A Game Changer For Wireless Clinical Devices:

The Impact of Wi-Fi 6/6E on Connected Medical Devices in Hospital Settings

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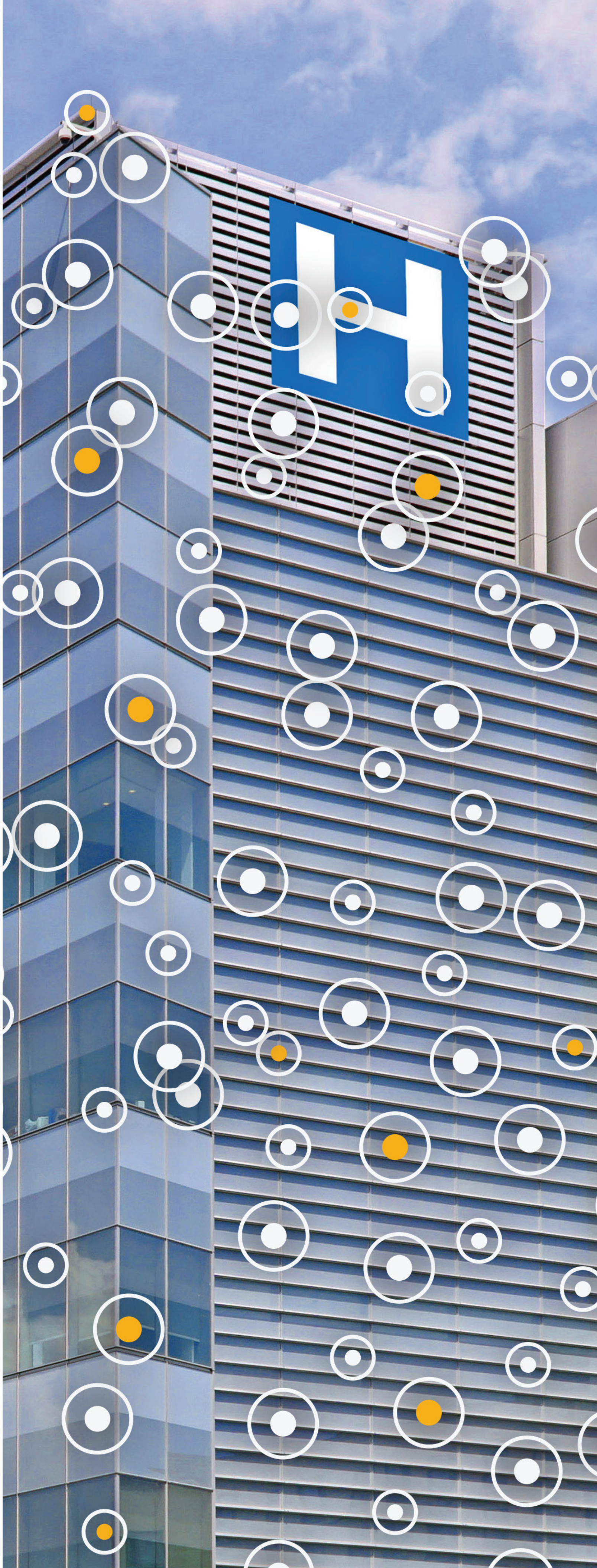
Wi-Fi networks are the indispensable backbone for connected medical devices in hospitals. Because of its performance, reliability, flexibility, security, and other advantages, Wi-Fi has become the dominant connectivity technology for clinical devices such as pulse-ox sensors, infusion pumps, patient monitors, defibrillators, ventilators, beds, and more. Wi-Fi has proven to be ideal for the needs of these devices in medical environments, however the increasing density of wireless medical devices is putting tremendous pressure on Wi-Fi networks, as more and more devices require an ever-growing volume of connections and bandwidth.

In this way, Wi-Fi has become a victim of its own success in medical environments, leading to the danger of congestion in an environment where the performance of these devices is so vital. As the number of Wi-Fi connected devices increases in hospitals, Wi-Fi networks can become overwhelmed not only by the number of devices making demands on the network but also the RF complexity of so many networks and devices operating in close proximity to one another. That kind of network congestion is a nuisance for consumer devices like tablets streaming music or movies, but the consequences are far more serious in medical environments, where medical devices perform critical roles in patient monitoring and treatment.



The solution to those challenges is a new version of Wi-Fi that has been released by the IEEE standards body and labeled Wi-Fi 6 and 6E by the Wi-Fi Alliance. Wi-Fi 6/6E delivers significant advancements in performance, efficiency, latency, and other key areas that collectively enable far more device density while avoiding network congestion. These new versions of Wi-Fi will have an enormous impact on connected device networks in clinical environments, where so many Wi-Fi dependent devices are packed into small physical spaces. Simply put, this new version of Wi-Fi is a gamechanger for hospitals because it will enable Wi-Fi to continue serving as the backbone of hospital connectivity, even as device density increases and as new devices put greater demands on networks. The advancements in Wi-Fi 6 and 6E are significant:

- **Dramatic increases in performance**
- **Far lower latency**
- **Wider operational spectrum for devices to utilize**
- **Extended battery life for mobile devices**
- **Higher device density through increased concurrent communications**
- **Lower network-to-network interference**
- **And other technical advancements that support new applications**

Feature	Wi-fi 4	Wi-fi 5	Wi-fi 6	Wi-fi 6E
Chanel Bandwidth	20, 40	20, 40, 80, 80+80,160	20, 40, 80, 80+80,160	20, 40, 80, 80+80,160
Frequency Bands	2.4 and 5 GHz	2.4 and 5 GHz	2.4 and 5 GHz	2.4 and 6 GHz
Maximum Data Rate	150 Mbps	3.5 Mbps	9.6 Mbps	9.6 Mbps
Highest Subcarrier Modulation	64-QAM	256-QAM	1024-QAM	1024-QAM
Spatial Streams	1	4	8	8
Underlying Technology	IEEE 802.11n	IEEE 802.11ac	IEEE 802.11ax	IEEE 802.11ax

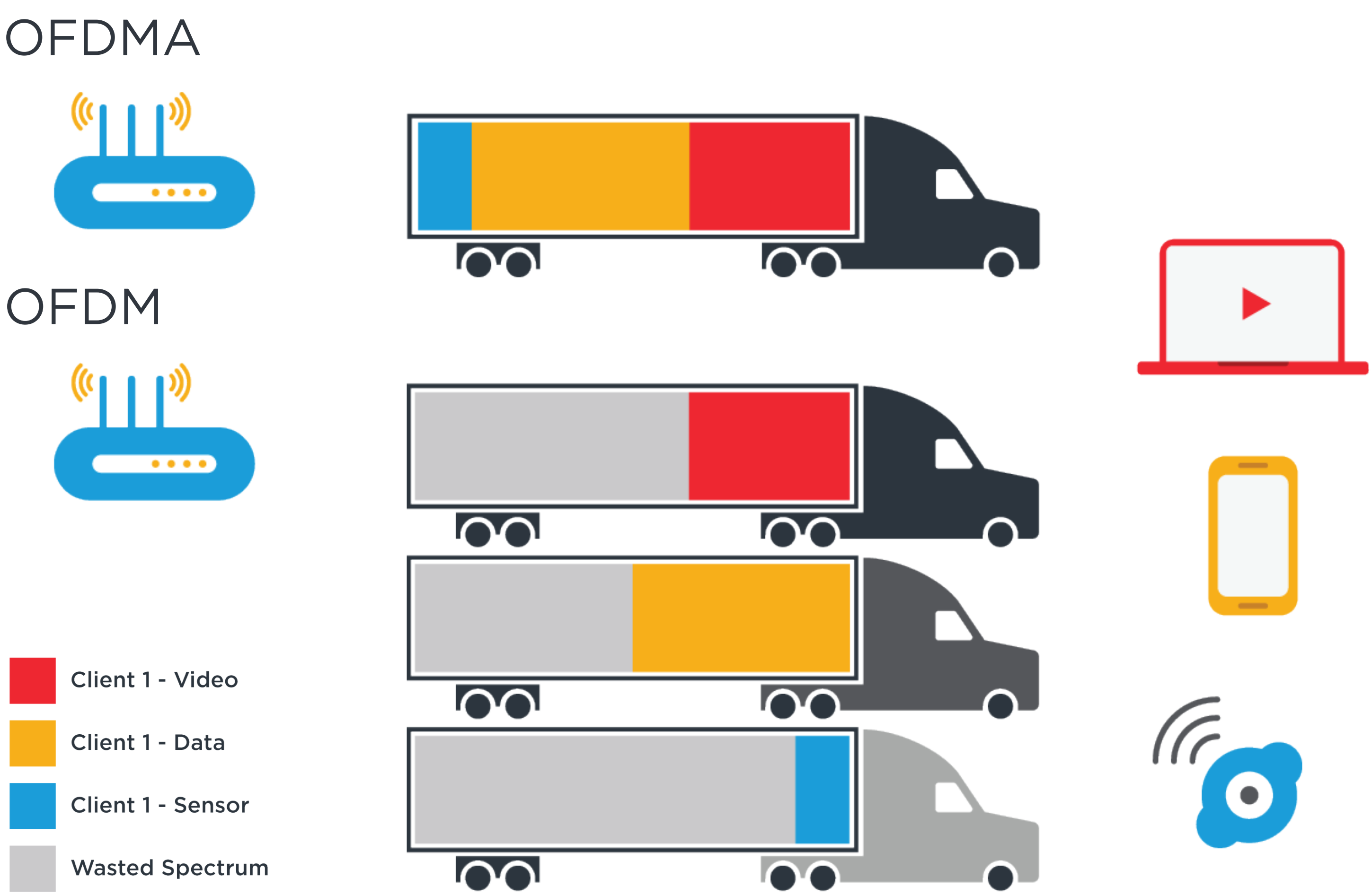
Before we continue, we should note that the benefits we discuss in this white paper will only be realized once the infrastructure to support Wi-Fi 6/6E is in place and operational in healthcare environments. Organizations do not necessarily have to be taking full advantage of every single feature in Wi-Fi 6/6E in order to see major improvements in performance, latency, and more, but the 6/6E infrastructure does need to be in place as a foundation. That is on the horizon, but product engineers should begin planning for the Wi-Fi 6/6E era now in order to deliver the next generation of clinical devices that take advantage of these upgraded networks.

OFDMA

Two of the most important technical enhancements in Wi-Fi 6/6E are OFDMA and MU-MIMO, which work in concert with one another to support much higher device density and device performance. These technologies accomplish this by allowing each Wi-Fi access point to organize spectrum temporally and physically in ways that establish stronger, higher-performing connections with each device in their domain.

Orthogonal Frequency Division Multiple-Access (OFDMA) is a centerpiece of Wi-Fi 6/6E's strategy for managing high device density in ways that deliver far lower latency, higher speed, and less network congestion. We view it as the most significant feature for connected medical devices in the new version of Wi-Fi. OFDMA makes it possible for access points to communicate simultaneously with multiple devices by sub-dividing a given wireless channel into sub-channels. Each device then only uses a small slice of each channel rather than an entire channel, allowing far more simultaneous device connections. To begin to understand OFDMA, let's look at a common analogy that is fairly effective at explaining the nature of Wi-Fi traffic, its many channels, and the delivery mechanism of data in a link. That analogy is to compare Wi-Fi traffic to parcels loaded on trucks and delivered up and down the freeway. And much like with shipping logistics, OFDMA is about optimizing the delivery of those parcels (packets of data, in this analogy) in the most efficient way as possible, while also making sure that small shippers have access to the same reliability and consistent delivery as the big shippers.

For this analogy, think of each truck as a frame in a Wi-Fi burst signal. Frames are chunks of the burst split up in time, like trucks moving down the freeway one at a time. There is only one lane of traffic, and each truck can only carry cargo from one sender,



OFDMA and MU-MIMO are complimentary

and at a fixed rate of speed (the speed of light, in fact, but let's not complicate the analogy too much). That means one truck might be half-packed with cargo from big shipper A, the next might have a single box from small shipper B, the next two might be full of cargo from big shipper C. In this arrangement, lots of potential data sits surrounded by empty space in a truck, waiting its turn to reach its destination. There's no carpool lane or bypass to expedite its delivery. Everyone waits the same. With OFDMA, the idea is to further subdivide Wi-Fi frames into subcarriers. What that means is that each frame can be further cut into portions of spectrum – divided and sorted at the receiving end to allow multiple concurrent users a chance to send data in each frame. In the truck analogy this might be expressed as: big shippers load out the left of the truck, a small shipper gets access to the middle for a few small parcels, and so on until the truck is full. Never again does a full truck need to be wasted on a single parcel. Efficiency jumps dramatically. And it's not a zero-sum game that disadvantages the big shippers: There was usually room for one more box. Everyone wins.

OFDMA gives access points the ability to plot and plan these frames based on the needs of the clients with the information available to the infrastructure. An entire 20 MHz channel can be divided into 242 multi-user subchannels in Wi-Fi 6, and those subchannels can be doled out to the clients as needed, as well as decoded separately to separate out whose parcels are whose. To briefly return to our analogy, that means 242 equal size parcels per truck, arranged in the way that makes the most sense for the overall network based on need.

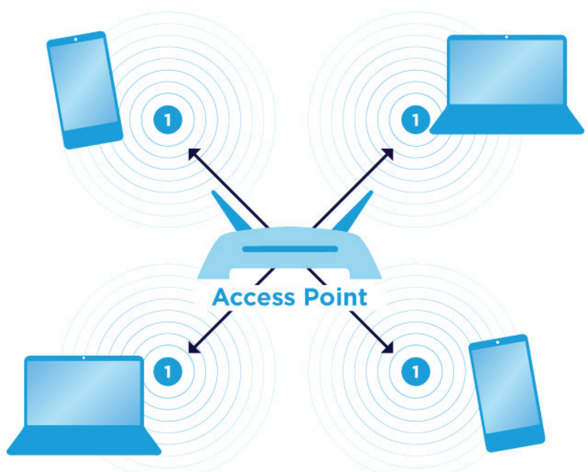
This analogy isn't perfect (for one, you should never load out just the left-hand side of a truck), but it expresses the key benefit of OFDMA: better management and utilization of the empty space inside the average Wi-Fi frame.

Bi-Directional MU-MIMO

Wi-Fi 6/6E uses MU-MIMO as a complementary technology to OFDMA to support higher device density while achieving far lower latency. Multi-User Multiple-In Multiple-Out (MU-MIMO) has been a feature of Wi-Fi since the release of Wi-Fi 5, but there is an important update to MU-MIMO in Wi-Fi 6/6E. In Wi-Fi 6/6E, MU-MIMO has additional functionality to support beam forming between medical devices and the access point back to the AP. This Bi-directional MU-MIMO enables access points to create spatial streams that focus RF activity in the physical direction of each device in their domain. This is achieved by using two or more antennas and creating an intentional interference pattern to focus signals toward the intended device or groups of devices – creating a stronger link with each device using up to eight spatial streams.

This not only boosts the strength of each device's connection but also reduces unfocused RF noise and can utilize less power in the process. This has the added benefit of reducing the overall volume of interference in environments with many access points and devices, preventing the physical space from becoming saturated in signals that potentially interfere with the performance of the networks, devices, and applications. Hospitals are particularly prone to this kind of saturated environment because of the number of devices and the physical characteristics of hospital's RF environments.

Together, OFDMA and Bi-Directional MU-MIMO achieve a previously-impossible level of coordination of devices on Wi-Fi networks. This is enormously impactful in healthcare settings where so many devices are in close proximity where a given access point needs to support so many devices. Emergency rooms are perfect examples of healthcare settings that will benefit from this. There are often 10-15 devices connected per bed as a baseline, but that number can jump to 70+ devices if a patient's condition is a medical crisis. Hospitals therefore need to plan for their Wi-Fi networks to successfully support the 70+ number, which prior to this new version of Wi-Fi meant adding more access points, building out more wireless infrastructure, and then facing the congestion of a very crowded RF environment. With the flexibility that OFDMA and MU-MIMO bring, settings like the emergency room bed in this example can be supported through the higher performance and density of Wi-Fi 6/6E rather than requiring the costly building of more infrastructure.

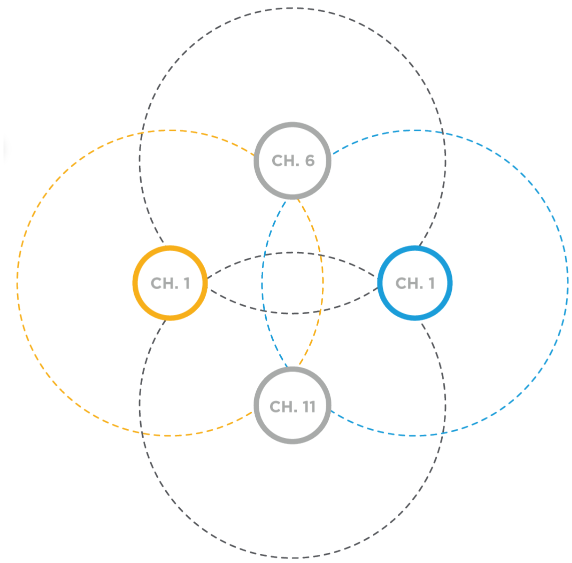


Multi-User MIMO (Up to 4 simultaneous)

BSS Coloring

Wi-Fi 6/6E is also designed to solve another source of congestion that is common in healthcare settings: overlapping Wi-Fi networks in the same physical space. Environments like clinics and hospitals often have a high proliferation of Wi-Fi access points whose RF range overlap with one another. The goal of all those access points is to maximize coverage, but the downside is a noisy wireless environment where the emissions of the multiple APs overlap negatively impacting the connectivity of devices.

Basic Service Set Coloring (BSS Coloring) addresses those challenges by intelligently organizing network



traffic in areas where multiple access points are overlapping. Prior versions of Wi-Fi struggled with overlapping networks, requiring devices communicating on overlapping channels to regularly pause communication, check to make sure it is safe to proceed, and only proceed if there was no competing traffic. This slows network performance, particularly in dense environments like those in healthcare. BSS Coloring alleviates this issue by allowing the access point to intelligently manage traffic occurring on the same channel by adding a prepend to their broadcast identifier in the form of a color. If a device hears a broadcast on its channel, but the broadcast is of a different color, the device can determine that it's for another service set and go ahead and broadcast without waiting. In doing this, we can categorize devices into association or affinity with a given access point with a high degree of likelihood that they will not interfere with each other, due to proximity. This will allow devices to talk to their nearest source of connectivity without fear of interrupting another service set or pausing communication when it could in fact communicate.

Faster Data Throughput

Wi-Fi 6/6E delivers a dramatic increase in data speed that is critical to supporting the growing number of connected devices in hospitals and the accelerating volume of data communication that these devices rely on. On paper, the data throughput of Wi-Fi 6/6E increases to 9.6 Gbps from Wi-Fi 5's rate of 3.5 Gbps thanks to increased efficiency in the way this new version of Wi-Fi uses the available wireless spectrum. That is roughly a 3x increase in data throughput, but the real-world increase in throughput is much higher when that faster architecture is combined with MU-MIMO, OFDMA and BSS Coloring – which collectively act as a "force multiplier" for the speed of Wi-Fi 6/6E.

We have seen testing reports that show the actual increase in speed is 100x-1,000x faster than prior versions of Wi-Fi, the importance of which cannot be overstated for medical devices in hospitals. As the number of devices continue to increase and as the applications on those devices become more bandwidth hungry, this massive increase in data speed enables Wi-Fi to continue being a reliable foundation for connectivity in hospitals.

Enhanced Device Roaming

One of the factors that make hospitals a more complex environment for Wi-Fi networks is how often connected devices physically move. Many devices regularly move with staff and patients from room to room or even from floor to floor rather than being in fixed positions. As devices move, they can move out of range of a given Wi-Fi access point and into range of a new access point that will take over that connection. Wi-Fi 6/6E has enhancements that better support roaming devices as they move into range of new access points.

Wi-Fi 6/6E manages roaming devices far more effectively and efficiently through the use of features in 802.11r, 802.11k and 802.11v that manage those connections in automated ways that optimize connectivity for a given device. A key takeaway for engineers is that 80.11r/k/v bring fast roaming to the enterprise network, which is fundamental in medical environments because of how mobile devices are. We should also note that BSS coloring plays an important supporting role in this in complex RF environments like hospitals where access points may be close to one another with overlapping signal areas.

Bolstered Security

Security is one of the major areas of enhancement in Wi-Fi 6/6E that will benefit medical devices. The new version of Wi-Fi will utilize WPA3-Enterprise 192-bit security in all bands, allowing clinical devices to operate on more secure connections than the open, unencrypted WLANs that prior versions of Wi-Fi employed. Encryption is the centerpiece of WPA3-Enterprise's architecture. This brings encrypted connections to hospitals, ensuring the protection of patient data. This is a key feature for product engineers designing products for HIPAA-regulated environments.
Wi-Fi 6/6E's security enhancements go beyond just the headline-grabbing encryption. Its use of WPA3 means that medical devices will establish connections in far more secure ways using Simultaneous Authentication of Equals (SAE) exchange rather than the prior pre-shared key (PSK) methodology. It also adds significant protections against weak passwords, bolstering a key area of vulnerability. There are also enhancements that make it easier for engineers to allow a broader range of devices to fully utilize WPA3, including devices with no display interface.

We should note that this new version of Wi-Fi allows medical organizations to utilize the level of encryption that aligns best with the type of facility the Wi-Fi network supports. WPA-3 Enterprise 192-bit is the gold standard, but healthcare organizations may opt to focus on SAE as the next best option at smaller sites like outpatient clinics and doctors' offices where there is typically no formal IT staff. Additionally, Wi-Fi 6 and 6E devices targeted at medical markets will be able to support newer implementations of the FIPS 140 standard such as FIPS 140-3, ensuring availability of the latest devices in the largest medical organization in the United States, the U.S. Department of Veterans Affairs.

6GHz Spectrum

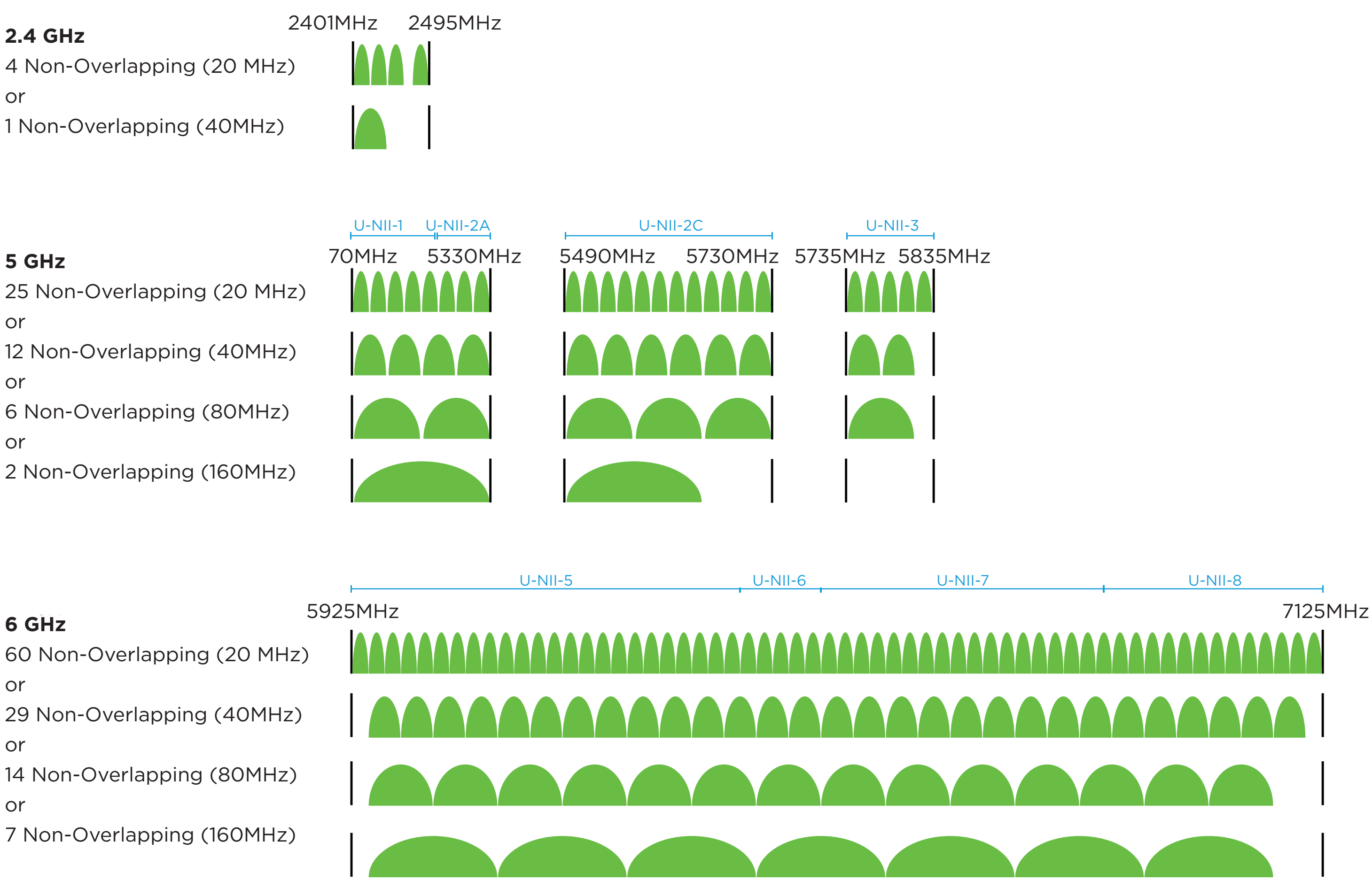
One of the most significant advancements in Wi-Fi 6/6E for clinical environments is the expansion of Wi-Fi's spectrum to include 6 GHz frequencies. This provides a tremendous amount of RF "real estate" for Wi-Fi networks to operate in, giving organizations a major tool for relieving network congestion not only today but far into the future. This assures that Wi-Fi will serve as a long-term connectivity platform for connected medical devices, not only with Wi-Fi 6/6E, but also with Wi-Fi 7 and beyond.

By adding 1.2 GHz of bandwidth in the 6 GHz spectrum, Wi-Fi can provide more than double the number of available channels for connected devices. This major increase in spectrum also allows organizations to spectrally segregate networks in ways that optimize the performance of devices. Multiple high-performance and low-performance Wi-Fi networks can be established on this wider spectrum without any overlap. As an example, devices directly responsible for patient monitoring and treatment could exclusively use a high-performance network assigned to a band in the 6 GHz range where the RF dynamics are relatively clean in order to ensure their performance. And lower-priority devices could be assigned to their own network in the 5 GHz range so they are not competing for connectivity with the higher-priority devices.

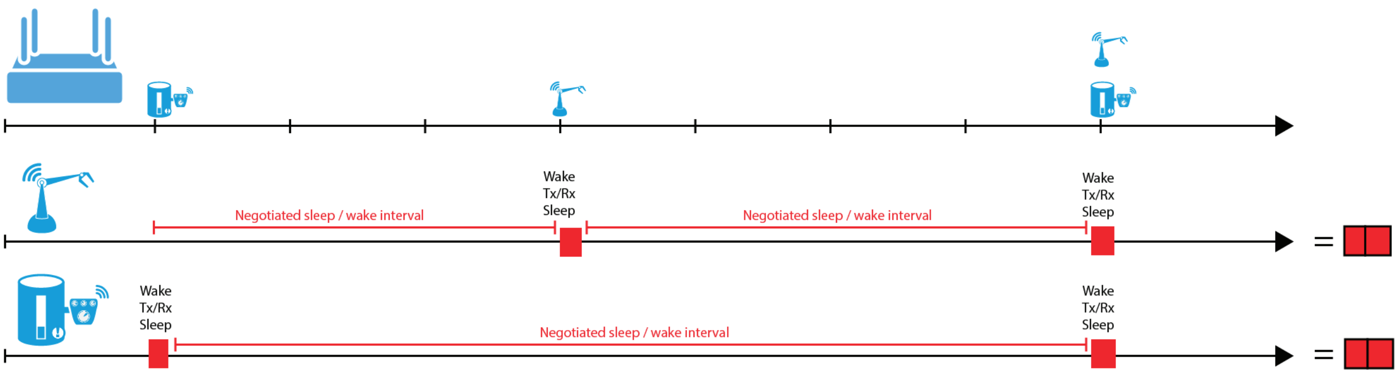
We should note that everything we have discussed here is dependent on regulatory approval of 6 GHz spectrum usage in the U.S. and around the world. Regulatory approvals for public use of 6 GHz are at various stages globally, and the Wi-Fi Alliance has been active in advocating for completion of those approvals. Once complete, this additional spectrum will ensure that Wi-Fi can continue to grow to support the number of devices relying on these networks globally.

Wi-Fi Channel Map

Note: Channel support varies by region. Channels shown are non-overlapping channels.



Sleep Negotiation with Negotiated Target Wake Time (TWT)



Energy Efficiency

Lower power consumption is another key advancement that will be vital for clinical devices. The centerpiece of Wi-Fi 6/6E's low power strategy is Target Wake Time (TWT) technology. Prior technologies like PS-Poll (DTIM) and WMM (APSD) are still supported in the new version of Wi-Fi, but most engineering teams will want to take full advantage of TWT because it enables much longer sleep times for clients that need to preserve battery through extended inactivity while still remaining connected to the network. For devices whose role can allow sleep for long periods of time, TWT dramatically improves power scheduling, extends battery life, and lowers network congestion. Additionally, TWT can be adjusted to meet individual or group device power needs rather than the whole network, providing flexibility and efficient power profiling for devices using the network. OFDMA also helps conserve battery power by enabling far faster channel access – an important way of achieving greater energy efficiency. In a medical environment, handheld analyzers and body work monitors can take advantage of TWT and be more aggressive in their power saving than a pole or bed mounted device. Since TWT is negotiated between the AP and the device, it can also be tailored to the battery condition of the connected device, prioritizing connectivity over performance.

Other Advantages of Wi-Fi 6/6E

In addition to the benefits discussed above, Wi-Fi 6/6E has a number of other advantages for hospitals. An important one is data integrity, which is a critical issue given the mobility of so many medical devices. The enhanced connectivity that Wi-Fi 6/6E delivers ensures that there is no loss of data as a patient or device moves through a hospital. Another advantage of Wi-Fi 6/6E is its ability to accommodate surges in demand for connectivity, for example when there is an influx of patients in the emergency room or during a public health emergency. The faster performance of Wi-Fi 6/6E will make it easier for transferring and accessing large medical files such as MRIs, X-rays, ultrasounds, and medical records. Performance will also be better for hospital applications that use the same Wi-Fi networks as clinical devices, including telehealth sessions, calls, and videoconferencing.

Laird Connectivity's Wi-Fi 6/6E Solutions

Laird Connectivity is the partner of choice for medical device manufacturers. Our growing portfolio of Wi-Fi 6/6E solutions, combined with our services, enable rapid deployment of products that meet the most stringent security standards and work in even the most difficult RF environments.

- **Sona IF573–This upcoming Wi-Fi 6E solution is the first of the Sona product line which is based on Infineon's leading AIROC™ CYW55573 chipset. A truly robust industrial IoT module, the Sona IF573 answers the call for next-gen wireless IoT. It is purpose built for industrial and medical IoT connectivity.**

- **Internal Antennas. Offering a range of true Wi-Fi 6E antennas covering 2.4/5/6 GHz in compact flexible packaging options with MHF1 and MHF4L connector types. The FlexPIFA 6E Flexible Adhesive-Backed PIFA delivers provides consistent performance across a broad array of environments, enclosures, and body-worn applications. The FlexMIMO 6E offers 2 x FlexPIFA antennas in a single package ideal for applications which require MIMO or Wi-Fi Diversity. The Mini NanoBlade Flex 6E is a flexible printed circuit board with peel-and-stick technology, designed to adher to the inside of a device housing.**

For more information about Laird Connectivity's Wi-Fi 6/6E solutions, visit:

https://www.lairdconnect.com/market/wifi-6-and-wifi-6e.

About the Authors

Andrew Ross is a Senior Product Manager at Laird Connectivity, where he leads the company's product development for Wi-Fi technology. He is responsible for development of Laird Connectivity solutions that help companies around the world take advantage of the next generation of Wi-Fi. Ross has more than 30 years of engineering experience in electronic design, including prominent engineering and product development roles at Silex Technology, B&B Electronics, Quatech, DPAC Technologies and Mosaic Semiconductor.

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About Laird Connectivity

Laird Connectivity simplifies wireless connectivity with market-leading RF modules, System-On-Modules, internal antennas, IoT devices, and custom wireless solutions. Our products are trusted by companies around the world for their wireless performance and reliability. With best-in-class support and comprehensive product development services, we reduce your risk and improve your time-to-market. When you need unmatched wireless performance to connect your applications with security and confidence, Laird Connectivity Delivers – No Matter What.

Learn more at www.lairdconnect.com.