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A Practical Guide to Power Over Ethernet (PoE) by Avaya

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ABSTRACT

This paper will discuss the highlights in the Power over Ethernet standard (IEEE 802.3af) and the earlier pre-standard PoE implementations. Common implementation issues are also addressed to help you avoid unpleasant surprises.

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A Practical Guide to Power over Ethernet (PoE)

Document Summary

This document contains basic, but practical information concerning Power over Ethernet. Powering devices like Access Points (APs), IP Telephones, Web Cameras, etc. through the Ethernet cable is a natural evolution in the networking industry. The Central Office in the PSTN historically powered analog phones for many decades. The PBX has also powered digital phones through the wires. Appliances, like Access Points and Web-based Cameras are positioned in hard to reach locations, like ceilings, and are therefore prime candidates for power through the Ethernet cable that connects them. There are benefits in powering IP telephones through the Ethernet cable. One is convenience and another is the ability to monitor devices.

This paper will discuss the highlights in the Power over Ethernet standard (IEEE 802.3af) and the earlier pre-standard PoE implementations. Common implementation issues are also addressed to help you avoid unpleasant surprises.

The first part of this paper describes the basics of the IEEE 802.3af standard that was ratified in June 2003. The second part of this paper describes practical differences in Power over Ethernet (PoE) implementations of Avaya and Cisco equipment compared to the standard and to each other. This paper is not intended to point out shortcomings of any other vendor, but it is beneficial to reveal subtle issues in vendor specific implementations of PoE that can cause issues during and after installation. Since many customers use a Cisco data infrastructure, Cisco specific examples are cited and compared to Avaya's products. A PoE checklist is included in Appendix A as a quick check to aid your implementations.

Table of Contents

A Practical Guide to Power over Ethernet (PoE)

1   Introduction

Voice over Internet Protocol (VoIP) is the convergence of traditional voice onto an IP data network to provide better application integration by using common protocols. This lowers costs by using one network infrastructure and even melding separate support staffs into one.   Other real-time traffic streams, such as uncompressed video and streaming audio are also converging onto data networks.

Convergence began with basic VoIP and, over time, has expanded traditional features and functions including powering IP endpoints. The idea to send power through cables to an end device is not new. Home analog telephones have been powered from the Central Office (CO) for scores of years. PBX type switches have also provided power to analog and digital phones in business offices for decades. The evolution to send power over a Cat-5 type cable is then a natural extension of an existing idea applied to a new platform – the data network.

It is interesting that the IEEE eventually based their standard on the Avaya (Lucent Technologies at that time) PoE scheme. This means that all Avaya products have been standards compliant even before the standard was ratified. This also means that proprietary implementations of PoE, like Cisco, had to convert from their vendor specific methods to the standards-based protocol. Older Cisco chassis-based switch blades required daughter cards or total blade replacement to provide compliant power to the newer standard. Adhering to the standard, titled **IEEE 802.3af**, is important because it allows power interoperability from any vendor's products. You can have confidence in Avaya's products knowing that Avaya led the IEEE standards committee with the ultimate solution for Powering devices over the Ethernet cable. No one implements Power over Ethernet (PoE) better than Avaya. Avaya can intelligently and dynamically apply the right amount of power to ANY vendor's products that are standards compliant. Please see section 5 of this paper for details.

2   Definitions

Before technologies are discussed, some important definitions must be learned.

End-Span. An End-Span, or Endpoint PSE is an Ethernet switch that is capable of sending Power over Ethernet up to 100 meters over copper twisted pair to an endpoint device like an IP telephone.

Mid-Span. A device that lies between the Ethernet switch (or hub) and injects Power through the Ethernet (copper) cable to the endpoint device. A Mid Span is not an access device like a switch or a hub. Its only purpose is to inject power from the middle of the link between an access device (switch) and the endpoint – hence the name "Mid" span.

Ohm. A measure of resistance using the Omega symbol - Ω

PD – Powered Device. A powered device is an endpoint that requires power. Many devices can accommodate power in more than one way such as a local transformer or Power over Ethernet. Examples of devices include IP telephones, Access Points, Web Cameras, magnetic card readers, etc.

PoE – Power over Ethernet is any scheme, either proprietary or standards-based, that defines how to send power through an Ethernet cable.

PSE – Power Sourcing Equipment. A PSE is a device that sends Power over Ethernet to the PD. End-Span and Mid-Span provide PoE, but there can also be other devices that send power to PDs.

Watt. A measure of power derived by multiplying current (Amperes) with resistance (Ohms). One Watt equals one Ampere across one Ohm's worth of resistance.

3   IEEE 802.3af – how it works

The phases between connecting a PD, power flow to the PD and power termination are:

PD (Powered Device) Detection

PD Classification or actual power determination

Power management, termination and PD re-discovery

PD Detection: The goal of this phase is to detect a valid PD. When a PD is connected to a PSE (Power Sourcing Equipment), a small DC current is sent from the PSE. A PSE is typically a switch (End-Span) or a power injector (Mid Span). If the resistive load of a PD is sensed at 25K Ω (+/- 1.25K Ω), the device may meet the 802.3af requirements for power. Not only does the resistive load need to meet the 25K Ω level, but the PD must also meet the resistance range during a short voltage ramp-up period.   The idea is to only power devices that are valid PDs and to protect non-PDs that could be damaged if they received power.

In a short amount of time, voltage is increased from 2.7 Volts to 10.1 Volts in 1.0 Volt increments. The resistance must remain between the range of 23.75K Ω and 26.25K Ω or power is removed almost immediately. <u>This is generally known as the 802.3af resistive signature</u> – adhering to both an initial resistive range and that same range during a voltage ramp-up period. Any device that does not present this resistive signature, will not receive power from the PSE. Additionally, any "signature" in the zones <u>beyond</u> 23.75 – 26.25 K Ω presents an invalid or non-compliant signature and power will not be applied. See appendix B for specifics on invalid and non-compliant signatures. Capacitance and inductance values are also measured when validating a PD to the IEEE 802.3af standard**.**

Table 1 – Parameters for a valid PD power signature

Valid PD Detection	Ramp-up Conditions	Resistive Signature Range
Initial Resistive load for a potential PD		23.75K Ω – 26.25K Ω
Required resistance during voltage ramp-up	2.7V – 10.1V	23.75K Ω – 26.25K Ω
Input capacitance	2.7V – 10.1V	0.05µF – 0.12µF
Input Inductance	2.7V – 10.1V	≤ 100µH

Note: Power in the 802.3af standard is expressed in watts assuming 48 volts to the PD. By design, a PD must accept a voltage variance. The standard mandates that "any PD will withstand 0 to 57 volts indefinitely without damage".

The IEEE 802.3af standard allows power on either the spare pairs or the signaling pairs. Ethernet uses signaling wire pairs 1,2 & 3,6. Power over these used pairs is sometimes called phantom power or inline power. Most End-Span PSEs (switches) use the inline power scheme, but they can also use the spare pairs 4,5 & 7,8 as an option.

Mid-Span PSEs use only the spare pairs 4,5 & 7,8 to transmit power. All PDs are required to accept power on either spare or signaling pairs. All Avaya products comply with this requirement and can be powered three ways; from the signal pair, the spare pair or one pair (7,8) as a further option to support external power supplies like a "brick" type transformer.

PD Classification: After detection, the goal of this next phase is to supply appropriate power. This can be done based on the IEEE 802.3af power class of the PD, or more intelligent algorithms can sense how much power is actually needed.

The IEEE 802.3af standard defines, but does not mandate, the use of power classes. This means a PD may advertise one, and only one power class. This is important for non-Avaya PSEs that logically allocate power from the total power pool and is discussed later in this paper. The following chart describes power (in watts) required by PDs and provided by PSEs.

Table 2 – IEEE 802.3af power definitions for each class of PSE and PD devices

Class	Usage	Minimum Power from PSE	Power Range at PD
0	Default	15.4w	0.44w – 12.95w
1	Optional	4.0w	0.44w – 3.84w
2	Optional	7.0w	3.84w – 6.49w
3	Optional	15.4w	6.49w – 12.95w
4	Reserved	Treat as Class 0	Future Use

The preceding chart not only describes the power ranges for endpoints, but also the power minimums for PSEs. The difference between the maximum PD power and the maximum PSE delivered power is needed to "push" the power across a potential 100 meters (328 feet) of copper twisted pair between the PSE and the PD. There is a natural attenuation of power from the PSE to the PD as the power encounters the impedance of the copper wire. Therefore, more power is needed from the PSE so the full PoE class maximum wattage is delivered to the PD.

IEEE 802.3af PD power class is derived from a classification signature measured in milli-Amps. The chart below describes the values that a PD presents to a current under a constant voltage. The values returned to the PSE then classify that PD into an IEEE power class.

Table 3 – Values used to assign PDs into IEEE 802.3af classes

Classification Signature	Conditions	Values
Current for Class 0	14.5V – 20.5V	0 – 4 mA
Current for Class 1	14.5V – 20.5V	9 – 12 mA
Current for Class 2	14.5V – 20.5V	17 – 20 mA
Current for Class 3	14.5V – 20.5V	26 – 30 mA
Current for Class 4	14.5V – 20.5V	36 – 44 mA

PD Management, Termination and Rediscovery: This final stage is steady state power management including continual power parameter sensing and detecting PD absence or violation of required parameters. Steady state powering involves a continual sensing of valid parameters. An example is a sudden short circuit of the wire pairs carrying power. This condition is detected and power is almost instantly halted by the PSE. If a PD is drawing power and is removed from the PSE port, power is again halted because another device could use that same PSE port and be damaged by erroneously receiving power. Lastly, if resistance, capacitance or inductance lies in the values listed in Appendix B, power is removed because the signature is now invalid or non-compliant. This is the end of the 802.3af material. The remaining sections are vendor specifics on implementing IEEE 802.3af PoE.

4 Static vs. Dynamic Power Allocation

Static Power Allocation

This method is used by many vendors because it is cheaper to implement. If a device advertises itself as a class-1 endpoint but needs only 1-Watt of power, the PSE will allocate 4-Watts of power to the port serving that device. This is done by logically allocating 4-Watts from the available power pool. Similarly, a class-3 device needing 8-Watts will be allocated 15.4-Watts of power. The problems with allocating the top of the class range power are:

More power is reserved than is needed. A 1-Watt device will be allocated 4-Watts because the top of the range for class-1 is 3.84-Watts plus a little more to travel over a possible 100 meters of Cat-5 cable.

Reserved power can deplete the total power pool even though it is not used. The resulting penalty from logically reserving more power than the PD requires is that available power is "logically" exhausted before all physical switch ports are used. For example, if a customer is using IP phones and those phones are PoE class-3, each physical port will be ready to send out 15.4-watts. If each phone only requires 7-watts, but 15.4-watts are reserved, 8.4-watts per port will logically consume part of the total power pool. Ten of these physical ports used will strand 84 watts of power from the power pool. 24 ports will strand 201.6 Watts. 96 ports will strand 806.4 Watts. This is a worst case example.

The assumption that each port connected to a Class-3 device should be ready to provide 15.4-Watts at any time doesn't make sense with IP telephones or any known standards compliant device. Very few if any devices operationally vary in power needs more than one Watt. An on-hook phone taking 8 watts will almost never require more than 9-Watts in the off-hook state. Very few if any PDs require more than 11 watts, so the assumption of having to apply 15.4 watts rarely happens.

Static power allocation results in a brute-force application that is wasteful and unintelligent. It is easy to calculate and deliver power based on the top of the power class, but it results in wasting or "stranding" power logically from the total power pool. The practical results are:

- ✓ Incurring low port density. A 48-port switch or switch blade may only provide power to 32 ports because power was logically exhausted.

- ✓ Buy larger power supplies. Systems with more than one power supply or chassis based switches usually have options to buy higher wattage supplies. A larger power supply can mitigate or even overcome the logical reservation limit, but at a cost of needlessly buying a large power supply you don't really need. Larger power supplies also cost more to run.

- ✓ Buy more switches. If larger power supplies don't solve the problem, buying more switches may be an alternative but can be very expensive. Many fixed switches have an internal power supply that cannot be upgraded, so buying more may be a solution to low port density.

- ✓ Manually configure a power ceiling for each port. Today, many vendors have implemented a feature that allows the administrator to manually set a power limit for each port. While this stops the wasting of stranded logical power, it is a manual process requiring the switch administrator to know the power needs of every device. Furthermore, the administrator must manually apply the power limit to each port and be ready to change that limit as devices move or are changed with other PDs.

Note: As you will see, Cisco and others use Static power allocation, but Cisco has created commands that can put a power limit on any number of ports to solve issues of low port density, buying larger power supplies or buying more switches. Manual configuration and maintenance is still a cost using this method.

Dynamic Power Allocation

This method is more expensive to implement in a switch or Mid-Span, but is less expensive to operate and allows full port density. Dynamic power allocation senses how much power is required and delivers that exact amount of power to the port leading to the PD. Dynamic, means that as the power requirements change, the power delivered to that port also changes accordingly. Since dynamic power allocation doesn't depend on the advertised PD class, the algorithm isn't confined to delivering 15.4-Watts for every port. Therefore, the size of the power supply can be smaller than a static power allocation design.

Unlike the preceding section on static power allocation, if a device advertises itself as a class-1 endpoint but needs only 1-Watt of power, the PSE will allocate 1-Watt of power to the port serving that device. There is no logical reservation from the available power pool. Similarly, a class-3 device needing 8-Watts will be allocated 8-Watts of power. There are no known problems with dynamically allocating the exact amount of power needed. In fact the advantages over the static allocation scheme are:

No more power is reserved than is needed. A 1-Watt device will be allocated 1-Watt.

The total power pool is not affected by reservations. There is no wasted power because there is no concept of reserving power from a pool. There is no logical pool to consider. Each device is given the amount of power it requires.

The assumption that each port connected to a Class-3 device should be ready to provide 15.4-Watts at any time still doesn't make sense with IP telephones or any other standards compliant device. Again, very few if any devices operationally vary in power needs more than one Watt. A phone taking 8 watts will almost never require more than 9-Watts. If a PD required 12.95 watts, 15.4-Watts would be supplied by the 802.3af specification. If, theoretically, all ports required 15.4-Watts, you could run out of available power due to a smaller power supply. This is not a known event in industry to date because very few if any Class-3 PDs require a full 12.95-Watts.

Dynamic power allocation results in an intelligent application that is applied to any vendor's PD. The practical results of this method are:

- ✓ Full port density. A 48-port switch or Mid-Span will provide power to all 48 ports.

- ✓ No need to buy larger power supplies. Operational costs are lower.

- ✓ No need to buy more switches to compensate for a logical reservation of power. The equipment footprint and operational/maintenance requirements are kept to a minimum.

- ✓ There is no manual configuration needed by a network administrator. Errors are avoided and time is saved because there is no manual effort required to administer power for PDs. Changes can be administered automatically or with a minimum of administrator effort.

5   PoE Implementation Details

Avaya's Implementation

The best method to provide PD power is not by PoE classification, but by delivering the exact amount of power required by the PD. Avaya uses dynamic power allocation in all of its products – Mid-Spans, P330, C360 and C460 switches and gateways like the G350 and G250.

All Avaya PSE devices detect the actual power requirements from the PD and can increase or decrease the power amounts dynamically. No proprietary protocol is needed to assess and calculate the power needs of an Avaya or other vendor's PD as long as the PD is 802.3af compliant. For Avaya products, this means a PD that has been powered for an hour, say an Avaya 4620SW IP phone, and an EU-24 Expansion Button module is then attached to that phone, the PSE power is almost instantly increased to the PD to cover the additional power needed by the EU-24. For Non-Avaya products, as a fictitious example, if a Logitech web camera required 3.9 Watts, a PoE class-based PSE would have to reserve and be ready to supply 7.0 Watts because the camera would be classified as class-2. If that same camera was connected to an Avaya PSE, the camera would receive 3.9 Watts plus an additional half Watt to traverse a potential 100 meters. The Avaya PSE would not have reserved 7-Watts because Avaya PSEs intelligently deliver the right amount of power to any vendor's PD. Avaya also powers dynamically. This means if any vendor's PD requires varying power over time, the Avaya PSE follows the changing demand and delivers exact power at any point in time.

Cisco's Implementation

Cisco provided proprietary power before the PoE standard was ratified. After ratification of IEEE 802.3af, Cisco supported both their legacy PoE scheme as well as the standard. Cisco uses CDP, a proprietary discovery protocol, to discover Cisco IP telephones. After discovering which Cisco phone type is connected to a switch port, the exact amount of power for that phone is logically reserved from a total pool of power available. If a non-Cisco PD is attached to the same switch port, the power class from the PD is read and the power limit at the top of the power class range is reserved from the same total power pool.

Cisco uses the advertised power class from non-Cisco PDs because the PD cannot participate in the proprietary CDP protocol and because Cisco does not sense exact power needs. The resulting penalty from logically reserving more power than the PD requires is listed in the previous "Static Power Allocation" section.

Please remember, vendors other than Cisco also use static allocation of power based on advertised PoE class and present the same implementation difficulties of low port density, requiring larger (or more) power supplies, purchasing more switches or as we will see, need manual administration to place a power cap for each port.

Another implementation detail for non-Cisco PDs using a Cisco Catalyst 6500 PoE platform is an approximate 11% power loss when using the IEEE 802.3af method of powering PDs. Cisco has details on this issue found here (see figure 7 in Cisco document):
http://www.cisco.com/en/US/products/hw/switches/ps708/products_white_paper0900aecd80233a77.shtml

No power supply is 100% efficient. Heat results from the inefficiency of power supplies. The approximate 11% loss is in addition to the natural inefficiency. Power loss occurs traveling from the power supplies, along the back-plane and through the PoE switch card of this chassis-based system. The result of this power loss is that a class-3 non-Cisco PD will have 17.3 Watts logically reserved to yield 15.4 Watts to the Ethernet cable to make up for the loss on this larger Cisco chassis-based switch.

                9

Below is a worst-case example of an 800-Watt power supply (not including power consumed by the switch itself), powering class-3 PDs. Assume each non-Cisco PD requires 7-Watts to operate and is therefore a class 3 device in terms of power.

Of the available 800 Watts, only 46 PDs can be powered because 17.3 Watts is reserved for each PD (800W / 17.3W = 46). The actual power demand is 322 Watts (46 * 7W = 322W). Therefore, 478 Watts is stranded because each PD has an additional 10.3 Watts reserved but never used (800W – 322W = 478W). If the class-3 PDs were Cisco phones, CDP would discover them and apply the exact amount of power they need for operation.

Cisco has addressed this issue with commands like "`power inline allocation`" and others. Details are in section 7.

Avaya's PSEs

The next natural question concerns implementation issues using Avaya's PSEs. Avaya uses best-in-class methods for all PSE equipment. There are no power transport inefficiencies to consider, no logical reservation of power, no additional money spent to upgrade power supplies, no unintelligent static allocation of power and no penalties when using any vendor's standards compliant PD. Another benefit of dynamic power allocation is the small number of commands needed to configure and maintain the switch or Mid-Span. As you will see, there are fewer commands and command options using Avaya PSE products.

All ports can be used on all of Avaya's PSE equipment – even with the most power hungry Avaya PDs listed in the table below. This table lists very conservative power consumption numbers for Avaya IP phones.

Values in the worst case row are not achievable in any customer environment. Values in the typical row are conservative and the actual power draw may be lower. Using the worst case values will prevent issues caused by switch configuration and is discussed earlier in this section.

Table 4 Avaya 46xx IP Phone Power Consumption in Watts assuming 48 volts.

Model	4601/02	4602SW	4606/12/24	4610	4620	4620SW	4620SW	4621SW	4625SW
Notes					Mfg Disc.	< 9/2004	>9/2004	4622SW	
PoE Class	Class 2	Class 2	Class 0	Class 2	Class 3	Class 3	Class 2	Class 2	Class 3
Typical	3.5	4.1	5.0	4.0	7.7	5.9	4.6	4.9	7.8
Worst Case	4.6	5.0	6.4	6.0	9.9	8.0	5.75	6.45	9.42

Table 5 Avaya 96xx IP Phone Power Consumption in Watts assuming 48 volts.

Model	9610	9620	9630	9630G	9640	9650	SMB-24	Gig-E Adapter
PoE Class	Class 2	Class 2	Class 2	Class 2	Class 2	Class 2	N/A	Class 3
Typical (Not Backlit)	*	4.6	4.6	*	*	*	0.35	*
Typical (Backlit)	*	4.9	5.2	*	*	*	0.6	*
Worst Case	*	5.30	5.58	*	*	*	0.9	*

Notes for table 5:

- Some 96xx models are not in production at the time this document was updated; therefore power values are not available at this time. These future power values are marked with (*)

- SBM24 is an additional 24-button button module that is powered from its associated phone. It is not recognized as a standalone PD, but still draws power as listed in the table. The addition of this module will **NOT** cause a class-2 phone to become a class-3 phone.

- The Gig-E adapter is a module that fits into all 96ss models except the 9610 and 9630G to allow Gigabit Ethernet data flow through the phone. The 9630G phone model has Gigabit Ethernet capability natively – that is without the Gig-E adapter.

Avaya's PSEs include:

Switches: P333T-PWR, C363T-PWR, C364T-PWR, C460 with PoE blades

Gateways: G250, G350

Mid Spans: 1152A1/X, 1152A2/X, 1152A3/X

6 Avaya Configuration

Avaya has PoE in both a chassis based switch (C460) and fixed switches (C360, P330) as well as 802.3af capability in the G250 and G350 gateways. They all function the same way using the same CLI. The output is slightly different and is shown in tables below. PoE is enabled by default, so there is no configuration needed unless PoE was previously disabled. The P330 (actually called the P333T-PWR) has two internal power supplies – one for the switching functions and one to provide 802.3af power to the ports. Redundant power for switching and powering ports is an option using external power supplies. Note that no power is available to ports on the optional expansion module (X330T16).

To check the PoE state, use the **"show powerinline"** command.

```
CSST-CJS-333PWR-18-1(super)# sho powerinline

External power supply is  405  Watts.
External power is not active
Actual power consumption is 34 W.

Port Inline                 Power       Powering
        Operational          Allocated   Priority
        Status               class
------  ------------------  -----------  ---------
 1/1    delivering power    class0        Low
 1/2    delivering power    class0        Low
 1/3    delivering power    class0        Low
 1/4    searching           class0        Low
 1/5    delivering power    class0        Low
 1/6    delivering power    class0        Low
 1/7    delivering power    class0        Low
 1/8    searching           class0        Low
 1/9    searching           class0        Low
 1/10   searching           class0        Low
 1/11   fault               class0        Low
 1/12   off                 class0        Low
 1/13   delivering power    class0        Low
```

There are four states under the Operational Status column.

Delivering power means detection has taken place and power is being supplied

Searching means a non-PoE capable device is attached and the switch keeps "searching" for a valid PD signature.

Off means powering that port has been administratively disabled using the **"set port powerinline"** command

Fault means a problem has been detected and no power is supplied.

The power allocated class column will always display class0. The Cajun switches do not rely on class to deliver power. This may be used in the future.

To enable or disable power to a port, use the **"set port powerinline"** command.

The **"set port powerinline priority"** command can change the default value of low in the powering priority. This column is used in the rare case where PD power requests exceed the capacity of the internal power supply for those ports. Low, high and critical are valid options. If all ports are set to low priority and more power is requested than can be delivered, power is removed from the highest physical

port. If that doesn't bring the total power into the power budget, power is removed from the next highest physical port and so until requested power is within the capability of the internal power supply.

The C360 series of Avaya switches have similar commands to the P330. The **"show powerinline"** command display is slightly different from the P330 in that it doesn't show the power allocated class column. Again, Avaya switches, Mid-Spans and gateway power schemes do not require or rely on an advertised class of power.

```
C360-1(super)# show powerinline

Port      Inline Operational        Powering
          Status                    Priority
------    -----------------------   ---------
 1/1      Delivering Power          Low
 1/2      Delivering Power          Low
 1/3      Delivering Power          Low
 1/4      Delivering Power          Low
 1/5      Searching                 Low
 1/6      Delivering Power          Low
 1/7      Searching                 Low
 1/8      Searching                 Low
 1/9      Searching                 Low
 1/10     Searching                 Low
 1/11     Searching                 Low
 1/12     Searching                 Low
 1/13     Searching                 Low
```

All ports have power enabled by default. Commands are:

Enable or disable power to a port or group of ports

Set port powerinline <mod/port> enable | disable

Assign a priority in case over-subscription requires shutting down port power

Set port powerinline priority <mod/port> <priority>

Low – (Default setting) standard priority for standard devices

High – higher priority than low for important devices

Critical – highest priority for critical devices like APs

Describe the PD for each port

Set port powerinline type <mod/port> "string"

The string is a text description of the PD.

7 Cisco Configuration

There are basically two different classes of Cisco switch PSEs, fixed and chassis. A fixed switch has very little hardware configuration ability if any after it is purchased. Fixed switches generally don't have redundant power supplies, few features and flexibility compared to chassis-based switches. Examples of fixed switches include the Catalyst 3560 and 3750. These are relatively inexpensive switches used for access to the network.

Chassis-based switches have a cabinet that houses cards or blades. These cards can be replaced with other cards to meet the changing needs of a business such as migrating from copper ports to fiber ports. Although more expensive, they offer more features, redundancy, and again, can be reconfigured to meet business changes or growth. Examples of enterprise switches are the Catalyst 4500 and 6500 series. Some chassis-based switches can operate with either one of two operating systems (OS) – Cat-OS and IOS. Cisco is migrating from Cat-OS to IOS and over time will only support IOS. But many enterprises still use Cat-OS and the command syntax is different than using IOS. This section does not list all possible commands for one or both OS platforms – just the most important commands to control PoE.

Fixed Switch Configuration

Fixed switches like the Catalyst 3560 and 3750 have power sensing enabled on all ports by default. This means all ports continually sense for a valid PD and if found, will provide power based on class for non-Cisco PDs. The **show power inline** command will display the total amount of power, the power used and power remaining for that switch.

```
Switch#show power inline
Available:370.0(w)   Used:114.8(w)   Remaining:255.2(w)

Interface  Admin    Oper        Power        Device          Class
                                (Watts)
---------- -----  ----------  -------  -------------------  ----------
Fa0/1      auto   on              7.0  Ieee PD              Class 2
Fa0/2      auto   on             15.4  Ieee PD              Class 3
Fa0/3      auto   on             15.4  Ieee PD              Class 3
Fa0/4      auto   on             15.4  Ieee PD              Class 3
Fa0/5      auto   on             15.4  Ieee PD              Class 0
Fa0/6      auto   on             15.4  Ieee PD              Class 0
Fa0/7      auto   on             15.4  Ieee PD              Class 0
Fa0/8      auto   on             15.4  Ieee PD              Class 0

...
```

There are three states under the Admin column, Auto, Never and Static. The syntax to apply one of these commands is: **power inline** {**auto**[max *max-wattage*]|**never**|**static**[max *max-wattage*]}

Auto is an automatic mode that senses the PoE class and then delivers the maximum power of that class's range if enough power is available. The example above displays 7.0 Watts for port fa/01 because it is a class 2 PD. Port fa0/2 displays 15.4 Watts because the PD on that port is a class 3 device. When all available power is allocated, no remaining ports can be powered.

Never is used to disable power and power sensing on that port (interface). Non-PDs like desk-top PCs are good candidates for this command.

Static is used to pre-allocate power to a port even before the switch senses a valid PD. This is a priority scheme to make sure the most important PDs always receive power.

The `max max-wattage` option for the Auto and Static states is used to restrict the use of higher power Cisco PDs. This command should not be applied to Avaya or other vendor PDs. Be careful when using this option because there are two reasons fixed switches will remove power from a port:

A PD requires more power than the Max option is set to provide

The Max option is set lower than the PoE class maximum value for a non-Cisco PD

You can detect if one of the two conditions listed above happens by using the `show power inline` command. If you see "`power-deny`" instead of "`on`", in the oper column, either the PD requested too much power or the max max-wattage value was lower than the IEEE class maximum value. You cannot use the `max max-wattage` option to save logical power to increase the number of PDs on a switch.

The Catalyst 3750 has a command to reclaim logical power for non-Cisco PDs beginning with IOS 12.2(25)SEC. This command sets a power ceiling that is more than the device will draw, but less than the max value of the PoE class range. The command is `power inline consumption default` `[wattage value].` This command can be applied in "global configuration mode" for the entire switch or individual values for each interface (port).

A global setting of 6 watts for every port would be:

Switch (config)# power inline consumption default 6000

An individual port setting for port 2 at 11 watts would be:

       Switch (config)# interface gigabitethernet 1/0/2

       Switch (config-if)# power inline consumption default 11000

This command is extremely useful if you are deploying non-Cisco class-3 PDs. The value is greatly diminished when deploying class 2 or class 1 PDs because the difference between the actual power-draw and the class maximum value is much smaller than with the class-3 range for IP telephones. Remember to allocate enough power for a worst case PD power draw and to traverse 100 meters of cable. Table 2 can help you decide how much additional power is needed to travel over 100 meters.

Catalyst 3560 and 3750 IOS Common Notes:

The "power inline" command was added to IOS 12.1(19)EA1

The "static" and "max" features were added to IOS 12.2(25)SE

Never use IOS earlier than 12.2(20)SE1 because power could still flow through a port even after the valid PD was removed. This could damage a non-PD device.

Catalyst 3750 IOS Specific Note:

The "power inline consumption" feature was added to IOS 12.2(25)SEC

End of Fixed Switch section

Chassis-Based Switch Configuration

A chassis-based switch like the Catalyst 4006, 4506 and 6509 can provide standards-based power if the correct line card (blade) is installed and the proper IOS or Cat-OS is running. This subsection focuses on the Catalyst 6509 since it is the widest deployed platform amongst businesses that use Cisco switches. IEEE 802.3af capable line cards have power sensing enabled on all ports by default. This means all ports continually sense for a valid PD and if found, will provide power based on PoE class for non-Cisco PDs.

These larger switches are more complex in both hardware and software and will require more commands to verify and configure than the smaller fixed access switches.

Examples shown are for the 4006 using IOS. The troubleshooting method is the same for 4500 and 6500 switches, but some of the commands may differ slightly.

  There are basically four commands to use to assess the state of an existing PoE switch:

Show system   [to verify the number of power supplies and their status]

Show environment power (or show power)   [to verify consumed power and reserve power]

Show module   [to verify the line (model) and daughter card (sub-model)]

Show port inline power   [to verify power used and allocated per port on a blade]

These commands start at the system level and go to the port level.

The power supplies should be verified before configuration takes place. Use the "`show system`" command to verify the power supply status. Verify how many power supplies are installed, their status, the total watts supplied and the total watts delivered.

```
Console> (enable) show system
PS1-Status PS2-Status
---------- ----------
ok         none

Fan-Status Temp-Alarm Sys-Status Uptime d,h:m:s Logout
---------- ---------- ---------- -------------- ---------
ok         off        ok         11,04:27:18    20 min

PS1-Type             PS2-Type
-------------------  -------------------
WS-CAC-1300W         none

Modem    Baud  Traffic Peak Peak-Time
-------  ----- ------- ---- ------------------------
disable  9600   0%      0% Wed Apr 7 2004, 04:22:48

PS1 Capacity: 1153.32 Watts (27.46 Amps @42V)
...
```

If total power should suddenly decrease, as in the case of a failed power supply, power is removed from the line cards beginning at the bottom of the chassis moving upwards until the actual load is within the remaining power budget. If a line card supports PDs, ports begin removing power beginning at the highest port down to the lowest port before power is removed from that line card. This is another reason the show system command can be very useful.

Next, use the `show environment power` command to check the power consumption status. The bottom line will show the total available power to the line card, the amount used by the line card and the maximum wattage allotted to each port on that line card.

```
Console> (enable) show environment power
PS1 Capacity: 1153.32 Watts (27.46 Amps @42V)
PS2 Capacity: none
PS Configuration : PS1 and PS2 in Redundant Configuration.

Total Power Available                       : 1153.32 Watts (27.46 Amps @42V)
Total Power Chassis Limit                   : 2940.00 Watts (70.00 Amps @42V)
Total Power Chassis Recommended             : 2940.00 Watts (70.00 Amps @42V)
Total Power Available for Line Card Usage   : 1153.32 Watts (27.46 Amps @42V)
Total Power Drawn From the System           : 687.12 Watts (16.36 Amps @42V)
Total Power Drawn by the Chassis            : 0 Watt
Total Inline Power Drawn From the System    : 163.592 Watts ( 3.895 Amps @42V)
Total Power Reserved as localpool for modules:  34.86 Watts ( 0.83 Amps @42V)
Remaining Power in the System               : 466.20 Watts (11.10 Amps @42V)
Configured Default Inline Power allocation per port: 15.400 Watts (0.36 Amps @42V)

Slot power Requirement/Usage :

Slot Card Type               PowerRequested PowerAllocated CardStatus
                             Watts   A @42V Watts   A @42V
---- ----------------------- ------- ------ ------- ------ ----------
1    WS-X6K-SUP1A-2GE        138.60   3.30  138.60   3.30  ok
2    (empty supervisor slot)   0.00   0.00  138.60   3.30  none
4    WS-X6348-RJ-45          100.38   2.39  100.38   2.39  ok
7    WS-X6148-GE-TX          111.30   2.65  111.30   2.65  ok

Slot Inline Power Requirement/Usage :

Slot CardType               Total Allocated   Max H/W Supported   Max H/W Supported
                            To Module (Watts) Per Module (Watts) Per Port  (Watts)
---- ------------------- ----------------- ------------------- -----------------
7    WS-X6148-GE-TX          163.592           850.08              15.400
```

Use the command `show module` to check the status of the PoE line card installed and the daughter card if applicable. Note the sub-model at the bottom of the display shows the inline power daughter card (WS-F6K-GE48-AF) installed on the line card (model) WS-X6148-GE-TX. The status should be "OK".

```
Console> (enable) show module 7
Mod Slot Ports Module-Type              Model               Sub Status
--- ---- ----- ------------------------ ------------------- --- --------
7   7    48    10/100/1000BaseT Ethernet WS-X6148-GE-TX     yes ok

Mod Module-Name         Serial-Num
--- ------------------- -----------
7                       SAD080505L0

Mod MAC-Address(es)                        Hw     Fw         Sw
--- -------------------------------------- ------ ---------- ------------------
7   00-0f-23-fd-50-60 to 00-0f-23-fd-50-8f 5.0    7.2(1)     8.2(1)

Mod Sub-Type            Sub-Model           Sub-Serial  Sub-Hw Sub-Sw
--- ------------------- ------------------- ----------- ------ ------
7   IEEE InlinePower Module WS-F6K-GE48-AF   SAD080505AG 1.0    8.2(192)
```

Finally, use the `show port inline power` command to verify line card variables.

```
Console> (enable) show port inlinepower 7
Configured Default Inline Power allocation per port: 15.400 Watts (0.36 Amps @42V)
Total inline power drawn by module 7: 163.592 Watts ( 3.895 Amps @42V)

Port   InlinePowered   PowerAllocated   Device      IEEE class
                       From PS    To PD
        Admin   Oper   mWatts    mWatts
-----  ------  ------  -------   -------  ----------  ----------
...
 7/13  auto     on      7865      7000     ieee        class 2
 7/14  auto     on     17303     15400     ieee        class 3
 7/15  auto     on     17303     15400     ieee        class 3
 7/16  auto     on     17303     15400     ieee        class 3
 7/17  auto     on     17303     15400     ieee        class 0
 7/18  auto     on     17303     15400     ieee        class 0
 7/19  auto     on     17303     15400     ieee        class 0
 7/20  auto     on     17303     15400     ieee        class 0
...
```

Column definitions:

Admin mode (**auto, never**). **Auto** will detect the PD class and apply power based on the top of that class. **Never** disallows port power and the searching algorithm for a PD on that port.

Oper mode (**on, off, faulty or deny**). Operational mode is the actual state of a port compared to the admin column which is the administered state. **On** means power is supplied by the port. **Off** means power is not being supplied by the port. **Faulty** means the port is unable to power the PD. **Deny** means the port cannot supply power because the system doesn't have enough power.

From PS is the logical power reserved from the available power pool.

To PD is the power level leaving the line card to the PD

Device type either IEEE or Cisco phone model number

The class of PD connected to each port

The third line showing the "Total power drawn by module x" displays the amount of power consumed by the PDs attached to it and does NOT include the power needed to run the module itself.

Don't assume that a PoE capable line card can support all ports with up to 15.4 watts. Each line card slot in the chassis is allocated about 1,000 watts regardless of the port density on any specific card. Cisco introduced the WS-X6196-RJ-21, a 96-port PoE line card. IEEE 802.3af support on this line card requires a PoE daughter card to manage 960 Watts for all ports. Again, worst-case, if class-3 PDs are used, only 62 ports could supply power. But using class-2 PDs, all 96 ports would give power.

Specific Commands for the Catalyst 4500 and 6500

4500 series:

The preceding 4 steps describe how many power supplies are active, total wattage available, total wattage used, wattage used per module (blade) and which ports are delivering power, etc. The following commands enable 802.3af PoE at the port level and apply a method for that port's power.

IOS release 12.1(19)EW and higher:

```
Switch(config-if)# power inline {auto [max[milli-watts] | never | static
[max[milli-watts] | allocation}
```

Power inline sets the interface (port) to sense for and apply power if a PD is connected.

Auto will sense the class of a non-Cisco PD and apply power of the top of the class range

Max[milli-watts] allows you to specify a power ceiling that is lower than the class maximum, but higher than the PD requires. Valid range is 2000 to 15400 milli-watts. This option will reduce the amount of logically reserved power and is especially important when using class-3 PDs.

Static acts the same as auto except that it pre-allocates power to that port during startup. This is useful for important PDs like access points and critical phones because it gives them priority over other PDs by pre-allocating power.

Max[milli-watts] allows you to specify a power ceiling that is lower than the class maximum, but higher than the PD requires. Valid range is 2000 to 15400 milli-watts. This option will reduce the amount of logically reserved power and is especially important when using class-3 PDs.

Never disallows power to a port – even if a PD is connected.

Allocation works much like the "**max**[milli-watt]" option of auto and static where you can specify a power ceiling for a port or globally for the entire switch. This command option allows you to specify a power value independently from the PD class. Therefore PD class value is not determined and no errors result from specifying a value that is above the class range for that PD. This can save time if more than one PD class is used. An example is having class-2 and class-3 PDs on a switch and setting the allocation value to 9-Watts. Class-2 ceiling is 7-watts, so using `power inline auto 9000` would not work for class-2 PDs because it exceeds the class limit. However, using `power inline allocation 9000` would work for both class-2 and class-3 phones because class limits are not considered. Valid values are 2000 to 15200 milliwatts. This option will reduce the amount of logically reserved power and is especially important when using class-3 PDs.

Cat-OS 8.3(1)GLX or higher

```
set port inlinepower mod/port {off | {auto | static} [max-wattage]}
```

Power inline - sets the interface (port) to sense for and apply power if a PD is connected.

Off – removes power and sensing from a port or group of ports.

Auto – delivers class-based power if a valid IEEE PD is connected

Static – powers a port to a specified value if a valid PD is connected. This value is lower than the class ceiling, but higher than minimum requirements of the PD.

Max-Wattage – a value of the maximum power used with auto or static mode. Valid range is 2000 through 15400 milli-watts. This option will reduce the amount of logically reserved power and is especially important when using class-3 PDs.

```
set port inlinepower mod/port consumption {wattage | auto}
```

Consumption – specifies power consumption limit on a per port basis and can be used instead of the previous command that used "auto" or "static". This command is not based on the PD's power class. This option will reduce the amount of logically reserved power and is especially important when using class-3 PDs.

Wattage – range is 2000 through 15400 milli-watts

Auto – uses IEEE or CDP limits without administrator knowing PD requirements

```
set inlinepower defaultallocation value
```

This command pre-allocates a default wattage value as a global command and can cause problems if not well understood and paired with another command. This command is only for Cisco phones – do not use this command for Avaya phones.

Notes for Catalyst 4500
IOS

12.1(11)EW Support "power inline" command was introduced on the Catalyst 4500 series switch.
12.1(19)EW Support added for static power allocation.
12.1(20)EW Support added for Power over Ethernet.

CatOS

8.3(1)GLX support for "set port inlinepower" command expanded for all options listed.

6500 series

IOS release 12.2SX and higher:

```
power inline {auto [max max-milli-watts]} | never | {static [max max-milli-watts]}
```

Power inline sets the interface (port) to sense for and apply power if a PD is connected.

Auto will sense the class of a non-Cisco PD and apply power of the top of the class range

Max[milli-watts] allows you to specify a power ceiling that is lower than the class maximum, but higher than the PD requires. Valid range is 4000 to 15400 milli-watts. This option will reduce the amount of logically reserved power and is especially important when using class-3 PDs.

Static acts the same as auto except that it pre-allocates power to that port during startup. This is useful for important PDs like access points and critical phones because it gives them priority over other PDs by pre-allocating power.

Max[milli-watts] allows you to specify a power ceiling that is lower than the class maximum, but higher than the PD requires. Valid range is 4000 to 15400 milli-watts. This option will reduce the amount of logically reserved power and is especially important when using class-3 PDs.

Never disallows power to a port and searching – even if a PD is connected.

Using the partial command **"power inline"** with no arguments defaults to auto mode and 15400 milli-watts

Cat-OS 8.5 or higher

```
set port inlinepower mod/port {auto | static | limit} [max-wattage][off]
```

Set port inline power specifies a power mode for a port or group of ports

Auto - will sense the class of a non-Cisco PD and apply power of the top of the class range

Static - acts the same as auto except that it pre-allocates power to that port during startup. This is useful for important PDs like access points and critical phones because it gives them priority over other PDs by pre-allocating power.

limit - Limits power on the specified port. This option allows you to specify power lower than the PD class, but higher than the PD requires. If the PD power exceeds the limit, power to the port will be disabled. The limit keyword is supported only on modules with the WS-F6K-48-AF daughter card.

max-wattage (Optional) The maximum power allowed on the port in either auto or static mode; valid values are from 4000 to 15400 milliwatts.

off Prevents the port from providing power to a PD. Syntax is "set port inlinepower mod/port off"

Two other commands are available but only apply to Cisco phones. Do not use these commands with Avaya phones.

```
set inlinepower defaultallocation value
set inlinepower notify-threshold value module mod
```

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Notes for Catalyst 6500
IOS

12.1(11)EW Support "power inline" command was introduced on the Catalyst 6500 series switch.
12.1(19)EW Support added for static power allocation.
12.1(20)EW Support added for Power over Ethernet.

CatOS

8.5 support for "set port inlinepower" command expanded for all options listed.

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Final Note: This paper is <u>NOT</u> intended to show disadvantages of Cisco switches. Differences between Avaya and Cisco methods and their consequences needed explanation to prevent implementation and maintenance issues for Avaya customers. Cisco methods and commands are stated in this paper because Cisco is the predominant infrastructure of many Avaya customers.

8   Future Directions

Power over Ethernet is still young and is changing. The IEEE 802.3af standard is being supplemented with a newer, but not yet ratified, IEEE 802.3at standard. This newer standard defines "double PoE" and seeks to raise the limit of 15.4 Watts per port to 30 Watts and possibly even higher to 60 Watts. The goal of this wattage increase is to power many more IP appliances. Eventually, notepads, USB hubs and other devices may be powered over the Ethernet.

Avaya will continue to drive and support future standards for power over Ethernet and other applicable standards in the data arena.

Appendix A   Implementation Checklist

Cisco Fixed Switches:

1. Verify power is administratively enabled on all appropriate ports.

    a. Use the command **"show power online"**

    b. Admin column values **Auto** or **Static** allow power, **Never** disables power to that port.

    c. **Max max-wattage** option with **Auto** or **Static** variables will allow power or pre-configure power to a port, <u>but will disable power to an Avaya phone</u> if set lower than the maximum value of the phones power class..

        i. If you see **"power-deny"** instead of **"on"**, in the oper column, either the PD requested too much power or the max value was lower than the class maximum value.

    d. If applicable, use the command in step 3 instead of the **Max max-wattage** command.

2. Check possibility of reclaiming logical power
    a. Reclaimed logical power is available beginning with IOS 12.2(25)SEC for a Catalyst 3750

3. Verify IOS is safe for PDs
    a. Use the command **"power inline consumption default"**

    b. Never use IOS earlier than 12.2(20)SE1 because power could still flow through a port even after the valid PD was removed. This might damage a non-PD device.

Cisco Chassis Switches:

4. Verify power supply(s) status and available power.
    a. Use the command **"show system"**

5. Verify power statistics at the line card level.
    a. Use the command **"show environment power"**

6. Verify module status, model and, if applicable, daughter card model
    a. Use the command **"show module <module number>"**

7. Verify module status, model and, if applicable, daughter card model
    a. Use the command **"show port inline power"** or **"show inline power"**
    b. Check admin column. **Auto** allows power, **Never** denies power on a port
    c. Check oper column. On means power is flowing. **Off** indicates no power is flowing. A problem exists if you see **faulty** or **deny**.
    d. Carefully check the column titled "Power from PS mWatts". This is logical power allocated for each port. The sum of this column reveals how much power is logically reserved from the power supply(s) at that time.

e. Check the column titled "Allocated to PD mWatts" to see the power amount leaving the ports on the line card.

8. Remember, each line card slot in the chassis is allocated about 1,000 watts regardless of the port density.

9. Power can be logically conserved by using the command(s)
   a. 4500 series IOS: **"power inline allocation default xxxx**"
   b. 4500 series Cat-OS: **"set port inlinepower consumption xxxx"**
   c. 6500 series IOS: **"power inline auto max"**
      or **"power inline static max"**
   d. 6500 series Cat-OS: **"set port inlinepower mod/port limit max"**

Appendix B   IEEE 802.3af Guard-bands and beyond

The IEEE 802.3af standard defines a lower and upper guard-band around the resistive signature range. Any PD value in the guard-band range is considered non-compliant. Additionally, PD values beneath or above the guard-band ranges are considered invalid signatures. Both invalid and non-compliant signatures mandate removing power almost instantly by the PSE.

Table B – Parameters for an invalid or non-compliant power signature

Parameter	Conditions	Range of Values	Condition
Voltage Ramp-up	V < 10.1V	12K Ω < or > 45K Ω	Invalid Signature
Input Capacitance	V < 10.1V	> 10 µF	Invalid Signature
Lower Guard-band	Start up and Steady State	12K Ω – 23.75K Ω	Non-Compliant
Upper Guard-band	Start up and Steady State	26.25K Ω – 45K Ω	Non-Compliant