AIRAYA
High Speed Wireless Broadband

Wireless Networking: The Next Wave

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During the past few years, wireless networks have achieved tremendous commercial success, and are widely expected to continue experiencing strong growth in the future. According to Frost & Sullivan, the Wireless LAN (WLAN) market grew 43 percent in 1999, and is estimated to reach $1.8 billion by 2006. On the one hand, the high acceptance of WLAN technology is warranted by its compelling value proposal. Wireless networks enable fast, untethered access to critical data, thus boosting the productivity of mobile professionals while eliminating the cost of installing wires and expensive retrofits.

Secondly, technological advances and higher volumes have brought costs down to the point where WLANs could successfully evolve from a niche technology to an indispensable solution for the broad market. Wireless infrastructure is no longer constrained to vertical markets and fortune-500 companies, but put in productive use in small offices, hotels, airports, cyber cafés, and networked homes. Although products may differ for each application, the underlying technology doesn't. The overwhelming majority of WLANs in operation today is based on one of the two dominant IEEE 802.11 standards, 802.11a and 802.11b. This paper explains the basic differences between the two flavors, and why 802.11a will be the long-term winner.

802.11b Backgrounder

Prior to the advent of the 802.11b standard, the wireless LAN market was essentially fragmented between two competing radio technologies, Frequency Hopping Spread Spectrum (FHSS) and Direct Sequence Spread Spectrum (DSSS). With peak data rates of 2 Mbps, both transmission schemes lacked the bandwidth required for large file transfers and bulky office applications. An IEEE committee effort therefore ensued to pursue a vendor-independent high-rate extension of the existing DSSS specification. Finalized and approved in 1999, the IEEE 802.11b standard (sometimes referred to as Wireless Ethernet, or Wi-Fi™) set a new benchmark with Ethernet-like data rates of up to 11 Mbps – a milestone that would mark the beginning of a new era in the WLAN space. The adoption and strong support of 802.11b has clearly been one the main engines behind growth in the worldwide WLAN market.

To maintain backward compatibility, 802.11b inherited the static nature and channelization of its 2 Mbps DSSS predecessor. In the U.S., an 802.11b network operating in the license-exempt 2.4 GHz band is limited to three independent channels. Other countries like France and Spain permit only one single non-overlapping channel due to additional regulatory constraints.

Coexistence Takes Center Stage

Unfortunately the scarce 2.4 GHz spectrum is contaminated with interference from a variety of intentional radiators, such as microwave ovens, cordless phones, HomeRF™ devices, and proprietary WLAN systems, and will soon be more so. The potentially greatest obstacle to coexistence in the 2.4 GHz band is introduced by Bluetooth™, a short-range cable replacement technology that is poised for widespread adoption. Due to its extremely fast hop rate of 1,600 per second, a Bluetooth transmitter can adversely impact or completely knock out 802.11b transmissions. Contrary to popular belief, configuring the 802.11b receiver to a different channel will actually not result in any significant improvement. Bluetooth signals are roughly evenly spread across the entire 2.4 GHz band, and the 802.11b protocol includes no mechanism to effectively avoid or combat such interference. For outdoor applications in crowded areas or for sensitive applications that depend on high availability of the wireless network, 802.11b is therefore not a suitable option.

Since the number of non-overlapping channels (three) defines the number of wireless subnetworks that can operate independently, it is also apparent that 802.11b doesn't scale well. Proponents of 802.11b have been quick to point to its 11 Mbps bit rate to create the misconception of Ethernet-equivalent system performance. The flaw in such a comparison is the simple fact that the 11 Mbps pipe must be shared among all users associated to the same channel. In contrast, today's wired networks have long overcome the bandwidth sharing issue through the concept of LAN switching, providing dedicated 10 or 100 Mbps Ethernet segments for small workgroups and even individual users. Because an 802.11b network cannot be broken into more than three "segments", its aggregate bandwidth is inadequate for most high-density environments with a large number of simultaneous channel contenders.

Enter 802.11a

The above shortcomings have driven vendors to further enhance their WLAN capabilities and embrace a more powerful technology – 802.11a. Although the IEEE 802.11a standard exists since 1999, compliant products have just recently arrived on the market. The reason lies in the relative complexity of 802.11a chip designs, as well as the limited availability of key components such as highly linear power amplifiers. These engineering challenges were overcome, however, and in late 2001 802.11a became a reality. Today, there is clear consensus in the industry that it has the potential to replace 802.11b as the dominant WLAN standard.

802.11a products are characterized by very high data rates of up to 54 Mbps – a five-fold improvement over 802.11b – using the Orthogonal Frequency Division Multiplexing (OFDM) transmission scheme. The basic idea of OFDM is to transmit a large number of simultaneous narrowband signals, each modulated with a low bit rate, but the sum yielding a very high data rate. The decision of the IEEE committee to select OFDM as the best high-rate waveform was largely due to its superior ability to mitigate multi-path reflections while making efficient use of the available spectrum. Multi-path effects usually occur when radio signals bounce off walls, cubicles, and other objects as they travel between the transmitting and receiving device. As a result, the original signal and the individual echoes each arrive at the receiver at slightly different times, thus degrading signal quality. In typical indoor environments, the multi-path performance of the wireless system is one of the primary factors that determine its range. Independent analysis shows that the indoor range of an 802.11a system is in fact highly competitive with its 802.11b cousin, assuming that all other parameters are equal.

Bit Rate	Modulation	Coding Rate	Mandatory
6 Mbps	BPSK	R1/2	Yes
9 Mbps	BPSK	R3/4	No
12 Mbps	QPSK	R1/2	Yes
18 Mbps	QPSK	R3/4	No
24 Mbps	16QAM	R1/2	Yes
36 Mbps	16QAM	R3/4	No
48 Mbps	64QAM	R2/3	No
54 Mbps	64QAM	R3/4	No

Table 1: Physical layer modes of 802.11a

A key feature of the 802.11a physical layer is to provide several data rates by combining different modulations and coding rates, as listed in the above table. This allows an 802.11a system to extend its coverage area well beyond the size of a 54 Mbps cell. As the distance between the 802.11a client and its access point increases, the connection will remain intact but speed will be gracefully reduced until the lowest common bit rate is reached, and vice versa.

Why Higher Data Rates are so Important

Constant advances in computing technology, more users, and more collaboration are among the factors that are driving the need for greater bandwidth and improved response times. Because of the shared nature of 802.11 networks, the number of collisions and subsequent retransmissions will grow quickly as more users are trying to gain access to the wireless medium, causing a snowball effect. Since higher bit rates translate into shorter packet transmit times, an 802.11a backbone can handle significantly more simultaneous clients than 802.11b. Furthermore, the 802.11a approach provides a better foundation for delay-sensitive traffic such as voice and video, and reduces the airtime exposure of packets to interference and interception by an attacker.

Of course, the user expectation for performance is very application dependent. Examples of new multimedia applications enabled by 802.11a are mobile video conferencing and wireless media streaming. A DVD-quality MPEG2 stream typically requires 6 to 8 Mbps actual throughput, and it is not too hard to anticipate the need for two or more applications to run concurrently. With its net throughput in excess of 25 Mbps, 802.11a provides a future-proof solution that won't require costly upgrades to accommodate future growth and new bandwidth-hungry applications.

The performance of 802.11a does actually not come at the expense of power efficiency. Conversely, the higher data rates of 802.11a allow a major reduction in average power consumption. Since an inactive radio consumes only a fraction of the energy required by an active transmitter, the duration of the transmission is the decisive factor. To transmit the same amount of data, an 802.11b system at 11 Mbps will need four to five times more time than a 54 Mbps system, therefore impeding its ability to enter the sleep mode.

Cleaner Spectrum at 5 GHz

Unlike 802.11b, 802.11a provides interference-free operation at a set of frequencies known as the U-NII (Unlicensed National Information Infrastructure) band. The U-NII spectrum is located at 5.15 to 5.35 GHz and 5.725 to 5.825 GHz. Because of sharing with primary satellite services, the 5.15 to 5.25 GHz segment is restricted to indoor operation, and different power limits apply.

Segment	U-NII1	U-NII2	U-NII3
Frequency Range	5.15 to 5.25 GHz	5.25 to 5.35 GHz	5.725 to 5.825 GHz
Bandwidth	100 MHz	100 MHz	100 MHz
Independent Channels	4	4	4
Power Limit	50 mW	250 mW	1 W
Outdoor Permissible	No	Yes	Yes

Table 2: Understanding the U-NII spectrum

Although segmented, the total spectrum available for 802.11a devices is more than three times that of the 2.4 GHz band, thus accommodating up to twelve non-overlapping channels. Scaling the 802.11a network can therefore be accomplished by placing clients on different frequencies, for up to 648 Mbps aggregate bandwidth – a nearly twenty-fold improvement over 802.11b. As discussed on page 2, this "segmentation" is especially important for environments with high concentrations of users, such as conference rooms, dormitories or crowded hot spots.

Because their signals travel in different frequency bands, collocation of 802.11a and 802.11b nodes will not induce a drop in performance in either network. Migrating to 802.11a is therefore not as costly or complicated as it might sound, and, most importantly, the move to 5 GHz will not obsolete the existing 802.11b infrastructure.

Incremental upgrades with additional 802.11a access points allow companies to make a gradual transition, adding high-performance "islands" for power users where required. Seamless roaming between 802.11a and 802.11b coverage areas will be enabled by dual-band client adapters, which are expected to reach the market soon. Don't count on upgrading 802.11b access points to 5 GHz, though – some vendors may claim that radio cards in current products can be replaced, but the different range characteristics will make this a somewhat tricky undertaking.

Conclusions

Advantages gained with 802.11a include higher data rates, better interference robustness and power efficiency, and especially greater scalability. From the perspective of AIRAYA, the trend is clear – the market will ultimately embrace 802.11a based on its technical merits, reduced deployment cost, and wide industry support. Healthy competition between chipset companies and system vendors will ensure that price points will soon approach those of today's standard 802.11b products.

However, 5 GHz technology still faces a number of challenges – primarily of regulatory nature, as 802.11a needs to be modified to satisfy the requirements of European spectrum authorities. The IEEE 802.11h supplement, expected to be finalized by the second half of 2002, will pave the road to acceptance in Europe by defining the appropriate frequency selection and transmit power control extensions.

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