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POWER OVER ETHERNET APPLICATIONS AND ITS EFFECT ON THE ELECTRICAL CONSTRUCTION INDUSTRY

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ABSTRACT

Power over Ethernet has proven useful for many applications in the construction and technology industries while only cracking the surface of its possibilities. This paper explains the history of ethernet and Power over Ethernet while describing how PoE is installed and ran. It discusses the cost of PoE in comparison to traditional power and internet systems and provides it's many pur-poses. When identifying the effect on the electrical industry, the advantages, and disadvantages of PoE are outlined and the problems and complications that accompany Power over Ethernet are ex-plained. Looking forward, this paper illustrates the next steps in the advancement of PoE and the excitement surrounding the possibilities of Power over Ethernet in the future.

KEYWORDS: *PoE, ethernet, technology, construction.*

INTRODUCTION

Technology has been an ever-changing force in society for the past decades and will only continue to grow in popularity and usefulness. Cellphones, machinery, artificial intelligence, and the internet are only a few examples of advancements in technology, and among these discoveries, came the advancement of ethernet. Ethernet is "a protocol that controls the way data is transmitted over a local area network (LAN)" and has many useful properties (Ullah, 2012). The name ethernet "came from the combination of words "Ether" and "Net". Ether, meaning "light-bearing", which stands for the use of light as a means of data-carrying medium whereas Net is a short form of network that represents a community or a group of

linked computers" (Ullah, 2012). This group of linked computers is called a network which allows any number of linked devices to share and receive information from one another. This is done by linking the network of computers using ethernet cables with the most common and recommended cable type being the category five cable, otherwise known as CAT5 cable. CAT5 cables include eight copper wires twisted into four pairs of unshielded cables with an 8-position, 8 contact registered jack (RJ45) at the end of the cable and are used for the transmission of ethernet (Shen, 2020). These CAT5 cables transmit ethernet by connecting one end of the cable, with the RJ45, to a computer or device and then spanning the cable up to 100 meters in length to the connecting device.

This connecting device can be the final destination, such as a computer, to allow for data transmission between the two computers, or this connecting device can be items such as a repeater or extending which are devices that allow multiple CAT5 cables to be grouped together and therefore increase the length available for spanning ethernet to be more than 100 meters. Through these connections, ethernet is used by one computer generating a signal that is sent through the cable, then through the connector, then the cable again until it reaches its final destination and is able to transmit the data (Ullah, 2012). Ethernet is useful in the fact that it allows multiple computers or devices to be linked together in a local area network (LAN) using cables to transmit data, without the need to connect to the internet. In many instances, this data using ethernet cable has a higher transmission rate than would be transmitted through the internet itself (Ghanti and Naik, 2016). Trivedi states that "ethernet is constantly evolving, adapting to the needs of the networking world, addressing the requirements of both operators and end-users, while making sure that the resulting technology is cost-efficient, reliable, and operates in a plug and play manner" which shows the importance and usefulness of ethernet (Trivedi, 2016). Since the discovery of ethernet, a new technology is known as Power over Ethernet has been gaining in popularity and interest all over the world and provides many uses.

Power over Ethernet, better known as PoE, "continues to draw interest from network cabling system professionals, enabling them to deliver both power and data over the existing Ethernet cabling in a unified infrastructure that is easier to expand, upgrade and maintain" as stated by Ronen and Feldman (2012). Power over Ethernet uses the creation of ethernet to not only be able to transmit data, but also power over the same twisted pair of CAT5 cables to a local area network of devices such as cameras, lights, and computers (Knisley, 2016). PoE

technology requires a select few devices to work properly with the first two devices being power sourcing equipment and a powered device. Power sourcing equipment (PSE) is a device that supplies the power, while the powered device (PD) is the device that received the supplied power (Knisley, 2016). The power sourcing equipment is connected to the ethernet switch and then transmits, using CAT5 cables, both power and data to all devices connected to the local area network that is PoE compatible (Lee, 2006). According to Frank Straka, "'pretty much any device that requires both data and power has become a candidate for using PoE—including lighting, AV equipment, building sensors, point-of-sale devices, and digital clocks in classrooms'" with the only limitation being the power required by these devices (Mclaughlin, 2020). The power required for each device is determined by the powered device (PD) sending a signal to the power source equipment to confirm the PoE connection and relay how much power the PD needs to operate (Lee, 2006). This power is then transmitted within the CAT5 cables where in most instances, two pairs of twisted wires are used to transmit the data while the other two pairs are used to conduct low-voltage DC to the PD's. In cases when more power is demanded by the PD's, all four pairs of twisted copper wires are used for PoE (Shen, 2020). The amount of power capable of being supplied by PoE has been increasing as the PoE standards and technology over time have been changing.

PoE was initially approved in 2003 for use by IEEE with the first standard being 802.3af which stated that the maximum power supplied by the PSE was to be 15.4 W (American Ceramic Society Bulletin, 2020) leaving 12.95W available at the PD with a voltage range of 37-57 V using 2 pairs of twisted wires in a CAT3 and CAT5 cable. Since then, the IEEE has ratified and approved three additional standards with the latest one in September of 2018, standard IEEE 802.3bt, to supply a maximum of 100W from the PSE leaving 71W available at the PD and a range of 42.1-57V applied using all 4 pairs of twisted copper wires within the recommended CAT6 cable (Shen, 2020).

	PoE	PoE+	UPoE, PoE++, or 4P PoE	Higher-power PoE
IEEE Standard version	802.3af (802.3at Type 1)	802.3at Type 2	802.3bt Type 3	802.3bt Type 4
Ratified	2003	2009	2017	pending
Maximum power from PSE	15.4W	30 W	60 W	100 W

Power available at PD	12.95 W	25.50 W	51 W	71 W
Voltage range (at PSE)	44.0–57.0 V	50.0–57.0 V	50.0–57.0 V	52.0–57.0 V
Voltage range (at PSE)	37.0–57.0 V	42.5–57.0 V	42.5–57.0 V	42.1–57.0 V
Twisted pairs used	2	2	4	4
Supported cabling	Cat3 and Cat5	Cat5	Minimum Cat5e	Recommended Cat6

Figure 1: Visual representation of PoE standards for reference (Shen, 2020).

PoE technology over the years has gone through many changes and advancements and according to Knisley, "Power over Ethernet (PoE) is clearly a disruptive development in the construction industry— and well worth learning about" (Knisley, 2016). PoE is able to run through the existing LAN infrastructure using the ethernet cables that are already installed in most buildings (Mendelson, 2018) and with PoE being able to transmit both data and power through the ethernet cable and provide this data and power to a PD with a single 8-pin, 8-contact RJ-45 connector, there is not a need for an AC receptacle (Ronen and Feldman, 2012). Without this need for an AC receptacle, PoE gives the freedom to "position devices where they are needed rather than where power cords dictate, and the long-term flexibility to move devices around to suit the changing operational needs of the business, are both highly desirable benefits for any organization" (Lee, 2006). In addition to the flexibility that comes along with PoE, PoE is also found beneficial in the way of its data-gathering capabilities.

Since PoE is a way of transmitting and gathering data, PoE can be used by technology to control aspects of the PD's that PoE supplies. When a PD is run with PoE and therefore connected to an ethernet cable, that PD is assigned an IP address that can be used to control the PD. This way of controlling devices can "help simplify management, configuration, and maintenance of connected devices, as network administrators and system integrators can immediately see and troubleshoot errors in the system when issues arise" (American Ceramic Society Bulletin, 2020). Meaning, any device connected to PoE can be viewed and controlled by a computer which allows for easier problem solving when it comes to powered devices. The Sinclair hotel in Fort Worth, Texas, took advantage of this aspect of PoE by using PoE to power and control its minibars, smart mirrors, window shades, and lights throughout the entire hotel. Being able to control PD's in The Sinclair hotel by using PoE was not only

found to be more convenient for the hotel but was also a way of saving money by being able to power on and off these devices with a click of a button (American Ceramic Society Bulletin, 2020). Being able to switch the power to devices on and off is not the only effect PoE has on the cost of data transmission and power.

MATERIALS AND METHODS

Installation and Cost of PoE

Power over Ethernet involves quite a different installation process than installing normal electrical wiring which therefore has a direct effect on the cost. In most buildings, ethernet is often already installed which automatically cuts the cost of having to install ethernet cables if one is wanting to run PoE. Furthermore, ethernet cables cost significantly less than traditional electrical wiring meaning even if a building needed all new wiring to run PoE, using CAT ethernet cables would save money in comparison to running traditional wiring to use AC power (American Ceramic Society Bulletin, 2020). In addition to the cost of ethernet cables compared to traditional electrical wiring, the installation process differs a great deal. With traditional wiring, one must take into account the cost of conduits, wiring, receptacles, switches, as well as the cost of labor required to install this equipment to run AC power into buildings. An IT manager states that when installing surveillance cameras in his building, "PoE significantly reduces this cost, providing a higher return on investment with no compromise in power, network or video quality" (Security Magazine, 2010). As well as Sheu states that PoE is useful in the business of live music because by replacing the wires and cables used in concerts with ethernet cables, the cost was substantially reduced (Sheu et al., 2016). By discovering that running and using PoE with ethernet cables saved money in comparison with traditional wiring and AC power, another advancement in the PoE industry was to find the best way to run this Power over Ethernet in existing infrastructures that already had existing ethernet.

The two most common ways to install PoE in existing buildings are to either upgrade the existing ethernet network switch to a PoE switch or to install a device called midspan in the infrastructure. By upgrading the existing network switch to a PoE switch, one will benefit by only needing one cable for a network connection but will run into the problem of PoE switches being quite expensive. Therefore, the next option is to install a midspan that is installed between the existing ethernet network switch and the powered devices that will be run by PoE. PoE midspans are significantly less expensive than a PoE-enabled switch and

offer the convenience of having multiple PoE ports to allow for as many PD's necessary and for the flexibility to add more in the future (Microsemi, 2012). While the midspan device itself costs less to purchase and replace, the user also benefits by a lowering installation cost and by only having to purchase midspans where they want to run PoE (Communications News, 2007). According to Ronen and Feldman, installing midspans is "the most cost-effective way to deploy PoE" (Ronen and Feldman, 2012) due to midspans many uses. Of those uses, comes the benefit of having a remote way of controlling PD's which can therefore protect costs associated with power charge. Midspans allow the total power consumption to be monitored and controlled by network administrators (Ronen and Feldman, 2012) and only supply power to the ports that are actively being used instead of PoE switches that supply all ports regardless of if they are being used (Microsemi, 2012). Since select ports can be automatically turned on or off throughout the day, that can save on power consumption by 70 percent. This is very useful in instances when devices start malfunctioning and need to be reset or turned off as this remote ability saves on an expensive service call. This ability is also a safety advantage as midspans can automatically detect and disconnect PD's from the source in cases of overload or short circuits (Microsemi, 2012). Not only can midspans automatically disconnect PD's, but they can also back up the power supplied to these powered devices.

When a powered device is plugged into an AC outlet and the power goes out, that device loses power and turns off unless connected to a single uninterrupted power supply device which will continue to send power to the devices connected to the UPS for a short period of time. In the cases of midspans, a "single UPS can be used to back up a PoE midspan serving 20 IP cameras on a network" and "without the PoE midspan, 20 UPS systems would be needed". As well, PoE allows for control to manage the multiple midspans and UPS systems so that they can be pre-programmed to continue to supply power to only the highest-priority devices connected to UPS's in case of low UPS battery levels (Ronen and Feldman, 2012). Therefore, for the argument of installing new PoE switches against midspans, midspans come with the benefits of being less expensive, more flexible, and reliable.

RESULTS

Effect on Electrical Construction Industry

PoE is undoubtedly affecting the way buildings are built, run, and controlled and provides a variety of opportunities for the electrical trade and the electrical construction and design of

infrastructure. PoE is aiding in the enhanced efficiency of smart buildings and as stated by Bloom, "with today's systems requiring so many appliances, it's the perfect time for electrical contractors to consider a PoE upgrade to ensure that their customer's building is ready for the 21st century" (Bloom, 2021). Installing and using Power over Ethernet is strongly suggested by many electrical contractors as the benefits of PoE are quite large and only continuing to grow. Although PoE provides many benefits to electricians, the effect on the electrical field may not be as beneficial.

As noted, PoE benefits from an easier installation process and requires less skill to install or upgrade than traditional electrical wiring. Installing PoE is less complicated as only one cable is needed to transmit both power and data instead of having to group multiple cables together to achieve the same goal without PoE and in most cases, ethernet is already installed in existing infrastructure. (Bloom, 2021). In addition, accessing PoE does not require the use of an electrical receptacle unless already installed and a skilled electrician is not needed to install these receptacles. In support, Blyler stated that "PoE-enabled devices don't require any accompanying AC power source, such as a wall socket. This aspect reduces the need for certified electricians to install conduits, wiring, and outlets throughout a facility. It also offers flexibility" (Blyler, 2004). Without the need for electricians to run the wiring, the user benefits from a reduction in cost, construction time, commission time, and error (Kulkarni et al., 2015). As the number of individuals involved in a project increases, so does the chance for miscommunication, errors, overlooks, and mistakes to be made. Therefore, in addition to the reduction in cost, the user may also benefit by not having to complicate the process even more by involving skilled electricians (Palmer, 2007). For this reason, even though PoE may be an interesting advancement in the electrical industry and supported by many, as PoE becomes more advanced and possibly the preferred method of transmitting data and power, PoE may eventually have a negative effect on electrical contractors.

In contrast to the advantages of PoE, Power over Ethernet is accompanied by a select few complications of its own. The first and most evident challenge of PoE is its limited uses, length of cabling, and minimal power transmission. As stated previously, the maximum length of the CAT cable running PoE is 100 meters with the possibility of adding extenders to increase the length. This limitation may make it difficult to run PoE long distances and therefore prove useless in some circumstances. As well, the latest PoE standard only allows 100 W of power at the power sourcing equipment and when coupled with voltage drop and

power loss, only 71 W are to be available at the load which limits the technology supported by PoE (Mclaughlin, 2020). The main technology PoE has been used for are systems such as LED lighting, phone systems, IP cameras, and to provide power and data to wireless access points.

In addition to the limited length and uses of PoE, the aspect of heat within the CAT cables causes a potential problem for PoE technology. Since the CAT cable includes 4 twisted pairs of copper wires, heat tends to build up in the cable as DC power flows through (Knisley, 2016). Just as in normal conductors, the hotter the cable, the more power that is lost during transmission which leads to Frank Straka of Panduit to recommend the use of 23-AWG copper conductors with foil tape for PoE applications to help dissipate heat in the large bundled cables (Mclaughlin, 2020). Overall, Ron Tellas of Belden states that the best cable for PoE uses "needs to effectively balance three things: low resistance, large bundle sizes, and high insertion loss margin" (Mclaughlin, 2020). These aspects that affect the heat within the cables used for PoE, if not handled correctly, could cause issues for PoE transmission.

Equally as important as the excessive heat buildup within the cables, PoE has been found to be accompanied by erosion and damage to the RJ-45 jack and plug. Each CAT cable used for PoE has an RJ-45 jack connected to the ends of the cable that is used to plug one end into the powered device and the other end into the ethernet switch or an equally compatible jack. Erosion or damage has been found to occur when a PoE connection is unplugged which causes an arc (spark) to happen between the plug and jack which can lead to minor carbon scoring. This carbon scoring can build up in the jack and plug if unplugged multiple times and lead to connection problems and poor data transmission. Frank Straka of Panduit states that this problem is unavoidable, but it can be managed through the design of the RJ-45 jacks. Straka explains how their "jacks are designed so that the place where the arc occurs is at a different location from where the plug's nominal resting point is. The jack's contacts also allow for significant scraping when inserted to remove any carbon buildup that may occur." In addition, Ron Tellas of Belden adds that "the best way to ensure that you don't create this arc is to turn the device off before disengaging the jack" (Mclaughlin, 2020). Although PoE is coupled with these complications and problems, many individuals still seem optimistic about the future of Power over Ethernet.

DISCUSSION

Future of PoE

As previously stated, PoE has been used in the past for systems such as wireless access points, monitoring systems, and lighting, but Susan Bloom seems hopeful that PoE in the future will aid in the creation of full-building automation by controlling multiple floors with multipurpose uses. Bloom urges "building owners and contractors to look at the data infrastructure and consider the use of PoE from a cost and value-engineering perspective" and states that "PoE can be a great option and a technology that really extends a contractor's reach" (Bloom, 2021). Galit Mendelson of Microsemi Corporation adds that by using PoE to control lighting and full-building automation systems, a building and workplace can see the advantage of being more productive and an easier infrastructure to maintain and control over a single IP network (Mendelson, 2018). Furthermore, Gao believes that with the help of PoE technology, smart home systems can be created to support the daily life of both elderly and physically disabled people who cannot live independently. By making a home more easily accessible, reliable, and safer, these smart homes could be the future with PoE technology (Gao et al., 2018). Many accredited individuals believe that PoE has a bright future including Lee, who proclaims that "PoE is undoubtedly going to change the way that many pieces of electrical equipment are powered. The benefits and flexibility that the approach provides are huge and make it impossible to ignore for businesses of all types" (Lee, 2006). As PoE continues to advance and more discoveries are made, there is no telling what direction Power over Ethernet will go next.

CONCLUSION

In conclusion, Power over Ethernet provides an alternative way to transmit data and power over a single cable in contrast to the traditional process which saves both time and money. This method of data and power transmission proves beneficial and useful in many applications and allows for a unique approach to the way buildings are powered. PoE may be the future of the electrical and technology industries in the form of a simpler installation process and through complete, automated smart homes.

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