infrastructure for a connected world

The Best of Both Worlds:
Wired and Wireless Connections

Introduction

A fast and reliable wireless network has become a requirement for commercial buildings. People are using wireless for just about everything, including wireless sensors to monitor different areas, offloading cell phones from the cellular network onto Wi-Fi, and as the primary office network.

People want to deploy Wi-Fi 6 with the understanding that it provides the necessary user experience both today and into the future. Wi-Fi networks that are slow and unreliable can lead to unhappy employees and customers. Wi-Fi 6 (IEEE 802.11ax) offers to further improve the wireless experience through features like higher data rates, better capacity, enhanced performance in areas with many devices, and improvements in latency.

Panduit has conducted experiments that prove when a wireless network is deployed along with a wired network, it delivers an improved and future-proofed wireless experience for everyone. The following observations and recommendations will be further explained throughout the document:

- **Improve the Wi-Fi network performance with a wired network**
  A structured cabling network that can off-load traffic onto a wired network will improve the Wi-Fi network by at least 40%
- **Future proof the Wi-Fi network with a wired network**
  As data rates increase and more clients come onto the network, a joint wireless and wired network will have a longer life as more devices are added to it
- **Power over Ethernet (PoE) is cost effective compared to other power options**
  PoE is the most cost-effective way to run power and data in a greenfield or brownfield environment, including the use of wireless
- **Avoid battery powered devices when possible**
  A complete wireless deployment may be cheaper upfront but cost more in the long run. Batteries eventually die and need replacement whereas a wired connection will last for many years

This white paper provides the methodology and metrics used to make these claims. Also, it offers a cabling recommendation for wired connections used in conjunction with a wireless network.

Wired is Best Practice

People often like installing wireless devices as it is viewed as the simplest and lowest cost method to support clients. However, the actual cost of a wireless network may be more hidden than the wired one. Hidden wireless costs can be in up front cabling costs as well as costs incurred after the network is running.

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Wireless Network Only vs. a Wired/Wireless Network

Many environments are conducive to having devices on both wired and wireless networks. For example, in many offices people may have a mobile phone on a wireless network and mobile laptops will be on the wireless network. When at the desk charging, these devices will be on the wired network and employees that need serious computing power will use a desktop on a wired network.

This section will analyze the impact of offloading devices from the wireless to the wired network.

Scenario for Analysis

In this case we examine the scenario shown in Figure 1 with 36 users, each with two devices (72 total devices). There is both a one Wi-Fi 6 access point and a three Wi-Fi 6 access point network configuration. For the scenario with one access point, the 72 devices are done in three different distances in concentric circles eight (16 devices) at 10 meters, 11 (22 devices) at 25 meters, and 17 (34 devices) at 40 meters. For the scenario with three access points, the 72 devices are spread out in two distances from the multiple access points.

This attempts to approximate people evenly spread out from the access point, each with two devices (a computer and a cell phone). The analysis is done at the worst-case point of the outer ring, which will have the worst performance as it is the furthest away.

It is also assumed in this scenario that for the devices at the outer ring distance, the wireless access point is performing at a factor of eight below its theoretical maximum data rate. Items that can cause this amount of degradation include:

- Distance between access point and source
- Reflections caused by objects and walls
- Interference from other wireless devices or neighboring access points

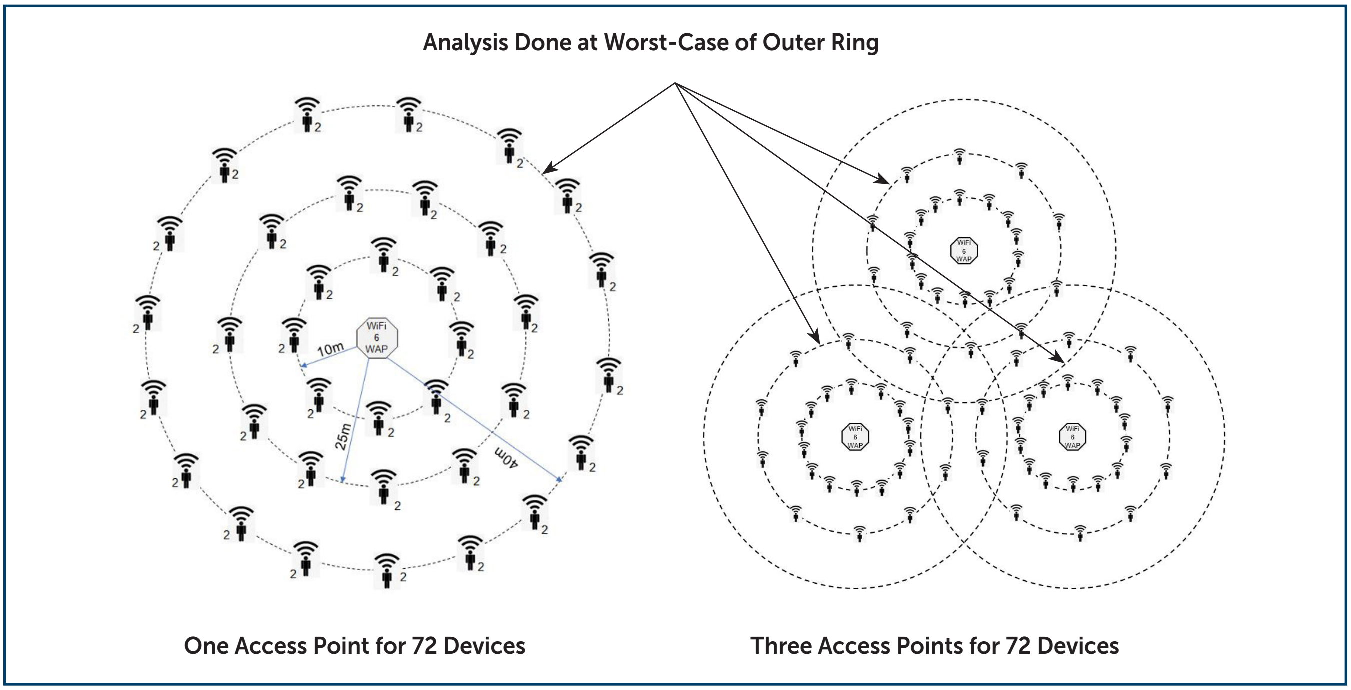


Figure 1. One and three access point scenarios for 72 devices. Analysis will be done at the outer ring (worst-case as it is the furthest away from the access point).

User Profiles

The user profiles in Table 1 were developed to understand network data rate demands. For the analysis done, high-end and middle user types were used.

Table 1. User Profiles Developed for Analyzing Network Demands.

User Type	Down Stream User Profile	Example Users
High-end	Mean DR = 5 Mb/s Burst DR = 500 Mb/s (for 5s) occurring every two minutes	Engineer, 4K video streaming, hospital imaging file transfers, programmers, and developers
Burst DR = 500 Mbps (for 5s) occurring every 2 minutes	Mean DR = 1 Mb/s Burst DR = 250 Mb/s (for 5s) occurring every five minutes	Engineer, 720p video, office worker with extensive network drive usage
Middle	Mean DR = 0.1 Mb/s Burst DR = 100 Mb/s (for 5s) occurring every 10 minutes	Office employee with primarily email, minimal network drive usage, some web browsing

Performance Metrics

To quantify a network's performance, two main criteria were considered:

- The probability that simultaneous requests occur
- Performance Ratio = (Actual Bandwidth Available)/(Required Bandwidth)

In this case, we would want to:

- Minimize the simultaneous requests that occur
- Achieve a Performance Ratio > 1 (meaning the actual bandwidth available is larger than the required bandwidth to support multiple simultaneous data requests)

Simulation Method

For cases where the 72 clients were offloaded onto the wired network, the clients were offloaded evenly from each ring as shown in Figure 2.

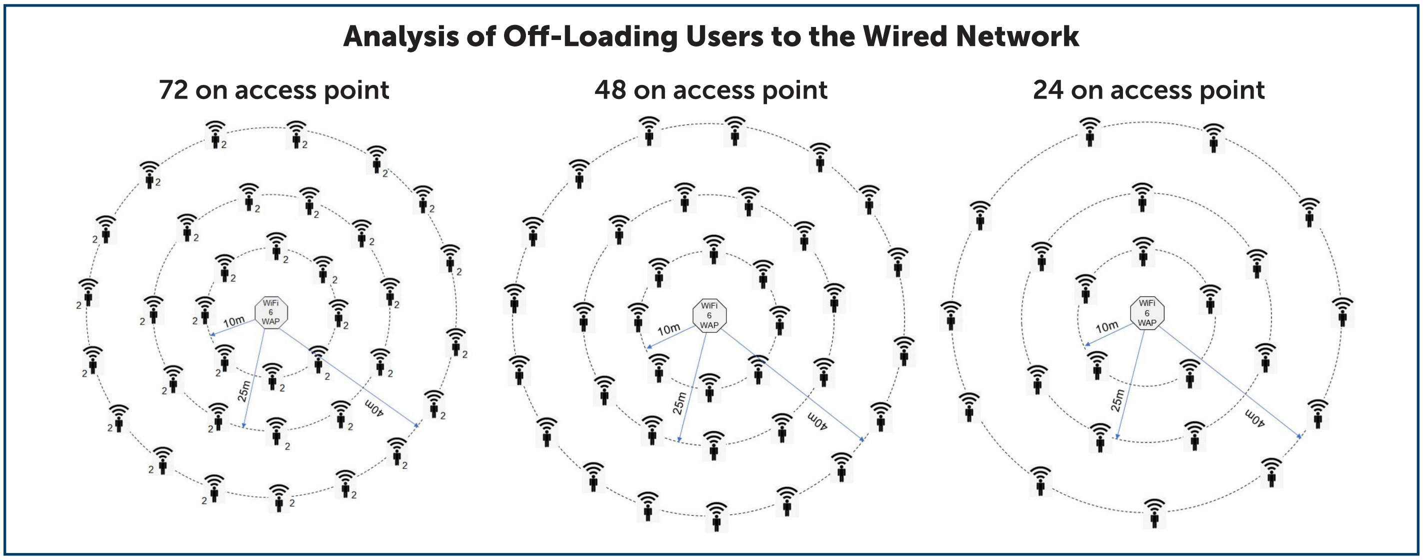


Figure 2. Example of how the wireless analysis was done with people evenly off loaded onto the wired network.

The analysis was done by looking at the time period of the bursting (i.e., short periods of heavy data usage) data requests from the clients (i.e., two minutes). The exact time when a burst of data was requested from a client was assumed to be random amongst the number of clients as shown in Figure 3.

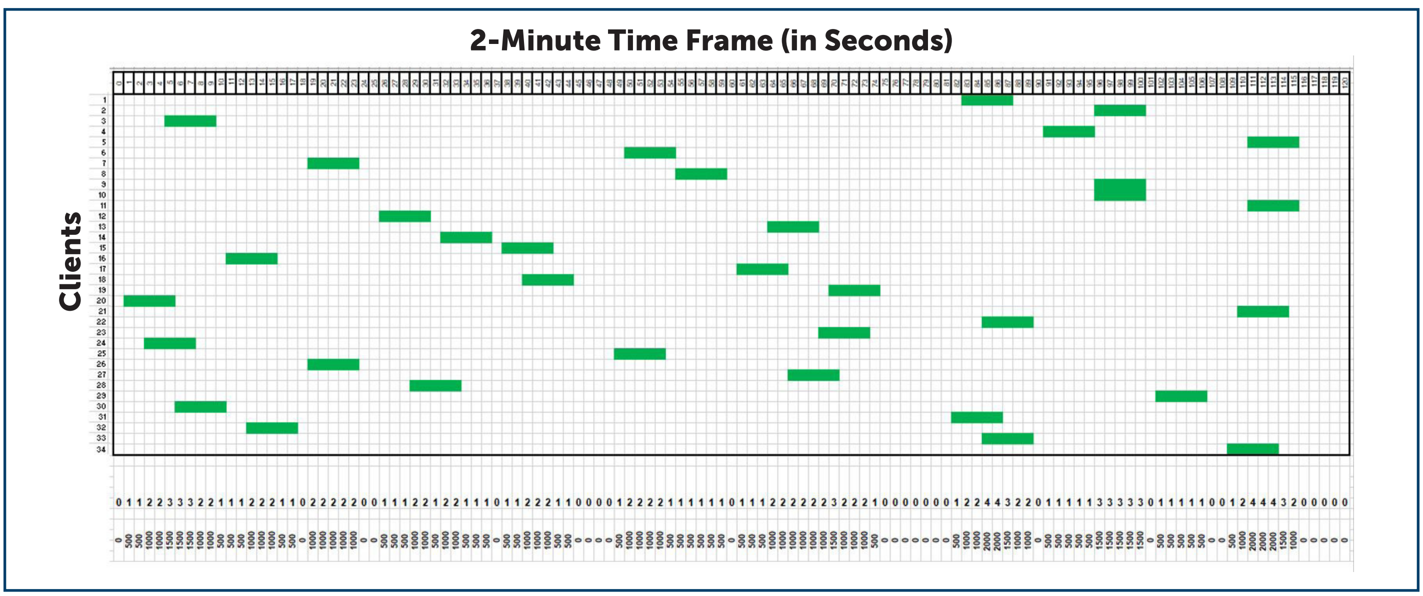


Figure 3. Two-minute probabilistic model used for analysis (34 clients).

Simulation Method — *(Continued)*

The probabilistic model was then summarized looking at the amount of overlap, showing the probability of simultaneous requests as shown in Figure 4.

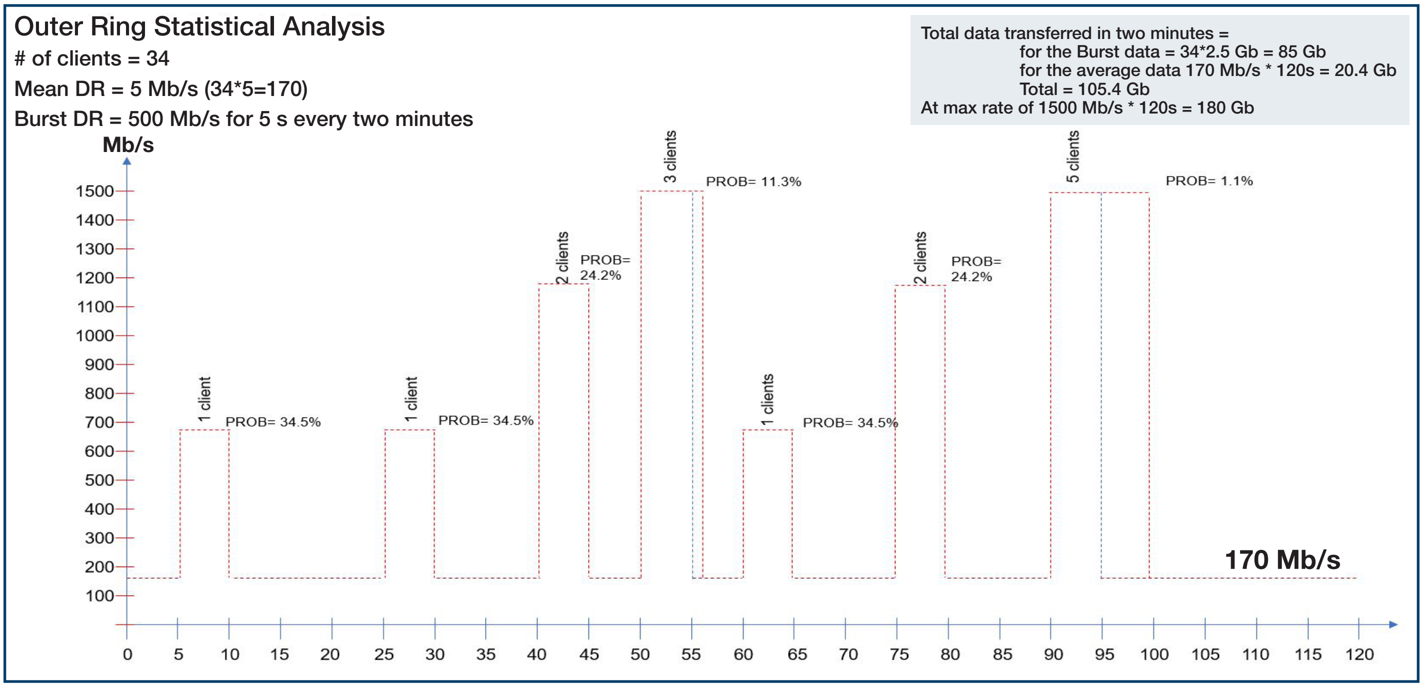


Figure 4. Outer ring statistical analysis summary.

Summary

The summary of the performance of the network when offloading to the wireless network is shown in Table 2 and Table 3.

The second column in Table 2 (“Clients on Access Point”) refers to the number of clients being served by the wireless access point (WAP) and the third column (“Clients on Wired”) refers to the number of clients being served by the wired network. The fourth column (“Performance Ratio [High End]”) evaluates the ratio between the actual bandwidth the WAP is capable of supplying divided by the needed bandwidth that the “High-End” clients need or require. Ideally a number above 1 is desired. The fifth set of columns (“Probability of Simultaneous Clients”) refers to the probability that 0, 1, 2, 3, 4, or 5 different clients will be simultaneously trying to access the wireless network.

When multiple clients simultaneously require service, the clients received data rate may be reduced due to the capacity of the WAP. As shown in Table 2, the fewer the number of wireless clients being served by the WAP, the lower the probability of simultaneous requests for service. Furthermore, the probability of simultaneous requests is reduced as the number of simultaneous clients is reduced. It is desirable to have no simultaneous clients requesting service, and hence it is desirable to have higher probabilities at 0 simultaneous requests. As shown in Table 2, only scenario 1-4 is reasonable.

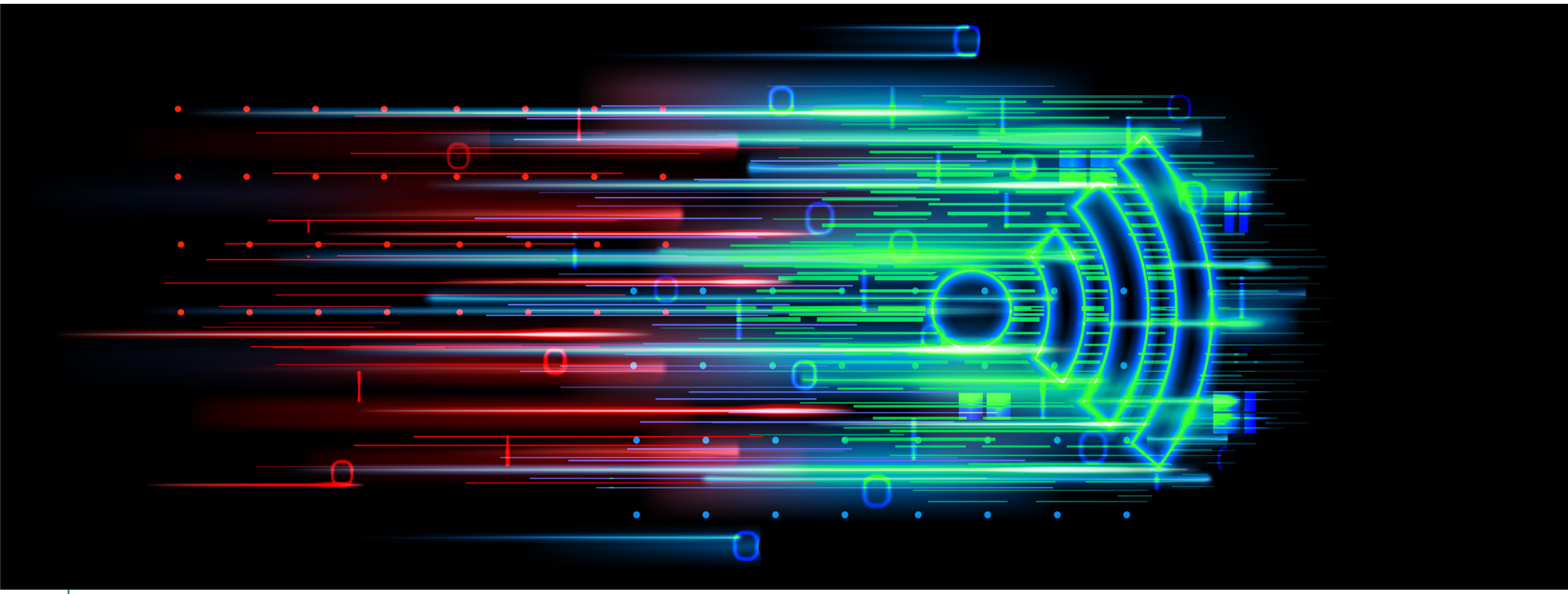
As more WAPs are integrated into the wireless local area network (LAN), as described in Table 4, the network performance is greatly improved. As shown in Table 4, scenario 3-4 has a great network performance, having a performance ratio > 4. The number of simultaneous client request for service is less than 12% and when a simultaneous event takes place, there is plenty of bandwidth available to support this event with no increase in delay.

Table 2. One Wireless Access Point Scenarios for 34 High-End Clients on the Outer Ring. These Scenarios Assume 20 20MHz Channels and Four Spatial Streams.

Single Access Point Scenario	Clients on Access Point	Clients on Wired	Performance Ratio (High End)	Probability of Simultaneous Clients					
				0	1	2	3	4	5
1-1	72	0	0.43	26%	32%	25%	11%	4%	1%
1-2	48	24	0.63	38.1%	37.5%	17.3%	5.6%	1.2%	0.2%
1-3	36	36	0.85	50%	35%	12%	3%	0.4%	0.1%
1-4	24	48	1.32	63%	29%	7%	0.8%	0.1%	0.01%

Table 3. Three Wireless Access Point Scenarios for 34 High-End Clients on the Outer Ring. These Scenarios Assume 7 20MHz Channels and Four Spatial Streams.

Three Access Point Scenario	Clients on Access Point	Clients on Wired	Performance Ratio (High End)	Probability of Simultaneous Clients					
				0	1	2	3	4	5
3-1	72	0	1.2	65%	28%	6%	0.9%	0.01%	0%
3-2	48	24	2.0	77.5%	20.2%	2.3%	0.1%	0%	0%
3-3	36	36	2.4	81%	17.6%	1.4%	0.1%	0%	0%
3-4	24	48	4.04	88%	11%	0.7%	0%	0%	0%



Summary — *(Continued)*

Table 4 and Table 5 summarize and highlight the network performance improvements in the above scenarios. The case where 1/3 of the devices are offloaded is highlighted because it is a reasonable amount of clients to offload from a network (assume 50% of devices are phones and the remainder are computers, some of which are mobile on the network and some people are at their desks plugged into the network).

As can be seen, moving 1/3 of the clients to a wired network in this case improves the performance ratio for the one and three access point scenarios by 46.5% and 67.7%, respectively, and increases the chance that there are no simultaneous clients by just over 12% in both cases.

Putting clients onto a wired network can be as simple as ensuring that when people return to their desk and plug their laptop and charge it, that action also connects the laptop to the wired network. Many laptop docking stations support this functionality.

Table 4. Improvements in wireless network performance for the scenario with one access point by moving clients to the wired network. The 33% line represents a reasonable number of clients to offload to the wired network.

One Access Point Scenario	Percentage of Clients on Wired	Improvement in Performance Ratio	Increase in Probability of Zero Simultaneous Clients
1-1	0%	—	—
1-2	33%	46.5%	12.1%
1-3	50%	97.7%	24%
1.4	67%	207%	37%

Table 5. Improvements in wireless network performance for the scenario with three access points by moving clients to the wired network. The 33% line represents a reasonable number of clients to offload to the wired network.

Three Access Point Scenario	Percentage of Clients on Wired	Improvement in Performance Ratio	Increase in Probability of Zero Simultaneous Clients
3-1	0%	—	—
3-2	33%	67.7%	12.5%
3-3	50%	100%	16%
3.4	67%	238%	23%

Wired and Wireless: A Future Ready Network

In the scenario with three access points, the 3-1 scenario (0% on wired) has a performance ratio above one, which indicates that it already has sufficient bandwidth. However, one other element to consider would be the impact of adding future devices onto the network (e.g., a growing office where more people are coming onto the network with their own devices).

Figure 5 shows the network performance of three access points for different percentages of clients offloaded to a wired network. The numbers below show the total number of clients on the joint wired and wireless system while maintaining the performance ratio greater than one.

- 0% on wired: 76 clients
- 17% on wired: 90 clients
- 25% on wired: 97 clients
- 33% on wired: 110 clients
- 40% on wired: 120 clients

As shown, offloading 33% of the network onto the wired network could support up to 110 clients versus only 76 with 0% on the wired network. That is an increase of 34 devices (45% more). Hence, the joint wired and wireless network offers improved future proofing.

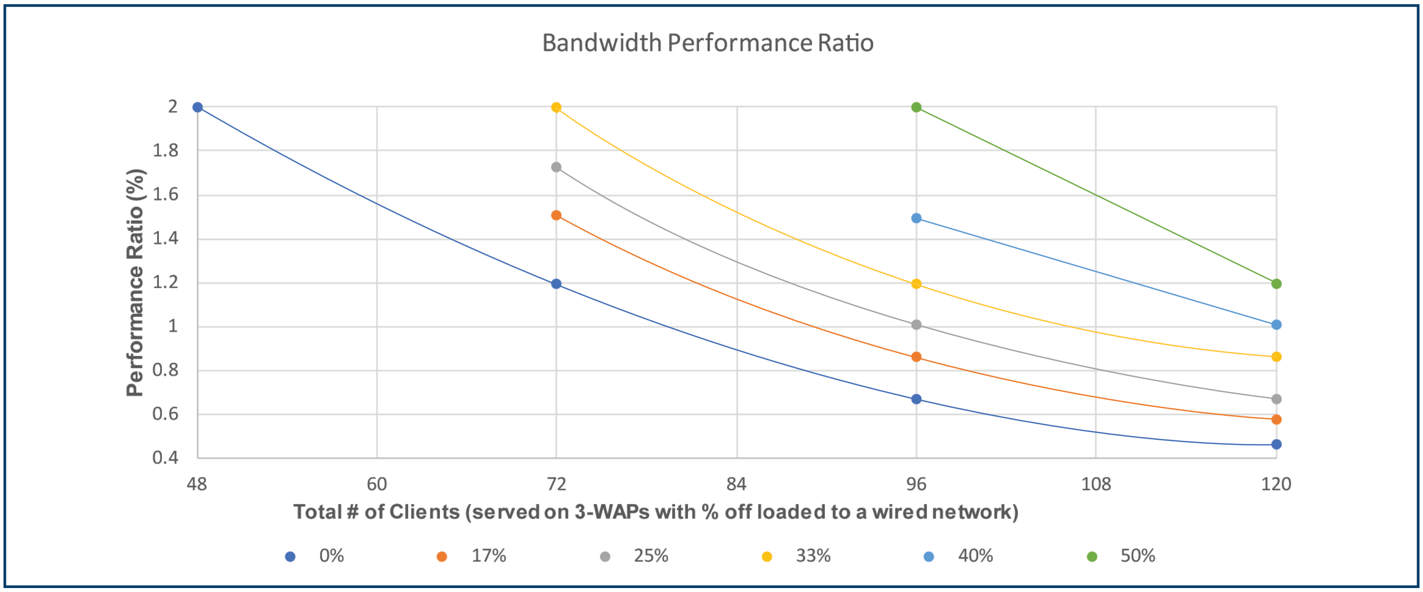


Figure 5. Three wireless access point network performance for different percentages of clients offloaded to a wired network for an increasing number of clients.

Run Less Wires with PoE vs. Wireless

PoE can deliver power and data over a single cable. Figure 6 illustrates how a wireless network actually requires more wires than a PoE installation. In this case, the wireless network requires four power wires and one data cable, whereas the PoE scenario only requires three data cables. It should also be noted that the cabling for wireless gets more expensive with more devices as low voltage cables are cheaper to install than power cables.

An estimate of cost savings is given in Table 6. As shown, installing more power drops ($200 per drop) will make the wireless network more expensive than installing more low voltage drops ($50 per drop) for the PoE network. This analysis assumes a greenfield installation where the power outlets are not currently available.

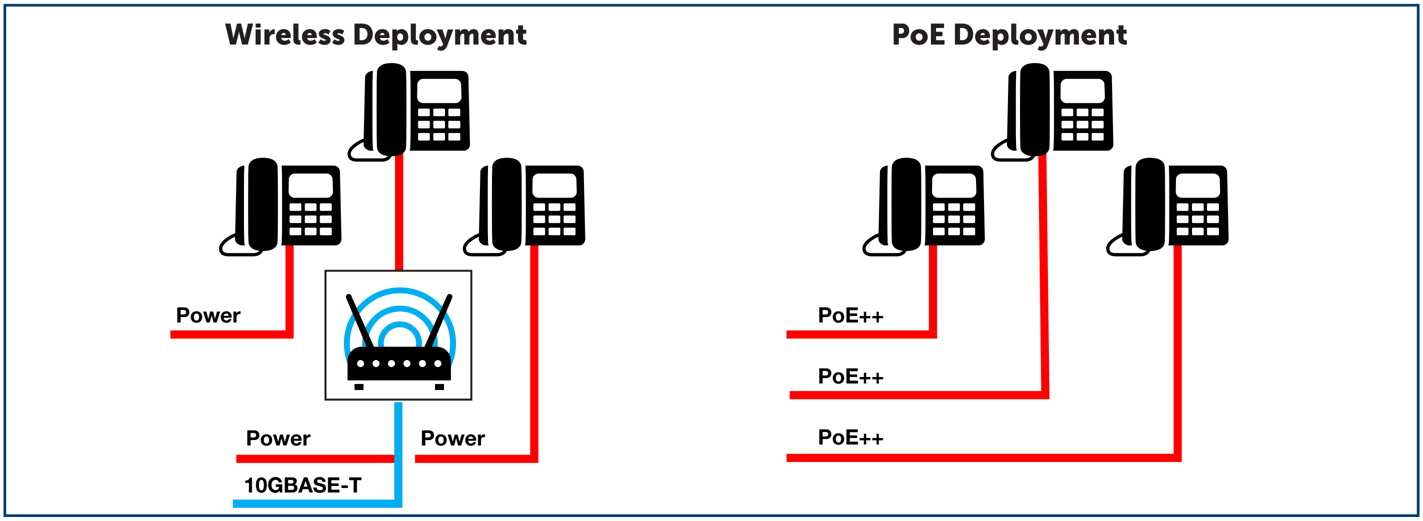


Figure 6. A PoE deployment requires three wires versus five wires with a network running off standard electrical outlets.

Table 6. Simple Three Device Example of Cabling Cost Savings with PoE.

Scenario (three devices)	Power Drops	Low Voltage Drops	Total Cost
Wireless	4 ($200 x 4 = $800)	1 ($50)	$850
PoE	0 ($0)	3 ($150)	$150

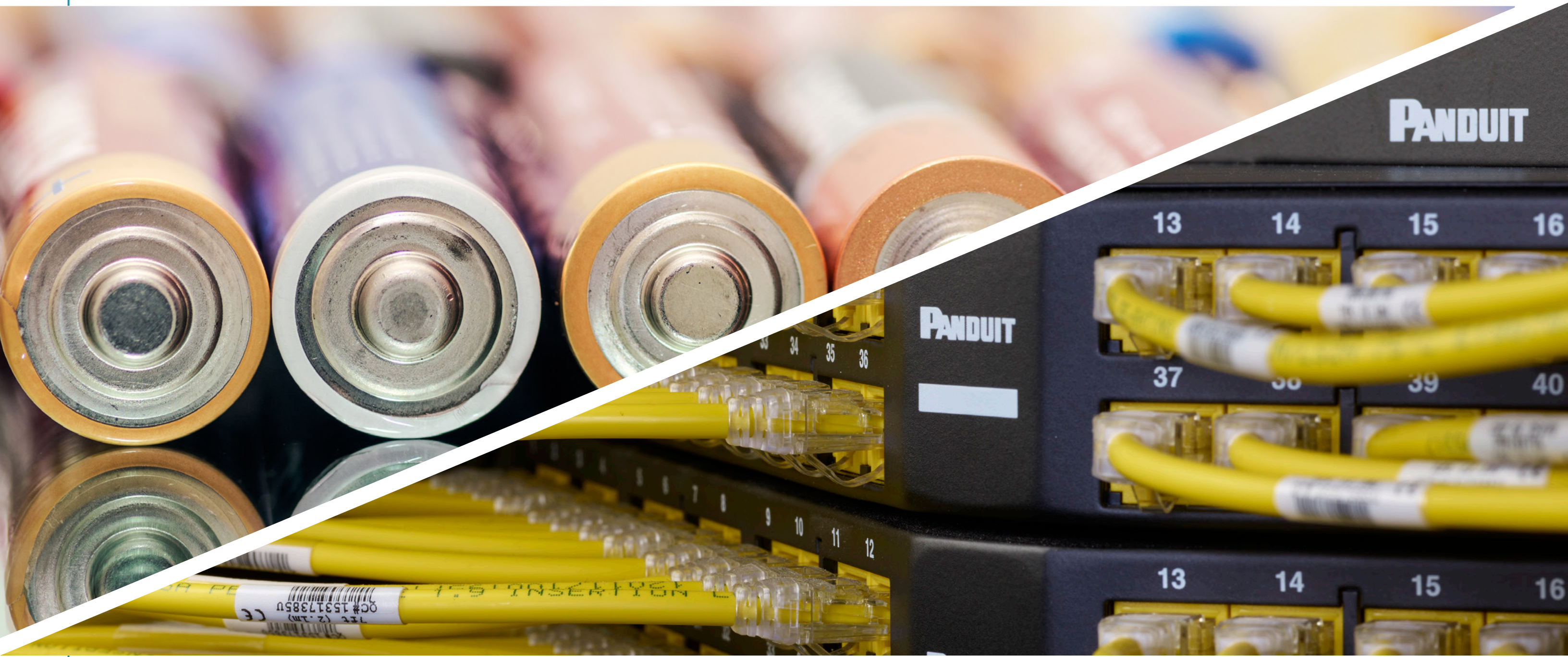
Battery Powered Devices vs. PoE Cabled Connections

For any given sensor network that relies on battery-powered sensors, a rough approximation is that over time, 30% of the sensors not considered mission critical will be down at any given time. The main reason for this is the magnitude and difficulty of replacing batteries as they fail. This is best understood through the following example:

Assume a one million square foot facility has specified 10 wireless sensors per 1,000 square feet. This is about 10,000 wireless sensors in that facility. These sensors are assumed to have a five-year battery life and the sensors being rolled out uniformly over the five years (i.e., 2,000 sensors per year). After five years, about 2,000 batteries will start failing per year. Considering there are about 200 working days per year, 10 batteries will need to be replaced per day to keep up with the failing sensors.

Now consider the challenges of replacing these batteries:

- Do you know where they are located?
- Are they in an area that is easy to access? Or would it require special hardware (e.g., a ladder) or may it require special circumstances (e.g., shutting down a piece of equipment)?
- How easy is it to replace the battery? Is the sensor easy to unmount/remount or has it been attached using some sort of one-time application such as mounting tape? Is the battery compartment easy to open or does it require a screwdriver? Is the battery compartment clean or is it corroded and requires cleaning?



Battery Powered Devices vs. PoE Cabled Connections — *(Continued)*

There is a rough estimate of about 20 to 30 minutes to replace each battery (Figure 7). This adds up to about 200 to 300 minutes per day (about three to five hours, or roughly ½ a full-time person). A wired network is generally regarded as requiring zero maintenance to maintain the current status quo.

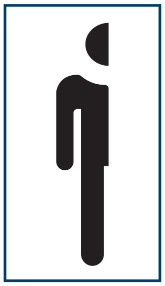


Figure 7. **For a 10,000-sensor battery deployment, half a full-time employee would be needed to replace batteries.**

Conclusion

A joint wired and wireless local area network allows for a truly robust and future-proofed network. A wired network running PoE can offer the following advantages when compared to a network that is only using wireless:

- Lower installed cost with a wired network when using PoE compared to running power drops
- Avoid the need to continually replace batteries longer term with a PoE cable connection
- Improve wireless network performance by offloading clients onto the wired network
- Improve your network's future-proofing capability by increasing the total clients the network can adequately support by offloading clients onto the wired network

This can translate into the recommendations for best practices to minimize costs and optimize network performance:

- Design your cabling infrastructure to ensure it can support PoE
- Utilize a low voltage network running PoE versus wireless setups using either batteries or electrical outlets for power
- Plan your network and cabling to allow people to offload their devices to a wired network

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