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WHITE PAPER

Managing PoE Technologies

Adding insight and understanding to a scarce resource on the network

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Sales@PathSolutions.com
www.PathSolutions.com

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A Power Over Ethernet (PoE) Tutorial

Power over Ethernet (PoE), which delivers power over LAN cabling to network devices, has become one of the most widely deployed technologies. While the benefits of PoE are substantial—in terms of cost savings, ease of deployment, improved energy efficiencies, and reliability—there are numerous pressures on network power utilization. This White Paper provides a tutorial on Power over Ethernet technology, including:

- *A review of the original PoE standards.*
- *An overview of PoE+ technology.*
- *How to solve power-related network issues.*
- *The future of Power over Ethernet technologies.*

Why Power Over Ethernet?

One of the earliest concerns about VoIP phones was the fact that the earliest models not only needed to be plugged into the network, but that they also needed to be plugged into a wall outlet for power. While it was easy to run a Cat3 or Cat5 wire to a new location, installing a power outlet was considerably more costly and complex — electrical contractors frequently spent hours installing breakers, conduit, junction boxes, and the plug itself, for many times the cost of the Cat5 cable. Imagine how expensive upgrading to VoIP phones would be if you had to install a $400 power outlet for every IP Phone.

A secondary concern regarding moving to IP phones involved power outages, reliability, and public safety. At some point, it occurred to VoIP vendors that an IP Phone will not work during power outages. If you think about it, the time that you *most* need your phone is during an emergency and how many emergencies involve power outages? That is why ethernet engineers set to work on providing reliable and simple power to IP Phones that could be backed up by UPS power from a central location.

PoE Goes Mainstream

As PoE technology progressed, additional uses for it surfaced. Security cameras, other security devices, intercoms, overhead paging, wall clocks, wireless access points, and new lighting systems all saw the benefit of having one inexpensive cable for both power and control. As momentum built behind the technology, early adopters discovered the need to manage their PoE Ethernet Switches. Network administrators needed to know important information in order to save money and run an efficient network:

- **PoE Power Draw.** How much power was being drawn by a given PoE Ethernet Switch? With each PoE device added to an Ethernet Switch, the amount of minutes of back-up power a UPS can provide drops. For example, UPS systems that initially provided 20 minutes of emergency backup power might only be providing three minutes today after all of the PoE ports are filled.
- **Budget Constraints.** PoE ports are more costly than standard Ethernet ports. In medium to large deployments, network engineers frequently buy more PoE ports, only to find that half of their PoE ports are taken by non-PoE devices—an underutilization of the PoE port. This can be avoided by simply keeping 'ordinary' Ethernet devices from using expensive PoE-enabled ports.

PoE Basics

Let's take a look at some of the basics of PoE technology and the IEEE 802.3af standard. In standard 802.3af PoE, Each Powered Device (PD) adds a small 'signature' circuit to the Ethernet wire inside the device. Each PoE port on a LAN switch looks for the signature and provides the requested power only if it sees that the device is PoE-enabled.

> **Note:** *Some early, pre-standard Cisco implementations used modified Ethernet signaling, rather than the standard signature technique. Back in October of 2002, Nortel (now Avaya) introduced one of the first standards-based PoE capable Ethernet Switches with the BayStack 460-24T-PWR Ethernet Switch, soon followed by many offerings from the other major networking vendors.*

Power Modes

The 802.3af defines two ***modes*** of supplying power. Modes simply designate which wires carry the power and were created to accommodate different wiring schemes. Mode A provides power on the Signaling Pairs of Wires. Mode B provides power on the Spare Pairs of wires. The terms *Spare* and *Signaling* can get very misleading in Gigabit Ethernet, since all pairs are used for signaling. Spare pairs refer to the wire pairs that WOULD be spare if the port was only running at 10/100 speeds.

The following pin-out table (Figure 1) and diagram of the TIA-568A & 568B wiring schemes (Table 1) show which color wire corresponds to which pins. Notice that in both cases, power is only supplied on one set of pairs or the other. 802.3af does not allow power to exist on BOTH sets of pairs at the same time. The PoE network port (not the IP Phone or endpoint) decides which sets of wires will supply power.

Note: *568A/B standards have no relation to PoE Mode A/B: EIA/TIA 568 is a wiring scheme and Mode A/B is a pin assignment for power.*

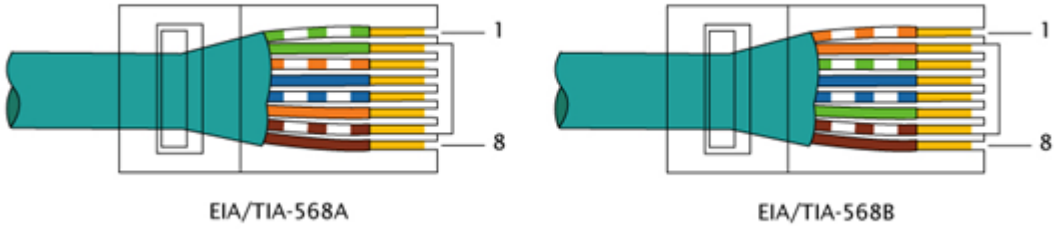

Figure 1: EIA/TIA 568 A&B Pin-Outs

	Mode A: "Signal" Pairs		Mode B: "Spare" Pairs	
PINS on Switch	Mode A – 10/100	Mode A – GigE	Mode B – 10/100	Mode B – GigE
Pin 1	Rx + Signal	TxRx A+ Signal	Rx + Signal	TxRx A+ Signal
Pin 2	Rx – Signal	TxRx A- Signal	Rx – Signal	TxRx A- Signal
Pin 3	Tx + Signal	TxRx B+ Signal	Tx +Signal	TxRx B+ Signal
Pin 4		TxRx C+ Signal		TxRx C+ Signal
Pin 5	Tx - Signal	TxRx C- Signal	Tx – Signal	TxRx C- Signal
Pin 6		TxRx B- Signal		TxRx B- Signal
Pin 7		TxRx D+ Signal		TxRx D+ Signal
Pin 8		TxRx D- Signal		TxRx D- Signal

Red: DC+, Blue=DC-

Table 1: 802.3af Mode A & B

PoE Classes

Given the huge range of devices that might request network power, the 802.1af committee decided to put devices into categories, depending on how much power the device required. For example, a tiny 1-line phone with no display requires far less power than an access point containing multiple radio transmitters and receivers.

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PoE Phones and other endpoints can signal to the PoE network what class of device it belongs to and how much power it may need. Class 0 devices are the mavericks of the world as they are unclassified. These rare devices might draw any power level from none to maximum—the only thing that we know for certain is that they are a PoE device. The other standard classes, 1 t

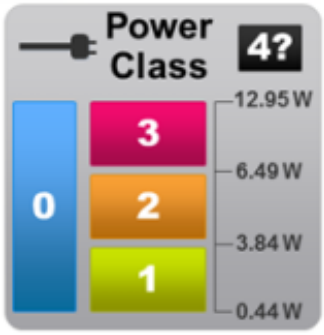

Figure 2: PoE Power Classes

Class	Type	Plain Language vDescription	Power Range (Watts)
0	1	Unclassified	0.44-12.94
1	1	Very Low Power	0.44-3.84
2	1	Low Power	3.84-6.49
3	1	Mid Power	6.49-12.95
4	2	PoE+: High Power	>12.95 – 25.50

Table 3: PoE Power Classes

range from very low power, to low power, to mid-level power consumption. A class 4 device is a newer class of device requiring PoE+ (802.3at) and needs to draw more than the 12.95 Watt maximum provided by the original standard PoE. Class 4 devices must be powered by 802.3at PoE+ ports, and may not function correctly on a 802.3af PoE port.

Older Equipment

If you are still running equipment that dates from 1999 through 2003: Many of Cisco's early pre-standard PoE switches used signaling schemes involving Ethernet pulses and CDP protocol to request power. Most of these switches only provided up to 10 Watts per port, defaulting at 6.3 Watts. This older scheme was not upgradeable to the IEEE 802.3af standard, which required hardware changes. If you have an older Cisco phone that won't power up on standard PoE, or if you have an older Cisco PoE switch that won't power up standard PoE equipment, it may be time for an upgrade.

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PoE+ Basics

While PoE devices became more efficient and better at conserving power, New Wireless Access Points, High Definition Cameras, and certain types of other security devices all continued to push the limits of the original PoE standard (802.3af) and the 12.95 Watt power restriction. The IEEE 802.3at task force committee was pleased with the success of PoE technology, but felt that higher wattages (power levels) would enable even greater types of applications. From May of 2007 through September 2009 these engineers developed Power-over-Ethernet PLUS (PoE+), which they dubbed 802.3at. PoE+ shares all of the items discussed in PoE Basics but adds some additional capabilities. The following chart shows some of the key differences between a PoE and a PoE+ device:

Property	PoE	PoE+
Standard	IEEE 802.3af	IEEE 802.3at
Type	Type 1	Type 2
Max Power at Powered Device	12.95 Watts	25.50 Watts
Max Power delivered at Switch	15.40 Watts	34.20 Watts
Voltage Range at PD	37.0-57.0 V	42.5 – 57.0 V
Power Management	Class 0 (unclassified) Class 1, 2, 3 negotiated @ initial connection.	Class 4 at initial connection 0.1 Watt steps negotiated continuously.
Cabling	Cat 3 & Cat 5	Cat 5

Table: 4 Differences between PoE and PoE+ equipment

The three key differences between PoE and PoE+ are:

- PoE+ can provide nearly double the power of PoE.
- PoE+ can negotiate power levels continuously.
- PoE+ disallows Cat 3 cable.

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Mixing and Matching PoE and PoE+ Technology

You can also mix and match PoE and PoE+ technology. For example, all PoE+ Ethernet Switches can support older PoE phones and devices. While this gives you maximum compatibility, it is usually more expensive –as that extra power capability (and larger power supplies) tends to cost more.

Powered Endpoint Device (PD)		Ethernet Switch or Supply (PSE)	Result?
PoE	plugged into	**PoE**	Okay.
PoE	plugged into	**PoE+**	Okay.
PoE+	plugged into	**PoE**	Device must notify user (somehow) if it is under-powered.
PoE+	plugged into	**PoE+**	Okay.

Table 6: Mixing and Matching PoE and PoE+

Note: *If you have a newer endpoint device (PD) that requires PoE+ but is plugged into an older supply that only provides PoE power levels, the device is required to have some way to notify you that it is being under-powered but the standard doesn't specify how.*

PoE+ Power Classes

When a High Power PoE+ device is attached to the network, it performs a two-step process for requesting power. The first step is similar to a PoE standard device. The only difference in this step from the original PoE standard is that all of the original PoE standard devices are now referred to as "Type 1" and PoE+ devices are Class 4 (an undefined class in the original PoE standard) and Type 2 as shown in Table 7.

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Class	Type	Plain Language Description	Power Range (Watts)
0	1	Unclassified	0.44-12.94
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4	2	PoE+: High Power	>12.95 – 25.50

Table 7: Negotiating PoE+ class and type

Original PoE switches should be able to notice Class 4 devices plugged into them, but will be unable to supply more than 12.95 watts of power, regardless of what the device asks for.

PoE+ Power Modes

Unlike the original PoE devices, which had only 3 classes set at the time the device was plugged in, the new PoE+ devices are much more sophisticated in negotiating for power. PoE+ devices can ask for power in much smaller increments and can renegotiate their power needs at any time, depending on what the device is doing. Such flexibility allows PoE+ devices to implement power-saving modes, such as "sleep" mode, which would use less power than when the device was initially started. For example, some Avaya phones are capable of switching the display backlight off, shifting the Ethernet speed down to 10Mbps, and turning off other features in order to minimize power usage during off-hours.

In the IEEE standard, all of this fancy negotiation is done using Ethernet Layer 2 LLDP messages sent between the Ethernet Switch and the endpoint device. Information exchanged between the Ethernet Switch and the powered device includes:

- **Power Source:** Normal, or Backup/conservation
- **Power Priority:** (Critical, High, Low)
- **Power Value:** (0-102.3 Watts in 0.1 Watt increments).

Power Source: This allows the switch to tell an endpoint that it is operating on backup power (and may wish to reduce power usage, or perform a safe shutdown).

Power Priority: This allows the switch to tell an endpoint what priority it has over other endpoints. If there is a power shortage, Low priority devices will lose power before High priority devices and Critical devices will stay on as long as possible, even if it means shutting off everything else).

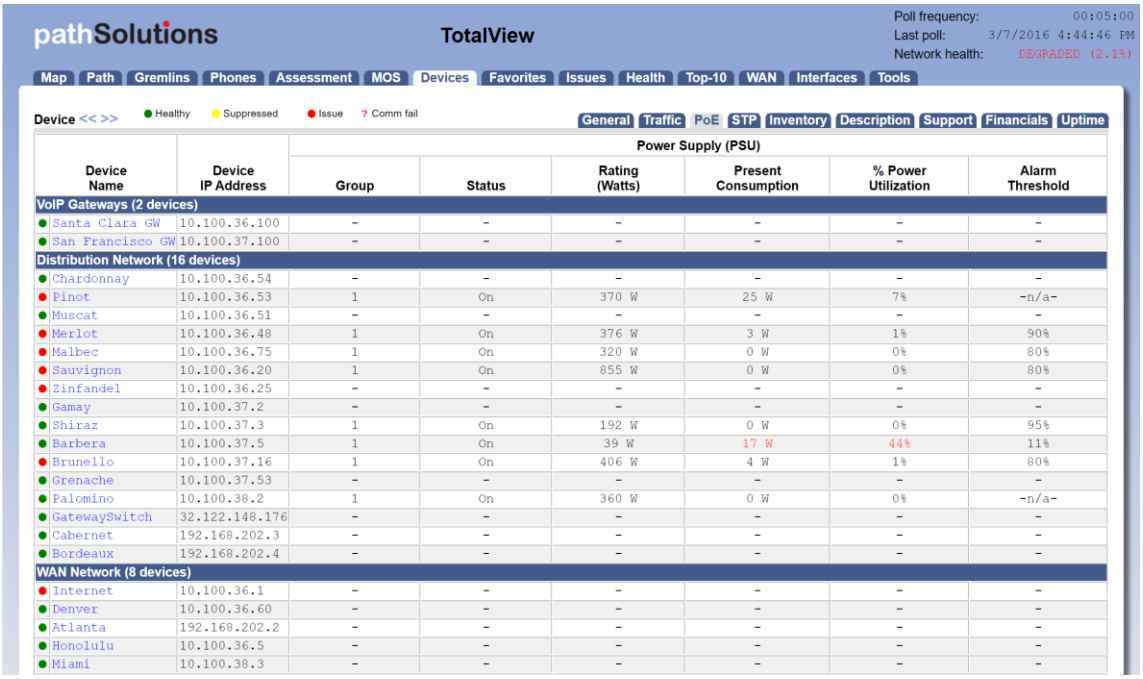
Power Value: This allows the switch to tell the endpoint how much power is available and what it is allowed to draw. The endpoint uses the same variable to ask for more (or less) power, depending on what is needed.

> **Note:** *In some earlier versions of Cisco equipment, the Cisco Discovery Protocol (CDP) was used to negotiate power instead of LLDP but it works in a similar fashion to the IEEE standard.*

Solving PoE and PoE+ Network Management Challenges

So now that the basics of PoE and PoE+ have been covered, what do network administrators need to watch out for? First, they will need to watch the network's power consumption at the switch level, power supply level, and at each individual ethernet port supplying or drawing power.

Regardless of whether there are any PoE switches or PoE powered devices on the network, it can be very helpful to monitor the health of the network equipment's power supplies. For example, PathSolutions TotalView for VoIP monitors the status and power consumption of each power supply, what percentage of utilization is running, and whether the power supply is running low on power. The following screenshot shows the power supply status for devices at the Ethernet switch level.



pathSolutions — TotalView

Poll frequency: 00:05:00
Last poll: 3/7/2016 4:44:46 PM
Network health: DEGRADED (2.1%)

Map | Path | Gremlins | Phones | Assessment | MOS | Devices | Favorites | Issues | Health | Top-10 | WAN | Interfaces | Tools

Device << >> ● Healthy ● Suppressed ● Issue ? Comm fail

General | Traffic | PoE | STP | Inventory | Description | Support | Financials | Uptime

Device Name	Device IP Address	Power Supply (PSU) Group	Status	Rating (Watts)	Present Consumption	% Power Utilization	Alarm Threshold
VoIP Gateways (2 devices)							
Santa Clara GW	10.100.36.100	-	-	-	-	-	-
San Francisco GW	10.100.37.100	-	-	-	-	-	-
Distribution Network (16 devices)							
Chardonnay	10.100.36.54	-	-	-	-	-	-
Pinot	10.100.36.53	1	On	370 W	25 W	7%	-n/a-
Muscat	10.100.36.51	-	-	-	-	-	-
Merlot	10.100.36.48	1	On	376 W	3 W	1%	90%
Malbec	10.100.36.75	1	On	320 W	0 W	0%	80%
Sauvignon	10.100.36.20	1	On	855 W	0 W	0%	80%
Zinfandel	10.100.36.25	-	-	-	-	-	-
Gamay	10.100.37.2	-	-	-	-	-	-
Shiraz	10.100.37.3	1	On	192 W	0 W	0%	95%
Barbera	10.100.37.5	1	On	39 W	17 W	44%	11%
Brunello	10.100.37.16	1	On	406 W	4 W	1%	80%
Grenache	10.100.37.53	-	-	-	-	-	-
Palomino	10.100.38.2	1	On	360 W	0 W	0%	-n/a-
GatewaySwitch	32.122.148.176	-	-	-	-	-	-
Cabernet	192.168.202.3	-	-	-	-	-	-
Bordeaux	192.168.202.4	-	-	-	-	-	-
WAN Network (8 devices)							
Internet	10.100.36.1	-	-	-	-	-	-
Denver	10.100.36.60	-	-	-	-	-	-
Atlanta	192.168.202.2	-	-	-	-	-	-
Honolulu	10.100.36.5	-	-	-	-	-	-
Miami	10.100.38.3	-	-	-	-	-	-

Screenshot 1: PathSolutions TotalView Power Supply Status

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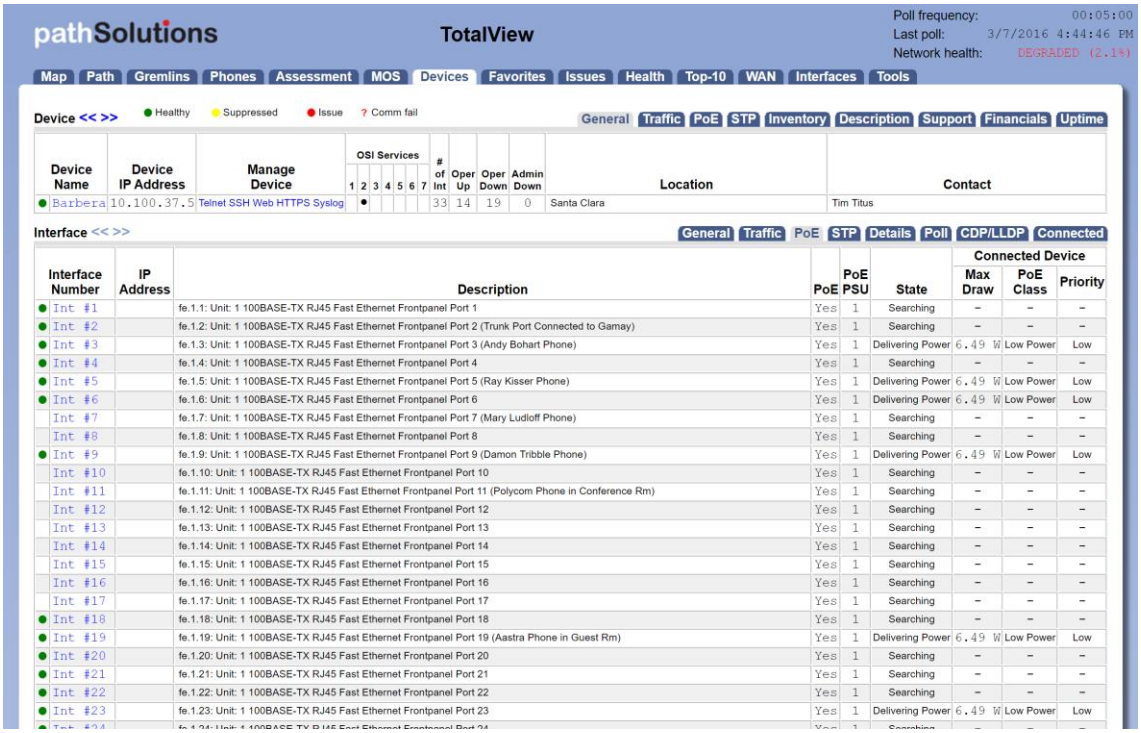
Keeping an eye on power supplies can help to avoid unpleasant discoveries. For example, you could have two power supplies installed in a network chassis (one primary and one backup). Unfortunately, when the primary power supply stops working no one may notice as the backup power supply continues to keep the network running. If the status of power supplies are not monitored and the remaining power supply is shut off by something like a circuit breaker trip, that network chassis no longer has power even though it has redundant power supplies.

The other level to manage Power on is at the individual Ethernet Port, where PoE and PoE+ devices attach to the network. Not only will TotalView show you what mode a PoE port is operating in but it also provides a view of relevant error counters and significantly decreases troubleshooting time. "MPS Absent" and "Invalid Signature" errors frequently point to broken or defective powered devices. Overload conditions and short-circuit errors typically are caused by wiring problems (or somebody re-wiring devices in use). "Denied" errors helps administrators discover devices asking for more power than the PoE/PoE+ Ethernet switch has available and may indicate that it is time to consider adding another power supply to your large Ethernet chassis.



Screenshot 2: TotalView: PoE Port Status

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Future Innovations

Various IEEE committees and LAN switch vendors are currently looking at new ways to expand the benefits of PoE and PoE+ technologies. Here are some of the innovations vendors are working on:

- **Double Power:** Some engineers are now experimenting with providing PoE+ level power on all four pairs of wire simultaneously. This would bring total wattage up to about 50 watts. As a temporary work-around, a few power-hungry devices (mostly wireless access points) are using two separate PoE+ Ethernet ports to draw more power.
- **EEE – Energy Efficient Ethernet:** Now that large racks of network equipment are being filled in massive data centers and large buildings, power engineers are looking at how they can lower the power needed by the network even further. Traditional Ethernet ports have always assumed that cables were the maximum 150 or 100 meters long with output signals and power strong enough to travel the full distance of a maximum-length cable. As it turns out, very few Ethernet links are to connections that far away (for example, in data centers patch cables are often only 1 to 3 feet long). New Ethernet chip sets allow switches to measure the length of the cable and then reduce power and signal output. This saves a tremendous amount of power while ensuring that there is just enough signal and power to reach the end of the (short) cable.
- **Avaya Energy Saver:** Many of the Avaya Ethernet Switches (such as the 4500 series) are offering new power-saving features, allowing PoE devices to shift to a lower power-consumption mode after business hours or when equipment is idle. Unused PoE devices can be switched off after hours and IP Phones may be shifted to a power conservation mode in order to use less power. Over time, these small changes can add up to significant energy savings across an office building.
- **PathSolutions Power Management:** PathSolutions continues to add new features, such as PoE, PoE+, and power-supply management, allowing users to gain total network visibility across their entire network. Within 12 minutes of installation, PathSolutions software begins automatically mapping network devices, finding weak-points, recommending solutions with network prescriptions, and tracking network trends.

Other Resources

More and more, companies and organizations of all sizes are considering PoE as a power supply option. While there are network management issues to address, it's clear that PoE is here to stay. For more information:

Specifications:

- **PoE—**The full specifications for PoE (802.3af) and PoE+ (802.3at) can be downloaded here: http://standards.ieee.org/about/get/802/802.3.html. The PoE+ (802.3at) standard supersedes and includes nearly all of the PoE (802.3af) standard.
- **4-Pair PoE and emerging standards—**A new specification, 802.3bt, specifies how 4 pairs of wire can be used for PoE power to support up to 100watts of power over even faster links, up to 10gig.

Network/VoIP Troubleshooting:

- **Webinar:** Troubleshooting VoIP Call Quality Problems, Quick & Dirty Secrets to Resolution
- The PathSolutions blog covers network performance issues in depth and the team welcomes topic requests.

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