INET SYSTEM OPERATIONAL FLOWS

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ABSTRACT

The integrated Network-Enhanced Telemetry (iNET) project is transitioning from standards development to deployment of systems. In fielding a Telemetry Network System (TmNS) demonstration system, one must choose and integrate technological building blocks from the suite of standards to implement new test capabilities. This paper describes the operation of a TmNS and identifies the management, configuration, control, acquisition, and distribution of information and operational flows. These items are discussed utilizing a notional system to walk through the mechanisms identified by the iNET standards. Note that at the time of this paper the efforts discussed are only at the very beginning of the design process and will likely evolve throughout the design process.

KEYWORDS

iNET, System Management, Metadata, Radio Access, Information flows

INTRODUCTION

The demonstration system is a realization of the TmNS (Telemetry Network System), which includes the items necessary to exercise or enable the capabilities in a useful and meaningful manner. One of the main uses for the system is the ability to retrieve data during a test mission from the on-board data recorder. This requires that a wireless two-way communication link be established from the mission control facility to the test article. The bounds for the system are identified in the context diagram below (**Figure 1**). The context diagram shows that most of the common items utilized for this demonstration are included as part of the TmNS.

This demonstration system has the goal to demonstrate the following capabilities:

1) Dynamically share spectrum resources among many concurrent activities based on instantaneous demand for telemetry resources

2) Manage this sharing appropriately through defined Quality of Service rules to ensure both defined priorities and fairness

3) Provide near real-time access to the test article measurements either directly from the data acquisition source or from onboard data storage

4) Command and control onboard equipment, parameters, legacy telemetry formats, and other functions from mission control

5) Provide over the horizon telemetry

6) Protect the integrity of telemetry communications

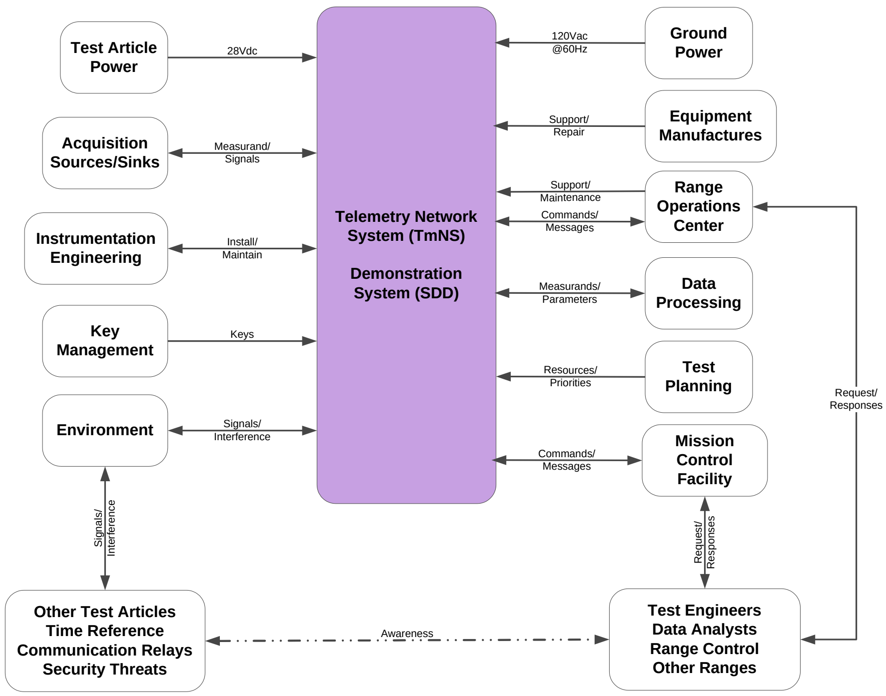
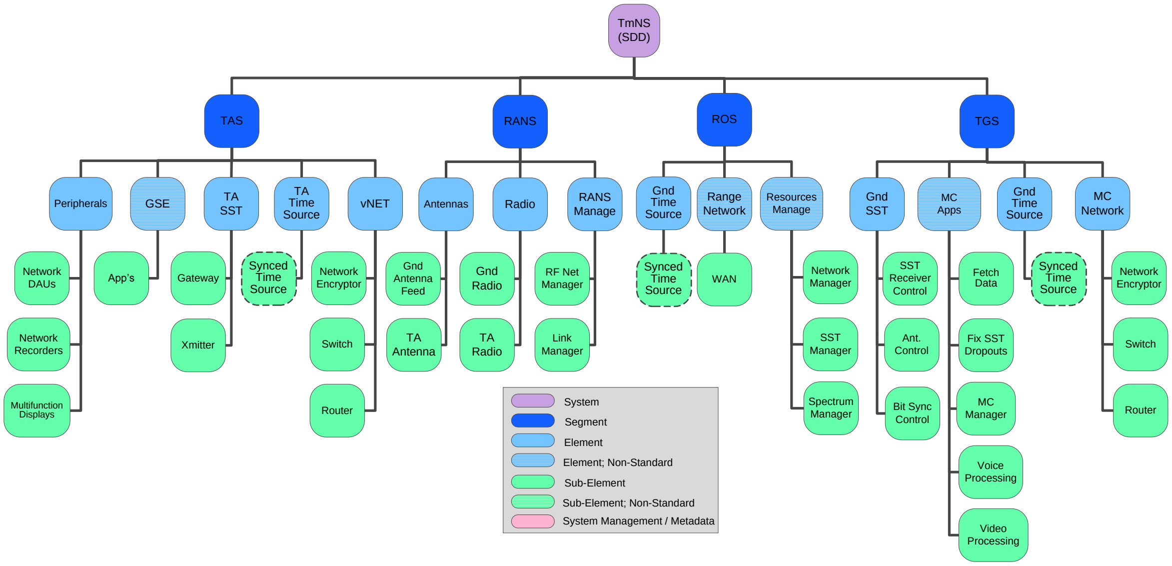


Figure 1: Demostartion System Context Diagram

CONCEPTUAL DESIGN FORUMLATION

The functional makeup of the TmNS is a composition of functions with flows illustrating the relationship of the functions. The system functional composition describes the structure of the system as a hierarchical structure broken into segments, elements, and sub-elements and is represented in the diagrams. The diagrams provided represent the functional breakdown of logical groupings of functionality.

The detailed tree of the TmNS demonstration system breakdown is illustrated in Figure 2 below. This does not directly show the relationship of the TmNS with the Metadata and System Management supporting elements but these elements touch every aspects of the system being managed. There are some items shown within the system hierarchy that are technically external



to the architecture but are captured to identify the functionality for the demonstration. A description of key blocks is described in the following paragraphs.

Figure 2: Demonstration System Structure

The TmNS block handles data transfer from acquisition sources (i.e. transducers, aircraft buses, etc) to data displays. The TmNS functionality is supported by system-level System Management and Metadata functions. The System Management functionality is rather broad in that anything that is managed has system management functions. Metadata functionality is also very broad in that it describes the implementation of the functions that needs to be communicated to operational aspects.

There are four segments the TAS (Test Article Segment), Radio Access Network Segment (RANS), ROS (Range Operations Segment) and TGS (Telemetry Ground Segment). The segment functionality is supported by the segment-level System Management and Metadata functions. The TAS block handles data transfer between the acquisition source/sinks, Ground Support Equipment (GSE), RANS, and establishes a logical connection with the TGS. The RANS block handles data transfer between the TAS and ROS through the open air interface. The ROS block handles data transfer between the RANS and TGS utilizing the existing range networks. The TGS block handles the data transfer between the ROS and data displays as well as processing to interface into the existing processing systems within the mission control facility. Over simplistically, the TGS is the consumer of information from the TAS, which yields a reciprocal functionality of the TAS.

The TAS acquires data from aircraft data sources (including measurands), transfers that data to other components, and provides the means to encrypt/decrypt the data stream to and from the RANS. The Vehicle Network (vNET) element provides the network connectivity for transferring data/information across the test article. The Test Article (TA) Time Source element receives GPS time and provides time to the TA. The TA Serial Streaming Telemetry (SST) element provides a gateway between vNET and legacy PCM systems. The Peripherals element provides the data sources and data sinks. The Ground Support Equipment (GSE) element provides the network resources and applications necessary to support operations and maintenance of the TA.

The RANS transfers data to and from the TA and ground. The RANS Management (RFM) element manages the data flow through the radio link and ensures data/information makes it to the intended destination and provides the code point services for the Radio. The Radio element provides the network to RF Bridge between the RFM and the antenna. The Antenna element collects and radiates RF energy, and combines and splits the RF energy between the network Radio and the PCM transmitter.

The ROS provides the resources necessary to integrate the TmNS demonstration capabilities into the existing range infrastructure and has the responsibility for managing the black-side elements within the system. The Range Network element provides the network connectivity for transferring data/information across the range, and provides a data stream to mission control facility. The Gnd Time Source element receives GPS time and provides time to the range. The ROS manages the RANS and Gnd Serial Streaming Telemetry (SST) components. The ROS also has the responsibility to maintain an awareness of the spectral resources.

The TGS provides the resources necessary to integrate the TmNS demonstration capabilities into the existing range infrastructure. The Mission Control (MC) network element provides the network connectivity for transferring data/information across the mission control room/facility, and provides the ability to encrypt/decrypt the data stream to and from the enclave. The Gnd Time Source element receives GPS time and provides time to the range. The Gnd Serial Streaming Telemetry (SST) element enables management of the SST components. The Mission Control Applications element provides a gateway between the TmNS data traffic and the existing telemetry processing, and provides the management and applications to communicate to the TA.

Message Flows

The blocks of the system hierarchy interact through messages that carry time, data, and management information across the system. The system messages/responses/interactions can be classified into a basic category of moving information or data that are further divided into three data groups, LTC/RC data, time data, and management data. These are primary informational units used to communicate across the system including among the elements, sub-elements, and external interactions.

- LTC (Latency & Throughput Critical) and RC (Reliable Critical) data carries critical data between data sources and the data sinks. The LTC and RC data includes many different messages including mission data packets.
- Time data is data from a time source to a time sink that provides for system-wide time synchronization.
- Management data are commands and status requests sent to managed components (i.e. data source/sinks, switches/routers, radio, etc.) and returns status and events from the

managed components. The management pathways are also used to configure components with the help of metadata that describes the configuration.

System/Segment Level Message Flows

The system/segment level messages flow between the TAS, RANS, ROS, and TGS. These messages carry data, time, and management information to and from the segments (Figure 3). The details of the messages between each segment level block are shown below.

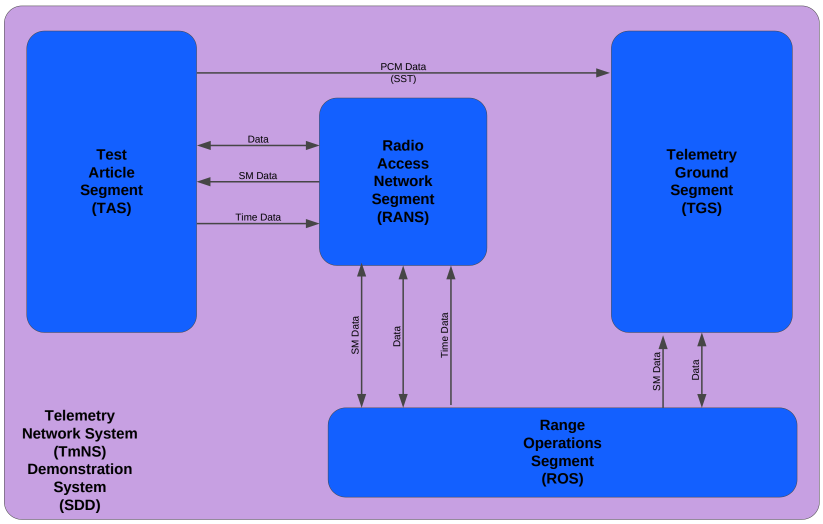


Figure 3: System Level Message Flow

In general, information of LTC/RC data flows from TAS to TGS however, provisions are made such that LTC/RC can flow from TGS to TAS. The RANS and ROS have no direct knowledge of LTC/RC data. The PCM data is maintained and connected as it currently does. All segments are managed thus management data is passed from managers to managed components. Time is required by the segments for timing, data correlation, logging, etc.

TAS Message Flows

Figure 4 below shows message flows for the TAS. Brief descriptions of the blocks are discussed below.

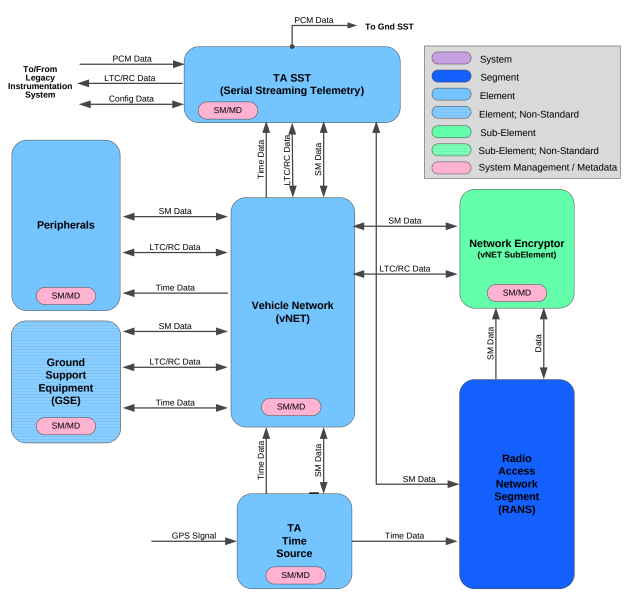


Figure 4: TAS Message Flow

Peripherals Element contains the data source and data sinks within the TA. The data sources or acquisition sources are the producers of LTC/RC data and the data sinks are consumers of the LTC/RC data. Time data is fed to these components for time tagging. The management data is used for command, status, and configuration.

VNET Element provides the network connectivity between components on the TA.

GSE Element provides maintenance and support of the instrumentation system on the TA.

TA SST provides the bridge/gateway between PCM instrumentation systems and the network data acquisition system. This allows LTC/RC data to flow into the PCM system as well as allow PCM data to flow into the vehicle network. This provides flexibility between the legacy PCM system and the network based system. RANS provides the network pathway to enable the ROS to control the PCM transmitter within the TA SST.

Time Source Element is fed by an external time signal that enables system wide time synchronization. The time source provides that time for distribution via the vNET as well as to legacy PCM systems/components.

RANS Message Flows

Figure 5 below shows messages flow for the RANS. Brief descriptions of the blocks are discussed below.

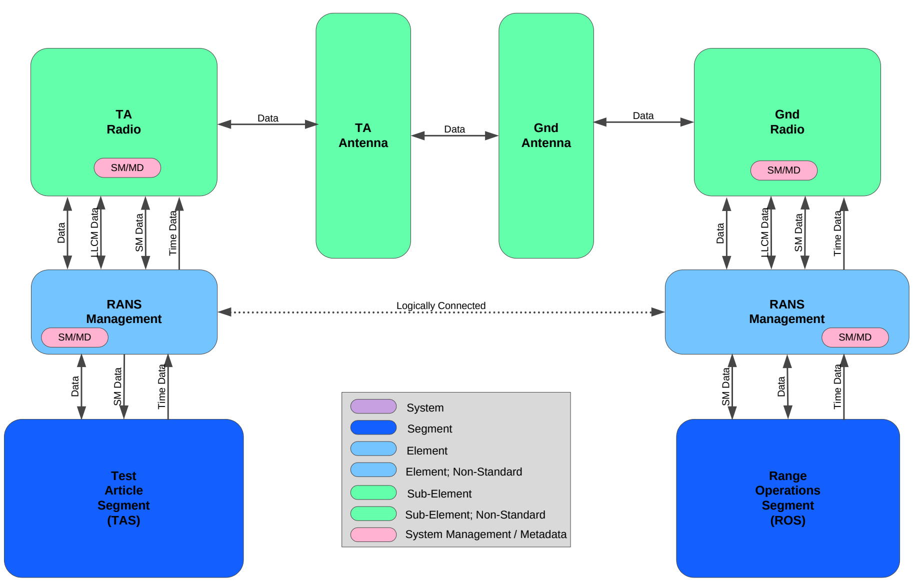


Figure 5: RANS Message Flow

Both the TA and Gnd Radios provide the bridge between network data and the RF signal. Each radio produces and consumes the RF signal creating a two-way RF link between the TA and the ground.

Both the TA and GS RANS Management manage the network traffic between the radios and the interconnecting networks. It provides the ability to allocate RF resources based on user requests, and route and manage IP traffic within the RANS.

Both the TA and Gnd Antennas provide the collection and radiating of RF energy. The antennas must combine and split the RF SST signal and the network RF signal between the TA and the ground.

ROS Message Flows

Figure 6 below shows message flows for the ROS. Brief descriptions of the blocks are discussed below.

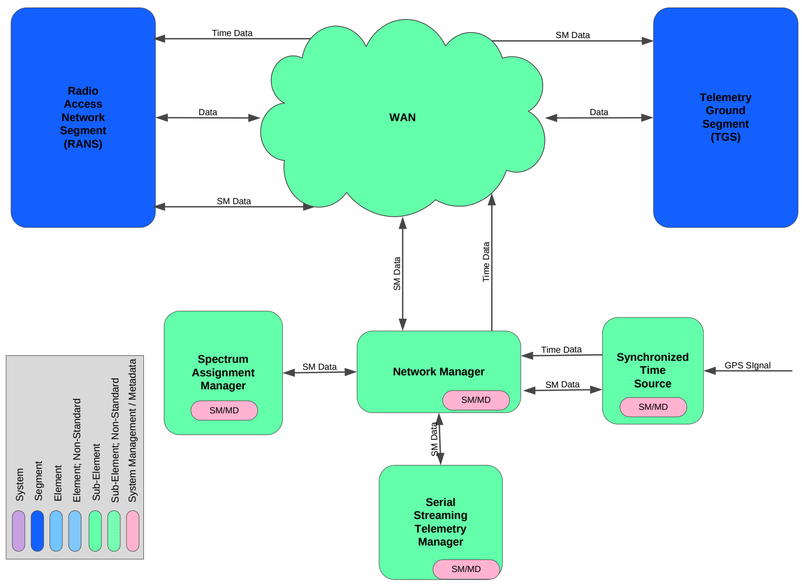


Figure 6: ROS Message Flow

The WAN (Wide Area Network) represents the range network infrastructure. The WAN from a TmNS perspective is given IP packets and moves those IP packets such that they can be received by the destination.

The Spectrum Assignment Manager provides the spectrum utilization and policies for utilization of the spectrum within the given range. This manager provides the accounting and scheduling of the spectral resources.

The Network Manager manages the WAN and RANS resources to ensure that data/information flow between the TA and mission control. This manager serves as the doorway for applications within the ROS to gain access to the black-side network.

The Serial Streaming Telemetry Manager manages the black-side SST resources. This manager manages the TA transmitter, the antenna control unit, SST receiver, and bit synchronizer.

The Synchronized Time Source sub-Element is fed by an external time source that enables system wide time synchronization. The time source provides that time for distribution via the WAN as well as within the range operations center.

TGS Message Flows

Figure 7 below shows message flows for the TGS. Brief descriptions of the blocks are discussed below.

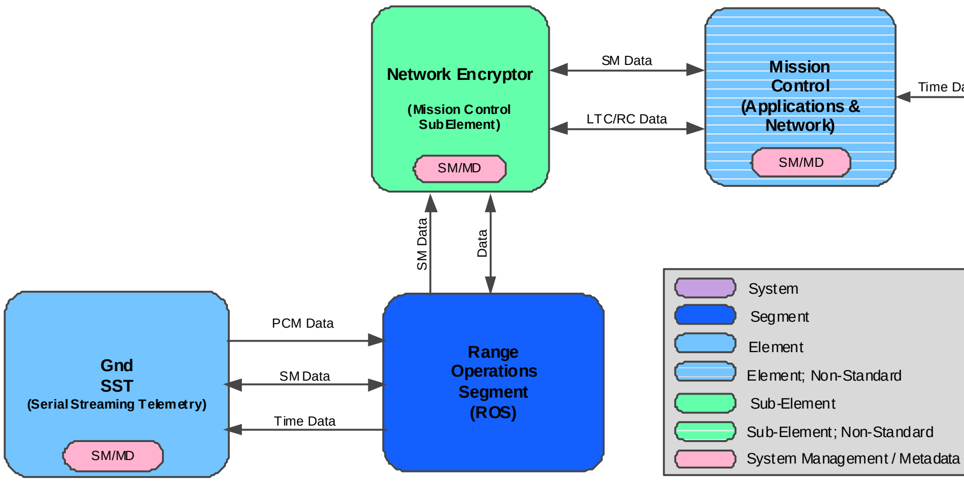


Figure 7: TGS Message Flow

Mission Control Application and Network Elements contain the data sinks and data sources within the TGS as well the network to interconnect them. The data sinks are consumers of LTC/RC data and the data sources are the producers of the LTC/RC data. Time data is fed to these components for time tagging and correlation. The management data is used for command, status, and configuration.

Gnd SST provides the bridge/gateway between PCM stream and the ground network. It also provides for the ability to remotely manage Gnd SST resources.

Time Source Element is fed by an external time source that enables system wide time synchronization. The time source provides that time for distribution within mission control.

A CONCEPTUAL DESIGN

A conceptual design is presented in Figure 8 below to visualize how the demonstration system might be realized. The following paragraphs will briefly discuss the concept design for each element that also includes a discussion on potential modifications to the existing functionality to the current deployed systems.

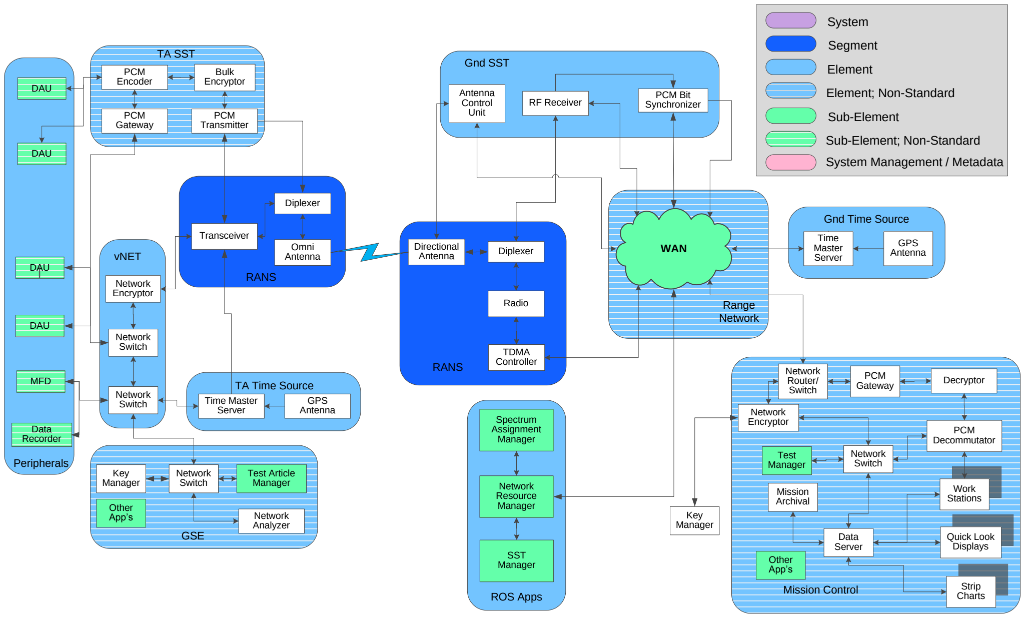


Figure 8: A Conceptual Design of a TmNS

Peripheral Element

Ranges have a large investment in data acquisition units and data recorders. Some of these devices have specialized data acquisition interfaces that are unique. Sometimes because of the uniqueness, the replacement cost can be costly. Therefore, by addressing the network from an interface perspective it also allows the customer to either buy a new network enabled peripheral or to modify the existing unit interface with a network interface or build a network gateway to the existing device or do nothing and continue to use the existing system.

TA SST Element

This element is basically an adaptation of the existing systems. The main addition is a PCM gateway that takes in the SST PCM data, packages it up into network messages, and sends them to the vehicle network. One could also make the gateway look like a DAU and format the network data into the serial streaming telemetry link. The line from the transceiver to the PCM transmitter represents the network control for the transmitter. The PCM encoder takes data from the DAUs via the existing bus standard (CAIS) and serializes the data, which is encrypted and then transmitted.

Vehicle Network Element

This element is somewhat new for airborne telemetry. The network switches provide the data pathways to enable the data sources to communicate with the data sinks. The PTP time that is distributed across the vehicle network requires that the switches have the functionality to make time corrections to the PTP time messages so that the constant timing delays are removed from the system giving the perception that data source time readers are connected directly to the time masters. Although, not explicitly called out as a requirement but for throughput efficiency, the switches must be able to support the multicast protocols. In addition, instead of switches some installation may desire a router for potential isolation of extended networks.

Ground Support Equipment Element

The main piece of the ground support equipment is centered on a computer so that the systems can be programmed, checkout, perform calibrations, analyze bus traffic, provide stimulus to the peripherals, etc. The major addition is likely software to manage the network and network analysis tools to aid in troubleshooting.

TA Time Source Element

This element is basically new for airborne telemetry. The GPS antenna is standard and used in existing installations. The time master is new because it provides PTP time to the time sinks (data sources) via the network. Today's systems provide time out of band from the data communications.

RANS Transceiver SubElement

This element is new for airborne telemetry. The transceiver is envisioned to be composed of a radio and router. The network radio must take in network data, convert that to RF waveform to SOQPSK, and perform the opposite when receiving. The radio will use a TDMA (Time Division Multiple Access) scheme for the RF network. The front end of the radio is anticipated to need a router to handle the incoming data from the vehicle network. The RF network element is considered a constrained resource in the TmNS system. This network being the constrained resource will have to make decisions on the data as far as priority and potential bandwidth reservations. These are accomplished through QoS protocols.

RANS TA Antenna SubElement

This element is envisioned to be a pure RF passive system that takes RF energy in and outputs RF energy. The airborne test articles typically use Omni-antennas which they radiate RF energy in all directions. The typical Omni-antenna can be used in this application with the addition of a diplexer. The diplexer is used to combine and de-combine RF energy based on the bands selected.

RANS Gnd Antenna SubElement

The heart of the GS antenna element already exists, the direction antenna and ACU (antenna control unit) to point it and track the airborne test article. The first modification is in the antenna feed to handle the RF bands and the diplexer to de-combine and combine the RF energy based on the bands selected. The directional antenna normally has two slip rings one for the vertical polarized SST RF signal and the other for horizontal polarized SST RF signal. The pedestal will need to be modified to add another slip ring for the network RF signal. In this design, the SST signal must be present on the test article in order to utilize the existing tracking mechanisms. It should be pointed out that normally the antennas are remotely located. Therefore, utilization of much of the existing infrastructure is highly desirable.

Gnd Serial Streaming Telemetry Element

This element is basically an adaptation of the existing systems. The main addition is a PCM gateway that takes in the SST PCM data, packages it up into network messages, and sends the data to the ground network interface. The line from the gNET interface network is used for managing the GSS SST element.

RANS Gnd Radio Frequency Network SubElement

Just as the TAS RANS Management element is new so is this element new for airborne telemetry. The network radio must receive the RF waveform like SOQPSK and convert that to network data and vice-versa for transmitting. The radio uses a TDMA (Time Division Multiple Access) scheme for the RF network. The front end of the radio is anticipated to need a router to handle the outgoing data into the ground network. The RF network element is considered a constrained resource in the TmNS system. This network being the constrained resource will have to make decision on the data as far as priority and potential bandwidth reservations. These are accomplished through QoS protocols.

Gnd Time Source Element

This element is new for airborne telemetry and will likely be required near where the radio is installed. It is anticipated that timing requirements may be desired for the RF link in order to maintain tight synchronization for the TDMA epoch. The GPS antenna and IEEE-1588 time grandmaster are commercial off the shelf devices.

Wide Area Network Element

The WAN network already exists for many ranges. Therefore, it was important to find a way to interface into the existing infrastructure. One of the challenges here was QoS. It was required to find a protocol that was widely supported by existing standard network devices that enable the TmNS to function with the necessary QoS. The use of the differentiated services (DiffServ) was a protocol that fit the basic need. However, DiffServ did not provide the traffic engineering that would be required to guarantee throughput.

In many ranges antennas can be clustered together to minimize installation facilities. Therefore, this element is primarily driven to establish a local LAN to tie into the local range WAN infrastructure. The network router will likely be required to tie into the WAN and switches are needed to tie together the network-enabled devices. It is unlikely that all the switches will require the PTP time (IEEE-1588) that is distributed across the LAN.

Mission Control Elements

Most ranges conduct multiple concurrent test missions having numerous project engineering stations. Physically there is no real significant change here except for the managers and software applications to process the network data.

CONCLUSION

The message flows represent the basic message exchanges needed by the TmNS to exercise the functions of the system to achieve the system level capabilities. The interactions were generalize in order to be able to apply networking technologies. The end goal being a system that leverages existing technologies and can be applied to meet the operational needs. The flows illustrate that the TmNS is basically just a complex managed data pipe. Additional decomposition will likely evolve the message flows into ensure performance measure can be satisfied. The messages flows can be mapped to technologies identified in the iNET standards. The technologies identified in the standards help formulated the componentization for the conceptual design. The conceptual design is used to explain the details of the TmNS will operate to satisfy the operational requirements.

ACKNOWLEDGEMENTS

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REFERENCES

The iNET work that has been publicly released is on the public side of the iNET portal and can be used to provide additional details. https://www.inetprogram.org/default.aspx