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*

Outline

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

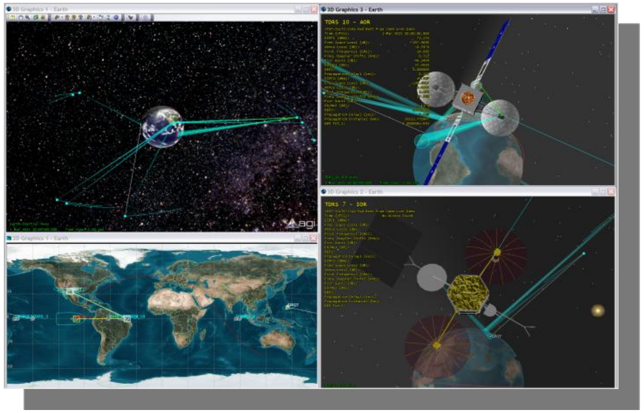
Architecting Challenges

- 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…

Meeting the Challenge: Architecture, Modeling & Simulation

Space Link Models



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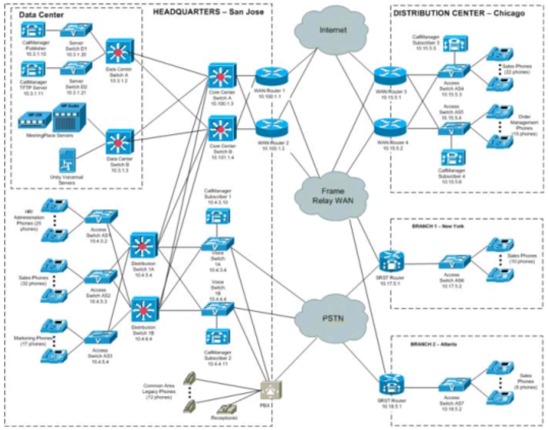
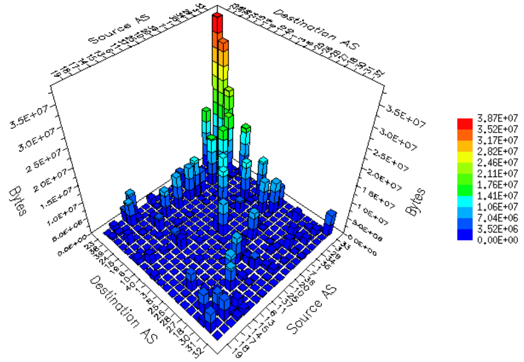
Network Topology & Protocol Models



Network Traffic Models



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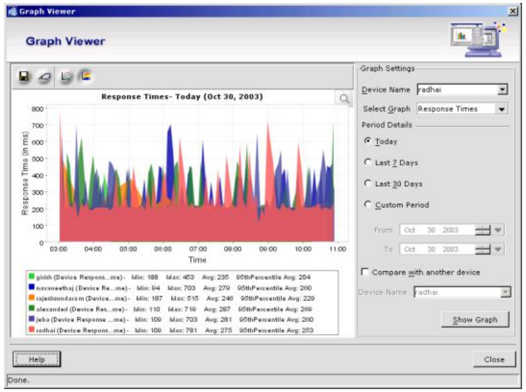
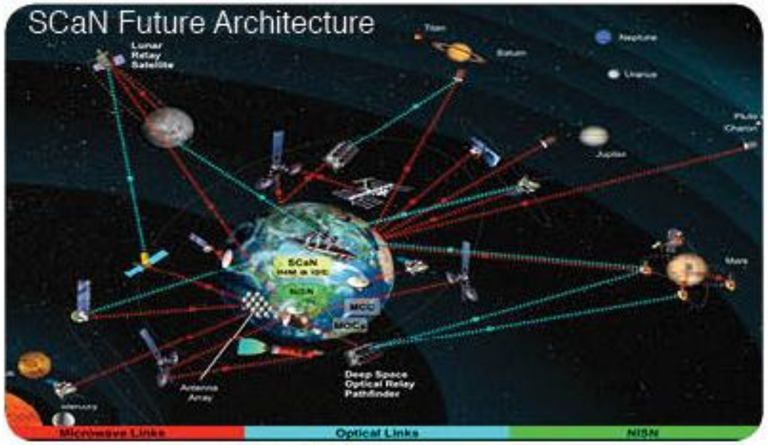
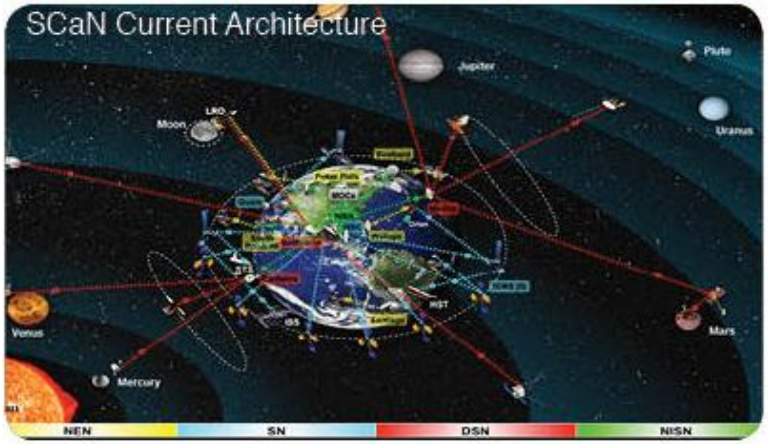
Network Performance



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

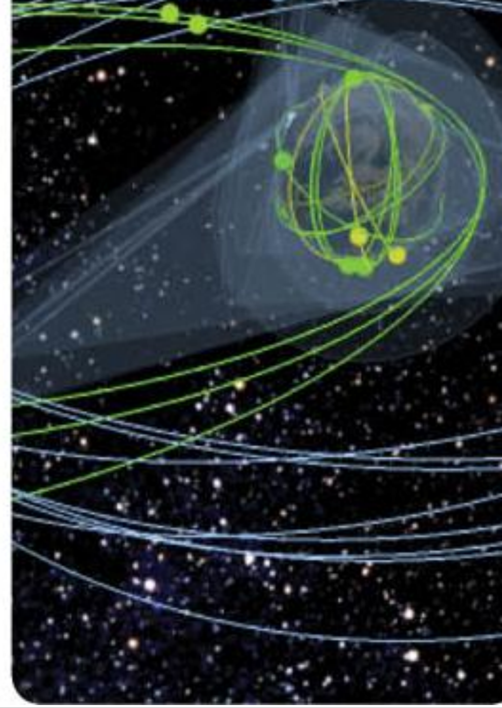
End-to-End Simulation:
•SGSS Link Layer Security Impact Assessment Study

Tools

Modeling Tools:
Core
MagicDraw

Simulation Tools:
QualNet
STK
STK/Scheduler

Integrated Tool:
GEMINI

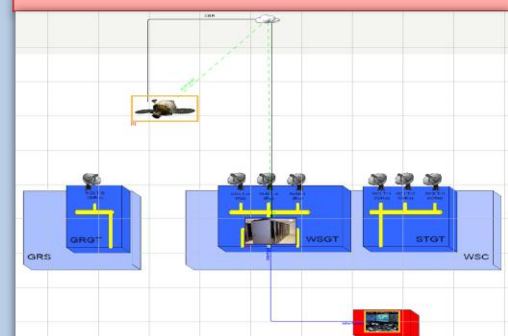


GEMINI Simulator

- 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)

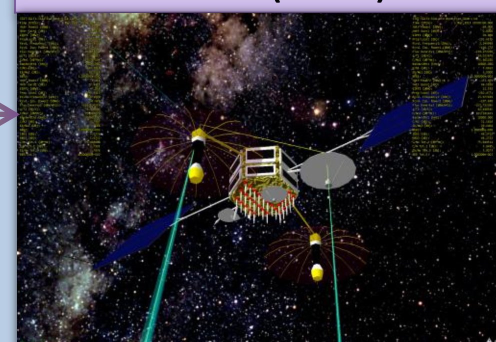


Custom GRC Software for real-time integration of two COTS software tools:

QualNet
(network simulator)

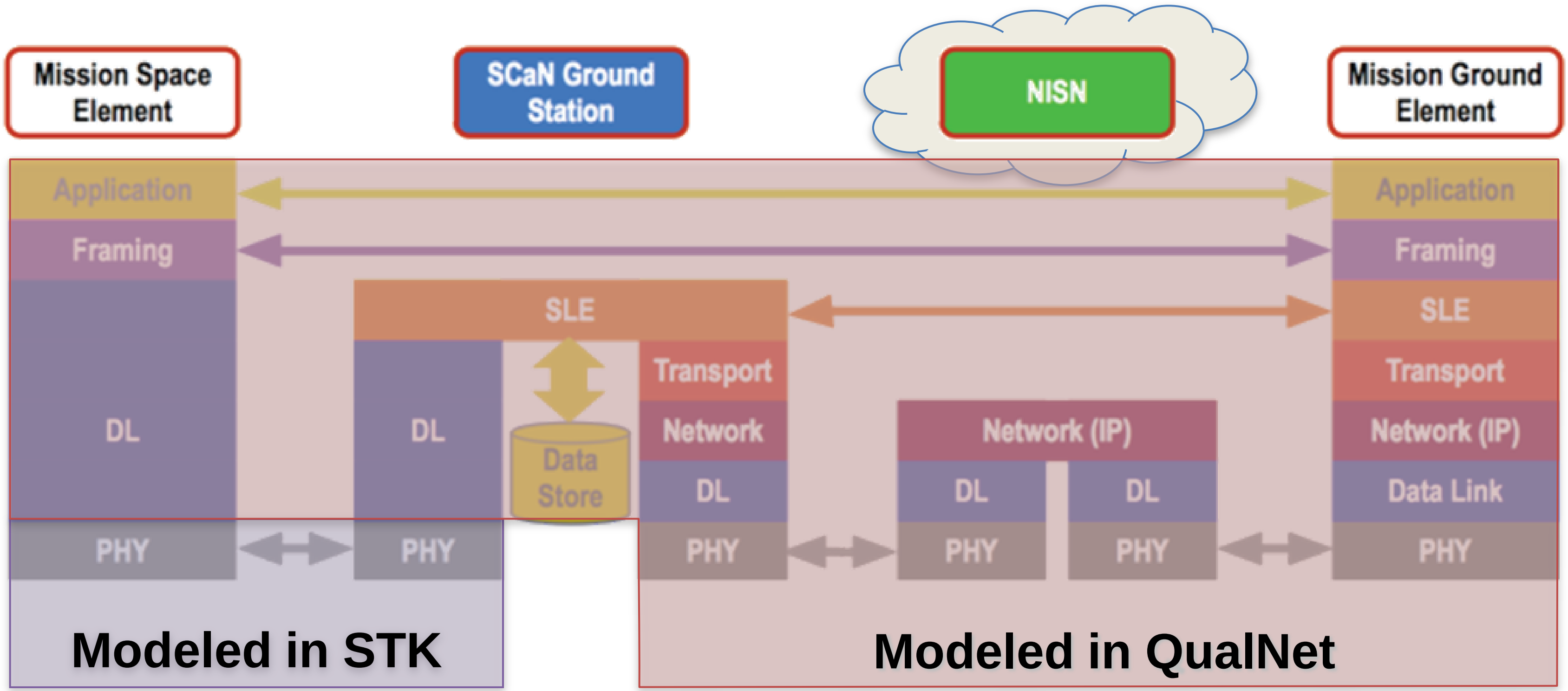
STK
(physics & RF simulator)

Space Segment Models (in STK)



GEMINI - GRC Environment for Modeling Integrated Network Infrastructure

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

CCSDS Link Layer Security Impact Assessment

Background

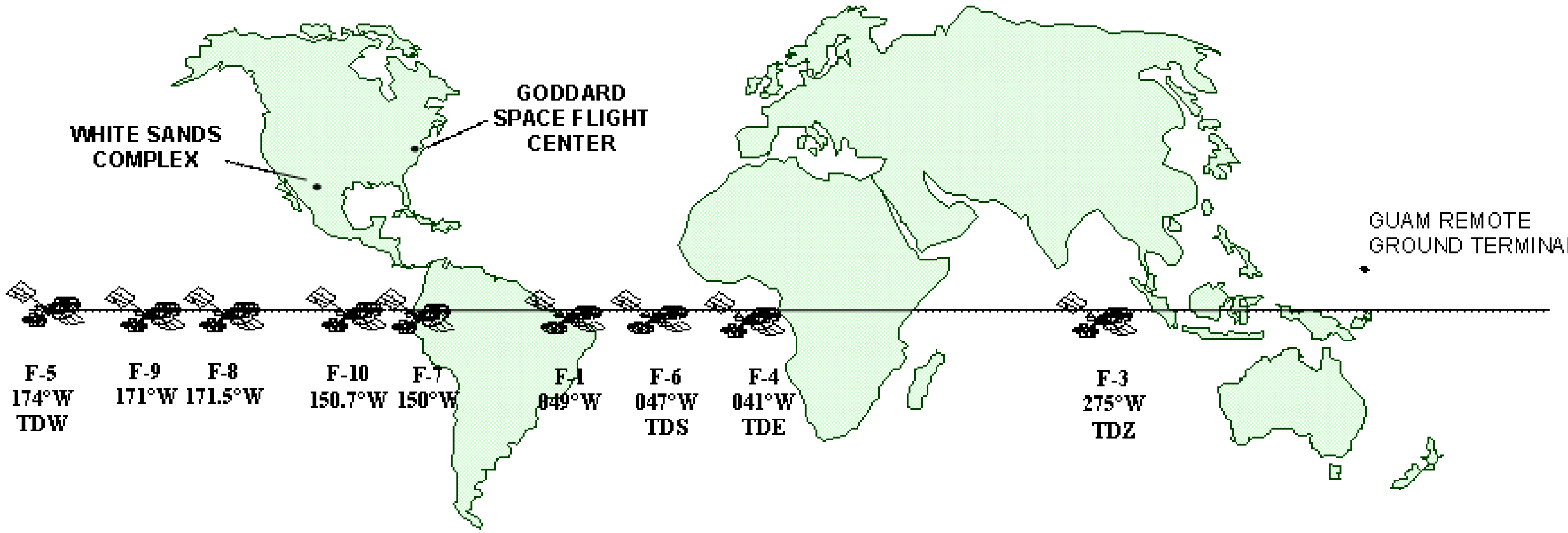
- NASA is the process of modernizing its Space Network
- Modernized architecture must support the proposed protocols for the Constellation Mission

Overview

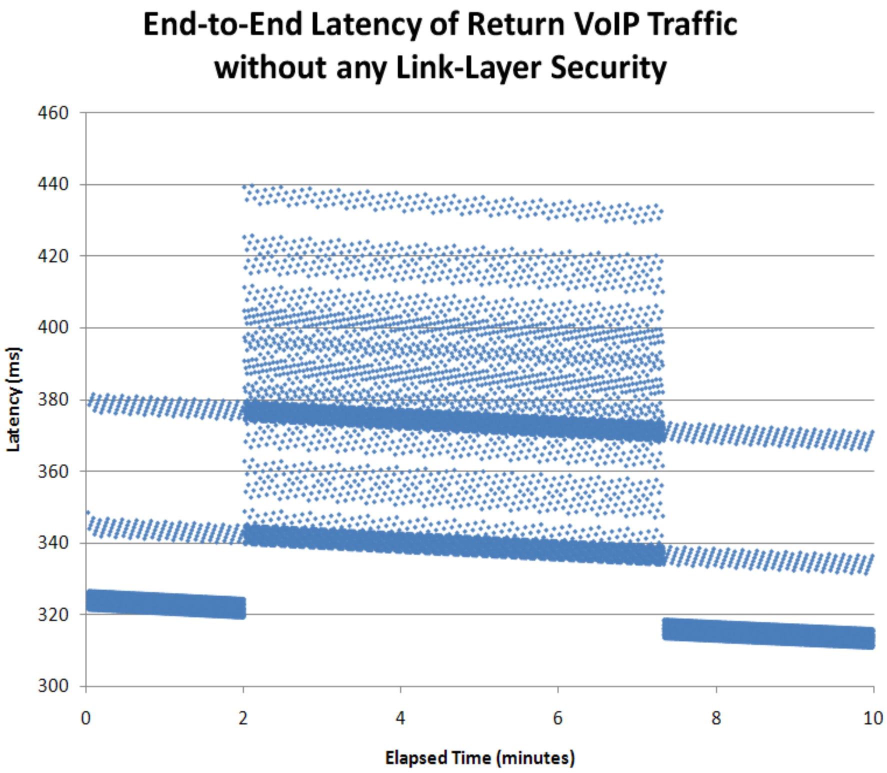
- LLS occurs at Layer-2 (Data Link) of the OSI Network Model
- Due to the desire for flexibility, LLS can be configured by the user to provide 3 different types of security services

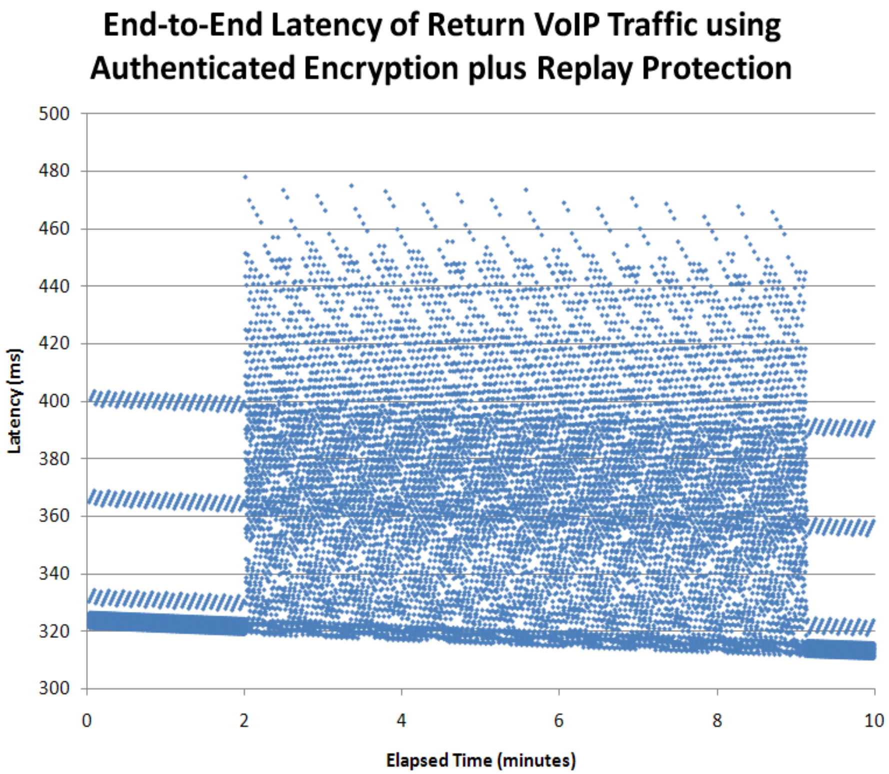
Scenario Time

- Orion in LEO orbit during July 2015



LLS Simulation Results





- 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

NASA Integrated Services Network Loading Study

Background

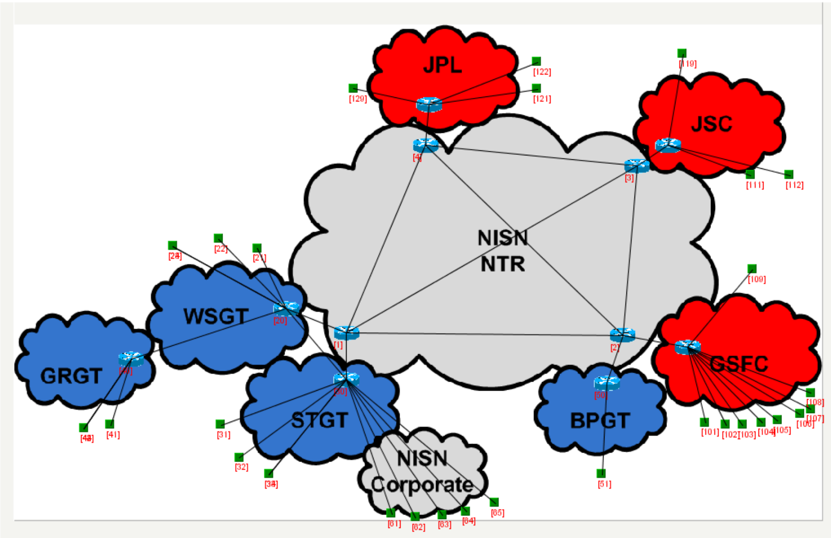
- NASA is the process of modernizing its Space Network
- Modernized architecture must be able to support both legacy and future mission traffic

Overview

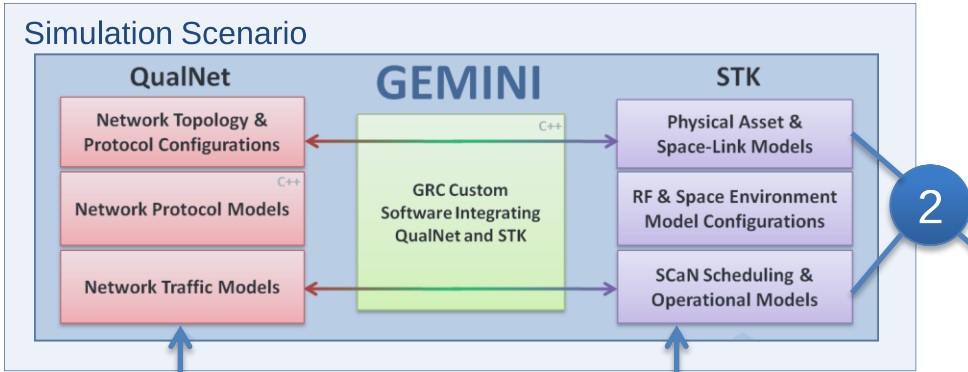
- NISN is the dedicated mission network connecting NASA’s Space Network (SN) facilities
- 2 Scenarios of projected traffic in July 2015
    - 14 expected customer missions
    - 5 additional missions that are plausible

Scenario Time

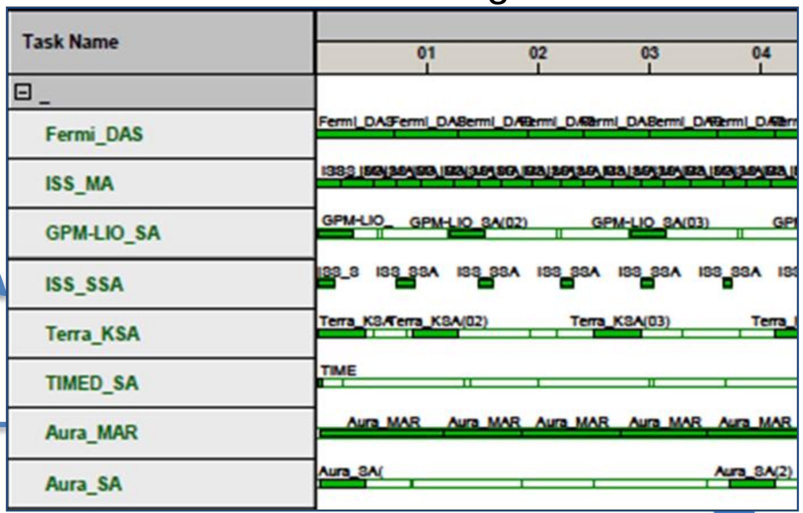
- July 2015



Scheduling Mission Traffic



STK/Scheduler Task Assignments



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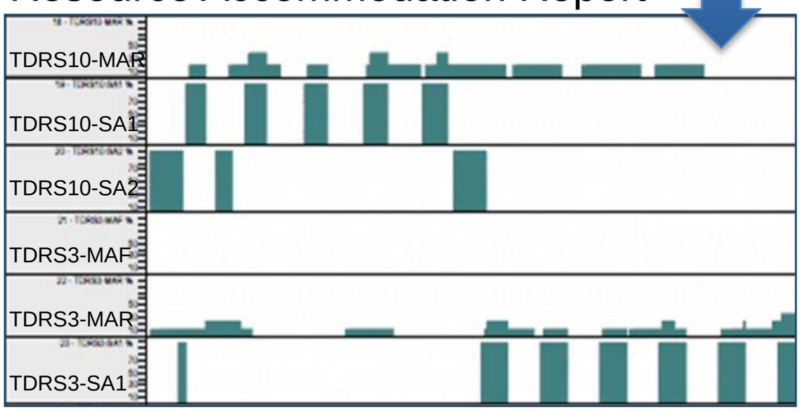
Custom GRC software uses schedule output combined with data from official documents to generate QualNet traffic for the network simulation

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

Resource utilization report included with results

Resource Accommodation Report



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

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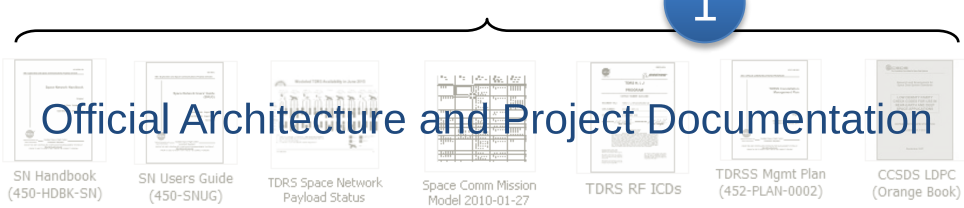


NISN Loading Study Topology & Traffic

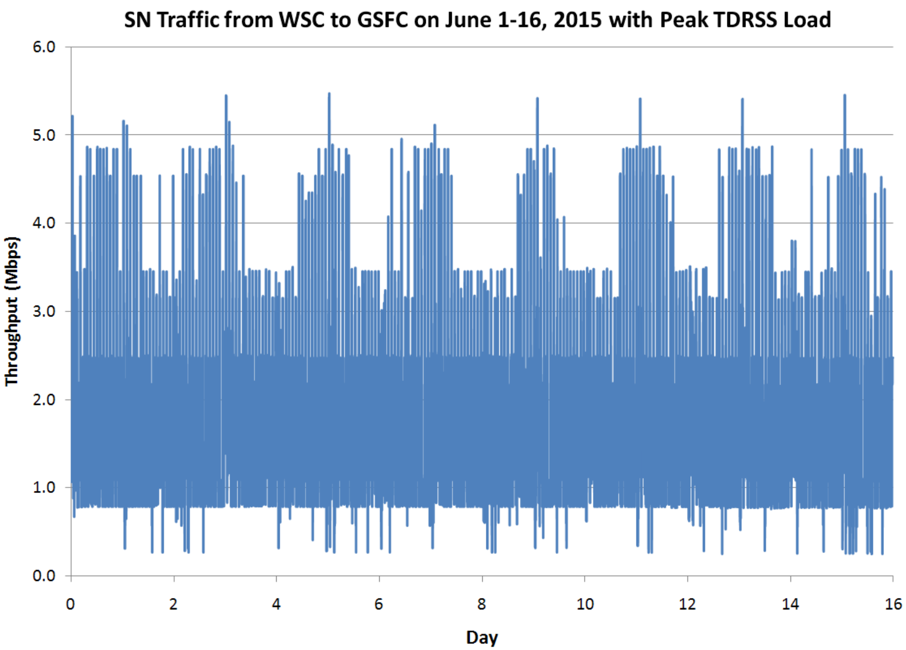
Topology

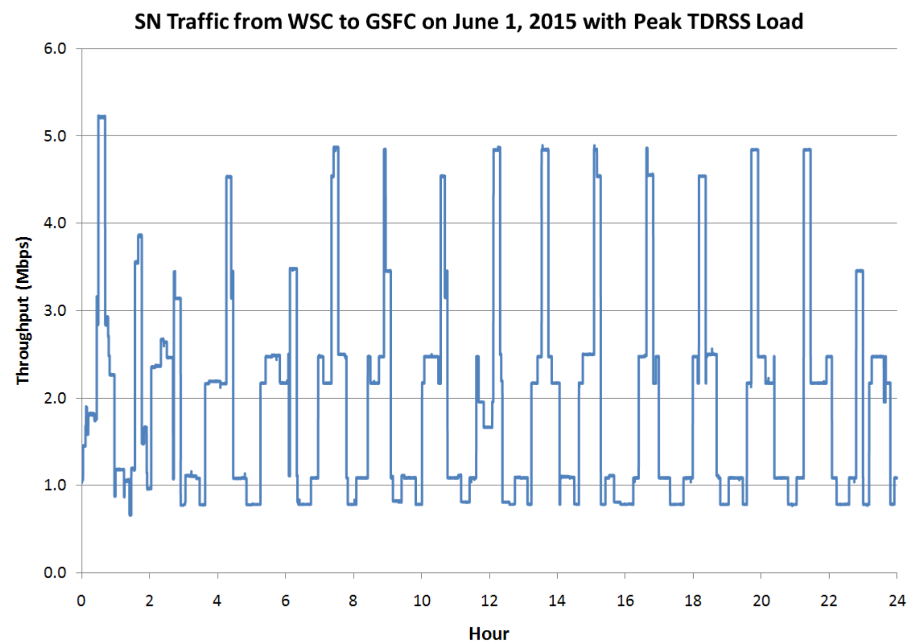
- Core NISN links based on AT&T (NISN's provider) published values
- Distribution and Edge networks projected to be upgraded with current GigE technology

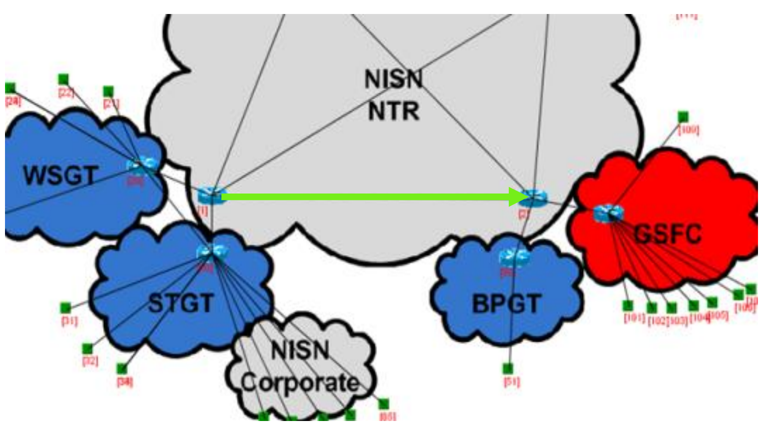
Traffic Types

- 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

NISN Loading Study Results







Background

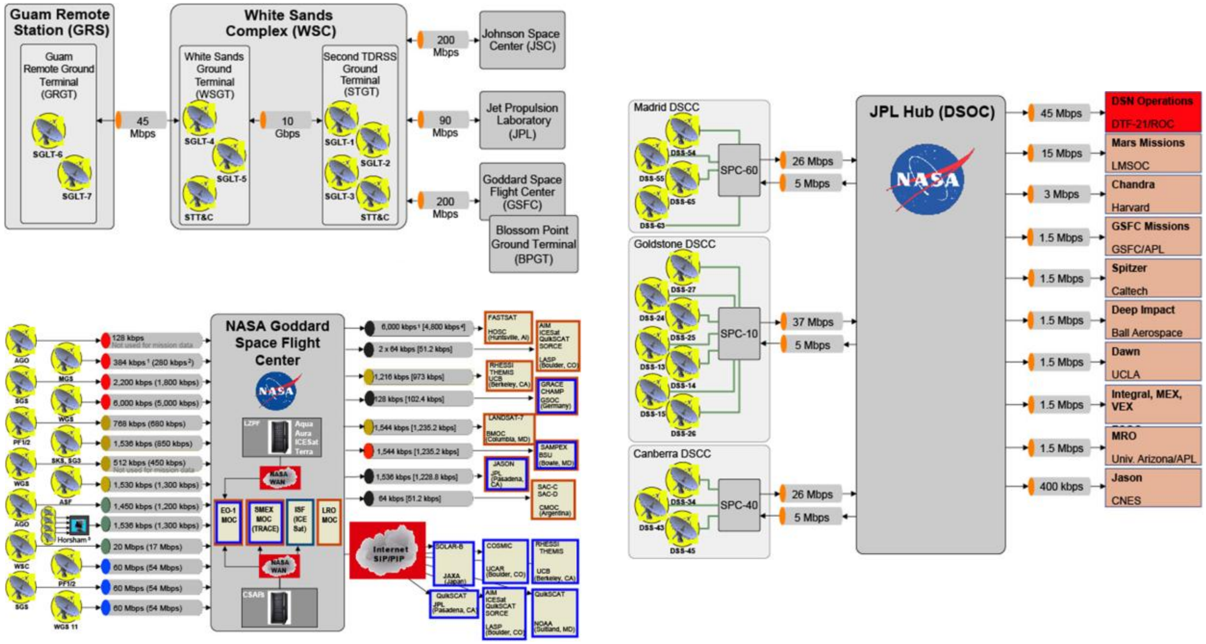
- NASA is exploring alternatives for its communication networks
- Each alternative requires a quantifiable network performance metric

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)

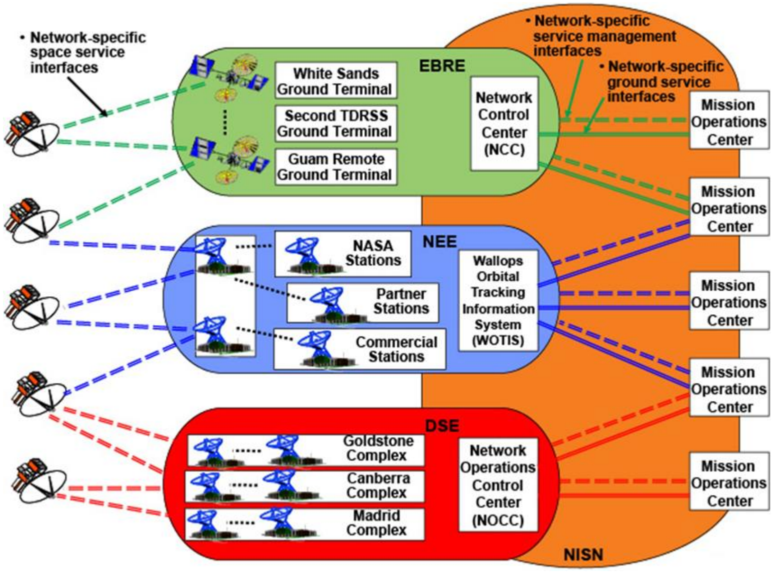
Scenario Time

- July 2018

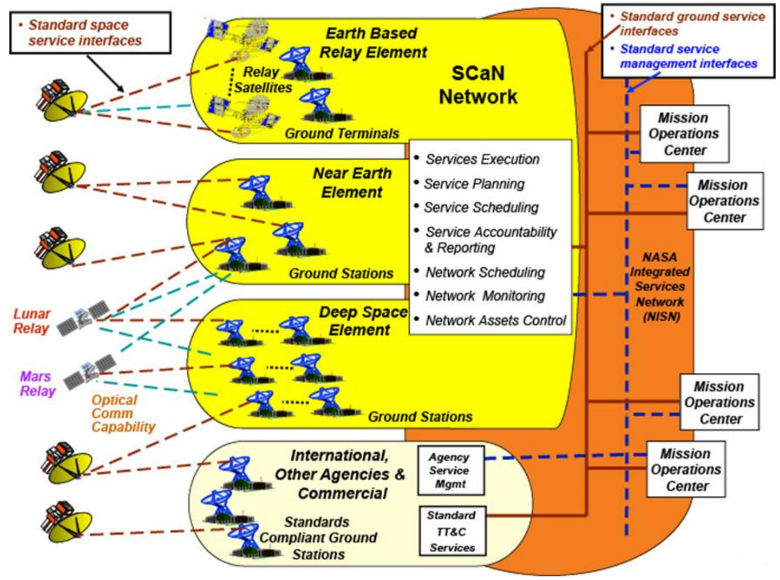


Integrated Network Management Architecture

Present NASA Space Communications Service Architecture

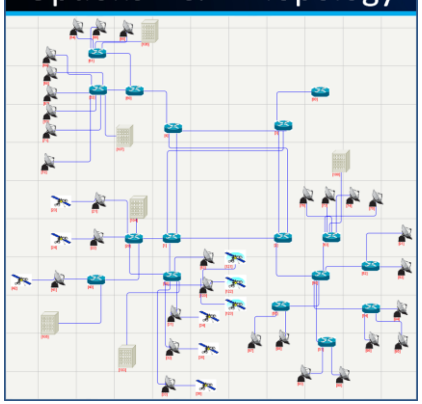


INM Communications Service Architecture

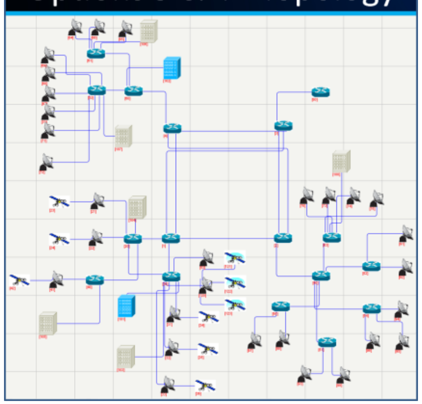


INM Communications Service Architecture Options in QualNet

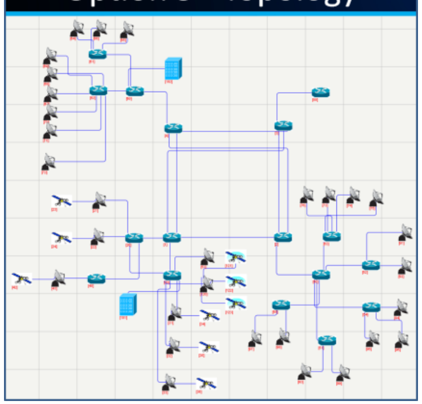
Options 1 & 2 - Topology



Options 3 & 4 - Topology

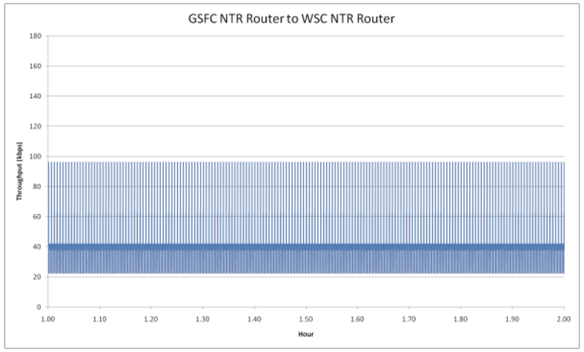


Option 5 - Topology

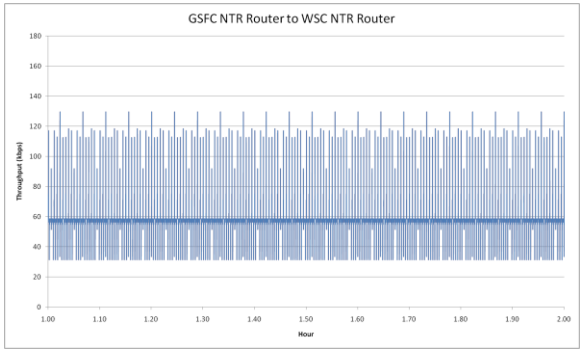


INA Comparison Results

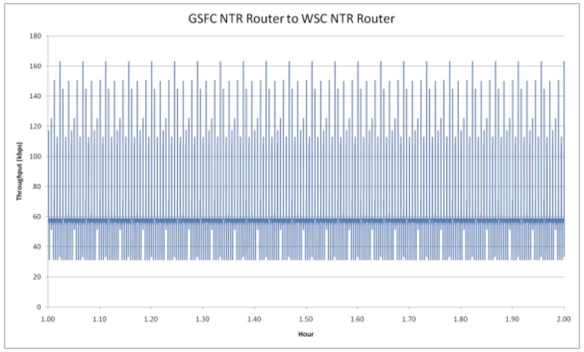
Options 1&2



Options 3&4



Option 5



Link	Traffic Type	Options 1&2	Options 3&4	Option 5
GSFC NTR Router to WSC NTR Router	Average Throughput	43.361 kbps	59.828 kbps	61.598 kbps
	Max Throughput	96.106 kbps	129.683 kbps	163.088 kbps

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?