70 and 80 GHz Wireless Backhaul for WiMAX Networks—Wi-X Supplement

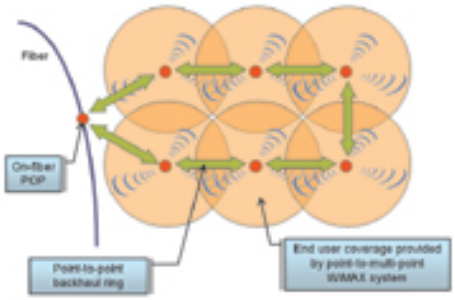
Little attention has been devoted to WiMAX backhaul needs and evolution. With multi-sectored antennas likely and high data throughput possible, conventional PTP wireless transport solutions will quickly reach capacity. Recently released spectrum at 70 and 80 GHz, referred to as &quotE-band,&quot is allowing a new breed of high-speed radios to be realized. Data rates to gigabit-per-second and beyond are possible in cost-effective radio architectures, opening up a whole host of new applications, including those that change the economics of WiMAX wireless backhaul networks.

By Dr. Jonathan Wells

WiMAX promises to bring high-speed data connectivity to a wide coverage area, opening up ubiquitous Internet access without costly investment in wireline, cable or fiber infrastructure. A great deal of consideration has been given to the access portion of WiMAX networks: the specification 802.16-2004 has been ratified. The WiMAX Forum estimates that there are already 400 &quotpre-WiMAX&quot or &quotWiMAX-ready&quot installations worldwide, with major networks in the USA (Clearwire), Australia (Unwired Australia), Ireland (Irish Broadband) and elsewhere.

A WiMAX Network's Building Blocks

To provide blanket, ubiquitous WiMAX coverage of a wide geographical area, several basic building blocks are required:
&#149 A fiber node (or POP) to provide connectivity to the metropolitan WAN or existing Internet infrastructure.
&#149 A high-capacity wired or wireless PTP backbone, often called the transport or backhaul network, to carry the high-capacity traffic from the fiber POP to each WiMAX AP at locations relatively close to the end-users. Ideally, a ring configuration of consecutive PTP links is used because of the rotational diversity it provides. If one point in the ring were to fail, full network integrity is maintained by simply rerouting traffic in the opposite direction around the ring, allowing time for maintenance and repair to be undertaken without any costly system outages.
&#149 A WiMAX PTMP data delivery system consisting of the APs providing the data connectivity to the many CPE at each subscriber's location.



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An example of this concept is shown in Figure 1. The number of links deployed will depend on the equipment employed, the area to be covered, the geographical location and topology of the network.

WiMAX Backhaul Alternatives

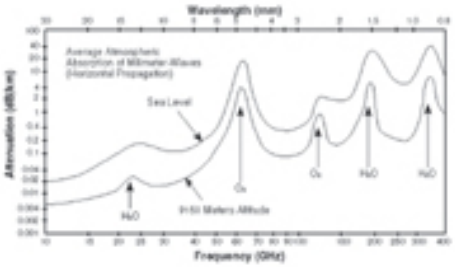
A WiMAX backhaul network is used to transport high-data-rate traffic from the fiber POP around the rest of the network. Such a backbone can be built using wired or wireless technologies. Wireless is usually preferred due to the high costs of trenching fiber in dense modern conurbations, or of leasing fiber from incumbents. Costs of laying new fiber in urban environments can run to as much as $250,000 per mile. Leasing costs of 45 Mb/s DS3 circuits average around $3,000 per month. Furthermore, existing fiber networks are poorly placed to serve end-customers. USA data shows 95% of the 750,000 US commercial locations with 20 or more employees are not served by fiber. Existing copper wiring is not a consideration because of its limited data-handling capabilities. Wireless, because of its cost-effective economics, fast time to install and commission, and scalable flexibility is therefore the natural choice for WiMAX backhaul.

When selecting wireless backhaul equipment, a WiMAX network architect faces many design decisions and trade-offs. Two important questions are:
&#149 What data rate?
&#149 Licensed or unlicensed technology?

What Data Rate?

The data rates delivered by WiMAX access points will vary enormously depending on the configuration of the network, the location of the subscribers and the system flexibility required. The 802.16-2004 specification defines a maximum data rate of 70 Mb/s. Users close to the AP could practically realize speeds close to this.

Broadcast towers will likely consist of multiple APs &#151 probably three to six WiMAX radios each broadcasting over 120&#176 down to 60&#176 sectors. Therefore, backhaul requirements for each tower location will be several hundred megabits per second and could reach up to 500 Mb/s. Future WiMAX releases could demand more, meaning additional flexibility needs to be accounted for. Consider the Wi-Fi evolution, where initial speeds of 11 Mb/s have been increased progressively to 54 Mb/s, and then 108 Mb/s through ongoing specification revisions. Who knows how far WiMAX will progress in the future?



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Licensed or Unlicensed Technology?

Licensed technology provides guarantees of protection from interference, intentional or otherwise. In return for a license fee, the user is given effective ownership of the required transmission spectrum, with full federal protection for that piece of spectrum. Unlicensed technology provides no such guarantees. Given the high data rates required for WiMAX backhaul, and the loss in revenue generating potential when such a system goes down, network designers will always choose licensed technologies.

A WiMAX radio is a poor choice as a backhaul solution. The WiMAX standard is designed to operate as a PTMP system and is very inefficient when configured in a PTP architecture. Practical throughputs of only a few tens of megabits per second are realizable. Conventional microwave radio is a better, although still limited, choice for WiMAX backhaul. Available at frequencies from 5.8 GHz unlicensed or 6 to 40 GHz licensed, microwave PTP systems are limited to practical data rates of up to 155 Mb/s or perhaps 300 Mb/s or so in more exotic configurations. This is because these frequencies are heavily regulated with only narrow channels available to individual users. Typically, maximum channel sizes of 28 MHz in Europe or 30 MHz in USA are the widest available, meaning high-complexity, high-cost radios are required to squeeze data rates of 150 Mb/s into such channels.

A New Backhaul Alternative: 70/80 GHz

In October 2003, the FCC made a historic ruling, opening up 13 GHz of spectrum at frequencies much higher than had been commercially available before. Of particular interest is the 10 GHz of bandwidth at 70 and 80 GHz. Commonly referred to as &quotE-band,&quot this spectrum provides, for the first time, the means to provide economical broadband connectivity at true gigabit data rates and beyond. The FCC ruling also permits a novel licensing scheme, allowing users cheap and fast allocations to prospective users. A ten-year license can be applied for, granted and purchased in less than 30 minutes, for the cost of a few hundred dollars. Then-FCC Chairman Michael Powell heralded the ruling as opening a &quotnew frontier&quot in commercial services and products for the American people.

Designed to co-exist, the 71 to 76 GHz and 81 to 86 GHz allocations allow 5 GHz of full-duplex transmission bandwidth; enough to transmit a gigabit of data (1 Gb/s or GigE) even with the simplest modulation schemes. With more spectrally efficient modulations, full-duplex data rates of 10 Gb/s (OC-192, STM-64 or 10GigE) can be reached. With direct-data conversion and low-cost diplexers, relatively simple, cost-efficient and highly reliable radio architectures can be realized.

Propagation characteristics at 70 and 80 GHz allow for transmission distances in excess of one mile with the highest carrier-class performance. Atmospheric absorption at these frequencies is not too much worse than at the popular microwave bands of 18 to 38 GHz. Rain does cause additional attenuation, but fortunately worldwide rainfall statistics are well-documented and radio paths can be planned accordingly. Data for the USA shows that currently available commercial equipment can achieve gigabit-per-second connectivity with 99.999% weather availability (equivalent to only five minutes of weather outage per year) over 80% of the country with links of one mile or more. For a lower 99.9% availability, distances of three miles can be routinely achieved. When configured in a ring, effective distances double for the same availability due to the dense, clustering nature of heavy rain and the diversity that the ring configuration provides.

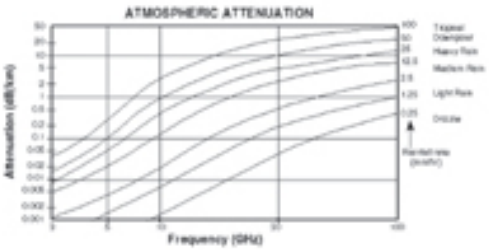
Why 70 and 80 GHz?

Atmospheric absorption varies significantly with frequency, as shown in Figure 2. At conventional microwave frequencies, atmospheric attenuation is reasonably low, until a peak is seen at around 60 GHz where absorption by oxygen molecules results in 15 dB/km attenuation, seriously limiting radio-transmission distances. After this peak is a large window where attenuation drops to less than 1 dB/km (effectively negligible) before rising again due to other molecular effects. This window has a minimum at 94 GHz, which is why this frequency has been previously exploited for military applications. It can be seen that the spectrum from around 70 GHz up to around 120 GHz exhibits low atmospheric attenuation and fortunately is relatively unused.

As with all high-frequency radio propagation, rain will limit link distances. E-band transmissions can experience 30 dB/km attenuation when in the presence of intense rain, as shown in Figure 3. Such intense rain tends to form in small clusters within a lower-intensity rain cloud, and is usually associated with a severe weather event that moves quickly across the link. Therefore, rain outages tend to be short, and only occur on longer-distance transmissions. Fortunately, the ITU and other bodies have collected decades of rain data from around the world, so rainfall characteristics are well-understood. With such information, it is easy to engineer radio links to overcome even the worst weather, or to predict the levels of weather outage on longer links.

Summary

WiMAX is an exciting technology that promises to bring high-speed data connectivity over wide coverage areas. There has been much focus on the access side of WiMAX networks, with little thought devoted to backhaul needs and evolution.



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For most WiMAX sites, fiber connections do not exist, so wireless provides the most compelling backhaul solution. Because they are designed as a PTMP technology, WiMAX radios themselves are a poor alternative, so most network designers therefore select conventional licensed microwave radio for their backhaul needs. This provides a solid solution, but is limited to data rates of around 150 Mb/s in cost-effective configurations. The more demanding WiMAX applications will have backhaul requirements that exceed this, and experience with wireless technologies like Wi-Fi, which has experienced increases in speed since it was introduced, has shown us that flexibility needs to be built into systems to avoid costly system upgrades or rebuilds in the future.

E-band radios operating at 70 and 80 GHz provide a compelling alternative to conventional microwave for WiMAX backhaul applications. They offer the

advantages of extremely high data rates, a flexible growth path, plus all the benefits of interference immunity guaranteed by licensed technology. When properly configured in ring topologies, transmission distances of two miles can be achieved with 99.999% weather availability, meeting the distance requirements of most urban WiMAX buildouts. Best of all, the inherent simplicity of a 70/80 GHz radio means it can be offered at a price competitive to a conventional high-data radio, significantly broadening the business case of any WiMAX operator.

References

1. FCC Bulletin 70, *Millimeter Wave Propagation: Spectrum Management Implications*, July 1997.

About the Author

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