A REGIONAL CCTV VIDEO DISTRIBUTION NETWORK

USING ATM AND INTERNET PROTOCOL ROUTING

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ABSTRACT

The California Department of Transportation, Caltrans, District 11 has deployed a unique, first of its kind, video distribution system in the San Diego region. This system is a Metropolitan Area Network (MAN) using a fiber optic backbone employing Asynchronous Transfer Mode (ATM) technology. This system carries a diverse range of services such as Internet Protocol (IP) and traditional telephone technologies. Whereas the traditional CCTV video system uses point-to-point high bandwidth analog video with analog switch technology and FM multiplexing, the San Diego system utilizes an all-digital video technology centered on the use of network protocols. This network is characterized by several distinct uses of technology. These include its ability to route video using standard networking protocols and to provide additional services for command and control of the roadside video equipment. Network management and remote software configuration is accomplished though a stand-alone management system. The video system establishes video paths between field-deployed cameras and the Caltrans Transportation Management Center (TMC) through creative use of remote access software. Command and control are accomplished through innovative utilization of a distributed digital network with tie-ins to the legacy infrastructure. Compared to traditional methods of video transmission, the digital solution adds significant capacity, increases flexibility, and simplifies deployment. Planned future enhancements will provide further efficiencies and flexibilities.

INTRODUCTION

The San Diego region started design of the MAN in 1995 and began deployment in 1998. Since the inception, the vision was to improve the Traffic Operations System Network (TOSNET) by creating an efficient high-speed system to communicate with all field elements along State routes. ATM was selected over more traditional communication protocols, due to the promise of a network that guaranteed levels of service from end-to-end. In early investigations, many of the common features found today in ATM were not implemented consistently, and in many cases, features had not been implemented at all. As design progressed venders began introducing features, including versions of IP over ATM. Implementation of these features would allow the proposed system to provide traditional network services. This opened the door for new developing applications to utilize the benefits of ATM without having to worry about a new protocol. At the same time, new technologies began to emerge allowing the digitizing of video and transmitting the resulting data over Ethernets. As a result, District 11 employed MPEG-1 digital video compression over IP as its video architecture.

Much of the field deployed equipment used to manage the freeway system is based on modems over analog lease and dialup telephone lines. The new fiber based communication system needed to be compatible with the legacy communication protocol, RS-232. This meant, modems would be removed, and the communication system would now talk directly with the equipment. After extensive market investigation, a suitable product line was identified allowing for a homogenous system that encompasses both the legacy system and the new high-speed portion of the infrastructure.

FIBER OPTIC CCTV NETWORK

The CCTV architecture consists of five basic elements: a camera system, communications network, network management, distribution system, and control software. Each will be discussed in turn. The architecture is summarized in Figure 1.

The Camera System

The camera system is a suite of components which work together to create a seamless video unit. The camera system is capable of acquiring traffic video, digitizing and transmitting the resulting data into a network infrastructure, and receiving and reacting to commands with feedback to the controlling system. Each camera site contains a full camera system and is strategically located adjacent to a state route to best acquire traffic video. The components of the video system consist of a camera, pan-tilt-zoom (PTZ) assembly, camera control receiver (CCR), MPEG-1 encoder and a terminal adapter (TA). The camera employs a low voltage input and has outputs for automatic iris control and NTSC video. The PTZ assembly allows the camera to be repositioned in azimuth (pan), elevation (tilt) and focal length (zoom) by remote control. The CCR is responsible for accepting remote commands for control of the camera and reporting camera state and position verification back to the controlling software. Functions of the CCR include PTZ actuation control, direct focus and iris control, and overlay of text on the outgoing video. Inputs to the CCR include an RS-232 port for receiving remote control commands, video, and power. Outputs include connections for the PTZ unit and power for the camera assembly at the top of the camera pole, and video to the MPEG-1 encoder. Control commands for PTZ received through the RS-232 port, are translated into local commands understood by the camera and its attached PTZ unit. Remote application software and the CCR communicate according to a specified ASCII-based protocol. In many cases this is vendor dependent, however Caltrans has adopted a standardized protocol to allow for consistency throughout the State. Each camera is connected to the communication system through multiple communication topologies.

The heart of the District 11 architecture is the MPEG-1 encoder. The encoder converts the NTSC analog signal from the camera into a compressed, digital signal, suitable for transmission by one of several communications media. The San Diego architecture utilizes an IP-based protocol. Each encoder creates a 1.2 Mbps digital stream. This data stream is encapsulated into standard ethernet frames and sent out over IP packets.

Utilizing IP as the transmission protocol allows data to be routed over diverse network topologies such as fiber-optic and copper cabling, utilizing off-the-shelf, low cost, consumer level equipment. An additional future benefit is the ability to send the same data stream to multiple points simultaneously using IP multicasting with little or no additional impact to the network.

The decision to use 1.2 Mbps was made to allow transmission of high quality, full frame rate video over a standard T1 telephone circuit. MPEG-1 will produce near studio quality video in near real-time. Latency ranges from approximately 400ms to 750ms. Using standard telephone circuits allows video data to be routed outside the facility without the specialized transmission equipment normally required in an analog environment. Anyone desiring a video feed from the system can call the local exchange carrier and order a T1 circuit and attach to an encoder in the field. As mentioned above, IP multicasting is not currently implemented in the IP over ATM environment. This limits the number of decoders allowed due to the one-to-one relationship currently required between the encoder and decoder. This limitation will be eliminated in the next implementation by employing both IP multicasting and point-to-multipoint ATM. The final design was completed in February 2000 for implementation in the second quarter of the same year.

Each decoder located in the TMC must be logically paired with an encoder in the field while transmitting video. There is not a one-to-one relationship between the numbers of encoders and decoders. There are far more camera/encoders in the field than decoders in the TMC, however, the system allows for the decoders to process data from any of the field encoders. The operators of the system in the TMC select the decoder's source. This then, becomes a form of digital switching utilizing IP streams to view different cameras. In other Districts, it is planned to have encoders reside either in field Hubs or in the TMC itself. In this situation, the remote encoder becomes the demarcation between a legacy analog CCTV network and the IP-based network using the state's Asynchronous Transfer Method (ATM) backbone.

Finally, the TA bridges the ISDN data originating from the T-1 circuits into RS-232. This link allows for remote access to the CCR over an RS-232 circuit. The TA also allows for remote testing via loopbacks and link diagnostics using proprietary network management protocols.

Communications Network

In District 11, the communications network is based on ATM over a fiber optic backbone. The fiber backbone is currently in its construction stage, and is being continually expanded throughout the metropolitan region of San Diego. A hierarchical distribution system is used to collect video and distribute data using communications Hubs and Data Nodes. Communications Hubs are strategically located at the TMC, and freeway-to-freeway interchanges. Hub-to-Hub, and Hub-to-TMC communications links are directly connected over single-mode multi-fiber cables. A separate distribution system, also using single-mode fiber, is used to inter-connect Hubs to camera sites and data nodes.

Digital video feeds from CCTV sites are directly connected to the nearest Communications Hub via 10BaseFL (Fiber Link) Ethernet over the distribution fiber. At the Communications Hub, the IP based video packets are packaged up into an OC-3c data format for transmission across the District ATM backbone. This format provides 155 Mbps transmission rate per fiber. At the TMC, the digital video data are presented in their original format from ATM layer. The resulting MPEG-1 data are decoded by one of the decoders and presented as NTSC baseband video. The output of this process is four NTSC analog video streams for internal TMC distribution including feeds to several live news broadcasting stations. A video switch matrix is available for analog video distribution within the TMC. This process is illustrated in Figure 2.

To facilitate command and control, the system needs to accommodate low bit-rate RS-232 data. This has been accomplished through the use of channelized T-1, ISDN, and TA's with

RS-232 interfaces. Full channelized T-1 circuits are run over the backbone cable between the TMC and Communication Hubs, and from Hub to Hub. Discrete channels within the T-1 are utilized to carry specific data types to various types of field equipment. In the case of video, a single channel is originated within the TMC. Based on the CCR design, up to 25 CCR's may be linked together on a single channel. This channel is transmitted to the Hub, where it is then multiplexed into additional T-1's for transmission to the next Hub, or to a Data Node. At the Data Node, a sub-rate multiplexer will replicate the data from the CCTV channel and transmit this information into an ISDN style circuit. Up to this point, all data have been transmitted over SM fiber optic cable. The ISDN circuits are copper twisted pair (TP). Up to five cameras may be accessed from the Data Node. A strong advantage to this architecture is the ability to send multiple channels down a single T-1 circuit to a Data Node, thus allowing the system to talk to other systems residing on their own, independent circuit. Since data from a single channel is replicated out to multiple sites, this, in effect, becomes a distributed multi-drop data bridge circuit allowing legacy equipment to operate within normal parameters. The communication system becomes a transparent digital replacement for local telephone exchanges providing analog multi-drop lease lines. Within San Diego, along with CCTV, the system has the ability to communicate with Changeable Message Signs, Traffic Count Stations, Traffic Monitoring Stations, Ramp Meters, and Traffic Signals, each on an independent communication channel, each with the ability to multi-drop as many devices as required.

Network Management System

The District 11 fiber optic network is a complex communications system that supports several services and end-user field devices. A formal network management system is used to assist in the management of this complex network. One network management station in the TMC supports the low-speed serial data network. All the T-1 field equipment and the site-specific TA's can be managed by this workstation. A second network management station supports the high-bandwidth backbone system managing the ATM and routed IP carrying the video. Both management systems use a proprietary network management protocol that continuously monitors the status of all equipment and links throughout the system. Each component within the system is fully manageable, allowing devices to be reconfigured remotely as required. Testing can be accomplished from within the TMC. Line quality and other issues normally tested in the field can now be done centrally. This saves time and manpower compared to traditional methods for field testing.

A video control system based on the Simple Network Management Protocol, or SNMP, is currently being explored. SNMP is an open protocol and is supported by many vendors. SNMP elements include a manager, multiple agents for managed devices, a management protocol and a distributed database of management information (called the Management Information Base, or MIB). The SNMP protocol is an Application Layer protocol using the User Datagram Protocol (UDP) and Internet Protocol as Transport and Network Layers respectively. The manager, acting through a network management station processor, manages the field device agents by reading and writing to the remote device MIB's. The network management station also contains its own MIB, detailing information on the field devices. Each field device manufacturer supporting SNMP will define a proprietary set of MIB elements for that device; however, the format of the MIB follows a standard called Structure of Management Information, or SMI.

In the District 11 CCTV architecture, the SNMP-based implementation will be used (among other things) to set up video paths between encoders and decoders acting, in a sense, as a video switch. The MIB's for the encoders and decoders include routing IP information that allows remote path establishment based on TMC operator camera selection. This will be discussed further in the section on control software.

In-Building and External Distribution

Once video data are converted to analog NTSC at the TMC decoders, they are fed to an analog video switch and thence to an in-building NTSC distribution network and a Radio Frequency (RF) based CCTV system. The NTSC network, providing high quality video, routes analog video to designated floor boxes in the TMC Operations Room, Observation Room, Computer Room, News Services, and other locations as desired. From the floor boxes, analog video cables are routed to the ATMS or other workstations as needed. The RF system is based on standard television channels and allows general users within the building to view the decoded video using a standard TV or TV card within a computer. This flexibility allows discrete control of high quality video and standard RF video to the targeted audience within the facility.

Investigation of feasibility, cost and desirability of routing digital video direct to the workstations to avoid unnecessary decoder expense is under consideration. This scheme would require each workstation to have a video board capable of displaying internally decoded MPEG video signals. The cost of the workstation modifications would have to be weighed against the cost saved by removing the decoders. To maintain compatibility with the District's IP-based video routing architecture, these workstation MPEG cards would have to allow access to the IP stack within the workstation and support the existing network management architecture.

Control Software

CCTV application processing is shown in Figure 3. This represents the system as it will look when the Version 2 Advanced Traffic Management System is installed in the TMC in mid-2000. CCTV video imagery is received from the Caltrans ATM network as previously described, where it can be switched to various display destinations, including NTSC analog monitors, large screen displays or display windows on the operator workstation. The ATMS workstations were originally equipped with video cards, capable of displaying NTSC video signals in a workstation window. However, the original manufacturer no longer makes video display cards. A replacement technology suitable for the advanced generation UNIX workstations has not yet been determined. This may present an opportunity to switch from NTSC analog distribution to all-digital distribution using MPEG format to the workstation.

The ATMS operator automatically controls camera switching by selecting the desired camera(s) on a GUI-based map. This results in a data command being sent to a video switch. Alternatively two cameras may be selected automatically in response to an unconfirmed incident. These selected cameras are intended to bracket the suspected incident location for confirmation purposes. The operator then may directly control camera pan, tilt, zoom, focus and iris through data commands sent to the selected camera control receiver in the field. The interface to the switch and cameras is through two serial ports on the ATMS Applications Server. These ports are wired to a demarcation point in the TMC computer room. The operator has control of CCTV remote functions using icons in the same window that displays the CCTV video. The current District 11 architecture uses a protocol translator that takes a legacy ATMS switch command and translates it to a form understandable to the CCTV video system.

The serial data stream used to control the remote CCR in the field is passed transparently from the RS-232 demarcation point to the selected camera using the low data rate serial network as discussed previously.

The Oracle configuration database in the ATMS database server is used to establish various parameters to properly operate the field cameras and route video to the selected monitor and display window or other display device (e.g. large screen display panel). The Camera Configuration Table includes camera location (postmile, freeway, direction of travel, x-y coordinates), camera ID, CCR ID, switch ID, switch LINE IN and the Unix device identifiers associated with the data lines for each camera and switch in the system. There is also a Monitor Configuration Table that sets up a switch LINE OUT path to a specific window or panel ID on a designated display device. Through an external application called Browse-Edit, a system manager can reconfigure the CCTV database tables to account for equipment changes.

One item currently being investigated for future implementation is an RS-232 to ATM interface. This system has the ability to create multi-drop environments through the ATM layer by establishing point-to-multipoint PVC's within the ATM fabric. It also allows video to be routed in native ATM with remote switching as part of the system design, all of which can be controlled through a remote system directly interfaced with the ATMS using ATM call setup.

SUMMARY

The San Diego regional CCTV distribution network is a unique approach to the delivery of high quality video to the TMC and promises to simplify the task of integrating freeway and arterial video surveillance systems. The use of a distributed network infrastructure to route video over a MAN provides a flexible, efficient information dissemination system capable of servicing a much broader user base. Future enhancements will simplify the control environment, architecture, and movement of data.

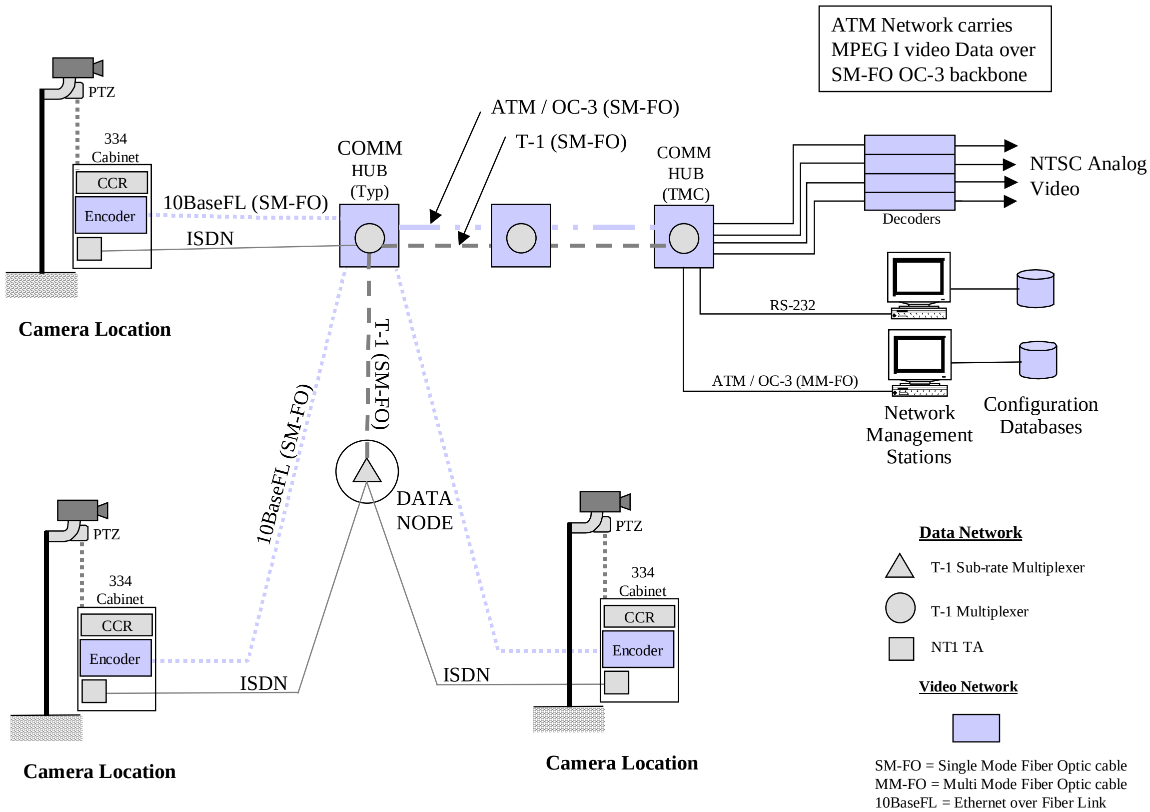

Figure 1. District 11 CCTV architecture – field to TMC.

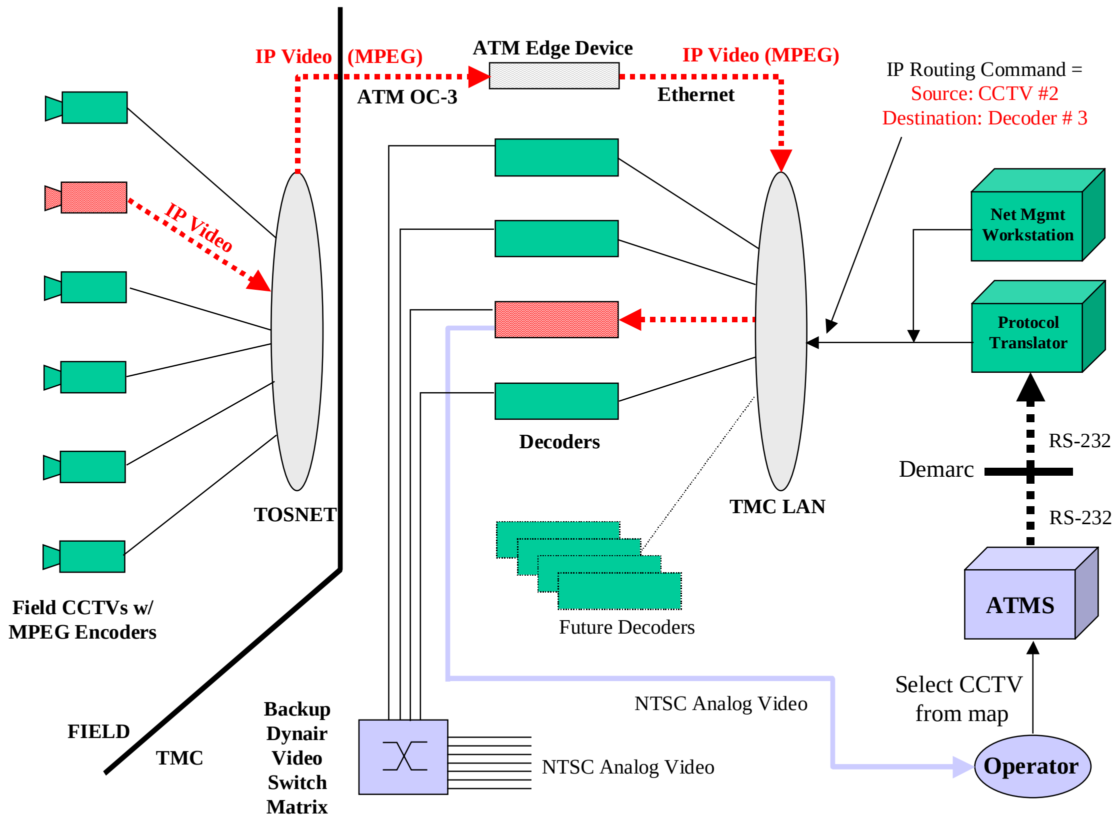

Figure 2. Internal TMC data conversion (ATM-to-Ethernet and digital-to-analog)

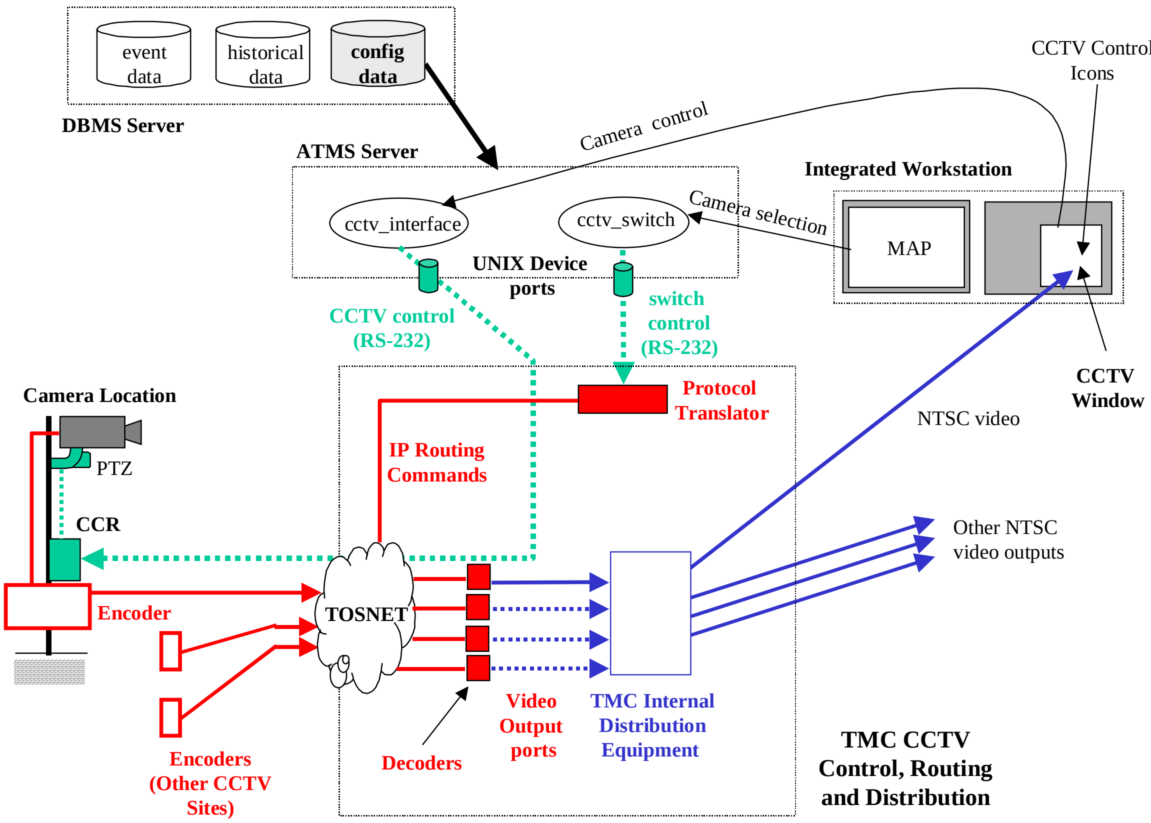

Figure 3. Advanced Traffic Management System (ATMS) CCTV control software.

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