Abstract

NASPI is a collaborative effort between the U.S. Department of Energy (DOE), the North American Electric Reliability Corporation (NERC), and North American electric utilities, vendors, consultants, federal and private researchers and academics. NASPInet is an effort to develop an “industrial grade”, secure, standardized, distributed, and expandable data communications infrastructure to support synchrophasor applications in North America. In some aspects NASPInet mirrors the Internet in its construct but not all. Some of the management and administrative features are similar while others such as the continuous streaming of data from phasor measurement units are not. This paper will broadly discuss the similarities and differences between the two networks.

1. Introduction

The North American Synchro-Phasor Initiative (NASPI) is a major effort by the North American electric power industry to create a robust, widely available and secure synchronized data (synchrophasor) measurement infrastructure for the interconnected North American electric power system with associated analysis and monitoring tools for better planning and operation, and with improved reliability. NASPI’s ultimate objective is to decentralize, expand, and standardize the current synchrophasor infrastructure through the introduction of a NASPI network (NASPInet) that will be composed of Phasor Gateways (PGs) and a Data Bus (DB). Once fully deployed, it is envisioned that the NASPInet could support hundreds of Phasor Gateways and thousands of Phasor Measurement Units (PMUs), each typically providing data continuously at up to 60 times per second.[1]

Synchrophasors are precise grid measurements now available from monitors called phasor measurement units (PMUs). PMU measurements are taken at high speed (typically 30 observations per second – compared to one every 4-10 seconds using conventional Energy Management System (EMS) technology). Each measurement is time-stamped according to a common time reference. Time stamping allows synchrophasors from different utilities to be time-aligned (or “synchronized”) and combined together to provide a precise and comprehensive view of the entire interconnection. Synchrophasors enable a better indication of grid stress, and can be used to provide valuable feedback to system operators or even trigger corrective actions to maintain reliability.[2]

The NASPI data infrastructure currently consists of a number of devices, most notably PMUs and Phasor Data Concentrators (PDCs). PMUs are the sources of synchronized phasor data, taking power system measurements at stations and substations. They transmit the data to PDCs or other data collection devices which may be located in the field or in a centralized control center. Field collection devices typically send the data to a PDC at a control center where data from a number of stations is collected and combined. The PDC time-aligns the inbound data and supplies it to applications as a collective group of synchronized measurements. Applications may include system visualization, trending and alarming, data archiving, phasor data enhanced state estimator, congestion management, etc. [3]

While almost everyone uses the Internet today, most of these users are unaware of the breadth of the management and administrative infrastructure that exists to ensure the Internet continues to efficiently operate.

One of these key administrative organizations, The Internet Society (ISOC), is a nonprofit organization founded in 1992 to provide leadership in Internet related standards, education, and policy. With offices in Washington D.C., USA, and Geneva, Switzerland, it is dedicated to ensuring the open development, evolution and use of the Internet for the benefit of people throughout the world.

The Internet Society provides leadership in addressing issues that confront the future of the Internet, and is the organizational home for the groups responsible for Internet infrastructure standards, including the Internet Engineering Task Force (IETF) and the Internet Architecture Board (IAB).
The Internet Society acts not only as a global clearinghouse for Internet information and education but also as a facilitator and coordinator of Internet-related initiatives around the world. For over 15 years the ISOC has run international network training programs for developing countries and these efforts have played a vital role in establishing Internet connections and networks in virtually every country linking to the Internet during this time. [4]

While the technical challenges of designing and deploying NASPInet are many, there is an equally daunting challenge to nurture and facilitate its administrative development and NASPInet may benefit by leveraging the concepts of the ISOC and other groups that manage the administrative aspects of the Internet.

2. Current State

Within NASPI, previously known as Eastern Interconnection Phasor Project (EIPP), each participating organization sets its own requirements for data management and handling. To support the EIPP endeavor the Tennessee Valley Authority (TVA) has made a substantial investment in developing a centralized EIPP Phasor Data Concentrator, called a “Super PDC”, and have set up a comprehensive database of phasor measurements. The initial objectives for the Super PDC, shown in Figure 1, were simple. First and foremost the project team wanted to create a system with an open and completely scalable architecture that specifically supported the most popular phasor data transmission protocols, in particular: PC37.118, IEEE1344, the BPA PDCstream and OLE for Process Control (or OPC).[5]

Figure 1 – Existing Super PDC Architecture

In the current working implementation of the Super PDC, all of these transmission protocols have been supported.

As can be seen in the above architecture, a wide array of protocols are currently in use. This leads to a level of management complexity that is not desirable or sustainable across an interconnect-wide deployment. Also, the Super PDC and its associated services are potentially a single point of failure.

Figure 2 – Generation II System

A new interim architecture has been contracted by the North American Electric Reliability Corporation (NERC) that will provide for multiple nodes and a centralized configuration management service is under development. This new architecture, shown in Figure 2, eliminates the single point of failure of the Super PDC by having all data sent to two connection point servers. This is a step in the right direction for the data archiving but other issues related to overall system management still exist in this proposal.

2. Proposed Future State

One of the key technical challenges facing NASPI is determining the future data and network architecture options for 2010 and beyond, when the initial phase of support from the Tennessee Valley Authority (TVA) for the Super PDC will require a transition to a long-term sustainable solution. The NASPI Data and Network Management Task Team (DNMTT) presented a vision for a massively distributed architecture based on a publish-subscribe model that includes the functionally of Phasor Gateways. This vision was...
articulated in a NASPInet requirements document, the basis for a DOE solicitation to develop a detailed NASPInet specification awarded in the fall of 2008.[6]

The overall philosophy of NASPInet as envisioned by the DNMTT was to establish a secure “data superhighway” that can provide for reliable connections between data suppliers, typically asset owners such as electric utilities, and consumers of data, typically other electric utilities, Independent System Operators, Regional Transmission Operators, Reliability Councils and other authorized parties. This network (Figure 3) would consist of two key components: Phasor Gateways and the wide area Data Bus.

Figure 3 – NASPInet Overview

2.1. NASPInet Phasor Gateway

Within the NASPInet architecture, the Phasor Gateway is the primary interface between an electric utility or other authorized party and the Data Bus. The Phasor Gateway shall perform the key functions listed below [7]:
1. Serve as the sole access point to the Data Bus;
2. Facilitate and administer registration of a user’s PMU, PDC, and signals;
3. Facilitate and administer the subscription and publishing of phasor data;
4. Administer and disseminate cyber security and access rights;
5. Monitor data integrity;
6. Manage traffic priority through the PG according to service classes;
7. Provide logging of data transmission, access controls, and cyber security for analysis of all anomalies; and
8. Provide Application Programming Interface (APIs) for interfacing with a user’s systems and applications.

2.1. NASPInet Data Bus

The Data Bus infrastructure shall enable the flow of synchrophasor and other information between Phasor Gateways and additional appropriate entities interacting with NASPInet. The major functional characteristics of the Data Bus shall include:[8]
1. Provide connectivity between Phasor Gateways (PGs) and all other elements of the NASPInet;
2. Facilitate reliable delivery of data and control flows of multiple data service classes;
3. Provide network access services including directory and naming, data accessibility, access control, and cyber security;
4. Enforce conformance with cyber policy, security, and access control policies and standards;
5. Provide network instrumentation and quality-of-service management; and
6. Be resilient to failures.

2.1. NASPInet Service Classes

NASPInet will need to accommodate five classes of data services for supporting different types of applications:[9]
- CLASS A: This data service class supports the needs of high performance feedback control applications. This class is characterized by very low latency and a fast data rate (e.g., 60 messages per second). Class A data shall be transmitted and received as quickly as possible with a high level of data availability (there shall be no data gaps).
- CLASS B: This service class supports the needs of feed-forward control applications, such as state estimator enhancement. The latency requirement for Class B data is less strict than that for Class A data. High availability of the data is also required.
- CLASS C: This class of data supports view-only applications such as visualization by power system operators. The tolerance for accuracy and latency for Class C data are less stringent than Class B data. The system shall enable end-user applications to retrieve data from many PMUs across a wide geographical area.
- CLASS D: This service class supports the needs of post-mortem event analysis and other off-line
studies. The system shall provide a high degree of data completeness and accuracy for this service class. However, latency of Class D data may be higher than Class A, B and C data since analysis of Class D data will generally conducted offline (hours or days later) with archived data, as opposed to an online data stream.

• CLASS E: Class E data primarily supports the needs for testing and Research and Development (R&D) applications. There are no guarantees on any attributes of this data class. Class E shall be given the lowest priority of all NASPInet data traffic.

2.1. NASPInet Common Services

The proposed NASPInet Architecture identifies a set of common services. These services are:

• Security – this service shall provide enabling services and infrastructure to ensure the appropriate access to and usage of NASPInet resources and information. Key components typically include Authentication, Authorization, Access Control, Confidentiality, Auditing, Non-Repudiation and many others.

• Management & Administration – this service shall enable the initial configuration and ongoing operation of NASPInet components and services, and will likely integrate or aggregate the analogous but more focused services within the Data Bus.

• Name & Directory – this service shall enable the system-wide registry of Phasor Measurement devices as well as the services, components, processes and other entities required by the Phasor Gateway and/or Data Bus components.

• Resiliency – This service and infrastructure to ensure critical system attributes such as Fault Tolerance, Availability, Disaster Recovery, Business Continuity and similar aspects.

• Instrumentation – In concert with NASPInet Management and Administration Services, this service shall provide visibility into key aspects of the NASPInet infrastructure such as performance, utilization and general health indicators.

• Data Management – this service shall enable the logical and physical architecture, storage, access and management of persistent and transient data within NASPInet. Key components typically include Relational Database Management engines, Storage Area Network infrastructure, Metadata Management, Hierarchical Storage Management, Information Lifecycle Management and other services.

At this point in time NASPInet has defined the following technical features:

1. Functional descriptions for both the Phasor Gateways and the Data Bus
2. Definitions for a set of service classes
3. A defined set of common services.

However, beyond these technical aspects, what is not yet defined adequately is the administrative structure and organizations necessary to support and maintain these features. A proposal by the authors to address this issue follows.

3. The Internet Parallel

3.1. Internet Society

As mentioned earlier, the Internet Society provides leadership in addressing issues that confront the future of the Internet, and is the organizational home for the groups responsible for Internet infrastructure standards, including the Internet Engineering Task Force (IETF) and the Internet Architecture Board (IAB).

One approach to facilitate the future management and oversight of NASPInet would be to formally establish the existence of the current NASPI organization much like the ISOC. While the current NASPI organization exists under the direction of NERC, the group has no formal authority with regard to NASPInet oversight. By establishing NASPI as a non-profit organization with a Board of Trustees and a written membership policy, the organization would be able to begin the process to formally manage NASPInet.

3.2 Internet Engineering Task Force

Continuing with the Internet model, the next organization is the Internet Engineering Task Force (IETF) which is a large open international community of network designers, operators, vendors, and researchers concerned with the evolution of the Internet architecture and the smooth operation of the
The Internet. It is open to any interested individual. The IETF Mission Statement is documented in RFC 3935.

The actual technical work of the IETF is done in its working groups, which are organized by topic into several areas (e.g., routing, transport, security, etc.). Much of the work is handled via mailing lists. The IETF holds meetings three times per year.[11]

The IETF currently has eight working areas and each area consists of about a dozen or so actual working groups. The areas are:
- Applications Area
- General Area
- Internet Area
- Operations and Management Area
- Real-time Applications and Infrastructure Area
- Routing Area
- Security Area
- Transport Area

In general, the IETF governance is through a Request for Comment (RFC) structure that began in 1969 and now numbers over 5000 entries. They are effectively the standards process for the Internet. The RFC process is well documented and has a formal submittal and review process.

Within NASPI, the existing task teams support a variety of functional areas. They are presently defined as:
- Data & Network Management (DNMTT)
- Operations Implementation (OITT)
- Performance and Standards (PSTT)
- Planning Implementation (PITT)
- Research Initiatives (RITT)

These task teams form a good starting point for the structure of an operational equivalent to the IETF within NASPI. However, if the future responsibilities of the task teams included a role similar to that of the IETF, then some additional teams may be required. A few areas currently not covered by the existing NASPI task teams are: Applications, Operations and Management, Infrastructure and Security.

3.3 Internet Assigned Numbers Authority

The Internet Assigned Numbers Authority (IANA) is the body responsible for coordinating some of the key elements that keep the Internet running smoothly. Whilst the Internet is renowned for being a worldwide network free from central coordination, there is a technical need for some key parts of the Internet to be globally coordinated – and this coordination role is undertaken by IANA.[12]

Specifically, IANA allocates and maintains unique codes and numbering systems that are used in the technical standards (“protocols”) that drive the Internet.

IANA’s various activities can be broadly grouped in to three categories:
- **Domain Names** - IANA manages the DNS root, the .int and .arpa domains, and an IDN practices resource.
- **Number Resources** - IANA coordinates the global pool of IP and AS numbers, providing them to Regional Internet Registries.
- **Protocol Assignments** - Internet protocols’ numbering systems are managed by IANA in conjunction with standards bodies.

Once again like the Internet, NASPInet will require a function similar to IANA to ensure that the synchrophasor system is grown and developed in a coordinated fashion. This coordination will require that duplicate synchrophasor names do not exist as well as other administrative functions similar to those listed above are well coordinated. In particular, within NASPInet the Management & Administration service and Name & Directory service will need this type of administrative coordination.

It is critical to mention that while many aspects of the administration of NASPInet may mimic the Internet, there are areas of operation that are unique. Some of these areas are:
- Intermingling of both streaming synchrophasor data with historical (bulk data sets) on the same data bus
- Disaggregation of native, whole PMU signals from IEEE C37.118-2005 into discrete signals.
- Quality of service management of the five (or more) distinct classes of service, A-E

It will be these differences and others that will challenge the DNMTT and the overall NASPI organization in trying to apply the internet model holistically to NASPInet but it will provide a very good start.

4. Next Steps

In coordination with NERC, the NERC project management team and the NASPI leadership team, the DNMTT will assemble a proposed organization structure with roles and responsibilities to address the common services functional areas. Also, the DNMTT will undertake a thorough review of the NASPInet specifications and completely identify all the functional areas needing administrative support. Lastly, the DNMTT will segregate out those areas
requiring special attention due to their significant differences from the Internet model.

Also, further review of the current all volunteer effort that supports NASPI needs to be evaluated. If NASPInet does build out, there will need to be some management organization in place to oversee the network. How will the proposed NASPInet get funded? Who will pay and based on what metric? While the technical challenges are many; so too are the management and oversight one.

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