United States Department of Transportation
400 Seventh Street, SW Washington D.C. 20590

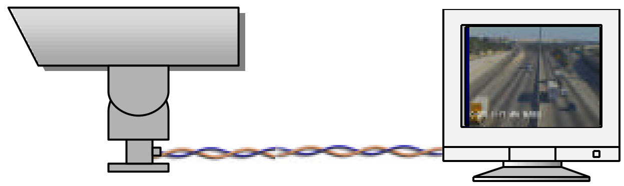
Prepared by Mitretek Systems

DSL for Traffic Video

Flyer

July 1999

Use Your Existing Traffic Signal Wiring for Full-Motion Video



Many traffic operations use “twisted pair” wiring, either owned by the public or leased from a local provider, to control field devices such as traffic signals or ramp meters. There are now commercially available communications technologies that can use this existing infrastructure to provide *full motion* traffic video *in addition* to the traditional field device control functions. These new technologies are called Digital Subscriber Lines (DSL).

The FHWA recently concluded a successful demonstration of this concept within the cities of Alexandria and Fairfax, Virginia. Here, traffic video prototypes were deployed over existing traffic signal wiring using DSL equipment.

Instead of re-cabling the city with fiber optic or other high-speed cable, this approach allows agencies to add video surveillance using their existing communications infrastructure and relatively inexpensive DSL equipment. Furthermore, these prototypes were installed and operational in one day.

Alexandria, Virginia Test Site

- **System**: DSL traffic video prototype
- **Applications**: Traffic management, incident detection, etc.
- **Functions**: Simultaneous full-motion video, camera control, and field device telemetry
- **Medium**: One twisted pair wire from the city’s existing infrastructure
- **Installation**: Installed and operational in one day

“We have been surprised by the high quality of the xDSL picture… The City is excited at the prospect of installing more cameras of this variety and is currently in the midst of a study to determine the feasibility and scope of the deployment.”

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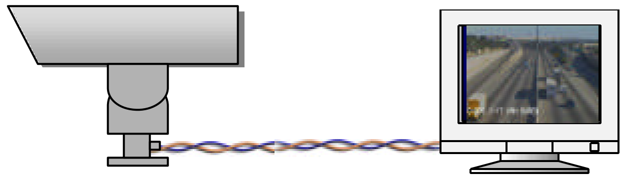
DSL for Traffic Video

Overview July 1999

Use Your Existing Traffic Signal Wiring for Full-Motion Video



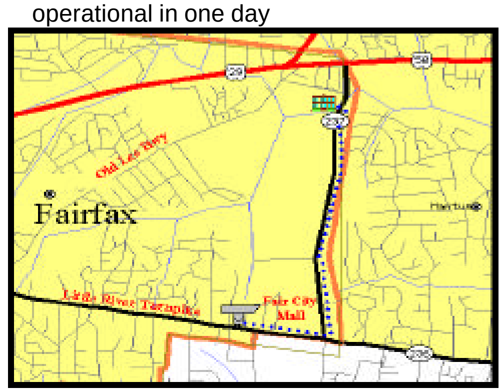
Digital subscriber line (DSL) technologies are used to implement high-speed data services on twisted pair wire. They also happen to be candidates for rapidly deploying Intelligent Transportation Systems (ITS) services over existing communications infrastructure. As part of a Federal Highway Administration (FHWA) concept study, the cities of Alexandria and Fairfax, Virginia, are demonstrating this concept with the application of these technologies to traffic video.

The ability to support such high-speed data-intensive applications on existing infrastructure can speed system deployment and provide substantial cost savings. It provides an alternative to those with communications problems that originate from financial constraint or infrastructure limitations. It also provides an option – perhaps an interim solution – for those planning to lease or install fiber-optic systems.

DSL technologies remain largely unknown to the transportation industry. The FHWA proof-of-concept was used to help establish, demonstrate, and evaluate their application within ITS, particularly traffic video.

Alexandria, Virginia Test Site

- __System__: Symmetric DSL (SDSL) traffic video prototype
- __Applications__: Traffic management, incident detection, etc.
- __Medium__: One twisted pair from the existing and unmodified cable plant
- __Performance__: DSL rates up to 2048 kbps simultaneously supporting full motion video (up to 30 frames per second and 560 x 480 resolution), camera control, and traffic controller telemetry
- __Installation__: Each system installed and operational in one day

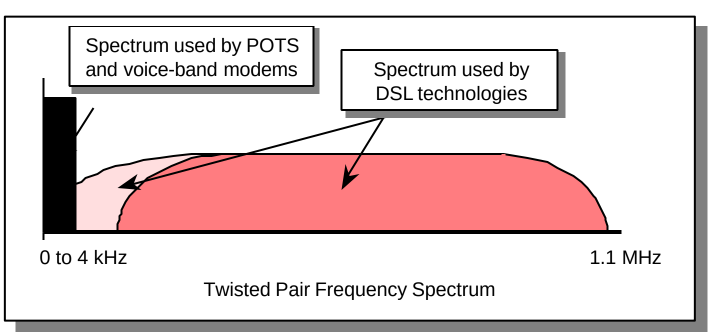


Fairfax. Virainia Test Site

Background on DSL

Telephone companies have long been developing methods of providing new high-bandwidth services to the home, and several strategies have been pursued to increase bandwidth of the "last mile", such as fiber-to-the-curb and hybrid fiber-coax. These are not yet practical for most users, but xDSL technologies can support such services during this – perhaps 20 year – transition period.

Twisted pair wire has much greater bandwidth available than is typically used. xDSL technologies utilize this available bandwidth and attain greater data rates by taking advantage of breakthroughs in modulation and digital signal processing techniques. Some of the DSL technologies use the entire twisted pair bandwidth, while others share the bandwidth with existing communications (e.g., plain old telephone service (POTS), voice-band modems).



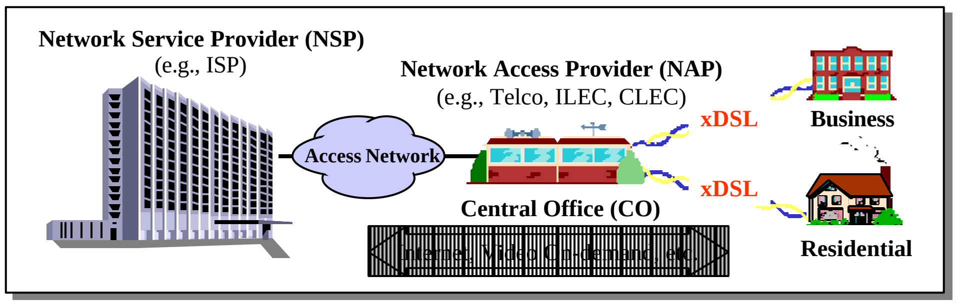
Twisted Pair Frequency Spectrum

There are over 13 forms of DSL collectively known as ***x***DSL, including:

- Asymmetric DSL (ADSL)
- Rate Adaptive DSL (RADSL)
- High Bit Rate DSL (HDSL)
- Symmetric DSL (SDSL)

Each has advantages and target applications.

The development of new DSL technologies and the enhancement of those above are extremely rapid. By year's end, many changes in these technologies will have occurred.

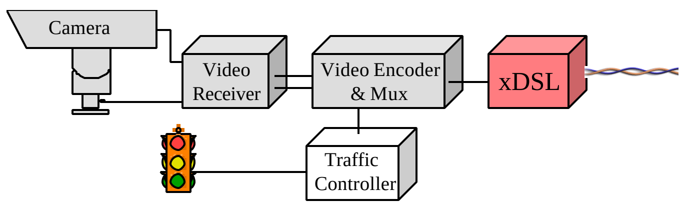


Although xDSL is often referred to as a service, it is more appropriately identified as a transport technology that enables high-speed services (e.g., Frame Relay and Asynchronous Transfer Mode (ATM)). Applications supported by these services include Internet access, video on-demand, LAN extension, etc., and the numbers and types of applications continue to grow.

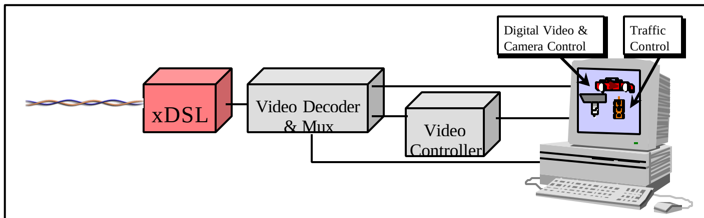
The xDSL equipment being developed to support these services and applications can also be used to support high-speed, data-intensive applications for ITS. Like the telephone companies, State Departments of Transportation (DOTs) have an enormous investment – and usually an extensive existing infrastructure – in twisted pair wiring. This provides an interesting alternative for those planning to lease communications or install new communication systems.

xDSL for Traffic Video

In their application to traffic video, xDSL technologies provide the ability to multiplex video transmissions over the existing twisted pair infrastructure currently used by DOTs for freeway management and traffic control.



Remote Site



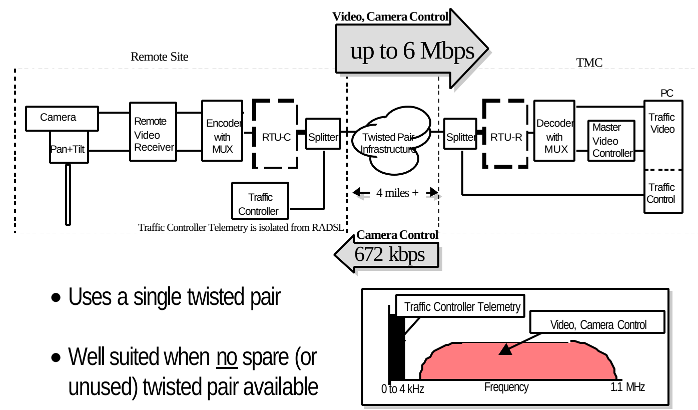
Traffic Management Center (TMC)

The general concept takes advantage of the fact that all non-DSL components comprise common and unmodified traffic video equipment. They are the components of systems in use today. Along with TMC computing resources, these would include:

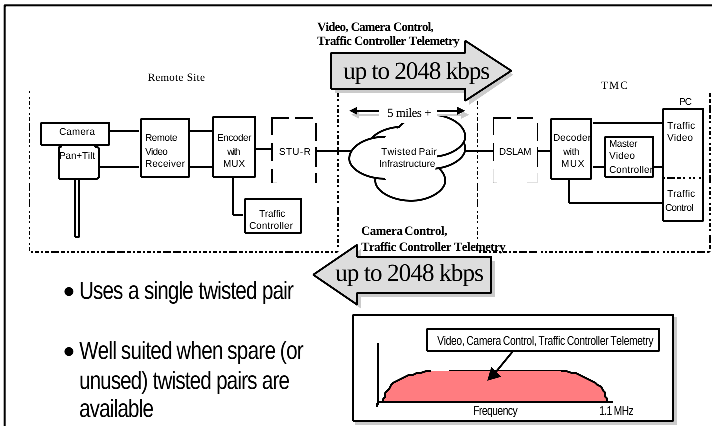
- Traffic video components (color camera, pan & tilt unit, remote video receiver, master video controller)
- A video encoder/decoder pair ("codec") with communications multiplexers

The field device, such as the traffic signal controller illustrated above, is merely the original equipment for which the twisted pair is used. xDSL system components provide the means of communication between equipment in the field and that at a TMC or intermediate communications hub.

Several xDSL technologies were considered for prototype, but while most can provide a solution, particular aspects make them more or less attractive, including: infrastructure limitations, equipment interfaces, and technology lifecycle and availability. The FHWA concept study considered the SDSL and RADSL technologies. While the concept is rather basic, one should still obtain the appropriate communications expertise when selecting any DSL solution.



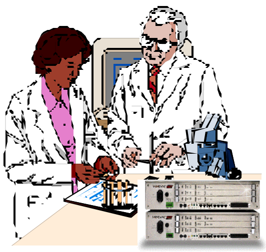
RADSL Prototype



SDSL Prototype

Regardless of the enabling DSL technology, the concept remains the same, "provide integrated traffic video and field device communications over the existing twisted pair infrastructure".

Prototype Evaluation



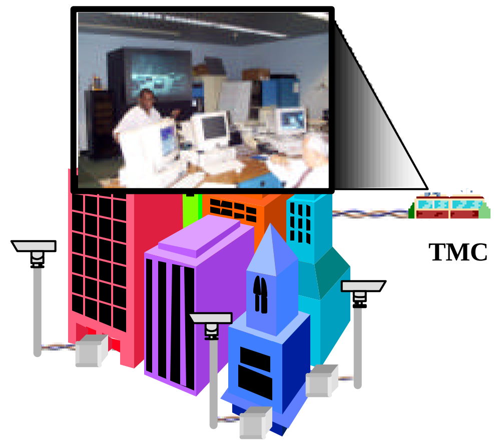
The FHWA study was conducted in two phases: an initial laboratory effort, and supplemental field-testing activities. Both of which included various qualitative and quantitative assessments to determine if the concept prototypes work, and if so, how well and under what conditions.

Laboratory tests showed the prototypes to operate within the limitations of their components. The xDSL equipment used in both prototypes performed well and functioned consistently when operating below their maximum distance-throughput values (e.g., 27,000 feet at 2048 kbps) – thresholds influenced by the twisted pair infrastructure, the DSL technology and product, and the DSL throughput. As with most digital communication technologies, the prototypes perform almost flawlessly until reaching these particular thresholds, then they fail.

Within these bounds, the video quality can be improved or worsened at the expense or benefit of video motion. The compromise becomes an issue of preference. When operating at higher throughputs (e.g. 2048 kbps) the prototypes are able to provide up to 30 video frames per second with 480x560 resolution, in other words, full motion video with DVD quality. At the lower DSL data rates, one must sacrifice motion for quality, or vise versa.

It's important to note that this performance would be the same regardless of what type of high-speed digital communication technology is used. The xDSL simply gives you the multi-megabit pipe.

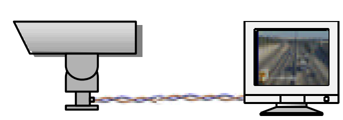
Performance is then conditional on the use of this communications resource and the capabilities of the end systems (the camera system and the codecs).



While conducting numerous laboratory tests, we could not possibly construct the endless number of scenarios one might encounter in the field. Furthermore, precisely duplicating realistic field conditions with any one of the test cases was unlikely. Therefore, field-testing activities were conducted to validate laboratory work and to demonstrate the concept in a true operational environment.

As illustrated on the cover, two sites were selected for field work, one within the city of Alexandria, Virginia, and the other within the city of Fairfax, Virginia. The SDSL traffic video prototypes deployed at these sites use a single twisted pair from the existing and unmodified cable plant and provide DSL throughputs of up to 2048 kbps to simultaneously support full motion video, camera control, and traffic controller telemetry.

Results from qualitative and quantitative field assessments were consistent with those collected in the laboratory. The field tests successfully demonstrated the capabilities of these systems and the potential for rapid deployment – each of these systems was installed and operational in one day.



Implementation

There are many issues involved when deploying a traffic video system, one of which is the choice of communications. Although commercially available xDSL equipment and services exist, they were not intended for applications such as traffic video. If choosing to deploy an xDSL solution, along with user requirements, there will be some additional infrastructure-, equipment-, operational-, and service-related issues to consider.

What type of twisted pair infrastructure is available?

While many traffic control and freeway management devices communicate over twisted pair, their communications architectures vary. Using the appropriate equipment, design, and/or services, xDSL-based traffic video systems can be implemented within any of them.

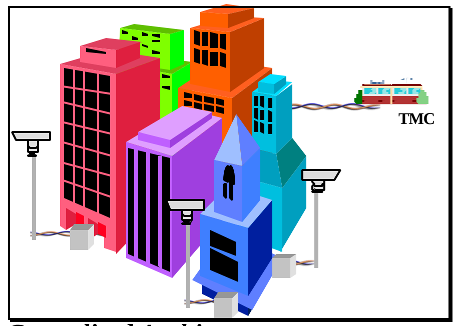
If twisted pair infrastructure is owned, how much is available? If the infrastructure is not owned, can twisted pair (dry copper) be leased?

With no unused (or spare) pairs available for dedicated use, an xDSL system that allows for POTS could be used to provide the video while isolating and preserving critical field device communication. With one or more spare twisted pair available, other xDSL systems (e.g., the SDSL prototype) offer potential solutions.

If no pairs are available, one could also lease dry copper from the local exchange carrier (LEC) for approximately $30/mile/month. This is different – and less costly – than leasing an xDSL service.

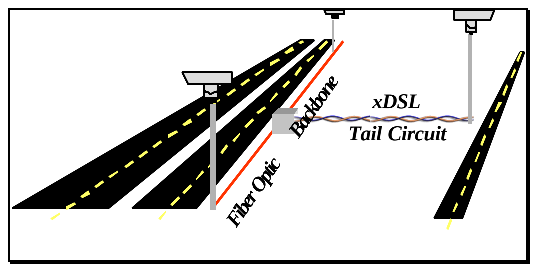
How far is the TMC or communications hub from the desired camera location?

The maximum distance at which the DSL equipment will operate is influenced by the twisted pair infrastructure, the technology and product, and the DSL throughput. Optimally, the DSL end-units could be separated by as much as 30,000 feet. As the technologies advance, this distance will increase.



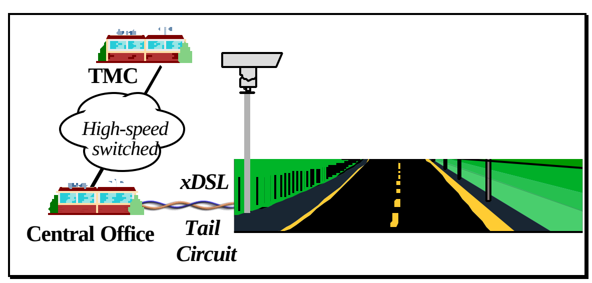
Centralized Architecture

A centralized architecture is often utilized in urban and densely populated suburban environments. In such instances, xDSL solutions provide direct access between the remote camera locations and the TMC



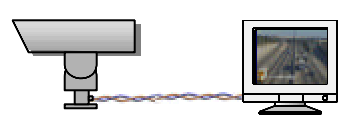
Distributed Architecture: High-speed backbone

One form of distributed architecture utilizes a high-speed backbone. Frequently used along major freeways, these architectures allow for xDSL tail circuits. For example, xDSL can provide the link between a camera along an arterial roadway and a communications hub along the backbone. This arterial location may be several miles away.



Distributed Architecture: Closed Loop (Dial-up)

A "closed loop" – another form of distributed architecture – is often used in rural environments where field devices are connected via dial-up circuits. Within this architecture, xDSL tail circuits between the remote location and a central office would be linked to the TMC using high-speed switched services. Unless switching facilities are owned by the DOT or local municipality, this implementation requires the availability of xDSL services from local network access providers.



What infrastructure related impairments exist?

Bridged taps, splices, loading coils, and various forms of noise will all affect DSL transmissions. The age of the twisted pair is also an issue. Such impairments will reduce the attainable distance-throughput thresholds, but the DSL technologies are fairly robust and designed to compensate for many of these impediments – except loading coils. xDSL technologies will not work with loading coils on the line.

Will video signals be multiplexed with other communications?

The need to integrate camera control and/or field device communications will require either multiplexing capabilities in the codecs or the use of a DSL technology that allows for POTS.

How many cameras are needed at any one location?

If available, one could use separate twisted pair to support collocated cameras. If individual pairs are not available, one could integrate multiple-camera systems on a single DSL circuit – a solution that would limit maximum performance due to shared bandwidth.

What are the recurring and non-recurring costs if the infrastructure is owned or if leasing dry copper (not an xDSL service)?

If the infrastructure is owned, non-recurring equipment costs can range from $2000 to $4000 per DSL – depending on system design, line quantities, technology and product, etc. If leasing dry copper, one would have an additional recurring cost. In either instance, the costs are far less than those associated with installing a fiber-optic system.

If intending to lease an xDSL service, will the local provider have that particular service available?

Those who must lease DSL services are obviously restricted to the local providers' offerings (both of cost and availability). Although the cost/benefit of DSL services is often far better that that of traditional T1 or ISDN services, consider leasing dry copper and purchasing the DSL equipment.

How will a DSL solution be used?

If planning to migrate to a new communications system, DSL technologies can be used to support temporary installations. Remember, the camera system and codec equipment used for these installations is the same as that which would be used for any other digital transmission technology. Migrating to the new system (e.g. fiber-optic) becomes a simple matter of replacing transmission equipment – all video system components remain. The xDSL equipment can then be used for a new site – temporary or permanent.

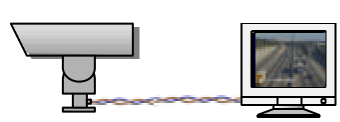
The DSL technology is also good for transportable video solutions, monitoring a special event for example. Recall the DSL-based prototypes were installed and operational in one day – without modifications to the cable plant.

In addition to traffic video surveillance, the DSL technologies can also be used to support other high-speed applications, such as multimedia dissemination (e.g. video and data to kiosks).

Who should help with a DSL solution?

If considering DSL for traffic video (or other applications), obtain the services of a communications expert.

Other issues involve xDSL product availability, systems interface compatibility, DSL equipment interoperability, etc. Ultimately, such considerations will depend on where and for whom the system is deployed.



Summary

xDSL technologies show great potential for their application to ITS. The FHWA efforts validate the concept of xDSL-based traffic video, but more importantly, they effectively demonstrate the value of this technology to the transportation industry.

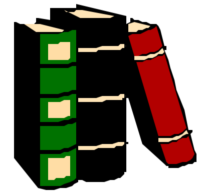
"We have been surprised by the high quality of the xDSL picture. The camera has been very useful in detecting incidents and congestion for the study area. It also has been quite beneficial as a public relations tool. The installation of the camera was very straightforward... We plan on moving the camera soon to test its capabilities at longer distances. The City is excited at the prospect of installing more cameras of this variety and is currently in the midst of a study to determine the feasibility and scope of the deployment."

David L. Jones, P.E.
Traffic Signal Systems Engineer
Alexandria, VA

Although the FHWA study focused on traffic video, the numbers and types of high-speed data-intensive applications will grow and subsequently increase the demand on transportation communication systems. The ability to support such applications on existing infrastructure offers many benefits.

To learn more about xDSL and the application of this technology to traffic video, refer to the following resources and contacts.

Resources:



"The Application of Various Digital Subscriber Line (xDSL) Technologies to ITS: Traffic Video Laboratory Assessments",
Biesecker, K. and Charleston, G., Mitretek Systems, February 1999.

ITS Electronic Data Library (EDL), document #9306
http://www.its.fhwa.dot.gov/

"The Application of Various Digital Subscriber Line (xDSL) Technologies to ITS: Traffic Video Field Assessments , "
Biesecker, K. and Charleston, G., Mitretek Systems, June 1999.

ITS Electronic Data Library (EDL), available July '99
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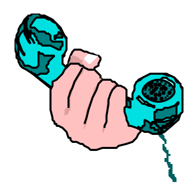
For further information on xDSL, visit the ***ADSL Forum*** at www.adsl.com

Contact:



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