Ground Systems Architectures Workshop (GSAW) 2011

Modeling and Simulation of Ground Communication Architectures for Space Networks

Dr. Kul Bhasin (NASA Glenn Research Center)
Michael Fuentes (NASA Glenn Research Center)*
Seth Matthews (NASA Glenn Research Center)*

*DB Consulting
Trends, Challenges, and Motivation

- Increasing Complexities of Ground Architectures
- Lack of a high-fidelity toolset to simulate End-to-End communication (full network stack) of space systems

Our Approach

- GEMINI Unified Toolset

Modeling and Simulation Case Studies for NASA’s Ground Communication Infrastructure

- Link Layer Security
- Ground Network Loading Study
- Network Loading Comparison

Conclusion
Integration of Communication Networks

- Improvement of communication performance by integrating NASA’s communication networks without impacting customer missions

Evolution of Customer Demand

- Provide new mission users higher data rates and more modern interfaces while continuing to support legacy space mission users

Architecting Challenges

- Measuring performance through real-world testing is difficult & expensive
- Predicting network application performance over space communication networks is very difficult to estimate through static analysis

*During formulation phases, network simulation can be used to evaluate architecture alternatives and predict expected system performance…*
Integrated Space Comm Ground Network Architecture, Modeling & Simulation Process

Trade Studies

Technical:
• Wallops Low Elevation Study
• SGSS NISN Loading Study
• INM Network Loading Comparison Study

End-to-End Simulation:
• SGSS Link Layer Security Impact Assessment Study

Tools

Modeling Tools:
- Core
- MagicDraw

Simulation Tools:
- QualNet
- STK
- STK/Scheduler

Integrated Tool:
- GEMINI

Ground Systems Architectures Workshop (GSAW) March 1, 2011
GEMINI Simulator

- Precisely quantifies network performance at all layers by modeling and dynamically simulating network traffic, protocols, topology, and space links for missions and projects.

- Allow the reuse of existing vetted models developed by subject matter experts across both the network simulation and the astrophysics simulation domains.

GEMINI Simulator

Ground Segment Models (in QualNet)

Custom GRC Software for real-time integration of two COTS software tools:

- QualNet (network simulator)
- STK (physics & RF simulator)

Space Segment Models (in STK)
GEMINI Design Concept

QualNet/STK Integration
- Integration occurs at the simulated physical/data link layer interfaces
- For simulation of outbound frame radiation across space links, our custom code queries the corresponding model in STK. STK responds with the link data for that interval.
Case Studies
Background
• NASA is the process of modernizing its Space Network
• Modernized architecture must support the proposed protocols for the Constellation Mission

Overview
• LLS occurs at Layer-2 (Data Link) of the OSI Network Model
• Due to the desire for flexibility, LLS can be configured by the user to provide 3 different types of security services

Scenario Time
• Orion in LEO orbit during July 2015
- Average Throughput of the 5 Megabyte file downlink was 120 Kbps
- Average VoIP latency of 346 ms
- Average jitter of 21 ms with worst-case of 129 ms

- Average Throughput of the 5 Megabyte file downlink was 90 Kbps
- Average VoIP latency of 358 ms
- Average jitter of 31 ms with worst-case of 167 ms
Background
• NASA is the process of modernizing its Space Network
• Modernized architecture must be able to support both legacy and future mission traffic

Overview
• NISN is the dedicated mission network connecting NASA’s Space Network (SN) facilities
• 2 Scenarios of projected traffic in July 2015
  • 14 expected customer missions
  • 5 additional missions that are plausible

Scenario Time
• July 2015
User Mission Set for June 2015 comes from the *Space Communications Mission Model*. Each mission is then modeled in STK with data based on service requirements.

Custom GRC software uses schedule output combined with data from official documents to generate QualNet traffic for the network simulation.

Service possibilities are compared against access intervals from STK models; custom algorithm deconflicts according to SCaN network priorities and generates realistic schedule.

STK/Scheduler Task Assignments

Resource utilization report included with results.

Resource Accommodation Report

Official Architecture and Project Documentation

STK/Scheduler Task Assignments

- Fermi_DAS
- ISS_MA
- GPM-LIO_SA
- ISS_SSA
- Terra_KSA
- TIME
- Aura_MAR
- Aura_SA
- Aura_SAI
- TDRS10-MAR
- TDRS10-SA1
- TDRS10-SA2
- TDRS3-MAR
- TDRS3-SA1
NISN Loading Study Topology & Traffic

Topology
• Core NISN links based on AT&T (NISN’s provider) published values
• Distribution and Edge networks projected to be upgraded with current GigE technology

Traffic Types
• User TT&C
• User Scheduling
  • Daily inquiry per mission
• User low-rate S-band return flows (e.g. first-look science data)
• SN Internal traffic (derived from notional Level 3 architecture)
  • TDRS TT&C
  • Monitor and Control
  • EI Logging and Log-Retrieval
  • SNOC Synchronization
Background

- NASA is exploring alternatives for its communication networks
- Each alternative requires a quantifiable network performance metric

Overview

- NASA’s communication architecture is currently comprised of three networks (Deep Space Network, Space Network, and Near Earth Network)
- Five proposed options (Three distinct topologies)

Scenario Time

- July 2018
Integrated Network Management Architecture

Present NASA Space Communications Service Architecture

INM Communications Service Architecture

INM Communications Service Architecture Options in QualNet

Options 1 & 2 - Topology

Options 3 & 4 - Topology

Option 5 - Topology
### INA Comparison Results

#### Options 1&2

![Graph showing throughput for GSFC NTR to WSC NTR Router]  
**Average Throughput**: 43.361 kbps  
**Max Throughput**: 96.106 kbps

#### Options 3&4

![Graph showing throughput for GSFC NTR to WSC NTR Router]  
**Average Throughput**: 59.828 kbps  
**Max Throughput**: 129.683 kbps

#### Option 5

![Graph showing throughput for GSFC NTR to WSC NTR Router]  
**Average Throughput**: 61.598 kbps  
**Max Throughput**: 163.088 kbps

<table>
<thead>
<tr>
<th>Link</th>
<th>Traffic Type</th>
<th>Options 1&amp;2</th>
<th>Options 3&amp;4</th>
<th>Option 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSFC NTR Router to WSC NTR Router</td>
<td>Average Throughput</td>
<td>43.361 kbps</td>
<td>59.828 kbps</td>
<td>61.598 kbps</td>
</tr>
<tr>
<td></td>
<td>Max Throughput</td>
<td>96.106 kbps</td>
<td>129.683 kbps</td>
<td>163.088 kbps</td>
</tr>
</tbody>
</table>
Conclusion

Summarizing the Unified Approach

• New systems-of-systems architectures that bridge disparate domains will likely find themselves ill suited for analysis using existing modeling & simulation tools.

• Our approach leverages partitions in the architecture – in this case, between the physical-layer functionality and the services provided by the data-link and higher layers of the OSI model – to interface the modeling and simulation tools used by both domains for an optimal solution.

Questions?