

Network Management Architecture in ITS Telecommunications Networks

Authors

Michael H. Chawner P. Eng.,
President & CEO

Robert D. H. Wu,
Director of Product Management

***i*MPath
Networks**

1431 Merivale Road
Nepean, Ontario K2E 1B9
Tel: (613) 226-4000
Fax: (613) 226-4602
www.impathnetworks.com

SUMMARY

In recent years, developments in the ITS industry suggest that it is an industry on the verge of explosive growth. In support of this, relatively complex telecommunications network infrastructures must be deployed to realize the vast majority of ITS services. The quality and manageability of these communications networks will play a pivotal role in determining whether or not ITS succeeds over the long term.

Unfortunately, communications Network Management Systems (NMS) have been largely ignored to date as a fundamental component of both the design and deployment of ITS communications networks. A similar oversight in building the public telephone network many years ago proved to be a costly error that has taken years and billions of dollars to correct. It would be tragic for the ITS community not to absorb the lessons learned in deploying the public telephone network as it strives to deploy seamless and manageable communications networks of its own.

This paper will illustrate the importance of Network Management in deploying large ITS networks based on the lessons learned from the public telecommunications industry. Within this framework, the paper will present guidelines for Network Management System deployment as it pertains to ITS.

THE EARLY DAYS IN THE PUBLIC TELEPHONE NETWORK

The public telecommunications network is an excellent, if not perfect, analogy to draw on when thinking of ITS communications networks. In fact, the technologies deployed in both cases are one and the same. As such, the problems experienced by the telecommunications industry in its early days lend a powerful message to the ITS community: a lack of Network Management Systems can lead to dire consequences.

When the public telephone network was first deployed, the entire network was designed with one service in mind – voice. In the early stages of the technology, vendors of telecommunications equipment were very limited in number. Sole-source solutions were quite common in an effort to avoid interoperability problems. Unfortunately, this did not allow the public telephone companies to easily adopt technologies and services that were offered exclusively by vendors other than those of the sole-source vendor.

The telecommunications equipment purchased was generally not designed to report performance abnormalities or outright failures. Detecting the source of a problem in the network was a crude task at best. The process relied quite heavily on having end-users complain repeatedly before network administrators set into motion a tedious troubleshooting procedure. This typically consisted of tracing customer-described faults along a telephone line until the source was discovered.

Configuring network equipment was an equally cumbersome task. The network administrators would have to send dedicated technicians into the field to program the network equipment locally. This was a time-consuming and expensive task given the significant amount of tuning and adjustment required to configure a telephone line for an

end-user. The long wait experienced by a customer between ordering phone service and actually receiving the service often led to high levels of customer dissatisfaction.

Finally, the collection of information pertaining to end-user usage accounting was very difficult given the fragmented, disparate networks and the lack of a centralized reporting scheme. In networks consisting of many different types of equipment, each with different reporting capabilities, network administrators were forced to manually consolidate reported information from a multitude of billing systems. In one exemplary case, over 28 different billing systems had to be manually consolidated. As more calling services were introduced to the market and the reporting flexibility became of paramount importance, a need for a flexible, automated billing system was evident.

As the public telephone networks grew, preventative maintenance and planning for network growth became a significant concern. The possibly detrimental effects of adding new network elements to the overall network were often poorly understood until well after the elements had been deployed. Resulting network failures were typically not acute in nature. Rather, they would happen gradually over time and, as a result, be very difficult to troubleshoot. This would in turn often require another costly upgrade of network elements.

The problems outlined above collectively called for a new paradigm or model for managing the increasingly complex public telephone network. The ad-hoc development and management of telephone networks without a centralized Network Management platform for monitoring and configuring was no longer tenable.

THE EVOLUTION OF NETWORK MANAGEMENT

The problems encountered in managing the increasingly complex public telephone network were finally addressed in the late 1980's with the adoption of Network Management System (NMS) standards. In the late 1980's, deregulation and a shifting competitive landscape forced the former monopolistic telephone companies to revamp their inefficient processes in an effort to retain their customer base and maintain their profitability. As such, the concept of Network Management was quickly adopted in the interest of achieving improved fault management, equipment configuration, usage accounting, performance verification, and network security.

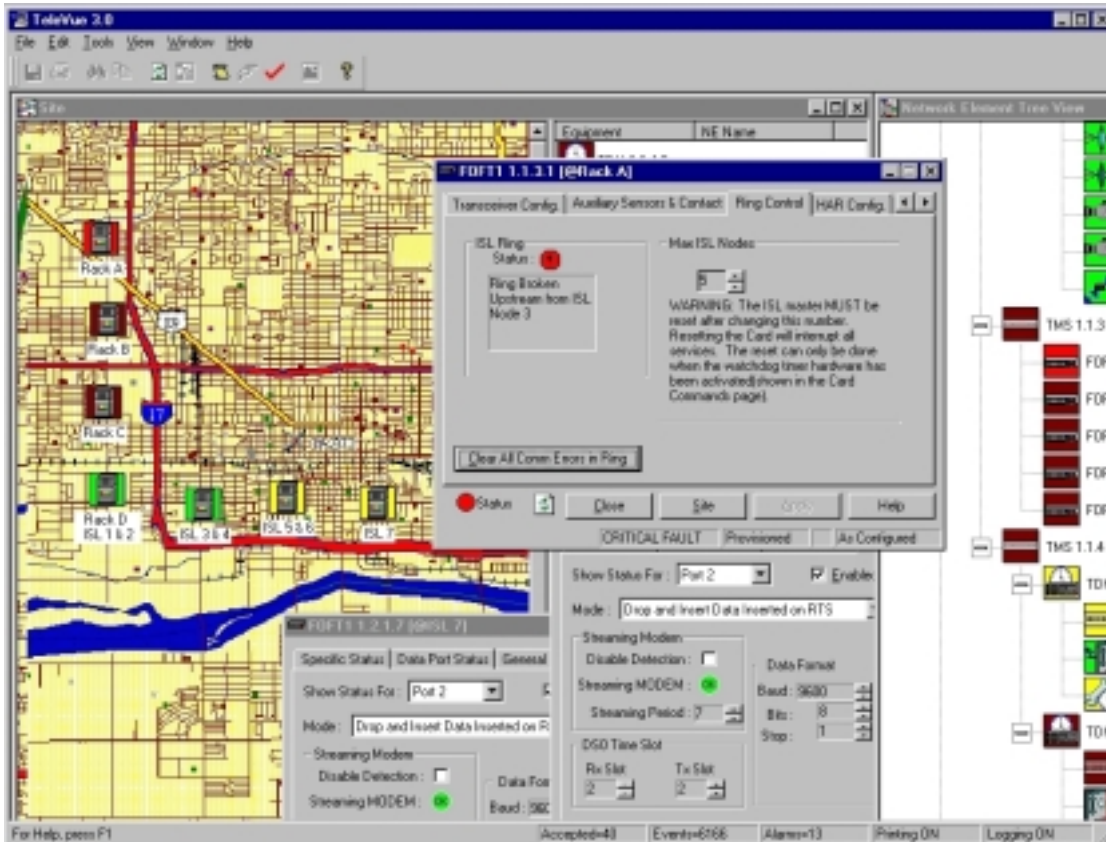
The results of this transformation were outstanding from the outset. Consider the improvements (listed in Table 1 below) experienced by one telephone operating company that implemented an integrated Network Management System (reported in a private study).

Table 1: Benefits of an Integrated Network Management Solution.

Network Management Activity or Process	Improvement (%)
Average time to analyze and isolate network faults (MTTR)	83%
Time to Change Network Configuration (from manual to automated)	57%
Enhanced Revenue Collection (Lost Data/Tape or Inaccurate Readings)	5%
Increased Reliability and Usage (Fault Prevention)	10%
Number of Resources required to change Network Configuration	33%
Operations Center Resource Requirements	40%
Average reduction of order processing and equipment programming errors	11%

Examining the improvements more closely, the reported fault management savings (MTTR) were achieved through the ability to pinpoint the source of network errors. This resulted in fast isolation and quick remove-and-replace processes. The following is an example of a fault management user interface.

Figure 1: Fault Management Interface with Alarm Notification and Fault Location

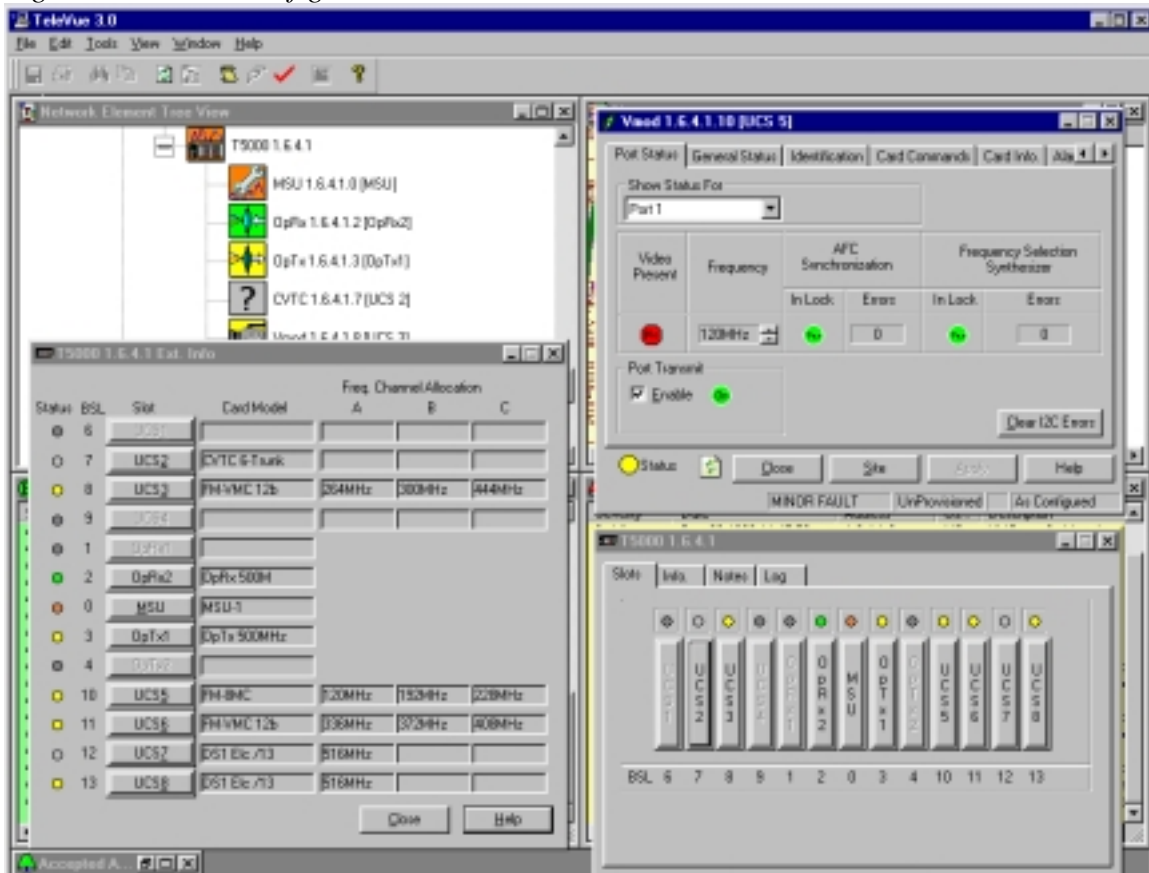


In the sample screen shown, a network failure has occurred and the location of affected equipment is shown flashing in red on the geographical map (on the left-hand side of the screen). The dialog box in the center of the screen further refines the location of the network problem so that network administrators can quickly take action to correct it.

A reduction in the time required to change a network's configuration was also enabled in the public telephone network by the deployment of equipment that is remotely configurable through a Network Management System, in contrast to previous generation of equipment that required local configuration. An additional benefit of this remote configuration capability was that network administrators could dynamically change routing algorithms. To maximize the efficiency of resource use, network operators could dynamically assign or switch bandwidth on network elements and connections during peak hours of usage. This is exactly analogous in concept to highway lane adjustments made by transportation officials during rush hour to accommodate increasing traffic flow in a particular direction.

Below is a sample screen from an NMS that allows for such dynamic bandwidth management.

Figure 2: Remote Configuration



In this example, the dialog boxes shown can be manipulated to alter the path that any given channel of video, voice or data follows back to a control center.

With regards to usage information accounting, the introduction of Network Management Systems enabled operators to *securely* collect raw data from the different network elements, consolidating the various formats automatically and presenting the integrated view to the independent billing software applications for flexible billing.

In spite of the clear benefits realized in adopting Network Management, the cost of doing so, as hinted above, was not low. The telecommunications industry was faced with significant problems as it began introducing Network Management. One of the most difficult challenges stemmed from the fact that first generation equipment was not remotely programmable (or *intelligent*). As a consequence, a large portion of the network infrastructure equipment had to be replaced. This upgrade cost could have been avoided had the original specifications for equipment taken into account network manageability.

In spite of these burdensome costs, equipment upgrades were pursued because the cost of not doing so was to lose network operability and suffer crippling maintenance costs.

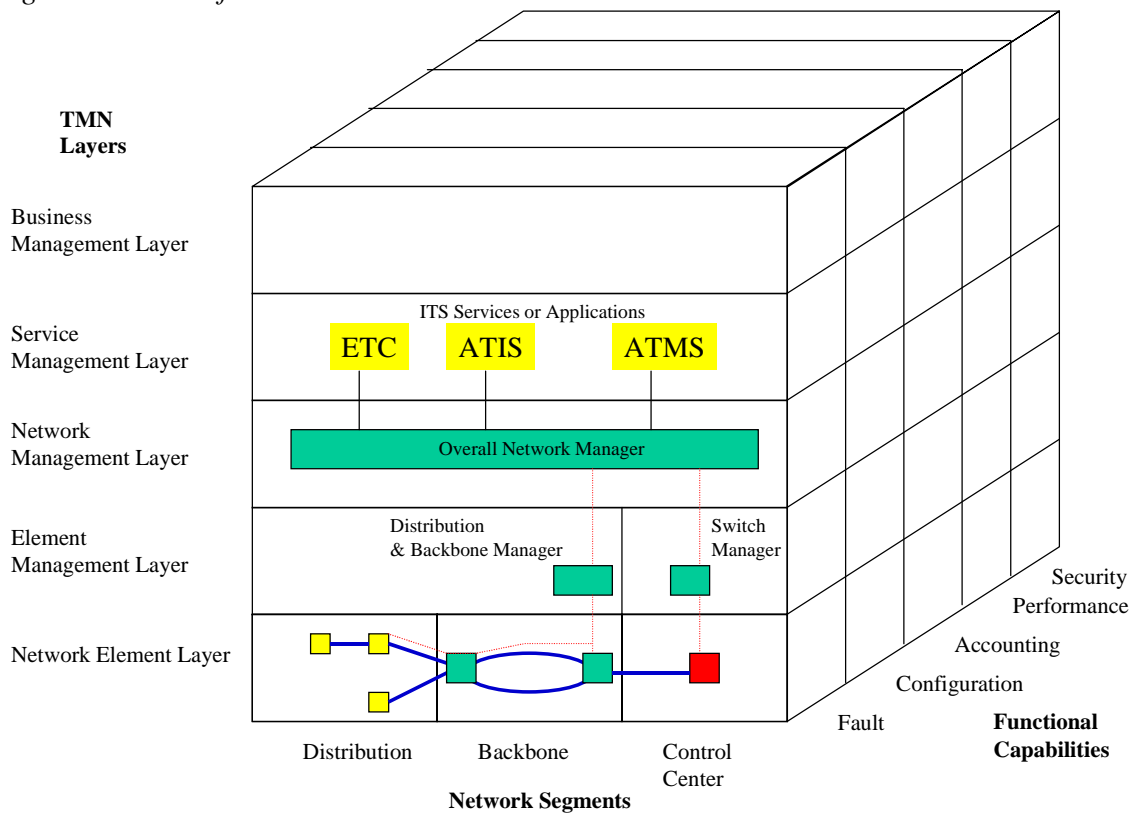
Furthermore, the benefits realized were significant enough to justify the upgrades on a pure return on investment basis.

A NETWORK MANAGEMENT FRAMEWORK

The sudden demand for Network Management Systems (NMS) in the 1980's resulted in a sub-industry of hundreds of NMS providers. This in turn led to a need for interoperability between systems, and the telecommunications industry decided that a framework for Network Management was needed. This framework would serve as guide for the future development of networks and Network Management Systems.

The International Telecommunications Union (ITU) eventually defined the Telecommunications Management Network (TMN) Recommendation M.3000. This recommendation consisted of a series of standards that collectively defined the framework. TMN essentially provides a checklist of the functional capabilities of various network elements, a guide for layered network architectures, and a building block approach to defining network investments. The following is a pictorial summary of the ITU's TMN functional architecture. Its relevance to different ITS systems is also depicted.

Figure 3: TMN's functional architecture



LESSONS IN NETWORK MANAGEMENT FOR THE ITS INDUSTRY

There are several lessons for the ITS industry inherent in the experiences of the public telephone companies over the last 25 years. These are succinctly described below.

1) ***Network Management is a Critical Tool***

Whenever a complex communications network is deployed, the ability to remotely monitor and configure the network is essential to the cost-effective operation and maintenance of that network.

2) ***The Need for Planning.***

The telecommunications industry's experience has clearly shown that without an early appreciation or vision for the importance of Network Management, it can be extremely costly to retrofit a network for Network Management as it becomes necessary. In other words, plan to deploy Network Management from the outset.

3) ***NMS Standards are Important***

A layered architecture based on open system interfaces is required to consolidate the capabilities of a multi-vendor network. In other words, it is important to build a network that provides a centralized mechanism for the collection and summary of information [either directly collected from network elements (devices) or via proxies (interpreters)]. This summary information can then be used to feed a multitude of applications (e.g., billing accounts generation) as required.

4) ***Every Network Element must be NMS-ready***

The key to achieving a truly manageable communications network involves ensuring that every network element or subsystem can interact with the central NMS. Each piece of equipment within the network must be manageable and consistent with the framework.

5) ***Use TMN as a Guideline***

ITU's TMN is an excellent guide for implementing Network Management capabilities. TMN provides a clear definition of the network management functional and architectural structures that should be considered.

NETWORK MANAGEMENT IN ITS

The need for Network Management capabilities in ITS has been highlighted as the key to building a highly reliable and available network on many occasions. As per Dr. Abernethy in (1), "it is clearly worth paying attention to installation standards and maintenance quality if critical failures are to be avoided."

There are many applications and services which may be offered within ITS. To limit the discussion, Advanced Traffic Management Systems (ATMS), Advanced Traveler Information Systems (ATIS), and Electronic Toll Collection (ETC) will be used to

illustrate the role of communications Network Management Systems within these ITS applications.

ADVANCED TRAFFIC MANAGEMENT SYSTEMS

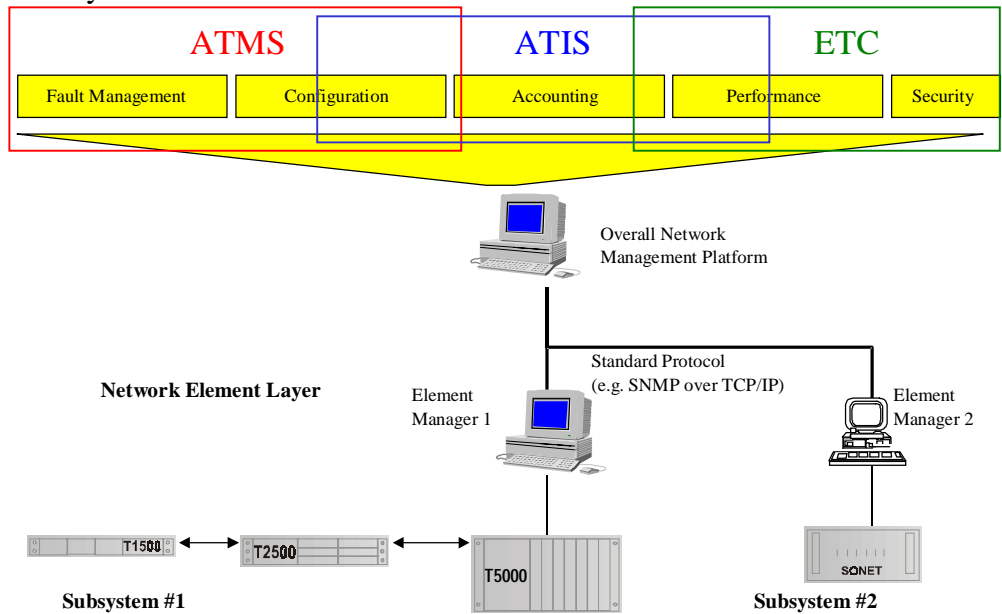
In Advanced Traffic Management Systems (ATMS), the challenge of the communications system is to integrate a multi-vendor platform, maintain a large network (i.e. high availability and low MTTR), operate the large network as efficiently as possible, and manage inter-networking between the legacy and new technologies. To achieve this, the ATMS Network Management System should adopt a layered network architecture (with proxies), concentrate on fault and configuration management functions, and deploy intelligent network elements as deep into its network as possible (i.e. right to roadside equipment at the edge of the network).

Fault Management capabilities are critical in maintaining a large network. Each network element should be able to report on failures and to correlate those reports in isolating the exact fault location. Consider a video link failure that results in a Traffic Control Center monitor losing its picture. Without fault management capabilities, maintenance personnel would have to spend time tracing and testing each device and link from the monitor to the camera to isolate the point of failure. With Network Management deployed, alarm notifications from field devices within the link would be raised. A quick analysis of these alarms would isolate the exact location of the fault. As per the sample improvement statistics cited in the previous section, operations time (and cost) can be significantly reduced, translating to substantial yearly savings for Departments of Transportation. Beyond the financial benefit, however, there exists the *public relations* benefit of having uninterrupted ITS service for end-users on an ongoing basis.

Configuration Management capabilities are also key in operating large ITS networks. Configuration management of each network element refers to the ability for these network elements to report on their current settings (e.g. serial numbers, channel configuration, etc.) and to change these settings in a coordinated network wide manner. Inventory management activities can also be minimized with the proper reporting capabilities, allowing DOT officials to save on their inventory accounting costs.

Bandwidth management capability in a Network Management System deployed for an ATMS will promote manageable network growth. This is because the optimized efficiency of the network achieved through dynamic bandwidth allocation means that equipment does not have to be added until a *true* performance bottleneck is encountered.

Figure 4: Layered Architecture



The aforementioned Network Management framework should play a very important role in enabling and maintaining successful ATMS networks. The layered architecture is particularly important because it allows Department of Transportation officials to support different vendor technologies. Referring to Figure 4, the layered architecture isolates each sub-system. These sub-systems can be differentiated based on geographical area, function, technology, or even by vendor. The network element layer (directly above the subsystem layer) allows each sub-system to have its own element manager with a proxy (interpreter) that interfaces with the standard, higher layer NMS platform. The platform can then serve as the collection point and integrates all the information provided from the field elements for the various Network Management applications (e.g. fault management, configuration management, etc.) or ITS functions (e.g. ETC, ATIS, etc.). A well defined architecture is crucial to an ATMS network because it provides the direction for growing the various components of the system and allows the ITS network operator to adopt multi-vendor solutions.

ADVANCED TRAVELER INFORMATION SYSTEMS

Advanced Traveler Information Systems (ATIS) are primarily focused on processing information collected by the ATMS for public or private users of the transportation system. Additionally, this information is often purchased by agencies that broker, resell, and/or repackage the information. The travel time delays introduced by an accident on a particular stretch of road or the most up-to-date scheduling information for light rail trains are examples of such information. In some cases, the ATIS will be required to track the usage of such information for accounting and billing purposes, similar to the case of the public telephone network.

ATIS is currently in its infancy and much of the information is shared freely or on a flat rate basis. However, the evolution of the telecommunications sector shows that billing

by the amount of information or bandwidth used is both acceptable and necessary (in the case of a commercial venture). In supporting ATIS functions, Network Management will be key to enabling business propositions or public accounting.

ELECTRONIC TOLL COLLECTION

In Electronic Toll Collection (ETC) systems, Network Management primarily serves the purpose of maintaining the integrity of information collected. This is critical because the information collected pertains to financial transactions in real-time. In addition, ETC applications often need to interact with the raw information collected by the ATMS network to provide pricing parameters based for congestion-based pricing models. For example, the price of using an interstate highway may be doubled during peak hours of usage, thereby encouraging drivers to access the highway during off-peak hours.

With ETC, the billing and accounting information generated by the electronic toll tags will be carried as data over the telecommunications network. Therefore all access to the network must be secure. Network elements must provide encryption, access checks, and verification of all security keys and passwords with the Network Management System. In addition, administration functions will be required of the Network Management platform to control and organize network access (i.e. access logging, encryption key setup, create user or network element profiles, etc.)

Much like ATIS, the ETC applications will require input from the ATMS network — especially for congestion-based pricing. A well-designed Network Management platform would consolidate the required network information to be presented to ETC software applications downstream.

CONCLUSION

In summary, the Network Management requirements of ITS networks are becoming more significant as networks grow and more applications are deployed. The management issues experienced in the public telecommunications industry are today appearing in some of the early deployments of ITS networks. The ITS industry should take precautionary measures today to avoid these mistakes by ensuring that Network Management is both planned for and deployed on ITS projects, thereby maximizing operational efficiencies and cost savings.

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