a single channel, thereby doubling the effective bandwidth. QAM is used with pulse amplitude modulation (PAM) in digital systems, especially in wireless applications.

Conventional Microwave Solutions (6 to 40 GHz)

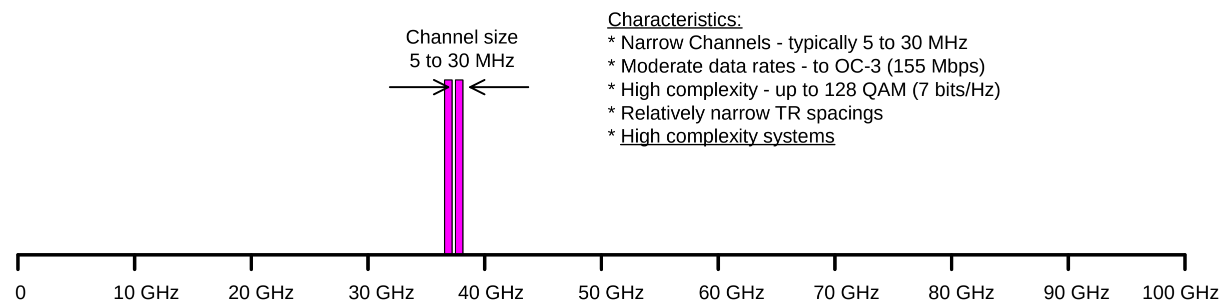


Figure 1: Illustration of Fixed Microwave frequency plan.
Note: Drawing not to scale. Channel sizes have been shown enlarged for clarity

GigaBeam's WiFiber 70/80 GHz Solution

Spectrum Usage and Simplicity of Design: GigaBeam's WiFiber wireless solution works in a very different way. While it is still a conventional radio in that it contains a transmitter, receiver and antenna, and it is installed and maintained in the same way as a microwave radio, the similarity ends there. A WiFiber radio operates at 71-76 GHz and 81-86 GHz -- much higher frequency bands than any other services using much greater spectrum bandwidth. Technical rules allow the full 5 GHz of bandwidth to be used to host both the transmit and receive data. The 10 GHz (10,000 MHz or 5,000 MHz used each way) is 357 times more spectrum bandwidth than a 28 MHz channel, and 333 times more spectrum bandwidth than a 30 MHz channel. Such wide channels easily allow the transmission of data rates of 1 gigabit per second and beyond, using the most basic of modems and modulation schemes. It is easy to see that a modem with spectrum efficiency of 0.2 bit/Hz (compressing 1.25 Gbps of data into 5 GHz of bandwidth) is significantly less complex than the 128 QAM (7 bits/Hz) of conventional high data rate microwave radios. Even data rates to 10 GigE (12.5 Gbps) can be achieved at 70/80 GHz with much greater simplicity and far more robust modems than a 155 Mbps Microwave Radio. GigaBeam will have 10 GigE (12.5 Gbps) by 4Q'06, and we are unaware of anyone even attempting to put 10 Gbps into a 30 MHz channel—in our view the physics are far too difficult.

It is also worth noting that the TR spacing at 70/80 GHz is 10 GHz, far greater than the typical 1 GHz or less at microwave frequencies. Thus the filtering to isolate the internal signals within the radio is far simpler and more robust than at microwave frequencies.

A comparative illustration to figure 1 is shown for a GigaBeam WiFiber radio in figure 2.

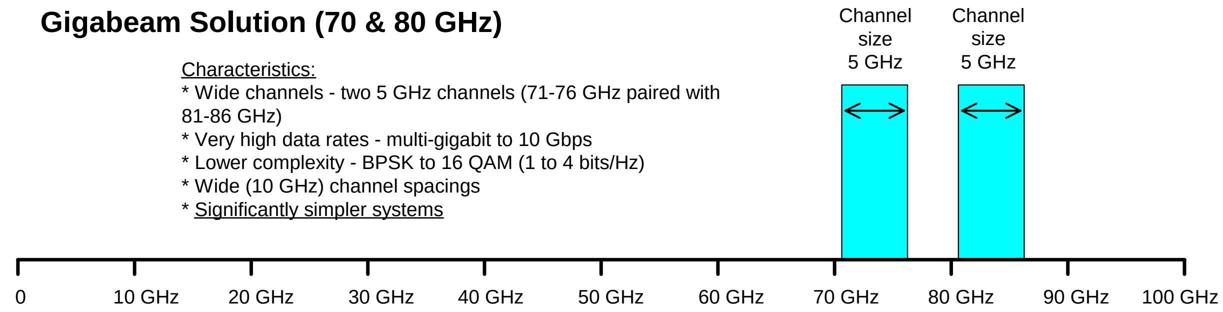


Figure 2: Illustration of GigaBeam's WiFiber frequency plan.
(Note: Drawing to scale, unlike previous drawing.)

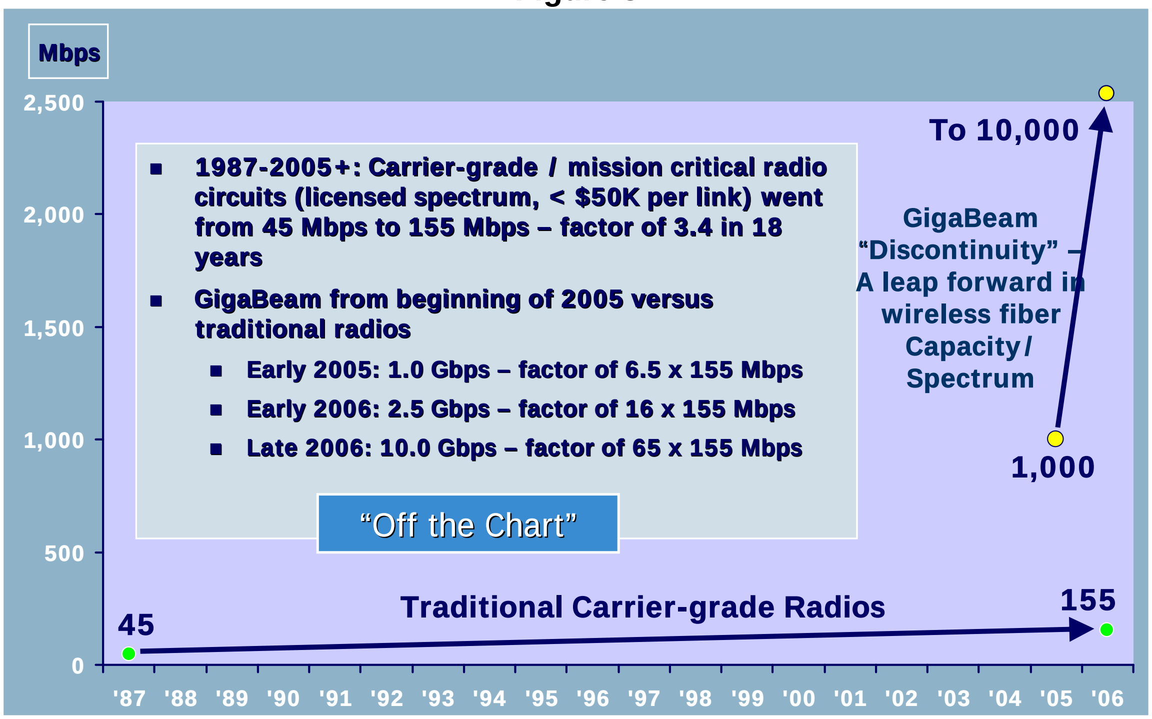
Distance: The next critical point of comparison is distance. We include in Appendix B a very detailed discussion of our distance reliability tradeoffs, but the short version is that, depending on whether it is a point to point application, or a PTP circuit as part of a ring, we are 99.999% reliable in 80% of the continental US to 1-2 miles, and in the other 20% to 0.7-1.4 miles. Cisco, in its *ex parte* filing as part of the rulemaking whereby the FCC licensed this spectrum pointed out that only 5% of business establishments with 20 or more employees are fibered, and 80% of the non-fibered are within a mile of a fiber node. For the high bandwidth local access and backhaul networking needs in most cities, our distance limitations still put us squarely in the middle of what carriers need.

Pricing: The final point of comparison is price. Our price, in carrier quantities is comparable to 155 Mbps radios—but we offer 6+ times the bandwidth—and well below the price of the much more complex 622 Mbps radios.

Summary: In less technical and more layperson terms, we suggest the following way to think about the above analysis. *PTP microwave radio technology does not have a technology problem, it has a regulatory problem*. FCC licensing has limited the number of MHz per channel, and with 300+ times fewer waves to ride, even the best of current technology struggles, at very high costs and with problematic reliability issues due to complexity, to achieve throughputs still well below our minimum of 1.25 Gbps. In January 2006, we will have 2.7 Gbps (2xGigE or OC-48) and by the end of 2006 we will have 12.5 Gbps (10 GigE or OC-192). *Our technology is a discontinuity*—yes, it is radio based but with more waves to ride, it is a far less complicated technology, which results in exceptionally competitive costs and carrier grade reliability (99.999%). Microwave technology is capped by the regulatory lack of spectrum, where as we are already at 1.25 Gbps and looking up at tremendous "headroom." This concept will have extreme importance when we get to the relationship between our offering and fiber, discussed below.

We graphically portray the discontinuity that is the basis of why our offering is transformational. Carrier grade radios (licensed spectrum, less than $50,000 per link) have only progressed from 45 to 155 Mbps over an 18 year period—a factor of 3.4—whereas our offering began at 6.5 times 155 Mbps, and will be at 65 times 155 Mbps by the end of 2006. Note that the 10 Gbps dot should actually be well off the chart.

Figure 3



Licensing Comparisons

Protection: Almost all fixed PTP microwave radios utilize licensed spectrum, giving users assurance that there will be federal protection against accidental or intentional interference. WiFiber uses similar licensed spectrum. However there is a vast difference in the licensing framework of the two products.

Microwave Licensing Cumbersome: Radio licenses in the fixed microwave bands have often been viewed as cumbersome because of the geographic-based licensing methodology used by the FCC. Since there are many users sharing the spectrum, which itself is heavily channelized, there is usually significant work to determine available and suitable frequencies for services. Such analysis can take several weeks. Only after frequencies are known can orders be placed with equipment vendors. This slow and expensive installation analysis and procurement cycle often results in deployment delays and has led to monopolistic holds on certain bands of spectrum by large communications companies.

WiFiber Licensing Simple and Fast: WiFiber's novel licensing structure, adopted by the FCC for all 70/80 GHz services, bypasses the bureaucracy and paperwork associated with traditional licensing. This licensing structure will allow most users to obtain a license for each individual link in less than an hour for less than $400.

WiFiber versus Fiber Optics for High Bandwidth Local Access and Backhaul

This discussion will be much shorter. Fiber optics is a recognized excellent solution for the following reasons. First and foremost, it offers superb bandwidth. While it is sometimes used for only 45 Mbps, it is typically used at speeds from 155 Mbps on up to 100s of Gbps. Wave division multiplexing technology long ago established that if a carrier wants more bandwidth, all that needs to be done is replace the optical electronics on both ends—in that sense many have called fiber “future proof” against more bandwidth needs. Additionally, when properly installed, fiber is very reliable. But even fiber is subject to cuts, building fires and floods, earthquakes, etc.—excellent reliability, but not perfect by any means.

Costs: The problem with new fiber is costs. The dominant portions of the costs are not the glass itself, or the electronics—it is the cost of laying the fiber, and especially the cost of trenching or other methods of protecting the strands. We offer the following way to look at those costs, understanding that every installation is different. One of our carrier customers gave us their average costs for laying fiber in Indianapolis, Indiana: $70,000 per mile for suburban areas, $150,000 per mile for urban areas, and $250,000 per mile or more in the core of Indianapolis. Of course, companies with preferential rights of way can cut those costs, but those are the situations that mostly have been tapped out. Also, of course, there can be many situations where the costs are higher, because of rivers, highways, railroads, off limits areas like military bases, and the like, let alone higher because costs in New York, Chicago, San Francisco, etc., are always higher than Indianapolis, often prohibitively higher. Our costs for a carrier grade order are less than $30,000 per mile—our costs will beat a great many, but not all, costs for new fiber builds.

Time-to-Market: In addition to the costs, there is the time to install factor. Fiber requires permission from every land and easement owner in the path. In urban areas, and most suburbs, such permissions are notoriously slow, difficult, and costly to come by. Our WiFiber wireless solution needs only 30 minutes or less on the Web at the coordinating data base, and $400 or less to secure regulatory permission. To be sure, to install the radios there must be building owner/controller permission at both ends. For end user oriented circuits, carriers have many buildings for the origination of the wireless circuits, and typically their customers have control over their buildings for the other end of those circuits. For backhaul, these are carrier facility to carrier facility applications, and carriers, as we said, control their own buildings. Finally, we note that for 80% of all commercial glass, our signal penetrates widows with minimal signal loss, reducing the need for roof rights.

Summary: GigaBeam's Value Proposition to Carriers

The essential thrust of this paper is the following:

- Broadband demand growth will continue at exceptional rates through any short or long range planning period. Phrased differently, network planners should be, and most certainly are, planning for significant increases in bandwidth and capacity headroom in their networks
- Network planners will have every reason to use existing fiber, and to lay new fiber where the costs are reasonable
    - The problem is that the low cost fiber lay situations have been largely tapped out, and new fiber lays are costly, and approvals very problematic
- Over the years microwave has been the only alternative, but microwave is a fraction of the bandwidth of fiber—it really is only good for some access situations (lower bandwidth, or longer range than two miles). For true backhaul, microwave speeds already look very slow, and will look progressively more out of date as network bandwidth needs increase
    - This is an FCC problem, not a technology problem: 28-30 MHz channels will never support 1-10 Gbps—i.e., such channels will not support fiber speed substitutes
- GigaBeam's founders convinced the FCC to authorize unprecedented amounts of contiguous spectrum - 333 times the 30 MHz worth of spectrum which is the most common limit of conventional microwave. This discontinuity in spectrum, leveraged by our technology, makes fiber speeds available (1-10 Gbps), with fiber reliability (99.999% availability) to distances of one to two miles (where most (80%+) of the high-bandwidth applications reside)
    - At a carrier price of under $30,000 per full link, we believe our solution is something every network planner should incorporate into short and long term network plans

Summary Message

In our message to carriers we stress the following: GigaBeam's WiFiber is the first wireless product that is simultaneously:

- ***A complement to fiber.*** Our product is being used to extend fiber networks for access, to open up new areas entirely, and to backhaul new applications like WiMax, thereby bringing more traffic onto existing fiber networks. Even fiber rich carriers like our first carrier customer, Indiana Fiber, see the benefit of extending their fiber rich networks, bringing on more traffic, and increasing the financial return on already existing network assets. In addition, WiFiber can be deployed more rapidly to improve time-to-market while fiber rights of way are negotiated and fiber is laid – which results in true access diversity when the WiFiber links remain operational.

- ***A back up for fiber.*** We have been selected by MCI as a prominent team member on the massive Federal Government GSA Networx bid, encompassing 15,000 federal buildings, for a ten year term, and estimated to be worth $20B. One of the many driving thrusts in that bid is the need to comply with Public Law 108-447, passed on December 8, 2004, which prohibits the use after July 1, 2005, of appropriated funds to provide telecommunications services for any Federal government owned building, unless it complies with a regulation or Executive Order that requires: (1) the provision of telecommunications services using redundant and physically separate entry points to Federal buildings; and (2) use of physically diverse local network facilities to provide such services. Those words, "physically diverse local network facilities" and "physically separate entry points" beg for wireless facilities at fiber—GigE and up—speeds. We are the only wireless offering at 1-10 Gbps. Diverse routing and separate paths will only get more important as time goes on
- ***A competitive substitute for fiber.*** As time goes on, we expect to see carriers relying on our WiFiber as an essential part of their core network for first circuit mission critical applications. Enterprises are already there.

We welcome the opportunity to work shoulder to shoulder with carriers to help deploy this new tool where the economics and network situations make it appropriate, and we are confident that there are a great many such situations.

In Appendix A, we set forth some decision tree diagrams to help illustrate the key points we have made above.

Further Information

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John Krzywicki, VP Marketing, Strategy and Business Development

Mr. Krzywicki graduated in 1972 from MIT with and S.B. in economics and from Harvard Law School with a J.D. in 1975. After two years as an antitrust and securities litigator, Mr. Krzywicki entered management consulting, and from 1979 to 2005 concentrated exclusively on telecommunications. He founded his own firm, Cambridge Strategic Management Group in 1989, which was sold to TMMG in 2002, and Mr. Krzywicki was the President of TMNG Strategy, before coming to Gigabeam in August, 2005. Mr. Krzywicki has consulted to telecom operators (wireline, wireless, and specialty), telecom technology providers (hardware, software, services) and telecom financers (VC, private equity) on five continents and has spoken at roughly 100 conferences in the US and abroad, and has been an expert witness in a dozen proceedings. He is responsible for strategy and business development and marketing communications at Gigabeam.

Jonathan Wells PhD, Director Product Management

Dr Wells graduated with a BSc in Physics and a PhD in Millimeter-wave Electronics from Bath University, UK in 1987 and 1990 respectively. His PhD thesis was on the development of novel, planar 94 GHz receivers. In 1998 Dr Wells was awarded an MBA with Distinction from Massey University, New Zealand's premier business school, with a specialization in strategic R&D management. Dr Wells has worked in a variety of technical and managerial roles around the world. He has built 183 GHz systems for satellite remote sensing and has undertaken theoretical studies at up to 600 GHz. Prior to joining Gigabeam in April 2005, Dr Wells was responsible for Stratex Networks' worldwide radio product portfolio and microwave strategy. Before this he worked at Adaptive Broadband where he had full business responsibility for the company's point-to-point terrestrial product lines. Dr Wells has over 20 published articles in refereed journals and is active on the WCA's Above 60 GHz Spectrum Development Committee. He is a Senior Member of the IEEE, and a Chartered Engineer and Member of the IEE in Europe.

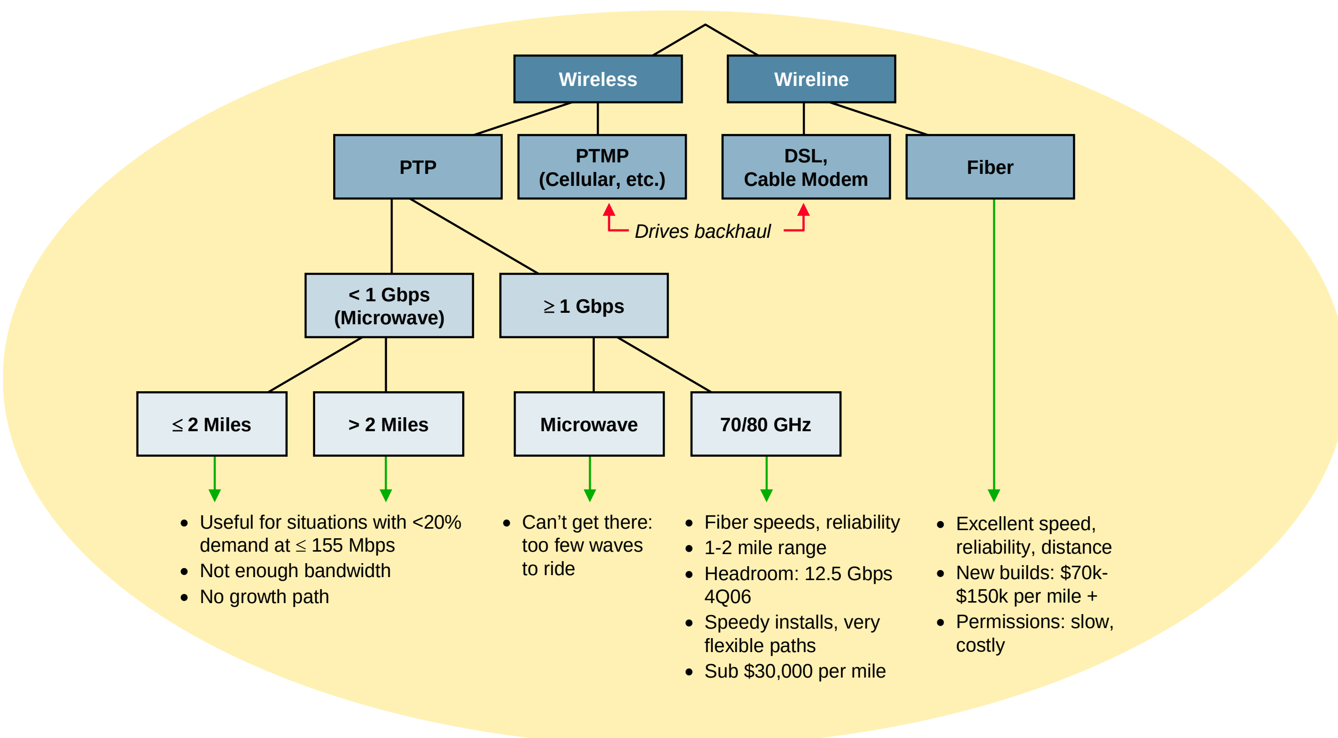
Appendix A

Decision Tree Analysis for Use of GigaBeam WiFiber™

The main body of this report provides the technological and business arguments as to why GigaBeam's WiFiber product is the only fiber speed, fiber reliability complement to, back-up for, and substitute/competitor to fiber. In this Appendix we use simple diagrams to illustrate the overall logic of how we believe network planners can think about the choices facing them and how WiFiber fits.

In the build up, the reader should keep in mind that the network planner will be looking at both the holistic "big picture" and the individual granular choices. We begin with where we are going, the tenth figure in the build up, so that the reader has a sense of the overall logic flow, before going into the granular detail. For convenience, since it is out of the flow, we label this Figure A:

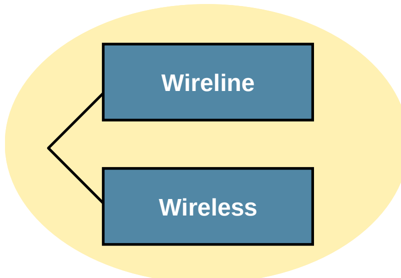
Figure A



To understand that big picture, we now turn to those granular choices, one-by-one.

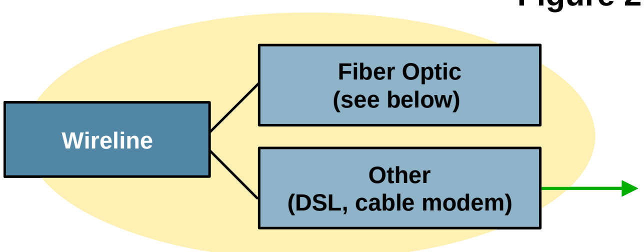
The first choice is the basic one of wireline versus wireless. Of course this choice, only gets made when both branches are considered so this is the place where we start.

Figure 1



The next choice is the wireline choice of fiber versus other terrestrial options. We list the characteristics of "other" first:

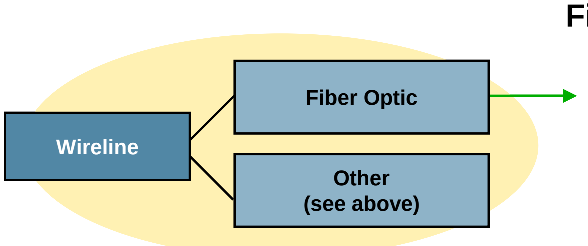
Figure 2



- Ubiquitous
- ≤ 24 MB, mostly ≤ 6MB
- "Best efforts" quality, so enterprises are <u>not</u> target market
- Sends demand, loads of it, to core network
- Drives demand in complementary way for fiber and WiFiber

Now we focus on the fiber optic branch:

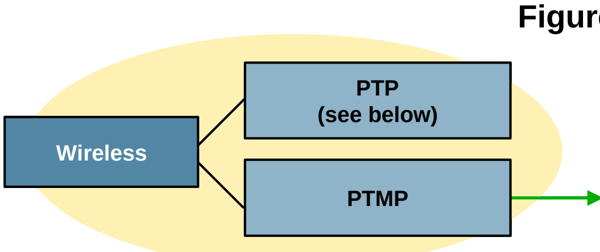
Figure 3



- High to very high bandwidth
- Excellent reliability
- Covers short and long distances
- Expensive to prohibitive to lay
- Approvals slow, costly, difficult
- Therefore, only 5% of establishments with 20 or more employees have fiber – nowhere near ubiquitous
- Excellent for backhaul and access when costs are right

Now we return to the wireless branch:

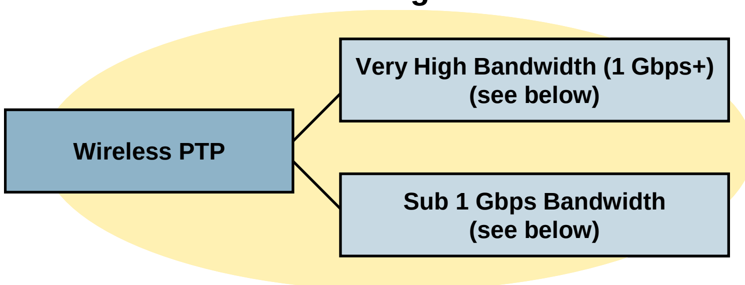
Figure 4



- Cellular, WiFi, WiMAX, MMDS
- Low bandwidth (≤ 1 Mbps now, ≤ 5 Mbps with 4G)
- Cellular is ubiquitous; other options strive for that
- Mobility is major feature
- Sends demand, loads of it, to core network: exploding growth
- Drives demand, in complementary way, for fiber and WiFiber

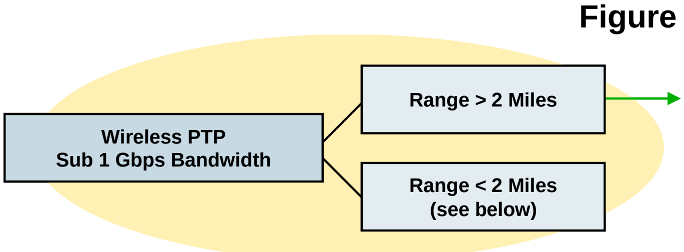
Next we look at the more complex PTP wireless situation, in five steps:

Figure 5



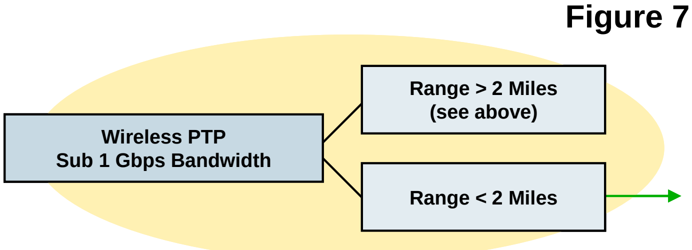
We look at the sub 1 Gbps situation first.

Figure 6



- Bandwidth does decline with distance
- Since 80% of businesses with 20+ employees ≤ 1 mile of fiber, this aims at <20% of markets that are beyond dense areas
- Sweet spot for 45 Mbps, 155 Mbps radios with range; long distances work against economics of fiber and WiFiber
- With enough demand, carriers will still find a way to 1 Gbps + solutions

Figure 7



- Works if growth path capped
- Even at 155 Mbps, WiFiber radios are competitive on costs but 6+ times the bandwidth

Now we move onto the very high bandwidth (1 Gbps+) options:

Figure 8

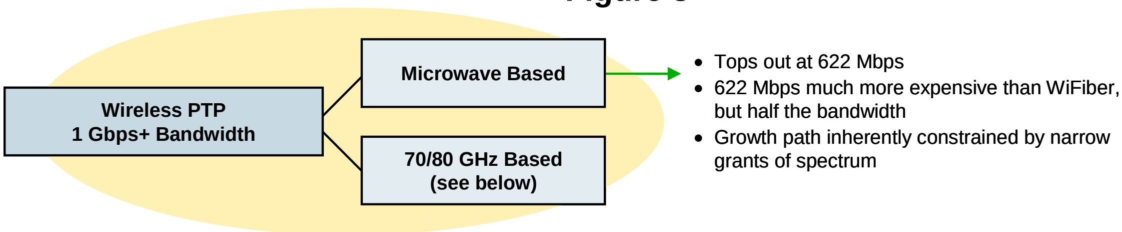
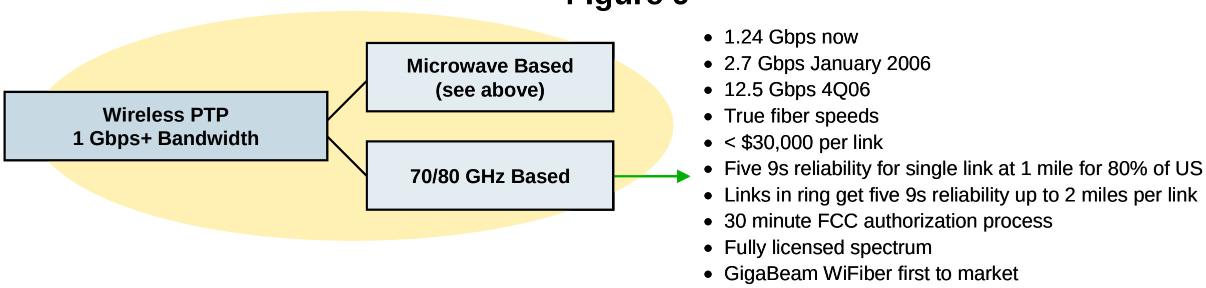
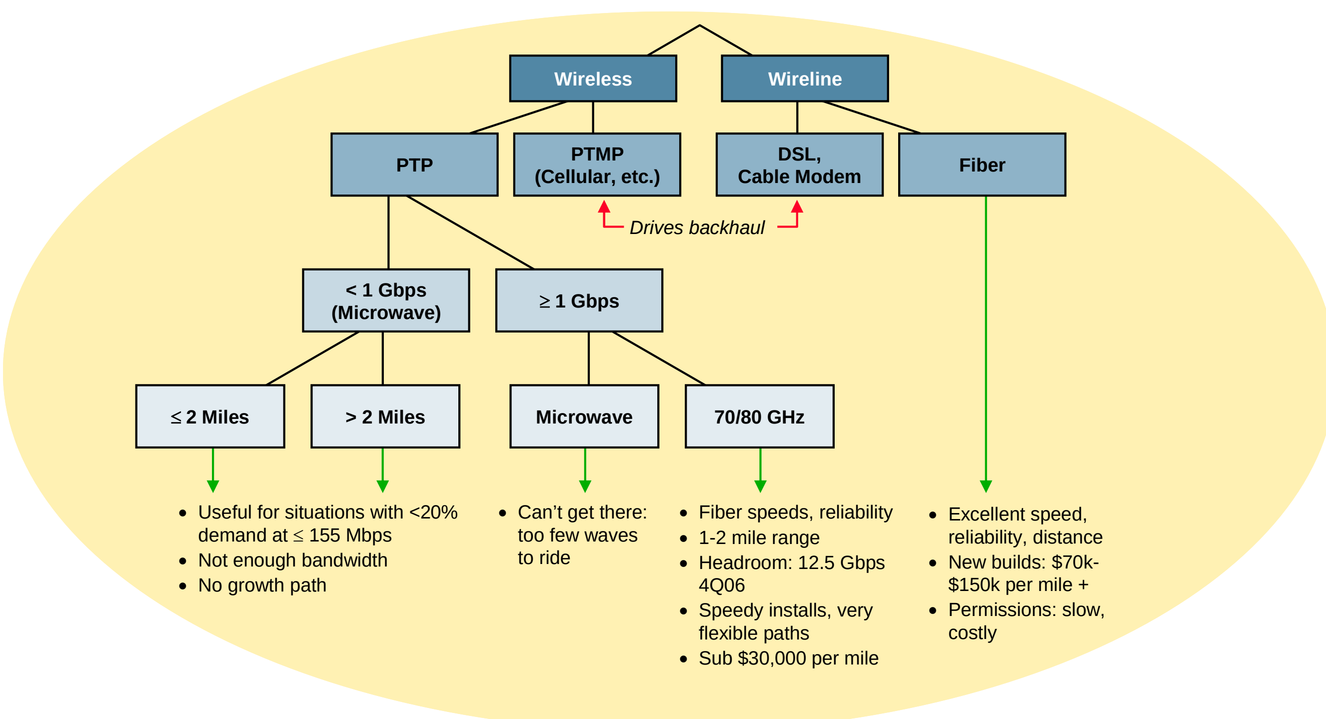


Figure 9



Now we integrate all of the previous branches into one chart. Without apologies, to make the visual readable, we summarize the various bullets from the previous single-branch charts.

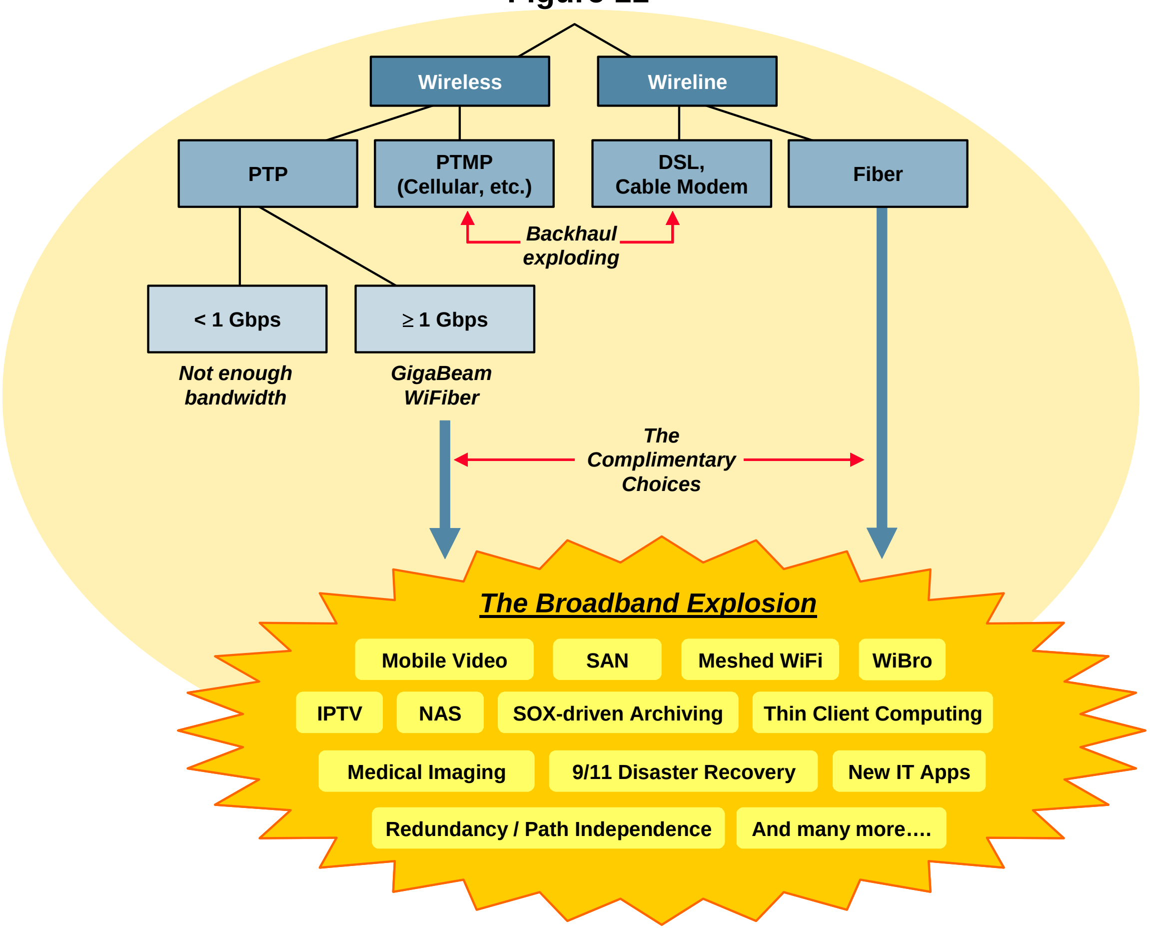
Figure 10



The final simplified chart makes the basic point:

GigaBeam's WiFiber is the only logical choice for high bandwidth access and backhaul that is a full complement to, back-up for, and competitor to fiber, for both immediate and future deployments.

Figure 11



Appendix B

Discussion of Range and Reliability Tradeoffs

The range and reliability of our radios are interrelated. The best way to think about these concepts is as follows:

- For 80% of the continental US, we provide 99.999% weather availability to at least one mile. For the rest of the continental US, we provide 99.999% weather availability to at least a kilometer. This level of reliability means no more than five minutes of downtime per year. These numbers are for single circuits in isolation

- For circuits that are part of a ring, the distances can nearly be doubled at "five 9s" (99.999%) weather availability, based on the rotational diversity of a properly implemented ring architecture. The short description of why is that our architecture is only susceptible to very intense rain—on the order of three or four inches per hour. The intensity of rain is generally inversely proportional to the size of the rain cell—therefore intense rain will not often knock out more than one link of a ring, and the services can travel the other way around the ring to reach the desired location. We stress that light rain, even if continuous or very frequent—of the sort associated with cities like Seattle—is not a problem. The issue is with torrential rains, of the sort associated with Florida and the Gulf States, and even in torrential rain, we can still push the signal to a kilometer.

- If less than five 9s of reliability is needed, then the distances go up accordingly. For four 9s, we can deliver up to 2+ miles, and for three 9s we can deliver up to 3+ miles (and all of these numbers apply to a single link—in a ring the distances can be extended by as much as two times based on ring design).

In summary, our technological proposition is a 1 Gbps point-to-point radio circuit, with carrier grade five 9s of reliability to a mile (and to two miles in a ring) using licensed spectrum is available at minimal cost to all. We close this discussion by again noting that Cisco and others have estimated that 80% of US businesses are within a mile of a fiber node, so the addressable market at five 9s of reliability is quite large.