Seamless and Manageable ITS Telecommunication Networks

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1.0 Introduction

Today's Intelligent Transportation System (ITS) telecommunication networks, in connecting roadside equipment to Traffic Control Centers, play an integral role in the transmission of critical information for the purposes of making travel safer and more efficient. Nonetheless, ITS network designs implemented to date are very fragmented and have high life-cycle costs associated with them. These designs will prove difficult to scale and manage in the future as the expanded view of services envisaged by the ITS community evolves into being.

To address this issue, the following paper describes a seamless and manageable ITS network that provides broadcast-quality video and is cost-effective. It allows a graceful migration to an all-digital network while allowing more flexible control of the bandwidth using a standards-compliant Network Management System (NMS) that is compatible with ITS Traffic Control Center applications.

2.0 ITS Network Requirements

Intelligent Transportation Systems aim to provide transportation authorities, commercial organisations and the general public with a broad range of services which are intended to make travel safer and more efficient. The following are some of the ITS services that are currently being researched and in some cases implemented.

Travel and Transportation

En-Route Driver Information	Management Route Guidance
Traveller Services Information	Traffic Control
Incident Management	Infrastructure Maintenance

Parking Management

Emissions Testing and Mitigation

Highway-Rail Intersection

Travel Demand Management

Pre-Trip Travel Information

Ride Matching and Reservation

Demand Management and Operations

Public Transportation

Operations and Management

En-Route Transit Information

Personalized Public Transit

Public Travel Security

Electronic Payment Services

Emergency Vehicle Management

Commercial Vehicle Operations

Vehicle Electronic Clearance

Automated Roadside Safety Inspection

On-Board Safety Monitoring

Vehicle Administrative Processes

Hazardous Material Incident Response

Commercial Fleet Management

Advanced Vehicle Control and Safety Systems

Longitudinal Collision Avoidance

Lateral Collision Avoidance

Intersection Collision Avoidance

Vision Enhancement for Crash Avoidance

Safety Readiness

Pre-Crash Restraint Deployment

Automated Highway Systems

Law Enforcement Policing/Enforcing Traffic Regulations

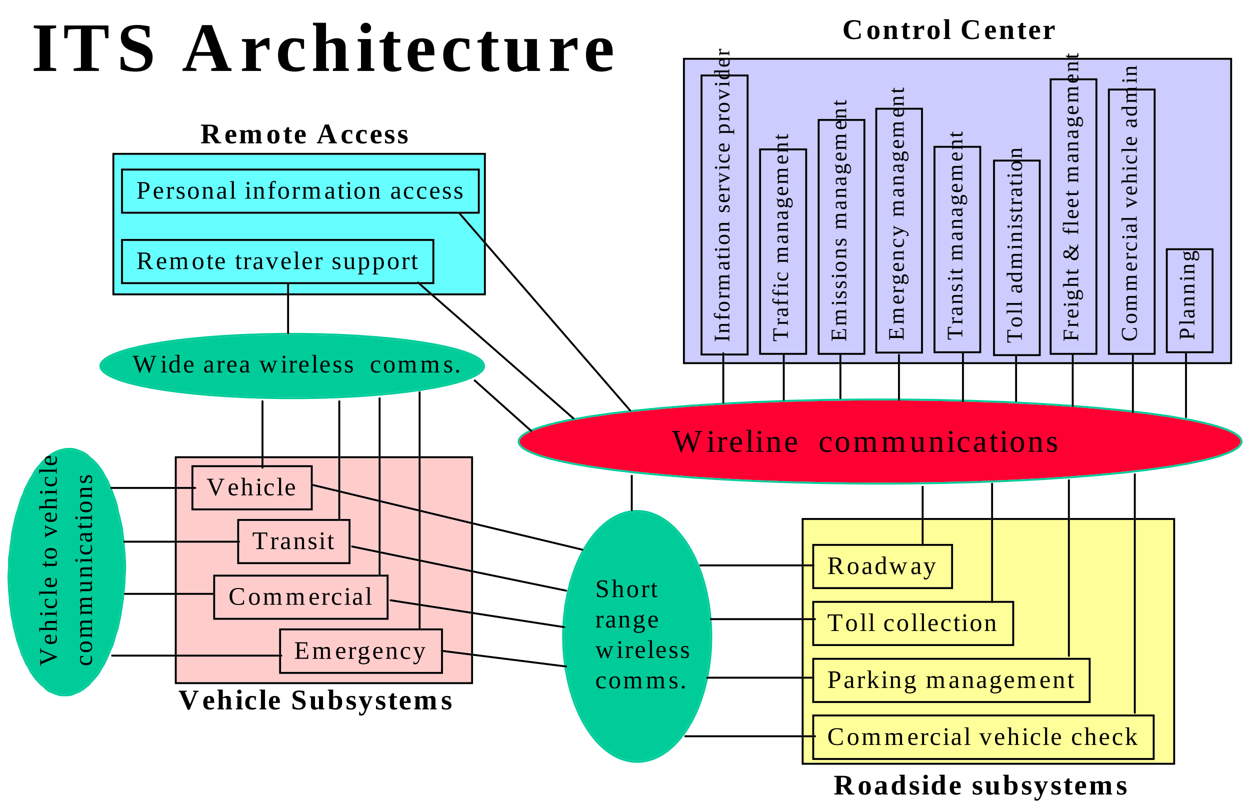
Vulnerable Traveller Services

Pedestrian Safety and Information Services

Bicyclist Safety and Information Services

To understand the overall telecommunication requirements of any one of these systems, one might turn to a generic ITS architecture paradigm like the ITS National Architecture model developed by ITS America. This is illustrated in Figure 1 below.

Figure 1



The model clearly shows four major subsystems, with the Control Center Subsystem, Roadside Subsystem, Remote Access Subsystem and Vehicle Subsystem all interconnected by a variety of telecommunications subsystems. By far the most complex of these is the so called "wireline communication networks." This is more commonly referred to as a wide area network or WAN.

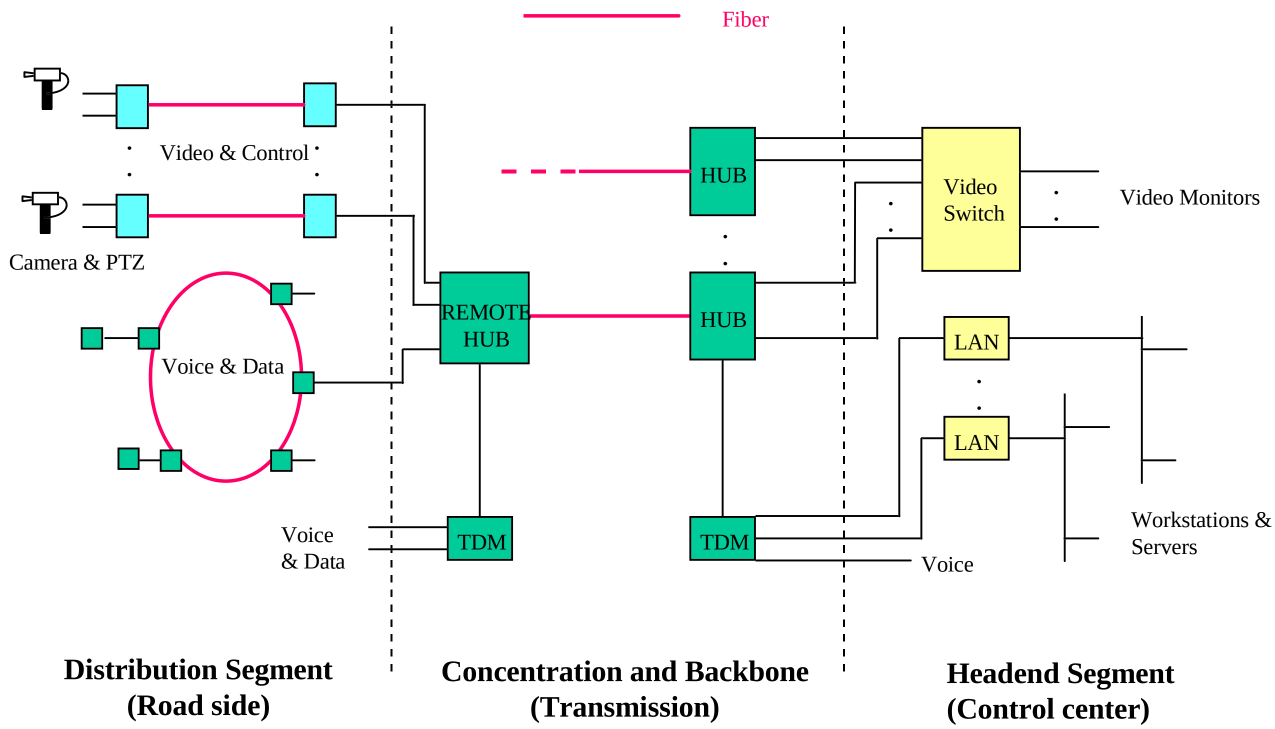
Traditional ITS communication systems are not very complex in nature compared to, for example, public telecommunications networks. Nonetheless, there are issues that an ITS WAN network must address. It must accommodate several communication formats to integrate video, voice and data for transmission over long distances. Furthermore, it requires an inordinately high number of broadcast-quality video circuits connecting the remote surveillance cameras to the Traffic Control Center. This poses a significant challenge to standard WAN equipment in both providing the bandwidth economically and accommodating the expected growth required if the ITS services outlined above are to be realised. Implicit in this statement is the need for WAN communications equipment that is tailored to the needs of ITS while still meeting accepted standards in the WAN marketplace.

3.0 Traditional ITS Networks

For the sake of simplicity, consider a typical Advanced Traffic Management System (ATMS) implemented by a Department of Transportation for monitoring and easing traffic flow. Such a system can be typically subdivided into three segments: the distribution segment, the concentration segment, and the head end segment. The distribution segment of the ITS system encompasses the roadside equipment such as video cameras, pan, tilt and zoom (PTZ) controllers, ramp controllers, changeable message signs, loop sensors, and the like. The concentration segment consists of these hubs which collect information from the distribution segment field devices, aggregate the data, and then transport the resulting signal over long distances back to the head end. At the head end, or the Traffic Control Center, the concentrated signal is processed to obtain the original signals generated in the distribution segment. Applications typically run at the head end include video switching, incident monitoring, data processing, traffic control, maintenance coordination and information distribution to other services such as police, ambulance and broadcast media. A typical network is shown in Figure 2 below.

Figure 2

Typical ITS Network



There are several limitations to such traditional ITS network implementations. Data communication is typically achieved through rudimentary point-to-point links with some systems operating in a poll/response multidrop fashion. Typically, the video and data networks have been deployed as separate, multi-vendor networks that are segmented and difficult to manage. To accommodate the multi-vendor environment, there is extensive media conversion in the distribution segment which degrades the video quality and reliability. For example, transmission from the camera is originally sourced in an analog baseband video format. This is then modulated for transmission over optical fiber. Upon arrival at the remote hub in the concentration segment of the network, the signal is detected and converted back to baseband video before being re-modulated by the video multiplexer at the hub (in the concentration segment) for another stage of transmission over optical fiber. At the head end segment, the signal is converted back to baseband video again by a demultiplexer before being transmitted to the appropriate monitor through the video switch. This modulation/demodulation process clearly leads to undesirable inefficiencies.

A second problem with the traditional approach concerns the manageability of the network. Even in cases where a network management system is deployed, its ability to monitor the network is usually confined to the concentration segment and does not reach out into the distribution segment. This limitation is serious, given that roadside equipment in the distribution segment is typically less robust and far more problematic. The end result is significantly higher costs over the life of the network.

To overcome some of these issues, some recent ITS projects have deployed SDH/SONET backbones for digital video and data transport. Although this approach provides scalability and is somewhat manageable, it still suffers from several drawbacks. Firstly, management of the network is typically confined to the concentration segment. Video quality can be relatively good but only at a significantly increased cost per video channel over and above existing technologies. This is due to the high bandwidth requirements of digital video solutions. The cost of providing a single video channel from a remote camera in the distribution segment to the Traffic Control Center using digital video is typically twice to three times that of existing methods.

To circumvent the issue of cost, an approach being taken with digital video is to leverage video conferencing technology and the emergence of digital video compression standards that require much lower data rates. A manufacturer can supply relatively inexpensive video encoder/decoder (codec) modules whose output data can map into standard telecommunication equipment in 64 Kilobit per second increments. The consequence of this low bit-rate approach is lower quality video that is not truly comparable to the broadcast-quality image available through existing methods. This is particularly true for some digital compression schemes when the video image being transmitted to the head end segment is rapidly changing, resulting in a "jerky", distorted image at the Traffic Control Center.

Overall, current approaches to ITS network implementation have resulted in very fragmented, and in some cases, expensive systems that have a high life-cycle cost. These solutions will prove very difficult to scale economically to meet the growing demands of the ITS services currently planned.

4.0 ITS WAN Trends

Before considering an alternative approach to ITS network design, it is important to recognize trends emerging in the design and implementation of ITS networks today. First and foremost, the use of fiber optics as the telecommunications medium of choice is unlikely to be displaced. With a theoretically limitless bandwidth, its inherent scalability is extremely attractive for applications such as ITS.

The use of SDH/SONET as a concentration segment backbone technology is steadily gaining acceptance in the industry. The alternative ATM solutions proposed are proving to be very expensive and, as such, are unlikely to be adopted on a large scale for some time.

To meet the growing reliability and efficiency requirements, the distribution portion of the network will begin to move away from the point-to-point single channel architectures prevalent today and will likely move toward add-and-drop and ring architectures. Higher data speeds are likely to emerge as more devices with Ethernet interfaces become available, thus requiring transmission rates in the order of Megabits per second (Mbps) rather than today's kilobit per second (Kbps) rates.

Digital video is certain to become the standard technology of the future, though its current cost and/or quality limitations (depending on the design approach taken) may restrict its deployment in some cases. Ultimately, the appeal of digital video lies in its inherent ability to permit more flexible interconnection with the all-digital, public telecommunications network. This in turn will facilitate the dissemination of information to the public as ITS systems become more entrenched in everyday life. An additional benefit of digital video is its ability to share the bandwidth with the data and voice requirements of a network, as opposed to requiring separate facilities for each.

Digital video in the short term has created an issue for the ITS network operators who have become accustomed to the high quality video provided by current analog systems. To achieve the same level of quality today, the bandwidth required would make a digital video solution very expensive. ITS network designs will have to become more flexible, then, by dynamically reconfiguring themselves to provide adequate bandwidth as and when required to any particular video, voice or data channel, in contrast to today's method of providing the bandwidth continuously to each channel.

As the importance of ITS gains public acceptance, ITS networks will inevitably grow larger and more complex. The cost of network maintenance will grow accordingly, owing in part to the skilled technicians required to continuously maintain the network. Consequently, a trend likely to emerge in the future is the absolute requirement for a *comprehensive* network management system. This system will be used to remotely monitor and configure the entire network down to the channel or port level, as opposed to simply determining whether or not a node is operating satisfactorily.

The fragmented solutions being used today in designing ITS networks must be revisited. A truly seamless and manageable network solution that permits an evolution from the existing technologies to the all-digital networks of the future is a must. Otherwise, the communications network itself risks becoming the road block to the timely deployment of ITS services.

5.0 The Seamless and Manageable ITS Network

To build a seamless and manageable ITS WAN network requires a design from the top down that is not a "hodgepodge" of predefined segments. The overall quality of the video signal should be set from end point to end point and not on a per segment basis. A cost target per video channel needs to be established below that of the current networks to ensure that ITS services can grow. The life-cycle cost must be lowered and the skill set of the maintenance technicians required must be understood beforehand to allow for adequate retraining.

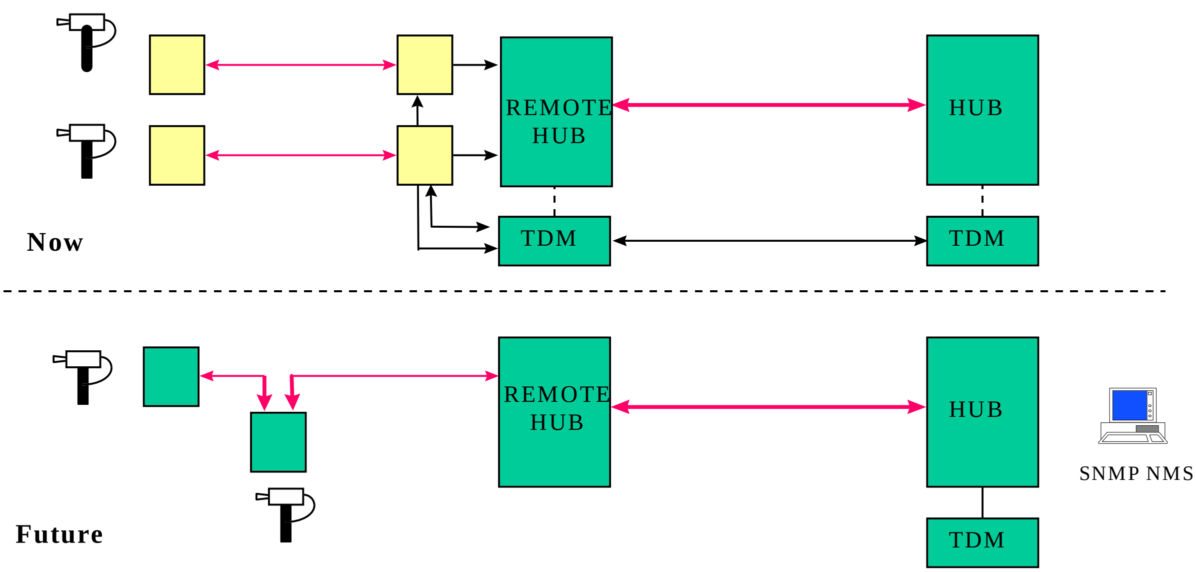
The following approach to ITS network design provides an evolutionary rather than revolutionary transition from existing network implementations. As such, the approach enables ITS project innovators who have already implemented phases of their network to protect their existing investments. Furthermore, the solution provides interoperability with existing industry standards and allows for a graceful migration to a fully digital environment.

The top half of Figure 3 below depicts the traditional use of point-to-point fiber optic modems in the distribution segment of an ITS network. The original video and data signals are modulated and transmitted over a fiber optic link to the hub node. Here the signal is demodulated into its constituent baseband signals. These signals are in turn fed into the remote hub node multiplexers for transmission back to the Traffic Control Center. The problem with this approach, as previously discussed, lies in the degradation of the video signal due to the modulation/demodulation process as well as requiring additional equipment at the remote hub to multiplex it onto the hub aggregate.

An alternative method for transmitting video, voice and data in the distribution segment is

Figure 3

Traditional versus Proposed Fiber Optic Communications

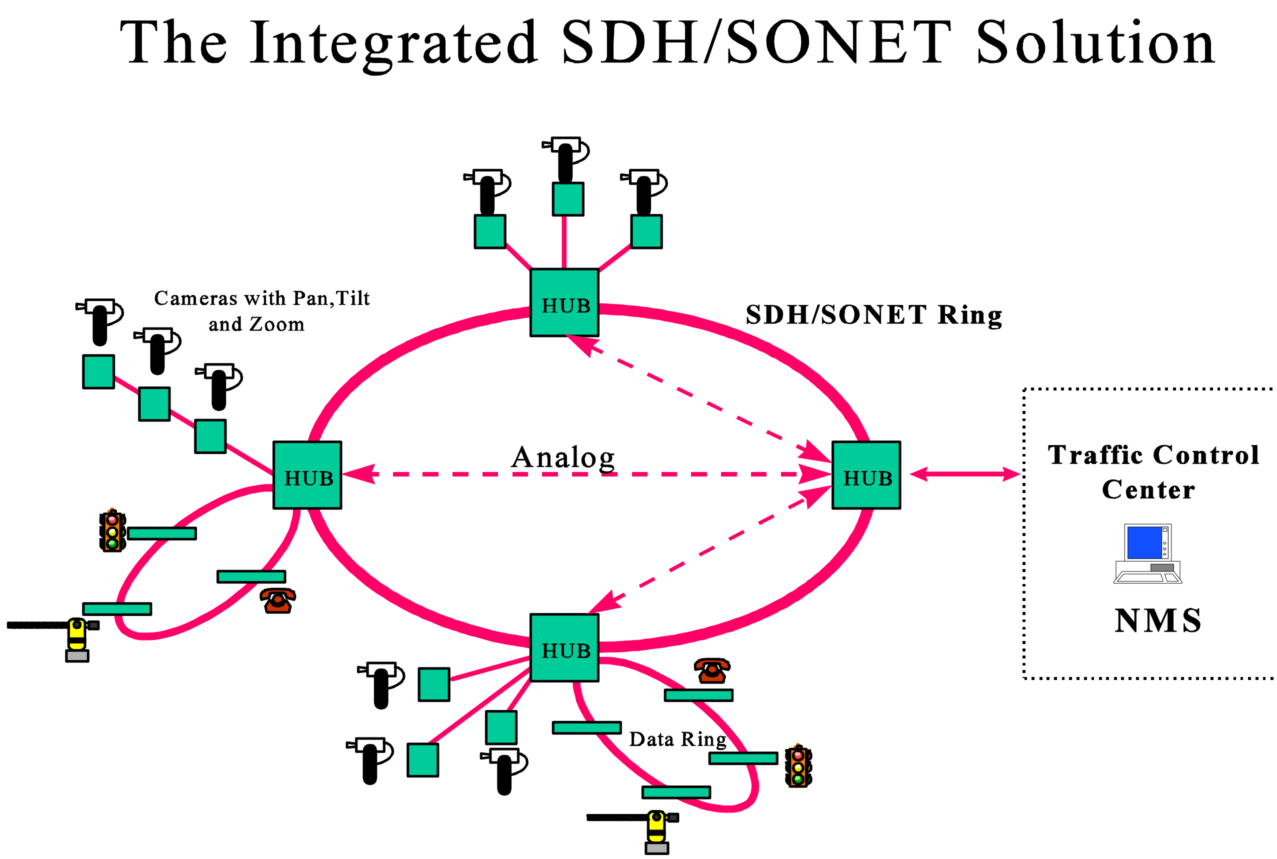


depicted in the lower half of Figure 3. The proposed method calls for the optical fibers from the remote cameras to be *optically* integrated into the concentration hub. This would effectively eliminate the need for the signal-degrading conversion to baseband at the remote hub node as is required in the traditional approach. Additionally, this approach, where used as an add-and-drop, can dramatically reduce the number of optical fibers required in the distribution segment of the network. Finally, this seamless approach allows network management to be extended beyond the concentration segment of the network right out to the remote camera locations.

Within the remote hub it is possible to integrate a SONET access capability such that the incoming video voice and data can be selectively routed onto the SONET payload under the control of the NMS or the ITS workstation software via the NMS.

A powerful variation of this approach overlays the analog network solution onto an SDH/SONET digital backbone network, as shown in Figure 4 below.

Figure 4



In this case, wavelength division multiplexing (WDM) allows an analog network to be overlayed onto the digital SDH/SONET ring network, thereby protecting investments incurred to date for analog equipment. This hybrid approach allows the analog and digital networks to become fully integrated such that the incoming video, voice and data signals can be *selectively* routed onto the SDH/SONET payload where applicable under the control of network management facilities.

Specifically, the routing of signals over this hybrid network occurs as follows. Voice and data signals are invariably routed onto the digital backbone for seamless transmission to the head end. In contrast, video signals can be transmitted either digitally along the SDH/SONET ring or on the analog network overlayed onto the SDH/SONET backbone. This approach permits the network operator to select between compressed, narrow-bandwidth digital video (at 1 to 6 Mbps) or broadcast-quality analog video (at 6 MHz) as and when required at the Traffic Control Center. Furthermore, under the control of the network management system, only a video signal that is required at any given point in time is back hauled to the Traffic Control Center. This optimizes the use of existing bandwidth and results in major cost savings as only a portion of all the video signals need to be viewed at any given time. This also serves to reduce the size and cost of the video switch at the head end as the number of video signals being switched has been significantly reduced.

The key to success for the seamless network described above is the network management system. Its function is to monitor and control the network elements in addition to allocating the bandwidth where necessary. As such, it must be capable of determining which camera is turned on and to which channel that camera has been assigned. The network management system will also determine if it is to be transported via the SDH/SONET ring as digital video or as full-motion video over the analog link.

The interface for the network management system must provide ease of use for this function. Thus, a command line/peer interface to the NMS is required to allow multiple vendors' software to control the NMS bandwidth manager for remote video switching. This command line interface will allow any external application for the NMS to be written for customized control of the network.

6.0 Conclusion

The ITS WAN, not unlike other network applications, is unique and has special needs. Today's oversimplified, point-to-point, segmented topologies do not represent scalable, manageable, end-to-end networks.

This paper has proposed a cost-effective, seamless and manageable ITS network design based primarily on existing technologies. It is tailored to the special needs of the ITS WAN while still providing standard interfaces. The hybrid approach overlays analog video networks onto a digital SDH/SONET network, thereby protecting investments in existing analog technology while providing for a graceful migration to exclusively digital networks. A single network management system monitors and controls the network providing bandwidth management for remote video switching. Thus, a cost-effective, scalable, seamless and manageable ITS WAN network has been achieved.