

**State-Based Network Management:
Resource Allocation using Web Services**

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Abstract

Research presented at this conference in 2004 concluded that the approach for network management employed in the electric grid provides a useful model for the next generation of telecommunications network management. In particular, firms attached to the electricity grid maintain individual realtime models of system state and are capable of performing transactions necessary for maintaining the stability and security of their networks while maximizing power flow. Tools and techniques based on web services are capable of providing a similar approach for closed-loop process that provisions telecommunications resources on a per-application and per-location basis with service quality.

The concept of State-Based Network Management (SBNM) is a new application whose goal is to assess network requirements, monitor condition of network elements, and to provision resources – as a repeatable batch process, as has been implemented successfully in the electric industry. Traditionally this lifecycle has been engineered once per contract, and SBNM proposes to perform it on demand and repeatedly.

The methodology employed in SBNM is “Valued Information at the Right Time (VIRT),” a concept developed by Hayes-Roth for adapting flight plans based on weather information obtained through publish-subscribe means. The current phase of SBNM is development of a semantic environment for

organizing network elements that may be provisioned and configured for circuit and packet communication, including service quality characteristics.

Introduction and Roadmap

The origin of this research, which was introduced at this conference in 2004, was a study of contrasts between network management approaches in electrical and telecommunication grids. In short, the conclusion was that, in North America, management of the electric grid has advanced to offer both visibility and control, while maximizing energy delivery and minimizing failure. While many telecommunications services possess an intrinsic capability to adapt themselves around failed components, the corresponding notion of network management remains largely limited to observation, not control. Moreover, the paradigm for activating instances of telecommunication services has been within the scope of Operational Support Systems (OSS), which characteristically have been decoupled from realtime sensors and telemetry.

Ensuing research has confirmed that the basis for the advanced capabilities in electricity are found in extensive modeling of system state independently by each participating firm, with a particular strength in adapting to unannounced changes in system topology. System state in telecommunications realistically is the collection of element/subsystem states for the purpose of event correlation and ideally fault diagnosis.

Given that the electric grid represents interconnection among transmission assets of independent firms, it is reasonable to

expect a plane of sophisticated messaging to accompany the transfer of energy. In the U.S. setting of wholesale competition and deregulation, messaging systems have evolved to a high level of functionality and timeliness. Members of the leading regional transmission organization share information such as status and orders by means of a service oriented architecture.

To fill this gap of telecom management theory and practice, we have proposed a new application that will enable operators to maintain the best set of provider resources to meet the user demands in a dynamic setting, to cover the spectrum of services and to be sensitive to quality. The foundation of this approach, which we have termed State-Based Network Management (SBNM), is a service oriented architecture and a smart-push publish-subscribe implementation.

This paper begins with a more thorough review of comparative network management systems in the telecommunications and electric transmission domains, augmented by requirements anticipated by network-centric operations and warfare (NCOW). Once context has been established, the paper will discuss web services and introduce the concept of Valued Information at the Right Time (VIRT), a framework for intelligent sharing of information. Finally, the architecture for SBNM will be presented and explained.

Comparative Networks and their Management

This section will provide a comparative look at networks and management techniques in telecommunications, electric

transmission, and future combat. The working definition of a network is a set of interconnected nodes for the purpose of transferring, respectively, low-level data, energy, and command/control/intelligence information. The role of information in the first and last of these cases is the object of value, and in the middle case, it is an external plane of telemetry and control.

In telecommunications, network management refers to two genres of software systems: for business operations – known as Operational Support Systems (OSS); and network operational management based on the use of the TCP/IP Simple Network Management protocols (SNMP). OSS capabilities can include applications for order processing, provisioning, service activation, testing, maintenance and repair, billing, and customer information [1]. These functions are central to telecommunications service providers and are increasingly integrated, distributed, and accessible to partner firms. While interactive, OSS systems as defined neither monitor the performance of network elements nor exhibit autonomy of control.

There are two fundamental types of SNMP-based Network Management: systems that poll elements for status, and those that are triggered by exception events [2]. Status information may be filtered or correlated in context of nearby devices or exhibited as part of a larger structure (i.e., topology). Interpretation, filtering, or diagnosis of event signatures is feasible but is beyond the scope of baseline commercial software, and the maximum extent of this functionality is to

interoperate with the corresponding OSS to generate, say, a work order [3].

Both kinds of network management systems operate largely in an open loop or in one closed by actions of a human operator. Each system contains capabilities, respectively, to control or to monitor complex, distributed information flows and their infrastructure. No complete integration is available between the systems for the benefit of either enterprise users or providers.

In contrast, a high level of automation and integration has been achieved in the operation of electric transmission networks, which has been complicated by the corporate unbundling of power generation and retail distribution functions. What we perceive as a power grid is a set of functional and legal relationships among businesses themselves and the assets that they share. The consequences of transmission network failure were analyzed at length at a previous ITCSM as the result of investigating a major outage that occurred in 2003 [4].

Interconnected firms are compelled to balance electric consumption and supply and are mandated to operate in a way that maintains overall network integrity (i.e., security). Moreover, these firms must accommodate a market in power sales that changes hourly. Retail distribution firms use telemetry data to model their networks and enter into contracts for future demand, automating these functions using technology known as System Control and Data Acquisition (SCADA) and Energy Management System (EMS). Retail firms are always at least partial owners of transmission

facilities (i.e., the grid) and may or may not own generating units, whose outputs are subject to control by the grid operator.

Retail distribution and transmission entities communicate both current status and future intentions, and each independently monitors and controls resources in its respective purview. While the business transactions are scheduled, the physical processes unfold in real time, resulting in an almost-continuous modeling exercise by each entity – with the privilege of adding capacity, removing demand, or isolating regions as a result of problems. The most important component of these continuously-run batch jobs is the acquisition of network topology based on telemetry data and lists of known component outages. In the transmission setting, little switching capability exists (flows follow Kirchoff's current law), and demand is both aggregated and localized).

The PJM Interconnect is the sole independent operator of electric transmission facilities in the mid-Atlantic United States. It operates an interactive realtime wholesale electricity market for its region, subject to its ability to deliver power across its network. Market participants interact with PJM through information systems that have a service-oriented architecture. Peer systems use XML to exchange operational and planning data (eDART) and to submit and obtain trading data (eMKT). These messages are exchanged between peer applications without using a browser, and are based on an ontology and XML documents that are custom and unique.

The third use case is termed Network Centric Operations, whose framework we will present from the perspective of the

U.S. Navy. NCO formalizes a transformation from physical asset-oriented warfare to that based on information whose model is the Internet. This goal of this approach is interoperability among information uses and sources, and whose focus is the user. One model for this is the Naval Command and Information Infrastructure (NCII), whose purpose is to embrace modern technology and methods as well as to support present and anticipated naval operations.

NCO parallels commercial interest in integration of all disparate information processing and storage systems, and its unique requirements include the high-consequence domain of sensors and weapons.

The similarities among these three cases are very significant: each domain is geographically large and rich with assets that must be controlled or configured in order to be effective. In each case, hierarchies of closed-loop control are desirable in order to maximize respective performance; an outer loop may allocate resource (i.e., logistics, provisioning, etc.) while an inner loop may inform usage or action any some moment. Each case also calls for interoperability through messaging among agents of similar importance.

In addition to obvious differences between problem domains, there are differences in the availability of feasible solutions. Our prior paper indicted that the electric transmission grid used communications messaging to optimize its functions of maximizing power flows and minimizing outages. In the telecommunications domain, there is a fundamental lack of interoperability between the processes that create services and

those that operate them; software for integrating SNMP network management with OSS is becoming available to service providers and potentially to enterprise users.

Web Services

While the TCP/IP protocol suite has brought compatibility and reliability of transport and network infrastructure, it has enabled network applications without making them interoperable. Standard hypertext markup language (HTML) and transfer protocols (HTTP) have made web browsing possible, but compatibility among applications cannot be assumed in the absence of standards. Berners-Lee has introduced the notion of the *semantic web* as an extension of the browsable web to facilitate interoperable sharing of information among software agents [6].

The purpose of the semantic web is to enable interactive, browserless interoperation of information systems. Its messaging scheme borrows the syntax of XML (extensible Markup Language) and introduces capabilities for meaning and interpretation. The semantic web provides various means to craft not only vocabularies but taxonomies of information, with the benefits of classification and inheritance. Additional mechanisms exist in the semantic web to capture relationship data and to establish standard usage of terms called ontologies. The results of these collective capabilities are both the interoperation of peer application systems and the ability of software agents to derive new interpretations of data within

prescribed contexts. Such systems are not intelligent per se, but they do have useful reasoning capabilities.

The concept of a service oriented architecture organizes an application as a collection of services. This is not necessarily a useful motivation to decompose an existing application into components, but it is a practical way to publish external-facing interfaces, especially those that would be used by trading partners. The scope of the interfaces could provide any mutually meaningful exchange of information, not just those transactions defined by, say, ANSI X.12 documents for electronic data interchange (EDI).

Ma notes that the practice of web services is in its infancy, although the underlying technologies (remote procedure calls, http transport, markup languages, etc.) are not new. The use of XML and SOAP messaging are a *de facto* standard for content distribution, especially when content is not static [7].

Among the use cases mentioned previously, the use of web services in management of power flows on the electric grid is well-established. A dictionary of data elements has been established, and numerous XML-based operations have been put into production. In telecommunications, as we will discuss in the following sections, firms are developing limited applications-level and embedded services for selected transactions and status inquiry.

Valued Information at the Right Time

One locus of information superiority, which is an aim of network centric military operations, is the individual warfighter, who could potentially be overwhelmed with incoming information and fail to act appropriately. An alternative approach to this situation would be a more structured collaboration between the information sources and their destinations – to be mediated by software agents. The name of this concept is Valued Information at the Right Time (VIRT), the work of Hayes-Roth [8].

Two approaches may fulfill the objectives of VIRT: an environment where users actively seek, acquire, and process relevant information (“smart pull”), or one where users wait to react to information filtered and forwarded to them (“smart push”) [9]. Latent issues with these approaches are, respectively, the need to organize data in anticipation of search, and the need to organize user decisions and reasoning. Adopting the smart push approach, however, would shift the significant burden of processing (i.e., attention) and memory to automation. A noncombat aviation case study of VIRT estimated that fifty million discrete samples in a flight of 4.5 hours, based on only meteorological information [10].

A use case for VIRT requires the creation of an ontology for that domain, which would define operational parameters, their relationships. Moreover, a VIRT case requires the documentation of the user’s intentions, reasoning, and input parameters. In addition to the instantiation, storage, and collection of the prior data elements, a “VIRT Engine” must

exist in software to monitor conditions and push valued information at the right time to the user. Design of the VIRT engine is in process at this time, and integration based on metadata core using commercial off-the-shelf database software is expected.

State Based Network Management

The concept of State Based Network Management (SBNM) is a new application whose objective is to assess communication requirements, monitor condition of communication elements, and to provision resources as a repeatable batch process, as has been demonstrated in the operation of the electric transmission grid. Typically, this lifecycle has been engineered once-per-contract, and SBNM proposes to perform it on demand and repeat it, say, hourly. This function can be performed by providers in the core of their networks; SBNM proposes to extend the provider edge to the enterprise customer, which is feasible in emerging services such as MPLS/VPLS.

The following figure depicts the architecture of SBNM, and each component will be defined below. The core of this architecture is the SBNM module, which alone defines the state of the entire communication system is a “VIRT User” in that it has revealed the conditions of effective operation and consumes administrative and realtime element status information in order to perform its duties.

The objective of SBNM is to acquire location-based, QoS-sensitive requirements for communication services and interact

with peer systems that represent communication facilities in order to obtain and maintain service. The scope of SBNM is intended to be service, to support applications with different classes of service, and to acquire different types of physical and logical services.

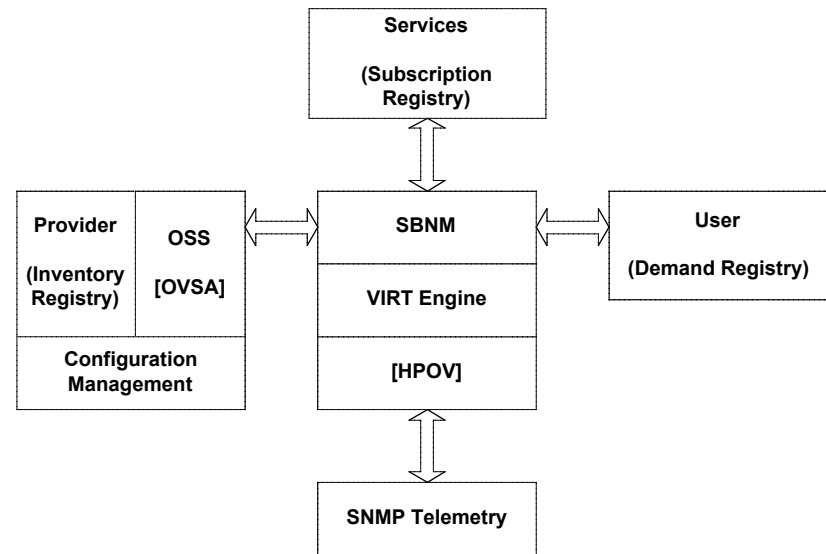


Figure 1. SBNM Architecture

The Services block represents a registry of services currently in production under the control of SBNM. It contains cross-referential information mapping a single user requirement (identified by location, class-of-service, and quality of service) to the corresponding network facilities used to implement it (identified by provider, endpoints, physical/virtual circuit/path

identifier as well as a pointer to device configuration information as applicable). While such subscription data may be local to its SBNM, it should also be accessible as a service.

The User (Demand Registry) block represents the functionality to obtain application and user requirements for endpoints associated with this SBNM node. Changes in requirements shall be pushed to SBNM and need only be identified by reference, minimizing the size of data exchanges.

The SNMP Telemetry block represents managed elements and other subsystems, primarily polled, trapped, or thresholdable via SNMP. These components communicate with traditional network management software such as Hewlett-Packard Openview Network Node Manager (labeled HPOV), which would correlate and interpret events.

The central block in this schematic contains tight integration of SBNM, VIRT, and the traditional network manager. Several use cases apply to this schematic block:

- The VIRT Engine shall receive filtered alarms from the network monitor and accordingly notify SBNM, which may select alternate infrastructure in order to fulfill application and user requirements.
- Upon provisioning of new services (or removal of expired services), SBNM would cause the monitor to update its topology and list of managed objects.
- SBNM would load (or remove) subscription parameters to VIRT's condition monitor.

Finally, the leftmost block represents network elements and their substitutes from internal and external service providers. Given that turnup of new subscriber services is often an administrative task if media facilities are already in place, some software development initiatives are underway to automate this functionality. HP Openview's Service Activator [OVSA] is capable of launching provisioning workflows based on SNMP events, although this process appears more scripted than service-oriented [11]. This design anticipates that chassis and cards will use XML for configuration management.

Conclusions and Future Work

State-Based Network Management has been conceived to fill a perceived requirement for agile allocation of telecommunication resources, a gap that no other system is known to fill. Development of SBNM is enabled only by the presence of web service tools and is further motivated by the overwhelming quantity of data in managed networks.

The presence of network infrastructure is essential to military network centric operations, so further research in this area is essential. This research also is a viable application of VIRT logic, which also accelerates new components of NCO.

Immediate tasks in this program are the continued search for and, alternatively, development of ontologies for the supply and demand for telecommunications services. Demonstration of SBNM will be requested to occur in the VIRT testbed when available, following which integration with SNMP will occur.

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