Traffic Control and Monitoring Center Interconnectivity

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ABSTRACT

Numerous cities throughout the country are in the process of developing traffic control and monitoring centers. These centers may be as small as a workstation monitoring a closed loop traffic signal system, or as extensive as the centers in Phoenix and Atlanta which monitor and control hundreds of miles of freeway. One of the key issues being faced today is providing communications between these centers and the many devices under their control.

This paper examines the Denver metropolitan area and the effort underway to develop a fiber optic communications network to allow data and video to be shared among two cities and four separate Colorado Department of Transportation offices. These control centers are all currently operational or expected to come on-line by December, 1998. Additionally, this paper presents a process to develop interconnection among numerous agencies sharing the same goal for traffic management.

INTRODUCTION

The Denver metropolitan area is undergoing extremely rapid growth in both the City and the surrounding suburbs. To combat the resulting traffic congestion, a number of agencies either have built or are in the process of building traffic management centers. Presently, these centers range from a workstation operating a closed loop system in Denver to the Colorado Department of Transportation (CDOT) interim traffic operation center (ITOC) which monitors and controls freeway operations throughout the metropolitan area.

The primary source of video and real-time traffic data for the region is CDOT. As local municipalities begin to build and staff operations centers, they have expressed a desire to monitor traffic as measured and viewed by CDOT. Additionally, CDOT desires the ability to monitor traffic and control their ITS elements at all of their facilities in the Denver metropolitan area. In response to these requests, CDOT and the Denver Regional Council of Governments (DRCOG) formed a committee to review the communications infrastructure in the region and to identify the communications needs of each agency. Following the committees findings and recommendations, CDOT, DRCOG, and Denver have pledged to begin the process of designing and building the necessary pieces to develop this infrastructure.
AGENCIES INVOLVED

This process involves the cooperation of three key agencies, CDOT, City and County of Denver, and the City of Lakewood. These agencies and their control centers are described below, and are shown in Figure 1.

CDOT

The Colorado Department of Transportation has two existing control centers, and the desire to provide monitoring and basic control at three more. These centers currently control 15 CCTV cameras, 8 VMS, and gates for HOV access. The existing control points are at Node Building 1 and the ITOC. Planned control, monitoring, or maintenance centers will be located at the CDOT HQ, CDOT Region 6 (R6), and CDOT Region 1 (R1) sites. Future expansion will include the addition of Node Building 2 at the I-25/US-36/I-76 interchange.

City and County of Denver

The City and County of Denver are in the process of installing the communications infrastructure necessary for a traffic signal control and management system. This infrastructure includes a control center at the Terracentre in Central Denver, and a small operations center in Coors Field. The City is also in the process of providing fiber optic communications to many City buildings, which will eventually allow control and monitoring functions throughout the City.

City of Lakewood

The City of Lakewood, located immediately west of the City of Denver, is in the process of building an Advanced Traffic Management System (ATMS) and traffic operations center. This center will control their traffic signal system, CCTV cameras, and variable message signs.

PROCESS METHODOLOGY

The ultimate goal of the project is to build a communications infrastructure in the Denver metropolitan area to connect all of the vital traffic operations and monitoring centers. Upon identifying all of the key agencies, the process is broken down into five parts to determine the communications for ITS applications necessary throughout Denver. The first three are based on the National Architecture, and the remaining are necessary for the construction process. Those five parts are:

1. Logical Architecture
2. Physical Architecture
3. Communications Architecture
4. Existing Infrastructure Assessment
5. Needs Assessment
**Logical Architecture**

The first step is to determine the logical architecture necessary for communications. By defining this at an early level, the physical and communications needs can be identified. For the purposes of this project, it has been assumed that each agency has sufficient communications resources for internal purposes. The logical needs at each traffic operations center, with respect to interagency communications are:

- **ITOC**: Traffic monitoring for incident detection, verification, and dispatch/response.
- **CDOT Region 6**: Maintenance of ITS elements. Remote control of HOV access.
- **CDOT Node 1**: Local control of HOV access.
- **CDOT Headquarters**: Traffic monitoring for incident detection, verification, and dispatch/response.
- **CDOT Region 1**: Traffic monitoring of the I-70 corridor.
- **City and County of Denver**: Traffic management during incidents and special events.
- **City of Lakewood**: Traffic management during incidents and special events.
- **City of Aurora**: Traffic management during incidents and special events.

**Physical Architecture**

Identifying the physical architecture that corresponds with the logical architecture previously identified is the second step. This step asks how the logical architecture is accomplished. The physical needs at each traffic operations center, with respect to interagency communications are:

- **ITOC**: Ability to view more than six CCTV images simultaneously. Improve the video image quality being transmitted. Ability to control cameras, VMS, and gates when necessary.
- **CDOT Region 6**: Control of CCTV cameras, VMS messages, and gates from the Region 6 offices for maintenance purposes. Ability to override commands from all other centers with respect to HOV monitoring and control equipment.
- **CDOT Node 1**: Control of CCTV cameras, VMS messages and gates in the event communications to other control centers is lost.
- **CDOT Headquarters**: Control of CCTV cameras, VMS messages and gates as necessary.
- **CDOT Region 1**: View current image on CCTV cameras. Control CCTV cameras under certain circumstances.
- **City and County of Denver**: View current image on CCTV cameras. Control CCTV cameras under certain circumstances.
- **City of Lakewood**: View current image on CCTV cameras. Control CCTV cameras under certain circumstances.
Communications Architecture

Based on the physical architecture that is necessary for each of the control centers, a communications architecture is developed. Decisions concerning end equipment and network protocols are discussed, but not made at this point. Following the high level decisions reached concerning the communications architecture, the necessary decisions about end equipment and network protocols are made.

Fiber Count

Based on the number of video cameras in the region, and the amount of data that is going to be passed among the centers, the number of fibers that are needed can be determined. In Denver, a key consideration for fiber count was a segment of the backbone where only 2 single mode fibers are available. As the development of the fiber optic network in the metropolitan area continues, the two fiber bottleneck will not be an issue, but will be used for redundancy in the event of technical difficulties. The network, however, is being designed to operate over 2 single mode fibers.

Logical Network

The CDOT Information Services (IS) division has taken an active role in this project for a number of reasons, including reducing the number of leased data lines connecting CDOT offices and limiting the number of different CDOT communications networks. The IS division has requested that all CDOT data and video be passed through one network. This network would include all of the CDOT operations centers shown on Figure 1. The CDOT IS division would also allow branch circuits to the non-CDOT locations, including the City and County of Denver, City of Lakewood, and City of Aurora.

The use of the CDOT IS network provides the opportunity to develop a Logical Network to permit each agency and location to monitor information, operate equipment as necessary, allow hierarchical control, and be independent of control center locations. Additionally, it permits the location of necessary network hardware at any location and the development of a redundant ring network. If a direct connection to each control site was provided from the cameras and controlled elements, a less reliable and robust star network topology would need to be used.

Hierarchical Network

The final necessary piece of the communications architecture is the development of a hierarchical network. The existing CDOT ITS equipment along the north I-25 corridor was developed to operate and maintain the reversible flow HOV facilities along that corridor. Future expansion of the CDOT ITS infrastructure through the north and northwest corridors is being driven by the development of HOV facilities. In the interests of improving traffic flow through the region, CDOT is willing to share the video feeds and data with the cooperating agencies.

CDOT is also willing to share control of the CCTV cameras on a priority basis with those agencies. To share this information, however, CDOT needs the ability to take control of the cameras at any point. This requires the development of a hierarchical network for camera control. This type of a network is in place for CDOT use, however, it will need to be expanded to include levels of control for the Cities of Denver and Lakewood.
**Existing Infrastructure Assessment**

Knowing the communications architecture that is necessary to operate the system allows a focused investigation of the necessary physical elements. As part of the development of the Denver Traffic Signal Control System (DTSCS), the City and County of Denver and DRCOG have been in the process of documenting existing, and acquiring new communications infrastructure throughout the area.

The City infrastructure has been acquired through various means, including public-private initiatives to share the cost of trenches, public-public initiatives with other City and State agencies, and through internal City projects, such as interconnecting several City buildings on a communications network. As a result, the City has acquired a fairly extensive communications infrastructure, which is shown in part in Figure 1.

Additionally, CDOT has been acquiring communications infrastructure in the area. A majority of the CDOT infrastructure has been acquired through major re-construction projects, but public-private initiatives through the Revised Model Deployment Initiative have proven successful too.

Finally, the City of Lakewood has worked with private communications providers to develop public-private initiatives to expand their capabilities as their new ATMS is being designed and constructed.

The results of documenting the existing communications infrastructure are shown in Figure 1.

**Needs Assessment**

Performing a needs assessment identifies the missing pieces that must be constructed and/or acquired to complete the project. This includes such items as communications infrastructure and electronics. In addition to the physical items that are needed, interagency cooperation is necessary to achieve the objectives of the project.
Reviewing the existing communications infrastructure in the region provides a topology for connecting the cooperating agencies. The primary goal of this project is to provide a direct fiber optic connection from Node Building 1 to both the ITOC and CDOT Region 6. Based on the existing infrastructure depicted in Figure 1, the most efficient use of existing infrastructure to reduce the time and cost necessary to meet the stated goals in a timely fashion, was developed. This routing, (streets and centers are shown in Figure 1) is:

- Node Building 1 to Coors Field
- Coors Field to the Terracentre
- Terracentre to the intersection of Alameda and I-25
- Alameda from Colorado Boulevard to Kipling
- Kipling from Alameda to the ITOC
- Colorado Boulevard from Alameda to I-25/Evans
- Evans and I-25 to CDOT Region 6
As is shown in Figure 1, there is a significant existing communications infrastructure along this route. There are, however, missing pieces. These pieces, including gaps in conduit, empty conduit, and incompatible communications media (e.g. twisted wire pair) are being designed and constructed through the efforts of DRCOG, CDOT, City and County of Denver, and the City of Lakewood as identified in Figure 3.

Communications Electronics

Node Building 1 was designed to communicate with the ITOC via a microwave link. The development of a fiber optic network provides significantly more capacity for communications. As part of the needs assessment process, the communications equipment in Node Building 1 is being studied, and alternative communications equipment is being proposed to enhance the communications abilities of Node Building 1.

The two key elements that are being investigated are the development of a hierarchical network and providing flexibility to view and control any cameras. As stated earlier, the present network configuration was designed for CDOT, not anticipating the participation of non-CDOT entities. The issues involved with changing this configuration are underway.

One of the key decisions by the agencies involved was to replace the existing video transmission equipment in Node Building 1. The existing NTSC video transmission system is being replaced with an IP system that is capable of transmitting all of the video signals simultaneously. The introduction of IP video transmission correlates with the decision to use a SONET network architecture.

Interagency Cooperation

The final element in the Needs Assessment portion of this process is the necessity for interagency cooperation. The development of the committee to review the communications infrastructure in the region was the first step in the project, and the agencies agreeing to share infrastructure and data demonstrates everyone’s willingness to work together for success. There are, however, a number of issues that need to be resolved as this process continues.

Foremost is the development of a hierarchical network that provides each agency control when desired as well as a method to resolve conflicts. All of the involved agencies are discussing this issue. With the implementation of a broadcast video system, the only conflicts that will arise result from each agencies desire for control.

The second key element is an agreement on operations and maintenance of the system and related infrastructure. To meet the stated goals of the project, the communications infrastructure used by CDOT to connect Node Building 1 to the ITOC to Region 6 will require infrastructure owned by CDOT, City and County of Denver, and the City of Lakewood. Additionally, the City and County of Denver will likely be housing signal regeneration equipment in the Terracentre which will not be accessible except by the City and County of Denver during non-business hours.

To solve this issue, all of the agencies have begun discussing the implications of this system, and the necessity of operations, maintenance, and access agreements. Once again, due to the willingness of the agencies involved to work together, these issues can definitely be solved,
however the agreements will need to be in-place when the system is operational or problems may develop.

CONCLUSIONS

The public agencies involved in this project have been willing to coordinate and cooperate with respect to decisions and sharing infrastructure. However, the methodology used to develop this system can be used effectively where there is contention between agencies, or where things are changing rapidly. Using the National Architecture for the design of the system permits each agency to identify their objectives, and then allow the communications experts to design a system around those objectives.

Likewise, the National Architecture facilitates changes as they occur. As additional agencies become involved in the process, their needs can be added, their impacts assessed, and the architecture modified to suit everyone’s needs. Finally, this system permits an efficient use of the resources available by allowing the communications experts to make the communications decisions.

As a result of this process, the Colorado Department of Transportation, City and County of Denver and the City of Lakewood will have the ability to share information and work together to manage traffic in the Denver metropolitan area in a safe and efficient manner.