Implementing Wi-Fi 5, 6, and 7 in Educational Facilities

WHITE PAPER

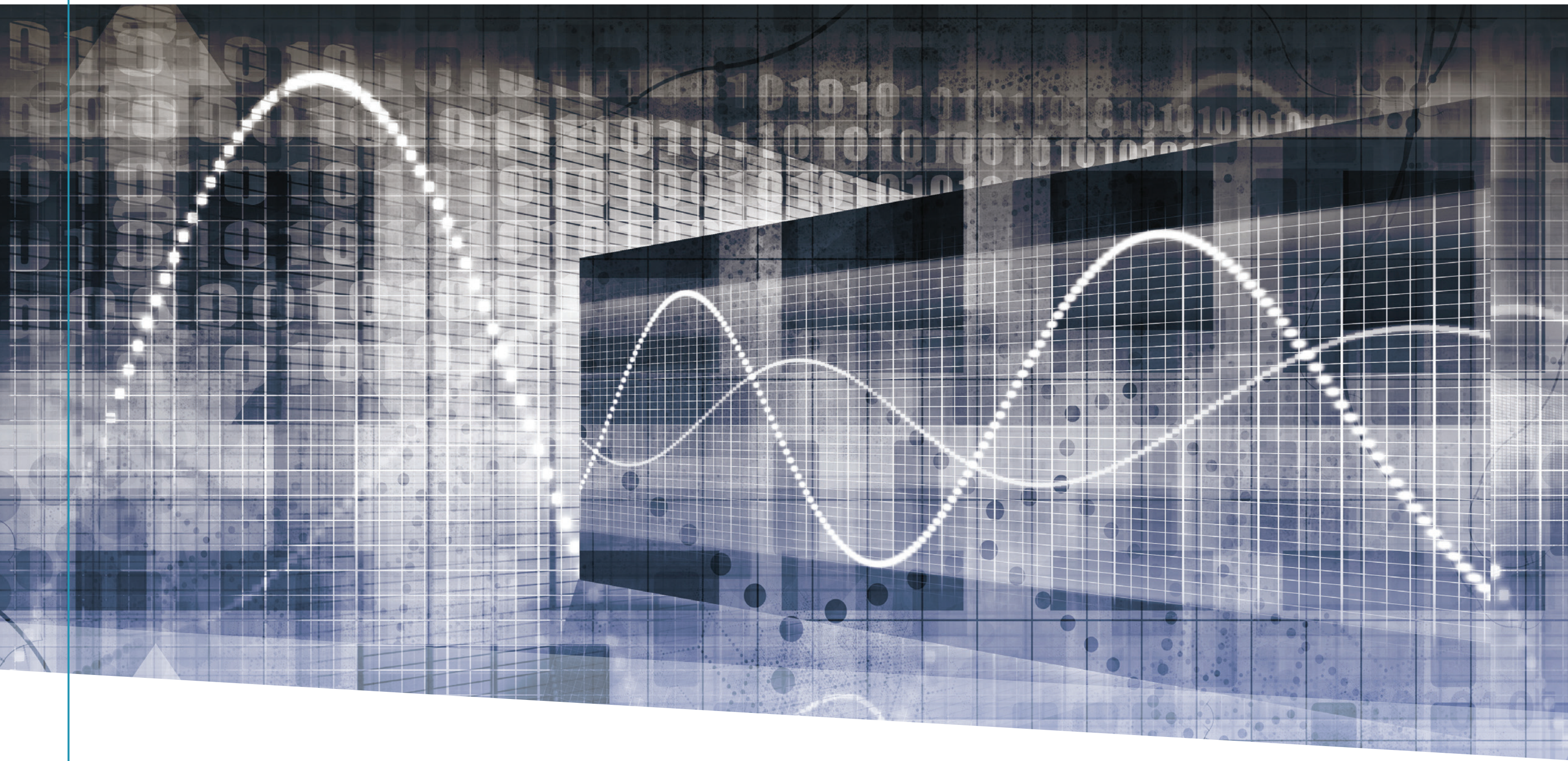
Introduction

Wireless Access Points (WAPs) have seen explosive growth within educational environments over the past few years due to the proliferation of wireless devices. WAPs have significantly increased the number of client devices they can simultaneously support from tens of clients to over 200 clients per WAP to accommodate the ever-increasing amount of client devices per person. By the year 2025, the average number of networked devices per person worldwide is expected to increase to between 6 and 10 per person.[1]

The standards and technologies supporting WAPs have also seen tremendous progress over a short period of time to accommodate this growth of wireless devices. In the span of just 10 years, wireless technology has seen 802.11n, 802.11ac (waves 1 and 2) and now 802.11ax (currently referred to as Wi-Fi 4, 5, and 6 by the Wi-Fi Alliance). Because it offers improved data rates and battery life for end devices, increased capacity and better performance in high density environments, and reduced latency, Wi-Fi 6 is poised to become the largest and fastest growing wireless standard in history.

[1]IoT: Number of Connected Devices Worldwide 2012-2015

https://www.statista.com/statistics/471264/iot-number-of-connected-devices-worldwide
https://www.cisco.com/c/dam/m/en_us/solutions/service-provider/vni-forecast-highlights/pdf/United_States_Device_Growth_Traffic_Profiles.pdf



Wi-Fi 4, 5, and 6 have seen significant improvements in the ability to accommodate more devices per access point, higher speeds for devices, and higher access point densities. While Wi-Fi 6 is not yet commonly deployed, engineers are hard at work on a next-generation Wi-Fi 7 (802.11be) which will offer significant improvements beyond Wi-Fi 6.

Figure 1 highlights the growth and decline of the different wireless access point technologies. As shown, 802.11ax (Wi-Fi 6) is expected to have both the quickest adoption of any standard and will have the largest number of units sold.

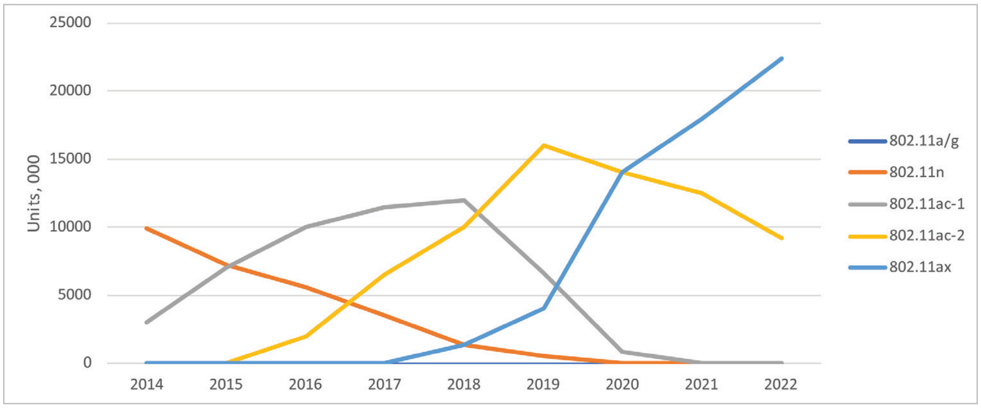


Figure 1. Growth of wireless access points. 802.11ax (Wi-Fi 6) is expected to grow larger and faster than any other standard.[2]

[2]Source: 650 Group, 2017

Although the evolution of wireless technology is continuing to progress, the depth and speed of its growth has put a strain on the underlying network and the cabling infrastructure that supports it.

The goal of this white paper is to:

- Provide an overview of the present and future wireless technologies
- Help readers understand the current Wi-Fi 6 standard and where Wi-Fi 7 may be heading
- Present detailed technical explanations about specific Wi-Fi 6 and Wi-Fi 7 features that will impact data rates and access point densities
- Give recommendations for the underlying cabling infrastructure based on this information

Wi-Fi Technology Overview

Table 1 summarizes the differences from Wi-Fi 4 to the future Wi-Fi 7.

The data rate shown in Table 1 (6933 Mbps for Wi-Fi 5 and 9607.8 Mbps for Wi-Fi 6) refers to the maximum data rate that would be required for the Wi-Fi port. This would be the case when it is providing the highest possible data rates for the maximum number of users.

Table 1. Differences from Wi-Fi 4 to Wi-Fi 7

	Wi-Fi 4	Wi-Fi 5	Wi-Fi 6	Wi-Fi 7
Traditional Name	**802.11n**	**802.11ac**	**802.11ax**	**802.11be**
Wi-Fi Alliance Certification Mark	Wi-Fi® CERTIFIED	Wi-Fi® CERTIFIED	Wi-Fi 6™ CERTIFIED	TBD
Bands	2.4 or 5 GHz	5 GHz only	2.4 GHz and 5 GHz Compatible with 6 GHz range	2.4, 5, and 6 GHz
Data Rates (Theoretical Maximum)	576 Mbps	6933 Mbps	9607.8 Mbps	> 10 Gbps
Spatial Streams	4	8 (theoretically unlikely to exceed 4)	8	TBD
Beamforming	Yes	Yes	Yes	Yes
Cabling Requirements	Category 6	Category 6A	Category 6A	2x Category 6A
PoE Requirements (Full Featured Access Point)	No restrictions w/802.3af PoE	No restrictions w/802.3at PoE+	Yes	Yes
PoE Requirements (Enhanced Featured Access Point)	—	—	No restrictions w/802.3bt PoE++	2x Category 6A

Note:

1) Restrictions are user programmable in Intelligent Power Management (IPM) enabled WAPs
2) An enhanced featured access point is targeted for very high-density environments like large public venues, hotels, and enterprise offices where the optional features within the access point are enabled to support this type of setting

Category 6A Cabling Required for Wi-Fi

Category 6A cables are the fastest-growing cabling segment on the market and are recommended for wireless deployments because they are required for 10GBASE-T and have optimal PoE performance. For best practice, Panduit recommends Category 6A cables for Wi-Fi 5 and higher.

Wi-Fi 7 and the Future

The next generation Wi-Fi 7 is currently referred to as extremely high throughput (EHP) and a standard is being developed by the IEEE 802.11be Task Force. While Wi-Fi 6 and Wi-Fi 7 currently can only operate in the 2.4 and 5 GHz spectrums, the FCC plans to allow a new spectrum between 5.925 and 7.125 GHz to open up for Wi-Fi. This new spectrum has 1200 MHz of additional bandwidth as compared to the existing 500 MHz bandwidth in the 5 GHz spectrum and 90 MHz bandwidth in the 2.4 GHz spectrum. In addition to the new bandwidth, the IEEE 802.11be Task Force is exploring Wi-Fi 7 technologies such as coordinated orthogonal frequency-division multiple access (OFDMA), coordinated null steering, and distributed MIMO to enhance beam forming and employ massive multiple-input and multiple-output (MIMO).

The 802.11be Task Force has a stated objective to use two Category 6A cables per access point to support the required bandwidth and to use an existing and common cable type.

Improvements from Wi-Fi 5 to Wi-Fi 6

Wi-Fi 6 Advantages

Wi-Fi 6 has the following advantages over Wi-Fi 5:

- **End device data rates improved speed of up to 4x.** OFDMA, beamforming, and improved modulation allows for improved data rates for end devices
- **Increased capacity.** OFDMA, improved MIMO, and beamforming help improve total capacity
- **Improved performance in environments with many devices.** Beamforming and utilization of the 2.4 GHz band helps with IoT devices
- **Increased battery life for end devices.** Wi-Fi 6 employs a “target wake time” (TWT) feature where it tells the Wi-Fi radio when to sleep and wake up to receive its transmission. This reduces power consumption with no impact on performance
- **Reduced latency to under 1 ms.** Improved latency performance with the use of OFDMA

Three key technologies that enable many of these abilities are OFDMA, increasing the number of bands, and beamforming. Increasing the number of bands and beamforming allow for better access point density.

Bands

Bands are the specific frequency range within the unlicensed spectrum in which the access point operates. Wi-Fi 5 uses the 5 GHz range, while Wi-Fi 6 can operate at the 2.4 GHz range and 5 GHz range with the potential to operate at the 6 GHz range. Wi-Fi 7 will operate at the 2.4, 5, and 6 GHz range.

Operating in multiple frequency ranges gives Wi-Fi 6 and Wi-Fi 7 the ability to service more users and have the potential for access point higher density. Additionally, transmission at the 2.4 GHz frequency allows for longer wavelengths which are better for penetrating solid objects such as walls and floors.

OFDMA versus OFDM

One of the biggest improvements incorporated into Wi-Fi 6 is the addition of OFDMA, which provides a 4x improvement in throughput, decreasing latency to 1 ms and enabling a much more efficient network. A simple way to think about the differences between OFDMA and OFDM is to explore the example of a semi-truck loaded with pallets. With Wi-Fi 5, the pallets were only packed with a single product. Typically, not all the pallets were filled to capacity with the single product. With OFDMA, products can be combined on the pallets, filling the semi with more products. Therefore, high bandwidth users would get extra bandwidth allocated from the low bandwidth users.

Figure 2 gives an example of the differences between OFDM versus OFDMA.

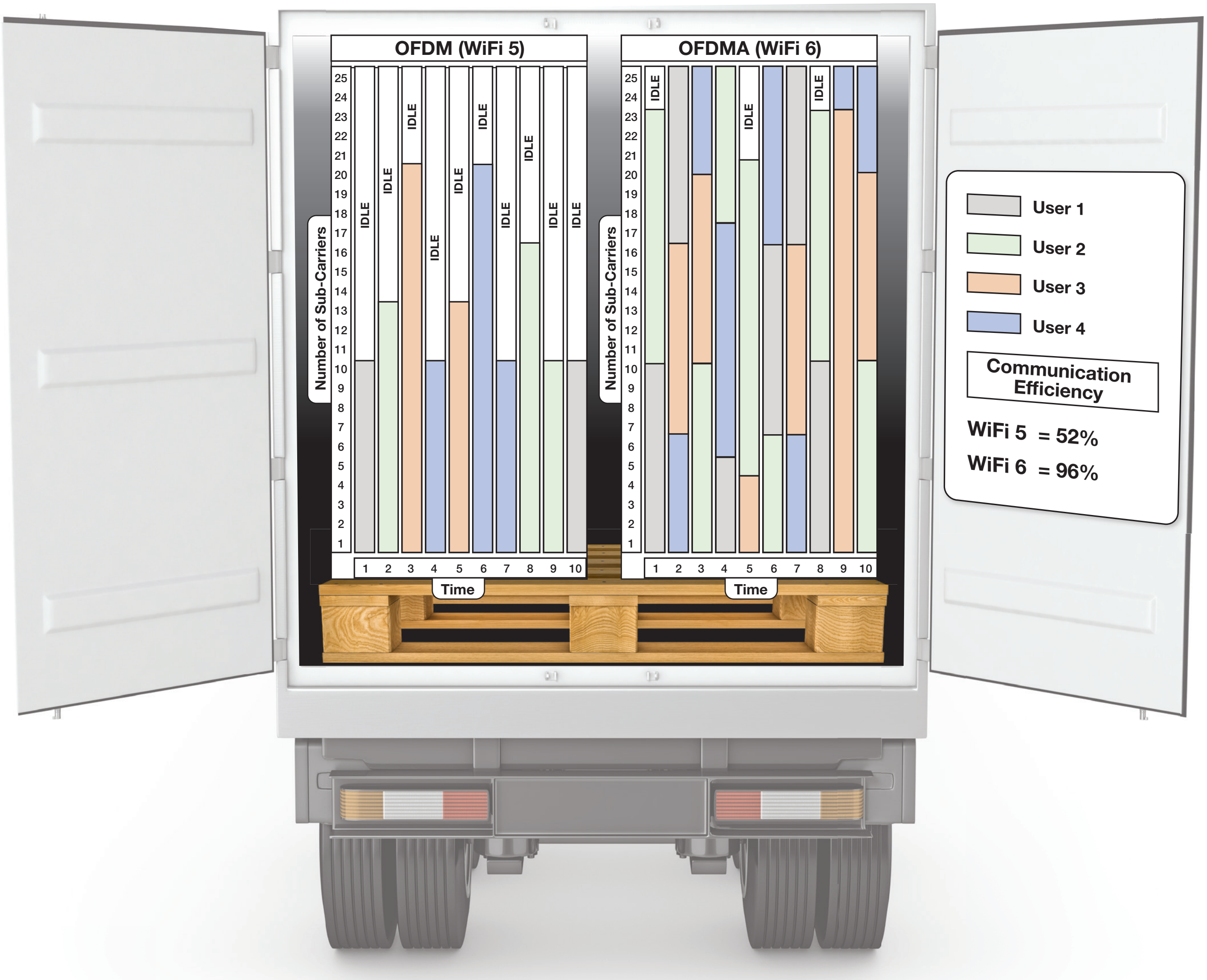


Figure 2. OFDMA in Wi-Fi 6 allows for more efficient use of bandwidth versus OFDM, as visualized by pallets in a truck. This improves throughput while reducing latency.

Beamforming and Spatial Streams

Beamforming shapes the radiation pattern of a multi-antenna WAP to focus the energy towards a client device(s) that they are communicating with as shown in Figure 3 (LTE Quick Reference – BeamForming). This is accomplished by modifying the phase of the signal from each antenna to cause constructive and destructive interference to occur (creating the “beams”). This allows improved signal strength (by as much as 3dB) at those devices which can be used for a higher data rate, a longer reach, and/or to spatially discriminate between client devices.

Beamforming technology enables an increased density of wireless access points, because it decreases the chances for contention from neighboring access points. A spatial data stream is an encoded communication data signal where multiple streams can be discriminated from each other at a receiver via an orthogonal code word(s). Each antenna can support one spatial stream and multiple streams can be transmitted within a beam. Both Wi-Fi 5 and Wi-Fi 6 can theoretically support up to eight spatial streams, though in practice Wi-Fi 5 implementations are only expected to use four. Multiple spatial streams can be aggregated at the receiver to linearly increase the data rate by the number of streams it receives. The higher the number of spatial streams, in addition to the increased data rate, allows the density of Wi-Fi 6 access points to be higher than the density of Wi-Fi 5 access points.

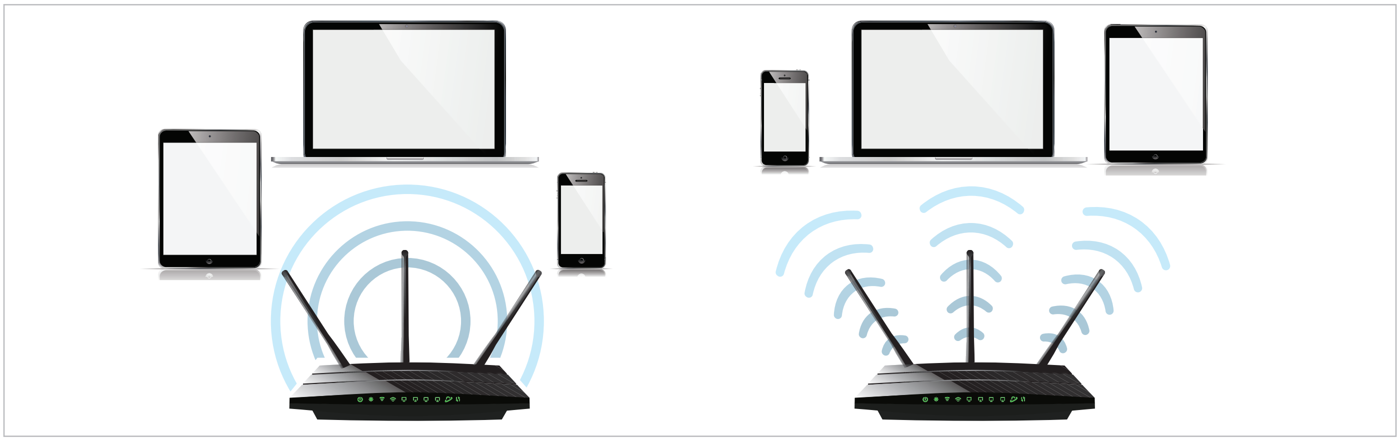


Figure 3. Example of beamforming with one spatial stream (left) and three spatial streams (right)[3].

What About 5G?

There has been some speculation that 5G is going to replace Wi-Fi because it will offer speeds and reliability similar to Wi-Fi. Rather than supplanting it, 5G is expected to be similar to prior cellular generations in that Wi-Fi will continue to be the network of choice within Enterprise indoor networks.

Bandwidth

Wi-Fi operates within the unlicensed spectrum. It has about 90 MHz of bandwidth within the 2.4 GHz region, about 500 MHz of bandwidth in the 5 GHz region, and about 1200 MHz of bandwidth in the 6 GHz region for a total bandwidth of about 1790 MHz. 5G operates in the licensed mobile spectrum where each carrier is allocated its spectrum and will have bandwidth at approximately 200 MHz. A comparison is shown in Figure 4.

Bandwidth available in:
BLUE = 2.4 GHz region, **GREEN** = 5 GHz region, **PURPLE** = 6 GHz region, **BLACK** = approximate 5G region

Figure 4. Comparison of available bandwidths of Wi-Fi and 5G.

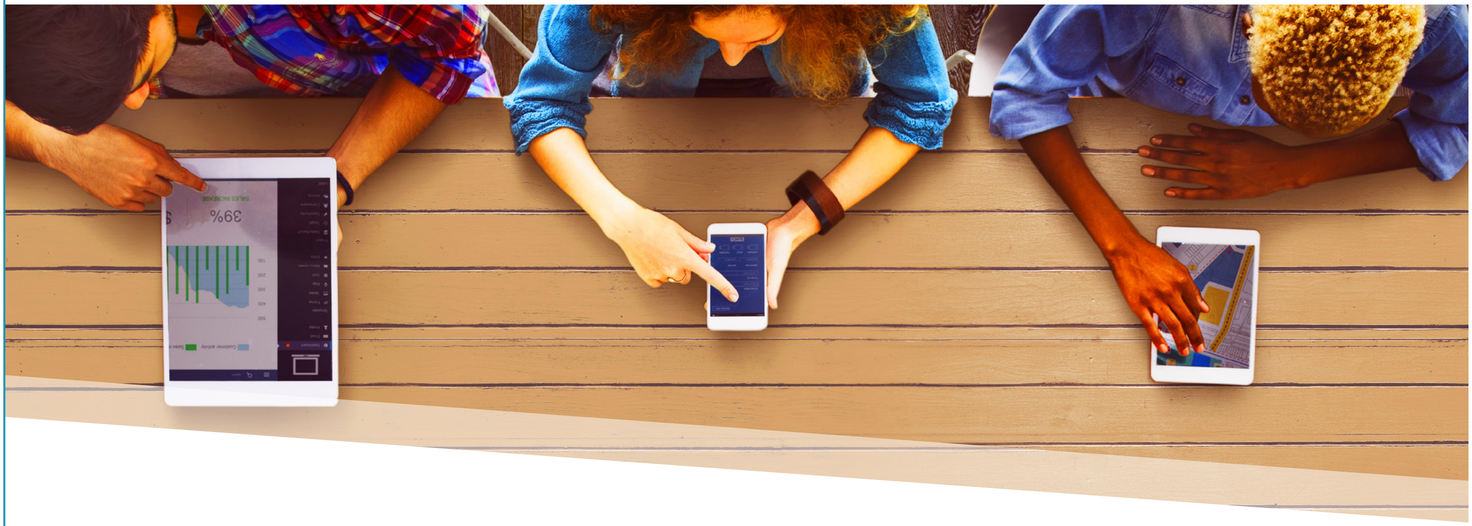
Capacity

The real key differentiator between 5G and Wi-Fi is capacity. Wi-Fi will still be preferred in areas with high user density (e.g., lecture halls, stadium, or residence halls with many networked devices). The capacity of a wireless system can be measured in its data rate density (i.e., $Mb/s/m^2$). For Wi-Fi 6 it is estimated to provide about 400 $Mb/s/m^2$. 5G is estimated to be about 10 $Mb/s/m^2$. One of the biggest reasons for the capacity difference is the fact that Wi-Fi has a much larger bandwidth available.

Indoor Networks

An indoor 5G network is expected to require an active DAS network where the cabling of choice is structured LAN cabling. This means it will need products like indoor small cells, 5G indoor radio units, a baseband to radio connect, and a core network connection. Its products will need to be duplicated for each carrier that the building wants to support indoors and typically requires a substantial investment.

[3]"LTE Quick Reference – BeamForming." ShareTechnote. 2019.



Wi-Fi is universal and can work with all devices rated for that type of wireless device. Therefore, on indoor networks, Wi-Fi is expected to be much less expensive to implement for universal coverage. With the rise of interest in Voice over Wi-Fi (VoWiFi), it is expected that Wi-Fi will tend to dominate in the enterprise indoor market.

Based on these factors, it is expected that the percentage of traffic offloaded by mobile devices to Wi-Fi from the cellular network will *actually increase* from 54% in 2017 to 59% in 2022. Offloading relieves the congested mobile data networks with additional capacity. With 5G entering the market, the offload could *further increase* to 71% by 2022.

Therefore, it is expected that 5G and Wi-Fi will coexist for the foreseeable future.

Impact on Cabling Design

Designing a robust cabling plant for Wi-Fi 6 and beyond is critical to ensure that:

1) The cable plant is designed to accommodate present and future data rates and PoE requirements
2) The cable plant has a future-proofed design to ensure that you can receive the maximum lifespan and ROI from your investment

Key information shared in this document includes:

1) Wi-Fi 6 of today will have data access needs up to almost 10 Gbps
2) Wi-Fi 6 and beyond will improve technologies such as beamforming and increased bandwidth over multiple bands to allow increased densities of access points
3) Future Wi-Fi technologies like Wi-Fi 7 are projected to exceed 10 Gbps, so Panduit recommends two Category 6A cables per access port to support data rates up to 20 Gbps

The first implication is that Category 6A is the standard, due to its superior ability to handle PoE and its ability to run data rates up to 10GBASE-T.

The second implication is that future Wi-Fi technologies may require at least two Category 6A cables to handle the necessary data rates beyond 10 Gbps.

The third implication is that due to technologies like beamforming, these access points may need to be spaced closer to each other and will see increased density. Therefore, an additional two Category 6A cables are recommended to handle the added wireless access points running at rates above 10 Gbps.

Based on these implications, the recommendation would be to run at least four Category 6A cables to each access point. Figure 5 highlights the Day 1, Day 2, and Day 3 usage of the four cables.

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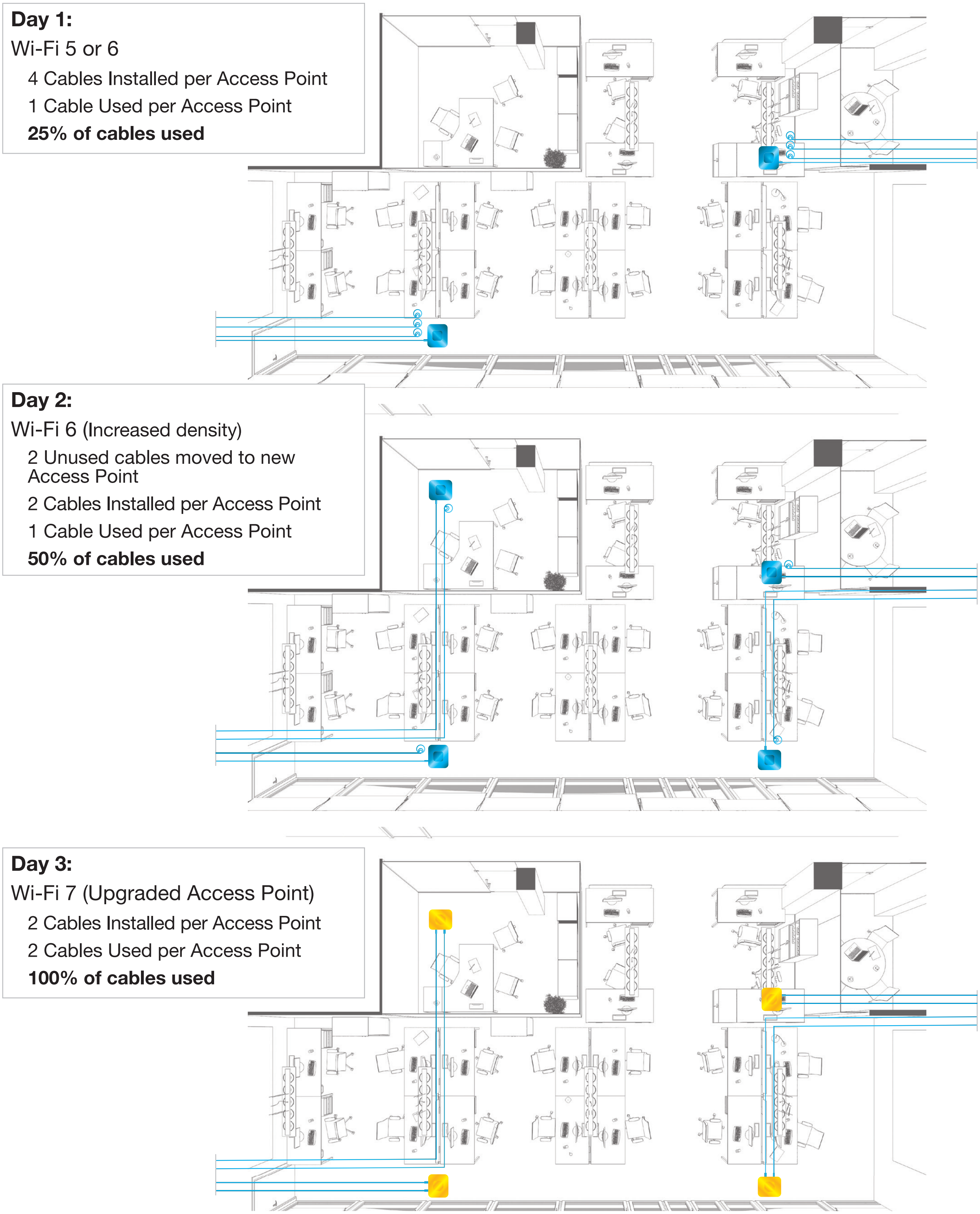

Figure 5. Example of four cables per access point being used to increase density (Day 2) and to support port aggregation for upgraded access point performance (Day 3), all using the same cabling infrastructure installed on Day 1.

The Cost of Running a Cable Today Versus Tomorrow

Currently, installing up to four cables where only one cable is initially used may be difficult to justify. However, having the cable already installed makes it easier, quicker, and cheaper to increase access point density or provide link aggregation when needed.

It is much more expensive to add cables when the walls are up and the building is occupied because additional costs are incurred. This includes an extra site visit charge, more time for installation because running these new cables is more difficult and time consuming, and overtime pay.

Table 2 gives the estimated costs for different installation options of four cables. The estimated costs are much more dependent on bringing in the labor to do the installation, rather than the cost of the physical cable. As shown, the total expense is less costly to put in all the cables up front.

Table 2. Cable Installation Options and Relative Costs

Option	Description	Initial Cost	Upgrade Cost	Total Cost
1	4 cables today	$200	$0	$200
2	2 cables today, 2 cables on Day 2	$100	$1,000	$1,100
3	1 cable today, 1 cable on Day 2 2 cables on Day 3	$50	$1,500	$1,550

Conclusion

Wi-Fi 6 and beyond will provide another leap in wireless technology and will require a Category 6A infrastructure that can run 10GBASE-T and PoE. (For additional information on cabling requirements to support Power over Ethernet, see Power over Ethernet with Panduit Copper Cabling.) These new wireless standards will use increased bandwidth and improved beamforming to allow for increased data rates and higher densities. Wi-Fi 7 and beyond will likely see data requirements past 10 Gbps and will require at least two Category 6A cables.

Planning a future-proof cabling infrastructure for supporting wireless standards up to Wi-Fi 7 means following the below recommendations:

- **Cable Type:** Category 6A cables to provide optimum PoE performance and to support data rates up to 10GBASE-T
- **Minimum Requirements:** Two Category 6A cables per access point to allow for speeds up to 20 Gbps with link aggregation
- **Additional Recommendations:** An additional two Category 6A cables per access point to allow for increasing the wireless access point densities
- **Save Money by Installing Today:** Installing links on Day 1 = $35 to $50; Day 2 = $500 or more

In summary, Panduit recommends that you run a minimum of two Category 6A cables per access point with up to four Category 6A cables per access point to cost effectively accommodate future speeds and increases in access point density. This will maximize ROI and ensure a robust cable plant with a long lifetime.

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