White Paper: Overview of Broadband Wireless Technologies

Wi-Fi

What is Wi-Fi?

The term Wi-Fi or WiFi refers to Wireless Fidelity, which is another name for a wireless network running under the 802.11group of standards defined by the IEEE (Institute of Electrical and Electronics Engineers).

Wi-Fi is generally used to wirelessly extend a Local Area Network (LAN) within a building or in a campus environment. It makes use of Spread Spectrum wireless technology, which means that the signal is modulated over a range of frequencies. This gives the signal greater reliability in high noise environments. Wi-Fi transmitters and receivers are almost exclusively designed to operate in the non-licensed IMS (2.4GHz) frequency bands. Two drawbacks of non-licensed frequencies are regulatory limitations on power output and interference from other transmitters. Some Wi-Fi equipment also operate in the 5.7GHz unlicensed (in some countries) or the 3.5GHz licensed frequency bands.

The 802.11 specification has been implemented in a number of different variations, namely:

802.11a
updated version of 802.11b. Operates in 5GHz bands (5.2 and 5.7) and offers max airspeed of 54Mb/s half-duplex (not throughput). Uses Coded Orthogonal Frequency Division Multiplexing (COFDM) as the signal modulation technique.

802.11b
Now the most widely deployed version of Wi-Fi. Operates in unlicensed 2.4GHz bands with max airspeed of 11Mb/s half-duplex (not throughput). Uses DSSS (Direct Sequence Spread Spectrum) modulation.

802.11g
Allows wireless data rates up to 54 megabits per second in the 2.4 GHz spectrum. Backwards compatible with 802.11a and 802.11b standards.
Mandatory modulation schemes are Complementary Code Keying (CCK), used in 802.11b, and Orthogonal Frequency Division Multiplexing (OFDM), used in 802.11a.
Two optional modulations are allowed if systems manufacturers chose to add them:
CCK-OFDM and CCK-PBCC.

Applications for Wi-Fi

Provides a wireless alternative to Ethernet LANs. This technology is suitable to provide local area “Hotspots” or wireless LAN connectivity.

Typical applications are wirelessly connecting users in offices, at home, airports, coffee shops, hotels, boardrooms etc.

This technology is not suitable for providing Broadband Backhaul services due to limited range, interference experienced in unlicensed frequency bands, limited security and limited throughput.

Advantages

- No frequency license is required
- Relatively inexpensive to deploy in a small area
- Relatively simple to deploy in a small area
- Many personal laptops and PDAs already have built-in Wi-Fi transceiver units

Disadvantages

- Prone to interference due to unlicensed frequency band
- No Quality of Service (QoS) for VoIP
- Distance limitation
- Not suitable to build IP backhaul networks
- Not secure

WiMAX

What is WiMax?

WiMax refers to the 802.16 set of standards from the IEEE and stands for “Worldwide Interoperability for Microwave Access”. The 802.16 standards were developed as broadband wireless communications standards for metropolitan area networks (MANs).

The original 802.16 standard, published in December 2001, specified fixed point-to-multipoint broadband wireless systems operating in the 10-66 GHz licensed spectrum. An amendment, 802.16a, approved in January 2003, specified non-line-of-sight extensions in the 2-11 GHz spectrum, delivering up to 70 Mbps at distances up to 31 miles. It must be noted that these throughput and range tests were conducted under ideal laboratory conditions with a Line Of Sight point to point link.

In 2001, the WiMax Forum was created in order to promote the standard and to help ensure compatibility and interoperability across multiple vendors

The term WiMax currently includes 802.16-2004 and 802.16e. (IEEE 802.16-2004 is also known as 802.16REVd or simply 802.16d and was certified in October 2004.)

On the radio frequency (RF) side WiMax employs Orthogonal Frequency Division Multiplexing (OFDM) technology. OFDM is similar to Frequency Division Multiplexing, but is much more spectrally efficient. OFDM also allows Non-Line of Sight (NLOS) applications, which greatly improves coverage in built-up areas.

Frequency ranges in which WiMax equipment is expected to be available includes:
2.3GHz, 2.4GHz, 2.5GHz, 3.5GHz, 5.8GHz and potentially 700MHz.

However, the 2.5GHz and 3.5GHz frequency ranges seem to be the most popular for initial product offerings.

802.16d

802.16d or 802.16-2004 is essentially the fixed version of WiMax.

The 802.16-2004 standard is meant to serve as a wireless replacement for DSL for areas where running copper wire does not make economic sense. It is also a viable solution for wireless backhaul of WiFi access points and potentially for the backhaul of Cellular Voice networks.

CPEs (consumer premise equipment) can either consists of an outdoor unit / indoor unit combinations which need be installed by qualified technicians or can be self-installable indoor units.

Currently there are no manufacturers of handheld devices who are developing embedded 802.16d data cards.

On the RF side 802.16d employs Orthogonal Frequency Division Multiplexing (OFDM).

Applications
- Alternative to copper in developing and underserved areas
- Alternative to xDSL and cable modems to deliver broadband services
- Wireless backhaul in cellular networks
- Wireless backhaul in Wi-Fi networks

Advantages over CDMA
OFDM technology enables operators to deploy this technology in Non Line of Sight (NLOS) applications. This gives WiMax an advantage over products based on CDMA technology.

Typical cell sizes are much larger that those required for CDMA to deliver the same data rate, thereby reducing the network roll-out costs for broadband operators.

Advantages over 802.16e
The 802.16-2004 standard has been ratified and therefore vendors can now manufacture base stations and customer premises equipment which are standards based, with the obvious associated benefits.

Disadvantages compared to CDMA
OFDM technology does not cope as well with noisy environments as CDMA, which is why WiMax equipment should preferably be deployed in licensed frequency bands.

OFDM receivers are substantially larger, require more processing power and are more expensive than CDMA receivers

Disadvantages compared to 802.16e
Operators looking to invest in a WiMax network must realise that 802.16e is not backward compatible with 802.16d. While some 802.16d vendors propose base station equipment with additional hardware complexity or software programmability to allow a switch to 802.16e, this is likely to result in a large cost penalty. Also, this will not solve the problem of having incompatible end-user devices. It is imperative for end-user devices to be low cost, which will most likely make it prohibitive to upgrade 802.16d end-user devices to be 802.16e compliant.

Additionally, an operator who deploys 802.16d and then attempts to roll in 802.16e equipment at a later date will be disadvantaged by having to split the available licensed spectrum between the two technologies. Without a true upgrade path from 802.16d to 802.16e and the necessity to preserve spectrum to support network growth, 802.16e provides the best long-term protection for an operator's WiMax investments.

802.16d has all the appearances of being an interim technology with no true upgrade path to 802.16e. It is anticipated that 802.16e will outperform 802.16d and benefit from economies of scale even for fixed applications.

802.16e

802.16e is the mobile version of WiMax. In addition, it also provides enhanced performance in fixed and nomadic environments. Some market analysts believe 802.16e to be the true future of WiMax.

The 802.16e standard has not yet been ratified, but a few vendors have already released very mature “Pre-e” WiMax products and are anticipated to offer a simple upgrade path to the standardized version, once the standard is ratified.

As already mentioned, 802.16e will not be backwards compatible with 802.16-2004, which could prove costly to operators wanting to implement 802.16-2004 first and then later upgrade to 802.16e. The reasons why the standards will not be backwards compatible are incompatibilities between the frequency carriers (tones) employed and MAC layer differences which allow 802.16e to support mobility.

802.16e employs Scalable Orthogonal Frequency Division Multiple Access (S-OFDMA).

Applications

- Alternative to copper in developing and underserved areas
- Alternative to xDSL and cable modems to deliver broadband services
- Wireless backhaul in cellular networks
- Wireless backhaul in a Wi-Fi network
- Portable or Mobile coverage (broadband access and value added services anytime, anywhere and at high speeds). Examples include:
    i. Emergency services
    ii. Police services
    iii. The perfect mobile office for professionals
    iv. Mobile VoIP services

Advantages over CDMA

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Advantages over 802.16d

The advantages of the 802.16e standard over the 802.16d standard can be summarised as follows:

Lower Cost

Portable and mobile applications have a strong track record for accelerating volumes created by demand for embedded chipsets in laptops and handheld devices. Therefore it is expected that mobile deployments of 802.16e will bring cost points down below solutions engineered solely for fixed applications using 802.16d.

Scalable System Bandwidth

With 802.16e, WiMax makes enhancements to the physical layer by employing Scalable Orthogonal Frequency Division Multiple Access (OFDMA). The ability to scale system bandwidth while maintaining constant symbol duration allows operators the advantage of being able to deploy today and grow their system bandwidth tomorrow at a lower cost and reduced network impact.

Higher Capacity

While 802.16d and 802.16e both support a variety of forward error correction techniques to increase the capacity of the broadband wireless system, the first generation of 802.16d products are not expected to implement such high-performing coding techniques. In contrast, 802.16e products are anticipated to deliver such capabilities from the first shipments. 802.16e also provides sub-channelization techniques to more efficiently manage channel quality, priority, power and bandwidth allocation among multiple end users.

Power Reduction

802.16e defines a series of sleep and idle mode power management functions to enable power conservation and preserve battery life for end-user devices.

Quality of Service

802.16e introduces Extended Real-Time Polling Service, which allows 802.16e to manage traffic rates and transmission policies, as well as improve latency and jitter. The advantages afforded by the QoS techniques are especially important in the support of Voice-over-IP applications.

Multicast/Broadcast
802.16e also supports multicast and broadcast services. Multimedia applications, such as IP TV, that make use of streaming video are greatly advantaged by multicast and broadcast capabilities to better manage bandwidth and content delivery.

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OFDM receivers are substantially larger, require more processing power and are more expensive than CDMA receivers.

Disadvantages compared to 802.16d
The 802.16e standard has not been finalised yet. This creates a reluctance in the market to move to WiMax as operators are unsure whether to

a) roll out 802.16d now and then upgrade to 802.16e later (see Disadvantages under 802.16d)
b) roll out 802.16 “pre-e” now and upgrade to the standardized version later
c) wait until the standard is ratified, in which case they may loose ground to their competitors

It is anticipated that the standard will be finalised sometime in 2007.

CDMA

What is CDMA and CDMA2000?

Code division multiple access (CDMA) is a form of multiplexing (not a modulation scheme) and a method of multiple access that does not divide up the channel by time (as in TDMA), or frequency (as in FDMA), but instead encodes data with a special code associated with each channel and uses the constructive interference properties of the special codes to perform the multiplexing.

CDMA also refers to digital cellular telephony systems that make use of this multiple access scheme, such as those pioneered by Qualcomm.

W-CDMA, which has been approved by the ITU, forms the basis of 3G GSM cellular networks.

CDMA2000 is the second generation of CDMA digital cellular also known as IMT-CDMA Multi-Carrier or IS-2000. It is the main route for CDMA operators to 2.5G and 3G cellular networks. 3GPP2, the standard-setting body behind CDMA2000, has created a set of standards that define the air interface and the Radio Access and Core Network changes that will enhance network capacity, improve speed and bandwidth to mobile terminals, and allow end-to-end IP services.

CDMA2000 is therefore a family of third-generation (3G) mobile telecommunications standards that use CDMA to send voice, data, and signalling data (such as a dialed telephone number) between mobile phones and cell sites.

CDMA2000 can be deployed in several phases. The first phase, CDMA2000 1x, supports an average of 144 kbps packet data in a mobile environment. The second release of 1x, called 1x-EV-DO will support data rates up to 2 Mbits/sec on a dedicated data carrier. Finally, 1x-EV-DV will support even higher peak rates, simultaneous voice and high-speed data, as well as improved Quality of Service mechanisms.

A key component of CDMA2000 systems will be a new Packet Core Network (PCN) that allows for the delivery of packet data services with more speed and security. The CDMA2000 PCN is one of the first steps in the evolution of CDMA2000 systems to All-IP and multi-media architecture.

Applications

- CDMA can be used as a Wireless local loop (WLL) technology to provide last mile access to fixed-line networks.
- CDMA is suited for data transfer with bursty behaviour and where delays can be accepted, like Wireless LAN applications.
- CDMA2000, with its high data rates is a viable alternative to 3G GSM networks for providing mobile cellular services. In fact, 3G GSM networks make use of a related, but incompatible technology called W-CDMA.

Advantages over WiMax
By the nature of the technology, CDMA operates well in noisy environments, although competing CDMA systems in the same area can still cause interference.

CDMA receivers and therefore handsets based on this technology are small and relatively inexpensive to manufacture.

CDMA is a proven technology to provide mobile voice/data services.

Disadvantages compared to WiMax
Multipath reflections are detrimental to CDMA signal to noise ratios.

CDMA cannot be used to provide Broadband services in Non Line of Sight (NLOS) applications.

CDMA suffers from the Near-Far effect, which becomes a limiting factor in rural areas. This is not a problem with OFDM.

Increasing the bandwidth throughput in CDMA dramatically reduces the cell sizes. Therefore, when using CDMA technology to provide Broadband services, cell sizes are much smaller than those of OFDM based technologies, such as WiMax. This has a huge impact on the roll-out costs of a network.

CDMA also suffers from the “Cell Breathing Effect” where effective cell sizes change according to the number of subscribers connected to a base at any particular time.

802.20

What is 802.20?
By Vikki Lipset

With WiMax poised to usher in the second coming of fixed wireless broadband, two Institute of Electrical and Electronics Engineers (IEEE) (define) working groups are turning their attentions to mobile broadband so you can use that high-speed connection on the road.
The emerging 802.16e and 802.20 standards will both specify new mobile air interfaces for wireless broadband. On the surface the two standards seem very similar, but there are some important differences between them. For one, 802.16e will add mobility in the 2 to 6 GHz licensed bands, while 802.20 aims for operation in licensed bands below 3.5GHz.

More importantly, the 802.16e specification will be based on an existing standard (802.16a), while 802.20 is starting from scratch. This means that products based on 16e will likely hit the market well before .20 solutions -- a distinct advantage for the WiMax Forum, the group currently backing 802.16 and its permutations.

The IEEE approved the 802.16e standards effort in February with the avowed intent of increasing the use of broadband wireless access (BWA) by taking advantage of the "inherent mobility of wireless media." The amendment to 802.16, which is also called the wireless metropolitan area network (MAN) standard, will enable a single base station to support both fixed and mobile BWA. It aims to fill the gap between high data rate wireless local area networks (WLAN) and high mobility cellular wide area networks (WAN).

The IEEE actually established the 802.20 Working Group before it gave the go-ahead to 802.16e and indicated that it intended to have a standard in place by the end of 2004, but the group has been mired in conflict (a battle for the chairmanship is currently underway) and has made little progress.

The 802.20 interface seeks to boost real-time data transmission rates in wireless metropolitan area networks to speeds that rival DSL and cable connections (1Mbps or more) based on cell ranges of up to 15 kilometers or more, and it plans to deliver those rates to mobile users even when they are traveling at speeds up to 250 kilometers per hour (155 miles per hour). This would make 802.20 an option for deployment in high-speed trains. The 802.16e project authorization request specifies only that it will "support subscriber stations moving at vehicular speeds"; Kiernan said the group has achieved speeds of 120 to 150 kilometers per hour (75 to 93 miles per hour) in simulations.

There is clearly some overlap between the two standards, but the party line from companies involved in the 802.20 standards effort, including Navini Networks and Flarion Technologies, is that the two are not competitive. The IEEE would not ratify a group that has competing interests with an existing group, argued Sai Subramanian, vice president of product management and strategic marketing at Navini. "If they are so obviously in conflict, why did IEEE approve two standards tracks?" Not everyone is buying that argument, though. "The bottom line is they're very similar," said Ed Rerisi, director of research at Allied Business Intelligence (ABI). "They do have some minor differences, but they both are aimed to serve similar users."

Essentially, 802.16e is looking at the mobile user walking around with a PDA or laptop, while 802.20 will address high-speed mobility issues, he said. One key difference will be the manner in which the two are deployed. "Our assumption is that the carriers are going to deploy .16e in their existing [.16a] footprint as opposed to deploying a more widespread footprint, like a cellular network, for example," said Rerisi. "802.20 is looking at more ubiquitous coverage ... and that will require a larger footprint."
Indeed, some argue that 802.20 is a direct competitor to third-generation (3G) wireless cellular technologies. Since mobile operators are spending millions to upgrade their networks in order to offer 3G services, it could be a tough sell to persuade them to invest in yet another network.
It doesn't have to be an either-or situation, though, said Ronny Haraldsvik, senior director of marketing strategy at Flarion Technologies, which has been heavily involved in the 802.20 standards process. He said that operators could deploy 802.20 as an overlay to their existing networks. "They don't have to walk away from what they have."

In the meantime, 802.16e's head start may actually work to 802.20's advantage by whetting users' appetites for mobile access, Rerisi suggested. "If 802.16e drives demand initially and people are getting thirsty for it, a .20 solution could be deployed on a widespread basis and take advantage of users wants and demands for high-speed data."
Ultimately, the fate of both standards rests with 802.16, he said. "I think that if there's success in the 802.16 market, it'll definitely portend good things for the 802.20 market."

PCL – Powerline communications

What is PCL

Broadband over power lines (BPL), also known as power-line internet or Powerband, is the use of PLC technology to provide broadband Internet access through ordinary power lines. A computer (or any other device) would need only to plug a BPL "modem" into any outlet in an equipped building to have high-speed Internet access.

BPL offers obvious benefits relative to regular cable or DSL connections: the extensive infrastructure already available would appear to allow more people in more locations to have access to the Internet. Also, such ubiquitous availability would make it much easier for other electronics, such as televisions or sound systems, to hook up. However, variations in the physical characteristics of the electricity network and the current lack of IEEE standards mean that provisioning of the service is far from being a standardized, repeatable process, and the amount of bandwidth a BPL system can provide compared to cable and wireless is in question.

PLC modems transmit in medium and high frequency (1.6 to 30 MHz electric carrier). The asymmetric speed in the modem is generally from 256 kbit/s to 2.7 Mbit/s. In the repeater situated in the meter room the speed is up to 45 Mbit/s and can be connected to 256 PLC modems. In the medium voltage stations, the speed from the head ends to the Internet is up to 135 Mbit/s.

Technology

Technology will deliver speeds of up to 200 Mbit/s at the physical layer and 130 Mbit/s at the application layer using HomePlug AV standard (interoperable with HomePlug 1.0 or Intellon's proprietary 85 Mbit/s Turbo mode, already available) or proprietary DS2 technology which is based on OFDM modulation with 1536 carriers and TDD or FDD channel access method. DS2 technology may operate between 1 and 34MHz. It provides a high dynamic range (90 dB) and offers frequency division and time division repeating capabilities. These characteristics allow the implementation of quality of service (QoS) and class of service (CoS) capabilities.

Experiences with Ascom's DS2 based system

The Ascom system consists of master devices and slave devices. CPEs (slave devices) connect through the medium to the master device or head-end device. Master devices can be set up in repeater mode to extend the range of the system. A CPE connects to the master device found in the "power cell". All communication takes place between slave and master, no slave to slave communication is permissible. The master devices transmit at –50dBms while the slaves transmit at –56dBm (desktop CPE) and –58dBm (wall adapter CPE). The noise floor was found to be around –70dBm.

3 Types of master devices exist, 2 of them can handle 64 CPEs with 1000 ethernet MACs in total. The other "mini-master" can handle only 32 CPEs with 64 ethernet MACs. The 2 bigger master devices mentioned previously are intended for low-voltage distribution and medium voltage backhaul applications respectively.

The system can use 2 types of coupling methods to inject the data signal into the power line: inductive or conductive. Conductive coupling is used when making a galvanic connection between the master and the power line. For this type of installation the power needs to be switched off during installation. Also, this method cannot be used where the impedance of the cable is lower than 20 Ohms, which would be the case when the cable splits up into multiple feeds running to homes. For low impedance environments or where the power cannot be easily switched off, an inductive installation is recommended. Ferrite cores are wrapped around the power medium to induce the signal. This method can only be used in situations where the shielding around the cable from the transformer is brought out of the cable and terminated onto the ferrite.

In a test it was found that the range of the system (without repeaters) does not exceed 100m, but this is highly dependant on the placement of the master device and the quality of the wiring. Up to 5 master devices can be configured as repeaters to extend the range.

The system operates between 2 MHz and 34 MHz with the capability of choosing 10, 20 or 30 MHz bandwidths.

Advantages

- Utilizes already existing copper infrastructure
- Higher speeds compared to wireless technology
- No electromagnetic spectrum license required

Disadvantages

- Limited range ~ 100m

- Signal can’t cross transformers
- High voltage can be dangerous to work on
- Expensive to deploy in WAN environments
- Simplex, shared medium
- Rumours of interference with HF radio equipment
- Interoperability?

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