IT@Intel White Paper

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Wireless LAN Design
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Accelerating the Enterprise Network Using 802.11n Wireless

The 802.11n wireless protocol will allow Intel to eventually use WLAN as the default network for most users—decreasing costs, reducing energy consumption, and increasing user productivity.

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Executive Overview

To design and deploy a wireless network that will be used by the majority of Intel employees and that operates as effectively as a wired LAN at a reasonable cost, Intel IT investigated moving to the 802.11n wireless protocol. We launched a six-month investigation that included laboratory testing, a small proof of concept covering several stories of a building, and, finally, a large-scale pilot certification that involved 1,000 employees in a five-story building. Based on the success of our investigation, we have decided to deploy 802.11n-based wireless LANs (WLANs) across Intel.

With multiple-input and multiple-output (MIMO) technology, higher data speeds, and increased range, 802.11n promised to deliver more reliability, stability, and coverage than the 802.11abg WLAN already in place, and higher data rates than the current wired LAN.

As expected, our investigation results showed that 802.11n met our requirements for the next-generation WLAN. Benefits included:

- Increased data throughput, with a maximum speed of up to 144 megabits per second (Mb/s), and increased speeds of up to 300 Mb/s in the future using the same WLAN infrastructure.
- Less signal interference and improved aggregation of frames.
- Lower costs than its predecessor due to fewer access points and switches.
- Improved employee satisfaction due to the higher speed and greater reliability.
- Backward compatibility with machines that are not 802.11n-enabled and with multiple OSs.

We have begun deploying 802.11n, with plans for completion by the end of 2010. This will coincide with our PC refresh program, which is currently replacing all of our 802.11abg laptops with 802.11n-enabled machines.

For Intel, the move to this new wireless standard has been a huge success. The 802.11n wireless protocol will allow Intel to eventually use WLAN as the default network for most users—decreasing costs, reducing energy consumption, and increasing user productivity.

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BUSINESS CHALLENGE

More than 95 percent of Intel's 80,000 employees use company-issued laptop computers, and they expect fast and uninterrupted wireless access to the Intel network to do their work. They carry their laptops as they move from cubicles to conference rooms to cafeterias, and they frequently travel to other buildings on their campuses or to other Intel sites worldwide.

Our third-generation IEEE 802.11abg wireless LAN (WLAN), diagramed in Figure 1, no longer met user expectations. It offered good coverage but limited speeds compared to the wired LAN, and it was expensive to deploy. As employees became increasingly dependent on wireless connectivity—and had higher user expectations of coverage and speed due to the proliferation of Wi-Fi* hotspots in recent years—we knew we needed to replace the current WLAN with a solution that operates as effectively as our wired network. Our goal was to meet users' needs while shifting default network access from wired to wireless across Intel and providing a high return on investment. The new WLAN needed to:

- Improve coverage, speed, and reliability. We needed a WLAN that was as fast or faster than 10 to 100 megabit Ethernet, and provided the same always-on reliability. We also required a much larger footprint from the new WLAN so that employees could find a signal anywhere they might choose to work at Intel sites.
- Reduce costs for equipment, support, and energy consumption. If we were able to use fewer access points (APs), costs for buying and maintaining hardware as well as energy would decrease.
- Increase user productivity. Faster speeds, greater coverage, and increased stability would enable employees to use their laptops without interruption across the enterprise.

Wireless Protocols

Wireless protocols have evolved over time, from the unstable, unsecured 802.11b in early 2000 to 802.11a, which brought more reliability on its 5.2-GHz band. The 802.11g protocol delivered the speed of 802.11a with greater range, but, as with 802.11b, used the 2.4-GHz band that is more susceptible to interference from microwave ovens, cordless telephones, Bluetooth* devices, and even baby monitors at home. 802.11g also has fewer free channels for use: three in contrast with 8 to 16 for 802.11a channels, depending on the country regulating the domain.

The introduction of 802.11n brought multiple-input and multiple-output (MIMO) technology, providing higher speeds and greater ranges to satisfy an ever-increasing base of mobile users. By taking advantage of the radio signal reflections that are inherent in office buildings, MIMO enhances transmission performance. After splitting the data stream into many individual streams, MIMO systems use different antennas transmitting on the same frequency channel at the same time to help ensure an amplified signal with higher stability.

Table 1 compares these wireless protocols.

Advantages of 802.11n

802.11n was ratified in September 2009, although pre-certification products had been available for some time from ISVs and OEMs. The 802.11n protocol provides significant improvements over its predecessors:

- Offers significantly higher data rate speeds, up to 600 Mb/s as compared to 54 Mb/s. Current commercially available APs can offer up to 300 Mb/s with a throughput that is three times or better than that of the previous WLAN standards.
- Uses multipath technology such as MIMO, which amplifies the signal and minimizes the interference caused by internal walls and metal.
- Brings improved aggregation of frames and efficiency in accessing the medium at the Media Access Control (MAC) layer, allowing multiple packets instead of just one, with shorter delays between transmissions.

Table 1. Comparison of IEEE 802.11 Protocols

Protocol	Data Rate	Maximum Indoor Range	Frequency	Issues
802.11a *Released October 1999*	54 megabits per second (Mb/s)	50 feet	5.2 GHz	• Requires more access points (APs) since range is shorter • Higher signal absorption by walls and other objects
802.11b *Released October 1999*	11 Mb/s	150 feet	2.4 GHz	• Interference from other devices operating in the 2.4-GHz band • Delivers the lowest throughput rate
802.11g *Released June 2003*	54 Mb/s	150 feet	2.4 GHz	• Interference from other devices operating in the 2.4 GHz band • Based on 802.11b, and subject to the same low throughput issues
802.11n *Released September 2009*	144 to 600 Mb/s	300 feet	5.2 GHz and/or 2.4 GHz	• Though some hardware suppliers have products that support this protocol on the market already, most are still working to catch up and cannot operate at full speeds until the release of new hardware and software

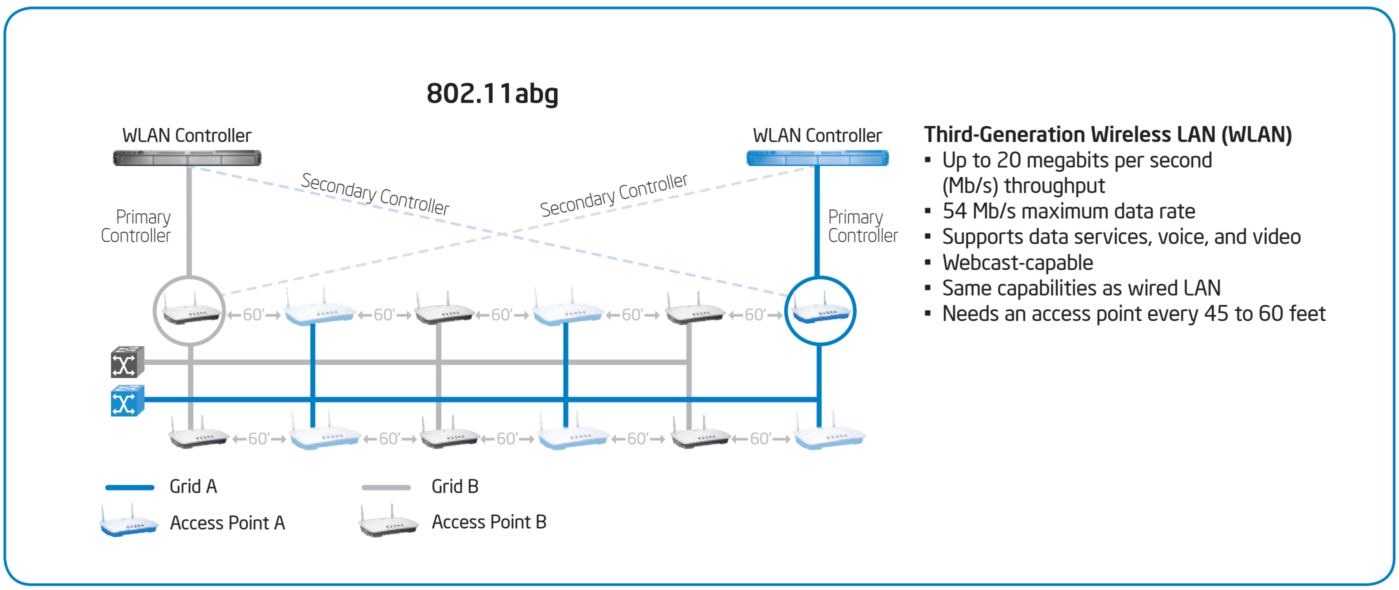


Figure 1. Our third-generation 802.11abg wireless LAN design uses access points every 60 feet and two separate grids for redundancy.

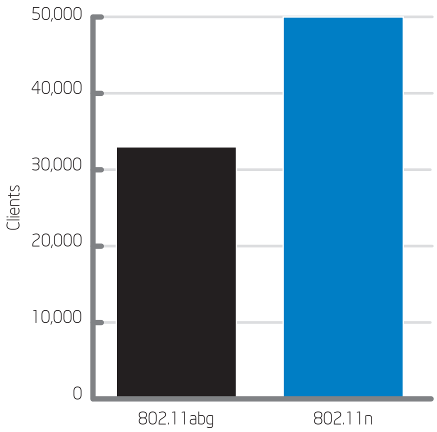


Figure 2. About 50,000 laptop PCs in the Intel environment—60 percent—are 802.11n-enabled as of December 2009.

Research led us to determine that 802.11n met the criteria we had defined, and we chose to test it as our wireless standard. There are about 83,000 laptop PCs in Intel's environment, and a key factor in our decision was the fact that 50,000 of these—60 percent—are 802.11n-enabled, as shown in Figure 2. By the end of 2010, this number will have reached close to 100 percent.

SOLUTION

We spent six months investigating the 802.11n protocol. First, we tested basic performance in a laboratory to make sure it worked as it should. We then conducted a proof of concept (PoC), in which we deployed a WLAN based on 802.11n over several floors of a single building. Our final large-scale pilot test was in a five-story general-purpose building (GPB), providing wireless coverage to 1,000 people.

Laboratory Tests

During laboratory testing, we tested the basic functionality to verify the reliability of the connection to the network. We also performed failover tests to check redundancy and stress testing to make certain of capacity.

Proof of Concept

The PoC was our first opportunity to implement the WLAN design outside the lab. We decided to enable 802.11n over the 5.2 Ghz band and not over the 2.4 Ghz band, due to its lack of available channels.

We installed approximately 15 APs that connected about 50 PoC participants to the new network in a small-scale, two-floor environment. We installed the new infrastructure alongside the existing production infrastructure to avoid disturbing other employees who were not part of the PoC.

The PoC allowed us to determine the following:

- Roaming behavior for smooth handoffs between APs.
- The coverage each AP provided.
- The best spacing interval between each AP.

The PoC also enabled us to test a variety of applications used in our day-to-day work, to help ensure there were no gaps. During this phase, we identified the need for new client software to properly support roaming requirements.

We also used the PoC infrastructure to validate one issue we had identified during the lab test: setting up the 40-MHz channel mode, which allows the 802.11n WLAN to run at data rates of 300 Mb/s, instead of 144 Mb/s with 20-MHz channels. We saw that running at the 40-MHz channel caused the APs to reboot frequently. This problem diminished once we supplied the APs with a 1-gigabit (Gb) uplink, however most of Intel's current switches only support 100 Mb/s. Since we did not want to replace all the switches, we decided to start at the 144-Mb/s rate and move to 300 Mb/s after the current switches reach end of life (EOL) and are refreshed.

Pilot Certification

To help ensure the new service was functioning properly, we conducted a six-week pilot certification in a five-story GPB, which included approximately 1,000 users. This building had one of the oldest WLAN networks at Intel, with equipment that was reaching EOL and had limited support. New infrastructure had been slated to replace the old, so we installed more than 100 802.11n APs, along with new WLAN controllers.

During testing, we had to upgrade client software in 30 percent of older laptops to be able to use the 802.11n protocol. We also had to make sure that their hardware supported either 802.11a or 802.11n. Much of this work was already in progress as part of Intel's PC refresh program, in which we replace machines on an optimized, user-segmented cadence.

Results

During the six-month investigation, no major challenges arose that concerned the team or affected the schedule. As expected, the 802.11n WLAN returned increased throughput, reduced costs, improved employee satisfaction, and was accessible by multiple OSs.

INCREASED THROUGHPUT

As shown in Figure 3, the 802.11n environment showed up to a 300 percent increase in throughput over the 802.11abg WLAN, from 20 Mb/s up to greater than 60 Mb/s. Data rates also increased by 300 percent, from 54 Mb/s to 144 Mb/s, illustrated in Figure 4. The new network also delivered more than 14x the speed of the wired 10 Mb/s rate in optimal conditions—a shared as opposed to a switched network. However, with a loaded network, this rate was not as fast. It also increased throughput while continuing to provide the same strong security coverage.

We found that the newest laptops provided the highest performance results. They had the advantages of having the latest software as well as 802.11n-enabled hardware. Surprisingly, even the older 802.11a laptops saw a minor boost in data rates using the new infrastructure. By the end of 2010, all of Intel's deployed laptops will be 802.11n-enabled, but until then, the infrastructure will support non-802.11n clients at slower data rates.

REDUCED COSTS

Because 802.11n requires fewer APs and switches, financial analysis indicates that we will achieve a significant cost savings over the previous WLAN design. Our design installed an AP every 4,500 square feet, as compared to 3,500 with the prior 802.11abg layout. For each new GPB, the costs for deploying cable would be reduced by 20 percent. In addition, we were able to negotiate a swap credit from our suppliers, resulting in lower cost on a one-for-one replacement of old APs for new. Overall, we estimated a minimum cost savings of 32 percent per GPB.

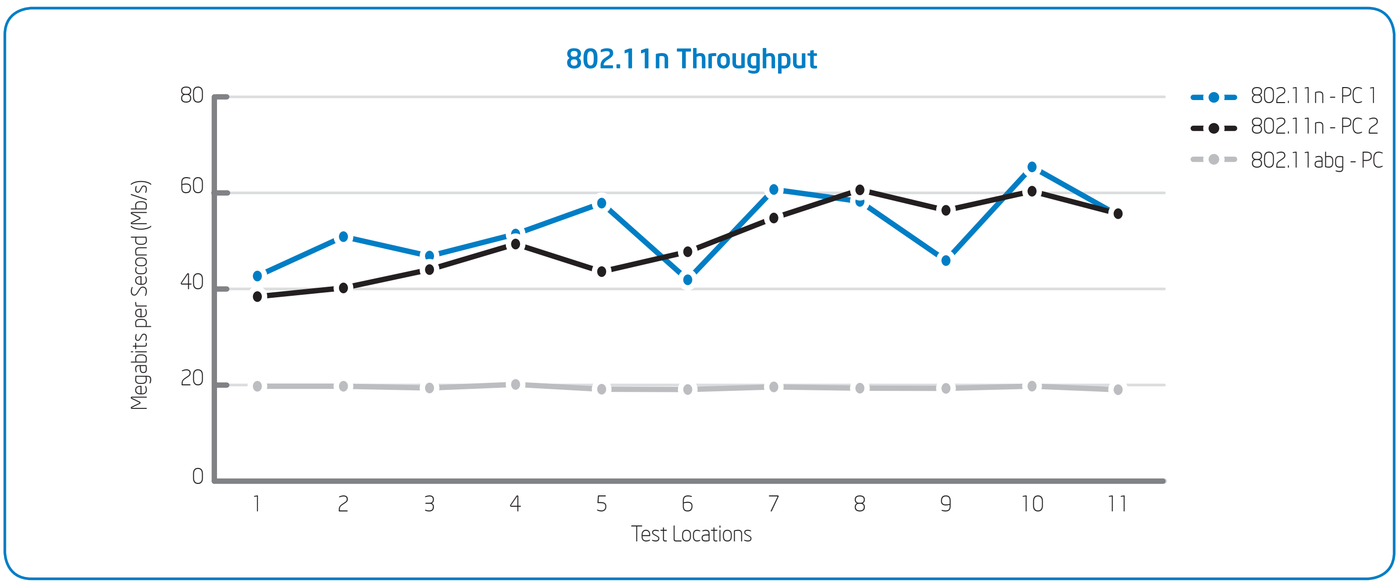


Figure 3. During the proof of concept, the 802.11n wireless network delivered increases in throughput of up to 3x the 802.11abg WLAN.

IMPROVED EMPLOYEE SATISFACTION

A faster, more reliable network means fewer user disconnections and higher employee productivity. Many users who participated in our PoC and pilot study had been connecting to the network with a wired connection, and they commented on how much faster their WLAN connection is now. The survey measured a 10 percent response rate, with 80 percent of responders rating their wireless network as somewhat to greatly improved, and 13 percent noting the WLAN had either improved or not changed. Once we upgraded software and dealt with hardware issues, no users had connection issues with the new protocol.

ACCESSSIBLE BY MULTIPLE OPERATING SYSTEMS

The majority of employees at Intel use PCs running Microsoft Windows*, and they had no trouble connecting to the new WLAN. For employees using computers based on Mac OS X*, results were similar. The few systems that had issues were addressed with a software upgrade and a hardware check. After these fixes, Mac users also saw higher WLAN performance.

Next Steps

Based on the success of our investigation, we decided to move ahead with deploying 802.11n throughout all Intel buildings. We have devised a five-quarter deployment plan to complete conversion to 802.11n wireless by the fourth quarter of 2010. The plan includes:

- Refreshing laptops at EOL and replacing them with new 802.11n-compatible laptops.
- Training Operations staff on the new 802.11n design and install process.
- Completing a radio frequency (RF) survey of all Intel buildings to determine how many new 802.11n APs are needed and where to put them.
- Creating a site design to see how this new WLAN infrastructure will connect to the existing infrastructure.
- Writing a bill of materials and ordering the equipment.
- Hiring a cable contractor to install the cable and equipment.
- Installing the new controllers and switches during a downtime window after the shipment arrives.
- Replacing old 802.11abg APs with the new 802.11n APs.
- Testing to help ensure connectivity and proper RF coverage after installation is complete.

This WLAN will be Intel's fourth WLAN design in a decade. Figure 5 provides an overview of the network architecture and capabilities.

As computer and wireless network technology continues to improve in performance and adapt to the latest approved wireless protocol, we will continue to upgrade Intel's WLAN to accommodate higher demand for a stable, fast alternative to the wired network.

In the near future, we envision WLAN as the default network access medium for nearly all use cases, from laptop computers to handheld phones accessing data, voice, and video.

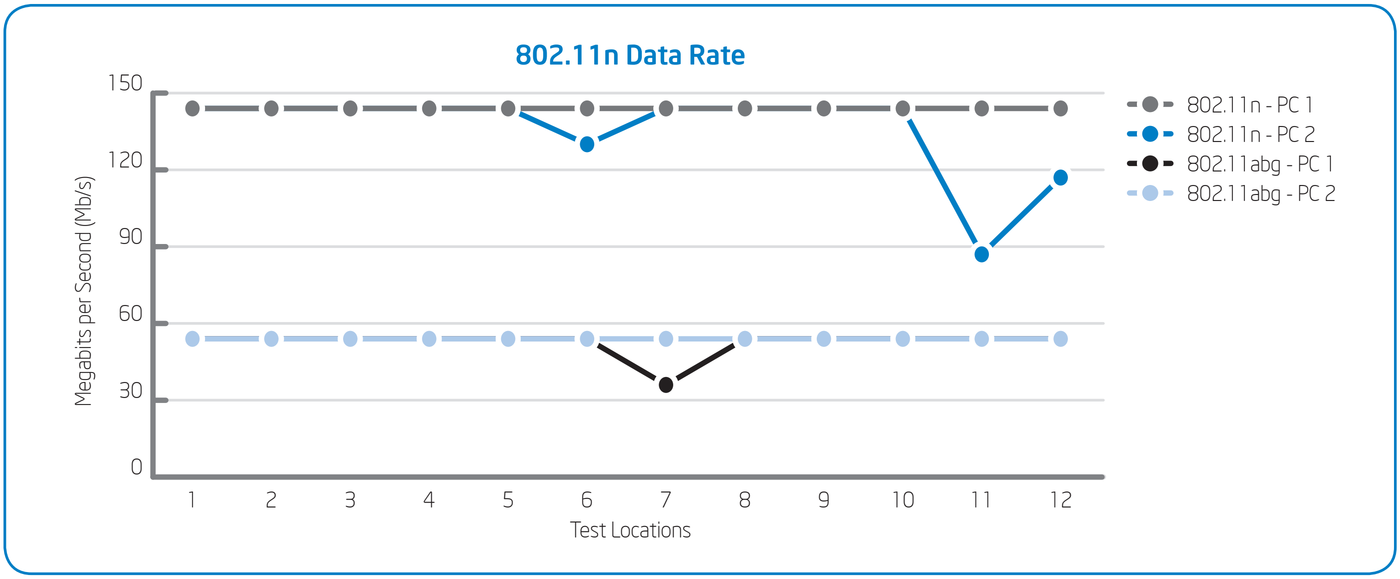
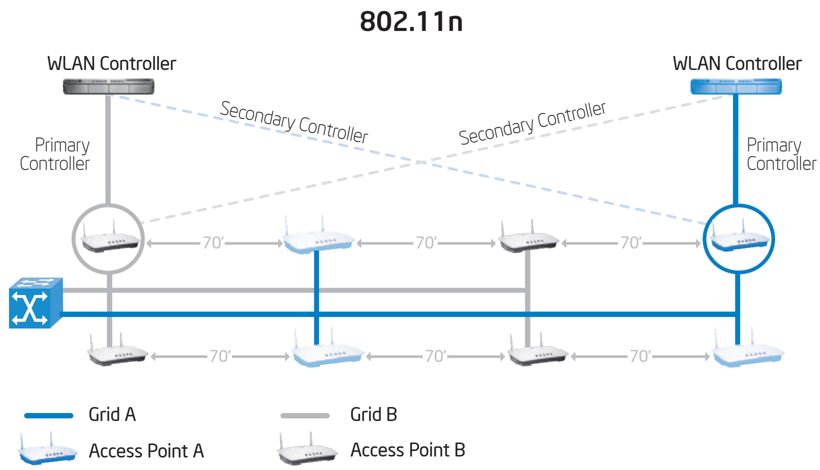


Figure 4. After a software upgrade, end users' 802.11n data speeds were up to 3x as fast as the 802.11abg wireless LAN. 802.11n was used in mixed mode, supporting laptops that were not 802.11n-compatible.



Fourth-Generation Wireless LAN (WLAN)
- Up to 65 megabits per second (Mb/s) throughput
- 144 Mb/s maximum data rate
- Supports data services, voice, and video
- Webcast-capable
- Same capabilities as wired LAN
- Needs an access point every 70 feet
- Throughput can be doubled to 100 Mb/s

Figure 5. The 802.11n protocol increases the distance between access points and switches, and reduces the size of controllers in wireless LANs.

CONCLUSION

For Intel, the move to 802.11n has been very successful. This wireless standard will allow us to eventually use WLAN as the default network for most users, and they will receive all the same voice, video, and data services that they access through the wired LAN today. It will provide cost savings, reduce energy consumption, and increase user productivity.

We are currently implementing 802.11n with 144 Mb/s throughout the enterprise, with plans to complete deployment by the end of 2010. We also have a clear path to the next level of performance at 300 Mb/s when we choose to change the infrastructure software configuration and upgrade the AP backhaul to 1 Gb/s.

FOR MORE INFORMATION

Visit our Web site at www.intel.com/IT for related white papers:

- "Wireless LAN as the Primary Network"
- "Architecture and Design of a Primary Wireless Network"
- "Managing and Monitoring a Primary Wireless Network"

ACRONYMS

AP	access point
EOL	end of life
Gb	gigabit
GPB	general-purpose building
MAC	Media Access Control
Mb/s	megabits per second
MIMO	multiple-input multiple-output
PoC	proof of concept
RF	radio frequency
WLAN	wireless LAN

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