White Paper
Networking | Wi-Fi 6
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IT@Intel: Building a Faster, More Secure Enterprise Network with Wi-Fi 6

Wi-Fi 6 is the next step in the evolution of Wi-Fi technology and has significantly improved network performance at several of our test sites

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Executive Summary

Intel IT is enabling business transformation on Intel campuses around the world by standardizing on Wi-Fi for wireless LAN (WLAN) access. Our exclusive use of a wireless infrastructure helps to improve employee mobility, job satisfaction, and productivity—as well as deliver network access in new construction faster and at lower cost.

Today, about 75 percent of Intel's workforce uses the wireless network as their main method of connectivity. Real-time services are challenging to support over Wi-Fi, and we closely monitor and manage reliability and stability of applications like voice and video. Other real-time services, such as chip design, requires consistent connection. This typically requires a wired LAN. Based on recent proofs of concept, we decided to upgrade to Wi-Fi 6 on two Intel campuses. This decision was based on the limitations Wi-Fi 5 presents in terms of latency, bandwidth, and radio frequency (RF) channel management. Wi-Fi 6 provides concurrent multi-user transmit/receive modes, faster speeds, and more capacity. These features enable new use cases in the workplace, and they enable a shift of existing use cases that have traditionally used wires, such as latency-sensitive design applications, to use WLAN.

Intel IT is working to provide a seamless and reliable network experience, covering all existing and future use cases. Upgrading to Wi-Fi 6 can help solve our WLAN challenges and enable new use cases to further increase the penetration in the campus access network.

Acronyms

AP access point
RF radio frequency
VoIP voice over internet protocol
WLAN wireless local area network

Background

Intel IT operates a worldwide computing environment that supports over 100,000 Intel employees. Many employees collaborate with teams across countries, time zones, and campuses. Employees connect to IT services through more than 200,000 devices. The majority of these devices are wireless business PCs, both mobile and desktop. An additional 70,000 are employees' wireless handheld devices. Visitors' wireless handheld devices can add up to another 50,000.[1]

Intel has been an early adopter in the use of Wi-Fi, starting in the early 2000s as an overlay network (see Figure 1), aimed initially to bring connectivity and mobility to open spaces such as cafeterias and conference rooms.

Wi-Fi 1 through Wi-Fi 3

Our initial global deployments used Wi-Fi 1 (802.11b). The next generation, Wi-Fi 2 (802.11a), enabled the transition to the 5 GHz spectrum, enlarging the overall usable RF spectrum from 60 MHz to 500 MHz, which enabled less interference. This allowed us to grow from 3 up to 25 non-overlapping channels, depending on the country's specific regulations. This proved particularly important in a dense enterprise environment as compared to consumer home usage. The client bandwidth also enlarged from a data rate of 11 Mbps to 54 Mbps.

In the third generation, Wi-Fi 3 (802.11g), WLAN security was enhanced to use improved authentication and encryption, enabling us to remove an additional layer of security mechanism. This simplified access for users and improved roaming times.

[1] Please note that these numbers are pre-COVID-19, before the majority of Intel's employees moved home to work.

Wi-Fi 4

With the evolution of Wi-Fi 4 (802.11n), the technology enabled the use of Wi-Fi across all of Intel's general-purpose buildings, both as the primary means of accessing the network and as an additional overlay network to the traditional wired LAN.

Wi-Fi 4, along with mobility for Intel laptops within campuses, enabled an array of new services ranging from secure guest internet access, employee bring your own device hotspot connectivity, location tracking, and wireless display in conference rooms.

Starting with Wi-Fi 4, we changed our WLAN strategy to reduce the number of LAN ports from two per person to one per person. All conference rooms and cafeterias were solely served by Wi-Fi.

Wi-Fi 5

With the convergence of IP services and the ability to deliver voice and video on the same data networks, Intel's Wi-Fi network has evolved to a high-density design, using Wi-Fi 5 (802.11ac) for maximum performance, serving 75 percent of Intel clients today. With Wi-Fi 5, the overall cost for the entire office network is three times lower due to eliminating cable and LAN ports.

Wireless Infrastructure Delivers Many Benefits

- A more flexible work style that promotes collaboration across global teams and greater productivity, according to Intel IT user surveys and observational studies.
- Improved business continuity due to the fact that employees can take work computers home and have them in the event that natural disasters or other events prevent them from coming into the office.
- Easier, faster, less expensive employee movements from office to office within a campus or to another campus.
- Simpler conference room wireless display connections can minimize the need to support such wired display ports as HDMI, DVI, and VGA.
- Enable additional services, such as augmented reality and IoT connectivity for future use.

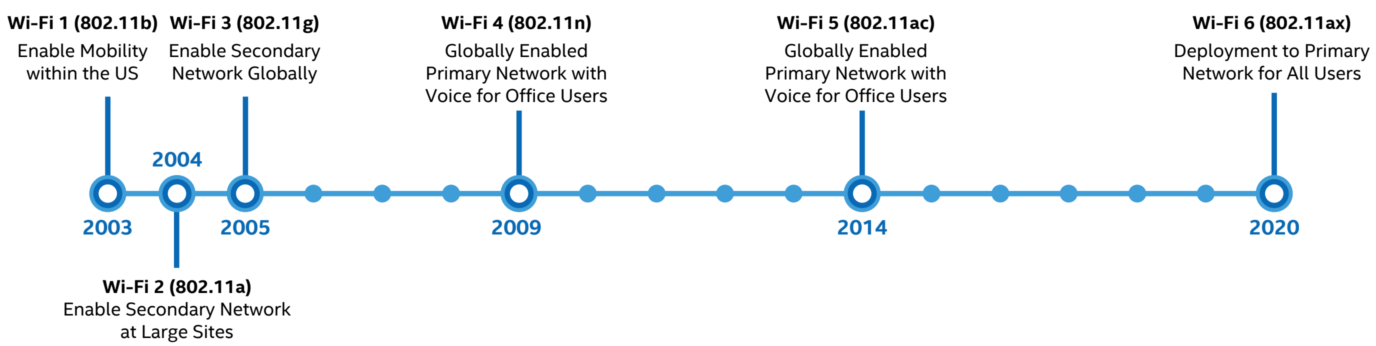

Figure 1. History of Wi-Fi deployment at Intel since 2003.

Today's Business Challenge

Wi-Fi 5, which is currently in place in all Intel sites, has a number of limitations. These limitations include predictability and throughput; we would like our system to adjust seamlessly as the number of devices increases, and to adjust to changing RF conditions.

Here are some of the limitations with Wi-Fi 5:

- **Reliability and stability.** Users in all parts of an Intel site (such as parts of a large building—individual desks, conference rooms, and so on) need to have stable and reliable Wi-Fi for work and meetings. In addition, each access point (AP) needs to work with other APs in the same space. It is challenging to get all devices and APs to use the radio spectrum efficiently and to deliver high quality for every user. It's not the average or median performance that matters, but rather the small number of potential problems or poor performance. Even one late packet out of 1,000 may degrade application performance.
- **Latency issues.** Latency specifically affects video and voice calls that happen over Wi-Fi, causing "lag" between video and audio, jittery voices, and other issues that specifically relate to audio and video. With Intel's ever-increasing number of video conferences (decreasing travel costs and pandemic risks), latency is a big issue. Quality of service mechanisms prioritize latency-sensitive traffic; for example, prioritizing live video calls over data backups are widely used. However, these mechanisms are limited in addressing all needs.
- **Security**. The use of Wi-Fi challenges Intel's traditional physical security in building access, as a user could be connecting from the parking lot without ever passing physical security. Therefore, all access to Wi-Fi must be secured. Our Wi-Fi network enforces authentication and encryption requirements, using Remote Authentication Dial-In User Service servers. We also use WPA2 for authentication, and a move to Wi-Fi 6 would enable us to adopt the more secure WPA3. On top of ensuring the high availability of the infrastructure, asking for authentication or checking authorization shouldn't add latency to the system, in addition to the latency already inherent in the network.
- **Network and client complexity**. Due to the volume of infrastructure and the number and variety of client devices at Intel, maintaining a consistent configuration is daunting. We may have differences in capabilities, as it would take us several years to upgrade from one generation to the next across all of Intel's sites globally. End to end, across the network and clients, consistency of capabilities and policies for a quality experience is key. This issue of network and client complexity is even more significant as Wi-Fi network technologies are changing at a faster rate than traditional networks.
- **Efficient use of shared RF resources.** Unlike wired Ethernet, where each host receives its own cable, the RF is shared among several clients (typically 15). Due to the finite number of RF channels available, and the fact that each Wi-Fi AP needs to be on a different channel than its neighboring APs, the overall bandwidth that the Wi-Fi network can supply within a given area is limited. Features like 80 MHz and 160 MHz channels are limited to consumer Wi-Fi today, and typically cannot be used in enterprise networks due to the limited number of channels available.
- **Unlicensed band usage challenges.** One of the main reasons for Wi-Fi success is its use of unlicensed RFs, which are free for everyone to use. As a result, the network needs to cope with RF interferences and co-exist alongside non-Wi-Fi devices sharing the same frequencies. This includes various consumer devices such as microwave ovens and security cameras. In addition, the Wi-Fi protocol includes built-in dynamic frequency selections, where the AP is obligated to change a channel once radar signals have been detected. Since an active voice call might be interrupted during this transition, it has to be done in minimal time.

Proof of Concept

We rolled out Wi-Fi 6 in two locations with a total of 323 clients (see Figure 2). Site 1 had 143 clients and 45 APs, located on one floor of one building. Site 2 had 180 clients and 12 APs, also on one floor of one building. The analysis in Table 1 is based on a three-month period of data collection. This is now the new deployment standard at Intel. Current AP count at Intel is around 200 and is expected to grow to 500 by the end of 2020.

With new features being introduced by both infrastructure and client, we are continuing to evaluate them as needed.

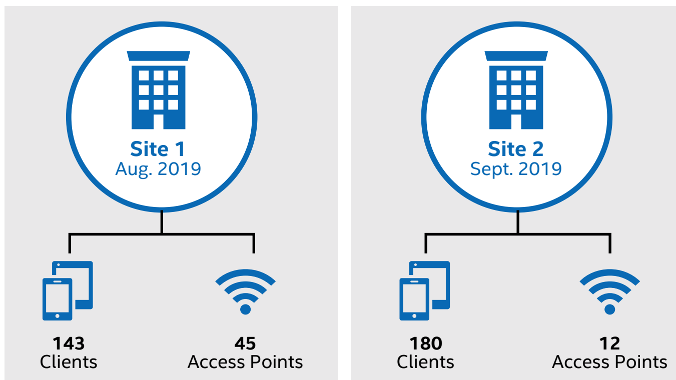

Figure 2. Our proof of concept included 2 sites, 323 clients, and 57 access points.

Table 1. Migration improvements from Wi-Fi 5 To Wi-Fi 6

Area for Improvement	Specific Change
Throughput of calls, data, and other network volume	30% improvement
Reduction in bad VoIP calls	28% reduction
Call quality (measured in count of poor calls)	28% improvement
Latency	20% improvement
Modulation	25% improvement
Various technical issues	Resolved

Results

Upgrading from Wi-Fi 5 to Wi-Fi 6 showed several specific improvements in these two locations.

Wi-Fi 6 Dashboard

During our Wi-Fi 6 test period, we created a dashboard to track all the relevant network performance metrics such as round-trip time, jitter, and packet loss for VoIP over WLAN (see Figure 3). The figure also illustrates that Wi-Fi 6 provided better results for all three metrics. Our proof of concept also tracked client connectivity status in real time and collected telemetry data to assess Wi-Fi 6 performance and features. To ensure performance, we used the latest drivers and conducted direct interactions with users to resolve issues.

Telemetry for Wi-Fi 6 included:

- Throughput
- Orthogonal Frequency Division Multiple Access
- WPA3
- Indoor location

Next Steps

Based on the successful Wi-Fi 6 proofs of concept, we expect to take advantage of the basic service set (BSS) coloring feature. BSS coloring allows differentiation of the AP. This means we can add more APs without colliding signals. Unlike previous generations, APs will be able to reuse a channel, regardless if their neighboring APs are already using the same channel. This will enable a dense AP deployment and allow us to break the barrier of using wider channels.

In addition, we expect that in the near future, we will upgrade to Wi-Fi 6E. This is expected next year (2021), and it will provide 59 new channels (depending on regulatory changes), more than double the number we have today (see Figure 4).

Wi-Fi 6E will provide an additional 1,200 MHz of the spectrum vs. 500 MHz available today. This will allow us to better avoid concurrent channel interference, improve our AP density, and also to enable wider 80 MHz and 160 MHz channels that will significantly improve the throughput (See Table 2).

Table 2. Future Plans for Improvement with Wi-Fi 6E

Specific Change	
Bandwidth	• 59 new Wi-Fi 6E channels • Wi-Fi 6 will allow the use of wider 80-160 MHz in enterprise networks
More clients per AP	Currently, Wi-Fi 5 enables 15 clients per AP at the same time, but they essentially take turns—only one can transmit at a time. Wi-Fi 6 will enable 9 of those 15 to transmit at the same time, so the throughput will be much higher. Using 6E, we expect to be able to deliver higher throughput and support more IoT-type clients
More clients	Longer wake time

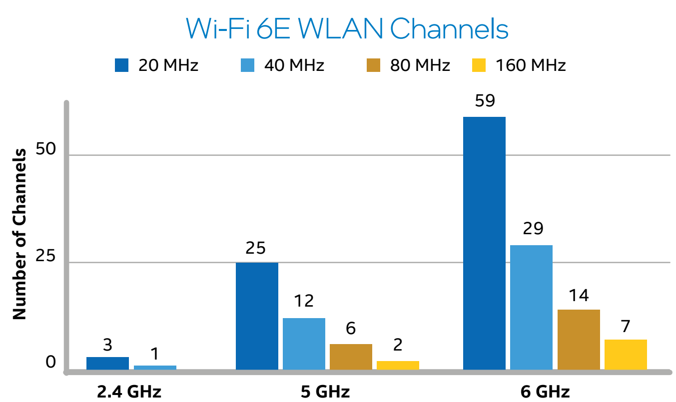

Figure 4. Planning for future improvements with Wi-Fi 6E.

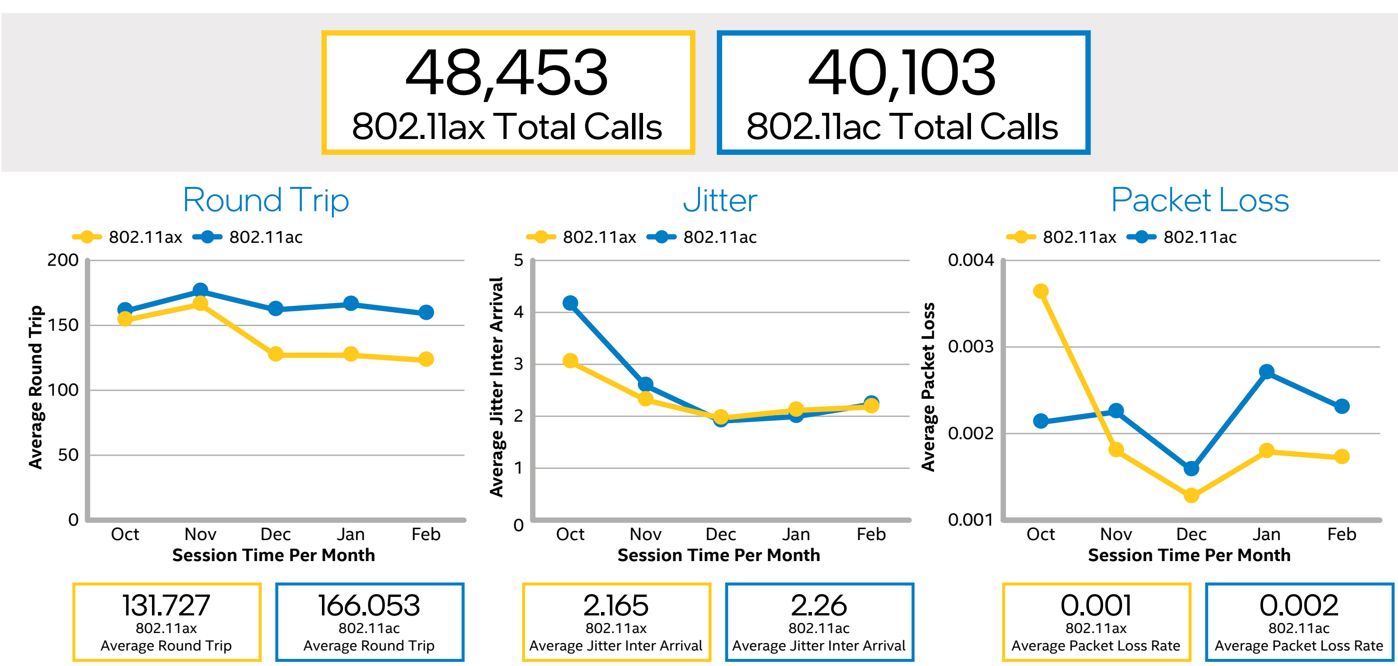

Figure 3. Our Wi-Fi 6 dashboard tracked various metrics of the project.

We also plan to take advantage of enhanced encryption capabilities with WPA3, which offers stronger security features than WPA2. The enterprise version of WPA3 requires 192-bit AES support, compared to 128-bit encryption for WPA2. WPA3 also uses more secure key exchange and handshake protocols.

Our Wi-Fi 6 roadmap has two parts:

- Beginning in 2020, on the client infrastructure side, all new platforms at Intel will be Wi-Fi 6 enabled.
- On the Wi-Fi network infrastructure side, the build-out to get to Wi-Fi 6 will take two to three years, starting in 2021.

Conclusion

Upgrading to Wi-Fi 6 helped us solve a number of challenges associated with WLAN bandwidth and stability, so that Intel employees can seamlessly and easily move from place to place and use Wi-Fi for all their connectivity needs, including data, voice, and video.

We expect to be able to consistently serve all Intel clients' access needs in the future by using Wi-Fi, and grow client usage from 75 percent to close to 100 percent. The technology will allow us to enable latency-sensitive design applications that today require the users to use wired LAN, along with new use cases such as Internet of Things and augmented or virtual reality.

Wi-Fi 6 will help enable us to stop wiring buildings for customer use, and to rely solely on Wi-Fi for network connectivity.

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