Power over Ethernet

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Wireless LAN access point, powered by a PoE splitter

Power over Ethernet or **PoE** technology describes a system to pass electrical power safely, along with data, on Ethernet cabling. The IEEE standard for PoE requires category 5 cable or higher for high power levels, but can operate with category 3 cable for low power levels.[1] Power is supplied in common mode over two or more of the differential pairs of wires found in the Ethernet cables and comes from a power supply within a PoE-enabled networking device such as an Ethernet switch or can be *injected* into a cable run with a *midspan* power supply.

The original **IEEE 802.3af-2003**[2] PoE standard provides up to 15.4 W of DC power (minimum 44 V DC and 350 mA [3][4]) to each device.[5] Only 12.95 W is assured to be available at the powered device as some power is dissipated in the cable.[6]

The updated **IEEE 802.3at-2009**[7] PoE standard also known as **PoE+** or **PoE plus**, provides up to 25.5 W of power.[8] The 2009 standard prohibits a powered device from using all four pairs for power.[9] Some vendors have announced products that claim to be compatible with the 802.3at standard and offer up to 51 W of power over a single cable by utilizing all four pairs in the Cat.5 cable.[10]

Numerous non-standard schemes had been used prior to PoE standardization to provide power over Ethernet cabling. Some are still in active use.

Contents

Advantages over other integrated data and power standards

This technology is especially useful for powering IP telephones, wireless LAN access points, cameras with pan tilt and zoom (PTZ), remote Ethernet switches, embedded computers, thin clients and LCDs.

All these require more power than USB offers and very often must be powered over longer runs of cable than USB permits. In addition, PoE uses only one type of connector, an 8P8C modular connector (often called RJ45), whereas there are numerous types of USB connectors.

PoE is presently deployed in applications where USB is unsuitable and where AC power would be inconvenient, expensive[note 1] or infeasible to supply. However, even where USB or AC power could be used, PoE has several advantages over either, including the following:

- Cheaper cabling — even category 5 cable is cheaper than USB repeaters, and the task of meeting building code requirements to run AC power cable is eliminated.
- A Gigabit connection to every device is possible, which exceeds 2009 USB and the AC powerline networking capabilities.
- Global organizations can deploy PoE everywhere without concern for any local variance in AC power standards, outlets, plugs, or reliability.
- Direct injection from standard 48 V DC battery power arrays; this enables critical infrastructure to run more easily in outages, and make power rationing decisions centrally for all the PoE devices. The *priority* for power-supply via PoE can be configured via the switches.
- Symmetric distribution is possible. Unlike USB and AC outlets, power can be supplied at either end of the cable or outlet. This means the location of the power source can be determined after cables and outlets are installed.

Uses

Some types of devices with PoE include:[11]

PoE 1140E VoIP Phone

- IP Security Cameras
- Network routers
- A mini network switch installed in distant rooms, to support a small cluster of ports from one uplink cable. (These ports on the mini-switch do not themselves provide PoE.) (In most modern VoIP phones a one-port switch is embedded to which a local workstation can be installed using another VLAN that the voice-VLAN used by the phone itself)
- Network webcams
- Network Intercom / Paging / Public address systems and hallway speaker amplifiers
- VoIP phones
- Wall clocks in rooms and hallways, with time set using Network Time Protocol
- Wireless access points
- Outdoor roof mounted radios with integrated antennas, 802.11 or 802.16 based wireless CPEs (customer premises equipment) used by wireless ISPs.
- Industrial devices (sensors, controllers, meters etc.)
- Access control and Help-points (intercoms, entry cards, keyless entry, etc.)
- Lighting controllers
- Remote Point of Sale (POS) kiosks

Terminology

Power sourcing equipment

Power sourcing equipment (PSE) is a device such as a switch that provides ("sources") power on the Ethernet cable. The maximum allowed continuous output power per cable in IEEE 802.3af is 15.40 W. A later specification, IEEE 802.3at, offers 25.50 W.

When the device is a switch, it's called an endspan. Otherwise, if it's an intermediary device between a non PoE capable switch and a PoE device, it's called a midspan. An external PoE *injector* is a *midspan* device[12]

Powered device

A powered device (PD) is a device powered by a PSE and thus consumes energy. Examples include wireless access points, IP Phones, and IP cameras.

Many powered devices have an auxiliary power connector for an optional, external, power supply. Depending on the PD design, some, none, or all power can be supplied from the auxiliary port,[13][14] with the auxiliary port sometimes acting as backup power in case of PoE supplied power failure.

Power management features and integration

Avaya ERS-5520 switch with 48 Power over Ethernet ports

Most advocates expect PoE to become a global longterm DC power cabling standard and replace "wall wart" converters, which cannot be easily centrally managed, waste energy, are often poorly designed, and are easily vulnerable to damage from surges and brownouts. A combination of G.9960 networking on existing AC power lines to an outlet where a PoE router is plugged in is capable of moving a gigabit per second to every device, with minimal wiring and participating fully in both AC and DC device power demand management.

Integration with the IEEE 802.3az standard, the energy management capabilities of the combined standard are expected to be formidable. However, that integration has not yet occurred.

Standard implementation

Standards-based power over Ethernet is implemented following the specifications in IEEE 802.3af-2003 (which was later incorporated as clause 33 into IEEE 802.3-2005) or the 2009 update, IEEE 802.3at. A phantom power technique is used to allow the powered pairs to also carry data. This permits its use not only with 10BASE-T and 100BASE-TX, which use only two of the four pairs in the cable, but also with 1000BASE-T (gigabit Ethernet), which uses all four pairs for data transmission. This is possible because all versions of Ethernet over twisted pair cable specify differential data transmission over each pair with transformer coupling; the DC supply and load connections can be made to the transformer center-taps at each end. Each pair thus operates in common mode as one side of the DC supply, so two pairs are required to complete the circuit. The polarity of the DC supply may be inverted by crossover cables; the powered device must operate with either pair: spare pairs 4–5 and 7–8 or data pairs 1–2 and 3–6.

Polarity is required on data pairs, and ambiguously implemented for spare pairs, with the use of a diode bridge.

Standard PoE parameters and comparison

Property	802.3af (802.3at Type 1)	802.3at Type 2
Power available at PD [note 2]	12.95 W	25.50 W
Maximum power delivered by PSE	15.40 W	34.20 W
Voltage range (at PSE)	44.0–57.0 V[15]	50.0–57.0 V[15]
Voltage range (at PD)	37.0–57.0 V[16]	42.5–57.0 V[16]
Maximum current	350 mA[17]	600 mA[17] per mode
Maximum cable resistance	20 Ω (Category 3)	12.5 Ω (Category 5)
Power management	Three power class levels negotiated at initial connection	Four power class levels negotiated at initial connection or 0.1 W steps negotiated continuously
Derating of maximum cable ambient operating temperature	None	5°C with one mode (two pairs) active
Supported cabling	Category 3 and Category 5[1]	Category 5[1][note 3]
Supported modes	Mode A (endspan), Mode B (midspan)	Mode A, Mode B

Powering devices

Two modes, A and B, are available. Mode A delivers phantom power on the data pairs of 100BASE-TX or 10BASE-T. Mode B delivers power on the spare pairs. PoE can also be used on 1000BASE-T Ethernet in which case, there are no spare pairs and all power is delivered using the phantom technique.

Mode A has two alternate configurations (MDI and MDI-X), using the same pairs but with different polarities. In mode A, pins 1 and 2 (pair #2 in T568B wiring) form one side of the 48 V DC, and pins 3 and 6 (pair #3 in T568B) form the other side. These are the same two pairs used for data transmission in 10BASE-T and 100BASE-TX, allowing the provision of both power and data over only two pairs in such networks. The free polarity allows PoE to accommodate for crossover cables, patch cables and auto-MDIX.

In mode B, pins 4–5 (pair #1 in both T568A and T568B) form one side of the DC supply and pins 7–8 (pair #4 in both T568A and T568B) provide the return; these are the "spare" pairs in 10BASE-T and 100BASE-TX. Mode B, therefore, requires a 4-pair cable.

The PSE, not the powered device (PD), decides whether power mode A or B shall be used. PDs that implement only Mode A or Mode B are disallowed by the standard.

The PSE can implement mode A or B or both. A PD indicates that it is standards-compliant by placing a 25 kΩ resistor between the powered pairs. If the PSE detects a resistance that is too high or too low (including a short circuit), no power is applied. This protects devices that do not support PoE. An

optional "power class" feature allows the PD to indicate its power requirements by changing the sense resistance at higher voltages. To stay powered, the PD must continuously use 5–10 mA for at least 60 ms with no more than 400 ms since last use or else it will be unpowered by the PSE.[18]

There are two types of PSEs: endspans and midspans. Endspans are Ethernet switches that include the power over Ethernet transmission circuitry. Endspans are commonly called PoE switches. Midspans are power injectors that stand between a regular Ethernet switch and the powered device, injecting power without affecting the data.

Endspans are normally used on new installations or when the switch has to be replaced for other reasons (such as moving from 10/100 Mbit/s to 1 Gbit/s or adding security protocols), which makes it convenient to add the PoE capability. Midspans are used when there is no desire to replace and configure a new Ethernet switch, and only PoE needs to be added to the network.

Stages of powering up a PoE link

Stage	Action	Volts specified [V]	
		802.3af	802.3at
Detection	PSE detects if the PD has the correct signature resistance of 19–26.5 kΩ	2.7–10.0	
Classification	PSE detects resistor indicating power range (see below)	14.5–20.5	
Mark 1	Signals PSE is 802.3at capable. PD presents a 0.25–4 mA load.	—	7–10
Class 2	PSE outputs classification voltage again to indicate 802.3at capability	—	14.5–20.5
Mark 2	Signals PSE is 802.3at capable. PD presents a 0.25–4 mA load.	—	7–10
Startup	Startup voltage [19][20]	> 42	> 42
Normal operation	Supply power to device [19][20]	37–57	42.5–57

IEEE 802.3at capable devices are also referred to as "type 2". An 802.3at PSE may also use layer2 communication to signal 802.3at capability.[21]

Power levels available[22]

Class	Usage	Classification current [mA]	Power range [Watt]	Class description
0	Default	0–4	0.44–12.94	Classification unimplemented
1	Optional	9–12	0.44–3.84	Very Low power
2	Optional	17–20	3.84–6.49	Low power
3	Optional	26–30	6.49–12.95	Mid power
	Valid for 802.3at (Type 2)			

4	devices, not allowed for 802.3af devices	36–44	12.95–25.50	High power

Class 4 can only be used by IEEE 802.3at (type 2) devices, requiring valid Class 2 and Mark 2 currents for the power up stages. An 802.3af device presenting a class 4 current is considered non-compliant and, instead, will be treated as a Class 0 device.[23]

Configuration via Ethernet layer 2 LLDP

LLDP-MED Advanced Power Management[24]:8

TLV Header		**MED Header**		**Extended power via MDI**			
Type (7 bits)	**Length (9 bits)**	**TIA OUI (3 octets)**	**Extended power via MDI subtype (1 octet)**	**Power type (2 bits)**	**Power source (2 bits)**	**Power priority (4 bits)**	**Power value (2 octets)**
127	7	00-12-BB	4	PSE or PD	Normal or Backup conservation	Critical, High, Low	0–102.3 W in 0.1 W steps

The setup phases are as follows:

- PSE (provider) tests PD (consumer) physically using 802.3af phase class 3.
  - PSE powers up PD.
- PD sends to PSE: I'm a PD, max power = X, max power requested = X.
- PSE sends to PD: I'm a PSE , max power allowed = X.
  - PD may now use the amount of power as specified by the PSE.

The rules for this power negotiation are:

- PD shall never request more power than physical 802.3af class
- PD shall never draw more than max power advertised by PSE
- PSE may deny any PD drawing more power than max allowed by PSE
- PSE shall not reduce power allocated to PD, that is in use
- PSE may *request* reduced power, via conservation mode[24]:10

Non-standard implementations

Cisco

Cisco manufactured WLAN access points and IP phones many years before there was an IEEE standard for delivering PoE. Cisco's original PoE implementation is not software upgradeable to the IEEE 802.3af standard. Cisco's original PoE equipment was capable of delivering up to 10 W per port. The amount of

power to be delivered is negotiated between the endpoint and the Cisco switch based on a power value that was added to the Cisco proprietary Cisco Discovery Protocol (CDP). CDP is also responsible for dynamically communicating the Voice VLAN value from the Cisco switch to the Cisco IP Phone.

Under Cisco's pre-standard scheme, the PSE (switch) will send a Fast Link Pulse (FLP) on the transmit pair. The PD (device) connects the transmit line to the receive line via a low pass filter. And thus the PSE gets the FLP in return. And a common mode current between pair 1 and 2 will be provided resulting in 48 V DC[25] and 6.3 W[26] default of allocated power. The PD has then to provide Ethernet link within 5 seconds to the auto-negotiation mode switch port. A later CDP message with a type-length-value tells the PSE its final power requirement. A discontinued link pulses shuts down power.[27]

PowerDsine

PowerDsine, now a Microsemi brand, sold midspan power injectors since 1999 with its proprietary *Power over LAN* solution. Several companies such as LevelOne, 3Com and Nortel followed PowerDsine's Power over LAN.[*citation needed*]

Passive

Numerous devices exist which make use of positive power received on pins 4 and 5 of the Ethernet cable, with negative return on pins 7 and 8. Power over Ethernet injectors exist which convert 110-240V 50/60 Hz AC power to 9V, 15V, 24V, 48V or 55V DC with currents ranging from 0.5A to 2.0A. In the common "passive" PoE system the injector does not communicate with the powered device to negotiate its wattage requirements, but merely supplies power. Passive DC to DC injectors also exist which convert a 9V to 36V DC input power source to a stabilized 24V 1A or 48V 0.5A PoE feed with pins +4,5 and -7,8. These DC to DC PoE injectors are used in a variety of different telecom applications.[28]

Notes

1. ^ Mains wiring must often be done by qualified and/or licensed electricians for legal or insurance reasons.
2. ^ Most switched power supplies within the powered device will lose another 10 to 25% of the available power.
3. ^ More stringent cable specification allows assumption of more current carrying capacity and lower resistance (20.0 Ohms for Category 3 versus 12.5 Ohms for Category 5).

Category 5 cable uses 24 AWG conductors, which can safely carry 360 mA at 50 V according to the latest TIA ruling.[*citation needed*] The cable has eight conductors (only half of which are used for power) and therefore the absolute maximum power transmitted using direct current is 50 V × 0.360 A × 2 = 36 W. Considering the voltage drop after 100 m, a PD would be able to receive 31.6 W. The additional heat generated in the wires by PoE at this current level (4.4 watts per 100 meter cable) limits the total number of cables in a bundle to be 100 cables at 45 °C, according to the TIA. This can be somewhat alleviated by the use of Category 6 cable which uses 23 AWG conductors.

802.3af Standards A and B

PINS on Switch	10/100 DC on Spares (mode B)	10/100 Mixed DC & Data (mode A)	1000 (1 Gigabit) DC & Bi-Data (mode B)	1000 (1 Gigabit) DC & Bi-Data (mode A)
Pin 1	Rx +	Rx + DC +	TxRx A +	TxRx A + DC +

Pin 2	**Rx -**	**Rx - DC +**	**TxRx A -**	**TxRx A - DC +**
Pin 3	**Tx +**	**Tx + DC -**	**TxRx B +**	**TxRx B + DC -**
Pin 4	**DC +**	**unused**	**TxRx C + DC +**	**TxRx C +**
Pin 5	**DC +**	**unused**	**TxRx C - DC +**	**TxRx C -**
Pin 6	**Tx -**	**Tx - DC -**	**TxRx B -**	**TxRx B - DC -**
Pin 7	**DC -**	**unused**	**TxRx D + DC -**	**TxRx D +**
Pin 8	**DC -**	**unused**	**TxRx D - DC -**	**TxRx D -**

See also

- Network switch, connects network nodes with independent pipes (efficient)
- Power line communication, data communication over mains electricity
- Switched-mode power supply, efficient electrical power conversion
- ITU-T G.hn, a home network using existing home wiring (power lines, phone lines and coaxial cables)
- Phantom power, long established standard technique to power microphones
- HomePlug Powerline Alliance, an industry trade group on datacommunication over mains electricity

References

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2. ^ *802.3af-2003*, June 2003
3. ^ IEEE 802.3-2005, section 2, table 33-5, item 1
4. ^ IEEE 802.3-2005, section 2, table 33-5, item 4
5. ^ IEEE 802.3-2005, section 2, table 33-5, item 14
6. ^ IEEE 802.3-2005, section 2, clause 33.3.5.2
7. ^ *802.3at Amendment 3: Data Terminal Equipment (DTE) Power via the Media Dependent Interface (MDI) Enhancements*, September 11, 2009
8. ^ "Amendment to IEEE 802.3 Standard Enhances Power Management and Increases Available Power". IEEE. http://standards.ieee.org/announcements/stdbd_approves_ieee802.3at.html. Retrieved 2010-06-24.
9. ^ Clause 33.3.1 stating, "PDs that simultaneously require power from both Mode A and Mode B are specifically not allowed by this standard."
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13. ^ IEEE 802.3-2008, section 2, clause 33.3.5
14. ^ IEEE 802.3at-2009, clause 33.3.7
15. ^ *a b* IEEE 802.3at-2009 Table 33-11
16. ^ *a b* IEEE 802.3at-2009 Table 33-18
17. ^ *a b* IEEE 802.3at-2009 Table 33-1

18. ^ Banish Those "Wall Warts" With Power Over Ethernet
19. ^ *a b* IEEE 802.3-2008, section 2, table 33-12
20. ^ *a b* IEEE 802.3at-2009, table 33-18
21. ^ "LTC4278 IEEE 802.3at PD with Synchronous No-Opto Flyback Controller and 12V Aux Support". http://cds.linear.com/docs/Datasheet/4278fa.pdf. 2010-01-11 cds.linear.com
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23. ^ IEEE 802.3-2008, section 2, clause 33.3.4
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External links

- ieee802.org: Download the IEEE 802.3 standards
- ieee802.org: IEEE 802.3af Task Force
- ieee802.org: IEEE 802.3at Task Force

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