Instituto Superior
de Engenharia
Politécnico de Coimbra

# PoE

## Structured Cabling

Tomás Faria Ramos
2022140175

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# Chapter 1

# Introduction to PoE

PoE, or Power Over Ethernet, describes any of several standards or ad hoc systems that pass electric power along with data on twisted-pair Ethernet cabling. This allows a single cable to provide both a data connection and enough electricity to power networked devices such as WAPs, IP cameras and VoIP phones.

## 1.1 Techniques

There are several techniques for transmitting power over Ethernet cabling. Three of them have been standardized by the IEEE 802.3 standard since 2003.

The three techniques are:

- Using the same two of the four signal pairs that 10BASE-T and 100BASE-TX use for data in typical Cat 5 cabling;
- Separating the data and the power conductors for 10BASE-T and 100BASE-TX, making troubleshooting easier;
- Using 4PPoE, which uses all four twisted pairs in parallel, increasing the achievable power.

The first technique transmits power on the same wires as data for 10 and 100Mb/s Ethernet variants. Power is transmitted on the data conductors by applying a common voltage to each pair.

Because twisted-pair Ethernet uses differential signaling, this does not interfere with data transmission.

For Gigabit Ethernet and faster, the first two techniques transmit power on wire pairs also used for data since all four pairs are used for data transmission at these speeds.

4PPoE provides power using all four pairs of a twisted-pair cable. This enables higher power for applications like pan-tilt-zoom cameras (PTZ), high performance WAPs, or even charging laptop batteries.

The IEEE PoE standards provide for signaling between the power sourcing equipment (PSE) and the powered device (PD). This signaling allows the presence of a conformant device to be detected by the power source, and allows the device and source to negotiate the amount of power required or available while avoiding damage to non-compatible devices.

## 1.2 Terminology

### Power Sourcing Equipment

PSEs are devices that provide source power on the Ethernet cable. These devices may be a network switch, commonly called an endspan or endpoint, or an intermediary device between a non-PoE capable switch and a PoE device, and external PoE injector, called a midspan device.

### Powered Device

A PD is any device powered by PoE, thus consuming energy. Examples include APs, VoIP phones and IP cameras.

Many powered devices have an aux power connector for an optional external power supply. Depending on the design, some, none or all of the device's power can be supplied from the aux port. The aux port can also act as backup power in case PoE-supplied power fails.

## 1.3 Power Management Features and Integration

Advocates of PoE expect PoE to become a global long term DC power cabling standard and replace a multiplicity of individual AC adapters, which cannot be easily centrally managed.

Critics of this approach argue that PoE is inherently less efficient than AC power due to the lower voltage, and this is made worse by the thin conductors of Ethernet.

Advocates of PoE point out that quoted losses are for worst case scenarios in terms of cable quality, length and power consumption by powered devices. In any case, where the central PoE supply replaces several dedicated AC circuits, transformers and inverters, the power loss in cabling can be justifiable.

# Chapter 2

# Standards

## 2.1 Development

### 2.1.1 Two and Four-pair Ethernet

The original IEEE 802.3af-2003 PoE standard provides up to 15.4W of DC power (minimum 44V DC and 350 mA) on each port. Only 12.95W is assured to be available at the powered device as some power dissipates in the cable.

The IEEE 802.3at-2009 PoE standard, also known as PoE+, provides up to 25.5W of power for Type 2 devices. The 2009 standard prohibits a powered device from using all four pairs of power.

The IEEE 802.3bt-2018 standard further expands the power capabilities of 802.3at. It is also known as PoE++ or 4PPoE. The standard introduces two additional power types: up to 51W delivered power (Type 3) and up to 71.3W delivered power (Type 4), optionally by using all four pairs for power.

Each pair of twisted pairs needs to handle a current up to 600 mA (type 3) or 960 mA (Type 4). Additionally, support for 2.5GBASE-T and 10GBASE-T is included. This development opens the door to new applications and expands the use of applications such as high-performance WAPs and surveillance cameras.

### 2.1.2 Single-pair Ethernet

The IEEE 802.3bu-2016 amendment introduced single-pair Power over Data Lines (PoDL) for the single-pair Ethernet standards 100BASE-T1 and 1000BASE-T1 intended for automotive and industrial applications.

On the two-pair or four-pair standards, the same power voltage is applied to each conductor of the pair, so that within each pair there is no differential voltage other than that representing the transmitted data. With single-pair Ethernet, power is transmitted in parallel to the data.

## 2.2 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.

The standards require Cat 5 cable or better for high power levels, but allow using Cat 3 cable if less power is required.

Power is supplied as a common-mode signal 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, an additional PoE power source that can be used in combination with a non-PoE switch.

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, 2.5GBASE-T, 5GBASE-T and 10GBASE-T, which use 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.

### 2.2.1 Powering Devices

Three modes, A, B and 4-pair are available. Mode A delivers power on the data pairs of 100BASE-TX or 10BASE-T. Mode B delivers power on the spare pairs. 4-pair delivers power on all four pairs. PoE can also be used on 1000BASE-T, 2.5GBASE-T, 5GBASE-T and 10GBASE-T Ethernet, in which case there are no spare pairs and all power is delivered using the phantom technique.

#### Mode A

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 form one side of the 48V DC, and pins 3 and 6 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 MDI-X.

#### Mode B

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

#### Detecting PoE

The PSE, not the 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 25k$\Omega$ 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 retain power, the PD must use at least 5 to 10 mA for atleast 60ms at a time. If the PD goes more than 400ms without meeting this requirement, the PSE will consider the device disconnected and, for safety reasons, remove power.

There are two types of PSEs: endspans and midspans.

Endspans (commonly called PoE switches) are Ethernet switches that include the power over Ethernet transmission circuitry.

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, 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

- Detection: The PSE detects if the PD has the correct signature resistance of 19 to 25.5kΩ;
- Classification: The PSE detects resistor indicating power range;
- Mark 1: Signals PSE is 803.3at capable. PD presents a 0.25 to 4mA load;
- Class 2: The PSE outputs the classification voltage again to indicate 802.3at capability;
- Mark 2: Signals PSE is 803.3at capable. PD presents a 0.25 to 4mA load;
- Startup: Startup Voltage;

- Normal Operation: Supply power to device.