The ABGs of Wireless LAN
Technology Overview

February 2003
Introduction

Wireless LANs (WLANs) using the 802.11 standard offer compelling value in office, public, and home LAN environments. Wireless connectivity eliminates the need to rewire buildings with multiple fiber or Ethernet cables. 802.11 is not an alternative to broadband; rather, it is a fast and friendly pipe to distribute broadband within a home or office environment. In addition, users can take advantage of WLANs at public access locations, also known as “hot spots,” at coffee shops, conference facilities, hotels and even airline terminals. 802.11 technology benefits significantly from the network effect and offers the flexibility to grow rapidly by minimizing the need for a large up-front investment. With data rates ranging from 11 Mbps to 54-plus Mbps (up to 108 Mbps in Turbo mode – not available in Europe), within public, office, and home environments. WLANs help companies increase productivity—the ability to work anywhere means employees can get more work done, and IT resources can be used more effectively.

Choosing the right WLAN technology is an important factor in determining the overall return on investment. This paper provides a brief overview of products based on 802.11 protocols. 802.11 technology is advancing very quickly, and products based on these protocols have different features and capabilities.

802.11b

Quick Spec: 11 Mbps, 3 non-overlapping channels, 32 users per AP, 2.4 GHz

802.11b products have been on the market for three years, and there are more than 30 million devices in use. With an average actual throughput of about 4.5 Mbps, 802.11b is fast enough for most network applications and file transfers. A very mature solution, 802.11b features many compelling advantages over other wireless standards.

When deploying 802.11b, fewer access points are typically needed because of the extended range capabilities. Because this protocol operates at a lower frequency, it will drain less power from laptops and other portable devices. Widely deployed, it is used in many business and public locations such as airports, coffee shops, and hotels.

The 802.11b protocol is based on a radio frequency modulation technique known as direct sequence spread spectrum (DSSS). DSSS is less susceptible to radio noise and interference because it spreads a transmission signal over a broad band of radio frequencies.

Benefits

- Most affordable: In most situations, 802.11b products are the lowest price points for client adapters, routers and access points (APs).
- Good growth path: Interoperates with dual-band and future 802.11 protocols such as 802.11g.
- Very compatible: Wi-Fi certification assures interoperability between equipment from different vendors.
- Longer range: Up to 500 meters in an open environment.
- Lower power consumption: 802.11b client cards typically require less power, so client devices operate longer when running on batteries.
- Large installed base of 802.11b networks.
Security
The Wired Equivalent Privacy (WEP) algorithm is used to protect 802.11b networks from unauthorized users and eavesdropping on transmitted data. WEP, which supports 48-, 64-, and 128-bit encryption, is secure enough for most homes and businesses when properly configured.

Where It Should Be Used
- Existing 802.11b networks: In locations where network density is not expected to change, and there is adequate throughput, 802.11b devices provide a reliable solution.
- Where range is a priority: 802.11b networks typically operate at longer range, in both open space and through walls, than 802.11a networks.
- Moderate performance: 802.11b is ideal when used in standard office environments, such as file and print sharing, database queries, or other low-bandwidth applications such as e-mail.

Examples include small businesses, warehouses, and large retail outlets.

Notes
- Cost in high-density deployments: Fewer non-overlapping channels may be an issue in high-density situations. 802.11b can be more costly in high-density or high-usage situations, so multiple access points may have to be deployed.
- Interference: Many common items use the 2.4 GHz band, including portable phones, microwave ovens and baby monitors. This can adversely impact performance.
- Security: 128-bit WEP is not considered a strong security solution. 802.11b networks should not be used in those situations where privacy is a significant factor, unless the products support 802.1x authentication and/or VPN over the WLAN feature. These products are typically more expensive.
Quick Spec: 54 Mbps, 8 non-overlapping channels, 64 users per AP, 5 GHz

Featuring faster speeds and aggressive pricing, 802.11a products are quickly moving into the market. 802.11a delivers up to 54 Mbps, although realistic throughput is approximately 27 Mbps. Some products feature a turbo mode that can produce even higher data rates. Due to higher operating frequency, however, range can be somewhat less than 802.11b systems, which operate at a lower frequency (2.4 GHz). In some scenarios, this can increase the cost of the overall system, because a greater number of access points may be needed.

Note that in addition to using a different frequency than 802.11b, 802.11a also uses a different modulation technique, orthogonal frequency division multiplexing (OFDM).

Benefits
802.11a offers certain advantages over 802.11b products:

- Highest speeds: Up to 54 Mbps, with turbo mode extensions for even faster connections (108 Mbps – not available in Europe).
- Higher density: More access points can be co-located, and each access point supports more users.
- Interference Free: Operates in the unregulated 5 GHz frequency range (for Europe please visit our local country web sites for detailed country by country regulatory information), with less possibility of interference from other devices.

Security
The WEP algorithms are used to protect 802.11a networks, but with stronger 152-bit encryption keys. When properly configured, this provides more protection than 802.11b networks.

Where It Should Be Used
- Bandwidth-intensive applications: 802.11a can provide up to 108 Mbps in turbo mode to each user (turbo mode not available in Europe).
- High-density networks: More channels and more users per AP can mean a more cost-effective deployment.
- Stronger security requirements: Stronger encryption keys offer more protection
- Interference exists: There is less possibility of interference from consumer appliances at the 5 GHz band, and there are more channels to choose from.

Examples include dormitories, convention halls, office bullpens, computer labs, and large conference rooms. Also, locations that use large files, such as graphic and video houses. Voice and video over IP (VoIP) is also an emerging application.
Notes
• Compatibility: Not directly compatible with 802.11b or 802.11g networks; however, can co-exist and access each other through a router.
• Shorter Range: Due to higher operating frequency, typically offers less range and is less capable of working through walls and floors. With this said, for any given range up to 200 feet from an 802.11a AP, a user will achieve at least twice the throughput when compared to an 802.11b connection.
• Power: 802.11a adapters generally consume more power, which results in shorter battery life in portable devices.

802.11g

Quick Spec: 54 Mbps, 3 non-overlapping channels, 2.4 GHz

802.11g is an extension to 802.11b, which is the technology used in the majority of wireless LANs installed today. 802.11g features data rates up to 54 Mbps, with realistic throughput of 7-16 Mbps. 802.11g operates within the 2.4 GHz band, and uses OFDM technology. Because of backward compatibility, an 802.11b device will connect directly with another 802.11g device at speeds of up to 11 Mbps. Note that the 802.11g specification is not expected to be ratified until approximately May 2003, although products based on the draft specification will be available in early 2003.

Benefits
• Higher speeds: Up to 54 Mbps peak throughput.
• Backward compatibility: 802.11b compatibility is written into the IEEE specification.
• Lower power consumption: Portable devices will operate over longer periods.
• Longer range: 2.4 GHz signals travel farther, and can work through walls and floors more effectively than 5 GHz signals.
Security

802.11g products will have the same security capabilities as 802.11b: 40-, 64-, and 128-bit WEP.

Where It Should Be Used

- Existing 802.11b networks: 802.11g works with existing 802.11b devices, and provides a smooth path for higher performance as needed while continuing to support the 802.11b investment.
- Range and connection speeds: When speed and distance are important, 2.4 GHz devices generally go farther, and the higher speed of 802.11g is three to five times faster than 802.11b.
- Lower cost: Although 802.11g is expected to be priced slightly higher than 802.11b, it will be less costly than 802.11a or dual band solutions.
- Examples include many of the same places 802.11 would be used, such as small businesses. The higher bandwidth may open up new applications scenarios, such as video product demonstrations delivered to palmtop devices in retail outlets. Also, in locations that use large files, such as graphics and video operations.

Notes

- Specification not ratified: While some manufacturers are releasing products in advance of the finalized specification, this may present interoperability, performance, and usability problems downstream. Some manufacturers are holding back product until the specification is ratified, currently expected in May 2003.
- Interoperability: Not interoperable with 802.11a devices; however, 802.11g and 802.11a can co-exist and access each other via a router.
- Peak performance: 802.11g can be slowed down when 802.11b clients are on the network.
- Fewer channels: 802.11g has fewer non-overlapping channels (3) than 802.11a (8).
**Dual-Band**

**Quick Spec:** 54 Mbps and 11 Mbps, 8+3 non-overlapping channels, 64 users per access point, 2.4 GHz and 5 GHz

Dual-band products are a good choice in environments that are just getting started with 802.11b networks but expect that faster speeds will soon be needed. Dual-band products offer both 802.11b and 802.11a functionality, in both PC Cards and AP products, enabling WLANs that can accept both types of clients. Dual-band clients automatically search for the “best” connection as users roam throughout the office or campus environment. Dual-band offers the best of both worlds.

**Benefits**
- Simultaneous operation: Both 802.11a and 802.11b technologies operate side-by-side, without interference. Users can select either band, or both.
- Enhanced roaming: The same WLAN adapter can be used in more places, such as home, work, and public hot spots, without configuration changes.
- Highest density: Up to 11 channels from both protocols are available, supporting more users.
- Protects WLAN investment: Supports both high- and low-speed network devices.
- Easier administration: Dual-band units combine two technologies into one, easing administration and support costs in environments where both types of devices are needed.
- Less interference: Devices have more channel options available.
- Many dual-band products feature improved security capabilities, enhancing the WEP standard and offering additional functions such as MAC address filtering.

**Where It Should Be Used**
Dual-band products offer the best of both worlds:

- Existing WLANs: Anywhere there is an existing WLAN infrastructure that may need to accommodate both 802.11a and 802.11b devices. Will also support 802.11g devices.
- Density: Wherever maximum density is needed, dual-band is the right solution. Dual-band products have more channels (11), so they can support more users. This can result in a lower deployment costs.
- Flexibility: Dual-band offers maximum speed and maximum range. A single configuration can support both network protocols, reducing the need to support multiple environments or reconfigure client devices as users move between them. This results in lower support costs.

Examples include businesses where offices are co-located with warehouses, large campus environments, people traveling between multiple WLAN network types, or any organization that wants to extend existing WLAN to support the other protocol.
Notes

- 802.11g speed: Existing dual-band products will work only with 802.11g products at speeds up to 11 Mbps (802.11b).
- Power: Unlike dedicated 802.11a, b or g devices, dual-band adapters will use more power, increasing battery consumption.
- Cost: Dual-band products typically cost more than single-band devices.

Proprietary Protocols—22 or 44 Mbps in the 2.4GHz Band

Quick Spec: 22 or 44 Mbps, 3 non-overlapping channels, 32 users per access point, 2.4 GHz, also referred to as enhanced 802.11b or, b+

Some WLAN vendors offer proprietary products that can improve the speed of 802.11b devices. These devices are not as fast as 802.11a or 802.11g. The additional speed is enabled by another (PBCC) encoding scheme. Not approved by any standards body, or certified for interoperability, they offer a marginal speed increase for little or no additional cost and many customers may benefit from these speed improvements.

Products characteristics

- Improved performance: Any performance increase in available only when connecting to devices made by the same manufacturer, and that have this proprietary mode pre-configured.
- Invisible: Cannot be assured of interoperating with other devices at higher speeds. There never will be an industry certification for these devices.
- Increased latency: Compatibility mode enables them to connect with other Wi-Fi components. However, there is often increased latency when switching between encoding schemes.
# Comparison of Wireless Standards

## WIRELESS IEEE STANDARDS COMPATABILITY CHART

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<th>802.11g Est. May '03</th>
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## WIRELESS IEEE STANDARDS COMPARISON

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<td>Standard Ratified</td>
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<td>Sept 99</td>
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<td>Raw Data Rates</td>
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<td>54 Mbps</td>
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<td>27 Mbps</td>
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<td>Modulation Encoding</td>
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<td># Channels/non-overlapping</td>
<td>11/3</td>
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<td>11/3 + 12/8</td>
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</table>

* Up to 72 Mbps in Turbo mode
** Up to 108 Mbps in Turbo mode
Frequently Asked Questions

What is an access point (AP)?
Access points are to wireless LANs what base stations are to mobile cellular networks. The base station in a mobile cellular network aggregates and manages all the mobile clients and interfaces with the public switched landline network. Similarly, access points (APs) connect the wireless LAN to the wired network. An AP is a device that both transmits and receives network data. It is typically connected to the wired backbone through the use of a standard Ethernet cable. Essentially, the wireless equivalent to a LAN hub, the AP receives, buffers and transmits data between the WLAN and the wired infrastructure. The number of users an AP supports is determined by the technology utilized. The AP, or the antenna connected to it, is generally mounted high on a wall or ceiling to enable line-of-sight transmission to the adapters. APs have ranges from less than 100 feet to 1,000 feet, depending on technology and configuration. Some routers also have APs built-in.

Do I need a wireless access point?
Typically, networks are set up with a wireless AP. This is called infrastructure mode. However, WLAN cards can be configured to ad-hoc mode, where computers talk directly to each other and do not need an AP. However, without an AP, the two computers will talk only to each other, not to the LAN or Internet.

What is a wireless network interface cards (NICs)?
LAN adapters take the form of PC NIC (network interface cards), PC cards (both 16-bit and 32-bit versions, such as PCMCIA and CardBus) for notebooks, USB for both notebooks and desktops, and PCI for desktops. NIC adapters provide the interface between the network operating system and the antenna, creating a transparent connection to the network.

What hardware components make up a WLAN network?
WLAN networks need, at a minimum, two 802.11 adapters in client devices such as laptops. Most WLANs have an access point, which connects wireless users to the wired LAN. Routers, hubs, and switches are also used to connect access points to the wired LAN—some manufacturers build these capabilities into the same package.
What is peer-to-peer network and how is it set up?
Also known as ad-hoc mode. A peer-to-peer network is a WLAN in its most basic form. Two PCs equipped with wireless adapter cards form a simple peer-to-peer network, enabling the PCs to share resources. An access point is not present in a peer-to-peer network. This type of network requires no administration or pre-configuration, but also bypasses the central server, inhibiting client/server sharing. Typical peer-to-peer applications include ad-hoc collaborative workgroups, sharing resources in small/branch offices, games, demos, or remote control of another PC.

What is infrastructure mode and how is it set up?
This WLAN setup requires a client adapter and access point. The access point is connected via Ethernet to the wired backbone (a cable/DSL router in the home, for example). The wireless clients access the network via the AP.
Can a product be upgraded from 802.11b to 802.11a or 802.11g?
In general, products cannot be upgraded from one protocol to another. Each protocol uses very different technology, chipset and adheres to unique specifications.

Will 802.11a replace 802.11b?
No. Each of these protocols has its own strengths and weaknesses. As well, there are tens of millions of 802.11b products already in use. This installed base will be around for a long time.

Can 802.11a and 802.11b be used on the same network?
Yes, in two ways. First, by using a dual-band AP. Second, by using two different access points these protocols can co-exist on the same network and access each other via a router.
Are 802.11b and 802.11g upward compatible with 802.11a?
No. 802.11b and 802.11g devices cannot communicate directly to an 802.11a network. A dual-band access point can be used, but technically, these are two different networks in the same airspace, each able to access the network resources.

Can I use an 802.11a card in an 802.11g network?
The two types of networks are not compatible. While both have connection speeds of 54 Mbps, they operate on different frequencies.

Is 802.11g backward compatible with 802.11b?
Yes. 802.11b devices are specified by the IEEE to work in 802.11g networks. However, 802.11g devices will have speeds of up to 11 Mbps, unable to operate at 54 Mbps.

Can I use 802.11g in an 802.11b network? Will there be a speed increase?
802.11g devices are specified by the IEEE to work in 802.11b networks. However, 802.11g devices will continue to operate at 11 Mbps, with no speed increase.

What is the impact of having both 802.11b and 802.11g clients on the same network?
As part of the IEEE specification, when 802.11g devices detect the slower 11b devices, 11g devices will start doing an RTS/CTS handshake (request-to-send/clear-to-send) for every packet prior to sending the actual packet. This can slow down network performance. It is optimal to have fewer 802.11b clients on the network or upgrade them to 802.11g.

When there is a combination of several 802.11b and 802.11g clients on an 802.11g-based network (802.11g access point and routers), the actual throughput for 802.11g (when connecting from 11g to 11g) is reduced from 22 Mbps down to approximately 10 Mbps, while 802.11b clients maintain throughput between 4-4.5 Mbps.

Why is the actual throughput of 802.11a slightly higher than 802.11g?
The IEEE specification/protocol as well as the timing are different with 11a at 5 GHz and 11g at 2.4 GHz, so there will always be a throughput difference. Timing refers to the precise thousandths and millionths of seconds that the product listen or wait before they transmit packets over the air.

Will 802.11g replace 802.11b?
At this time, we expect that both lines of products will be available through the end of 2003. 802.11b products are expected to be more affordable through 2003.

Will 802.11g replace 802.11a?
No. Each of these protocols has its own strengths and weaknesses. We expect that 802.11b-only, 802.11g-only & dual band 802.11a/g products will be available in the market throughout 2003. After that, we expect that 802.11g and dual band 802.11a/g products will represent the majority of demand from our customers.
Which will have the best range? 802.11a, 802.11b, 802.11g?
The range of a wireless system is based more on the frequency band that it operates in vs. the standard that it uses. Although makers of 802.11a equipment might disagree, the 5GHz frequency that 802.11a wireless equipment operates in results in a shorter range than 802.11b or g products when used in the typical residential environment.

802.11b and g-based equipment operates in the lower-frequency 2.4GHz frequency band, which suffers from less signal reduction when passing through the walls and ceilings of your home.

Note that 802.11b and 802.11g's range advantages will tend to be neutralized if your wireless LAN is set up in an "open field" environment that has no obstructions between the Access Point(s) and client(s).

Will WEP slow down my wireless performance?
Although the calculations required to encrypt data with WEP can impact the performance of your wireless network, it's generally seen only when running benchmarks, and not large enough to be noticeable in the course of normal network usage. The performance penalty on enabling WEP will generally be a little higher when using a router that incorporates a built-in WLAN access point, because of the added load of WEP encryption on a CPU that is already handing routing and switching functions for Internet sharing. When using a stand-alone access point, the performance penalty is usually imperceptible.

Can cordless phones interfere with my wireless network?
Depending on the protocol you are using, yes. 2.4 GHz phones, baby monitors, and microwave ovens can interfere with an 802.11b network. 802.11a networks operate in a different frequency range, where there is less interference.

When using WEP, does encryption need to be at the same level?
Yes. Encryption settings must be identical between all points on the wireless network.

What about Bluetooth?
Bluetooth is a technology specification for small form factor, low-cost, short-range wireless links between mobile PCs, mobile phones, and other portable handheld devices, and connectivity to the Internet. Bluetooth covers a range of up to 10 meters in the 2.4GHz spectrum. Because 802.11b and 802.11g WLANs also operate in the same band, there may be interference issues.

What is WPA?
Wireless Protected Access is a new security guideline issued by the Wi-Fi Alliance certification body. The goal is to strengthen security over the current WEP standards by including mechanisms from the emerging 802.11i standard for both data encryption and network access control. For encryption, WPA has Temporal Key Integrity Protocol (TKIP), which uses the same algorithm as WEP, but constructs keys in a different way. For access control, WPA will use the IEEE 802.1x protocol. The Wi-Fi Alliance plans to implement these new security mechanisms as optional features beginning in early 2003, and require them for Wi-Fi compliance later in the year.
**What is 802.11?**
802.11 can mean 2 things:
1) The umbrella term for the IEEE 802.11 family of physical and software layer protocols OR
2) The first version of WLAN, ratified in 1997. This protocol offers 2Mbps in the 2.4GHz frequency. Although a few early adopters checked it out, 802.11 products were not widely supported by manufacturers and they quickly lost traction to the much faster 802.11b solutions.

**What is a wireless LAN bridge?**
Also called extension points, wireless LAN bridges are used to connect LANs in different buildings. A wireless LAN bridge connected to the network in one building can transmit and receive data from another bridge in an adjacent building, much like a point-to-point radio. Wireless LAN bridge products support fairly high data rates and ranges of several miles with the use of line-of-sight directional antennas. Wireless LAN bridges provide an alternative to more expensive leased lines and underground cabling projects.