

•
•
•
•
•
•
•

Kimley-Horn and Associates,
Inc.
1515 Arapahoe St.
Suite 500, Tower 1
Denver, Colorado 80202
(303) 228-2300

Kimley-Horn and Associates

CDOT Tiered Communications Network

• • • • • • • • • •

*Prepared for ITS America, 11th
Annual Meeting and Exposition*

Gregory D. Krueger, P.E.
Systems Engineer
Kimley-Horn and Associates, Inc.
1515 Arapahoe St.
Suite 500, Tower 1
Denver, CO 80202
Phone: (303) 228-2312
Fax: (303) 228-2336
Email: gkrueger@kimley-horn.com

Co-Authors

Bill Kaseck, Colorado Department of Transportation, Region 6
Bob Wycoff, Colorado Department of Transportation, ITS Section

CDOT Tiered Communications Network

Greg Krueger, Kimley-Horn and Associates, Inc.
Bill Kascek, Colorado Department of Transportation, Region 6
Bob Wycoff, Colorado Department of Transportation, ITS Section

Abstract

CDOT is preparing a three-tiered communications network strategy that is intended to be deployed throughout the state. The first tier (Tier 1) is a statewide network connecting all of the CDOT offices. The second tier (Tier 2) is a regional network connecting CDOT offices, cities, counties and other agencies. The third tier (Tier 3) is a local network that is intended to reduce fiber needs along each corridor and provide system access throughout the Tier 1 and 2 networks.

The intent of this network is to provide a statewide standard for communications for ITS to meet the growing demand for a statewide system. By providing this standard both new and existing ITS deployments can be designed to tie into the statewide communications network, thus providing the opportunity to share data and video throughout the state.

This paper describes the concept of the Tier 3 communications network. The development of the Tier 2 network has been described in previous papers presented at ITS America in 1998 and 1999. The development of the network, including a “proof of concept” stage are occurring during late 2000 and early 2001, and will be added to the final paper.

Introduction

The Colorado Department of Transportation (CDOT) has been deploying ITS elements for the past 10 to 15 years. The early deployment strategy was to provide one fiber from each device to a hub or node facility because the cost of fiber was less than the cost of more expensive multiplexing equipment.

Over the past few years, however, the existing fiber plant installed in this method has been used up. Adding new devices required either additional fiber or a complete revision of the communication plan and system architecture. CDOT has chosen to revise the communications plan and develop a communications architecture that will accommodate both existing field devices as well as planned and unplanned future development.

There has also been a push through a number of statewide and regional initiatives to deploy a statewide network for CDOT and a series of regional networks to permit the sharing of data and video amongst various agencies. It is critical to CDOT that the architecture selected for the local communications be compatible with both the statewide and regionwide systems.

In the effort to deploy a statewide network that takes into account the limited fiber plant, CDOT is developing a tiered communication network. The intent of this network is to provide a statewide standard for communications for ITS to meet the growing demand for a statewide system. By providing this standard, both new and existing ITS deployments can be designed to tie into the statewide communications network, thus providing the opportunity to share data and video throughout the state.

Tier 1 Network

The Tier 1 Network is the statewide shared resources network. This network is intended to tie all of the CDOT regional and other key offices together. The CDOT Tier 1 Network will use Cisco SONET TDM equipment (Cisco Model 15454), operating at data rates of OC-12 to OC-48.

Tier 2 Network

The Tier 2 Network is a regional network, such as the Metrowide Fiber Optic Network in Denver. This network is intended to supplement the Tier 1 network on a regional basis, as well as to use existing fiber optic cable deployments. The regional Tier 2 networks will use Nortel JungleMUX equipment as a local network.

Tier 3 Network

The Tier 3 Network is a very localized network to connect field elements to a node or regional hub. By using the same networking technologies as the Tier 2 Network, transmitting data and video over the Tier 2 network will be easier than traditional methods of networking elements in a hub type facility.

JungleMUX

The Nortel JungleMUX (JMUX) was selected by the CDOT ITS Program Office for numerous reasons¹. These include the use of standard SONET protocols for expansion, and the ability to accept numerous types of inputs. The capabilities of the JMUX that are important to providing a standardized communications platform are²:

- Integrated SONET drop and insert multiplexer.
- Supports multiple configurations – i.e. JMUX 1 does not have to be set up the same as JMUX 2 with respect to input cards and channels used.
- Provides multiple interfaces, including Voice, Data and Video.
- Designed for harsh environments.
- Allows for external network management which will permit remote problem solving from any point on the network.
- Modular design for ease of maintenance, configuration flexibility and expansion.
- Redundancy at critical nodes through the network
 - Performs path protection switching in <3 ms
 - Disaster recovery capability in <0.5 ms/node
- Multiple configurations for flexibility – can be modified depending on resources, both financial and infrastructure availability, including
 - Point-to-point

¹ Other devices are available that have similar functionality. These include options from Teleste Networks and Vbrick systems. In addition, Wave Division Multiplexing was investigated.

² JungleMUX Product Overview, Hadi Saadat.

- Linear add/drop
- Self-healing unidirectional path switched ring
- Multiple rings
- Multiple rings plus spurs

This functionality and flexibility is highly beneficial to the development of a statewide standard. For instance, in Denver, the Metrowide project (in conjunction with the US-6 project and others) deployed a full fiber ring connecting multiple CDOT and City operations centers. This deployment permits significant redundancy and flexibility in the overall network design. In Pueblo, however, there is very limited communications infrastructure being deployed, which limits both the redundancy and network configuration. The JMUX permits both setups to function and communicate over the Tier 1 Network.

Integration with Tiers 1 and 2

Figure 1 shows the integration of the three tiers that make up the proposed CDOT communication network. At the lowest level are the field JMUXes, identified as JMUX 1.1 to 1.n and 2.1 to 2.n (note, this figure may be modified to include the Signal Depot at a later time). These are individually located in the field and communicate with the “Master” JMUX on each chain, which is located in a node or central hub type facility, such as the CDOT Region 6 offices.

The next level, Tier 2, is shown as the Metrowide network. The Master JMUXes tie into the metrowide network. The metrowide network will use the Nortel JungleMUX equipment operating at bandwidths of OC-3 or OC-12 as necessary to transmit the data and video images across the network. Only two nodes are shown in Figure 1, however the metrowide network is a ring.

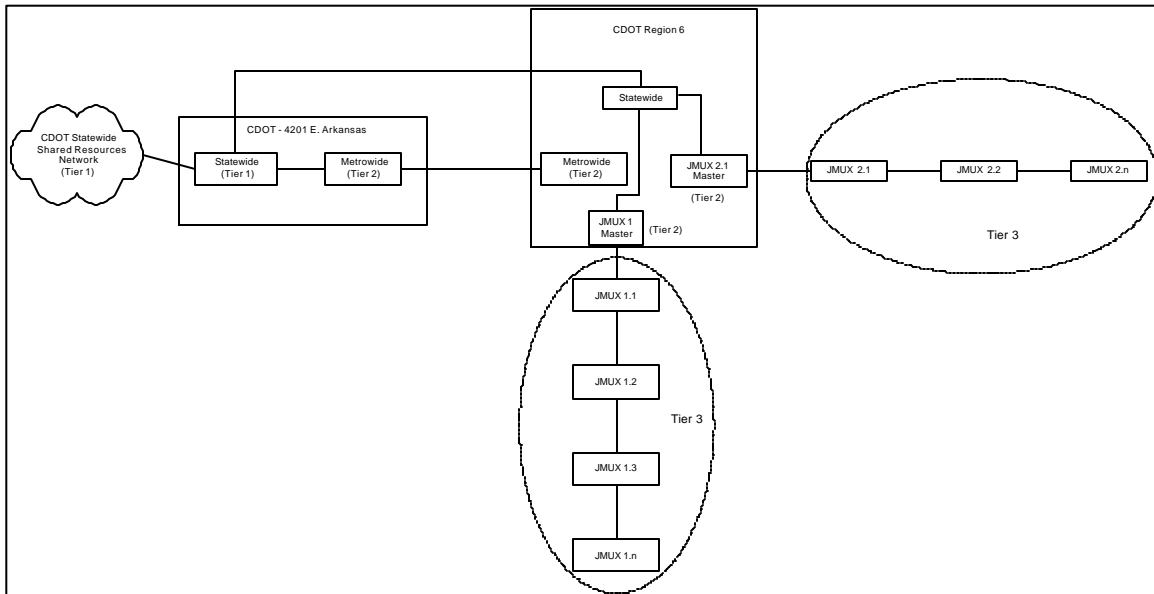


Figure 1. Three Tiered Network Approach.

The final level, Tier 1, is shown as the shared resources “cloud.” Once the data and video from the JMUX is transmitted to the Tier 1 network, all of the nodes on the network will have access, depending on security. This permits the statewide TOC to view road conditions, modify DMS messages, and perform other traffic management techniques in real-time.

As of June 2000, The JMUX is limited to a bandwidth of OC-3. The bandwidth is being increased to OC-12 to permit fast Ethernet (100Base-T). The OC-12 version of the JMUX should be released by the end of 2000. If the bandwidth needs of a corridor are greater than OC-12, a second daisy-chain JMUX equipment will be necessary along a corridor. This is represented in Figure 1 by the JMUX 2 chain.

Internet Protocol (IP) over SONET, ATM over SONET and the JMUX systems all use the same concatenated SONET structure to transmit voice, video and data. This structure permits SONET to allocate the channel and bandwidth necessary for each device, as well as the routing. Typically, SONET allocates a DS-3, OC-3 or OC-12 channel as necessary. With the JMUX, the JMUX is responsible for managing the usage of the bandwidth.

The JMUX is a stackable communication device. Each JMUX has a maximum of 16 ports in a 2” high rack-mounted (19” EIA rack) chassis. Additional chassis can be added with an electrical DS-3 interface connecting the chassis’.

Fiber Count Analysis

CDOT has typically used home run connections for all field devices into a node or other communications hub facility. When there were very few field devices, this method was acceptable. However, as the number of field devices has increased, this method is no longer an option. Additionally, there have been a number of public/private and public/public initiatives that have provided CDOT with fiber along interstate corridors, such as I-25 and I-225, without the option of adding additional fiber.

CDOT has, therefore, begun to research new options to maximize the existing fiber plant while maintaining the same level of functionality and connectivity. Along the US-36 corridor, for example, add-drop transceivers were placed at each device, creating a series of rings for the various device types that can be expanded along the entire corridor as new devices are installed.

The Tier 3 option, however, provides a different solution to maximize the use of fiber. By multiplexing all data and video at various points along a network, the existing fiber can be used very efficiently.

Three options for the configuration were discussed. Two included tying multiple field devices to each JMUX through other multiplexers and direct fiber connections. The third requires one JMUX per interchange or concentration point of devices. The first two options are extensions of the old philosophy of one device per corridor, however, as fiber is used up, JMUXes are installed to permit more devices to be added.

The third option, however, only requires four fibers along any given corridor. These four fibers are necessary for the OC-3 (or OC-12) ring. A few additional fibers may be used to tie in cameras or other devices that are not close enough to the interchange to permit a direct connection.

The recommendation for CDOT is to use the third concept along corridors where there is a dense population of ITS devices. In Denver, this would include the Central Valley area of I-25 and along I-25 south of Colorado Blvd. Where devices are more widely spaced, or more fiber is available, the first two concepts may be appropriate.

Bandwidth Analysis

To properly design a fully integrated ITS network, the bandwidth requirements for each segment must be identified. The bandwidth requirements will determine the necessary equipment needed to connect the ITS devices, and the fiber needed to accommodate the regional network.

Assumptions

To accurately describe the bandwidth needed to interconnect the existing and proposed devices, assumptions were made about the bandwidth requirements for each device. The assumed bandwidth needed per device is shown in Table 1. These values are conservative to permit future, long-term, expansion throughout the region.

Table 1.
Assumed Bandwidth Requirements
Per Device

Device	Bandwidth
ATR	28.8 kbps
CCTV	10000.0 kbps
HOV GATES	28.8 kbps
HAR STATION	64.0 kbps
HAR SIGN	28.8 kbps
RAMP METER	28.8 kbps
VMS	28.8 kbps

For the purposes of this study, all proposed or future equipment was evaluated as if it were existing. This will result in higher bandwidth requirements, giving room for additional growth to new devices as technology in ITS continues to develop.

Bandwidth Analysis

The bandwidth required for each corridor (I-25, I-225, I-70, I-270, US-36, and C-470) was determined from CDOT supplied information including maps, GPS, and other plans and studies. The results of each corridor are shown in Table 2. I-25 was broken into three segments (120th St. to 6th Ave, 6th Ave. to Colorado Blvd., and Colorado Blvd. to Lincoln Ave.).

Table 2
Corridors In Study Area

Segment	Segment Description
I-25	120th Ave. to 6th Ave.
I-25	6th Ave. to Colorado Blvd.)
I-25	Colorado Blvd. To Lincoln Ave.
6th Ave	Kipling St. to I-25
U.S. 36	Sheridan Blvd. To I-25
C-470	Wadsworth Blvd. To I-25
I-225	I-225 To I-70
I-70	Pecos St. to York St.
I-270	I-76 to I-25

These corridors corresponded with the layout of ITS devices both existing and planned throughout the Denver region. In the Denver region, there are four CDOT operated hubs, nodes or concentration points that have access to the Tier 1 or 2 network. These are Nodes 1 and 2, CDOT Region 6 and the Traffic Operations Center. The bandwidth analysis along these corridors was analyzed by each concentration point. Only the analysis for Node Building 2 is provided here.

The CDOT communications node building #2, located at I-25 and 70TH Avenue will be responsible for collecting the information transmitted along the OC-3 fiber lines running along U.S. 36 and I-270 (As shown in Figure 2). Any future ITS expansions along the two mentioned corridors will also go through node building #2.

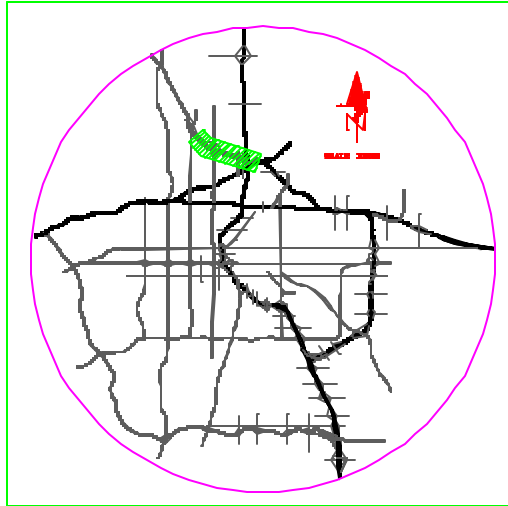


Figure 2. CDOT Communication Node Building #2 Coverage

The U.S. 36 corridor requires approximately 40,288 kbps (40.3 Mbps). The breakdown of devices along US.36 is shown in Table 3. As the U.S. 36 corridor continues to have growth along its frontage, it is expected that additional devices will be installed and the bandwidth requirements will increase proportionately.

Table 3
Bandwidth Requirements along U.S. 36

Devices	Number of Devices	Bandwidth (kbps)
ATR	6	172.8
CCTV	4	40,000
DMS	3	86.4
HOV GATE	1	28.8
Total		40,288

The I-270 segment is relatively new; thus the level of monitoring is still being developed. This new segment of I-270 allows traffic to go directly from I-70 to U.S. 36. The bandwidth requirements for the I-270 segment is 28.8 kbps as shown in Table 4.

Table 4
Bandwidth Requirements along I-270

Devices	Number of Devices	Bandwidth (kbps)
ATR	1	28.8
Total		29

The total bandwidth required along the two corridors that will communicate directly to the CDOT communication node building #2 is 40.3 Mbps. As the corridor continues to expand, new devices are likely to be placed on the south half of I-270 from I-76 to I-70. These communications will also go through the CDOT communication node building #2.

Conclusions and Recommendations

Similar analysis were done for the other three facilities to determine the bandwidth being transmitted through each. The four CDOT facilities will provide the Denver area with an ITS network which will be able collect and distribute traffic information. Table 5 provides a summary of the bandwidth requirements each corridor evaluated in this study.

Table 5
Bandwidth by Corridor

Segment	Segment Description	Bandwidth Required (Mbps)
I-25	120th St. to 6th Ave.	191.3
I-25	6th Ave. to Colorado Blvd.)	0.3
I-25	Colorado Blvd. To Lincoln Ave.	61.2
6th Ave	Kipling St. to I-25	40.3
U.S. 36	Sheridan Blvd. To I-25	40.3
C-470	Wadsworth Blvd. To I-25	0.2
I-225	I-225 To I-70	10.5
I-70	Pecos St. to York St.	40.2
I-270	I-76 to I-25	28.8

The 3 Tier communication network identified by CDOT is a solution that solves many of their needs and addresses future concerns for not just CDOT, but the many jurisdictions in Colorado. Foremost, the three-tier approach provides CDOT with a statewide communications architecture that addresses their data, video

and voice needs, both inter-office and in the field. By developing and deploying this architecture, all of the statewide requirements and ITS growth can and is addressed.

The second advantage is that this system provides a standard for the entire state to deploy. The Tier 2 ring in the Denver area has fiber drops in the offices of the City and County of Denver, the City of Lakewood and the Regional Transportation District (RTD). By specifying the Tier 2 and 3 devices statewide, these agencies can gain access to the CDOT network and share traffic data and video across a standard platform, with standard inputs and outputs.

Other advantages to this deployment include the standards-based approach that uses telecommunications based standards. These standards are independent of the field devices being used, which is another key advantage. As field devices change, the network equipment does not need to be replaced. Rather, the input or output cards are simply upgraded to provide the desired level of functionality.