INET SYSTEM DESIGN CONCEPTS

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ABSTRACT

One of the core philosophies of the integrated Network Enhanced Telemetry (iNET) project is to leverage standard networking technologies whenever possible to both reduce development cost and to allow standard networking applications to function. This paper presents decisions about the system's behavioral design and other decisions affecting the selection and design of system components. The TmNS is a network of networks that must be integrated into existing range processes. An overall guiding tenet for the TmNS is *enhancement* rather than replacement. As such, this enhancement is melded with pre-existing devices, approaches, and technologies. Overall, the pre-existing Pulse Code Modulation (PCM) data delivery mechanism is augmented with bi-directional, reliable, TmNS-provided communication.

KEYWORDS

Network, System, iNET, TmNS

SYSTEM OVERVIEW

The Telemetry Network System (TmNS) is a network system to enhance existing telemetry systems in order to leverage networking technologies to gain test efficiencies. The system shall be designed to be a general-purpose network with a capability to meet the majority of flight test needs of the United States Air Force, Army, and Navy, and will be interoperable among test ranges. The system will efficiently support programs with both large and small (less than 100) numbers of measurands, and supporting Test Article (TA) components shall be small enough to be accommodated in fighter sized aircraft.

Figure 1 identifies the primary operational segmentation of the TmNS to help describe the operation of the system. Note that the segmentation for the Radio Frequency (RF) subsystem is split between the TA, the Antenna sites, and the Range Operation Center (ROC).

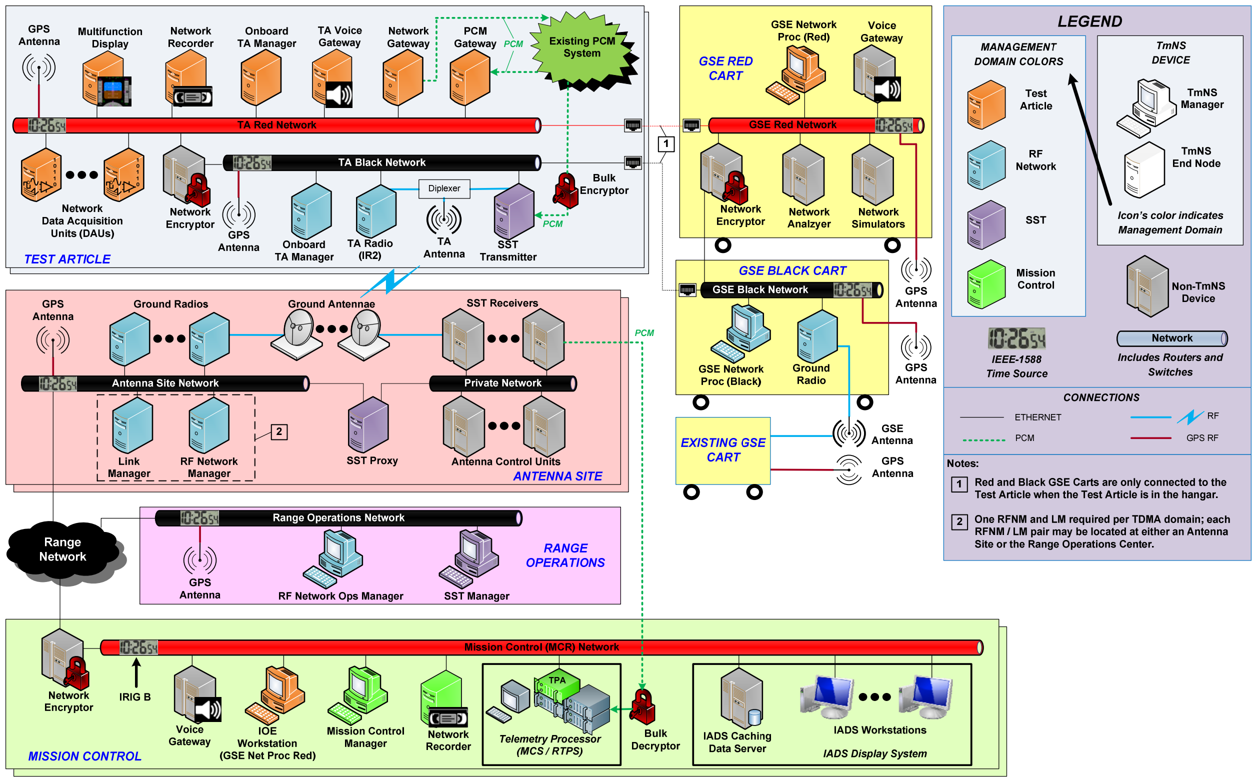

Figure 1. TmNS Demonstrations Overview

SYSTEM SEGMENTATION

The TmNS consists of five major subsystems. These subsystems are functional groupings to help communicate the functionality of the TmNS.

Test Article (TA) Subsystem

The airborne TA subsystem interfaces data sources with recording and telemetry transmission devices. The TA subsystem consists of the resources necessary for any particular test application and resides in the test aircraft. In general, the TA subsystem will consist of the following components: network switches, network routers, TA resource managers, network Data Acquisition Units (DAU) with Signal Conditioning (SC), network recorders, network encryptors, and other auxiliary components necessary to make the system functional. The number and type of components necessary for a particular test are solely dependent upon the location, number of measurements, and types of data to be collected in that test. The TA subsystem also provides the means to interface into existing Pulse Code Modulation (PCM) systems.

Radio Frequency (RF) Subsystem

The RF subsystem connects the TA subsystem with the Range Operations subsystem. The RF subsystem consists of the resources necessary for interconnecting with the range infrastructure. In general, the RF subsystem will consist of the following components: network radios, network switches, network routers, RF resource managers, and other auxiliary components necessary to make the system functional. The number of components necessary for a particular range is dependent upon the range resources as well as the number of RF domains needed for test operations. The RF subsystem relies on the Serial Streaming Telemetry (SST) signal from existing telemetry systems for tracking the TA.

Range Operations Subsystem

The Range Operations subsystem provides the means for interfacing the RF subsystem components within the antenna sites with the Range Operations Center (ROC). The Range Operations subsystem has the ability to remotely manage the resources within the antenna sites (or Ground Stations) such as the tracking antennas, network devices (switches and routers) and the range infrastructure network which provides the means to interconnect the range facilities. The range operations subsystem has the ability to manage all resources located on the black-side of the system. Therefore, it can communicate with components on the TA that are not behind the network encryptor.

Mission Control Subsystem

The Mission Control subsystem provides the means for interfacing into existing telemetry processing systems. The Mission Control subsystem consists of the resources necessary for processing TmNS data messages, communicating with the red-side of the TA, and communicating with the telemetry processors. In general, the Mission Control subsystem will consist of the following components: network switches, data servers, telemetry processing adaptors, network recorders, network encryptors, and other auxiliary components necessary to make the system functional. The telemetry processing adaptors are specific to the existing telemetry processing systems.

Ground Support Equipment (GSE) Subsystem

The network GSE subsystem provides various support functions necessary to maintain and archive the TmNS metadata, to perform maintenance on the TA components, and to perform limited data reduction on the network data. The GSE is available to the user as deemed necessary to support the TA components. The user shall have a choice of any number of the GSE subsystems that will provide the level of support needed. It is envisioned that a copy of the GSE will reside in the Mission Control Room (MCR) to support the instrumentation engineer support role in the MCR.

SYSTEM-WIDE DESIGN DECISIONS

The TmNS is a network of networks that must be integrated into existing range processes. An overall guiding tenet for the TmNS is enhancement rather than replacement. As such, this enhancement is melded with pre-existing devices, approaches, and technologies.

Overall, the pre-existing PCM data delivery mechanism is augmented with bi-directional reliable communication provided by the TmNS.

1) Networking concepts in acquisition devices and network fabric appliances are adopted rather than created. Some new features supporting bidirectional control are added.

2) Prior to design of the TmNS, areas that needed enhancement were coordinated among stakeholders to create standards to guide vendor interoperability of components in the system:

    a) The Test Article Standard Working Group (TASWG) created a standard focused on the test article network fabric, devices, and network protocols that would aid in interoperability with respect to data acquisition and the acquisition control on the test article. The primary underlying technologies utilized are classic Internet Protocol (IP) and an adapted common data messaging format (TmNS data messages) based on a hybrid found among existing (competing) formats at the time.

    b) The System Management Standard Working Group (SMSWG) created a standard providing a unified approach for discovering, configuring, statusing, and controlling devices connected anywhere within the TmNS. The primary underlying technologies utilized are SNMP and FTP.

    c) The Metadata Standard Working Group (MDSWG) created a standard for describing system configuration (Metadata) in a common fashion. The eXtensible Markup Language (XML) schema defined in this standard provides an approach for describing the configuration of all of the components in the TmNS as well as their logical and physical interrelationships. The TASWG and SMSWG standards describe standardized mechanisms for delivery of the Metadata to individual components for system initialization and major reconfiguration.

    d) The RF Network Element and Communications Link standards describe the new devices necessary to provide the bidirectional communication utilized by the TmNS, the RF Network Manager (RFNM), and radio units. This standard describes both the air interfaces and the wired network interfaces that these units should conform to and the functionality that these units should provide in order to be interoperable.

The intent of the standards is not only to encourage interoperability across vendors, but also to provide components that allow for the TmNS to be an open system. That is, while particular demonstrations are to be shown in the early phases, the TmNS is not targeted at these particular deployments alone. The intention is to provide an approach including tools and building blocks that will be used long into the future in ways not even foreseen by the iNET program. Success of the Internet as an open system inspired this goal.

SYSTEM INPUTS AND OUTPUTS

The TmNS utilizes an IP network. IP is chosen based on the success and description of the Internet Engineering Task Force (IETF) hourglass approach. That is, the simple (skinny) IP layer is the basic interoperability between networked components. Figure 2 is a TmNS specialization of the classic IETF IP hourglass figure.

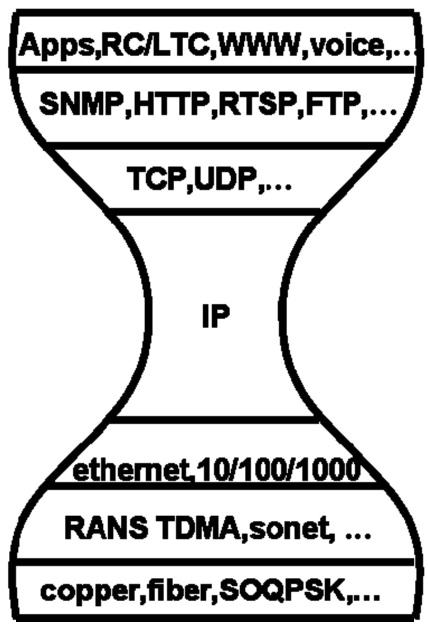

Figure 2. IETF Hourglass Showing IP as Interoperability Neck

Advantages gleaned by utilizing this approach include:

1) Flight test is a seamless part of the overall range network.

2) Support is provided for a globally unique addressing scheme as well as private address spaces.

3) Lower level networking protocols are isolated from and interoperate with applications (e.g. RF network based on communications link standard).

4) Ample pre-existing tools and libraries for management are available.

5) Standardized dynamic routing can be utilized (e.g. can support range to range handoff switching as well as range network updates, load shifting, and partial outages).

6) Reliable communication is supported through higher level protocols [e.g. Transmission Control Protocol (TCP)].

7) Peer-to-peer communication, point to multi-point transmission (multicast), and broadcast are supported.

8) Standardized Quality of Service (QoS) via delivery mechanisms (regardless of lower level transport) based on Differentiated Services (DiffServ) Code Points (DSCPs) provided in the IP headers.

System Behavior in Response to Inputs

The behavior of inputs to the TmNS is primarily parallel. It has been chosen to be a network of networks. At any moment it could be responding to many network requests concurrently. The use of the TmNS network includes:

1) Standardized mechanisms to load component configurations.

    a) Simple Network Management Protocol (SNMP) and File Transfer Protocol (FTP) (based on the System Management Standard) are the chosen technologies.

    b) FTP file to load and report configurations from network components.

2) Standardize Metadata for component configuration.

    a) Components maintain their configurations.

    b) Components are configured from MDL instance documents.

    c) Components respond with their "As Configured" configuration in MDL instance documents.

3) Hierarchies of managers are utilized in order to reduce the complexity of managing large systems.

    a) All managers in the TmNS are themselves manageable.

    b) The System Management Standard specifies a consolidated management approach to how managers can manage other managers in the system.

    c) Small deployments may not need to organize managers into hierarchies.

4) The TmNS uses standardized technologies for data delivery in order to encourage interoperability without the need for extra glue logic or software.

   a) Components producing data utilize the TmNS data message formats described in the Test Article Standard.

   b) Low latency message delivery is accomplished at the IP layer (common across the full system) utilizing User Datagram Protocol (UDP)/multicast.

   c) Data retrieval utilizes TCP/unicast (again over IP).

5) TmNS components that queue data (e.g. routers) during the delivery process utilize IP layer DiffServ rules for providing Quality of Service.

   a) Industry standard DSCPs and rules utilized by typical network devices are chosen for use by the TmNS.

6) Non-standard DSCPs are discouraged since they may not work correctly when TmNS data is transported across non-TmNS portions of a range network.

Files and Databases

The TmNS is primarily a network; it does not provide a large portion of database files. A Metadata file describes the configuration of a system. Each component in the TmNS is responsible for maintaining (and providing upon system management request) its current configuration in a file that complies with the Metadata Standard.

Safety, Security, and Privacy Considerations

Existing range network approaches for meeting safety, security, and privacy are adopted by the TmNS. Components for network encryption/decryption are specifically called out and placed at boundaries where data protection is needed. System management concepts provide for authorization by way of utilizing SNMP version 3 with passwords and encryption when needed.

Hardware / Hardware-Software Systems Design Choices

The TmNS is composed of a set of components that work in parallel. The portioning of functions into components was modeled after network appliances typically found on the Internet. Some TmNS components (e.g. routers and switches) are almost exact functional matches to network appliances that are found on the Internet. This design choice was made to minimize the complexity of any one item and to aid the possibility of creating a broad array of configurations.

The parallel nature of the TmNS is supported by autonomous components. The components are connected to each other and form the system. That is, components act autonomously, but because they are connected together, flows passing between them coordinate them as a system.

Each component's network connection is utilized to support three basic types of flow that were standardized through working groups:

1) Management:

    a) Used for configuring, statusing, and reporting.

2) Time:

    a) Distribution of time through the network is accomplished utilizing the IEEE 1588-2008 standard.

3) Data (Measurements):

    a) Using two delivery mechanisms defined.

        i) Latency/Throughput Critical Data, which supports connectionless service using UDP and multicast mechanisms.

        ii) Reliability Critical Data, which supports connection-oriented delivery using TCP mechanisms.

These flows are not explicitly tied together through state machines but do interact with each other. For example, changes in time affect when and how management occurs as well as the marking and logging of data. Changes in management can affect the rate and type of data that is flowing. Data flowing is reflected in management status updates.

CONCLUSION

The TmNS provides a standardized way to leverage commercial networking technologies to enable the ability to conduct telemetry operations with a wide variety of operational choices. Leveraging standard IP networking technologies at the core of the TmNS provides the ability to scale the TmNS to future unforeseen applications just as the Internet has scaled. Although the TmNS has specific performance challenges beyond what standard IP networking provides, the system segmentation partitions the challenges into smaller, more manageable subsystems/networks so that the challenge is contained and adequate solutions can be applied in ways that still maintain network compatibility.

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