White paper

Multiple Choice: Is 802.11 a, b or g best for your industrial wireless LAN? (Or is it n, for none of the above?)

Intermec

Wireless LAN technology has been standardized, but user needs and working conditions are not. There are multiple wireless LAN standards – notably 802.11 a, b, g and n – because a materials handler in a distribution center has different needs than a Web surfer in a coffee shop. Baud rates, frequencies and communication channels separate the standards, but don't tell you which is best suited to your needs and operating environment.

Selecting the most appropriate wireless LAN protocol requires an understanding of their basic characteristics and limitations, and how various performance attributes relate to your current and future needs. This white paper profiles enterprise wireless LAN standards and explains how their individual performance characteristics relate to reliability and performance in common industrial use cases.

Use Case Considerations

Network reliability is the most important attribute for industrial applications. Warehouse operations slow to a crawl if the WMS can't wirelessly direct picking and putaway operation. Production lines can stop if businesses lose the ability to track their work in process or manage materials. Reliability involves more than the network simply being up or down. It means ensuring coverage to every corner of the facility where transactions take place and that connectivity will be maintained when other wireless devices and production machines are in operation. Coverage and resistance to interference are very important considerations when planning industrial wireless LANs.

Industrial users need more network reliability than office users, but they have lower speed requirements. Typical industrial applications involve using a mobile computer with an integrated bar code scanner for entering stock numbers, location codes and shipping label information into a database. Data collection applications are characterized by short bursts of wireless traffic that transmit a short string of characters. For example, the commonly used Serialized Shipping Container Code (SSCC) found on shipping labels only encodes 18 characters. High-speed networks aren't needed for typical bar code applications. Commonly used networks, which accommodate file transfers and Web browsing for office applications, can easily accommodate most data collection applications, even when supporting hundreds of concurrent users.

Data collection systems can coexist with other applications on 802.11b networks, but network capacity can become a concern when new bandwidth-hungry applications or new security protocols are layered onto legacy systems. Organizations that may add converged voice/data, streaming video, imaging, real-time locating systems (RTLS) or high-volume RFID applications to their data collection systems should use a wireless LAN technology that provides a clear migration path to support higher bandwidth needs. The 802.11g standard is an excellent option for these applications, and can be implemented in a way that complements and leverages legacy 802.11b systems. 802.11g provides about five times more throughput that 802.11b, but is backward compatible with 802.11b and can be used concurrently.

Devices and access points are available with dual radios to support 802.11b and g. Integrated 802.11b/g systems offer full compatibility with the dominant wireless LAN protocol used in industrial, office, mobile and consumer environments (802.11b), and provide a seamless migration path to higher-bandwidth, next-generation networks. Combining 802.11 b and g in industrial environments has proven to be a very practical and popular approach. Market share data reflects this: In 2007, 802.11b/g technology accounted for 79.5 percent of all shop floor wireless LAN implementations, according to market research firm Venture Development Corp. (VDC).

Understanding the Specs

The main differences among 802.11 a, b, g and n technologies are their frequencies and transmission speeds. Regardless of radio technology, range decreases as speed increases. As noted, network speed often is not a critical differentiator for selecting an industrial wireless LAN protocol. Frequency has more impact on industrial network performance and cost. Frequency relates to performance because sources of RF interference impact each frequency differently, which is an important consideration since industrial networks are often subject to a variety of environmental interference. Frequency also relates to cost, because frequency is a major variable on system range. The shorter the range, the more access points required, and the higher the system purchase, installation and maintenance costs. Awareness of potential interference, as well as balancing coverage and throughput needs, are essential to implementing a reliable wireless network.

802.11b is by far the most widely deployed wireless LAN protocol. It meets most needs for industrial, office and home users alike, whether for reporting inventory and production transactions to an enterprise system or for going online to surf the Web and check e-mail. Interest is growing in higher-bandwidth networks as enterprises consider new applications, add users to their networks, and seek to strengthen security. For example, the emergence of voice-over-IP (VoIP) wireless LAN telephone capabilities, imaging applications, RFID data collection and stronger security protocols like WPA2 all add to bandwidth demands. 802.11b can still satisfy many of these needs today, but the emergence of new technologies and business processes creates a more compelling case for next-generation networks in industrial environments.

The table below provides a convenient comparison that highlights the differences among 802.11 a, b, g and n technologies. The sections that follow explain some of the differentiating performance characteristics of these protocols and their implications for industrial applications.

Frequency
802.11a systems operate in a different frequency band (5 GHz) than 802.11b/g (2.4 GHz) which prevents interoperability between 802.11a and 802.11b/g systems. The 802.11n standard establishes separate 2.4 GHz and 5 GHz versions of the technology.

Bluetooth technology also operates at 2.4 GHz frequency, but because of its relatively low power and different transmission protocols, Bluetooth does not cause interference for 802.11b/g systems and can be used concurrently. Many 802.11b/g wireless computers also include Bluetooth radios to interface with peripheral devices.

Data Rate
Data rate is the amount of information that can move through the network, usually expressed in megabits per second (Mbps). Wireless LANs rarely, if ever, attain their top theoretical transmission speed or the data rates listed on product spec sheets. The presence of other wireless devices, the amount of metal, liquids, thick walls and other RF-unfriendly materials in the usage environment, security protocols, and network architecture all impact and limit actual throughput. Most industrial applications don't require high data rates, so robustness and reliability are often more important considerations.

Bandwidth
Bandwidth is the measurement of both the quantity of data and the number of users that the network can support at any point in time. Bandwidth declines as the distance from the signal source increases. Data rate alone does not determine bandwidth, because the number of available channels and access points are important variables. While 802.11a and g technologies have comparable practical data rates, 802.11a is considered a higher-bandwidth technology because it has more channels and thus can support more dense access point populations (however 802.11a's limited range makes more APs necessary for large-area deployments). 802.11n, which can operate at the same frequencies supported in the 802.11a and 802.11b/g standards, has the most available channels, which is one reason it is the highest-speed option.

Since the data rate is similar between 802.11a and 802.11g, the difference in their respective bandwidth is determined by the number of channels and the number of access points deployed. 802.11a has more channels than 802.11b/g (11 vs. 3) and can more easily support multiple channels and dense AP populations. However, 802.11b/g has been able to provide better signal strength coverage and provide a complete network infrastructure with only three channels, even though there is benefit to the number of channels offered by 802.11a. The robustness of 802.11b/g is a major reason it is the technology of choice for industrial environments, where there is often significant RF noise and potential interference from other electromechanical devices, metal racks and equipment, and stored materials.

Range
Wireless coverage is measured by the range in which a mobile device can maintain a useable wireless LAN connection. Range is impacted by the available signal-to-noise ratio available at different carrier frequencies and data rates. Different frequencies also have different range characteristics. The RF propagation characteristics at 5 GHz operation exhibits a higher loss than that of 2.4 GHz. Thus a 802.11a wireless LAN infrastructure requires more access points than a 802.11b/g network to cover the same area. The 802.11n standard specifies the use of multiple-input multiple-output (MIMO) technology that is not included in 802.11a/b/g standards. MIMO technology is a major reason 802.11n is expected to have more range and throughput than 802.11a/b/g systems.

Characteristic	802.11a	802.11b	802.11g	802.11n*
Operating frequency	5 GHz	2.4 GHz	2.4 GHz	2.4 or 5 GHz
Channels**	11+	3	3	14
Maximum data rate	54 Mbps	11 Mbps	54 Mbps	600 Mbps
Operating range	30 m	100 m	100 m	70 m
Interoperable with:	802.11n	802.11g, n	802.11b, n	802.11a, b, g***

* The IEEE 802.11n standard has not been ratified, so specifications are subject to change. Pre-standard products are available on the market (primarily for home computer users).
** The 802.11 standards are international, but channel availability is subject to national regulation. All channels may not be available in all countries.
*** If the same frequency is used.

Interoperability
The 2.4 GHz version of 802.11n is backward-compatible with 802.11b/g systems, which means 802.11b/g devices can communicate with 802.11n access points, and 802.11n devices can communicate with 802.11b/g APs. In these mixed-use environments, the data rate is limited by the slower protocol (e.g. 802.11b/g devices don't communicate at 802.11n speeds when used with 802.11n access points). 5 GHz 802.11n systems are also backward-compatible with 802.11a technology.

Outlining the Options
Each 802.11 wireless networking standard is well suited for different specific environments and applications. 802.11b has the clearest and most use cases, and is the most widely deployed wireless networking protocol by far. The 802.11a standard was ratified about the same time as 802.11b but had a much different adoption curve. 802.11g is emerging as the next-generation standard for many current 802.11 a and b users, though industrial and data collection applications may not currently need the additional bandwidth afforded by 802.11a. 802.11n is on the horizon, but is not considered enterprise ready. The standard is not expected to be ratified until 2009, and early products built to draft specifications have been targeted to the home computing and entertainment markets. The following sections provide overviews of each of the 802.11 wireless networking standards, explain how their specifications impact performance in industrial environments, and provide guidance to the use cases where each technology is advantageous.

802.11a
The 802.11a standard was ratified around the same time as 802.11b, but 802.11a has remained a niche technology while 802.11b became the most widely adopted wireless networking standard in history. 802.11a is clearly faster than 802.11b, but the speed advantage is offset by other performance characteristics that pose problems in industrial and other environments. Most notable is range. The limited range that 802.11a provides relative to alternative 802.11-standard technologies means more access points are needed to provide coverage. For enterprises who need reliable communication throughout factories, warehouses and distribution yards covering tens or hundreds of thousands of square feet, the cost for additional access points is significant. With more hardware, there is also more that can go wrong, and more time required for system administration.

For these and other reasons, 802.11a is best suited for environments where high throughput is needed for a relatively small coverage area. Usage patterns reflect this, as 802.11a systems have been adopted by some retailers, who can use a few access points to cover a store to support applications that may stream video promotions to in-store video screens, and support VoIP for store associates. Industrial environments have two needs that are well served by 802.11a. First, when there are significant distances between the access points and the network connection can't be easily bridged with wiring, 802.11a can be used as a backhaul wireless network to bridge the gap without interfering with the 802.11b/g wireless network. The linked 802.11a access points can utilize high-gain directional antennas to partially offset the range limitation of 5 GHz technology. The second need arises when attempting to abate interference in the 2.4 GHz frequency band used by 802.11b/g networks and other wireless devices. Fewer devices use 5 GHz, resulting in a less crowded frequency band with fewer potential sources of interference.

802.11b
The 802.11b standard hits the sweet spot for range, speed and reliability for many industrial, office and personal computing needs. 802.11b is the dominant protocol used in factories and distribution centers and is fully capable of handling applications other than data collection, including voice communication by VoIP. 802.11b is also fully compatible with 802.1x, FIPS and other strong security protocols that enterprises are increasingly upgrading to for wireless network protection, including the WPA2 standard that satisfies the retail industry's PCI compliance requirements.

802.11b has dominant market share for industrial wireless LAN installations, where robustness and reliability are the most important performance characteristics. The throughput provides excellent responsiveness for bar code, RFID and speech data collection applications, even if it appears relatively slow on paper when compared to alternative protocols. The speed and reliability have proven ideal for picking and putaway confirmation, receiving, work-in-process tracking and inventory control applications. 802.11b networks also provide the backbone for many VoIP telephony systems. 802.11b also supports unified communications, where phone calls, pages, text and e-mail messages are delivered to mobile computers, PDAs and smart phones used in industrial and office environments.

802.11b is very well suited to meeting most industrial wireless LAN user needs, which is reflected in its market share and high user satisfaction ratings. But 802.11b is not ideal for all use cases. As noted, there are advantages to using 802.11a equipment to provide backhaul networking over large areas. 802.11a and 802.11g are proven technologies that provide higher throughput, which is useful for high-bandwidth application and multiple-application networks, with 802.11g providing the additional advantage of backward-compatibility with 802.11b systems.

802.11g

802.11g delivers the bandwidth advantages of 802.11a without the range and reliability limitations of 5 GHz technology. As a 2.4 GHz technology, 802.11g provides a migration path for 802.11b users and a bridge to 802.11n systems. This is not to suggest 802.11g is an interim technology. Most industrial users will never need the bandwidth of 802.11n (which is being positioned as a potential Ethernet replacement for offices) and will not want to pay the higher costs associated with purchasing and supporting the emerging technology. 802.11g is more mature than 802.11n, more proven in industrial environments, and is chosen much more often by 802.11b users as their next-generation wireless LAN backbone. Dual 802.11b/g access points are available to support evolving systems.

As a 2.4 GHz technology, 802.11g has the same resistance to interference and robustness as 802.11b. It is an excellent alternative for legacy 802.11b users with growing bandwidth needs (recall that 802.11b/g accounted for 79.5 percent of shop floor wireless LAN implementations in 2007). 802.11g access points and devices can be implemented for the areas or applications where higher throughput is needed, while simultaneously supporting legacy 802.11b devices. In contrast, for legacy 802.11b facilities a complete rip-and-replace upgrade would be required to install 802.11a technology, which is incompatible with 802.11b/g.

802.11n

802.11n is on the horizon but hasn't been proven as a viable technology for industrial enterprise applications. To date only pre-standard products have been released, and no ruggedized industrial models have been developed. 802.11n can be implemented as either 2.4 GHz or 5 GHz technology, and will provide backwards compatibility with 802.11b/g and 802.11a systems, respectively. The signature characteristic of 802.11n technology is its data transmission speed of up to 600 mbps, which is more than 10 times faster than 802.11a or g and about 55 times faster than 802.11b. The speed may enable 802.11n to replace physical Ethernet cable in some office and home settings, but offers few if any practical advantages for manufacturing, distribution and other industrial applications. 802.11n access points are expected to have less range than 802.11b and g models, so organizations must assess whether the extra speed is worth the expense of the additional APs needed to provide coverage.

Conclusion

The business market has room for 802.11a, b, g and n networks, and each is advantageous for specific use cases. Because 802.11b has been the best and most widely used protocol for industrial and data collection applications doesn't mean it will always be the most appropriate. Conversely, the availability of faster or newer technologies does not by itself provide a compelling business case to implement them. White collar and consumer markets drive most wireless LAN technology development, so industrial users must carefully consider whether new features and capabilities are truly advantageous for enterprise operations. When considering new wireless technology, consider the specific characteristics of industrial environments and evaluate the products and vendors to determine if there is a roadmap or a history of adding new radio features when it makes sense for the customers they serve.

It is important to work with partners who understand the differences between wireless LAN technologies and can provide a range of solutions. Intermec has helped companies integrate wireless networking and data collection systems into thousands of factories, warehouses, distribution yards and other industrial environments. In 1985 Intermec introduced the first data collection terminal with integrated wireless LAN connectivity and since then has pioneered many development in industrial wireless networking, including the introduction of the first switched RF backbone to interface with enterprise wireless LANs, the first access point to support dual radio frequencies, the first 802.11-standard wireless LAN, the first 802.11a access point, and the first 802.11b/g dual access point.

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611885-01A 05/08

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