Future Proofing the Video Transmission for ITS

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ABSTRACT

Scene analysis using CCTV signals is an increasingly important tool in managing a highway surveillance network. Video compression, required to transmit video signals over Standards based Ethernet or SDH networks, can throw away valuable video scene information - required for effective scene analysis software. Software analysis will become even more significant in the future as camera counts increase, thus video compression can limit the future use of these tools. Transmission networks are now available which have all the benefits of the standards based networks but with the ability to carry full bandwidth uncompressed video signals along side Ethernet and traditional low speed data services.

KEYWORDS

CCTV, Transmission, Fibre Optics, Compressed Video, Uncompressed Video, Ethernet, Future proofing

INTRODUCTION

Today, CCTV is an invaluable tool in managing highway systems. Whether the cameras are used for incident detection and management, for number plate monitoring, or for any of the many other applications, it is clear that the number of cameras at the roadside will continue to increase. The challenge for the transmission system has been how to get the camera signals from the roadside to a point where they can be used or processed. The development of video compression technology and the resulting reduction of the information bandwidth required to be sent, has made possible the use of standards based communication systems such as Ethernet or SDH for the transmission, thus taking advantage of all the benefits associated with these types of network systems.

However, during the compression process, information within the video signal is discarded which cannot later be recovered. With the increasing use of video processing software which benefits from the maximum amount of video content information, the process of compressing a video signal just to make it more convenient for the transmission system starts to limit the future usefulness of the delivered video signal itself.

As the sophistication of video processing and scene analysis software continues to increase, both for its intrinsic usefulness and to cope with the ever increasing number of cameras, the limitation associated with using compressed video transmission threatens to become more and more significant. This in turn limits the future usefulness of the cameras for the management of the highway.

Thus the challenge for the transmission system of the future is not only how to get the camera signals from the roadside to the point where they can be used or processed but also how to ensure that important video scene information is not thrown away in the process.

The purpose of this paper is to discuss whether this limiting of the possible future proofing of the CCTV transmission for ITS Systems can be avoided. The paper also discusses and illustrates how transmission networks now available can provide the benefits of Ethernet and SDH networks whilst simultaneously carrying uncompressed video signals. This type of transmission network not only allows all the video content to get to the point where it is going to be used or processed but also ensures that no video scene information is lost in the process - effectively future proofing the transmission network.

HIGHWAY MANAGEMENT CCTV

The number of cameras used on the roadside is increasing as CCTV becomes a more important tool for the management of a highway network. The cameras are used for a number of applications. These include:

- Incident detection
- Incident management
- Vehicle tracking
- Traffic flow control
- Highway lane control
- Emergency control
- Driver information systems
- Security services applications

TRADITIONAL VIDEO TRANSMISSION

The challenge for the transmission system historically was to get a picture from the camera to the user who would view the video signal on a monitor. Traditional transmission systems designed specifically for the video were in the main point- to-point, limited in transmission distance capabilities, non resilient and unmanaged. This could be a significant draw back when used with a serious highway management system where information is required 24 hours a day and fast response is paramount. With the introduction of video compression technologies, the bandwidth required for the video transmission could be significantly reduced by throwing video scene information away. This allowed the use of standard networks, such as Ethernet or SDH, and resulted in the ability to take advantage of the benefits associated with their capabilities. These benefits include:

- Resilient networks – dual redundancy
- Drop and insert architectures
- Virtually unlimited transmission distance
- Integrated switching and routing
- Anywhere to anywhere connections
- Simultaneous multi-site viewing
- Integration with other signals
- Very large capacity networks

VIDEO COMPRESSION

An uncompressed video signal requires ~130Mbit/s of bandwidth from the transmission network. In order to carry many video signals, compression has to be used for the cost effective transmission of multiple video signals over an Ethernet or SDH network. Compression can bring the bandwidth requirement down to between 25Mbit/s to 64kbit/s per camera signal, depending on the video quality requirement and the bandwidth available. Various compression standards are used in the CCTV market to fulfil this requirement. These include:

- MPEG2
- MPEG4
- H263
- H264
- Wavelet
- MJPEG
- MJPEG 2000

The choice of which technology to apply was typically determined not only by when the decision was made but also by the cost and capabilities of the respective compression algorithms. The capabilities of the compression algorithms have improved with time in terms of reduced bandwidth requirement versus quality. However, backward compatibility has not been maintained. This continues to be a serious problem when selecting a specific technology. Some manufactures try to accommodate future improved technologies by using DSP based non-algorithm specific architectures. However, as the technology moves forward so does the processing power requirement. Hence older DSP based systems no longer have the capacity to move to the newer algorithms.

Video compression can use compression ‘within a frame’ as well as compression ‘frame to frame’. A static low content video scene can be sent with a minimum of bandwidth. As the scene content increases with more detail so the ‘within the frame’ bandwidth requirement is increased. As the motion within the scene is increased so the ‘frame to frame’ bandwidth requirement is increased. The bandwidth requirement can be further compromised if low latency compression is required for Pan Tilt Zoom

(PTZ) camera type systems. Thus choice of algorithm should include specifications for the worst anticipated case in terms of scene detail, activity, latency and resolution. These can then dictate the algorithm and the overall bandwidth requirement of the network.

It is important to note however, that all of these algorithms throw video information away which cannot be recovered. If the Ethernet or SDH networks could accommodate the uncompressed video bandwidth then this would be the algorithm of choice.

LIMITATIONS OF VIDEO COMPRESSION

The traditional limitations with the use of video compression associated with viewing quality and response latency are still an issue for some applications. Moreover, other issues are now coming to the fore. The five more significant of these are:

- the inability to take the huge advantages of third party scene analysis software either at the time of installation but more significantly at any time in the future.
- The total loss of the system when the network crashes together with the skilled network support resource needed to reinstate and maintain the network. Large video systems >150 cameras require sophisticated network capabilities above and beyond what is normally required for a relatively simple data network. The network needs to have these capabilities from day one and can significantly increase the price of the network components.
- the simultaneous multiple agency use of the video each with its own transmission limitations.
- System latency
- Frozen frames

- *scene analysis software*

The use of sophisticated scene analysis software is becoming a significant tool for the processing of the CCTV images. This is not only because the number of cameras is increasing and the use of human operators becomes impractical, but also because the software capabilities are improving and becoming more successful. These software applications can be developed independently of the transmission system and their usefulness is dependent on the quality of the video scene information available to them. It is important that the video transmission system does not compromise or limit future use of any such software packages. This effect can currently be demonstrated when using video processing software such as for smoke detection in tunnels. For a system which could raise an alarm within a few seconds of the first appearance of smoke when presented with a uncompressed video stream, this is delayed until virtually the whole scene is filled with smoke when presented with a MPEG4 video stream. It is also demonstrated with the inability of 'off the shelf' commercial traffic flow software, even for the most simple functionality, to operate with a compressed video stream reduction. Not to mention the reduction in the reliability some ANPR video processing software when used with compressed video streams. The sophistication of scene analysis software and the requirement for more detail from the video stream is only going to increase in the future. The way to maximise the video scene information available is to avoid compressing the video at all. By this method it is clear that the system can be future proofed against any incompatibility between any scene analysis software and the method used to transmit the signal to it.

- ***Network capabilities***

The use of a total IP based system for the transmission of the video does put demands on the network above and beyond what would be normally required for a relatively ‘simple’ data network. These demands may only become apparent as the camera count increases. Large systems, >150 cameras but sometimes smaller depending on the type of network, can require network work routing protocols which are not available within low cost ‘simple’ networks. The result of not having them can be a significant amount of network congestion which, at the minor end of the spectrum, leads to non access to certain signals, but will ultimately lead to a network crash. This leads onto the other issue of a fully IP network based system. IP Networks do crash all the time. We have all experienced this. This would mean in the case of a fully IP network based CCTV transmission system that non of the camera signals would be available. The use of a separate transmission system specifically designed for the collection of video to a distribution point, control room or processing point prior to being put onto a IP network ensures that the video will always be available at that location even in the event of a network crash. Also the IP network support resource to reinstate and maintain the network can result in an expensive overhead associated with operating a IP network.

- ***Multiple compression***

Another limitation which can be caused by compression results from the requirement of multiple users to simultaneously view the same video signal. If the collection of the video to a distribution point has used compression and the onward routing also requires compression maybe even to another quality level, the video signal may have to be brought back to an uncompressed format in order to do this. Recompression of a previously compressed signal can be problematic. The way to ensure that a video signal can be onward routed to any user from a distribution point is to transmit the signal to the distribution point in an uncompressed format.

- ***Latency***

Latency is the delay between an operator trying to move a camera, by for example moving a joy stick, and the image on the viewing monitor actually moving. A figure of merit used by some agencies suggests that total latencies in excess 250ms is unacceptable for a user to cope with over extended periods. An uncompressed transmission system does not have any significant latency. The transmission latency associated with the speed of light is 5 microseconds for each kilometre travelled. Thus even a 1000 kilometre transmission distance would only result in a 10 milliseconds delay to the camera and back, not noticeable in a CCTV system. Note this latency is present regardless of how the video is transmitted. However, for a compressed video system, if frame to frame compression is used, such as within the MPEG standards then the video has to be buffered at the encoder and at the decoder. This on top of possible network delays results in a latency target of 250ms difficult to achieve in an incident scenario. An incident scenario is when the video image has the most information content within the frame and the most activity frame to frame. This scenario, when the video is needed most, puts the most demands on the video compression.

- ***Frozen Frames***

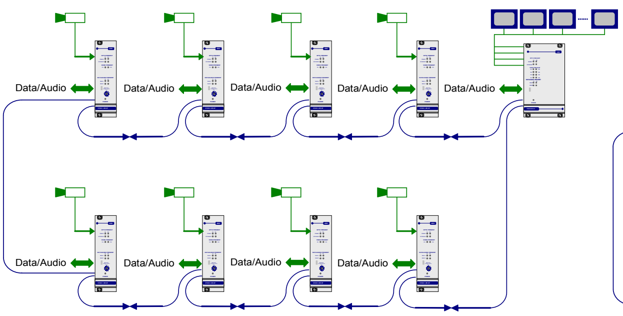
A frozen frame is when the display shows a video image which suddenly freezes in time and does not update. The display can then mislead the operator as it is not providing a current image from the camera. As a compressed video system has to buffer and store complete image frames, there is the possibility, albeit this may be a fault condition, that this frame store no longer becomes updated and it continues to put out the same frame all the time. In safety critical applications this can result in a ‘fail to danger’ situation. In uncompressed video transmission does not include a frame store, as a result will never, even in a fault condition, be able to mislead the operator by displaying an ‘out of date’ image.

UNCOMPRESSED VIDEO TRANSMISSION NETWORKS

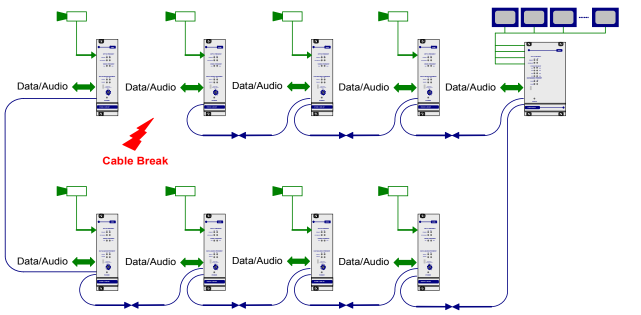
The range of AMG transmission equipment has been designed to replicate the benefits associated with the standard network capabilities without compromising the video. The AMG transmission does not compress the video and is immune from the limitations listed above.

For the video collection it is possible to collect channels of video and distribute Ethernet and low speed data or audio signals on a single unit located at the roadside. These can be connected on a dual redundant ring architecture with a single fibre daisy chaining between each unit. The benefits of this approach are the minimal use of fibre, ease of camera addition, the ability to drop off signals at multiple locations and the effectively unlimited transmission distance. The dual redundant capability ensures that the operation is maintained in the case of a fibre break or in the case of loss of power at a unit. The AMG3700 series units are the equipment to be used for all the collection of all the cameras (approximately 1000 off) on the UK highways within the NRTS project.

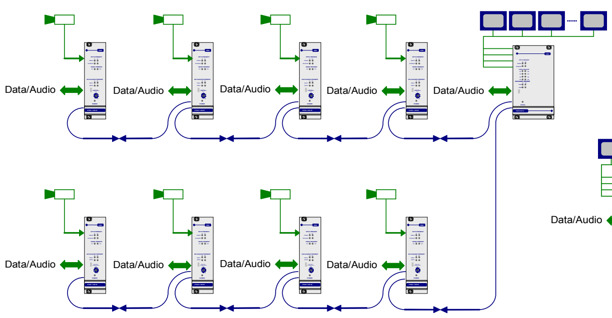
Dual redundant rings



Automatic and immediate recovery



Single and dual direction spurs



Dual site linear redundancy

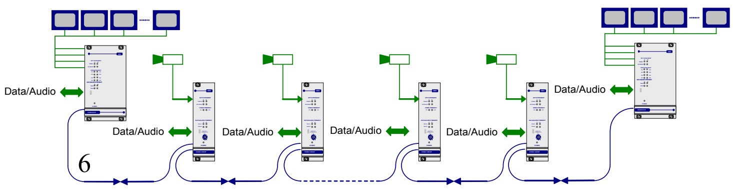


Figure 1 – Typical uncompressed video collection architectures

The system can be fully managed via industry standard SNMP or via a proprietary GUI to highlight any faults in the fibre, whilst full operation is maintained. It also monitors video availability and loss of power.

For high channel count video distribution, resilient and managed equipment can collect and distribute video from multiple locations.
Figure 2 below shows the system known as the “Birmingham Digital Ring” currently in use on the motorway network around Birmingham in the UK.

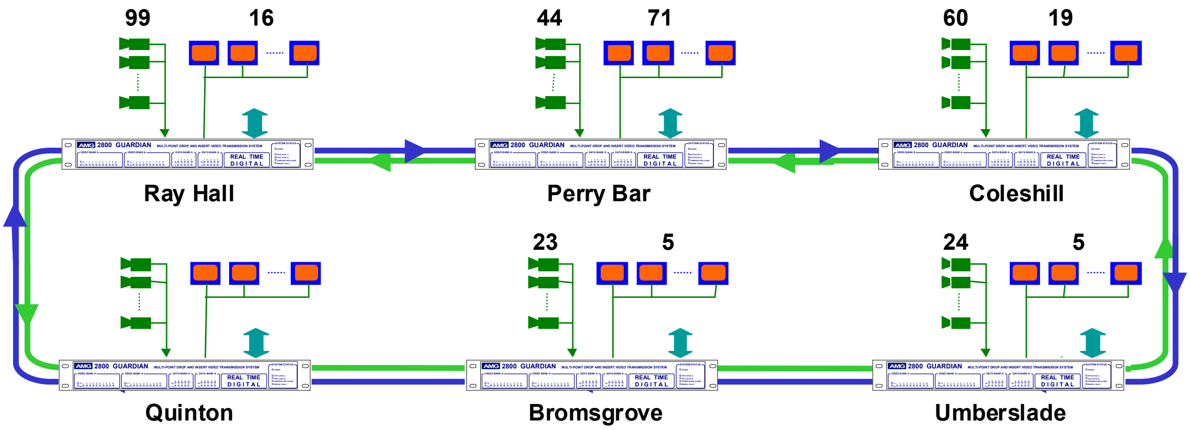


Figure 2 – Typical uncompressed video distribution architecture - as implemented on the “Birmingham Digital Ring”

CONCLUSION

When it comes to future proofing CCTV transmission for ITS systems, it is clear that careful consideration needs to be given to a number of key factors.

This paper has highlighted the problems relating to the use of compressed video alongside scene analysis software and also the backward compatibility and inconsistency issues with the various compression standards. We also know that from an operational point of view there is trade off between response latency and video quality which can affect the manageability of CCTV systems.

From the examples discussed we know that products exist which have all the benefits of standards based networks without the compromise associated with video compression.

It is clear that any organisation planning the development of a new highways surveillance system needs to give due consideration to the method chosen for transportation of the video signal. The wrong choice made at the outset could seriously limit the effectiveness of the system as well as restrict the ability of future up-grades to take advantage of the expected advances in the capabilities of important tools like scene analysis software.