Unique Considerations of IP Video Security Infrastructures

Infrastructures are complex. Many assume due to the simplicity of connecting an Ethernet cable to the cable modem, the connection of IP camera, access control devices, and other IP/PoE devices is just as simple. Nothing can be further from the truth. Infrastructure is the heart of any system. We often mistake the failures of the devices connected to the infrastructure as a failure of the device itself, rather than the infrastructure construction.

Designing an infrastructure is a complex process and made even more so by the specifications we rely on. It's not because they're false, but because they represent fixed values that often result in applying equipment that falls short of accomplishing its goals. There is also a paradox in designing infrastructures for IP video security applications. While networking is a matter of physics leaving no room for variations, variables are valid only within certain conditions. This means a system based on an infrastructure that will operate properly under daylight may not do so when those conditions change.

This article will examine the considerations in designing an IP video security infrastructure.

The basic considerations are:

- Number of devices connected to the network
- Number of devices routed to a single location
- Type of cabling used or already installed
- Cable length (usually the longest cable distance must be taken into account)
- PoE source (in most cases, you will be dealing with devices powered by PoE)

The goal is to have a reliable connection maintained over a number of conditions. Because of this, it is important to start with the devices you are connecting to. The most challenging part is taking into consideration both the bandwidth and the required PoE power of the video cameras. Bandwidth is part of the camera's functions in terms of its Megapixel size. The rest is up to you. The number of images per second codec and compression determine the bandwidth.

There are simple rules concerning bandwidth.

First of all, note that the higher the Megapixels, the higher the bandwidth.

Second, the codecs have a huge effect on the bandwidth requirements. If we start with H.264 as a baseline MJPEG can require up to six times more bandwidth. A single stream of 4K may require up to 50Mbps that brings into consideration the compression ratio applied. Compression ratios are associated with the codecs they are compressing and the combinations of the two have their limits. In some cases, a camera may offer the ability to continuously stream video at one compression and also provide individual alarm images of a higher resolution and at a different code.

This requires taking into account the bandwidth required for both continuous and alarm image. Fortunately, many of these settings can be controlled as part of the operator setup.

Lastly, the most important bandwidth consideration is the network itself. To know how much network bandwidth is available, the device bandwidth must be matched to all of the devices on the network. For most security equipment, that would be 100Mbps. Next is to acknowledge that within any bandwidth, only about half is available for actual data (video) transmission. The other half is taken up by overheads that contained information regarding its transmission and reception points. Generally, H.264 requires about a safe allocation of 2Mbps. However, high megapixel codecs and the use of other codecs could yield a requirement of up to 8Mbps or reduce the number of cameras that can be transmitted over a single connection by a factor of four.

The next device consideration is PoE. Many people believe that IEEE standards are actual standards when it comes to PoE. However, there are a wide range of voltages and wattages that can qualify as being within an individual power class. This applies to both the device being powered and the source of PoE. A camera may require the highest source voltage of 40 volts and the highest source wattage of 15.4 watts to be considered as IEEE 802.3af, Class 3. There are some cases if a PoE source output only 37 volts and 7 watts, it can also be legally considered as Class 3 compliant.

The surge factor is also another consideration regarding PoE powered devices. With any consideration of power, it takes more power to turn on a device than to maintain its operation. For video security cameras, this applies to both startup and accessory functions such as day/night operation, LEDs, or auto back focus. If the surge applied when turning on these functions exceeds the ability of the source to provide it, or rises for more than approximately 40ms based on the safety built into the 802.3 PoE standards, the PoE source will stop transmitting power. It remains in that state until the port is reset either by turning the power off and on, or by disconnecting and reconnecting the Ethernet cable.

This is the primary reason that a customer will interpret this type of problem to be a camera failure when it was working during the day and failed during the night. They will return the camera back to the manufacturer only to be told that there is nothing wrong with the camera. The solution is simple and two folds. First, even when a manufacturer states a specific PoE power for a camera, always count on the maximum Class power source. For example, the manufacturer states that a camera requires 10 watts and is 802.3af Class 3, you should always have a PoE source of 15.4 watts. Next, average any surge that might be present as requiring at least 20% more power. In this case, a 10 watt camera would really need about 12 watts, putting it within the limits of a full Class 3 source of 15.4 watts. The problem will usually occur when the surge exceeds a particular class, especially transitioning from Class 3 to Class 4.

Once we have determined the bandwidth and power requirements of the connected device or remote site device, we need to turn our attention to the source that will provide PoE power and receive the signal. This is often in the form of a network PoE switch. The considerations regarding bandwidth and PoE are the same for the camera and remote device. There are concerns regarding the lack of standards and how specifications are determined.

There are several factors to take into consideration. First, networking equipment is tested and specifications are determined with a packet size of 64 bytes. However, even the smallest 1-2 megapixel cameras will approach the limits of packet size testing at around 1538 bytes, while cameras with 2+ megapixels are higher. Therefore, networking products are not tested to packet sizes required for transmitting video cameras. While many switch specifications will state they handle Jumbo Frames, it is restricted to port programming at 1Gbps speeds. In networking, the 100Mbps camera output must be matched to the bandwidth input speed of the switch port. The second switch consideration is the switch fabric which connects all of the switch ports. Its bandwidth must be at least 2 times greater than the sum of the highest bandwidth of all the ports. There is no standard for this and the actual bandwidth is a reflection of the switch cost. With regards to PoE, be careful not to mistake the total power supply for the PoE budget, or power allocated for the camera PoE power. They are different. If the total power is allocated to PoE, there would be no power left for the switch functions. Additionally, if all ports required PoE, then the switch could easily overheat and fail. There should be anywhere from a 10 to 25% separation between the total switch power supply and the PoE budget. Finally, there are no standard methods used to allocate PoE power within a switch. It could be equally divided as more ports are connected. It could be programmed or it could be fixed to each port.

Now it's time to connect the source to the remote device. This is the most important and overlooked aspect of infrastructure design. This process begins with the type of cable. Installed cables may already be present, or you may have the option to install new cables. Let's review the advantages and disadvantages of the major types of cables used for most security applications.

The 4 major types of cables are:


Coax


Cat 5e/6


Single Pair


Fiber

- **Coax**: Hundreds of thousands analog systems have existing coax connections in the past couple of decades.
- **Cat 5e / Cat 6 (Ethernet Cable)**: This is the standard cable for network connections.
- **Single Pair**: Single pair consists of two wires .It is commonly used for alarm and access control applications.
- **Fiber**: This is mostly used for long distance and outdoor applications.

Cat 5e and Cat 6 consist of 8 wires, which is commonly referred to as four pairs. They are used for networking connections. Under the IP transmission and PoE standards, 2 pairs (4 wires) are used. Each of the sets is referred to as “A” or “B”. The standard requires that IP/PoE devices operate over either. Within the “A” or “B”, one pair is used for data while the second pair is used for PoE transmission. The usage of multiple wires has advantages for network transmission. Running cables in parallel reduces resistance to power transmission. Cable twists are standard in Cat cable.

Twisting reduces noises because the twist cancels out noise reducing resistance. The size of the wire is also standard at 24 AWG. The standardization of Cat cables services as the bases of IP transmission in determining its limit at 328 feet (100m). This also applies to power delivered to a device powered by PoE. Starting with a source of 15.4 watts (802.3af, Class 3), the resulting power after 328 feet is 12.95 watts. For a source starting at 30 watts, the resulting power after 328 feet is 25.5 watts. Other than Cat cable, there are no other types of cable that can be used for IP/PoE without the use of a media converter.

Using Cat cables also allow for transmitting PoE power higher than the current 802.3at source limit of 30 watts because it only requires a single pair. Camera manufacturers have used the second pair to develop cameras with the ability to receive PoE on two pairs to what is in effect 802.3at. Given the highest voltage used for 30 watts which is 57 volts, up to 37 watts can be safely transmitted on a single pair and up to 74 watts can be transmitted using two pairs. This has given rise to the “60 watts PoE cameras”. This application is restricted to Cat cables because of the required two pairs.

Keeping power in mind, this concludes that both coax and single pair will have less power handling capacity than Cat cable even though they are both single pair transmission mediums. This means that both signal and power are carried over the same cable run. There are several other important considerations for each. While Cat cable is used to set a fixed resistance yielding the resulting power and fixed bandwidth over 328 feet (100m), coax has no such standards when it comes to IP/PoE transmission. Generally, the Cat 5e resistance for 1,000 feet is approximately 22-27 ohms. In order to have similar results, coax would need the same resistance values. However, that isn't the case. Coax resistance various event within the same category of cable such as the standard RG59. Differences in resistance will affect performance.

The resistance for Cat 5e cable also has standards in regards to the number and tightness of the twists. These features affect noise cancellation within a cable. Single pair has no such standards and in fact, can also be found in flat wire configuration with yields to little or no noise rejection. Noise in effect is resistance to digital signals.

Finally there is fiber. This transmission method is the most extensive, requiring extra equipment for transmission and reception. Its advantages are extreme transmission distance and prevention against lightning strikes and high power surges due to its glass structure. The problem is fiber does not transmit PoE. Its use will require local power sources and power supplies. Fiber also has to be matched so that it's a completely matched fiber system. The modems used must match the fiber of which, there are several considerations based on single or multimode, and the transmission frequency.

The wire is the most important consideration of any infrastructure. This consideration combined with costs is based on determining if any existing cables should still remain. This is where extenders in the form of media converters are used. Extenders take into account several considerations.

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For almost three decades, video security systems have existed in the form of analog. Video coax cable was the primary method of transmission with a limited distance of approximately 750 feet. Analog systems required separate power located at the camera site. New technologies often solve one problem and create others. IP/PoE systems eliminate the need for local power, saving installation costs for local power and power supplies. The drawback is the limited restriction of 328 feet and the required use of Cat 5e or above cable.

Tens of thousands of cameras are waiting to be converted to IP, but already transmitting over coax at distances of two and a quarter times greater than the Ethernet limit. The advent of extenders helped solve this problem. Additionally, the use of extenders for Cat cable and even single pair alarm wire help to add to the types of IP/PoE conversion while extending distances as far as 3,000 feet. The use of extenders requires taking several considerations into account.

The first and most important is to carefully read the specifications. A statement can be true but may not apply to your applications. For example, let's take a look at IP/PoE transmission over coax. A manufacturer's product can state that it has this feature and will meet your transmission requirement of x number of thousand feet. However, a careful reading of achieving this requires RG6 cable, while you have RG59 installed. You need to maintain a 100Mbps bandwidth and provide your cable with 12.95 watts of power. But as both bandwidth and power decrease with distance from many types of extensions, you've realized that both are much less than the extended distance you required. In conclusion, depending on a product to make a simple specification statement is not enough when it comes to infrastructure considerations and especially with regards to extenders.

The difference between infrastructure products, cameras, and recording devices is that the latter can be judgmental. You can visually judge if you accept a camera by the quality of its picture or how easy a recording device is to operate. The same is not true for infrastructure, which is based on physics and is either black or white. There is no middle ground and little forgiveness. When the bandwidth isn't enough, the picture will appear as mosaic (individual blocks) or out of focus or with no picture at all.

In any event, it's not a judgment call. The same situation exists with PoE. The 802.3 PoE standards has safety measures built in to prevent transmitting power if no connection is made, or shut down power in the event of a short. Once a connection and the power level required by the connected device are established, any raise in power for a period of time approximately more than 40ms will turn off power from the source.

Let's review this in practical terms. A multiple PoE cameras installation is completed during the day. During the night, several accessory features on the cameras are activated such as Day/Night filtering and turning on LED. The PoE power increases sharply at first in order to active the functions. This is known as surge power, prior to settling back to a lower operation level. The surge power required exceeds the power available from the PoE source and all PoE power is shut off. The camera remains in the off position until it resets.

This often is a manual reset by powering down and up the PoE source or disconnecting and reconnecting the cable. In any event, the camera remains off. Depending on the number of cameras and the amount of PoE power, this usually doesn't affect all the cameras so a person commonly mistakes this for a defective camera. The same is true with bandwidth.

Within a network, you can think of both bandwidth and PoE as a bank with a set amount of funds. Each camera is a person withdrawing money. At some point, you run out of money and the next person who makes a request either gets less than they requested or nothing at all.

This helps to illustrate how important networking infrastructure is. It is made even more important by the differences between data and video networks. Data network requires bandwidth, which even at the smallest megapixel cameras is 96% less than video, while PoE for VoIP phones can be about 40%. Every component within the transmission affects all the components and the performance of the infrastructure as a whole.

Summary: How to Determine What You Need

Developing a bill of materials for an infrastructure is not difficult if you have the right information. There is one word of caution. Infrastructures are unique. Each is individual so don't depend on drop down menus; it simply will not work. Note if one component within the infrastructure changes, take the time to see if the rest of the components need to be changed.

What Questions Do I need to Ask to Design a Network Infrastructure for by IP/PoE Video Security System?

First, work with individual collection points. This could be when all devices (cameras/access controller) are routed to a single location or when there are multiple locations as in the case of individual IDFs.

For each location, determine:

- The cameras and number of cameras to a single location
- What are the manufacturer and model numbers for each camera? This information will help to determine the bandwidth and PoE requirements.
- How many cameras are going to this location? If there are different cameras from different manufacturers, please list all of these by number.
- Break down these numbers further by those that are 290 feet and those greater than 290 feet from a network connection and PoE source. Many of you may think of IP/PoE limits in terms of 328 feet (100m), but conservative planning takes into account wire bends which can contribute to increase resistance and decreased performance.

Type of cable:

Existing installations, those which will convert from analog to IP, probably already have either coax or fiber installed. New installations will use Cat 5e or Cat 6. For coax, almost all existing installation will have RG59, but it's important to confirm. Very old installations may even use aluminum shield cables, which will probably have to be replaced due to its high resistance. Fiber is more complex as you have to first determine the mode, single mode or multimode. Than you have to know the fiber size, which is usually a function of the mode. Single mode will generally be 9/1.25 while multimode can either be 62.5/1.15 or 50/1.25 depending on the distance. Regardless, your fiber modems must be match to both of these aspects and bandwidth.

The type of cable will also determine if you need extra equipment because only UTP or Ethernet cable can be directly connected within a network. Coax, single pair, and fiber will all require some form of media conversion.

Cable length:

At each collection point, divide your device connections between those less than 290 feet and those greater than 290 feet. For the latter, use the longest cable distance as your reference and determine the type of extenders required to meet the bandwidth and PoE device requirements. Using any device in the transmission path will require you to take into account its effect on bandwidth and PoE.

Network and PoE source:

This can be most difficult part. While there are many IEEE standards governing network interconnections and PoE, the most important ones we are concerned with have no standards at all. There are many from determining a real PoE budget, to how PoE is programmed, to internal switch bandwidth (sometimes called switch fabric), and to the ability of an individual port to pass the required bandwidth from a camera.

There are two important things to keep in mind. First, your bandwidth must remain consistent throughout the transmission path. Your PoE source must be able to provide, not only the power required to operate your device and any other devices in the path, but also provide power in the event of startup surges to avoid PoE shut downs.

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