Power over Ethernet: Empowering the Digital Home

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1. Origins of Power over Ethernet

While the idea of having data and power on a single cable is not unique and has been used since the invention of the analog phone, the original Ethernet standard, known as IEEE Std. 802.3, did not support powering data terminal equipment. As Ethernet became the prevalent data transmission technology in the Enterprise and Small Medium Business (SMB) segments, and its speed and Quality of Service capabilities improved, it began to be used for Voice over IP (VoIP) communications. VoIP, much like analog telephony, could benefit from power being transmitted with data packets, allowing centralized VoIP phone backup. Along with VoIP deployment proliferating, IEEE 802.11 Wireless LAN (WLAN) protocols became a popular extension to wired Ethernet. Ideally, the available wireless coverage is provided with the minimum number of WLAN Access Points (APs) and this sometimes requires the APs to be located in special locations, where AC power is not always available. The VoIP and WLAN applications triggered the IEEE 802.3 work group to create the Power over Ethernet (PoE) Task Force (IEEE P802.3af) in 1999. After four years of work, in June 2003 the IEEE 802.3af standard was ratified and it is incorporated into clause 33 of IEEE Std. 802.3™-2008.

2. The IEEE 802.3af Standard Overview

IEEE 802.3af Components

IEEE 802.3af defines two types of equipment: Power Sourcing Equipment (PSE) and a Powered Device (PD). PSEs are further defined as either Endspans, switches that inject power, or Midspans, hubs that receive data from switches on one side and transmit data and power on the other. While Midspans must use wires 4, 5, 7 and 8 of the cable to transmit power, Endspans may also use wires 1, 2, 3 and 6. The following Figure 1 and Figure 2 provide examples of these deployments.

Figure 1: Endspan PoE deployment

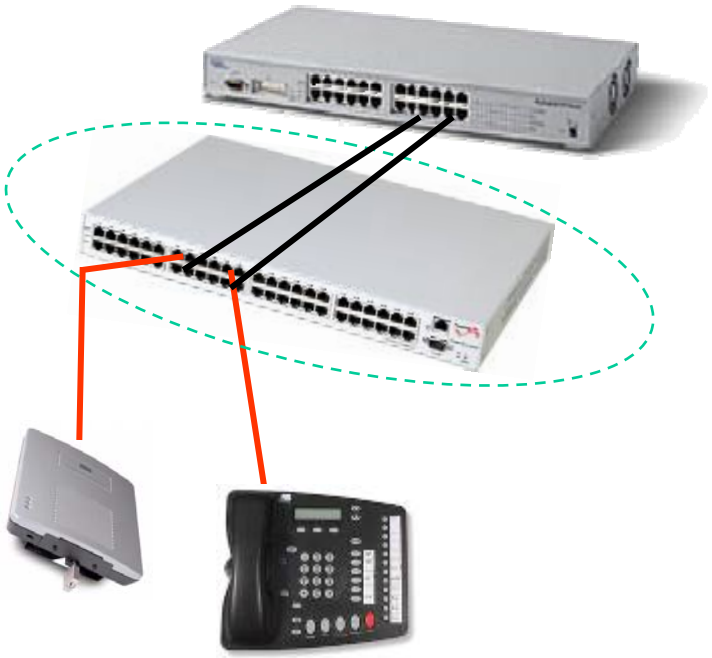

Figure 2: Midspan PoE Deployment

IEEE 802.3af Power Feeding

Power is transmitted via phantom feeding, on the external side of the pulse transformers, with 1500V isolation from the data circuitry of the Ethernet switch.

IEEE 802.3af Safety Mechanisms

Being an extension to a standard that had millions of devices in the field that could potentially be damaged by receiving power, the specification includes a detection mechanism, in which only devices that present a 25KΩ signature are powered. For the same reason, device disconnection was mandated, so that ports are not left open after a PD is unplugged. Device disconnection can be done in one of two methods, AC-disconnect or DC-disconnect. Another safety mechanism is overload detection, which makes sure devices do not take more power than allowed by the standard.

IEEE 802.3af Power Management

The IEEE 802.3af standard allows for PDs to consume up to 12.95W at a maximum current of 350mA. This translates into a minimum power of 15.4W to be transmitted by the PSE. The power loss is due to the 20Ω of a CAT-3 cable 100 meters long. The PSE must output a voltage between 44V and 57V. This removes the need for a certified electrician to install PoE equipment because it is under the maximum 60V Separated Extra-Low Voltage.

One of the aspects that influence most the cost of implementation of multi-port PSE's is the size of the power supply, i.e., how many watts, on average, a PSE can deliver to each of its ports. While the IEEE 802.3af standard includes a classification mechanism, in which the PD declares to the PSE what would be its maximal power consumption, this mechanism is not granular enough to be effective. It includes only 3 useful classes: 3.84W, 6.5W and 12.95W. This means that if a device requires 6.6W, it must demand 12.95W. Also, the typical power consumption is normally as little as 20 percent of the maximum power consumption, meaning that a lot of power can be wasted by doing static allocation based on the classification results. More updated protocols like link layer discovery protocol (LLDP) offer more granular, software controlled power management.

3. What else can be Powered?

In addition to IP Phones and WLAN Access Points, other devices are typically powered via PoE, such as network cameras, Bluetooth® Access Points, RFID readers, bar code readers, thin clients and others. There is even a PoE electric guitar. In fact, with newer silicon geometries such as 65nm and 40nm, the power consumption of Ethernet appliances is constantly on a downward curve further opening the possibilities for PoE capable devices. It will not be long before a netbook designed with high performance, low power CPUs, such as the Intel® Atom™, or ARM®, will need only an RJ-45 jack with PoE powering up the netbook. Many conference-room utility Ethernet switches such as 5-port Fast Ethernet switches and 16-port gigabit Ethernet switches are now powered by PoE CAT-5 cable, saving the cumbersome power cables.

However, there are limitations to applicability of 802.3af. Several devices such as video phones, IEEE P802.11n APs, and pan-tilt-zoom cameras cannot be powered with 12.95W, which is the maximum limit set by standard. These devices require power that is in the range of 15W to 30W.

Therefore, a group known as the IEEE 802.3at Task Force has been working to enhance the PoE standard to allow applications that require as much as 25.5W. The IEEE P802.3at standard is expected to be ratified in the second half of 2009 and will be backwards compatible with IEEE 802.3af as well as include extensions that permit powered devices to negotiate its exact maximum power requirements.

With the support for higher power will come the ability to support additional applications such as WiMAX Subscriber Stations (SS), Fiber-to-the-Home (FTTH) optical network terminators (ONTs), 3G pico and fempto cells and even laptop computers. While some of these applications require as much as 50W, most can be powered within the proposed IEEE 802.3at limits. However, unlike IEEE 802.3af, IEEE 802.3at does not preclude two powered devices to be powered using a single CAT-5 cable, therefore opening the possibility for devices to be built that consume up to 51W. This would potentially allow even desktop computers to be kept alive using PoE, thereby increasing reliability in the case of power failures, especially advantageous in geographies such as developing countries or areas that are susceptible to brown and/or black out.

4. PoE and the Digital Home

The path to the Digital Home, with ultra fast internet access, is paved with PoE. Both FTTH (IEEE Std. 802.3ah-2004) and WiMAX (IEEE 802.16 Working Group) rely on PoE to bring power to the outdoor entry points into the home network. The deployment of 3G fempto cells can be eased with PoE, as they can be deployed either on the roof or in the attic of a house. Inside the home, PoE can enable WLAN, video telephony and network cameras, as well as things like home automation devices. PoE can also be used to power network storage and inkjet printers, so needed in the age of digital photography. With PoE, all of these devices can be:

- Deployed in the best place for their usage, without being constrained to closest place to a power outlet
- Monitored and reset over the network
- Operated even in the case of a power failure with only the power sourcing equipment needs to be backed-up

5. A New Generation of Convergence

While the Ethernet and IP communities were accelerating the convergence of voice, data and video, known as triple play, a new convergence of data and power also emerged. The ability to provide power on the same Ethernet cabling infrastructure offers flexibility, lower operating expenses and manageability of the power grid.

1) Flexibility is gained, through the ability to locate and operate Ethernet equipment without commercial power availability. This is applicable not only in the office and typical IT environment, but also in the telecommunication carrier networks. ATM and TDM technologies are giving way to Ethernet and the additional capability of PoE enables ease of deployment for WiMax pico-cells, mini base stations, top-of-the tower Ethernet equipment and other types of communication equipment.

2) Lower Operating and Capital expenditures are achieved by removing the need to install, maintain, fix and certified commercial power sockets. Reusing data cables and removing the need for certified electricians offer major savings.

3) Manageability of the Power Grid: PoE convergence with data networks allows the IT manager or carrier network management to monitor in real time the

consumption and connectivity of the power distributed in the network. In modern networks where there is interest in ENERGY STAR ® compliance, "green" and power-savings this is of particular interest. Power and data flows through the same network and offer administrators ability to manage the miniature power plant of the organization, a capability that is not offered by commercial power. It also offers the capability to shut-down, turn-on, and reduce or increase power budgets for each appliance in the network. PoE provides the infrastructure to measure, monitor and isolate the in-office power network.

6. Summary

PoE has come a long way towards becoming the backbone of VoIP, WLAN and IP Security infrastructure at the Enterprise. The home is the new frontier now ready to reap the benefits of this mature, advanced and cost effective technology that distributes data and power on a single Ethernet cable.

7. Biographies

Daniel Feldman serves as a Director of Marketing at Microsemi's AMS Group, in charge of the P&L of all products in the PoE and Ring Generation markets, including ICs, modules and Midspans. He is a member of the IEEE 802.3at Task Force and Chairs the Ethernet Alliance PoE/PoEPlus Technical Committee. Previously, Mr. Feldman worked for PowerDsine as a Senior Product Manager, at IC4IC as the System Architecture Group Manager, as a VHDL Engineer at NICE Systems and as VLSI Engineer at RAFAEL. Mr. Feldman holds a B.Sc. (Cum Laude) in Computer Engineering from the Technion in Israel.

Michael Zimmerman is a Senior Director, SMB and Metro at Marvell Semiconductors, responsible for Metro Ethernet and Small-Medium Business Ethernet product lines . Michael Zimmerman held business and architect positions in ADC, Nortel and IAF. Mr. Zimmerman holds a B.Sc.EE. (Summa Cum Laude) and MBA (Dean List) from Tel Aviv University, Israel.