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Broadband Wireless: Now Playing in Select Locations

New services are just arriving, and net architects need to get set on the specifics

Wireless has come a long way in the last decade. While the technology was once most widely used by cops getting instructions from dispatchers, these days everyone from soccer moms to the CEO is chatting away on digital flip phones.

So much for past and present: The future is where the real story of wireless lies. Soon, broadband wireless networks will be in place, transporting more data than any other form of wireless connection. And broadband boasts some big benefits over wired networks. For one thing, it can be deployed faster. For another, it offers a lot more flexibility in terms of adapting to changing bandwidth requirements. Of course, broadband wireless has its downsides too. Deployment may be fast, but it also can be expensive—maybe too expensive for wide scale rollouts.

But broadband wireless is on the way, and net architects who want to judge wisely need to understand its capabilities and limitations. First, learn about the different architectures—from spectra to frequencies and bandwidths to licensing requirements. Then compare the costs to deploy a wireless vs. a wired network. Also find out about the different wireless services, which carriers are offering them, and what new services are expected over the next few years. Finally, find out how wireless error rates compare with those of wired LANs, whether all vendor equipment runs under the same standards, and whether inclement conditions will seriously degrade performance.

The good news for users: The learning curve isn't very steep. All the services use common networking interfaces and protocols, and as a result all applications can run unchanged. Where available, the technology works extremely well. The upshot? If carriers can deliver service, there's no shortage of bandwidth-starved customers ready to buy.

Why Wireless?

Understanding why wireless broadband is compelling means knowing what it is—and what it's not. Wireless broadband is not mobile communications. Antennas—unlike those used for cell phones or wireless LAN devices—are typically about 12 inches in diameter, are often located on rooftops, and are pointed in a precise direction. The wireless link is part of the provider's network infrastructure—called the last mile by some, and the wireless local loop by others.

What broadband wireless is is much less expensive than fiber. Running fiber to metropolitan buildings can cost up to $250,000 per mile. Pointing an antenna from the top of a building to other rooftops costs one-tenth that—or less.

Now consider that demand for bandwidth is growing by a factor of 10 every five years. Radio spectra were recently auctioned off to fixed-wireless carriers around the world. And new infrastructure technology could do something to lower the costs of deployment. Darcy Shurin, president of Smart Consulting (Kirkland, Wash.), says prices for conventional point-to-point microwave radios dropped from $25,000 per pair to less than $15,000 per pair over the last three years.

Also consider this: Fewer than 10 percent of buildings have fiber running to them. It's no wonder that LECs (local exchange carriers) can't keep up with the demand for T1 (1.544-Mbit/s) and higher services. And though wireless broadband may not replace other access technologies (such as fiber and digital subscriber line), it will grab more than 12 percent of the overall broadband market, according to market research firm The Strategis Group Inc. (Washington, D.C.). That amounts to $5 billion in service revenue in the U.S. by 2003. And, according to Ray Nettleton of Formus Communications Inc. (Denver), an LMDS (local multipoint distribution service) provider, within five years wireless broadband will be available anywhere in the world through a combination of terrestrial and satellite links.

Broadband Specifics

Those are some impressive facts and figures. But before net architects can really take advantage of wireless broadband, they have to get set on the technology specifics. Generally speaking, wireless broadband refers to a carrier service that uses digital technology and supports multiple customers. Data rates range from 128 kbit/s to 155 Mbit/s on the high end. T1 or multi-T1 connections are the current sweet spot, but the technology can readily accommodate higher rates, such as DS-3 (45 Mbit/s) or OC3 (155 Mbit/s). Services supported include local and long-distance telephony, private network connections, and Internet access.

Carriers use different frequencies to deliver services. The bands most commonly used in the U.S. are located at 1.9, 2.4, 2.5, 5, 24, 28, 38, and 42 GHz. Different countries have different allocations.

The type of spectrum is important. Some bands are licensed, while others are unlicensed. Operation in the 2.4- and 5-GHz bands is unlicensed, so providers can get service up and running quickly and at lower cost (since they're not encumbered by licensing fees). But there's less unlicensed bandwidth than licensed. For instance, the 2.4 GHz unlicensed band offers only 80 MHz of spectrum. This is less than 10 percent of (licensed) LMDS spectrum allocations, resulting in a lower number of subscribers that can be supported.

Also, because the unlicensed bands are available to anybody, performance can be lower if different providers choose to offer competing services in the same area. Two ISPs (Internet service providers) operating in the same coverage area could limit throughputs to half of what might normally be possible, for instance. And since there are no governing bodies overseeing unlicensed spectrum, the carriers have to figure out a solution. Still, in spite of these limitations, such services could be very attractive to smaller and medium-sized businesses because they're very competitively priced. As for low-frequency bands that offer more bandwidth, there's MMDS (multichannel multipoint distribution service), at 2.5 GHz. It has 200 MHz of bandwidth, and since it is a licensed band, interference from other providers is not an issue. A number of ISPs are using the MMDS band to target small and medium-sized businesses, in some cases relying on a hybrid approach—wireless for the downlink and PSTN (public switched telephone network) for the uplink. In general, lower frequencies translate into much larger coverage radii, as large as 35 miles. Both Sprint Corp. (Kansas City, Mo.) and MCI Worldcom Inc. (Jackson, Miss.) have acquired companies with MMDS spectrum so they can use wireless for the local loop.

Higher frequencies (24 GHz or above) are sometimes called the millimeter wave band, because of the millimeter size of their wavelengths. These licensed bands are much larger, and at 28 GHz, the LMDS band, carriers have more than 1 GHz to work with. With modulations offering an effective throughput of 1 bit per second (4 QAM, or quadrature amplitude modulation) to about 4 bit/s (64 QAM) for every Hz of frequency, 1 GHz represents up to 4 Gbit/s of aggregated throughput (after coding overhead). However, this rate gets divvied up among customers and between neighboring cells or portions of cells called sectors. At these higher frequencies, connection distances shrink to about two miles. Since the bands are licensed, users should experience no interference.

Urban Affairs

Unlike PCS (personal communications services) carriers that must deploy service across large geographical areas spanning multiple states before they can attract subscribers, LMDS wireless broadband carriers can operate in dense ur- ban areas. They select specific metropolitan areas, install a hub on a centrally located building, and begin offering service using point-to-point or point-to-multipoint links.

The key issue is line of sight, since signals do not penetrate buildings or other structures (this is the case with all frequencies). The carrier arranges with building owners to locate remote-site equipment, which consists of small antennas and interface gear that attaches to standard telephony or networking lines. The carrier then presents its services to tenants of the building using conventional physical connectors and communications interfaces.

Obviously, carriers target buildings that are not serviced by fiber. To minimize the overhead of negotiating access to rooftops, carriers are striking deals with large real-estate management firms to obtain access to many buildings at a time. ISPs offering unlicensed or MMDS spectrum follow a different strategy. Thanks to lower frequencies, they can service larger radius zones, allowing them to target smaller businesses in more remote locations as well as home office users. Links can be point-to-point or point-to-multipoint. In these deployments, the customer usually purchases the remote-site radio equipment.

Regardless of technology, the biggest obstacles to widespread deployment today are availability of equipment and the cost per subscriber. For example, LMDS base stations cost approximately $250,000, plus $3,000 per subscriber (port charge) at the remote site. But prices will drop over the next 12 to 24 months as volumes ramp up. Smart's Shurin predicts price declines of 15 percent to 30 percent for infrastructure over this period, with LMDS ports declining to $1,500.

Architectural Issues

Still, a full understanding of the capabilities and limitations of wireless broadband networks means knowing the architectures. There are three primary links in the architecture: the link to the customer network, the link between the carrier network and other networks, and the wireless connection (or airlink).

The link at the customer site is easy to understand—and easy to install. It's based on standard networking inter- faces and protocols like E1/T1, fractional E1/T1, fractional T3, and 10/ 100Base-T. From the user's perspective, the network is indistinguishable from a wireline network. On the back end, the carrier uses standard interfaces such as DS-3 or OC3 ATM to connect to other networks.

The airlink is the part undergoing the most change, as different vendors work on different approaches. The bandwidths of radio signals across a link vary from about 10 to 50 MHz, though approximately 10 MHz is typical of deployments today. This 10 MHz is just one sliver of the carrier's overall spectrum holding. The carrier needs to plan its frequency carefully because it may need multiple overlapping hubs in a geographic area that don't interfere with one another. In addition, hubs may divide their coverage area into sectors, each with its own radio channel. Sectors typically vary from 15 to 90 degrees wide. The carrier must also balance deployment costs against capacity as more spectrally efficient modulations result in reduced coverage range.

Key developments are occurring in point-to-multipoint network technology. Most of today's broadband wireless networks are point-to-point, meaning that each connection employs dedicated radio and interface equipment at both hub and remote-site locations. But with a point-to-multipoint network, the coverage beam from the hub illuminates a number of different buildings. Each building is assigned specific time slots in a TDMA (time-division multiple access) approach. (This is similar to how IS-136 and GSM [global system for mobile communications] cellular networks operate.) Since the radio equipment at the hub communicates with multiple remote sites, a point-to-multipoint architecture represents a more efficient hardware design than a point-to-point architecture.

But the complexity of the equipment is considerably greater, and equipment costs are high since vendors are trying to recoup their development costs. In fact, deploying a point-to-multipoint architecture today is still more expensive than deploying a point-to-point architecture. But this will change. According to Jeanette Noyes of International Data Corp. (IDC, Framingham, Mass.), point-to-multipoint technology is essential to drive down per-subscriber costs so that wireless can effectively compete with other broadband technologies.

TDMA does more than enable a point-to-multipoint architecture. It also allows the carrier to allocate different amounts of bandwidth among customers dynamically. With dynamic bandwidth allocation, carriers can offer both CBR (constant bit rate) and VBR (variable bit rate) services at different price points. Customers that need certain throughput can pay for a premium service. Customers willing to accept varying bandwidth can obtain a discount. The net result is a broader set of offerings.

From a customer perspective, the point-to-point approach looks identical to a point-to-multipoint. But right now, no carriers offer point-to-multipoint services. Two vendors—Netro Corp. (Santa Clara, Calif.) and Wavtrace Inc. (Bellevue, Wash.)—are expected to start offering point-to-multipoint equipment soon, and there are many others in the wings.

Ring It Up

Despite the advantages of a point-to-multipoint architecture, some carriers and equipment vendors are working on a simpler approach, called "consecutive point." Here, large rings made up of multiple point-to-point links between buildings are built in metropolitan areas. Using an OC3 (and eventually higher) airlink, carriers can deploy service through add/drop multiplexers in a fashion similar to fiber. Building a ring also lets the service provider offer increased reliability through redundancy. And it’s not an either-or proposition: Carriers could choose a consecutive-point approach for initial service and then overlay it with point-to-multipoint once demand increases and costs decline.

Another thing to keep an eye on: the allocation of radio spectrum between hub-to-remote and remote-to-hub communications. The traditional approach has been frequency-division duplex (FDD), where separate frequencies are used. This results in a fixed amount of bandwidth being allocated in each direction.

An alternative is time-division duplex (TDD). Here, the same frequency band is used for both uplink and downlink communications. Across a short interval of time, 2 milliseconds in one system, the hub transmits to the remote site, and then for the remainder of the time, the hub receives from the remote site.

The upside here is that the system can dynamically adjust the amount of bandwidth allocated to uplink and downlink simply by changing the ratio of time between the two links. Also, the use of just one frequency not only makes frequency planning simpler, but also it allows the use of certain radio bands (e.g., the LMDS B band). Such bands can cause problems for FDD because the band is not wide enough to offer sufficient space (called the guard band) between sending and receiving frequencies for radios to be built at reasonable cost. This is not a problem with TDD, which uses only one frequency.

The big benefit of TDD is increased service flexibility. Since data traffic tends to be asymmetric, a TDD approach results in more efficient use of spectrum, and ultimately lower priced services—or at least improved margins for the carrier. It also allows the carrier to do what many ISPs do: oversubscribe. In other words, the total amount of bandwidth sold to subscribers can exceed the carrier's backbone connection. TDD makes this possible by allowing instantaneous bandwidth to be dynamically allocated among customers.

Spectrum of Services

So much for the inner workings. Net architects also want to know just who's offering service today. First, find out whether service is already available for the coverage areas of interest. If it isn't, it probably will be in the next year. Also look for a variety of approaches: Qualcomm Inc. (San Diego) has developed a version of its PCS technology that will allow cellular and PCS carriers to furnish data-only service of up to 2 Mbit/s with only a 1.25-MHz spectrum commitment. Meanwhile, billions of dollars are being spent on low-earth-orbit (LEO) satellite systems that will deliver broadband services, but these won't be available for several years yet.

Meanwhile, carriers will have to define the types of services and amount of bandwidth they want to offer. Some of these carriers—like Teligent Inc. (Vienna, Va.) and Winstar Communications Inc. (New York)—furnish complete telephony and Internet services. Others, like Advanced Radio Telecom (ART, Bellevue, Wash.) concentrate on Internet access only. Most carriers also offer such services as Web hosting, e-mail, and news services. As for bandwidth, they're best equipped to handle fractional T1 through multiple T1s, although with point-to-point links they could offer T3 or OC3 speeds as well.

While the licensed carriers have hundreds of megahertz of spectrum to dish out, carriers with unlicensed spectrum have lower overall capacity. Their bandwidth is also not necessarily guaranteed, which is fine for some customers but not for others.

What about error rates? The radio links engineered with forward-error correction deliver error rates comparable to wireline or fiber connections. As for degradation of service due to rain or snow, carriers take this into account, using the maximum reliable link for that particular geographic area. How about system reliability? Vendors claim 99.995 percent to 99.997 percent for their equipment. Bottom line: Aside from possible startup glitches, reliability is very high.

It's also wise to look into standards. All fixed wireless deployments are from the single owner of the equipment. Hence, there is little pressure for standards, and most vendor solutions are proprietary. Nevertheless, there are a number of standards efforts under way, including IEEE 802.16 (which defines physical and medium-access-control layers for wireless broadband), although the relevance of these standards remains to be seen. This is because most broadband wireless deployments involve a single vendor. Standards may give operators more options, but they're not essential. Since equipment is fixed, it doesn't have to interoperate with multiple networks, as it does in the cellular world.

Of course, no discussion of technology is complete without a few words on pricing. Generally, services need to be less expensive than wireline to attract attention, especially compared with T1 connections. New carriers like Teligent plan to cut customers' current payments by as much as 30 percent.

As for wireless ISPs, prices vary dramatically. But Concentric Network Corp. (San Jose, Calif.) is currently offering 384-kbit/s service for $150 per month. Clearly, being aggressive with pricing is the name of the game for wireless carriers.

Other Resources:

Table 1: Wireless Bands

Radio Band	U.S frequency allocation	Typical application	Maximum range	Characteristics
ISM (industrial, scientific, medical); no license required	902 to 928 MHz; 2,400 to 2,483 MHz (most commonly used); 5,725 to 5,875 MHz	Internet access	25 miles	Low deployment cost; well-suited for ad hoc networks; lowest overall capacity
LMDS (local multipoint distribution service)	27.5 to 28.35 GHz; 29.1 to 29.25 GHz	Internet access and telco services	2 miles	Highest deployment cost; can serve many customers
MMDS (multichannel multipoint distribution service)	2,500 to 2,655 MHz; 2,655 MHz to 2,690 MHz	Internet access and telco services	35 miles	Lower deployment cost than LMDS; lower capacity
28 GHz	28.6 to 29.5	Internet	2 miles	Similar to LMDS

	GHz	access and telco services	though spectrum allocations are generally smaller

Table 2: Service Schedule

Year	Service feature
1999	Increased rollout of service based on point-to-point architecture
2000	Deployment of point-to-multipoint and consecutive-point networks
2001	Increased service flexibility such as dynamic bandwidth allocation; VOIP (voice
2002	Radio channels up to 50 MHz in both point-to-point and point-to-multipoint networks; much lower deployment costs than self-configuring systems

Links

Net architects boning up on **broadband wireless** can check out this list of representative organizations, vendors, and service providers. It's by no means exhaustive, but it can serve as a useful starting point for additional research.

- **Standards groups and industry associations**

IEEE 802.16 Working Group on Broadband Wireless Access Standards: http://grouper.ieee.org/groups/802/16

Wireless Communications Association International:www.wcai.com

Digital Audio Visual Council: www.davic.org

- **Unlicensed industrial, scientific, medical (ISM) band service providers**

Airwire Inc.: www.airwire.net

Com-Pair.Net: www.com-pair.net

Spectrum Wireless Inc.: www.spectrumwireless.net
Worknet Communications: www.worknet.net

- **MMDS (2.5 GHz) service providers**

Concentric Network Corp.: www.concentric.net
Speedchoice (now owned by Sprint Corp.): www.speedchoice.com
Wireless One Inc.: www.wireless-one.com

- **Millimeter band (24 to 42 GHz) service providers (includes LMDS, 38 GHz)**

Advanced Radio Telecom: www.art-net.net
Formus Communications Inc.: www.formus.net
Nextlink Communications Inc.: www.nextlink.com
Teligent Inc.: www.teligent.com
Winstar Communications Inc.: www.winstar.com

- **ISM band equipment providers**

Aironet Wireless Communications Inc.: www.aironet.com
Lucent Technologies Inc.:www.wavelan.com
Proxim Inc.: www.proxim.com
Solectek Corp.: www.solectek.com
Speedcom International: www.speedlan.com
Wavespan Corp.: www.wavespan.com
Wi-LAN Inc.: www.wi-lan.com

- **MMDS and LMDS/millimeter-band equipment providers**

Adaptive Broadband Corp.: www.adaptivebroadband.com
Harris Corp.: www.harris.com/harris
Hughes Network Systems: www.hns.com
Hybrid Networks Inc.: www.hybrid.com
Lucent:www.lucent.com
Netro Corp.: http://www.srtelecom.com
Newbridge Networks Corp.: www.newbridge.com
Nortel Networks: www.nortel.com
P-Com Inc.:www.p-com.com
Spectrapoint Wireless: www.boschtelecominc.com/index.htm
Spike Technologies Inc.: www.spike.com
Stanford Telecommunications Inc.: www.stelhq.com
Triton Network Systems Inc.: www.triton-network.com
Wavtrace Inc.: www.wavtrace.com