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INITIAL INET RF NETWORK TESTING

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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 properly. This also provides the best long-term scalability to new unforeseen applications much as the Internet has grown through its open standards. Unfortunately, the Radio Frequency (RF) channel characteristics do not fully lend themselves to the typical physical layer approaches utilized by Internet Protocol (IP) technologies. The iNET project is developing the Telemetry Network System (TmNS) RF Network to provide a flexible two-way IP telemetry capability. The Developmental Flight Test (DFT) phase is currently under way to perform initial flight testing of the RF Network. This paper provides an overview of the planned RF network testing and the expected results. Current results from flight testing will be presented at the conference.

KEYWORDS

Telemetry Network System (TmNS), RF Network, Testing, iNET

INTRODUCTION

The integrated Network Enhanced Telemetry (iNET) project is an effort to enhance telemetry capabilities through the use of networks. Due to the ubiquitous nature of communication networks, particularly Internet Protocol (IP) networks, there are many well-defined and proven networking technologies that can be utilized within a network-based system. One of the core philosophies of the iNET project is to leverage standard networking technologies whenever possible, which will reduce development cost as well as allowing standard networking applications to function. This approach also provides long-term scalability to future applications.

The iNET project has defined a Telemetry Network System (TmNS) which, at the highest level, is a network of networks. One of the networks in a TmNS is the vehicle network, or Test Article (TA) network. The TA network is an IP-based network that consists of various network components, some of which acquire data and generate network packets containing the data, and some of which record and/or process the acquired data after receiving it from the network. Other IP-based networks are present on the ground and may consist of mission control rooms and other range infrastructure. The networks on the ground are connected to the TA network via the Radio Access Network (RAN) segment of the TmNS.

Spanning across all of the segments of the TmNS are the standardized system management interfaces and the common Metadata Description Language (MDL). A high-level view of the TmNS can be seen in Figure 1.

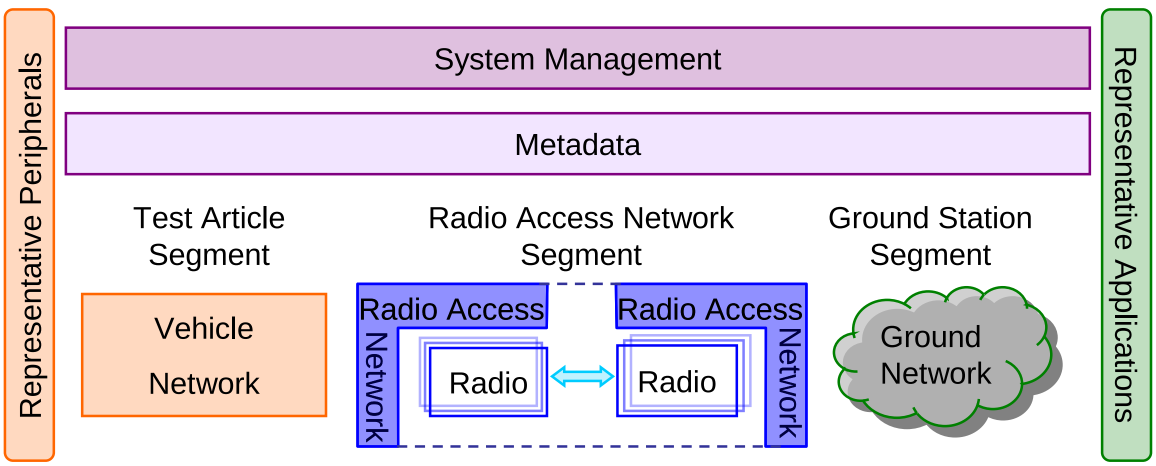

Figure 1. TmNS Network

A key technology being developed within the RAN segment of the TmNS is the two-way IP telemetry link. In addition to allowing established IP protocols to function correctly, this two-way link will allow authorized personnel in the ground station segment to remotely monitor the health and status of the TA and its onboard devices while simultaneously providing an avenue to communicate upstream to the TA and its devices. This introduces to the ground station user a capability to remotely reconfigure devices on the TA while in flight, thus reducing time and costs associated with flight testing.

The iNET project is currently in the DFT phase and will be performing extensive in-flight RF network testing later this year. Data from these tests will be collected, processed, and analyzed to determine the effectiveness of the RF network. Results of this testing are planned to be presented at the 2014 International Telemetry Conference (ITC). Areas of interest throughout DFT include, but are not limited to, RF link statistics, IP performance, Low Density Parity Check (LDPC) performance, Automatic Repeat reQuest (ARQ) performance, Antenna to

Antenna (A2A) handoff, and iNET radio health and status. This paper focuses on the testing approach of the RF network.

INET RF NETWORK CAPABILITIES

The information in this section comes directly from the iNET RAN Standard version 0.7.9.2.

Architecturally, the RAN segment is divided into three elements:

1. Radio Element (Radio) – provides the capabilities necessary to transform between RF formats and digital formats (e.g., modulation / demodulation, and timing of transmissions / receptions)

2. RF Network Element (RFNE) – provides management of resource sharing, traffic management, communication protocol implementations, scheduling and queue

3. Antenna Element (Antenna) – provides the interface between the Radio elements located in TAs and on the ground and the RF spectrum (Air Interface)

In the Aeronautical environment, the RAN segment will support the sharing of one RF frequency by multiple tests using a Time Division Multiple Access (TDMA) scheme.

The RAN segment supports mobility of a TA during a test through handover and relay operation.

- The RAN segment supports a TA moving from one antenna to another while continuing to participate in the same TDMA regime on the same frequency (intra-TmNS handover). The RAN segment also supports a TA moving from one antenna to another and switching to a different TDMA regime on a different frequency (inter-TmNS handover).
- The RAN segment supports relay operation for a TA required to operate beyond the limit of one radio-to-radio link in two manners:
    a) A TA may be handed off to an antenna that is remote from the Mission Control Facility so as to require additional network links to the range network.
    b) A second aircraft, configured as a TA but not being tested, may stay in range of an antenna on the ground and serve to relay wireless communications to/from the TA under test.

The RAN segment supports Quality of Service (QoS) for distinguishing priorities among different TAs and for distinguishing different QoS levels within a test. Within a test, different QoS levels can be provided for different data streams being telemetered from TA to ground and/or for different command-and-response actions initiated on the ground. The RAN segment supports QoS which makes decisions on the order in which packets will be presented to the radio for transmission over a shared TDMA channel.

The RAN segment supports data delivery for tests with diverse security constraints that require TA and ground networks to be divided into red and black network segments by security devices.

For some ranges and some tests, it may be possible to use guards or data diodes in the ground network. The RAN provides multiple flexible capacity management and QoS approaches to allow basic functionality for constrained security conditions and improved performance when security conditions are less constrained.

The RAN segment supports cross-band operation of TAs using spectrum allocated from the L, S and C telemetry bands concurrently. The RAN can provide multiple physical network uplink or downlink paths through the use of multiple radios on the TAs and in associated ground stations [1].

The RAN segment supports a two-way IP telemetry link providing ground station users the ability to communicate up to the TA while simultaneously monitoring the health and status of the TA and its components.

PLANNED RF NETWORK TESTING

As the DFT phase of the iNET project continues, a series of flight tests will take place, and data will be collected to validate the performance of the RF network in its entirety. The following sections will describe in greater detail the specific data to be collected with each representing a test area of interest.

For all flight tests, data generators will primarily be used to simulate multiple Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) network traffic flows at various priorities and rates. This simulated traffic will be shaped to resemble real TmNS network traffic. There will be iNET TA components integrated into the tests producing real data; however, the bulk of TmNS network traffic will be simulated. Voice over IP (VoIP) will be used to generate the higher priority voice traffic for all tests. The different data flows will exercise the capability of the iNET radios to provide the QoS according to the different rates and priorities of those data flows.

For a majority of all flight tests, static Transmission Opportunity (TxOp) schedules will be utilized for all active RF links involved in the test. These static schedules will provide different scheduling scenarios by varying how the TxOps are divided between the RF links. For example, a series of tests may be run with a balanced TxOp schedule between the active RF links (50/50 TxOp schedule), or more TxOps may be scheduled for the downlink providing fewer TxOps to the uplink (80/20 TxOp schedule). In some cases, a dynamic TxOp schedule will be supplied to the active RF links involved in the test using a Link Manager (LM).

RF Link Statistics

The quality and reliability of the RF link is of great importance. During all flight tests, specific radio statistics will be collected at a constant rate from all TA and ground iNET radios actively involved in the test using an automated script. These statistics include, at a minimum, the current transmit power, the Received Signal Strength Indicator (RSSI), the Carrier to

Interference plus Noise Ratio (CINR), and the queue lengths. Additional parameters may be added when deemed necessary.

These statistics will be captured with IEEE 1588 synchronized time so that each data point can be traced back to a specific time or event in the test and correlated with data collected at other locations in the test. This data may become increasingly interesting when debugging link drop-out events. The RF transmission power of a source radio may be compared to the RSSI reported by the destination radio at a given point in time during the test to determine when a signal began to degrade or at what point the signal was too poor to maintain the link. When used in conjunction with Time and Space Position Information (TSPI) data, these statistics can help to validate the RF network performance based on location, distance, and geographical considerations.

IP Performance

The iNET radios must handle with high reliability all IP traffic traveling into their wired interface at rates that do not exceed the physical limitations of the RF link. When rates entering the iNET radios on their wired interfaces do exceed the capacity limitations of the RF link, delays or drops must occur on the lower priority traffic classes while higher priority classes are forwarded using the available capacity. During all flight tests, specific IP related measurements will be taken that include end-to-end latency, end-to-end throughput, jitter, and IP packet drops. All IP packets entering a source iNET radio on its wired interface and the corresponding packets exiting the destination iNET radio on its wired interface will be captured to collect these measurements. Each TA and ground iNET radio actively involved in a test will have their wired interface tapped so that the necessary IP data may be collected. All IP traffic will be analyzed as a whole as well as individually by class or traffic type. Additional measurements will be taken when deemed necessary.

All measurements will be captured with IEEE 1588 synchronized time so that each piece of data can be traced back to a specific time or event in the test and correlated with data collected at other locations in the test. These measurements will be analyzed in conjunction with the RF Link Statistics. For example, if IP packet drops are measured, it would be informative to see what the iNET radio queues looked like around the time of the drops. It is also expected that the corresponding TSPI data will be valuable when performing IP performance analysis.

LDPC Performance

During all flight tests, specific data will be collected at a constant rate from all TA and ground iNET radios actively involved in the test using an automated script. This data which includes the LDPC blocks per burst, LDPC blocks sent, LDPC blocks received, LDPC blocks dropped, and LDPC Block Error Rate (BER) will help to analyze overall LDPC performance. Additional data will be collected when deemed necessary.

The LDPC data will be collected with IEEE 1588 synchronized time so that each piece of data can be traced back to a specific time or event in the test and correlated with data collected at other locations in the test. This data will be analyzed in conjunction with the IP performance and

RF link statistics data and is expected to benefit from being analyzed with corresponding TSPI data. This data will help to understand dropouts on a link for a particular location of the TA as well as LDPC drops versus total IP end-to-end throughput.

ARQ Performance

During DFT, ARQ will be primarily analyzed based on its effects on TCP and UDP IP traffic. The IP performance measurements outlined above will be collected with ARQ disabled and enabled at a variety of data rates and IP protocols. The difference in IP performance while ARQ is enabled versus IP performance with ARQ disabled will help to validate ARQ performance. In addition, RF link statistics and TSPI data will be utilized to characterize and possibly identify conditions (i.e., distance, position, terrain) that may improve or degrade ARQ performance. ARQ retires will be collected at a constant rate from all TA and ground iNET radios actively involved in the test using an automated script. All data will be collected with IEEE 1588 synchronized time so that each data point can be traced back to a specific time or event in the test and correlated with data collected at other locations in the test.

A2A Handoff

A2A handoffs require a lossless handoff from one antenna to another. Each antenna is linked to a single iNET radio so an A2A handoff could also be defined as a handoff from one iNET radio to another. It is important that all data is drained from the old iNET radio's queues prior to the new iNET radio becoming the active radio. A2A handoffs are performed when a TA antenna hands off from one ground antenna to another. To accomplish this, an LM will be used to monitor the RF link statistics (outlined above) of all active ground iNET radios. When the LM determines the active RF downlink degrades below a pre-determined threshold, the LM will automatically command a handoff from the currently active ground antenna to the new ground antenna. A successful handoff is completed when the ground iNET radio's queues are drained and the new link is established without data loss.

While A2A handoffs are being tested, the RF link statistics, IP performance, and LDPC performance data outlined above will be collected with IEEE 1588 synchronized time so that each piece of data can be traced back to a specific time or event in the test and correlated with data collected at other locations in the test. This data used in conjunction with TSPI data will provide potentially critical information that can be used to characterize what may result in successful or unsuccessful A2A handoffs.

iNET Radio Health and Status

In addition to the data and measurements outlined above, during all flight tests some iNET radio health and status parameters will be collected at a constant rate from all TA and ground iNET radios actively involved in the test using an automated script. This will provide additional debugging information if needed for additional diagnosis. These health and status parameters include, but are not limited to, IEEE 1588 synchronization status, IEEE 1588 offset from master, internal temperature, voltage, current readings, memory usages, and error/fault logging. This data will be collected with IEEE 1588 synchronized time and used in conjunction with all data outlined above in the event of test failures and correlated with data collected at other locations in the test.

EXPECTED RESULTS OF RF NETWORK TESTING

As a result of preliminary testing performed in the iNET System Integration Lab (iSIL) at Southwest Research Institute, there are certain results that are expected to be observed during DFT RF network testing. Although it is impossible to completely simulate all of the dynamics of a live flight test inside a laboratory, many performance characteristics of the two-way IP telemetry link were analyzed.

Based on the laboratory analysis, it is expected that 5 Mbps of end-to-end throughput can be achieved in each direction across the RF link, as long as the scheduled TxOps for each link direction allow enough transmission time. When the data rate entering the source iNET radio on its wired interface exceeds the physical limitations of the RF link, the iNET radio will delay or drop the lower priority class traffic while maintaining the performance of the higher priority traffic. For example, it was observed in the lab that Best Effort (BE) UDP traffic was dropped while Expedited Forwarding (EF) VoIP traffic maintained its performance without drops. This was observed when the BE UDP traffic rate was increased beyond the current capacity of the RF link.

It is expected that end-to-end latency of EF VoIP traffic will remain below 200 ms as long as the TxOp schedule allows the data rate to be maintained. This is independent of other traffic classes because the radios have been observed to drop lower class traffic in the event that the link input rate exceeds the limitations of the RF link. In other words, the iNET radios have been observed to maintain EF VoIP performance despite total traffic loads. The end-to-end latency of the other traffic classes is expected to remain low as well; however, they will vary depending on the available bandwidth.

It is anticipated that there will be no IP packet drops recorded while the link maintains a healthy signal and the data rates do not exceed the capacity limitations of the RF link. All drops that occur will be intentional and based purely on QoS. This includes A2A handoffs. It has been observed in the iSIL that A2A handoffs can be achieved without losing data, so it is anticipated that they will occur as such during DFT.

CONCLUSION

As the iNET project continues to progress, DFT is the primary focus of the development effort. An extensive number of tests will be performed in the months to come that will help validate the RAN segment of the TmNS network. Specifically, the two-way IP telemetry link will be thoroughly tested to ensure reliability and performance. A series of flights will take place allowing the RF link to be tested in a number of different scenarios and pushed to its limits. Handoffs will be performed and a large quantity of data will be collected. During the process, IP performance will be validated and, in doing so, one of the core philosophies of the iNET project will be realized. That philosophy is to leverage standard networking technologies whenever possible to both reduce development cost and to allow standard networking applications to function. Although there was no data to present at the time this paper was written, results will be available and presented at the 2014 ITC.

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REFERENCES

[1] integrated Network Enhanced Telemetry (iNET) Radio Access Network (RAN) Standard version 0.7.9.2