Understanding Extended Distance Network Transmission

Extended Transmission is rapidly becoming a key component to IP CCTV network systems. As IP cameras and digital network recorders improve in quality, along with the advent of cloud storage, the criteria for system performance will depend on digital signal transmission solutions that maintain high data rate with minimum data loss.

Many video network systems require point-to-point bi-directional communications to maintain their secure or “closed circuit” status at distances greater than the current Ethernet limit of 100 meters. The Analog video systems transitioning to IP expose the challenges of higher costs for installing additional UTP cables and extra equipment while rendering existing coax useless.

All of these challenges can be addressed with the use of extended distance Ethernet transmission solutions that can run over long distance UTP or Coax. However, networking standards and testing methods for small file size data transmission rarely work when applied to large file video frames transmitted at high speeds and long distances. Furthermore, the growing desire to power IP cameras and other devices using Power over Ethernet (PoE) adds more stress and consideration to network transmission. These considerations require a clear understanding of existing transmission methods and testing requirements to validate claims.

Even top-performing cameras and recorders can be rendered useless or fall below their standard performance by the transmission systems' inability to handle data and power requirements.

Challenges Facing Video IP Security Networks

a. The standard Ethernet transmission distance is limited to 100 meters/328 feet of UTP. Taking into account the 5 meters required on both sides for connections at a total of 10 meters, you now only have in 90 meters or less than 300 feet remaining for transmission signal.

b. While distances can be regenerated, they require the use of a network switch or Ethernet repeaters resulting in additional installation and cost considerations.

c. There is a strong need to convert regular “Open Networks” used for CCTV as “Closed Circuit Security Network” (CCSN).

In most installations, control centers are usually located at distances greater than 100 meters from cameras. Casinos, larger industrial complexes, college campuses, and shopping centers which require parking lot surveillance, are all examples of applications that require transmission distances of more than 100 meters.

The need for extended distance network is not always apparent. Many are familiar with connecting an Ethernet cable or using WiFi to access global information. The simplification of network access often produces a tendency to overlook the security aspects it. CCTV is not limited by analog or IP signals; CCTV is required to be “Closed Circuit”. The best method to ensure security is to limit access to CCTV network. This limited access requires all connections remain within their own network and with limited or no outside access. Virtually every day, we read about the most secure networks (including government sites) being breached and information stolen or altered. This insecurity is created any time a network or network device is exposed to the web.
The Potential is Great

The use of IP for video security applications is increasing rapidly. While both analog and IP camera system sales are growing, IP is growing much faster and often at a higher rate with more complex systems. Over the next few years, IP systems are forecasted to surpass analog cameras by three to one with sales reaching approximately 9 million units by 2015. It is reasonable to assume that not all connections will be restricted to 100 meters.

Looking at projections for encoder sales over the same period is also noteworthy. Encoder sales are expected to increase while the use of network recorders is expected to double. All of these devices require digital transmission paths.

Security products, especially cameras, are a great investment. In the mid-to-late 1980's, video cameras transitioned from tube to chip images, thus making them virtually an age independent component. It is difficult to project the life-span of a video security camera; yet many installations from that period are still active.

The current challenge in video recording stems from the increased use of digital and networking mediums. VHS time-lapsed recorders are no longer in practice. Digital Video Recorders are evolving into Network Video Recorders while at some point will be replaced by cloud networking. However, the stable and reliable CCD analog cameras continue to perform. In current economic environments, the challenge to update can incur greater digital equipment costs compared to their analog predecessors. The largest cost consideration is rewiring which can often exceed the cost of the equipment itself.

There are many projections regarding average analog camera sales per year. Conservatively, if we go back 10 years when IP was at its infancy, the figure is estimated at 10 million cameras per year worldwide. This would mean approximately 100 million analog cameras are still functioning today. Adding the average growth of about 1.5 million encoders reveals the potential that as network-based IP digital systems continue their rapid growth. Current analog systems will eventually be replaced by IP cameras.

A Coax cable has a distance limitation commonly cited at approximately 1000 feet (305 m). This limitation was resolved by the use to Unshielded Twist Pair (UTP) transceivers. Currently, it is estimated that almost 12 million channels of analog cameras are operating over UTP at distances up to 6,000 feet (1828 m). Now, add several thousand channels of fiber that currently carry analog camera signals. Current estimations show that potentially about 1% of analog cameras, over a million channels, could be converted to IP cameras each year.

As time progresses, technology decreases product costs which holds true in respect to all aspects of analog and digital IP systems. All costs decrease with the exception of labor. As equipment costs decrease, labor costs increase in regard to salaries, health care, and transportation. Decreasing costs for improved IP cameras and recorders quickly outweigh the labor cost of replacing coax cable with UTP.

The solution is to keep existing coax cable or UTP and use it to connect to IP cameras.

What do we need to know about extended distance data transmission?

Many extended distance data transmission products use components from technologies designed for applications other than extended Ethernet transmission. While providing lower cost products and a quicker time to market, their inability to deal with high frequency, large data packets, and need for high power consumption often outweigh any advantage over new technologies specifically designed for IP video and mega-pixel camera transmission.

The following technologies are the most commonly used for extending Ethernet distance.

VDSL

As with any technology, viewing product specifications is hardly sufficient to make an educated decision. The extension of an Ethernet signal does not solely involve distances greater than 100 meters or the ability to carry signals over coax cable. Many security cameras are being powered over cable by industry standards, IEEE 802.3af, and more recently, the high-power version IEEE802.3at. Like Ethernet transmission, the ability to power devices using PoE is limited to 100 meters. The challenge of extended transmission is two-fold, 1) data and 2) data plus power. This heightens awareness of the technologies necessary for extending Ethernet and power.

Similar to many current technologies used in video security applications, extended distance transmission technologies have their origins in consumer applications. Internet Service Providers (ISP) are confronted with similar cable distance restrictions. This led to the development of Very High Speed Digital Subscriber Line 2

Understanding Extended Distance Network Transmission
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(VDSL2) technology. This technology is used for high-speed internet connection at home, however when applied to video security applications, there are several significant defects.

1. **Bandwidth**: VDSL2 data rate rapidly decreases with distance. A VDSL2 device rated to operate at 100Mbps may function at significantly shorter distances than what appear on the product specification sheet.

2. **Uplink vs. Downlink**: Since VDSL2 was designed to primarily feed information in one direction; the focus was on increasing the downlink (remote site to source) bandwidth not uplink (source to site). The difference in bandwidth is almost 40%.

3. **Power**: VDSL2 requires significant power to push the signal through long wires.

![Typical VDSL-2 performance showing bandwidth drop-off with distance](image1)

![VDSL-2 performance verses Vigitron with Symmetric bandwidth](image2)

*Figure 1: Differences in VSDL-2 and Symmetric Bandwidth*

A device indicating its Ethernet port is capable of transmitting 10Mbps/100Mbps is not a guarantee that its system actually transmits 10Mbps/100Mbps of data. In most cases, several factors limit the amount of bandwidth a system can handle, including differences between upload and downloads.

**What do the Bandwidth and Packets limitations of VDSL2 mean to you?**

Understanding the limitations of VDSL2 requires knowledge of signal transmission over a network. First, we must consider the difference between port bandwidth and usable signal bandwidth. Port bandwidth is most often seen in product specifications. The typical port bandwidths are 10Mbps and 100Mbps. **Mbps** stands for Million Bits per Second and is used in referencing to data transfer speed (This is not to be confused with Megabyte which is expressed as MB). An IP signal is transmitted along with several embedded information which are necessary in directing the data. These are considered overhead and take away from the available bandwidth for the actual data. While there are no industry standards specifying the practical percentage of actual data rate to the total Ethernet rate, the more conservative you are the better. A conservative and safe measure would be allocating about 46% for overhead and leaving 54% for actual signals.

The Ethernet data is divided into small segments called “Packets” which come in different sizes. The larger the packet the more information contained within but the more difficult it is to transmit. Packet sizes are usually determined by the information source. After sending each packet the transmitter expects an acknowledgement from the receiving side. If the packet is corrupted or not received the transmit side will not receive the acknowledgement, will timeout after a certain period and will resend the same packet. Therefore a low quality transmission link will have a much lower effective data rate when the packet sizes are larger.

A Request for Comments (RFC) has been established defining the various packet size used in network transmission. While RFCs are termed requests, if the specification is accepted it does become a standards document. The RFC for network packet transmission is called RFC-2544. It includes packet sizes ranging from 64 bytes to 1514 bytes. As with any form of transmission the bigger the signal, the more difficult resulting in fewer signals transmitted. The following are differences between packet size and number of packets transmitted.
<table>
<thead>
<tr>
<th>Size: Packet Size (bytes)</th>
<th>Ethernet: Number of Packets transmitted per second</th>
</tr>
</thead>
<tbody>
<tr>
<td>64</td>
<td>14880</td>
</tr>
<tr>
<td>128</td>
<td>8445</td>
</tr>
<tr>
<td>256</td>
<td>4528</td>
</tr>
<tr>
<td>512</td>
<td>2349</td>
</tr>
<tr>
<td>768</td>
<td>1586</td>
</tr>
<tr>
<td>1024</td>
<td>1197</td>
</tr>
<tr>
<td>1280</td>
<td>961</td>
</tr>
<tr>
<td>1518</td>
<td>812</td>
</tr>
</tbody>
</table>

As the size of each individual packet increase, the number of transmitted packets is reduced.

The difference between the number of transmitted packets for the smallest packet size and number of transmitted packets for the largest packet size is almost 95%. Video cameras are generally in the 1518 packet size range while some large megapixel cameras generate packet sizes over 1518, referred to as “Jumbo Frames”.

**ODFM**

ODFM, Orthogonal Frequency Division Multiplexing, can be better understood if you relate a transmission line to a garden hose. The diameter represents bandwidth and the water running through it represents data packets. The larger the diameter of the hose, the greater the water flow and vice versa.

The Ethernet bandwidth is fixed to 10MHZ or 100MHZ. OFDM divides the total bandwidths into several sub-carrier narrow bandwidth signals. While this process of dividing the signal has the advantage of increasing signal quality, it decreases the amount of available data bandwidth; further restricting the ability to transmit very large packets and Jumbo frames necessary for megapixel cameras. In brief, the bandwidth available for each sub-carrier is far less than the total available bandwidth.

**BPL**

BPL, Broadband over Power Line, is a technology developed to transmit data over existing power lines. The major restriction here is the bandwidth of power line systems which were designed to handle frequencies in the range of 50 to 60 Hz; however, the BPL maximum data rate should be 500Mbps. To achieve this goal, it is required to divide the maximum frequency into subcarriers, similar to ODFM, and then modulate each frequency to ride over the power.

The VDSL2, ODFM, and BPL technologies share several common disadvantages when it comes to transmitting IP video. First, they must modulate the signal. In doing so, the data packets need to be de-packetized and modulated. At the receiving end, the signal is demodulated and packetized again. The result is never the same as the original and many components in the original signal will never fully recover.

This process affects the ability of these technologies in IP video systems to do Multicasting. Multicasting is quite common in IP video transmission systems and is used to reduce transmission bandwidth, as multiple streams can be combined into one stream. Multicasting is virtually a mandatory requirement of large IP video systems.

Another issue is the power requirement. These technologies require higher levels of energy to operate. Most transceivers using these technologies cannot be powered by a PoE source due to their high power requirements and need to use local power supplies. The need for a local power supply negates the cost advantages of using PoE to power the camera, complicates installations and increases cost.

Further, and perhaps more damaging, is the product’s reliability and environmental limitations. Transceivers are usually designed with small enclosures and when they consume high power, they operate at higher temperatures. This degrades their internal components significantly and shortens their life span. As these devices become heat generators, their ability to operate under high temperature conditions becomes extremely limited. Also exposure to high ambient temperatures will further reduce their operating lifespan.
What most product specifications don’t tell you about Bandwidth and Packets?

- Most product specifications express transmission in terms of the Ethernet port bandwidth. But they do not inform you of the actual transmission bandwidth.
- They do not inform you how much of the bandwidth is lost due to overhead.
- Some product specifications indicate a maximum distance but don’t indicate what data rate can be achieved at the maximum distance.
- They do not tell you if the transmitted distance applies to data and PoE transmission or if it indicates data transmission distance only and an additional remote site power supply is required.
- Most specifications base their bandwidth and “Packets per Second” testing on 64-byte packets a figure that cannot be applied to video transmission, so performance is often misleading.
- Almost none have proven test results for RFC-2544 conformity showing real world operating packet and bandwidth losses.
- They can not transmit Jumbo frames reliably.
- Most extenders cannot comply with “Multi-cast” requirement.

Power is Key

The main goal of a transmission system is to maintain transmission bandwidth and avoid data losses. Figure 1 displays the actual test results of a VDSL2 extender. By the time that it reaches 1000m its bandwidth has decreased by almost 20%.

Also, the difference between download and upload data rates result in an additional 40% decrease making it easy to see its limitations in handling megapixel cameras. These limitations are common to VDSL2 transmission equipment.

There are an increasing number of network switches that provide Power over Ethernet (PoE) often using IEEE 802.3af. With increasing demand for more power, a new and more powerful PoE standard IEEE 802.3at has recently been introduced.

These standards make compatibility easy among different manufacturers’ equipment. They also provide important safety features which protect both the Power Sourcing Equipment (also known as PSE, PoE switch, or Midspan), and the Powered Device or PD (camera). These standards also require several fixed classes of power to be available at the end of a 100m cable run.

PoE Class Chart

<table>
<thead>
<tr>
<th>Class</th>
<th>Classification Current (mA)</th>
<th>Power Range (W)</th>
<th>Class Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0–4</td>
<td>0.44–12.94</td>
<td>Classification Unimplemented</td>
</tr>
<tr>
<td>1</td>
<td>9–12</td>
<td>0.44–3.84</td>
<td>Very Low Power</td>
</tr>
<tr>
<td>2</td>
<td>17–20</td>
<td>3.84–6.49</td>
<td>Low Power</td>
</tr>
<tr>
<td>3</td>
<td>26–30</td>
<td>6.49–12.95</td>
<td>Mid Power</td>
</tr>
</tbody>
</table>

Figure 2: PoE Class Chart

Many types of extenders consume up to 6 watts or more from an IEEE 802.3af source with an end power of maximum 12.95W. This results in little or no available power for the cable loss and requires using local power supplies.

Transmission of VDSL-2 signals consumes a great deal of power. Some devices require over six watts just to power one device. A total of 12 watts is needed just for powering the transmitter and receiver. This must be taken from the PoE power source which reduces the available for powering camera. If class 0 and class 3 require 12.94 watts to be available at the end of the 100 meter cable run and 6 watts is used just to power the VDSL device, then the remaining power will only allow cameras or other powered devices operating at class 1 and class 2. Worse off are some devices pushing power without complying with the standard safety features of PoE. Cable shorts and opens go undetected that can lead to damaging equipment. Finally the high-power demand of these devices often requires the use of a local power supply which adds to the cost of installation specially when there are no power sources available at the camera site.
Multi-Camera Transmission Challenge

In general, IP camera signals, with the exception of very high frame megapixel cameras can be transmitted over 10Mbps connections. Even after we account for the highest packet overheads, approximately 5.4Mbps can be reserved to safely transmit IP video stream. If we are using high compression codecs such as H.264, it is possible that up to four cameras to be carried on a single 10Mbps link and up to 40 on a 100Mbps link.

Some ODFM extender providers offer connection of up to five transceivers, four at the camera sites and one to receive the signals using simple BNC coax “T” connectors. This approach severely reduces each camera bandwidth as if they are practically connected to a Hub.

To better understand this, think of a four-way intersection with no traffic lights and no rules. Cars cross that intersection at will. In this example, it is likely that many cars will crash or collide and never make it to the other side. This is similar to what happens to data when a hub is used. For this reason the use of hubs is almost never recommend or it is limited to small data files moving at slow speeds.

The best solution is to use point-to-point connections that are terminated at a network switch, which is similar to an intersection with traffic lights. Cars or data movements are highly controlled and all data safely transmitted. However the addition of switch equipment to existing networks can pose security concerns if the IP addresses are programmable. The IP addresses need to be fixed to avoid security issues.

Complexities of powering remote equipment at extended distances

Determining the maximum distance of power transmission in a system beyond 100m where is a complex matter that depends on several factors. The most important factor is that the extended system should maintain the safety features established by IEEE802.3af/at standards. These safety features are designed to protect the PSE and PD from damages due to abnormal power conditions. It requires that the PSE and PD communicate with each other. In a standard PoE system the process starts with the PSE sending out a detection pulse to see if a valid PD is online. The PD responds by reflecting a certain resistance that is much higher than the cable resistance. Once detection is achieved the PSE sends second pulse for classification. After receiving the power class, PSE turns on the PoE to power the PD. The current starts flowing and PD makes the power available to its load. This will force the PD input voltage to drop due to voltage drop over the transmission cable. If the voltage is less than a threshold the PD will shut down for “Low Voltage”. This is the main reason that most PoE systems do not work at extended distances.

Some PoE approaches called “Always On” connect an external power source to the transmission cable. This solution removes all the safeguards of standard PoE and in the case of opens or shorts (the latter being the most damaging) the flow of current cannot be turned off safely. In addition, the forced power is fed without regard to PD classes. This means only one class of power is available and only at a specific cable distance.

Keep in mind, power consumption within a system is not constant. While shorts and opens are a matter of defects, temperature has an effect on PDs and their loads. The Wire resistance changes with temperature and can affect the required current. Therefore, while a manufacturer’s product can boast of having the greatest distance at operating temperature as high as +50°C, but the actual operating temperature that the extender plus its large power supply can operate will be much shorter. Consideration for extenders operating in high temperature is important for environments that usually have high temperatures such as the United States southwest or the Middle East.

Power supplies generate heat. The higher the power, the higher the heat, the greater the possibility that the heat transmitted to the extender will result in a shorter product life-span and less product reliability. This also impacts the type of environment that an extender can operate within.

In summary, transmission of data and power using above technologies presents many significant challenges to video surveillance network systems. They limit growth potentials for projects that demand increased bandwidth and power. In common applications of extenders, the need for local power supplies limits environmental performance which restricts their flexibility. Localized power cannot conform to operating temperature ranges of -40°C to +75°C. Many of these limitations are not clearly noted in products specification sheets.
The Solution for Remote Power

One of the most cost-effective and reliable methods of providing power to a camera at an extended distance is using Pass-Through-PoE (PTP™) method. The PTP eliminates the need for site power to the extenders, allowing the extenders to operate at a wider temperature range and lowers installation costs associated with extra power supplies. This method conforms to the safety measures by IEEE 802.3 standards.

![Figure 3: PoE System showing PTP™](image)

With “Pass Through PoE™” Extenders and camera can be powered directly from a source PoE switch to eliminate the extra cost required for on-site local power

Figure 3: PoE System showing PTP™

What product datasheets don’t tell you about extended distance PoE?

Most specifications indicate the amount of power available at a certain distance, but do not indicate if:

- **a.** Some specifications just state power over Ethernet without providing the maximum possible class or power figure at maximum distance.
- **b.** Many specifications do not indicate that a separate power supply is required for operation, even when using a PoE switch.
- **c.** Many specifications do not indicate if the PoE is “always on,” resulting in disabling IEEE 802.3 safety features.
- **d.** Many specifications only indicate that their devices provide PoE without stating their conformity to IEEE 802.3 specifications.
- **e.** Many specifications do not indicate the ability to handle IEEE802.3at power level.

Solving the Problems, Simplifying the Products

Requirements for new approaches to problem solving have been developed from increased system requirements. The growth of IP video security networks requires that transmission systems developed for specific applications ensure that peak performances can be maintained. Reducing installation cost while satisfying required performance can occur through the use of existing analog coax cables. To satisfy these needs Vigitron has developed the MaxiiCopper™ Vi2400 series Ethernet extenders over coax cables. The MaxiiCopper™ Vi2300 series can extend Ethernet over new or existing UTP cables.

The concept is similar in terms of extending Ethernet over UTP and Coax, however the technology and market approach is quite different. Vigitron’s MaxiiCopper™ uses a process known as **Symmetric Bandwidth (SBW™)** which maintains a constant bandwidth throughout the specific distances, for both uplink and downlink, extending as far as 5,000 feet. This results in **Virtual Zero Packet Loss (VZPL™)**. Since MaxiiCopper™ does not re-packetize the data it provides the lowest signal latency in the industry. It also supports “Multicast” that most extension technologies are not compliant with.

The combination of **Symmetric Bandwidth (SBW™)** and **Virtual Zero Packet Loss (VZPL™)** results in compliance to RFC-2544 standards for TCP/IP transmissions at the upper limits of 1,518-byte packets. The MaxiiCopper™ ability to handle Jumbo Frames which is required for larger Mega-Pixel cameras and high frame rate transmission makes it a necessary part of high performance installations.
Vigitron has tested MaxiiCopper™ products under RFC-2544 standards. The company is in the continuously certifying its transmission performance with the leading camera manufacturers’ highest pixel-count cameras. This process ensures camera manufacturers and their customers top level system performance that cannot be downgraded by extended transmission limitations.

Most Vigitron IP products accept common standard power inputs of 12 VDC, 24 VAC or PoE. Being PoE capable allows more control over the remote sites from a single PoE source that maintains enough power to operate extenders and the remote site camera.

The Pass-Through-PoE (PTP™) feature eliminates the need for remote site power reducing installation costs. This feature keeps the extender inactive during PoE initial process until the PoE power is turned on by the PoE source. Vigitron’s green Low Power Consumption (LPC™) design results in maximizing available camera power while conforming to 802.3 af/at standards. By requiring very low power, minimal internal heat is generated, increases extender reliability and helps to achieve an operating temperature range 0f -40°C to +75°C.

Vigitron’s MaxiiCopper™ products maintain hardened performance under temperature range of -40° C to +75°C. Products are type-tested using the demanding NEMA-TS2 traffic environmental standards and result in the proof of ability to operate under "Hardened" (HRD™) extended temperature environments.

Another advantage of MaxiiCopper™ products is the diversity of wiring types. The most common network cabling is Unshielded Twisted Pair or UTP. As applications for network cameras grow, many cameras will be installed in outdoor environments require Shield Twisted Pair or STP, which provides not only environmental protection for the cable, but also additional grounding to protect equipment from damage during lightning storms. The cable characteristics of STP differs from that of UTP and in many cases results in shorter transmission distances. This is not the case with Vigitron’s MaxiiCopper™ products which are designed to operate with both types of cabling.

The MaxiiCopper™ Vi2300 and Vi2400 series combine wide temperature operation, ability to be powered by PoE with minimal power requirements, and STP cable compatibility. These products are a perfect solution for indoor and outdoor extended distance power and data transmission applications.
What makes Vigitron’s approach to extended distance data and power transmission superior?

**MPC™** stands for **Mega Pixel Certified** that covers three areas:

a) Compliance to RFC2544 for TCP/IP packet loss transmission.
b) The ability to handle Jumbo frames ranging from 1518 to 9000 Bytes.
c) Individual test for each camera brand.

**HRD™** stands for **Hardened** as applied to the ability to operate under extended temperature ranges from -40°C to +75°C.

**VZPL™** stands for **Vertical Zero Packet Loss** maintaining the number of packets transmitted and received with vertically no loss of information.

**PTP™** stands for **Pass Through PoE** allowing first the PSE to connect to the PoE camera then Vigitron’s Ethernet extenders use the PoE power supplies.

**EPTP™** stands for **Extended Pass Through PoE** operating in the same manner as PTP™ with power handling capacity up to 60 watts.

**SBW™** stands for **Symmetric Bandwidth** resulting in identical upload and down bandwidth with little loss over maximum distances.

**LPC™** stands for **Low Power Consumption** allowing for transceivers use the minimum power.

**As the saying goes**, a chain is only as strong as its weakest link; a video security system is only as good as the quality of its transmission system. Understanding the information provided in a manufacturer’s product specification sheet is an important first step in designing a reliable and well performing system.
Vigtron is the leading manufacturer of analog and digital CCTV transmission equipment. We are proudly supplying innovative transmission solutions that have made thousands of CCTV projects easier and simpler to install, providing cost savings on time and labor. We are here to help you achieve reductions in the cost of installing CCTV systems by using our products. Call Vigtron and let us show you the difference that Vigtron products make.