CDOT Region 6
Communications Study

Tier 3 Communications Plan Concept
Technical Memorandum

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Tech Memo 1

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Introduction

The CDOT ITS Program Office 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.

This memorandum describes the concept of the Tier 3 communications network. The details and "proof of concept" will be identified in a later task, upon agreement with this concept and formalization of the network and device layout plans. This proof of concept, as defined later, will include input from the key product vendors and engineers.

This memorandum is also intended to make recommendations about the general location of multiplexors and other electronics to maximize the use of the existing CDOT fiber optic cable.

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 utilize 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.

Nortel JungleMUX

The Nortel JungleMUX (JMUX) was selected by the CDOT ITS Program Office for numerous reasons. 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 are[1]:

- 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
  - 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 statewide 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.

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

[1] JungleMUX Product Overview, Hadi Saadat.

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’.

Tier 3 Functionality

One of the goals of this project is to provide a design for five corridors in the Denver area that minimizes the use of fiber optic cable. This is to be performed by daisy-chaining JMUX equipment in the field for the most efficient use of fiber possible. Figure 1 shows this coming out of CDOT Region 6. Connected to JMUX 1 (Master) are JMUXes 1.1 through 1.n, and connected to JMUX 2 (Master) are JMUXes 2.1 through 2.n.

Figure 2 shows one concept for connecting individual elements to each JMUX in the chain. JMUX 1 in Region 6 is connected to each of the system controllers, in addition to the Statewide network (This figure may be modified to add the Signal Depot in the future). The JMUX in the field (1.1 through 1.n) is connected to the field elements through a series of add/drop multiplexers.

Each add/drop multiplexer chain requires a master of some sort in the main cabinet to transmit the information, either data or video, to the JMUX from the chain. This master is responsible for the addressing along a specific link, as well as error checking and disaster recovery in more sophisticated add/drop chains.

Connected to the master add/drop multiplexer is a series of multiplexers, one in each cabinet along the route. These tie in to individual field elements.

Figure 2 shows an add/drop multiplexer for video applications. Although this technology should be fairly similar to that of a data add/drop multiplexer, a review of cut sheets from a number of manufacturers failed to identify any that are readily available. The JMUX is an add/drop multiplexer which could be extended to each field device. New catalogs and cut sheets are being ordered to determine if there are other options available for video add/drop multiplexers. If add/drop video multiplexers are not available, an alternate solution for video will be prepared, as shown in Figure 3.

Data Transmission

There are two types of data transmission available with the JMUX; high speed and low speed. For data, most, if not all, ITS field devices require a low-speed connection of less than 38.4kbs. Higher bandwidths are possible with the JMUX, however, since the field elements do not support those bandwidths, the added expense of the high-speed data units is not necessary. Additionally, the higher speed data units do not have connections that are compatible with typical ITS devices.

The bandwidth analysis portion of this task may revise this recommendation based on the need identified in the field, and the proposed distance between JMUXes. If, for instance, the bandwidth analysis and research of available transceivers and multiplexers will require data rates at the JMUX higher than 38.4kbs, a different solution may be necessary that will utilize DS-1 circuits.

Video Transmission

Video Transmission over the JMUX is not well defined at this time. The information available from the NORTEL web site is minimal at best, and the presentation referenced earlier does not provide adequate information. The following discussion is based on deductions from the two available sources. Further research and discussions with NORTEL will be documented in the final version of this memorandum.

There appear to be two video transmission and control methods; VMAPPER-10 and VMAPPER-40. The VMAPPER-10 uses Virtual Tributaries (VT) to transport the video image. VT is the SONET structure designed for transport and switching of sub-DS3 payloads. VMAPPER-40 uses Signal Processing Elements (SPEs) to transmit data through the SONET network. An SPE is an atomic bundle of signal processing functionality which can be allocated to a single group.

The primary difference is that a virtual tributary is an established link through the network of a predetermined size. The SPE is much more dynamic and better able to handle the changes associated with new equipment, new CCTV cameras and requirements for higher quality video images.

The general features of the JMUX with respect to video include:

- Support of standard 525 line, 30 frames/second interlaced NTSC (ANSI/EIA-170)
- User controlled compression which can compress the image by a factor of between 20 and 350. Note that this is not an industry standard compression like MPEG-2.
- Transmission of high quality, full 30 frames/second transmission rates can be achieved at bandwidths as low as 6Mb per second

JMUX Location Recommendations

There are three options for locating a JMUX in the field. The first is a one-way application, the second is a two-way application, and the third is to place one JMUX at each interchange.

The one-way application is demonstrated in Figure 2. Each JMUX cabinet contains one ring for DMS, one for traffic signals and/or ramp meters, one for video, and others as needed. Along the I-25 corridor, for example, the JMUX cabinet may be located at the northern end of a segment (e.g. Colorado Blvd.), and tie in elements to the south (e.g. from Colorado Blvd. to I-225) as bandwidth and fiber is available.

The second option is a two-way application. In the two-way application, each JMUX cabinet would be located in the middle of a segment, with separate north and south rings for each device type. Along the I-25 corridor, for example, the JMUX cabinet may be located at Yale, with separate rings extending to the north to Colorado Blvd. and to the south to I-225. This will require additional multiplexers in the JMUX cabinet, but will reduce the length of each of the add/drop rings. Ultimately, this reduces the fiber count needed for each corridor.

The third option is to place one JMUX at each interchange. In this configuration, each local device (Ramp Meter, ATR, CCTV, etc.) would be directly connected to a JMUX. The advantage of this configuration is that fewer fibers are needed. The disadvantage is that more JMUXes are required along a corridor and the cost associated with the additional JMUXes.

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.

Figures 4, 5 and 6 show three different JMUX configurations as described earlier, and how those configurations impact the fiber usage along the various corridors.

Figure 4 shows the one-way configuration described earlier and shown in Figure 2. This configuration requires 12 fibers to connect the devices along the generic corridor. In parts of Denver, there are only 12 fibers available. This leaves no spare fibers in the event one has a problem, or if a second JMUX ring is required along the corridor for additional capacity or newer technologies that may not be compatible with existing JMUXes.

Figure 5 shows the two-way configuration described earlier. This configuration requires between 8 to 10 fibers along the generic corridor. Like the concept described in Figure 4, the 12 fiber limitation may become an issue if a second JMUX ring is required.

Figure 6 shows the concept of one JMUX per interchange or concentration point of devices. The generic corridor shown assumes that these concentration points are at each interchange. There are a total of 4 fibers required for this configuration along the corridor. An additional fiber or two may be used to connect cameras between interchanges to the cabinet, however, this still leaves 6 fibers along the corridor for future use or spares.

It is recommended that the concept shown in Figure 6 be used 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 concepts shown in Figures 4 and 5 may be appropriate.

Other Options

There are other alternatives available to produce similar results to those described in this memorandum. These alternatives have been researched by the CDOT ITS Program Office, but are mentioned here as a future reference.

There are two other options for field multiplexing of data and video over a SONET network. The first option is from Teleste networks at (www.teleste.com/cctv/) using their Infinitus series. The second option is from Vbrick Systems at (www.vbrick.com/products/products.html) using the Vbrick model 1000, 2000, or 3000.

The other option for minimizing fiber count while maximizing bandwidth is the use of wave division multiplexing (WDM). WDM maximizes fiber usage by operating at multiple wavelengths. This would allow, for example, four separate OC-48 channels on one “group” of fiber (A group of fiber is the fiber necessary for SONET equipment to operate. The JMUX uses four fibers.). The advantage of WDM is the virtually limitless bandwidth available. The disadvantage is the cost of the equipment, which is significantly higher than anything else being considered for or by CDOT.

Conclusions

The JMUX solution identified above presents an affordable and effective method of maximizing fiber usage at a reasonable cost. By providing a statewide standard for communications, CDOT can derive a number of key benefits, including:

- Maintenance crews only need to be trained on one component throughout the state.
- Purchase of elements can be negotiated to obtain better long-term prices for a statewide contract, as opposed to a project by project or region by region purchase.
- Meeting the spirit of the National ITS Architecture by providing a statewide standard for communications.