Wireless Backhaul for 4G LTE and WiMAX Networks

Jonathan Wells PhD
Managing Partner
AJIS Wireless Consulting

S. Jay Lawrence
President and CEO
GigaBeam Corporation

Executive Summary

Next generation 4G technologies such as LTE and WiMAX promise to deliver an entirely new range of mobile broadband services. The dramatic growth in data rates, driven by open standard smartphones running data hungry applications, will drive a significant increase in mobile backhaul requirements. Microwave radios have long been the global technology of choice for backhaul infrastructure. Millimeter-wave radios at 70/80 GHz are a natural complement to these systems for delivering higher capacities for data intensive 4G networks. This paper explores these how these products can be configured to build backhaul network topologies for next generation LTE and WiMAX networks.

Introduction

The last few years have seen significant changes in the way we use mobile networks. A mobile phone is no longer just for talking and texting. We take pictures, download music, record videos and distribute them through our social networks to the global community via the wireless mobile infrastructure. Cellular phones connect us to the internet, anywhere, anytime, effectively making the mobile network a broadband internet pipe. Enterprise customers are leveraging the wireless network with their mobile workforces, running business critical enterprise applications on their cell phones.

Such mobile wireless data growth shows no sign of slowing down! There are now five billion mobile phone subscribers around the world, with more than one billion subscribing to mobile broadband packages. Broadband-enabled smartphones and devices such as Apples' iPhone and iPad are transforming the mobile landscape, exponentially increasing backhaul traffic. Analysts forecast that mobile data traffic will increase 66-times by 2013[1].

Next Generation LTE and WiMAX Networks

In order to satisfy this demand, newer wireless technologies are being introduced that deliver higher broadband speeds to data-hungry mobile consumers. Advanced third and fourth generation (3G and 4G) networks are being planned and implemented, which

[1] The Mobile Internet Report, Morgan Stanley, Dec. 2009.

promote peak data speeds of 40 Mbps (the 3G HSPA and its variants), and up to 100 Mbps mobile and 1 Gbps fixed (4G LTE). In the USA, Verizon Wireless is actively deploying LTE networks, with a target to have 20–30 markets operational by the end of 2010. AT&T's HPSA enhancements are planned to cover 90% of the carrier's US 3G footprint by the end of 2011.

WiMAX is moving beyond a local solution to regional and even national networks. For example, Clearwire is deploying a national mobile broadband WiMAX network in multiple markets throughout the United States. Clearwire's investors include Google, Intel, Sprint, Time Warner, Bright House and various others, several of which are reselling Clearwire's WiMAX services under their own brands. Clearwire is targeting coverage of as many as 120 million people by the end of 2010. Similarly nationwide WiMAX networks are being rolled out in Russia by Yota and by UQ in Japan.

Next Generation Network Backhaul Requirements

Point to point (PTP) wireless links have been employed in mobile networks for connecting together cell sites and cellular base stations for more than 30 years. At the end of 2009, there were approximately four million cell sites in the world, and approximately 50% of these were connected by PTP wireless. Use of wireless backhaul is particularly strong in Europe where over 80% of all cell sites are interconnected wirelessly.

Wireless is a popular solution for backhaul requirements for several reasons. It can be deployed rapidly and cost-effectively, enabling services and circuits to be established quickly in a competitive environment. Wireless backhaul also takes advantages of the same infrastructure that the cellular base stations use; sharing the same towers, shelters and power supplies. Finally, PTP wireless can also be inherently more secure than fiber optic or other wired connections, as it is immune to cable cuts and theft (a particular problem with copper-based solutions in developing countries).

With the rapid progression of wireless standards, delivering higher data rates and requiring more and more backhaul capacity, plus improvements in transport protocols, cell sites often support several links satisfying legacy, current and sometimes future services. Cell sites are also becoming smaller to support the increased data rate needs and to enable efficient frequency reuse. Typical 3G cell sites in the US are spaced approximately 1.7 km (1.1 miles) apart in urban areas, and twice this in suburban areas. 4G networks will have much smaller cells. Parts of Clearwire's first US network in Baltimore had an average base station spacing of just 400 yards.

High capacity microwave is especially advantageous for supporting 4G wireless standards. Today, a cell site in a market with high data traffic will typically have 25 Mbps of backhaul capacity, but this will grow tremendously as future standards and services are added. Analysts' are typically expecting 300 Mbps average backhaul per site by end 2012. Carriers are providing forecasts that by 2015 the average US cell site will require 200 Mbps of backhaul, core cell sites will require 400 Mbps of backhaul, and wireless hub sites will require a full 1 Gbps of backhaul. Further back in the network, fiber connections to the MSC (mobile switching center) will be 10 Gbps for the smaller transport providers and 100 Gbps for the core routers.

Ultrahigh Capacity Wireless Backhaul

The key to transmitting ultrahigh data rate traffic wirelessly is spectrum. As data rates increase, proportionally larger frequency bandwidths are required to support the increased data rate, as shown in Figure 1. In the sub-6 GHz region, popular wireless LAN (Local Area Network) and WAN (Wide Area Network) standards exist that can support practical data rates of up to several tens of Mbps. In the microwave bands of 6 to 40 GHz, popular for long distance transmission, cellular backhaul and enterprise connectivity, data rates of up to a few hundred Mbps are available. Higher data rates are not possible as regulators deliberately slice the available spectrum into narrow channels to encourage competition and permit users to use the services without interference. Only at the higher millimeter-wavelengths are channels large enough to support the highest data rates. In order to transmit data at speeds of 1 Gbps and above, the millimeter-wave frequency bands of 60, 70 and 80 GHz have to be utilized.

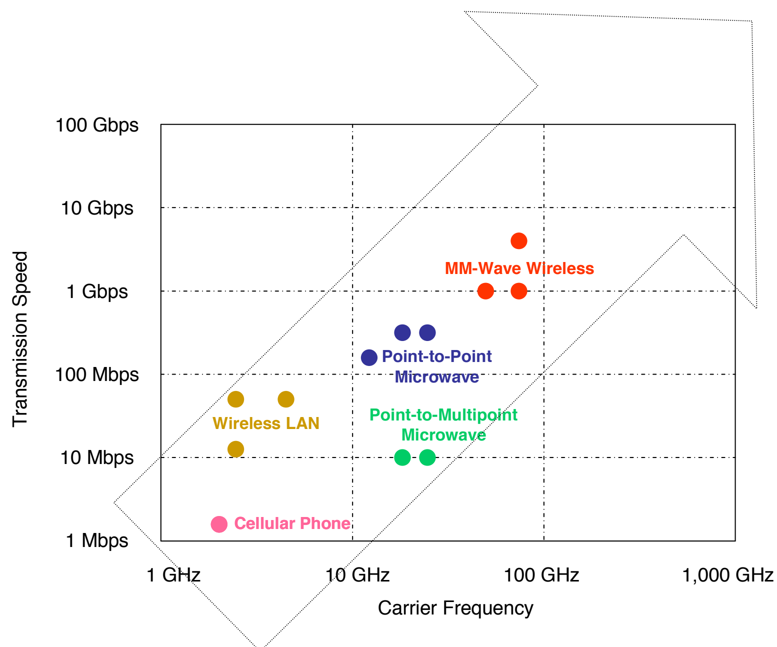

Figure 1: To transmit higher data rate traffic, a high carrier frequency is required.[2]

[2] From Wells, J.A.: Faster Than Fiber: The Future of Multi-Gb/s Wireless, *IEEE Microwave Magazine*, vol. 10, no.3, pp. 104-112, May 2009

Figure 2 shows a typical 70/80 GHz radio that is capable of transmitting 1.0 Gbps of customer data over a distance of 1-2 miles with 99.999% carrier-class weather reliability (outages due to rain of less than 5 minutes a year). This radio offers systems operators an ultra-high data rate, low cost alternative to metropolitan fiber lines.

Figure 2: Photographs of a 1.0 Gbps 70/80 GHz radio with a 2ft antenna in typical installations. (Photographs courtesy of GigaBeam Corp.)

Utilizing Ultrahigh Capacity Wireless In Next Generation Networks

High capacity microwave radios in the 6 to 40 GHz bands are a widely accepted technology for supporting 4G wireless network infrastructure. These compact, spectrally efficient radios utilize high modulation schemes up to 256 QAM to deliver high data rates in the limited channel sizes available in the bands. Throughputs of up to 350 Mbps can be achieved in the highest 56 MHz channel sizes. Higher data rates can be achieved by paralleling hardware and using adjacent channels or transmitting in different polarizations. Millimeter-wave radios at 70/80 GHz, which also offer higher capacity transmissions up to 1 Gbps over distances of several kilometers, will also play a role in 4G backhaul.

There are a variety of ways in which next generation networks will be configured, and similarly, a number of ways in which high capacity 6-40 GHz microwave and 70/80 GHz millimeter-wave radios can be utilized within these networks. Figure 3 shows four such network topologies.

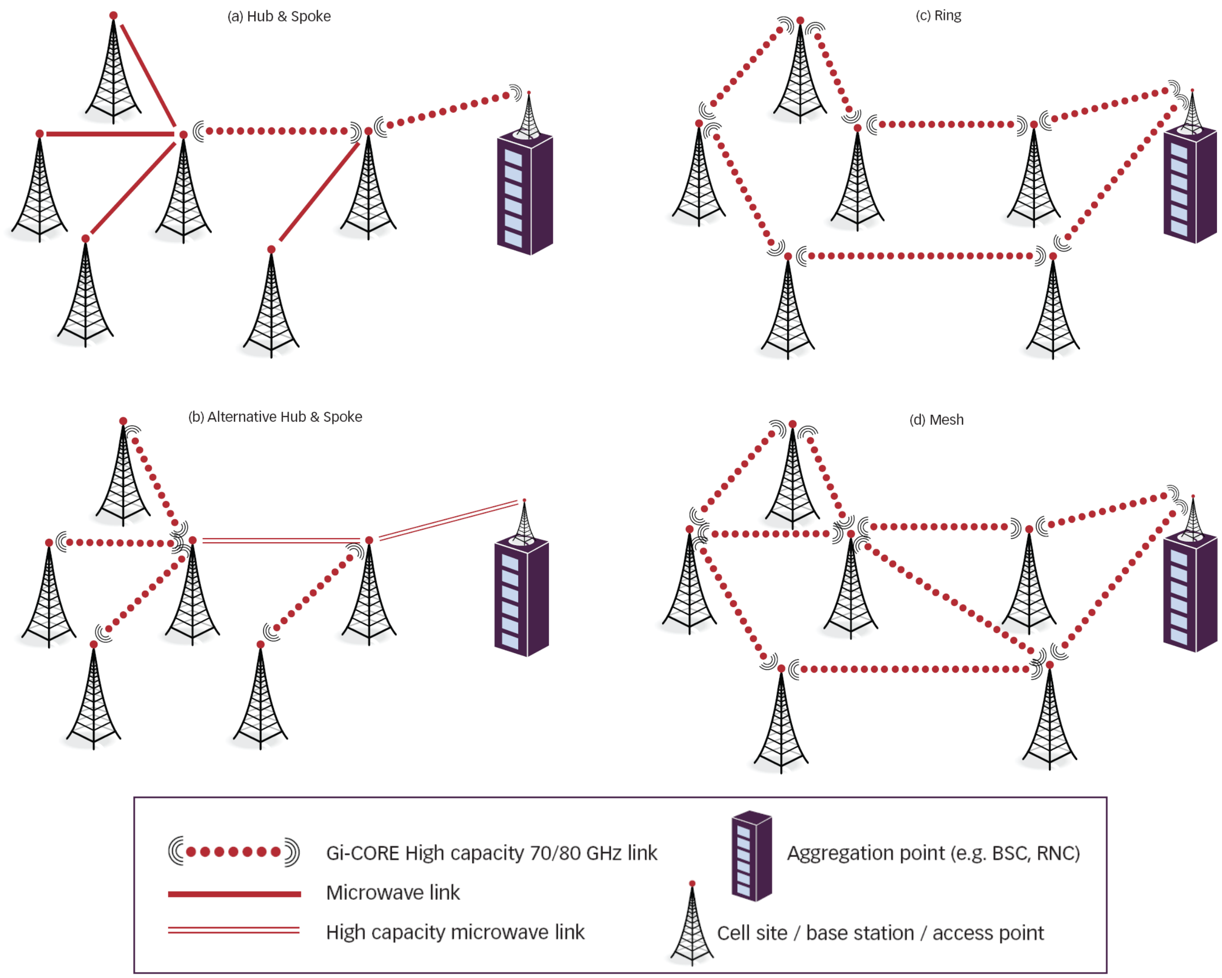

Figure 3: Four possible network topologies for next generation networks.

Hub and Spoke
One major strength of 70/80 GHz radios is their ability to transmit data rates in excess of 1 Gbps. Therefore they offer significant advantages in aggregating traffic from various cell sites. In a traditional hub and spoke arrangement, high capacity microwave radios can be used to connect the outlying base stations, supporting data rates of several hundred of Mbps, whilst 70/80 GHz radios are used to aggregate these and carry the combined data traffic at Gbps data speeds back to the managing network controllers.

Alternative Hub and Spoke
A different perspective of the hub and spoke network topology is that the much higher number of outlying cell sites around the edges of the network will cause spectrum allocation and frequency planning problems. Since 70/80 GHz millimeter-wave radios operate in unused spectrum, many countries permit light licensing, whereby licenses

can be obtained quickly and cheaply, and full interference protection guaranteed. For this reason, an alterative view of a hub and spoke network is that licensed millimeter-wave radios will be more cost-effective around the edges of the network, lowering licensing costs, removing frequency planning issues and easing interference concerns. High capacity microwave radios, configured in parallel co-channel, cross-polarized configurations can then be used to provide the aggregated backhaul, since microwave radios offer longer distance transmissions. The same topology can be effectively applied in dense metropolitan networks, whereby 70/80 GHz radios can often satisfy the bulk of the end connectivity with better economics than microwave radios.

Ring
Ring topologies are common in fiber optic networks and becoming increasingly popular in wireless networks. In a ring configuration, each node has a pair of paths to every other node, building inherent path diversity and protection into the network. Thus a ring is much more robust than a hub and spoke configuration. However, if one link in the ring becomes congested because of an excess of traffic at that one location, the entire ring is affected. For this reason, wireless rings need to utilize high capacity radio links to ensure that congestion is minimized. Thus 70/80 GHz radio devices with their superior data rate handling capacities are ideal for this application.

Mesh
In a mesh configuration, each node has at least two, and often more, connections to other nodes in the network, with each link having to carry an increased traffic load from multiple base stations. Similar to the ring configuration, the higher data carrying capacity of 70/80 GHz radios makes them more applicable to mesh networks than lower capacity microwave radios, since the millimeter-wave radios offer higher throughput and more economic licensing.

All four network scenarios are feasible, with many more pros and cons to each. However the potential role in which high capacity millimeter-wave links can play in each topology can be seen.

Conclusions

Mobile data traffic is growing exponentially, driven by broadband-enabled smartphones running multi-media applications. Next generation technologies such as LTE and WiMAX are being introduced to deliver these higher broadband speeds to mobile consumers.

A new generation of high capacity radios have recently emerged at microwave and millimeter-wave frequencies that supports higher data rates and new networking protocols for backhauling such next generation networks. Microwave radios are now available that can offer data rates to 350 Mbps in compact, cost-efficient architectures. 70/80 GHz millimeter-wave equipment is also available that offers data rates to 1 Gbps over several kilometers distance in similar compact designs. Both technologies can be used to complement one another in backhaul networks, with the millimeter-wave equipment dominating in the capacity intensive parts of network. The superior economics and ease of millimeter-wave licensing will also be beneficial for more cost-effective wireless implementation in dense networks.

About The Authors

Jonathan Wells PhD is Managing Partner of AJIS LLC, a wireless technology consultancy providing specialized advice on all aspects of microwave and millimeter-wave wireless devices, products and business. Jonathan can be reached at jonathan@ajisconsulting.com or at +1 925 200 5124.

S. Jay Lawrence is President and CEO of GigaBeam, a leading provider of fixed wireless millimeter wave and microwave radio communication equipment as well as design and implementation services. Jay can be reached at jlawrence@gigabeam.com or at +1 919 206 4426.

About GigaBeam

GigaBeam is the operating name for GigaBeam Acquisition Corporation which is a private company with the most accomplished fixed wireless millimeter-wave radio business to date. GigaBeam's product portfolio ranges from broadband wireless access solutions to ultra-broadband Metro Ethernet core solutions. With solutions deployed in over 20 countries world wide, GigaBeam's users include large enterprises such as Google, Fidelity, the DoD, NASA, municipalities, universities, medical centers, financial institutions, various international departments/ministries of defense, and other government agencies.

For more information, visit www.gigabeam.com or call +1 919-206-4426.