The Role of Geospatial Information Systems in Utility Telecommunication Infrastructure Management

3002013394

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3002013394

Technical Update, November 2018

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ACKNOWLEDGMENTS

The Electric Power Research Institute (EPRI) prepared this report.

Principal Investigator
J. Simmins

This report describes research sponsored by EPRI.

The following individuals provided critical information to this report:

T. Godfrey
J. Herman
J. Estrada
K. Oleksak

This publication is a corporate document that should be cited in the literature in the following manner:

The Role of Geospatial Information Systems in Utility Telecommunication Infrastructure Management. EPRI, Palo Alto, CA: 2018. 3002013394.

ABSTRACT

This report investigates some of the more popular network management systems (NMS) and their relation to enterprise geospatial information systems (GIS). The report looks at the geographical capabilities of NMS and the gaps between NMS functionality and usefulness to the enterprise. Also discussed is what is needed in future projects to bring the world of telecommunications asset management in line with the rest of the utility enterprise.

Keywords
Telecommunication
Geospatial Information System (GIS)
Geographic Information System
Network Management System (NMS)

ELECTRIC POWER RESEARCH INSTITUTE

Deliverable Number: 3002013394

Product Type: Technical Update

Product Title: The Role of Geospatial Information Systems in Utility Telecommunication Infrastructure Management

PRIMARY AUDIENCE: Utility telecommunication asset professionals

SECONDARY AUDIENCE: Utility GIS professionals

KEY RESEARCH QUESTION

What is preventing the integration of telecommunication asset data with the rest of the utility enterprise?

RESEARCH OVERVIEW

This research was the result of a review of prior Electric Power Research Institute (EPRI) reports, an Internet literature survey, and informal discussions with several key utilities that are trying to incorporate their telecommunications asset management into an enterprise management strategy.

KEY FINDINGS

- The telecommunications domain of utilities lags behind the electrical network in enterprise integration.
- There is no agreement on an enterprise semantic model for telecommunications network management.
- Proprietary enterprise and network management systems dominate the domain without an easy solution for interoperability and GIS integration.
- Enterprise coordination of telecommunications asset management is hampered by lack of standards and interoperability.

WHY THIS MATTERS

Without the use of a semantic model and integration standards, the complexity of integration has been found to increase with the square of the number of applications. This puts a burden on the utility that is unnecessary and avoidable.

HOW TO APPLY RESULTS

This report complements the prior reports on network management and telecom network metrics, to include a geospatial model of the network. The combined set of data representing the network across these three perspectives provides a foundation for telecom network planning. The application of this data in the telecom planning process is the subject of a planned follow on project. The results also point to a longer term opportunity to develop telecom network models using a similar approach to power system network models and eventually enable integration between them.

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INTRODUCTION

What Is a Geospatial Information System?

"A geographic information system (GIS) is a framework for gathering, managing, and analyzing data. Rooted in the science of geography, GIS integrates many types of data. It analyzes spatial location and organizes layers of information into visualizations using maps and 3D scenes. With this unique capability, GIS reveals deeper insights into data, such as patterns, relationships, and situations—helping users make smarter decisions" [1].

Figure 1-1 illustrates the "layers" possible in a GIS.

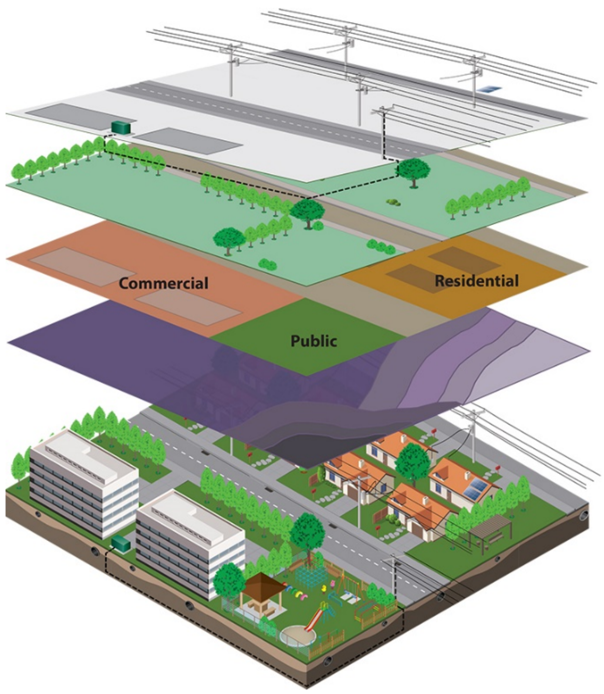

Figure 1-1
An artist's rendition of the "layers" possible in a geospatial information system and how they might be related
Source: Peery [1]

The primary uses of a GIS include the following:

- Identifying problems, especially across data sets.
- Performing forecasting and planning.
- Monitoring change in assets or environments.
- Establishing priorities amongst competing projects.
- Responding to events and managing the response.
- Visualizing and understanding trends.

Use of Geospatial Information Systems by Telecommunication Companies

The use of GIS by telecommunications companies has been *de rigueur* for decades, coming about during the era of deregulation in the 1990s [2]. Coincidentally, this era was also when many electric utilities were converting from automated mapping and facilities management systems and paper maps to true GIS. GIS has allowed telecommunication companies to ascertain and plan the most suitable method of transmission, plan wired and wireless networks, and target customers. GIS allows the ingestion and analysis of geodemographic data from both current and anticipated customer populations. For example, GIS can be used to determine the most cost-effective means of servicing new customers. Topography, population density and affluence, predicted population trends, and capital costs all factor into the calculation of a new telecommunication transmission route. It may be more cost effective to route new transmission lines to new communities through a comparatively tortuous route rather than expand current duct space along a more direct route.

Mobile telephone companies use radio propagation models to find the best sites for building cellular base stations. Propagation models in GIS can inform engineers of the terrain, vegetation, and other obstacles that may interfere with radio signals. Engineers need to site cell towers higher than the surrounding area and away from vegetation or buildings that may cause "dead zones" in the service territory. Data from the U.S. Geological Survey, county and city sources, and satellite imagery are readily combined in a GIS and used for analysis.

In an asset-intensive industry, such as telecommunications or electric utilities, updating and maintaining good records of asset history and health are major components of running a profitable organization. For example, telecommunication equipment is no longer upgraded based solely on age; market factors are considered, as well, so that each infrastructure upgrade is also intended to attract and keep new customers. GIS provides the level of automation needed in planning, designing, building, and upgrading telecommunication infrastructures. This relieves some of the constant pressure to improve operational efficiencies. A list of common telecommunication GIS uses by Barata [3] includes the following:

- Updating topographic maps supplied by city councils
- Overlaying routing and network elements and prepare cabling and piping maps
- Preparing cabling diagrams incorporating cable junctions and connection boxes
- Updating all these maps, plans, and diagrams in predetermined time scales
- Preparing maps, drawings, and sketches required by external bodies, both for work to be carried out by engineers in the field and in reply to specific requests made by third parties for data capture and conversion

Table 1-1 lists some advantages of GIS in infrastructure management.

Table 1-1
Advantages of infrastructure management using geospatial information systems

Key Advantage	Function Definition
Enterprise integration	Ability to integrate with other engineering and operations tools such as work management, outage management, planning, and so on.
True engineering system	Has intrinsic analytical capabilities and supports a variety of engineering design and analysis tools.
Multi-user edition	Can be edited by several technologies and persons simultaneously.
Data access and reporting	Self-serve reporting and analysis tools are available, including web publishing and sharing.
Version and conflict management	Visualize any number of versions. Highlight and resolve conflicts.
Software as a service	Many packages allow cloud or web-based implementations.
Mobile capability	Able to use phones, tablets, laptops, head-mounted displays to visualize and interact with data. Can be used in conjunction with other applications such as work management in the field.
Scalability	GIS applications are scalable vertically and horizontally.
Vendor sustainability	Most vendors have been in business for decades and will be for the foreseeable future. Vendor replacement projects are common and well-documented.
Large, qualified user base.	GIS understanding and skills are well known and plentiful.
Extensive toolset	Large selection of tools for obtaining, ingesting, and comparing data from various data streams. Integrations with spatial analytic packages, machine learning, and software languages such as Python. Ability to leverage unmanned aerial vehicle (UAV) data, satellite data, and remote sensor data.
Enabling technology	Ability to provide real-time updates (such as weather), plan truck routes, compare telecommunication asset location to other utility assets, and provide historical perspectives such as service history.
Cost basis	GIS is probably an existing application in most utilities and, therefore, introducing new data is relatively inexpensive.

2
USE OF GEOSPATIAL INFORMATION SYSTEMS FOR TELECOMMUNICATION IN UTILITIES

As reported by the Electric Power Research Institute (EPRI), the NMS becomes more of an enterprise tool if it interfaces with GIS, the asset management system, and the work management system [4]. GIS provides additional value in that the telecommunications asset infrastructure is one of many possible “layers” to the GIS. Utilities expressed a need for geospatial correlation (“single pane of glass”) across the different layers of the electric utility [4]. The added ability to exchange data with a GIS platform allows the utility to visualize network and supervisory control and data acquisition (SCADA) information at one time. The SCADA information might include the location information for transmission and distribution (T&D) lines, substations, and service crews. GIS supports the entire enterprise and provides a platform for cross-business collaboration. As a result, the GIS can provide information on the as-designed, the as-built, and the as-operated telecommunications network model and is able to relate any of these models to the rest of the enterprise assets. This allows the following advantages:

- Enables visualization of entire network and relationships between network components (upstream and downstream devices).
- Allows “layers” of network infrastructure to be turned on and off.
- Allows overlay of telecommunications network with electrical grid (ability to display transmission and distribution system components).
- By definition, GIS is an enterprise tool that spans the entire organization.
- Several products discussed with utilities were reported to have a mapping system within the product or an application programming interface (API) to Google Maps.

Esri’s ArcGIS was reported to be able to display NMS device location, status, and alerting in the same GIS system that presents SCADA (energy management system or distribution management system) information. Other utility GIS platforms may also have this ability. This is not meant as an exhaustive list, so absence from this list does not mean that an interface is not available.

Several utilities reported having their fiber optic information in the same GIS database with T&D (typically Esri ArcGIS). However, several others said that they also maintain a parallel GIS-related records system tailored to telecommunication. These packages provide abilities to maintain extensive details on items such as the fiber splicing configuration and wavelength assignments.

The use of a telecommunication-specific, outside-plant GIS records management system is an improvement over the outdated practice of maintaining the information in a set of disparate, static documents. This has often been the first step when an electric utility constructs a fiber optic network. Records were created with tools such as AutoDesk AutoCAD for physical routes, Microsoft Excel spreadsheets for splicing details, and Microsoft Visio diagrams for equipment interconnections.

The lack of a complete, centralized, GIS-based network management system has serious implications for work in the field. Crews are at risk of inadvertently causing damage to equipment and outages due to out-of-date or inaccurate spatial information. Replacement of static, records-based management with enterprise-wide, telecommunication-specific GIS tools is becoming more common [5].

The main gap that has now been identified is the integration of the outside-plant-focused GIS tools with the multiple, inside-plant-focused NMS tools used for various types of network equipment that is connected across the fiber infrastructure.

The following sections describe some of the NMS tools that the utilities interviewed have been using and the current ability of the tools to integrate with outside-plant GIS tools.

MegaSys Telenium

High-Level Survey of the Product Capabilities

The Telenium Network Management software suite architecture follows the Telecommunications Management Network (TMN) model and also includes fault, configuration, accounting, performance and security (FCAPS) abilities. Telenium offers Copper, Blue, and Spectra packages, which are targeted toward network device designers, small- to medium-sized operations, and large-scale service providers.

The main strength of the product is its ability to integrate with legacy equipment and many proprietary telemetry and monitoring protocols, such as TL1, DNP3, SNMPv1, SNMPv2c, SNMPv3, ASCII, PDS, TBOS, MCS11, NETCONF, LARSE, DCP, DCPF, DCPX, FARSCAN, MOSCAD, PING, CLI, SYSLOG, DMS, Badger, NEC N21, 5ESS, IMUX 2000, PRESIDE, P4, DCM, MXVEW, and LLDP. A current list of supported network elements resides on the MegaSys website at https://www.megasys.com/downloads/disvenpu.asp.

Integration Capabilities and Gaps

Telenium has a graphical user interface (GUI) and the ability to view the physical network against a static geographical map or to display the logical topology in a statically arranged fashion. The tools to view and customize the physical and logical network displays are as follows:

- **Graphic Screen Manager (GSM).** A GUI that dynamically displays database information. A geographical GSM presents alarms and their network locations, and the graphical manager depicts real-life representations of physical equipment.
- **Network View.** Used to view the topology of a telecom network. Network View displays pipes, port names, port loads, and alarm counts, as well as other information. The network can be presented in a variety of different formats.
- **Graphical Editor.** Provides a development environment for creating maps and equipment displays, enabling users to create custom graphics based on their needs.
- The only GIS system integration that is claimed is with the open-source OpenStreetMap (OSM). This integration allows Telenium to use any OSM information as an overlay onto the base layer. Examples of useful types of information are weather or forest fire data. The product literature does not mention integration with ESRI ArcGIS or other enterprise grade

GIS. However, in discussion with the vendor it was learned that the ability to link the Telenium NMS with a utility's GIS is a custom solution that has been done as requested in the past.

Nokia Network Services Platform

The Nokia Network Services Platform (NSP) is main enterprise and carrier grade NMS for IP/MPLS and Carrier Ethernet networks. Below the NSP, various modules may be added for additional capabilities in specific areas.

The Nokia 5620 Service Aware Manager (SAM) is a product that several of the interviewed utilities have experience with. It has been renamed as the Network Functions Manager for Packet (NFM-P) and has become a module that runs under NSP. Nokia states the following about the NFM-P product [6]:

> "The NFM-P module…provides comprehensive IP infrastructure management for configuration, provisioning, assurance and mediation of IP network devices, domains and services across IP access, aggregation, metro and core. This includes mobile management from backhaul to packet core (including the latest Nokia cloud-based EPC solution), as well as IP/microwave transmission." [https://networks.nokia.com/products/network-services-platform/nfm-p]

IP route and path analytics are integrated into NFM-P via the Control Plane Assurance Manager (CPAM). The CPAM delivers multivendor IP route and path analytics to help simplify IP/MPLS control plane management. It provides proactive and real-time visualization, troubleshooting, and analysis of IP control plane protocol changes and their impact on IP routing, MPLS paths, and IP/MPLS service infrastructure.

High-Level Survey of the Product Capabilities

Nokia states the following about the NFM-P product capabilities [6]:

> NFM-P IP infrastructure management provides base Fault, Configuration, Accounting, Performance and Security (FCAPS) management with many advanced extensions for IP/MPLS tunnel management, templates and automated creation. This includes management of policies for device configuration, including for physical and logical resources, buffers, queuing, QoS marking/forwarding and access control lists (ACLs).

Geospatial Information System Integration Capabilities and Gaps

Maps are used as a visualization tool in NFM-P but only in terms of network topology. Supported nodes normally contain a configuration element for entering latitude and longitude coordinates. Today the NFM-P does not use those coordinates in a topology view. The product roadmap plan includes a geographic topology map to leverage latitude and longitude coordinates in a future release planned for late 2019.

Cisco Prime Infrastructure

Cisco Prime Infrastructure is a single, unified solution that provides wired and wireless lifecycle management, as well as application visibility and control [4]. With the Cisco Identity Services Engine (ISE), it facilitates policy monitoring and troubleshooting, and with the Cisco Mobility Services Engine (MSE) it enables location-based tracking of mobility devices.

High-Level Survey of the Product Capabilities

The Cisco Prime Infrastructure NMS provides for "provisioning, monitoring, optimizing, and troubleshooting both wired and wireless devices." The types of Cisco infrastructure products that are supported are Catalyst switches, wireless controllers, mobility service engines, wireless access points, identity service engines, UCS servers, and virtual machines.

Geospatial Information System Integration Capabilities and Gaps

The NMS tool uses graphical interfaces and logical network topology diagrams. Regarding physical layer maps, there is a capability to import location data of network assets and the physical structures that house them. GIS data can be imported in Keyhole Markup Language (KML) format. Maps are used to visualize networks and services and to support management and troubleshooting tasks.

The integration with GIS is a static rather than a dynamic process. The KML format supports Google Earth rather than an enterprise-scale GIS system such as ESRI ArcGIS.

Ciena Blue Planet

High-Level Survey of the Product Capabilities

Ciena calls their Blue Planet product an "intelligent automation platform." As a platform, it can support multiple modular functional capabilities. The software suite includes the following:

- Inventory
- Multi-domain and network function virtualization orchestration
- Route optimization and assurance
- Analytics
- Manage, control, and plan

The inventory component federates data from multiple, independent network inventory systems. This is analogous to the way that a network "manager of manager" system federates the operational management data from a set of independent network management systems.

Multi-domain service orchestration supports the automation of end-to-end service delivery across a heterogeneous network. It operates across both physical and virtual domains.

The route optimization and assurance functions provide network management and performance analytics, including evaluation of traffic and routing paths. It provides performance optimization, capacity analysis and planning for alternate paths, and post-event diagnostics of failures and disruptions.

The analytics functions provide a network-level view of behavior based on machine learning algorithms. The goal is to support capacity planning and design for reliability and robustness.

The manage, control, and plan functions provide automation of the lifecycle operations of packet and optical networks. It unifies planning and network and service management through the use of software-defined networking control techniques.

Geospatial Information System Integration Capabilities and Gaps

Blue Planet provides open APIs on the "northbound" interface. This enables access to the system and data and the ability to integrate with enterprise applications. On the "southbound" interface, Blue Planet integrates with multiple vendors' systems. Ciena offers a library of resource adapters to provide support for third-party network devices and systems. No information specific to GIS data integration is contained in the product literature.

Summary

There are three main findings from this research:

- Utilities have telecommunication-specific, outside-plant GIS systems that are in parallel to, or only partially integrated with, T&D enterprise GIS.
- For inside plant equipment, NMS systems lack any integration with the T&D enterprise or other GIS.
- One example of the impact that these gaps create was provided by project participants. It is the inability to quickly and easily determine what systems and services are carried on a particular fiber optic line segment. With T&D lines located in rights-of-way, it is not unusual for the utility to be required to relocate a structure; for example, to accommodate a road widening project. When fiber optic is part of the line the information technology or telecom group is required to prepare for the scheduled outage, often with short notice. The present state of affairs has staff pulling information from multiple NMS systems and static records to compile the necessary information as the first step before a plan can be created that clears communications traffic from the fiber line segment.

3

PARALLELS WITH THE COMMON INFORMATION MODEL FOR ELECTRIC NETWORKS

Common Information Model Description

Dealing with numerous, heterogeneous data sets has been an industry problem since the beginning of the digitization of grid data. Standards were recognized as a solution to this problem, particularly in the back office. The common information model (CIM) is a set of open standards for representing power system components, processes, and documents that were originally developed by the Electric Power Research Institute (EPRI) in North America and are now a series of International Electrotechnical Commission (IEC) standards, each with a specific focus (see Table 3-1).

Table 3-1
Summary of the three common information model standards

Standard	Modeling Focus
IEC 61970	Information exchange among systems directly involved with the operation and planning of the overall interconnected electric grid that rely on power system network models to analyze the behavior of the entire interconnected grid at all voltage levels. This often involves interactions between systems at various different participants in the grid, such as regional transmission operator (RTO), transmission system operator (TSO), distribution system operator (DSO), microgrid, generator, and consumer.
IEC 61968	Information exchange among systems supporting business functions that support power system operations, maintenance, and customer support. This includes major business functions such as asset management, work management, meter data management, customer information, geographic information systems, and engineering design.
IEC 62325	Information exchange among systems directly involved with electricity market business processes such as transmission capacity allocation, forecasting, bidding, contracts, clearing, and settlement.

Source: EPRI [7]

All three standards are based on a single, unified model under the IEC. These standards were begun as part of the EPRI Control Center Application Programming Interface (CCAPI) project, with the aim of creating a common definition for the components in power systems for use by energy management system application programming interfaces (APIs) [8].

Proprietary formats for sharing data between applications have typically required numerous translators to import and export data. As an increasing number of applications exchanged data, this resulted in exponential growth of the complexity of integration. The need to simplify integration complexity drives the adoption of a model-based data exchange approach in the electric power domain and incentivizes investment in CIM. These standards have the following three primary uses:

- To facilitate the exchange of power system network data between organizations
- To allow the exchange of data between applications within an organization
- To exchange market data between organizations.

Because of EPRI's leadership, adoption of the CIM has increased, but it still faces challenges. An enterprise-wide view of the electric grid is complex due to the number and type of assets stored in the many heterogeneous data sources within a utility. Every CIM implementation competes with the cost of doing nothing, because existing systems may have proprietary interfaces with significant lifespans and investments in both the technology and the knowledge. When integrating proprietary systems into a CIM-based model, some information in the model may not exist and may need to be added to the standard. Unfortunately, virtually every CIM implementation requires the standard to be extended to be compatible with the unique needs of each utility. The CIM is vendor neutral, designed to provide the flexibility needed for integration. This may result in semantic ambiguities among different software vendor products. Nevertheless, the CIM provides the best path forward for integration, as it promotes a common understanding of the underlying data, which is necessary for defining correct data flows.

The Need for a Common Semantic Model in Telecommunication

Utilities experience many of the same issues with their telecommunication networks as they do with their electric networks. Disconnected workflows spread throughout the organization and information silos with disparate data management processes make having a holistic view of the network difficult, if not impossible. This makes data sharing and communications using shared data equally difficult, leading to inefficiencies and extra expense as miscommunication causes rework or wrong work.

Individual telecommunications equipment elements are managed through the use of a particular vendors element manager. Equipment vendors have created their own NMS software to management the aggregated elements as a network. There is, in general, a lack of interoperability between network management systems of different vendors.

The broad adoption of SNMP by the telecommunications vendor community has not solved the interoperability issue, mainly due to the semantics challenge. SNMP is only a protocol and therefore requires customized MIBs to be created for an NMS to be used with a particular vendor's equipment. The newer protocol and language of NETCONF and YANG has some promise to improve the situation but at present does not appear to be a full solution to the issue of a common set of semantics for network management.

Several attempts have been made to suggest a semantic model approach to telecommunication integration [9, 10], but nothing compared to the 20-plus year effort of the IEC to develop the CIM. Although advances have been made to separate business functions from communications services [11], no leading semantic standard has emerged. As a result, the telecommunications network management enterprise architecture remains fragmented, with few standards. Integration with GIS, asset management, and work management applications will have no common language among them.

Without the establishment of a common semantic model and the associated standards for integration, any sort of communications network model management becomes difficult, if not impossible. Different groups within a utility and external entities use the telecommunications network models. Today, these telecommunication models are typically maintained independently in various data repositories and application. Often, variations of the same data are manually entered into each application. This approach is not only inefficient but also leads to modeling inconsistencies and errors. Telecommunications engineers spend significant amounts of time entering, synchronizing, validating, and correcting duplicate information. These activities intrude on the performance of system engineering tasks. Outage analysis and post-event analysis are cumbersome when information is trapped in disparate systems. Finally, satisfying the need to validate planning models with real-world data is difficult to do with independently maintained models that contain similar, if not duplicate data.

4 CONCLUSIONS AND RECOMMENDATIONS

This project investigated some of the more popular NMSs and their relation to enterprise GISs. The report described the geographical capabilities of several NMS systems in use by project funders and the gaps between the NMS functionality and usefulness to the enterprise. It also addressed what is needed in future projects to bring telecommunications asset management in line with the rest of the utility enterprise.

This research was conducted by reviewing prior EPRI work in this area, conducting a vendor literature survey, contacting vendor subject matter experts, and holding discussions with several key utilities that are trying to incorporate their telecommunications asset management into an enterprise management strategy.

The major conclusions of the research are the following:

- The telecommunications domain of utilities lags behind the electrical network in enterprise integration.
- There is no agreement on an enterprise semantic model for telecommunications network management.
- Proprietary enterprise and network management systems dominate the domain without an easy solution for interoperability and GIS integration.
- Enterprise coordination of telecommunications asset management is hampered by a lack of standards and interoperability.

5
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