Power over Ethernet: Empowering Digital Transformation

Introduction

Digital transformation, Internet of Things (IoT), mobility, high-performance wireless (802.11ac Wave 2 and Wi-Fi 6/802.11ax), and smart connected solutions and deployments have seen rapid growth in momentum in recent years. With the emergence of these technology trends, Power over Ethernet (PoE) – having already revolutionized and expedited the adoption of IP telephony in the enterprise market – continues to gain popularity as an increasingly efficient medium for power delivery over the network. This paper focuses on providing a deeper view into Power over Ethernet (PoE) as a technology; its evolution over time; and its drivers, applicability, and use in today's market across different industries such as digital buildings, healthcare, retail, and IT. It will also introduce Cisco's unique innovations in the PoE space, the latest offerings delivering Cisco® Universal Power over Ethernet (Cisco UPOE®+ and Cisco UPOE) technology, and the partner ecosystem for the Cisco Digital Ceiling solution.

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PoE and PoE+

PoE is a widely used LAN switching infrastructure technology that allows DC power to be provided to an endpoint over a copper Ethernet cable. Power is passed from Power Sourcing Equipment (PSE) over the existing twisted pair Ethernet cable that provides the data connectivity to Powered Devices (PD) such as IP phones, video cameras, wireless access points, point-of-sale machines, access control card readers, LED luminaires, and other industrial and building automation applications, thereby reducing the amount of building material required to power and connect these devices.

The power requirements of endpoints vary based on their application, complexity, and function. For instance, basic IP phones might draw approximately 6W of power, whereas contemporary LED lighting fixtures can draw up to 50W for routine operation. Standards-based PoE is implemented following the specifications in IEEE 802.3af (2003) and IEEE 802.3at (2009), which accommodate different power levels. PoE does not affect the network performance of 10/100/1000 Mbps links to the PD. Due to the emergence of possibilities for newer applications and network endpoints, IEEE is working to standardize methods of transmitting higher levels of power than those supported by these prior standards.

The IEEE 802.3af PoE standard provides up to 15.4W of DC power on a port of the PSE (network side). Only 12.95W of this is assured to be available at the PD, due to power dissipation in the cable itself. The increasing power requirements of PDs led to the introduction of the IEEE 802.3at standard, known as PoE Plus (PoE+), which provides up to 30W of DC power on a PSE, assuring 25.5W of power to a PD due to power dissipation. In both of these standards, PoE delivers electrical power over two pairs of the four twisted pairs of Class D/Category 5e or better cabling. The PSE uses only signal pairs – that is, the pairs formed by pins 1 and 2 and pins 3 and 6 – to transport power from the PSE to the PD and leaves the spare pairs – consisting of pins 4 and 5 and pins 7 and 8 – idle. This architecture can deliver up to 30W per port.

Cisco Universal Power over Ethernet (Cisco UPOE+ and Cisco UPOE)

In recent years, the enterprise workspace has continued to evolve, with increasing numbers of building devices and workloads converging onto the IP network. This has fueled increasing demand for PoE to support newer devices as well as devices with greater power requirements (more than 25.5W). To meet this demand, Cisco introduced Universal Power over Ethernet (Cisco UPOE+/UPOE) technology, which triples the power delivered per PSE port up to 90W. The network's ability to deliver even higher levels of power to endpoints over Ethernet has in turn significantly enabled the enhancement of the PoE powered endpoint landscape. With Cisco UPOE+/UPOE, devices with higher power requirements such as telepresence systems, Virtual Desktop Infrastructure (VDI) clients, nurse call systems, LED lighting fixtures, digital signage, compact switches, and IP turrets for financial trading floors, among others, can now be powered by the network, without requiring separate AC electrical wiring or any change in the preexisting Ethernet cabling. The converged network can deliver superior services and control with a lower total cost of ownership.

Cisco UPOE+/UPOE uses the same cabling standard as PoE. However, instead of delivering power over two of the twisted pairs, it provides the capability to source up to 90W of power by using all four twisted pairs of standard Ethernet cabling (Category 5e or better). It does this by using two PSE controllers to power both the signal pairs and the spare pairs. Cisco UPOE+ assures a minimum of 71W of power to the PD. Figure 1 presents the architectural difference between PoE/PoE+ and Cisco UPOE/UPOE+.

Figure 1. Comparison of PoE/PoE+ and Cisco UPOE

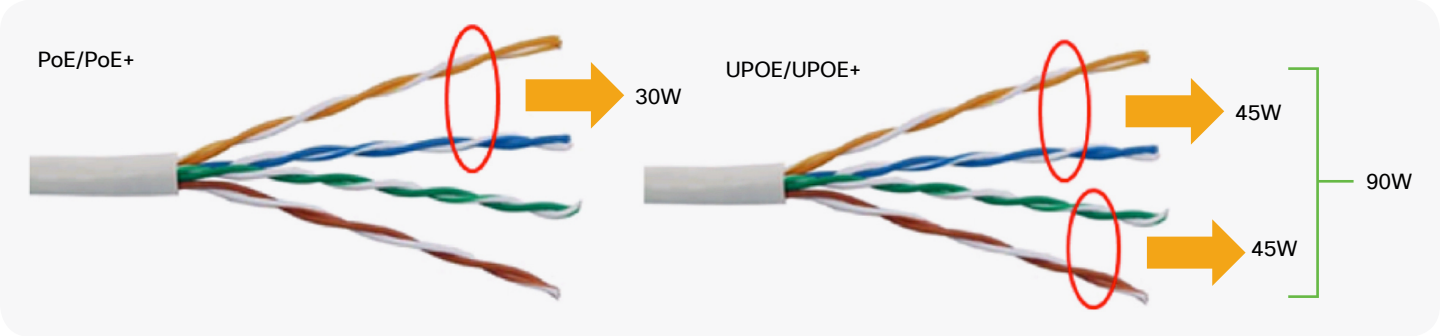


Table 1 summarizes the comparison between PoE, PoE+, and Cisco UPOE, UPOE+.

Table 1. PoE, PoE+, and Cisco UPOE+, UPOE comparison

	PoE	PoE+	Cisco UPOE	Cisco UPOE+
Minimum cable type	Category 5e	Category 5e	Category 5e	Category 6a
IEEE standard definition	802.3af	802.3at	Cisco proprietary	Cisco proprietary
Maximum power per PSE port	15.4W	30W	60W	90W
Maximum power to PD	12.95W	25.5W	51W	71.3W
Twisted pairs used	2 pairs	2 pairs	4 pairs	4 pairs
Distance	Under 100 meters			
Performance	No impact to network performance of 10/100/1000 Mbps links to the PD			

Device classification

PSEs and PDs are categorized as **Type 1 or Type 2**. Devices that provide up to 15.4W or draw up to 12.95W of power (802.3af compliant PSE or PD, respectively) belong to the Type 1 category, whereas devices that can provide up to 30W or draw up to 25.5W (802.3at compliant PSE or PD, respectively) belong to the Type 2 category.

PDs are further classified based on the amount of power they draw, falling into classes 0 to 4. The PSE uses the PD's class during the hardware-based handshake to determine the amount of power it should allocate for the particular PD. Classification information defined by the IEEE specification is as follows:

- Class 0: For PDs that don't support classification
- Classes 1 through 3: Partitions PDs into three distinct power ranges
- Class 4: Includes the new power range defined in IEEE 802.3bt

Table 2 further describes the PD classifications.

Table 2. PD device classifications

Class signature	Type	Minimum power levels output at the PSE	Maximum power levels at the PD	Class description
0	Default, Type 1	15.4W	0.44 to 12.95W	Classification unimplemented
1	Type 1	4.0W	0.44 to 3.84W	Very low power
2	Type 1	7.0W	3.84 to 6.49W	Low power
3	Type 1	15.4W	6.49 to 12.95W	Medium power
4	Type 2	Treat as Class 0 30W	12.95W to 25.5W	High power

PoE PSE/PD detection and power negotiation

The first step when any device connects on a PoE-enabled port of a PSE is for the PSE to detect whether the device is a true PD. To do this, the PSE sends a detection voltage pulse on the wire to the device and measures the current. If it gets a valid detection signature (valid ranges are defined in IEEE 802.3af/at), it is detected as a PD. The PSE then sends a short voltage pulse on the pairs to measure how much power the PD needs. The PD responds to the pulse by briefly drawing a predetermined amount of current, which the PSE uses to determines the class of the device (Table 3).

Table 3. PD class to current mapping for detection

Class	Power (W)	Class (mA)
0	0.44 to 12.95W	0 to 4 mA
1	0.44 to 3.84W	9 to 12 mA
2	3.84 to 6.49W	17 to 20 mA
3	6.49 to 12.95W	26 to 30 mA
4	12.96 to 25.5W	36 to 44 mA

If either the PSE or the PD are of Type 1 (maximum 15.4W capable PSE or Class 0 to 3 PD), this hardware-based handshake terminates and the required power (up to 12.95W) based on the PD's class is provisioned on the PSE port. A standard Type 1 PSE supplies only one-event classification as described above, regardless of the class setting of the PD.

If both PSE and PD are of Type 2, a second handshake of either of the following two types happens:

- Hardware-based two-event classification
- Software-based Link Layer Discovery Protocol (LLDP) classification

Two-event classification: The initial classification voltage pulse event is repeated as a signal to the PD that the connected PSE is indeed a high-power PSE and is able to source the higher power levels associated with 802.3at power. Once the PD passes the second classification event as a class 4 PD, it is provided full class 4 802.3bt power.

LLDP classification: Link Layer Discovery Protocol (LLDP) is a vendor-neutral link layer protocol used for advertising identity, capabilities, and neighbors on a LAN. LLDP uses type, length, and value fields (TLV) to convey information. IEEE 802.3at defines LLDP for power negotiation greater than 15.4W and up to 30W. Cisco UPOE+/UPOE uses the same negotiation method to provide up to 90W, contingent on a successful four-pair handshake by using "4-wire power via MDI," which is a new subtype for Cisco specific OUI TLV. The TLV is used to exchange four-pair capabilities before enabling all four pairs and providing up to 90W of power.

Table 4. PSE/PD negotiations based on type

PSE type	PD type	Methods applicable
Type 1	Type 1	One-event classification
Type 1	Type 2	One-event classification
Type 2	Type 1	One-event classification (PD class between 0 and 3)
Type 2	Type 2	Two-event classification or LLDP (PD class 4)

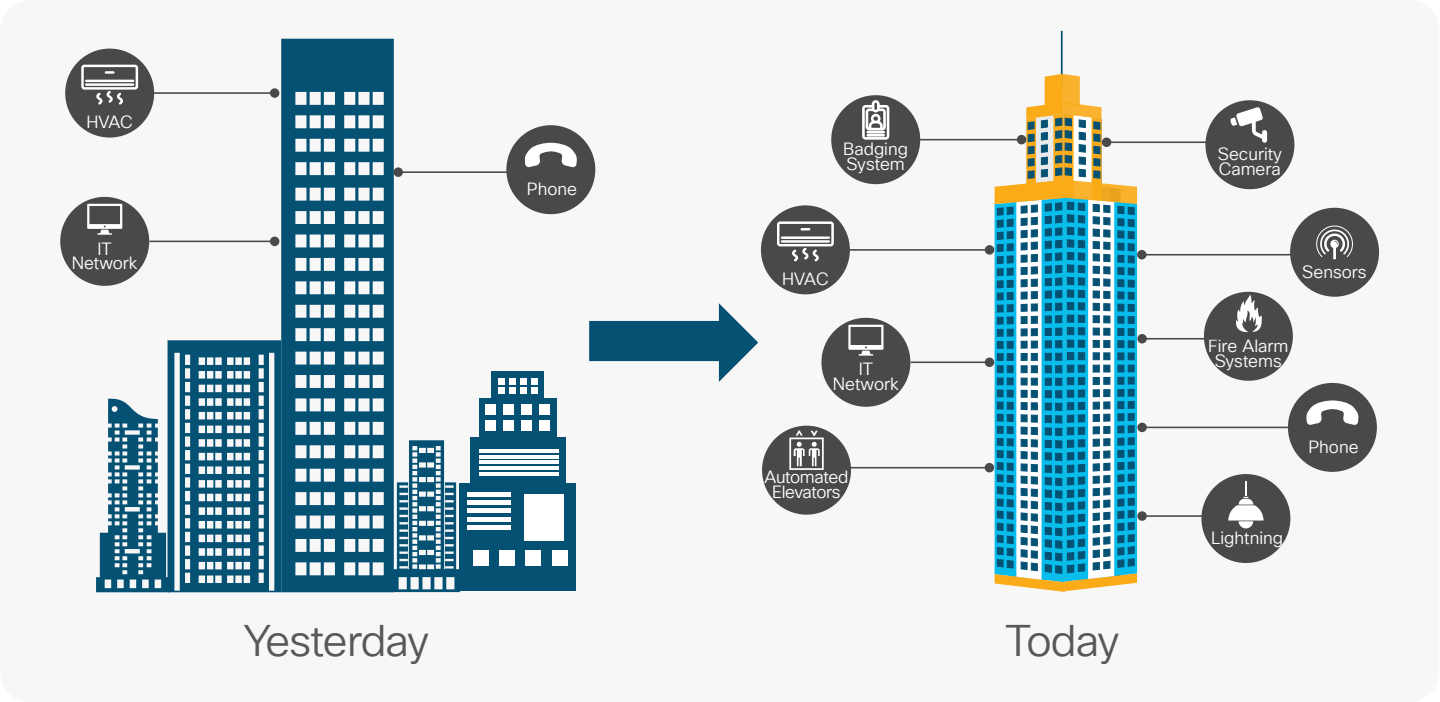
Applications of PoE

In today's world of digital transformation, organizations are gaining competitive advantage by giving employees tools to be more connected, engaged, and mobile to achieve nonstop connectivity, rich collaboration, and security everywhere. In this industry shift, PoE is proving to be a simple, efficient, and cost-effective solution for endpoint connectivity. PoE is enabling newer applications and compelling use cases, not only in modern digital building architectures but also in more conventional industries such as hospitality, retail, healthcare, and IT.

Digital buildings and connected lighting

The ever-increasing array of building networks is making buildings extremely complex. Subsystems such as security cameras, lighting, advanced sensors, badging systems, and HVAC are siloed and are difficult to manage and control centrally on a single network (Figure 2). PoE provides a means of converging these independent systems over a common medium – the IP network – and enables them to communicate with each other using a preferred common language, such as Constrained Application Protocol (COAP).

Figure 2. Growth in building subsystems



Consider some of the following digital building automation use cases:

- In the event of a fire, the fire alarm system, in addition to raising an alarm, triggers color change and blinking of network-connected lighting over the emergency exit path, making it much easier for employees to find the fastest way out
- Personalized private office experiences are enabled by building systems that can detect an employee's presence and automatically profile in-room temperature and lighting mood, configure their IP phone, etc., based on the user's preferences and settings
- Data aggregated over time from motion sensors on office LED lighting fixtures can be used to determining employee occupancy behavior, enabling better planning and decision-making on more optimized seating

Over the last decade, the remarkable adoption of LEDs in lighting can be attributed primarily to the following advantages LEDs have over traditional lighting systems:

- Higher energy efficiency and reduced energy consumption
- Longer life expectancy
- Low-voltage and cold temperature operation
- Brighter, dimmable, no mercury content

The Cisco Digital Building Solution enables provisioning of DC power as well as data connectivity for in-ceiling LED lighting fixtures using PoE or Cisco UPOE. The lights are brought onto the IP network by connecting them via Category 5e (or better) cabling to Cisco Catalyst® Digital Building Series Switches deployed in the plenum space of the floor. This eliminates the need for any electric conduit installation. Power as well as operation of the lights is controlled via software without having to make any physical changes to the environment.

Figure 3. Centralized (left) and distributed (right) lighting architectures

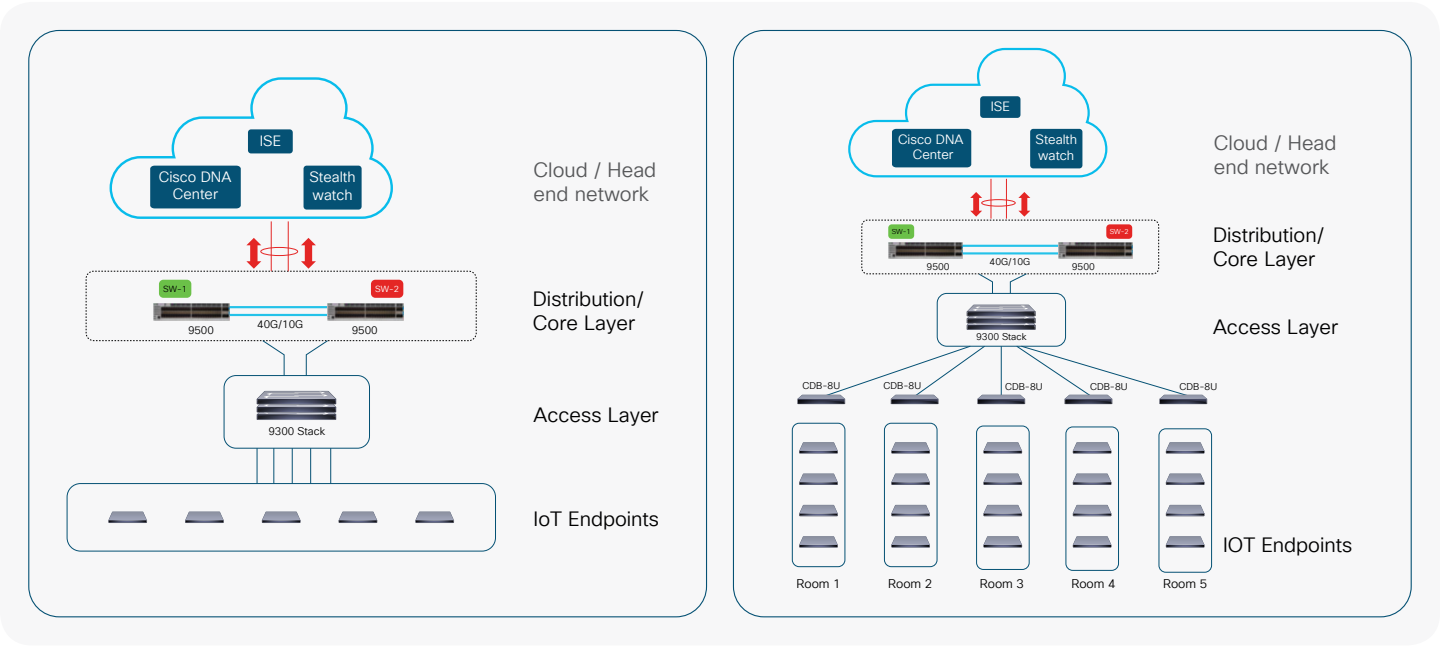


Figure 3 shows the recommended connected lighting network architecture options. In the centralized model (on the left), the lights connect directly to the stackable PoE or Cisco UPOE switches in the Intermediate Distribution Frame (IDF). This model entails longer cable runs from the lighting fixtures but provides better availability due to the advanced high-availability features on these switches. In a distributed deployment (on the right), lights are plugged into small form-factor, fanless, in-plenum PoE and Cisco UPOE switches over much shorter cable runs. The compact switches further connect to the IDF using regular Ethernet uplink connections. For more details on these architectures, refer to the Cisco Digital Building Network Architecture Guide available here. The solution helps reduce power and lighting costs, simplify installation, and create desirable environments in an automated and controlled fashion.

Enterprise IT

Figure 4. Increased power requirements for access points due to increased capabilities and bandwidth requirements

As the enterprise workspace evolves, network endpoints require increased power. Powering up wireless access points and IP phones using PoE has been the norm for a number of years now. With enhanced wireless capabilities and drastically increased bandwidth (802.1ac Wave 2 and Wi-Fi 6/802.11ax), the power requirements of access points have also increased (Figure 4). Cisco UPOE as a powering option, along with Cisco Multigigabit technology, delivers an apt solution for the best performance without the need for any new cabling to reach speeds beyond 1 Gbps. Even personal telepresence systems and high-power video surveillance cameras can now be powered using Cisco UPOE. For flexible network connectivity in collaborative workplaces (PoE to desk), compact desktop switches are being deployed outside the wiring closet, closer to the users and endpoints being connected. Cisco compact switches (Cisco Catalyst 3650-CX Series Switches) can be powered by Cisco UPOE from uplinks and can further pass PoE power through to end devices such as IP phones, access points, and access badge readers. VDI clients used to provide multitenancy and anytime-anywhere access are also powered with Cisco UPOE using standard Ethernet cabling infrastructure.

Healthcare

Healthcare professionals are looking for increased mobility and access to patient records, medical systems, and applications to record vital signs and drug dosages regardless of their location. Medical organizations are looking at thin or zero clients as a preferred solution for providing this access, as they offer a highly available, secure, and consistent virtual desktop experience for users. These clients have power requirements that are met with Cisco UPOE. Cisco UPOE also delivers both data and power to advanced nurse call systems that are being deployed in hospitals today. In addition, PoE is used for powering standard IT applications such as wireless access points and IP phones installed in healthcare facilities. Overall, the solution helps converge campus and medical networks and provides for improved safety and system management by reducing the number of cords in sensitive areas such as the intensive care unit and patient rooms in a medical facility.

Retail

Figure 5. A retail system powered by PoE

The retail space is seeing many new applications and uses for PoE and Cisco UPOE. Access points provide wireless connectivity to enable Cisco Connected Mobile Experiences for shoppers, helping stores to analyze visitor behavior and enhance personal engagements with customers. Stores are using "focus lighting" to attract customers to specific ranges of products. These lighting systems can be powered and controlled over PoE or Cisco UPOE. Manufacturers are implementing PoE and Cisco UPOE powering capability into digital signage and interactive kiosks that are now being used extensively in retail stores to display media, information, and advertising content and provide access to online catalogs with click-to-chat capabilities. Checkout counters have Point-of-Sale (POS) terminals, IP phones, sensors, card swiping machines, etc., all of which now have Ethernet power options (Figure 5). For simplicity and expense reductions in cabling, deploying a Cisco compact switch at the checkout counter and connecting endpoints to it using short Ethernet cables is a fitting solution.

Cisco PoE innovations

PoE pass-through

The PoE pass-through feature enables provisioning of IP applications in locations without access to power outlets. It is supported on the Cisco Catalyst 3560-CX Series Switches (WS-C3560CX-8PT-S). The compact switch uses uplinks to draw power for itself over the Ethernet cable from a Cisco UPOE enabled switch in the wiring closet, and further passes it to PoE devices connected directly to it. This greatly simplifies cabling challenges closer to the user and is ideal for wiring-constrained and space-constrained applications. The pass-through power can be combined with power from the switch's auxiliary input to provide higher PoE budgets for the connected PDs.

Perpetual PoE/UPOE

Perpetual PoE and Perpetual Cisco UPOE allow a Cisco switch to provide uninterrupted power to a PoE-powered endpoint, even when the switch goes through a reboot. The PoE-powered device continues to work and get the last negotiated power as long as the switch continues to receive power from its source. With this feature, any maintenance upgrades or software reloads do not cause power disruption to the endpoints. It is very effective in deployments where temporary loss of data connectivity is not as critical as power to the end devices, as in connected lighting and healthcare. In these switches, the power subsystem is controlled by an independent Microcontroller Unit (MCU) that remains up even when the primary CPU (which runs the operating system) goes down. The MCU continues to grant power to PDs as long as the power supply is connected to the switch.

Fast PoE/UPOE

Fast PoE and Fast Cisco UPOE enable provisioning of prenegotiated PoE or Cisco UPOE power to PoE endpoints within 5 seconds of switch reboot due to a power failure. This helps ensure minimum downtime for the PoE endpoints in the event of a power outage. In this feature, the PoE subsystem gets initialized and starts to provision power to the connected endpoints without waiting for the Cisco IOS® Software daemon to come up. Fast PoE is very helpful in connected lighting use cases. The feature expects no changes in the PD connectivity during the switch reboot.

Refer to the respective switch data sheets for information on these PoE features.

Key benefits of PoE

- **Safe:** PoE uses a relatively low voltage and hence is not as prone to causing electrical hazards.
- **Cost-effective:** PoE eliminates electrician costs for installation of wiring and endpoints as well as the need for wall circuits. Combining power provisioning with data analytics and centralized control can lead to further optimization of expenditures. For example, capabilities such as scheduled power on and off, motion-sensing lighting, differentiated power modes (hibernate and sleep), etc. prove to be extremely helpful in reducing overall costs and carbon footprint.
- **Simple:** PoE does not require complex AC circuitry or wiring. Devices can be powered up simply by plugging in an Ethernet cable that might already be needed for data connectivity. It also eliminates the need for any AC-to-DC adapters for the endpoints and reduces deployment times owing to validation of PoE device interoperability from industry leaders.

- **Flexible:** Devices can be positioned and powered at nearly any location. PoE deployed using Cisco Catalyst compact switches and Digital Building Series switches drastically increases the accessibility of the endpoints. Installation of remote or outdoor equipment can be done without having to connect to AC power.
- **Reliable:** The central power backup for the network inherently provides PoE reliability. Advanced PoE features such as Perpetual and Fast PoE/UPOE on Cisco switches help ensure high levels of power delivery and continuity.
- **Manageable:** Cisco EnergyWise® and other endpoint vendor-specific software provides advanced analytics, control, and management capabilities across network domains.

The Cisco UPOE ecosystem

The Cisco Catalyst Digital Building Series Switches are the industry's most power-efficient switches, optimized for low-voltage PoE deployments and connectivity. They lay the foundation for powering and converging disparate building subsystems onto a single IP network and are fully budgeted for delivering up to 90W of power on each of their ports. The Cisco Catalyst 9300 Series Switches are Cisco's newest and next-generation stackable enterprise switching platforms built for security, IoT, mobility, and cloud. They deliver leading PoE capabilities with high-density Cisco UPOE+/UPOE and PoE+ scaling to 384 Cisco UPOE ports per stack. Cisco Catalyst 9400 Series Switches are Cisco's leading modular enterprise switching access platforms, supporting up to 384 Cisco UPOE+/UPOE ports on a single chassis.

Table 5 provides details on the Cisco UPOE+/UPOE offerings in the Cisco Catalyst family of switches. Table 5. Cisco UPOE+/UPOE offerings in Cisco Catalyst switches

Series	Product ID	Description	Cisco UPOE ports	Power supply requirements
Cisco Catalyst 9400 Series	C9400-LC-48H	48 Cisco UPOE+ ports	Cisco UPOE+ on all ports	Refer to data sheet
	C9400-LC-48U	48 Cisco UPOE ports	Cisco UPOE on all ports	Refer to data sheet
Cisco Catalyst 9300 Series	C9300-24U	24 Cisco UPOE ports	Cisco UPOE on all ports	1 PWR-C1-1100WAC and 1 PWR-C1-715WAC
	C9300-48U	48 Cisco UPOE ports	Cisco UPOE on up to 30 ports	2 PWR-C1-1100WAC
	C9300-24UX	24 Multigigabit Cisco UPOE ports	Cisco UPOE on all ports	2 PWR-C1-1100WAC
Cisco Catalyst 4500E Series Switches	WS-X4748-12X48U+E	48-port Cisco UPOE line card with 12 Multigigabit ports	Capable of up to 60W per port up to 1440W; that is, 24 Cisco UPOE ports	Refer to data sheet
	WS-X4748-UPOE+E	48-port Cisco UPOE line card	Capable of up to 60W per port up to 1440W; that is, 24 Cisco UPOE ports	Refer to data sheet

Series	Product ID	Description	Cisco UPOE ports	Power supply requirements
Cisco Catalyst 3850 Series Switches	WS-C3850-24U	24 Cisco UPOE ports	Cisco UPOE on all ports	One PWR-C1-1100WAC and one PWR-C1-715WAC
	WS-C3850-48U	48 Cisco UPOE ports	Cisco UPOE on up to 30 ports	Two PWR-C1-1100WAC
	WS-C3850-24XU	24 Multigigabit Cisco UPOE ports	Cisco UPOE on all ports	Two PWR-C1-1100WAC
	WS-C3850-12X48U	48 Cisco UPOE ports with 12 Multigigabit ports	Cisco UPOE on up to 30 ports	Two PWR-C1-1100WAC
Cisco Catalyst 3650-CX Series Switches	C3560CX-8PT-S	Cisco **UPOE powered input;** 3560-CX PD PSE switch 8 Gigabit Ethernet PoE+, uplinks: 2 x 1 Gigabit Ethernet copper	2 Cisco UPOE uplinks for powering	Refer to data sheet
Cisco Digital Building Series Switches	CDB-8U	8 x 10/100 Fast Ethernet Cisco UPOE ports	Cisco UPOE on all 8 ports	Fixed internal power supply

Cisco has partnered with multiple organizations and independent software vendors that bring exceptional domain expertise in lighting, building automaton, and controls in an effort to accelerate the digital building transformation. Some of these are as follows:

Cree Inc. | Molex | Philips | Eaton | Hill-Rom

More information on the partner ecosystem is available here:
https://www.cisco.com/c/en/us/solutions/digital-ceiling/partner-ecosystem.html

Summary

In summary, PoE technology is becoming a vital part in the digital transformation journey. PoE's advantages are multifold, and with today's industry trends it is an enabler for compelling applications and use cases. Cisco is leading the way with its PoE innovations, partner ecosystem, and next-generation enterprise offerings.

Additional resources

Cisco Digital Building Solution: https://www.cisco.com/c/en_in/solutions/workforce-experience/digital-building/index.html

Cisco Digital Building white paper: https://www.cisco.com/c/dam/en/us/solutions/collateral/workforce-experience/digital-building/digital-whitepaper.pdf?CAMPAIGN=Digital+Building&COUNTRY_SITE=us&POSITION=link&REFERRING_SITE=cisco%2Ecom+homepage&CREATIVE=Digital+Building

Cisco Digital Building At-a-Glance: https://www.cisco.com/c/dam/en/us/solutions/collateral/workforce-experience/digital-building/at-a-glance-c45-738207.pdf

Cisco Multigigabit technology: https://www.cisco.com/c/en/us/solutions/enterprise-networks/catalyst-multigigabit-switching/index.html

Case studies

- **Marriott:** https://www.cisco.com/c/dam/en/us/solutions/collateral/workforce-experience/customer-marriott.pdf
- **Alpiq:** https://www.cisco.com/c/dam/en/us/solutions/collateral/workforce-experience/digital-building/customer-alpiq.pdf
- **Miami-dade county public schools:** https://www.cisco.com/c/dam/en/us/products/collateral/enterprise/operational-efficiency/miami-dade-schools-voc-case-study.pdf

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