## Industrial Video Monitoring Effects on Network Bandwidth and Storage

Advances in storage and network technology have given a big boost to industrial video monitoring. Remote monitoring is now possible thanks to Internet Protocol, (IP), connectivity between cameras, video servers and remote clients and every day more IP cameras using Ethernet are replacing the legacy digital cameras with coaxial connection.

This new trend in video monitoring technology strongly relies on the bandwidth of the communication networks used to connect the video monitoring system with remote clients. Video can consume a lot of bandwidth, affecting the performance of a network if the traffic is shared with other applications (e.g. internet, file exchange, etc.); for this reason, it is a good practice to set a separate network dedicated to the video system.

In the case of electrical utilities and other industrial customers, it is not always easy to dedicate a network exclusively to a video system; also, the available bandwidth of the existing network is usually very low and has to be shared with critical data (i.e. SCADA). These conditions raise a challenge for the setting up of a video system for monitoring remote sites.

Bandwidth limitations can be overcome by adjusting three important parameters that affect the quality and bit rate of a video stream: compression, resolution, and frame rate.

### Video Compression

Video coming from any type of camera must be digitized to be stored and streamed. The resulting digitized video is usually a high-quality video with good definition but with extremely high bit rates of over 1 Gb/s for HD cameras [1, 2]. Such bit rates are impractical for streaming and storing video even with the latest technology in hard drives and networks. To overcome this problem, the digitized video must be compressed.

Compression techniques consist of applying mathematical transforms to the video data to find redundancies in the data and eliminate them. The raw digitized video is then reduced to only the basic information needed to re-build it. For video, independently of the compression technique used, there will always be a compromise between quality and bit rate, therefore the reconstructed video will have a lower quality than the original video, and that quality will be usually inversely proportional to the compression ratio.

The first way of compressing video, and still one of the most common ways used in video surveillance, consists in treating the video as a flow of independent pictures or frames and compressing each frame using the *intra-picture* coding JPEG. With this compression codec, called Motion JPEG or MJPEG, it is possible to get compression ratios on the bit rate of 10:1 [3]. Although an improvement compared with bit rate for uncompressed digitized video, it is still high for applications with very low bandwidth networks (less than 1Mbps).

A different trend in video compression techniques improves the compression performance by taking advantage of the large amount of temporal redundancy in video content. Usually in video surveillance, much of the depicted scene is essentially just repeated in picture after picture without any significant change, so video can be represented more efficiently by sending only the changes in the video scene rather than coding all regions repeatedly. This kind of techniques is known as *inter-picture* coding [4]. The MPEG standards are based on this technique of compression. With this compression codec it is possible to get compression ratios on the bit rate of 30:1 [3]. This is the compression codec used in DVDs.

Widely used video compression codec, H.264, is based on the same principles as the MPEG standards, but uses different coding technologies that improve the performance compared to its predecessors. It has achieved up to 50% in bit rate savings compared with MPEG-4 coding schemes without affecting the quality of the video [5]. This is the codec used to compress high definition video.

**Video Resolution**

Video resolution defines the number of pixels in each of the frames in a video stream. This is another parameter that has to be adjusted when bit rate is a concern because the higher the resolution, the more the amount of pixels in each frame and therefore the higher the bit rate of a video stream [6].

**Frame Rate**

Frame rate is the number of frames in a fraction of time in a video stream; it is expressed in frames per second (fps). The frame rate also affects directly the bit rate of a video stream.

In video surveillance 30 fps for NTSC system and 25 fps for PAL system, is considered live video. The reason for these numbers is not performance but just a remnant from the old days when analog television technology relied on the electricity frequency supply to generate video. Back then, a video frame was formed by successive horizontal lines of light projected on a screen. Not all lines were projected at the same time but a set of odd video lines were projected in one electricity cycle and a set of even lines were projected in the next electricity cycle. Therefore, it took two electricity cycles to create a video frame, which means that in North America for example, where the electricity supply has 60 cycles per second (60Hz), TV systems would generate 30 frames in a second.

Nowadays, streaming and/or recording video at 30 fps is a waste of bandwidth and memory for some applications. One study suggested that in order to get a good performance in automatic intruder detection at least 8 fps were needed [7]; this frame rate can even be lower in the case of large area scenes with very low activity typical in electrical substations.

The chart below provides some examples of the bandwidth and storage requirements for an IP based video monitoring system. There are hundreds of possible combinations with the parameters that can be control and the table below shows only a small amount of these combinations. In this table, we are only considering the Bandwidth and Storage used by one channel of video, at 4 possible resolutions, 3 levels of compression and 5 frame rates. Note that the amount of motion in the video affects the compression and thus also the overall bandwidth and storage.

| Resolution | Compression level | Frames Per Second (fps) | Bandwidth (Kbps) | Storage (GB per day) |
|---|---|---|---|---|
| CIF (352x240) | H.264 Level 5 (High) | 1 | 11.5 | 0.115 |
| | | 5 | 34.5 | 0.46 |
| | | 10 | 69 | 0.7475 |
| | | 20 | 115 | 1.265 |
| | | 30 | 172.5 | 1.863 |
| | H.264 Level 3 (Medium) | 1 | 115 | 0.115 |
| | | 5 | 46 | 0.4945 |
| | | 10 | 80.5 | 0.874 |
| | | 20 | 126.5 | 1.38 |
| | | 30 | 178.25 | 1.91705 |
| | H.264 Level 1 (Low) | 1 | 23 | 0.253 |
| | | 5 | 69 | 0.7475 |
| | | 10 | 115 | 1.265 |
| | | 20 | 184 | 2.07 |
| | | 30 | 253 | 2.76 |

| | | | | |
|---|---|---|---|---|
| 2CIF (704x240) | H.264 Level 5 (High) | 1 | 23 | 0.253 |
| | | 5 | 80.5 | 0.874 |
| | | 10 | 126.5 | 1.38 |
| | | 20 | 230 | 2.53 |
| | | 30 | 310.5 | 3.358 |
| | H.264 Level 3 (Medium) | 1 | 23 | 0.253 |
| | | 5 | 80.5 | 0.874 |
| | | 10 | 149.5 | 1.61 |
| | | 20 | 241.5 | 2.645 |
| | | 30 | 333.5 | 3.68 |
| | H.264 Level 1 (Low) | 1 | 34.5 | 0.46 |
| | | 5 | 126.5 | 1.38 |
| | | 10 | 230 | 2.53 |
| | | 20 | 391 | 4.255 |
| | | 30 | 540.5 | 5.865 |
| 4CIF (704x480) | H.264 Level 5 (High) | 1 | 46 | 0.4945 |
| | | 5 | 161 | 1.7365 |
| | | 10 | 276 | 2.99 |
| | | 20 | 471.5 | 5.0945 |
| | | 30 | 621 | 6.7045 |
| | H.264 Level 3 (Medium) | 1 | 46 | 0.4945 |
| | | 5 | 172.5 | 1.863 |
| | | 10 | 287.5 | 3.105 |
| | | 20 | 506 | 5.52 |
| | | 30 | 678.5 | 7.36 |
| | H.264 Level 1 (Low) | 1 | 69 | 0.7475 |
| | | 5 | 264.5 | 2.875 |
| | | 10 | 448.5 | 4.8415 |
| | | 20 | 793.5 | 8.5675 |
| | | 30 | 1046.5 | 11.3045 |
| 720Px (1280x720) | H.264 Level 5 (High) | 1 | 115 | 1.265 |
| | | 5 | 425.5 | 4.6 |
| | | 10 | 747.5 | 8.05 |
| | | 20 | 1276.5 | 13.8 |
| | | 30 | 1690.5 | 18.285 |
| | H.264 Level 3 (Medium) | 1 | 126.5 | 1.288 |
| | | 5 | 460 | 4.945 |
| | | 10 | 805 | 8.625 |
| | | 20 | 1380 | 14.835 |
| | | 30 | 1840 | 19.895 |
| | H.264 Level 1 (Low) | 1 | 184 | 2.07 |
| | | 5 | 701.5 | 7.59 |
| | | 10 | 1219 | 13.225 |
| | | 20 | 2070 | 22.425 |
| | | 30 | 2852 | 30.82 |

| | | | | |
|---|---|---|---|---|
| 1080Px (1920x1080) | H.264 Level 5 (High) | 1 | 253 | 2.76 |
| | | 5 | 943 | 10.12 |
| | | 10 | 1690.5 | 18.285 |
| | | 20 | 2829 | 30.475 |
| | | 30 | 3956 | 42.78 |
| | H.264 Level 3 (Medium) | 1 | 287.5 | 3.105 |
| | | 5 | 1035 | 11.155 |
| | | 10 | 1794 | 19.32 |
| | | 20 | 3013 | 32.545 |
| | | 30 | 4243.5 | 45.77 |
| | H.264 Level 1 (Low) | 1 | 437 | 4.715 |
| | | 5 | 1598.5 | 17.25 |
| | | 10 | 2829 | 30.475 |
| | | 20 | 4899 | 52.9 |
| | | 30 | 6497.5 | 70.15 |

Table 1: Typical bandwidth and storage requirements with various resolution, compression and frame rate parameters.

**Summary**

It is possible to install a high performance digital video monitoring systems on low bandwidth networks. Bandwidth and storage consumption from streaming video feeds can be overcome by edge processing and storage of video, however, if this is not possible, compression techniques can effectively be used to minimize the impact. Streaming high definition video from a remote site to a central monitoring center will consume a large amount of bandwidth and storage but this level of video quality is not normally required for industrial monitoring purposes. Tuning the resolution, frame rate and compression level, users will be able to obtain very good quality video from their remote sites that will not overwhelm network and storage capacity.

**References**


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