White Paper

Cisco Universal Power Over Ethernet: Unleash the Power of your Network

Introduction

Enterprise workspace is quickly evolving with new networked devices to improve communication, collaboration, security, and productivity. Power over Ethernet (PoE), a way to deliver electrical power over LAN cabling to networked devices, has been widely deployed over the years to provide power to various endpoints in the enterprise workspace environment. Cisco® Catalyst® 4500E, a market leader of PoE technology, continues to innovate to deliver Universal PoE (UPOE) technology with up to 60 watt power to enable even broader endpoint support, with additional benefits of higher availability, lower OpEx, and faster deployment.

This paper provides an overview of the Cisco UPOE technology. It describes how Cisco has evolved PoE technology to UPOE, the use case examples of UPOE to simplify enterprise deployment, and UPOE architecture and operations.

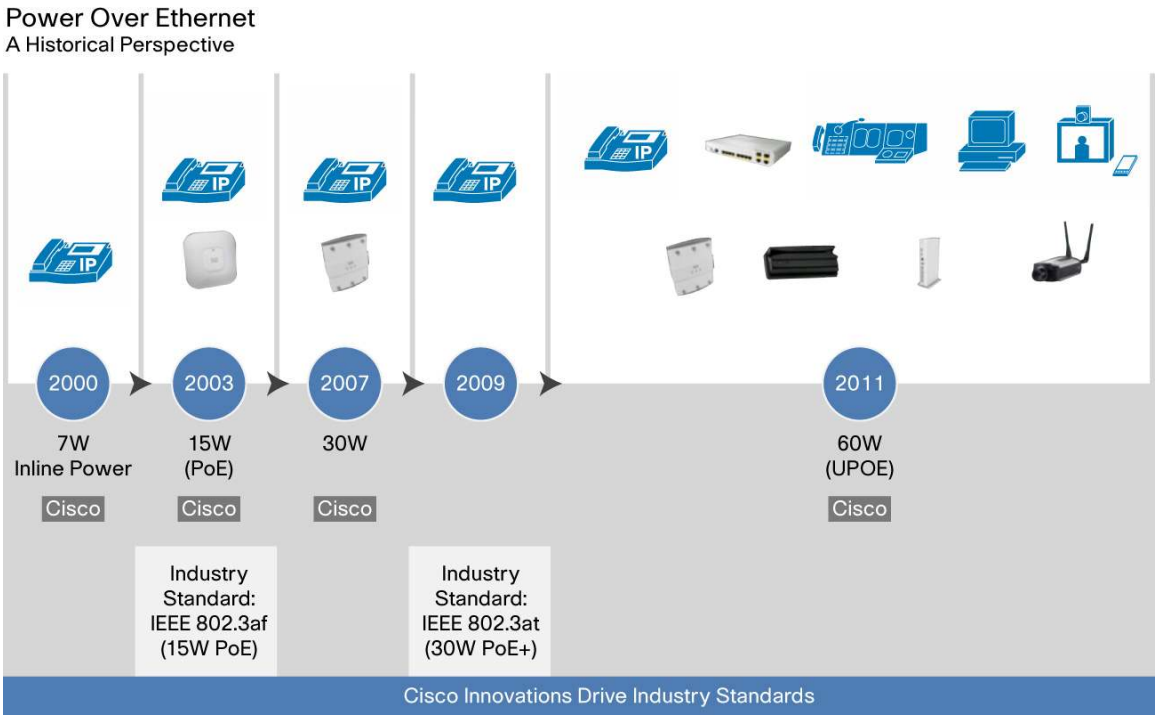
Evolution of PoE Technology

In recent years, enterprise workspace is increasingly converged to IP network infrastructure. PoE is one of the mostly widely deployed technologies to provide power to networked devices, with the following primary benefits:

- **High availability** for power and guarantees uninterrupted services, a requirement for critical applications (e911).
- **Lower OpEx** by providing network resiliency at lower cost by consolidating backup power into the wiring closet.
- **Faster deployment** of new campus access networking infrastructures by eliminating the need for a power outlet for every endpoint.
- Combined with Cisco EnergyWise and Energy-Efficient Ethernet (EEE), helps meet **corporate sustainability** mandates while **lowering energy** costs.

As the enterprise workspace evolves with more and more end devices for communication, collaboration, security, and productivity, the need of PoE is also evolving to support newer end devices with increased power requirements. Flowing Figure 1 shows the PoE evolution.

Figure 1. Evolution of PoE Standard and Cisco Delivery with Cisco Catalyst 4500E



Cisco has been leading Power over Ethernet technology since 2000; the first generation of Cisco prestandard PoE delivered up to 6.3W to the end devices over the Ethernet cables that transport data traffic. This prestandard PoE supported endpoints such as Cisco IP phone 7906G/7911G/7941G and so on.

In June 2003, the IEEE approved a standard, IEEE 802.3af, for Power over Ethernet technology. The standard specified a 15.4W maximum power delivery from the network device, also known as power sourcing equipment (PSE), to an end device, also known as a powered device (PD). The average maximum power available to the PD is 12.95W after accounting for cable loss. This expands broader end device coverage such as Cisco IP phone 7941G-GE/7961G-GE/7985G and wireless access points.

To support more emerging end devices with higher power requirements, IEEE introduced new standard, 802.3at, to scale up to 30W power delivery. This further expands the end devices coverage to a broader range including newer devices such as IEEE 802.11n wireless access points, security surveillance cameras, and so on. Cisco Catalyst 4500E was the first Ethernet switch in the industry to introduce 30W PoE technology in 2007, two years before the IEEE 802.3at standard introduction, and later become compliant with the IEEE 802.3at standard when it was ratified in 2009.

As more networked devices emerge in enterprise workspace and become more efficient in terms of power consumption, there are more opportunities to take advantage of the benefits of PoE technology to simplify the provisioning and deployment of these devices and save costs. PoE technology has the potential to deliver up to 60W per device, which allows a much wider range of device support. Cisco UPOE leapfrogs the industry to provide 60W PoE per switch port to enable new deployment options in next-generation workspace environments.

Use Case Examples of UPOE

Cisco UPOE simplifies network infrastructures and delivers lower total cost of ownership for connected environments such as virtual desktop infrastructure (VDI), financial trading floor, enterprise workspace, conference rooms, hospitality guest suites, and retail. Partnerships with industry leaders and in-house development together have resulted in a variety of end devices that are compatible with Cisco UPOE. A few notable end devices are:

- Samsung integrated display VDI zero clients
- BT IP turrets
- Cisco Catalyst compact switches
- Cisco Personal TelePresence® systems
- Building management and physical security devices

The following sessions describes several UPOE use case examples.

Virtual Desktop Infrastructure

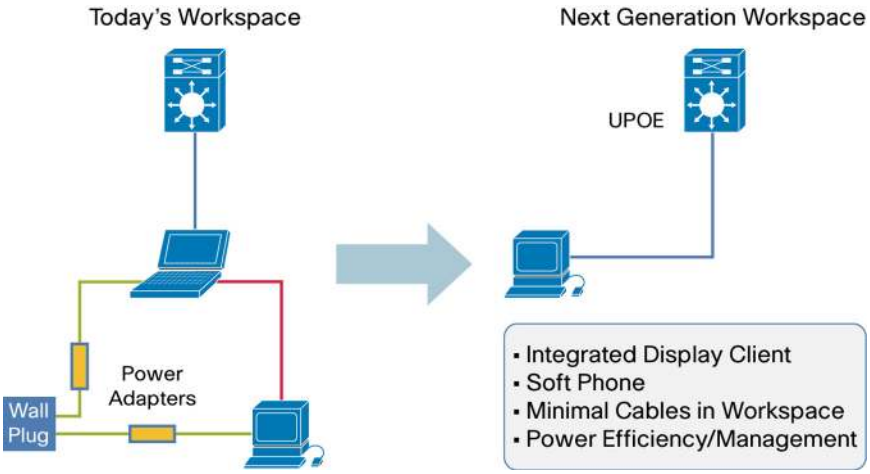
Virtual desktop infrastructure (VDI) is becoming more popular in enterprise to address increasing challenges of security, changing global business dynamics, TCO requirements, and increasingly mobile and diverse workforce. VDI fundamentally changes the way that employees, partners and consultants work by providing anytime, anywhere secure access to desktops hosted and managed in the data center. It provides these benefits:

- Compliance, data security, and control
- Rapid desktop deployment and scaling
- Total cost ownership with benefits such as centralized and streamlined desktop lifecycle management

In a VDI deployment, an end-user device can be a thin client that provides an optimized, lower cost device designed specifically to interact with a hosted virtual desktop. UPOE can greatly simplify this deployment by providing PoE power to the thin client and its display. The following deployment options require by UPOE:

- Integrated Display: To simplify the workspace, vendors start to integrate thin client, softphone functionalities into the display monitor to provide one integrated endpoint to the end users. With the advancement of technologies, the power consumption of this VDI thin client display can fall into the range of 50W. For example, the Samsung 220 display monitor offers integrated thin client function with less than 51W power consumption. With UPOE, the VDI system can be powered by UPOE power to provide a very flexible plug-and-play deployment, see Figure 2 below.

Figure 2. VDI with Integrated Display



- Backpack VDI module with IP Phone: Cisco VXC 2100 is a compact device that is physically integrated with the Cisco Unified IP Phone 8900 or 9900 Series, to provide end-point for users.
- Standalone VDI device: Cisco VXC 2200 is a sleek, standalone, small-footprint zero client device. With UPOE, users can power both the VXC 2200 as well as native LED displays.

UPOE provides the following benefits in the VDI deployment:

Deployment flexibility: By providing data as well as power to the workspace, network administrators now have flexibility to respond to changing business needs to provide access to employee, guests, or contractors.

Lower cost of ownership: UPOE helps business to lower the cost of ownership through:

- Converging the power to central location and removing the need of wall plug
- Highly efficient switch power supply in comparison of power adapters in every user office
- Optimizing stay-on time through network rather than relying on individual users
- Reduced cable clutter

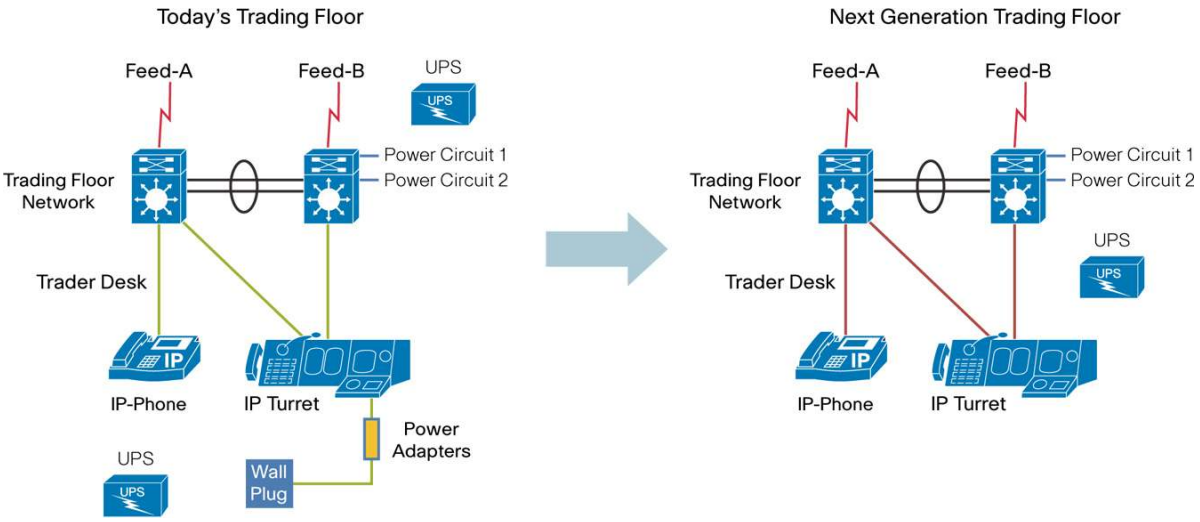
Financial Trading Floors

In today's IP trading floor design, network planners need to respond to traders' requests for multiple screens, live video feed, conference calls, and lightning speed to get feed updates. All these request high availability, multicast and buffering architecture as the key features for the network. Cisco Catalyst 4500E is switch of choice with right features set to address primary trends that are shaping today's IP trading floor design. This platform not only provides line-rate unicast and multicast switching with consistent low latency to all user access ports but also delivers rich borderless network services critical for financial deployments. Some of these services include high availability with full hardware redundancy and software features like In-Service Software Upgrade; application visibility with Flexible Netflow (FnF) and hosted applications like WireShark.

One of the primary devices in the IP trading environment is the IP turret system that provides integrated communication tools for financial traders. Today, IP turrets are powered by wall power with backup UPS power sources under each trader's desk for high availability. With UPOE technology, the IP data and power can be converted to a single highly resilient networking infrastructure with Cisco Catalyst 4500E, see Figure 3. This

greatly reduces the total cost of ownership by simplifying the cabling and consolidating backup power into the closet.

Figure 3. Financial Trading Floors Enabled by Cisco Catalyst 4500E



Cisco is partnering with the following market-leading IP turret vendors to deliver this solution:

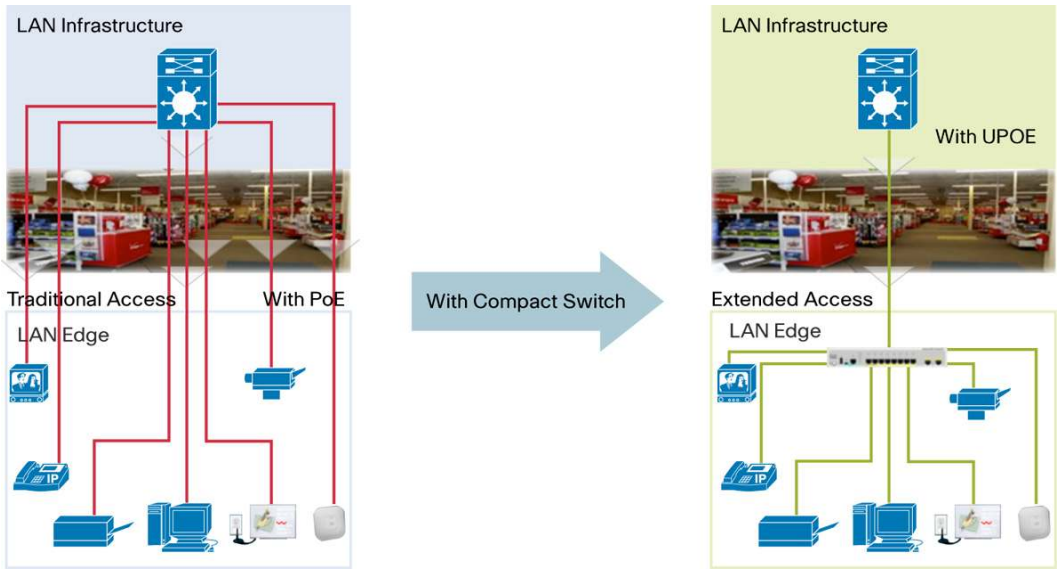
- British Telecom
- IP Trade
- Speakerbus

Hospitality and Retail Environment

Customer experience plays a primary role in hospitality and retail sector that relies heavily on repeat customers. Retail industry is leveraging the advancements in technologies to create a positive experience on their customers, thus improving their profitability. In addition, rising energy costs are giving more attention than ever to sustainable business practices, and innovation on Cisco Catalyst 4500E is addressing these initiatives.

UPOE enables powering multiple endpoints by using POE pass-through on Cisco's latest compact switches, 3560C or 2960C, see Figure 4. This enables advanced security services to reach the network edge and deliver Power over Ethernet and Gigabit Ethernet connectivity for deployments outside the wiring closet. This solution reduces wiring constraints and enables network consolidation.

Figure 4. UPOE in Retail Deployments



Primary benefits include:

Energy management: With centralized management, hotels can now manage turning on and off room devices in much more streamlined fashion. This not only lets customers get a ready room by the time they check in, but also the hotel saves energy cost by turning off selected devices when the customer walks out of the room.

Operational easiness: UPOE powered compact switches enable hotels to plan for upcoming conferences or seminars on a need basis.

UPOE Architecture

As defined in IEEE 802.3af and IEEE 802.3at, PoE delivers electrical power over two pairs out of the four twisted pairs of cable in Class D (also known as Cat5e) or better, cabling as specified in ISO/IEC 11801:1995. A PSE uses only signal pairs, the pairs 1, 2 and 3, 6, to transport power from the PSE to the PD and leaves the spare pairs, the pairs 4, 5 and 7, 8, idle. This architecture can deliver up to 30W per port. (Refer to Figure 5.)

Figure 5. PoE and PoE+ Architecture

UPOE uses the same cabling standard as PoE. Instead of delivering power over two twisted pairs, it provides the capability to source up to 60W of power by using all the four pairs of standard Ethernet cabling (Cat5e or better).

The architecture for a 4-pair system is pretty straightforward; it is an extension of the 2-pair design. The 2-pair system uses one PSE controller to power the PD through the signal pairs of the cable. In the new 4-pair system two PSE controllers will be used to power both the signal pairs and the spare pairs. Figure 6 shows the UPOE architecture.

Figure 6. UPoE Architecture

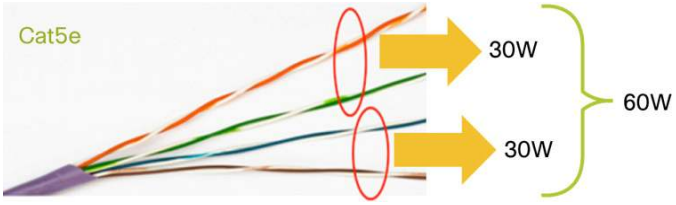


Table 1 summarizes the primary comparison between PoE, PoE Plus, and UPOE.

Table 1. PoE/PoE Plus/UPOE comparison

	PoE	PoE Plus	UPOE
Minimum cable type	Cat5e	Cat5e	Cat5e
IEEE standard definition	802.3af	802.3at	Cisco proprietary
Maximum power per PSE port	15.4W	30W	60W
Maximum power to PD	12.95W	25.5W	51W
Twisted pair used	2-pair	2-pair	4-pair

UPOE cable heat dissipation

Cisco UPOE is an efficient mechanism for power delivery since it uses all four twisted pairs within the Ethernet cable to deliver power (as opposed to two twisted pairs used by PoE Plus). This effectively reduces the channel losses by half for the same power delivered over UPOE vs. PoE Plus. Moreover, the recommendation published by cabling standards - ISO/IEC and TIA/TR-42 as part of formal liaison committee with IEEE 802.3 - indicate that UPOE can be supported over the same standard cabling infrastructures that conform to PoE Plus requirements. Results as following in Table 2.

Table 2. Test Results from TIA TR-42 and ISO/IEC

TIA TR-42 Recommendation			ISO/IEC Recommendation		
Temperature Rise	**Max Current per twisted Pair**	**Max Power @ 50V**	**Temperature Rise**	**Max Current per twisted Pair**	**Max Power @ 50V**
5	420mA	37.5W	**5**	420mA	37.5W
7.5	520mA	45.2W	**7.5**	550mA	47.4W
10	600mA	51.0W	**10**	600mA	51.0W
12.5	670mA	55.8W	**12.5**	680mA	56.4W
15	720mA	59.0W	**15**	720mA	59.0W

With maximum 51W UPOE capacity, temperature for 100-cable bundle increased 10 degrees. This is as required by PoE Plus cable standard request defined in 802.3at.

UPOE Operation

This section describes the UPOE operation steps to detect, classify, and negotiate power and subsequently power up the PD.

PD Detection, Classification

The hardware detection and classification mechanism for UPOE follows the IEEE 802.3 standard. The PSE and the PD use a set of physical layer mechanisms to detect the connection of the endpoint and subsequently classify the endpoints into different categories that map to different levels of power requirements. Table 3 lists the PoE classes.

Table 3. PoE Classes

Class	Usage of class	Minimum Power Levels Output at the PSE	Maximum Power Levels at the Powered Device	Class description
0	Default	15.4W	0.44 to 12.95W	Classification unimplemented
1	Optional	4.0W	0.44 to 3.84W	Very Low Power
2	Optional	7.0W	3.84 to 6.49W	Low Power
3	Optional	15.4W	6.49 to 12.95W	Mid Power
4 **4**	Reserved in 802.3af 802.3at	Treat as Class 0 30W	12.95W to 25.5W	High Power

At power-on, a UPOE device is treated as a PoE device and allocated 15.4W as the default power. After power-on the PSE and PD go through a power negotiation phase to determine exactly how much power will be provisioned from the PSE to the PD.

UPOE Power Negotiation

UPOE uses the same CDP and LLDP power negotiation mechanism and algorithms for inline power negotiation with an extended range of allowing requests up to 60W contingent on PSE hardware capability and power budget. With UPOE, we introduce a new CDP and LLDP TLV to accommodate the 4-pair PoE functionality. It is mandatory for any PD requiring 4-pair PoE functionality to implement at least these CDP/LLDP TLVs and have them enabled administratively or by default.

- **UPOE LLDP TLV**

  A new LLDP TLV, "**4-wire Power-via-MDI**" TLV, is introduced for UPOE. This TLV is present in the LLDP packet in all modes of operation, that is, 802.3af, 802.3at, and beyond. The PD can use this TLV to advertise its 4-pair related capabilities and requirements to the PSE; the PSE can power the PD accordingly.

Table 4 shows the LLDP frame format.

Table 4. LLDP Frame Format

TLV Type	TLV Information String Length	Cisco OUI Identifier	Cisco OUI Subtype	PSE/PD Capabilities
7 bits	9 bits	3 octets	1 octet	1 octet

The values of the fields in the TLV are as follows:

TLV Type = 127 (Org Specific TLV)

TLV String Length = 5 (5 bytes)

Cisco OUI Identifier = 00-01-42 (0x000142)

Cisco OUI Subtype = 1

This TLV is required to be implemented by PDs and PSEs that need 4-pair PoE negotiation.

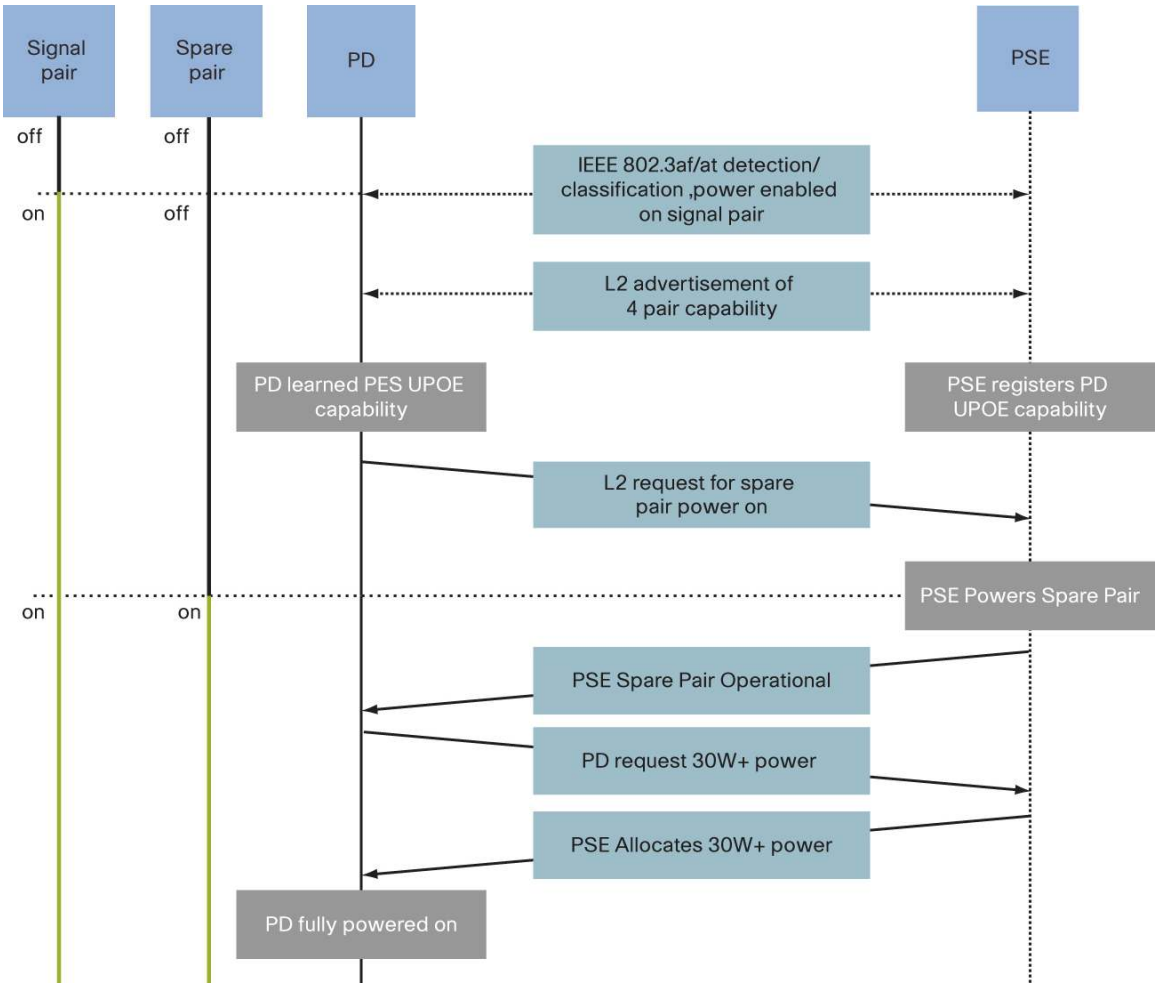
- **UPOE CDP TLV**

  A new CDP TLV, "**Spare Pair PoE**" TLV, is also introduced for the same purposes. It is one octet long and has the same structure as the PSE/PD capabilities field of the LLDP TLV, see Table 5.

Table 5. PSE/PD Capabilities field

Bit	Function	Value/Meaning
0	4-pair PoE Supported	0=No 1=Yes
1	Spare pair Detection/Classification required	0=No 1=Yes
2	PD Spare Pair Desired State	0=Disabled 1=Enabled
3	PSE Spare Pair Operational State	0=Disabled 1=Enabled
B 4:7	Reserved	

Figure 7. UPoE Operation



With this new CDP and LLDP TLV, the PSE and PD follow these steps, as illustrated in Figure 7, to negotiate UPOE power requirement:

1. The PD is first powered up as per IEEE 802.3af/at specifications on the signal pair only.
2. The PD and PSE keep advertising their respective 4-pair PoE capabilities through the UPOE CDP or LLDP TLV defined previously. When a PD receives this TLV from the PSE, it knows that this is a 4-pair PoE capable PSE and hence it can request a power level beyond 30 Watt. When the PSE receives this TLV from PD, it knows that this is a 4-pair PoE capable PD and it can enable power on spare pair.
3. The PD may request the spare pair to be enabled at any point of time after the PD is powered on the signal pair and the 4-pair TLVs are exchanged. The PD signals this to the PSE through the UPOE LLDP or CDP TLV by setting the “PD Spare Pair Desired State” bit. On receiving this request, PSE sends a request to the PoE port firmware to enable power on the spare pair. It takes a finite time duration for the power to be enabled on the spare pair, as the port goes through a sequence of events.
4. When the PSE has successfully enabled power on the spare pair, it sends the UPOE TLV to the PD with the “PSE Spare Pair Operational State” bit set to indicate that it has successfully powered on the spare pair.

5. If the PD likes to request more than 30W power, it may do so only after receiving a TLV from the PSE indicating that the PSE Spare Pair Operational state is Enabled. Once the request is received by the PSE, if the PSE has enough power budget, it allocates the requested power to the port and advertises this back to the PD. The PD is fully powered on only when it receives this response.

   If the PSE does not have sufficient power budget or its configuration restricts the maximum power to the port that is less than the PD's requested power, the switch simply responds back with the currently allocated power to the PD. Thus, the PD should only power hardware based on the "Allocated Power" field that has been previously advertised by the PSE.

UPOE Splitter

To provide flexible deployment, the UPOE splitter is designed to support end devices that don't support PoE natively but can benefit from being powered over PoE.

The UPOE splitter receives both data and UPOE power from the PSE over the standard Ethernet cable. On the other end of the splitter, it splits into a standard Ethernet cable that is capable to transport both data and PoE/PoEP power and a DC connector that is used to transport only power. Depending on the end device situation, the splitter can operate in the following two modes:

- **PoE pass-through mode.** In this mode, the Ethernet cable of the splitter passes through both data and PoE power, and the DC connector passes through power only. Between the Ethernet cable and the DC connector, they share the UPOE power up to 51W. For example, in a VDI deployment as shown in Figure 8, the UPOE splitter is used to connect to a dedicated PoE/PoEP-capable thin client to provide both data and power over its Ethernet cable and to the display monitor to provide power only over its DC connector.
- **Non PoE pass-through mode.** In this mode, the Ethernet cable of the UPOE splitter only transports data, while its DC connector provides power up to 12V. This mode supports end devices that have separate Ethernet port and power input, or it can simply provide Ethernet connectivity to one end device, while providing power to another end device in the work space. For example, in the IP turret example as shown in Figure 9, the Ethernet cable of the splitter is connected to the Ethernet port of the IP turret to provide network connectivity, while the DC connector powers up the IP turret.

Figure 8. PoE Pass-Through

Figure 9. No PoE Pass-Through

Since the splitter doesn't support the negotiation mechanism to negotiate power with PSE, we need to configure the "forced mode" on the PSE port that connects to the splitter.

The UPOE Splitter is designed to protect any damage being made to the powered device that is not compatible with UPOE in the "forced mode".

Cisco Catalyst 4500E UPOE Line Card

Cisco UPOE was first introduced on Cisco Catalyst 4500E Series switching platform, the most widely deployed modular access switching platform in the industry. The platform has time and again demonstrated leadership in this PoE technology innovation.

A new line card, WS-X4748-UPOE+E, has been introduced to support UPOE. The primary features for this line card include:

- UPOE: capable of up to 60W per port simultaneously on 24 ports
- Capable of up to 30W of inline power per port on all ports simultaneously
- Energy Efficient Ethernet 802.3az
- Backward IEEE 802.3af/at and Cisco pre-standard PoE
- LLDP-based dynamic power negotiation capability
- Nonblocking 48 10/100/1000 Mbps ports
- IEEE 802.1ae and Cisco TrustSec® capability in hardware
- L2-4 Jumbo Frame support (up to 9216 bytes)

Power Supplies Consideration for UPOE Deployment

For UPOE deployment with Cisco Catalyst 4500E, it is recommended to use one of the following two AC power supplies:

- PWR-C45-4200ACV
- PWR-C45-6000ACV

Table 6 lists the maximum number of PDs that these two power supplies can support in a combined mode.

Table 6. maximum number of PDs supported

	Standard 802.3af Classes 0 and 3 (15.4W per Port)	Standard 802.3at Class 4 (30W per Port)	Cisco UPOE (60W per Port)
4200WAC	374	192	96
6000WAC	384	269	134

For more detailed information regarding these power supplies, check the power supply specifications at http://www.cisco.com/en/US/docs/switches/lan/catalyst4500/hardware/catalyst4500e/installation/guide/0aspecs.html.

The **Cisco Power Calculator** helps to calculate the power supply requirements for a specific PoE configuration. The results will show output current, output power, and system heat dissipation. It also provides the list of power supplies and their power management modes that meet the requirements.

For a more detailed power calculation for any specific configuration, use the Cisco Power Calculator at http://tools.cisco.com/cpc.

Summary

Cisco Universal PoE, with its 60W capability, enables wide range of use cases with boarder end devices support. It simplifies the enterprise deployment with lower OpEx, higher availability, and faster deployment. It provides transparent transition with maximum interoperability and backward compatibility with existing PoE and PoE Plus deployments. Cisco Catalyst 4500E, industry's most deployed modular access switching platform, is the first in the industry to deliver Universal PoE technology. Together with its high performance, maximum resiliency, deep application visibility, and Cisco TrustSec security, Cisco Catalyst 4500E with UPOE continues to enable and transform the next-generation enterprise workspaces.

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