WHITE PAPER

Intelligent Transportation Systems and Communications

ITS systems truly get up to speed only when they're integrated with carefully designed broadband communications networks

In a large midwestern state, a county road commission collects traffic data at major intersections, and then transmits the data via wireless broadband networks to enable real-time remote traffic signal control. In a major European capital, built-in roadway sensors detect traffic tie-ups due to accidents or weather, then immediately transmit the information to the centralized traffic control center via a high-speed wireless communications network. Sensors mounted on highway-bridge infrastructures communicate with Department of Transportation control facilities to identify conditions that could lead to structural failure. Through applications such as these and many, many others, Intelligent Transportation Systems (ITS) are beginning to revolutionize traffic management and control all around the world. But ITS systems can't do it alone.

Communications are the lifeblood of intelligence. Without the ability to gather data and distribute information, the intelligence in a system will have virtually no impact on its surroundings. This is particularly true in ITS where access to and influence over the transportation system can only be achieved with an effective communications network. Only then, can ITS achieve its full potential.

AN EFFECTIVE COMMUNICATIONS SYSTEM FOR ITS MUST BE DESIGNED AS A CAREFULLY PLANNED NETWORK

The Need for a Network

An effective communications system for ITS must be designed as a carefully planned network. If allowed to grow organically or on a piecemeal basis, it is unlikely to have the capabilities needed to meet current needs. A piecemeal strategy also severely limits the expansion capabilities of a network that will be required to grow as ITS capabilities evolve. This suggests that the roadmap for the communications network to support ITS is worthy of the same study and planning required for all other long-range plans made in managing transportation needs.

Analogous Architectures

A common architecture design for complex networks is referred to as hierarchical or layered. The roadway system is itself a layered architecture running from the streets in a residential neighborhood to the expressways and providing high volume backbones through a region. A communications network may be designed using a similar hierarchical structure.

Layered Communications Networks

There are four essential layers in a roadway network:

- Expressways
- Arterial Roadways
- Secondary Roadways
- Residential Streets

Similarly communications networks are also organized in a hierarchical fashion and consist primarily of four main types:

- Backbone Layer
- Backhaul Layer
- Distribution Layer
- Access Layer

Each of these network layers has a primary function that drives its most important characteristics. Similar to intersections in roadways; each network layer is interconnected through Points of Presence (POP) that allow communications traffic inside and outside of that layer. The POPs also serve as the main interconnection points between layers and end use devices.

Just as arterial and secondary streets may be accessed directly by businesses or residences located on main streets, it is frequently appropriate

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to allow devices with high volume communications needs to reside directly on the analogous network layers such as the backhaul or distribution layers.

A variety of both wired and wireless technologies may be integrated to provide communications in each of these layers. Wireless technologies, particularly those devices which are easily deployed and make use of unlicensed spectrum, have made network build out substantially easier and less expensive than was previously possible.

Now, let's take a closer look at the layers of the communications network, their functions and relationship to the corresponding roadways.

Expressways, or Backbone Layer

The backbone layer of a communications network is analogous to the regional expressway system, moving large amounts of data between a limited number of fixed points. Virtually all of the communications traffic that travels vast distances within a regional communications network will move through the backbone.

The bandwidth required on the backbone is measured in hundreds of megabits or higher. Depending on the size of the region it serves, the backbone may require between three and 10 points of presence. Points of presence are frequently co-located with other large fixed facilities such as traffic management centers or vehicle garages. Licensed microwave and fiber are the traditional communications building blocks for communications backbones. More recently, unlicensed point-to-point microwave has become a viable alternative.

Since so much of the communications traffic on the network passes over at least a portion of the backbone, reliability is a crucial requirement. Any loss in availability can be extremely disruptive to the entire network.

A major technological challenge for wireless in this environment is compensating for the variations in the propagation path between the endpoints of a link. Despite the fact that these are point-to-point communications links, typically located well above surrounding terrain, propagation variations or fading often occur and the radios must compensate for this via a variety of adaptive techniques.

When these devices operate in unlicensed spectrum, the lack of human management of spectrum use imposes a need for automated spectrum management to deal with the variety of disparate and uncoordinated uses this spectrum supports. The overall goal of these techniques is to ensure that the backbone network's availability is not compromised.

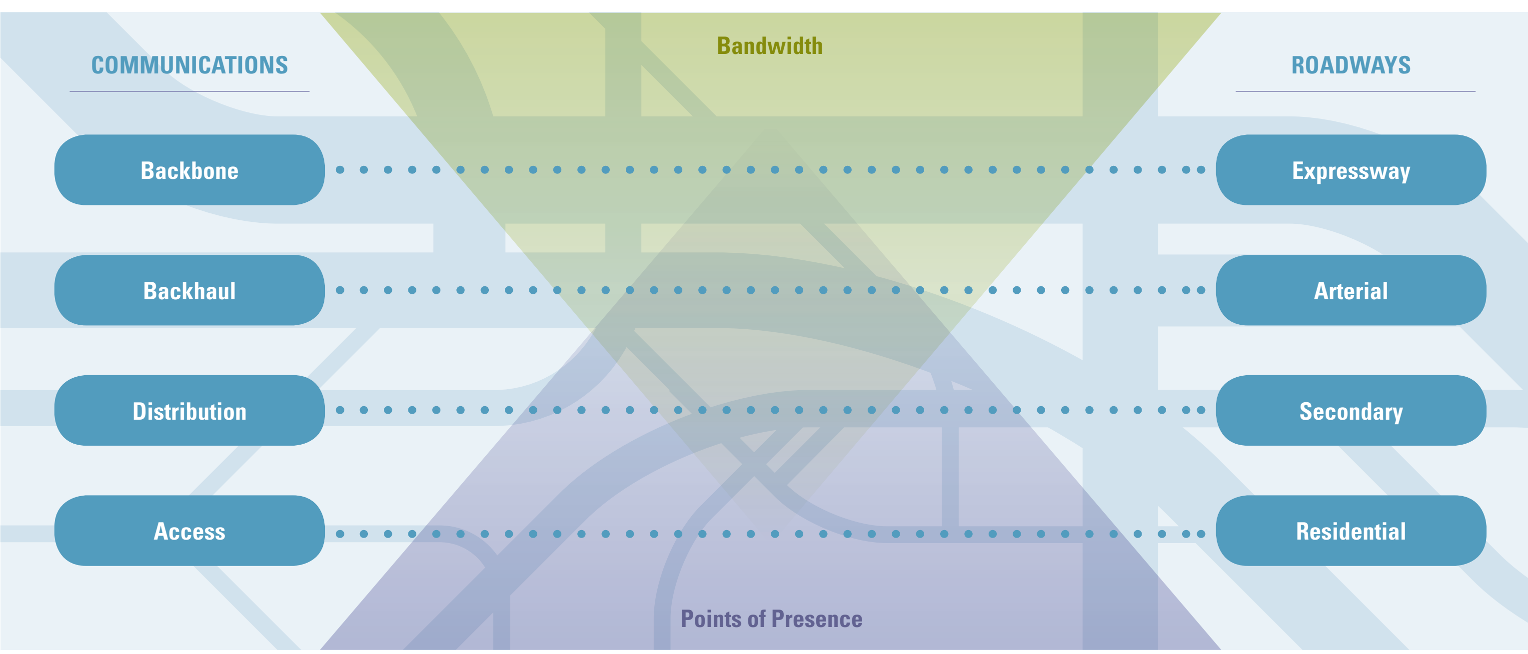
Arterials, or Backhaul Layer

The next layer in the communication network is the backhaul layer. Its job is to provide high bandwidth connectivity (tens of megabits) within its domain as well as to and from the communications backhaul. This layer is comparable to the major arterial roads in an area. In aggregate, the backhaul layer may carry more traffic than the backbone layer but, since it is more localized, any segment of the backhaul layer only sees a fraction of the total system traffic. Each segment of the backhaul layer is largely autonomous, moving communications traffic between nodes within its reach as well as to and from the backbone layer. Communications technologies normally used for backhaul are point-to-point.

Secondary Streets, or Distribution Layer

The distribution layer is analogous to the secondary streets in the roadway system. This layer need not

Below: A pictorial representation of the levels of a communications network alongside those of a typical roadway system.



handle large volumes of traffic on individual segments. Its main purpose is to multiply the points of presence of the network to a high enough number that will achieve the necessary accessibility. Bandwidth required is relatively low, compared to the backbone or backhaul layers, usually less than 10 megabits. In this layer, point-to-multipoint capability can provide sufficient bandwidth while permitting a much more cost-effective implementation than pure point-to-point.

Although an additional, lower layer—the access layer—may be appropriate in some instances, it is likely that most ITS needs will be met at the distribution layer. The bandwidth needs of applications like video surveillance and the density of points of presence when intersection traffic signals are connected to the network tend to match the characteristics of this layer.

ANY ITS NETWORK IS ONLY AS EFFECTIVE AND AS ADVANTAGEOUS AS ITS SUPPORTING COMMUNICATIONS NETWORK

Residential Streets, or Access Layer

The access layer provides the final spreading to the network POPs, making the network accessible to a large number of end users. In this way, it is similar to the residential streets in the roadway system, including the grids and cul-de-sacs of modern suburban housing developments or the back alleys of older inner city neighborhoods. Average bandwidth needs at the access layer are typically modest—under one megabit per user. Of course, since there may be a fairly large number of users supported by each access point, bandwidth needs may jump up quickly. In the ITS environment, many professionals do not believe an access layer will be needed until direct communications with individual vehicles becomes a system requirement.

Wireless technologies needed in the access layer are all point-to-multipoint because of the high spreading factor that is needed, such as many end users per access point. Suitable technologies include both WiFi and WiMAX, each of which will have slightly different use case scenarios.

Mesh Networks

Mesh networks are another wireless topology that orders the relationship between the nodes of the network and the way they interact. Mesh topologies are often employed in situations where extremely high reliability is required, such as in the backbone layer of a network using either microwave or fiber links. More recently, mesh techniques have been applied to the distribution and access layers of networks and can, if used appropriately, improve reliability and reduce network costs if used carefully.

The best analogy to meshing in the roadway network may be the traffic circle, or round-about. It can dramatically improve traffic flows and access to roadways but imposes certain restrictions on traffic behavior and loading levels.

Roadmap to ITS

The many structural similarities between communications networks and roadway networks can serve as a virtual roadmap to successful ITS networks. Because of these similarities, designers and operators are able to plan and manage their communications networks in ways that are similar to the planning and management of the roads themselves. Every jurisdiction should have a specific networking plan or roadmap, guiding its unique network deployment decisions.

The communications needs and complexity of ITS networks will increase over time, as more locations are added and as more equipment is deployed at existing locations. Because of complex system interactions and unintended consequences, ITS communications planners must balance immediate needs and existing budgets with the long-term needs and future savings made possible by planning ahead. The process is analogous to that of planning the road system, and in both cases, high-speed wireless communications networks and equipment play a crucial supporting and enabling role.

The bottom line is, any ITS network is only as effective and as advantageous as its supporting communications network.

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