Understanding Extended Distance Network Transmission

A White Paper by Neil R. Heller, VP Business Development Vigitron Inc.

Extended Transmission is rapidly becoming the key component to IP CCTV network systems. As IP cameras and digital and 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 one hundred meters. Analog video systems transitioning to IP expose the challenge of higher costs for installing additional UTP cable and extra equipment, while leaving existing coax useless.

All of these challenges can be solved 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. Furthermore, the growing desire to power 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, improvement necessities, and testing requirements to validate claims.

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

Challenges Facing Video IP Security Networks

a. Length limitations of network transmission of 100 meters/328 feet. The requirement to account for 5 meters on either side for a total of 10 meters to be allocated for the connection thus, resulting in 90 meters or less than 300 feet.

b. While distances can be regenerated it requires the use of a network switch or other sources of immediate equipment, resulting in additional installation and cost considerations.

2. The need to maintain the secure "closed circuit" aspect as Open Network-Closed Network-**CCTV** becomes **CCSN** (Closed Circuit Security Network).

In most installations control centers are usually located at distances greater than 100 meters. 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 of us 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 security aspects. 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 its network. This limited access requires all connections to 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. We create this insecurity any time a network or network device is exposed to the web.

The Potential is Great

Many generally agree that use of IP for video security applications is increasing. 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 almost three to one with sales reaching almost 9 million units by 2015. The assumption that not all connections will be restricted to 100 meters is reasonable.

Looking at projections for encoder sales over the same period is also very noteworthy. Encoder sales are expected to increase while the use of network recorders will double. All of these devices require 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 age independent of the last replacement 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 lapse recorders are no longer in practice. Digital Video Recorders are morphing into Network Video Recorders and, at some point, they will be replaced by cloud networking; however, the stable, reliable CCD analog camera continues 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 the average analog camera sales per year. Conservatively, if we refer 10 years ago when IP was at its infancy, the figure may stand at 10 million cameras per year world-wide. That would mean approximately 100 million analog cameras are still functioning, then, adding the average growth of about 1.5 million encoders reveals the potential that as network-based IP digital system continues their rapid growth. Current analog systems are required to find some conversion method.

Coax cable has a distance limitation commonly cited at approximately 1000 feet (338 meters). These limitations were resolved by the use to Unshielded Twist Pair (UTP) transceivers. Currently, estimations uncover the operation of almost 12 million channels of analog cameras operating over UTP at distances up to 6,000 feet (1818 meters). Now, add several thousand channels of fiber that currently carry analog camera signals. Estimations become difficult when deciding how many can be converted to IP. Due to the transitions occurring in recording and storage technology, this will not be a problem. Potentially, at 1% per year, over a million channels could be subject to this conversion.

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 have decreased, labor costs have increased in regard to salaries, health

care, and transportation. Decreasing costs for improved network cameras and recorders quickly outweigh the labor cost of replacing coax cable with UTP.

The solution is to keep existing transmission media via coax cable or UTP and using it to connect IP cameras.

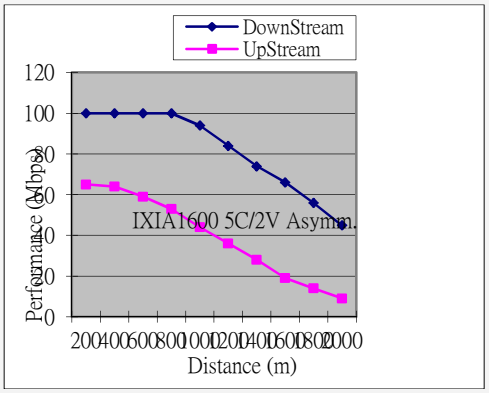
Extended Transmission: The need to understand.

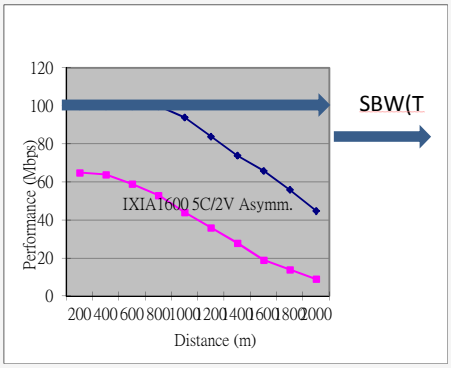
As with any technology, viewing product specifications is hardly a means to make an intelligent decision. An extension of Ethernet signal does not solely involve distances greater than 100 meters or the ability to carry signals over coax cable. Many security cameras are being powered over cable by industry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

Similar to many current technologies used in video security applications, extended distance transmission has its origins in consumer applications. Internet Service Providers (ISP) is confronted with similar cable distance restrictions. This led to the development of Very High Speed Digital Subscriber Line 2 (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 rapidly decreases with distance. A VDSL2 device rated to operate at 100Mbps may function for significantly shorter distances than what appear on the product specification sheet.
2. **Uplink vs: downlink.** As VDSL2 was designed to primarily feed information in one direction, the focus was on downloading (remote site to source) and not uploading (source to site). The difference in bandwidth is almost 40%.
3. **Power:** VDSL2 requires significant power as it must packetize and push the signal.

Figure 1: Differences in VSDL-2 and Symmetric Bandwidth





Typical VDSL-2 performance showing bandwidth drop-off with distance **VDSL-2 performance verses Vigitron with Symmetric bandwidth**

A device indicating its Ethernet port is capable of transmitting 10Mbps/100Mbps is not a guarantee that it's system actually transmit s10Mbps/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 limitations of VDSL2 mean to me?

Bandwidth and Packets

Understanding the limitations of VDSL2 and everyday performance 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. Note the difference between the use of lowercase b Mb and uppercase B MB. **1 MBps (megabyte per second) = 8 mbps (megabits per second).** An IP data is transmitted along with several embedded information which assist in directing the data. These are considered overhead and take away from the amount of bandwidth available for the actual signal. While there are no industry standard specifics what would be the practical percentage of IP data to the total Ethernet rate, the more conservative you are the better. A conservative and safe measure would about 46% to overhead leaving 54% for actual signals.

The available bandwidth is also indicates the amount of information that can be transmitted. Packets 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 source information. 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.

Size :Packet Size (bytes)	**Ethernet: Number of Packets transmitted per (pps) second)**
64	14880
128	8445
256	4528
512	2349
768	1586
1024	1197
1280	961
1518	812

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

The difference between the number of packets transmitted for the smallest packet size and number of packets transmitted 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”.

What product specifications don't tell you about Bandwidth and Packets?

Most specifications express transmission in terms of the Ethernet port bandwidth.

a. They do not inform you of the actual transmitted and received bandwidth.
b. They do not inform you how much bandwidth is lost.
c. They often express the longest transmitted distance but omit the bandwidth available at that distance.
d. They do not tell you if the transmitted distance applies to PoE transmission or if a separate remote site power supply is required for power.
e. Most specifications base their bandwidth and Packets per Second testing on 64bytes a figure that cannot be applied to video transmission, so performance is often misleading.
f. Almost none will have proven test results for RFC-2544 conformity showing real world operating packet and bandwidth losses.
g. Jumbo frames are not obtainable reliably with VDSL2 so don't expect to see this quoted in a specification.
h. Some products indicate a maximum distance but don't indicate what data rate can be achieved at the maximum distance.

Power is Key

The main goal is maintaining bandwidth and avoiding losses in a system performance. Figure1 displays the actual test results of a VDSL2 extender. By the time that it has reached 1000m its bandwidth has decreased almost 20%. Also, the difference between download and uploads result in an additional 40% decrease making it easy to see the limitations in handling megapixel cameras. These losses are common to VDSL2 transmission equipment.

More network switches are providing Power over Ethernet or PoE often using IEEE standard of 802.3af. With increasing demands for more power, a new and more powerful PoE standard ,EEE 802.3at, has recently been introduced.

These standards make compatibility easy between different manufacturers' equipment. They also provide some important safety features which protect both the equipment providing the power (Power Sourcing Equipment or PSE (PoE switch or Midspan)), and the Power Device or PD (camera). The standards not only require different fixed classes of power found at the end of the a 100m cable run, but also provide for safety measures for protecting PDs.

PoE Class Chart

Class	Classification Current (mA)	Power Range (W)	Class Description
0	*0–4*	*0.44–12.94*	*Classification Unimplemented*
1	*9–12*	*0.44–3.84*	*Very Low Power*
2	*17–20*	*3.84–6.49*	*Low Power*
3	*26–30*	*6.49–12.95*	*Mid Power*

Figure 2: PoE Class Chart

Many types of extenders consume up to 6 watts or more from an EEE 802.3af source with an end power of 12.95. This results in little or no available power for the cable loss. The result is extra cost of external power supplies.

VDSL-2 signal transmission requires using a great deal of power. Some devices require over six watts just to power one device. A total of 12 watts is used up just for powering the transmitter and receiver. This must be taken from the PoE power source which reduces the available camera power. 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, than the remaining power will only allow cameras and other power devices operating at class 1 and class 2. Worse off are some devices pushing power without complying with the standard safety requirements. 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, adding to cost and limiting installation special when there is no power source is available at the site.

Power Complexities

Determining extended distance where power is concerned is a complex process that depends on several factors. The most important factor is that the extended system should maintain the safety features established for 802.3af and 802.3at standards. These safety features are designed to protect the PSE and PD from damages due to abnormal power conditions. This requires that the PSE and PD communicate with each other. In a standard PoE system the process starts with the PSE sending out a pulse to see if a standard 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 then detects the power class and power is sent to the PD, turning it on. The current starts flowing and a load is applied to the system, stabilizing the voltage at a value below which will result in the power being turned off. Some approaches called “always on” will 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 voltage is fed without regard to PD classes. This means only one class of voltage is available and only at a specific cable distance. Any variation can be dangerous when either not enough power applied or too much power available that potentially damage the PD.

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. 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 +50C, but the actual operating temperature that the extender plus its large power supply can operate will be much lower. Consideration for extenders operating in high temperature is important for environments that usually have high temperature such as the United States southwest or the Middle East.

Power supplies generate heat. The higher the power, the higher the heat, and the greater the opportunity 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 VDSL2 equipment presents many significant challenges to video surveillance network systems. They limit growth potentials for projects that demand increased bandwidth and power. In common operation, the need for local power supplies results in a limited environmental performance which restricts their installation ability. Localized power cannot conform to operating temperature ranges from -40C to +75C. 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 to provide power to a camera site is to extend the range of power from the source to the site using"Pass Through PoE" **(PTP™)**. It 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 of conforms to the safety measures by IEEE 802.3 standards.

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 the product datasheets don't tell you about PoE and extended distance?

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 an external PoE power source for powering a PoE camera.
- **c.** Many specifications do not indicate if the power 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 ability to handle 802.3at.

Solving the Problems, Simplifying the Product

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 pre-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 represents a major change. Vigitron's MaxiiCopper™ uses a process known as **Symmetric Bandwidth (SBW™**) which maintains bandwidth consistency throughout the specific distances, extending as far as 5,000 feet. Bandwidth is maintained in both uploads and downloads resulting in a process of **Virtual Zero Packet Loss (VZPL™).** Since MaxiiCopper™ does not re-packetize the data it provides the lowest signal latency in the industry.

The combination of **Symmetric Bandwidth (SBW™)** and **Virtual Zero Packet Loss (VZPL™)** results in compliance to RFC-2544 standards for TCP/IP transmissions to the upper limits of 1518 byte packets. The MaxiiCopper™ ability to handle Jumbo Frames which is required for larger Mega-Pixel cameras and higher 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 cannot be downgraded by extended transmission limitations.

Most Vigitron IP products accept standard power inputs most commonly found in security applications. Models in the series can be powered by +12 VDC, +24 VAC or from a 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 is accomplished using Vigitron's green **Low Power Consumption (LPC™)** design which lowers the unit's power requirement by more than 80%, compared to conventional methods resulting in the most available camera power while conforming to 802.3 af/at standards. By maintaining these standards, PSE and PD communication ensures device protection in the event of power surges, under power conditions, and power shorts. In addition, by requiring only approximately one watt of power, minimal internal heat is generated increases extender reliability and helps to achieve an operating temperature range 0f -40C to +75C.

Vigitron's MaxiiCopper™ products maintain hardened performance under temperature conditions from -40 C to +75C. Units are type-tested using the demanding NEMA-TS2 traffic environmental standards and result in the ability to operate under "Hardened" extended temperature environments **(HRD™).**

Another advantage of MaxiiCopper™ products is the diversity of wiring types. The most common network cabling are UTP, or Unshielded Twisted Pair. As applications for network cameras grow, many of them will be installed in outdoor environments which cannot use UTP. These installations require STP or Shield Twisted Pair, 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, result 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 power by PoE with minimal power requirements, and STP 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. brandbrand.youtube.com/user/Pepsi?v=Rcf01QTcO6E

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

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

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.

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.

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.*

Vigitron IP Products

MaxiiCopper ™

Vi2401

Vi2301

Vi2404

Vi2304

Vi2408

Vi2308

Vi2416

Vi2316

MaxiiCollector ™

Vi2804

Vi2804P

MaxiiPower ™

Vi2208/Vi2216

ViewMate ™

Vi0021

MaxiiGuard ™

Vi2001

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