LINK VALIDATION AND PERFORMANCE MEASUREMENT WITHIN THE NASA SPACE NETWORK

Amit Puri, Kirill Lokshin, Felix Tao
Ingenicomm, Inc.

David Cunniff, David Glasscock
ITT Corp.

Raj Ramlagan
ASRC Aerospace Corp.

ABSTRACT

The National Aeronautics and Space Administration (NASA) Space Network (SN) consists of a Space Segment, composed of the Tracking and Data Relay Satellite (TDRS) fleet, and a Ground Segment that includes the White Sands Ground Terminal (WSGT), Second TDRS Ground Terminal (STGT) and the Guam Remote Ground Terminal (GRGT). Collectively, the SN Ground Segment is commonly referred to as the White Sands Complex (WSC). Traditional methods of latency and performance measurement across the component links of network have relied on the use of simplified test patterns and basic data formats that are often specific to the instruments providing the measurements. These tests do not often correlate to the operational data normally transferred through the network.

This paper discusses an alternative approach to performance measurement within the Space Network. By embedding and extracting performance metrics directly within simulated data sets that closely resemble operational traffic, performance measurement can be combined with link verification and validation to provide a single, comprehensive set of test and measurement activities.

KEY WORDS

NASA Space Network, TDRSS, Link Latency Testing, Link Performance Measurement

INTRODUCTION

The NASA Space Network (SN) is an infrastructure mechanism to provide data relay services to end users by operating a bent-pipe relay system between customer platforms and customer ground facilities. The SN consists of a Space Segment, which is composed of the Tracking and
Data Relay Satellite (TDRS) fleet, and a Ground Segment, which includes the White Sands
Ground Terminal (WSGT), Second TDRS Ground Terminal (STGT) and the Guam Remote
Ground Terminal (GRGT). The WSGT and STGT are located near Las Cruces, New Mexico,
while the GRGT is located on the island of Guam and it is linked to the WSC through the NASA
Integrated Services Network (NISN).

The primary role of the SN is to provide data acquisition services to a wide variety of Earth-
orbiting satellites, as well as the International Space Station (ISS), the McMurdo TDRSS Relay
System (MTRS), and the South Pole TDRSS Relay (SPTR).

The SN service provision is subject to support requirements expressed in individual customers’
Mission Requirements Requests (MRR) document. For each project, the Detailed Mission
Requirements (DMR) document contains the detailed support requirements for the project, as
well as comprehensive plans to meet those requirements. These detailed requirements include
specific latency constraints for services provided by the SN.

**CURRENT PERFORMANCE MEASUREMENT METHODS**

The methodology of latency and performance measurement within the SN was examined by a
2008 study conducted by Jaluria and Anderson of HTSI [1]. The study examined three different
performance measurement scenarios in use within the SN infrastructure. These include two
scenarios designed to test the performance of a particular ground terminal, and one scenario
designed to test the performance of the link between the SN sites. These scenarios are detailed
below.

![Diagram](image)

**Figure 1:** Analog performance test scenario. This configuration tests the performance
of the pre-demodulator RF processing chain at WSC.
The first of the performance measurement scenarios, shown in Figure 1, focuses on determining the latency through the front-end analog equipment connected to a particular antenna, consisting of the LNA, the down-converters, the secondary amplifiers, and the channel filters. The test configuration uses an RF signal generator to inject a known signal pattern into the analog circuit input to the LNA, and measures the delay introduced to the pattern on the output of the analog filters using a time interval counter.

The propagation delays through the RF processing chain can be represented as the sum of two distinct components: the delay due to the finite-speed propagation of the signal in the physical media, and the group delay induced by the electrical transfer function of the RF signal chain components. With proper calibration, these latencies can be consistently measured to an accuracy of 10-20 ns.

The second performance measurement scenario, shown in Figure 2, focuses on determining the latency through the entire ground terminal processing chain, from the antenna to the network gateway.

The WSC uses a set of legacy test systems, such as a 1970’s-vintage PDP-11/03-based Data Generator, to generate test data with embedded PB-4 timestamps, which can then be compared to the output of the processing chain. The delta of the originally generated time and the time measured on the output of the system indicates the delay through the system for the particular
data rate used in the test; this delta can be measured to the resolution of the timestamps used, resulting in a nominal accuracy of 1 microsecond.

The third performance measurement scenario, shown in Figure 3, focuses on determining the latency through the network link between Guam and WSC. The LAN/WAN performance between the two sites must be routinely measured by the SN network engineers, as path delays are different between the prime and redundant circuits; measurements are made after circuit outages, routine maintenance on the circuits, or communications equipment changes.

![Figure 3: Link test scenario. This configuration tests the performance of the Guam-White Sands network infrastructure.](image)

The test configuration does not use any specialized test and measurement equipment, and relies on the use of standard Internet Control Message Protocol (ICMP) PING and PING ECHO messages between the two NISN gateways to determine approximate round-trip latency. To perform the test, a network engineer at one site will directly invoke an ICMP PING operation from one gateway to the other; dividing the resulting round trip time (RTT) by two provides an approximate measurement of the one-way latency across the LAN/WAN link. Due to the limitations of the ICMP protocol, this measurement is taken at a millisecond resolution, and thus cannot provide latency statistics with a higher precision.

**INTEGRATED LINK VALIDATION**

The first two performance test scenarios – analog performance measurement and end-to-end performance measurement – were found to be generally sufficient to determine the latency and performance of those portions of the SN. However, the network link validation configuration was considered unsatisfactory, because the use of the PING tool produced rough estimates of the latency, and because the traffic generated by this tool bore no resemblance to the nominal operational traffic of the SN.
An alternative approach is to deploy test equipment that will generate traffic more closely resembling nominal operational traffic; timing information can be directly embedded within this traffic, allowing a single test scenario to verify both the integrity of the link and the latency and performance characteristics of the network.

One variant of this approach, which Jaluria and Anderson reported as being a common practice within WSC, is to use a PRBS generator to perform a long-loop test across the link between the two sites. For example, operators could establish a serial loopback circuit through Guam, with a Fireberd PN pattern generator at WSC serving as the source and sink for the test data. The Fireberd synchronizes to the received PN code and measures the delay between the transmitted and received patterns; dividing this delay by two results in an approximate one-way latency measurement with millisecond accuracy.

However, using a raw PN pattern introduces a number of limitations to the test configuration. First, the pattern is necessarily distinct in format from the operational data carried by the LAN/WAN link; operational traffic cannot be simulated without sending the pattern through encapsulation/decapsulation systems at either end of the network, which would affect the resulting measurement. Second, the configuration is intended for use directly through an end-to-end serial channel; it is not possible to inject the data directly into the network link at the gateway level. Thus, an alternative test method is sought.

![Diagram of test setup](image)

*Figure 4: Nominal placement of the SN PTS. The primary objective of this test scenario is to validate the performance of the Guam-White Sands communications link.*

The approach shown in Figure 4 uses a set of dedicated SN Performance Test Sets (PTS), one located at each SN site, to simulate operational traffic on the Guam/WSC link. During the test, one PTS acts as a data source, while the other acts as a data sink and performance measurement tool.
The SN PTS, shown in Figure 5, is a custom-built, portable system designed for ease of transport between SN sites. The PTS provides a modular software framework that allows individual functional blocks to be configured into an end-to-end data flow. Each SN PTS is configured to provide both network and serial (RS-422) input and output channels, to allow for flexibility in accessing test data inject points at either the SN gateways or the SN front-end-processors (FEPs). In their nominal configuration, each SN PTS is connected directly to the NISN gateway at each site.

To more closely simulate the operational traffic on the LAN/WAN link, the source PTS is configured to generate a simulated telemetry stream in Consultative Committee for Space Data Systems (CCSDS) Telemetry (TM) format. This stream consists of sequential fixed-size telemetry Transfer Frames (TFs), which contain packetized PRBS data with embedded timing information. The high-level data flow though the source SN PTS system is shown in Figure 6.

When the test data is generated, timing information is embedded in the Time Code field of the Space Packet Secondary Header for each generated Space Packet [2]; these Space Packets are then encapsulated in Transfer Frames for transmission across the SN network link. The Transfer Frames are transmitted at a fixed data rate, which is specified according to the operating parameters of the SN service being simulated.
The sink PTS is configured to receive and validate the simulated CCSDS telemetry stream, and to determine the latency of telemetry through the system by examining the embedded timing information present within the simulated Space Packets. The high-level data flow through the receiving SN PTS is shown in Figure 7.

The received telemetry Transfer Frames are time-stamped during the frame synchronization process; these time-tags are applied to the extracted Space Packets during the telemetry processing stage. Each Space Packet’s time-tag is compared to the timestamp embedded in the Space Packet during the simulation process to determine the one-way latency through the SN link. Simultaneously, the content of the Space Packet is validated against the original PRBS pattern to determine the integrity of the link; errors during the transmission process are detected via the pattern comparison, and Bit Error Rate (BER) and Packet Error Rate (PER) statistics are generated for the link.

CONCLUSIONS

The proposed test methodology is an improvement over the existing latency and performance test and validation methods for the NISN network components of the SN, since it allows the operational usage of the NISN link to be more closely modeled by the test configuration. In particular, the ability to generate simulated CCSDS data in a format matching that of the expected operational traffic allows for any network conditions specific to the format, size, or relative timing of the traffic to be detected and analyzed. This permits more accurate evaluation of both the impact of particular types of operational data on network latency, and the integrity of particular types of operational data across the network link.
In addition, the use of simulated operational data allow for latency measurements to be taken at the precise data rate used by each service provided by the SN. This is a marked improvement over the use of ICMP PING, since the ICMP protocol does not allow test engineers any substantive control over the effective rate at which PING data is injected into the network link; the resulting measurement is essentially that of the latency at some nominal ICMP data rate rather than at the rate of any particular SN service.

REFERENCES
