Extending video's reach

Citywide surveillance systems depend on an effective backhaul infrastructure design

By Jasper Bruinzeel

Without a doubt, video-surveillance systems are becoming more and more popular. As a result, public-safety agencies are exploring ways to use them in critical locations within their jurisdictions. Besides traditional facility-based solutions—i.e., cameras placed throughout a police department building, jail facility, or city hall—there is a growing interest in placing cameras in remote locations. Examples of such locations include downtown areas, high-crime neighborhoods, busy intersections, malls, shops, parking lots and garages, parks, and water department sites.

From a system management perspective, it is fairly easy to tie together a multitude of locations into a single solution. Assuming use of a digital, software-based video management system (VMS), and as long as proper Internet Protocol (IP) network connections exist, cameras can be brought together into one unified, virtual system. However, the difficulty concerns the nature of the surveillance-camera traffic.

Traditional IP network applications include Web-browsing and e-mail. In these applications, the traffic is "bursty" in nature, meaning that only periodic bursts of data are sent or received over the network connections; for example, only when the user sends an e-mail or requests Web-site content. After data communications are complete, the network resources are again available for other purposes. Another factor is that these applications are not time critical. Small delays (in the order of less than a second) generally will go unnoticed. In contrast, in the case of a surveillance application, high-capacity video is streaming on a continuous basis, and using up the network resources constantly. Also, video streaming is a real-time application, one in which live video is required to stream without interruptions, in a smooth and predictable manner.

Additionally, with the advent of higher and higher resolution cameras, often referred to as "megapixel" cameras, bandwidth requirements are ever increasing.

For example, a traditional 4CIF resolution camera (704 x 480 pixels) would require about 2 Mb/s of bandwidth at 30 frames-per-second (FPS), in high-motion conditions using H.264 encoding. In comparison, the bandwidth requirement for a 1080p high-definition camera (1920 x 1080 pixels) jumps to about 13 Mb/s. (See Figure 1.) These factors make surveillance very much a "killer application" for communication systems, particularly when using wireless networking, which often is the only practical choice for reaching remote sites that are disconnected from the wired network.

A typical citywide digital, IP surveillance network has the following core components: digital IP cameras and edge enclosures; communications infrastructure (wired, wireless and/or cellular); and the back-end solution (including the server, storage, VMS, and monitoring facilities). Figure 2 shows a complete surveillance network with all of the above components, and depicts multiple backhaul options. This article focusses primarily on the backhaul infrastructure design. In order to reach remote locations, when considering wired connections, fiber is generally the only available option (since copper-based Ethernet cabling is limited to 300-foot distances). However, using wireless networking offers the option of building your own wireless network or using a 4G (LTE) cellular connection.

When designing the backhaul to connect remote camera sites with the central management server and monitoring system, it makes sense to first consider the possibility of implementing a wired (fiber) solution. Often, active or dark fiber is available at various government facilities, and sometimes at other locations throughout the city, e.g., in support of traffic applications at certain intersections. Occasionally, pre-deployed conduits are available that make it cost-effective to run fiber to certain locations.

For fiber connections, distance is generally not an issue, since single-mode fiber connections enable distances exceeding 10 miles. The real problem is that extending fiber, without preexisting conduit, is expensive and time consuming. There normally is no business case to justify the high expense of building out fiber if connecting surveillance cameras is the sole purpose. Consequently, wireless technology is the logical alternative.

Indeed, in most citywide surveillance systems, wireless technology plays a key enabling role for cost-effectively building out the system. However, if the wireless part of the network is not properly designed, the end user is likely to be disappointed with the performance of the network.

When building a wireless network, the 4.9 GHz public-safety spectrum is strongly recommended as the primary band, in order to avoid interference and maximize performance. This licensed band is available at no charge to municipalities and public-safety organizations nationwide and, in most instances, is still highly underutilized. In the 4.9 GHz band, a total of 50 MHz of spectrum is available. With a typical channel size of 10 MHz, 5 channels are available, and frequency re-use is now fairly easy to implement. When using the most recent wireless technology and when operating in line-of-sight (LOS) conditions without interference, typical sustained throughput per 10 MHz channel is about 50 Mb/s.

The 4.9 GHz band also could be augmented with unlicensed bands. While the 2.4 GHz and 5.8 GHz bands generally are very crowded and normally should be avoided, the more recently introduced 5.4 GHz band—with 255 MHz of available spectrum—is typically the best bet. Its vast amount of available spectrum enables the use of larger (20 or 40 MHz) channels, with throughput per channel of roughly 100 or 200 Mb/s, respectively.

The current generation of outdoor radios generally based on Wi-Fi (11n) chipsets and protocols. Lower-cost radio products largely will use the Wi-Fi protocols without modifications. However, one major issue with the standard Wi-Fi protocol comes into play when two or more wireless cameras stream simultaneously to a shared base station radio. The two client radios

CAMERA BANDWIDTH REQUIREMENTS (HIGH MOTION CONDITIONS, H.264 ENCODING), IN MB/S

Resolution	Image Size	Total Pixels	1FPS	5PS	12FPS	30FPS
CIF	352x240	84,480	0.04	0.16	0.3	0.5
4CIF	704x480	337,920	0.18	0.6	1.2	2.1
D1	720x480	345,600	0.18	0.7	1.2	2.2
1-megapixel	1280x800	1,024,000	0.5	1.9	3.6	6.4
2-megapixel	1920x1080	2,073,600	1.1	3.9	7.4	12.9
5-megapixel	2592x1944	5,038,848	2.6	9.5	17.9	31.4

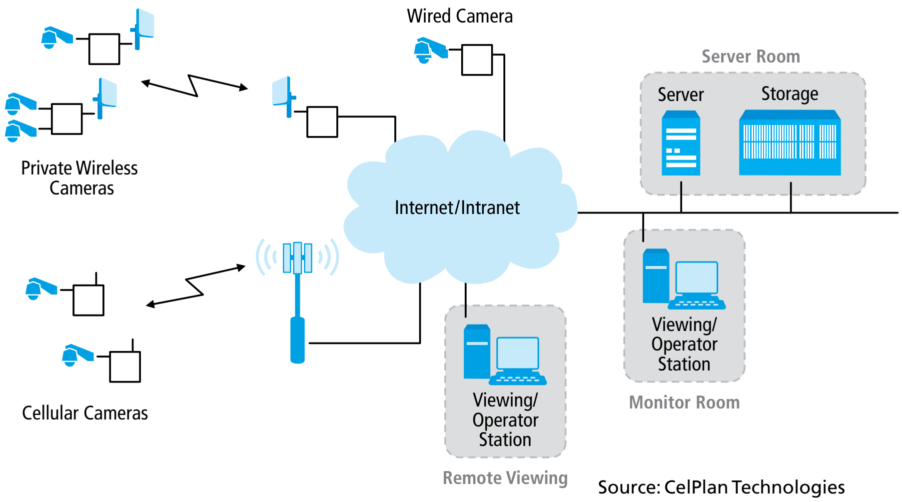
Source: CelPlan Technologies

can send a video data packet in any timeslot; however, in streaming video, packets will be sent on a continuous basis, so there is a very good chance that the two wireless cameras will send their data packets at the same time, in the same timeslot. Logically, in this case, a collision will occur and the base station will not receive either packet. When this occurs, the base station will not acknowledge receipt of the packet and the wireless cameras will realize the packet is lost after a certain time lapse. The camera will then wait a random number of timeslots before retransmitting the data packet.

Although the packet eventually gets through the link, the result is an unpredictable time delay, which is not ideal at all for our killer application of steaming video. Use of a scheduled protocol mitigates this problem, by providing pre-assigned timeslots for each wireless camera to transmit its packets individually, avoiding the aforementioned collisions.

In order to build a stable wireless network for video applications, use of higher-cost radios also is recommended. Features of such radios would include a scheduled protocol, 2x2 MIMO (multiple input multiple output), synchronization for collocated radios, support of the 4.9 GHz and 5 GHz bands in a single radio, and support of full feature sets in 5, 10, 20 and 40 MHz bandwidth. Integrating the radio electronics with the antenna device also is advised, in order to avoid cable losses, which improves the receive sensitivity of a radio significantly. The use of directional antennas (in a multi-radio configuration, if needed) generally is preferred, to reduce self-interference and to focus the antenna gain—for both transmit and receive modes—specifically in the direction of the other radio end.

CITYWIDE SURVEILLANCE NETWORK



Source: CelPlan Technologies

Building out a wireless network to reach remote camera sites still can be expensive or difficult. If distances are simply too long or lots of obstructions exist, making it difficult to create LOS connections between radios in the network, cellular technology could be considered as an alternative. In addition, the use of cellular technology makes a system more suitable for changes. For example, it is possible to redeploy a wireless camera unit without having to worry about adjustments to the wireless network, assuming of course proper cellular coverage.

When using cellular technology, it is important to ensure that LTE-based (4G) cellular service is available in the target area. Also, selection of an unlimited data plan is a crucial factor; for instance, at 2 Mb/s throughput, a single camera will stream about 20 GB in just one day. In our experience, at this moment, cities and other government entities are in a unique position to negotiate such unlimited plans at very reasonable monthly rates in support of their citywide surveillance systems. However, the end user should realize that resolution and frame rate may need to be compromised when using cellular technology.

Ultimately, designing a citywide video surveillance network is complex and a careful design process is required. The first step is a review of the desired camera locations, suitable camera types and bandwidth requirements. In the next step, one should match any existing fiber and networking resources. Finally, one should select the wireless solution and design best suited to reach remote sites. Over recent years, both wireless and cellular technologies have made a considerable leap forward, resulting in a multifold increase of bandwidth in support of surveillance cameras. Although wireless network bandwidth is not directly comparable with that of fiber connections, when designed correctly and when expectations are aligned with reality from the beginning, wireless citywide surveillance solutions can be developed as a powerful tool in support of public safety. n

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