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Reactive Routing: DTN/BPv7

Reactive Routing Project Team Members

TCT Networks Staff:

- Michael Moore: Chief Engineering Officer
- Dr. Ronny Bull: CEO and Chief Science Officer
- John Cook: Chief Technology Officer, Emulation Team Lead
- David Cook: IT Support and Integration Specialist, Emulation Team
- Joshua Waszkiewicz: Software Engineer

Consultants:

- Scott Burleigh: Bundle Protocol (BP) and ION expert

Reactive Routing Development:

- Joel Seif: Documentation, Commercialization Planning

Who we are:

TCT Networks Corporation *(formally Adirondack IT Solutions, LLC)*, is a U.S. based small business focusing on networking & systems research and development (R&D).

We were formed in 2023, and are located in the heart of New York, USA, nearby many R&D facilities and the Beyond Visual Line of Sight (BVLOS) corridor. Excellent location for drone application testing.

Web: https://tct-networks.com

What We Do

- Real-time, embedded software applications
- High Performance Computing (HPC) systems
- Resilient/secure networking solutions
- Distributed systems development
- Delay Tolerant Networking (DTN) solutions for networks operating in challenging/contested environments
    - Space communications
    - Underwater communications
    - UAV/Aerial networks
    - Terrestrial Mobile Ad-Hoc Networks (MANETs)

A Little Contact Graph Routing (CGR) Background

DTN uses Contact Graph Routing to direct when network communications happen

- Because the necessities of “contact” are *predictable* (clear communications path)
- Because most NASA Space Comm is point-to-point (little actual networking)
- Because there are very few vehicles “out there past LEO”
- Because the communications systems are necessarily simple (little computation available)

Contact Graph planning complexity is compounded by increases in ‘relay station’ sharing.

Reaction to unplanned disruptions requires ground response to amend a Contact Plan.

Reactive Routing provides a way to avoid disruption by sensing performance trends at remote stations, and sending alerts to contact planners, prior to failure.

- Correctable Error Trends
- Background noise sensing
- Signal-to-Noise Ratio trends

TCT Networks DTN Reactive Routing

Reactive protocol is a network term applied to a process that creates on-demand routing information, as needs surface; subsequent route discovery and dispatch can then be applied.

DTN Reactive Routing is similar; it is an innovation in space networking by which unplanned changes in link performance are detected and analyzed, enabling proactive automatic and immediate adjustments to the CGR “contact plans” on which route computation in DTN can be based.

DTN Reactive Routing changes to contact plans will result in route revisions that will reallocate traffic load per the revised transmission opportunities.

DTN Reactive Routing leverages information that can be supplied by the Physical layer, information not traditionally supplied to upper network management layers.

Why Do This?

Reactive Routing enables a DTN BPv7 station to recompute routes and revise its bundle forwarding decisions automatically in responses to changes in the properties of communication links.

Reactive Routing has potential to:

- Improve link utilization
- Minimize throughput loss
- Minimize DTN network management workload
- Apply to all DTN-based networks supporting government space agencies, academic research, and commercial space entities.

Why Do This?

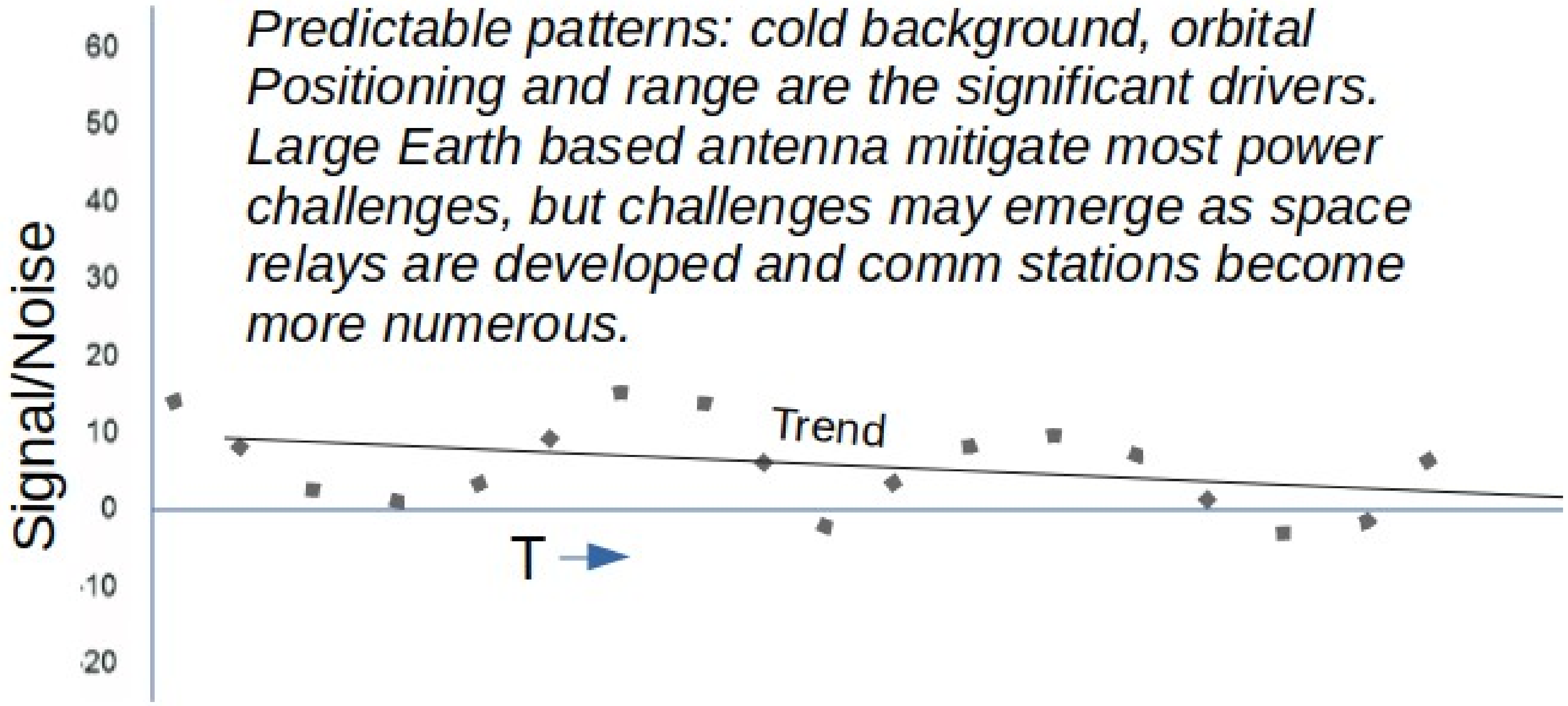
Without Reactive Routing:

- A station could not mitigate certain types of problems without ground planner interventions such as:
    - Recognizing a communications problem
    - Reacting to the problem by changing a contact plan

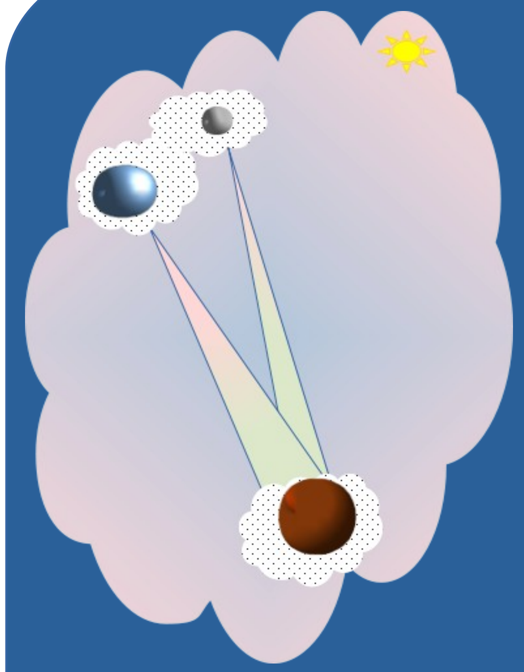
With Reactive Routing:

- Channel degradation *prior to failure* (e.g., correctable bit errors are increasing is detected at remote node; remote node uses alternate contacts as available.)
- Remote node proposes a *Contact Plan* change
- Ground controllers implement a change, possibly automatically

Link Performance Parameter Example



Reactive Routing is one of several steps on the path to Autonomous Solar System Internet.

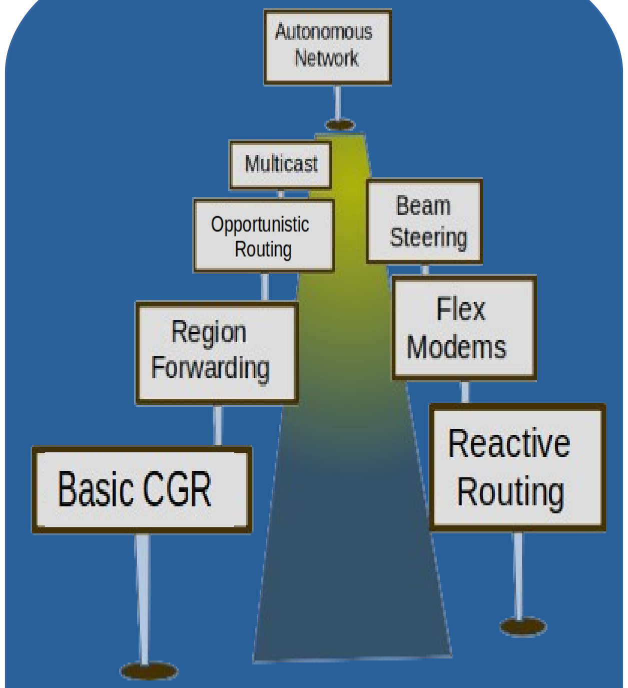


The two faces of DTN:
Delay: Long Distance
Disruption: MANETs

We look for how DTN fits in with cog radio, smart antennas, and other features associated with evolving Software Defined Radio (SDR) technologies.

We use a ‘vision’ of what we think will be practical SDR for space, in ten years.

We look to identify standards and the ideation behind them to guide DTN into efficient, commercial space network systems; Application Programming Interfaces (APIs), Protocols.



Road map to Autonomous Solar System Internet

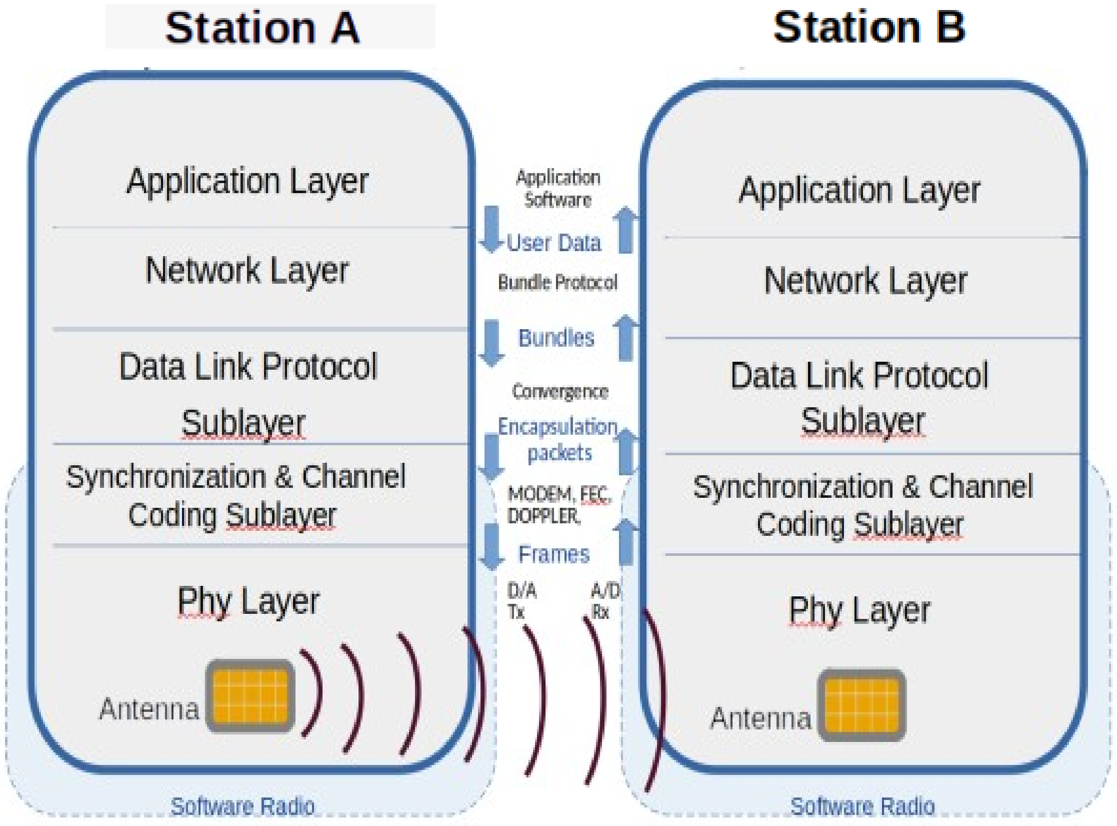
SDR is a Network Component, more-so than a traditional MODEM

SDR role is expanding within a Network

- Does traditional MODEM functions (Phy)
- Deals with spectrum phenomena
- Has information that is ‘non-traditional’
  - About signal quality
  - About data rates
  - About Frame characteristics

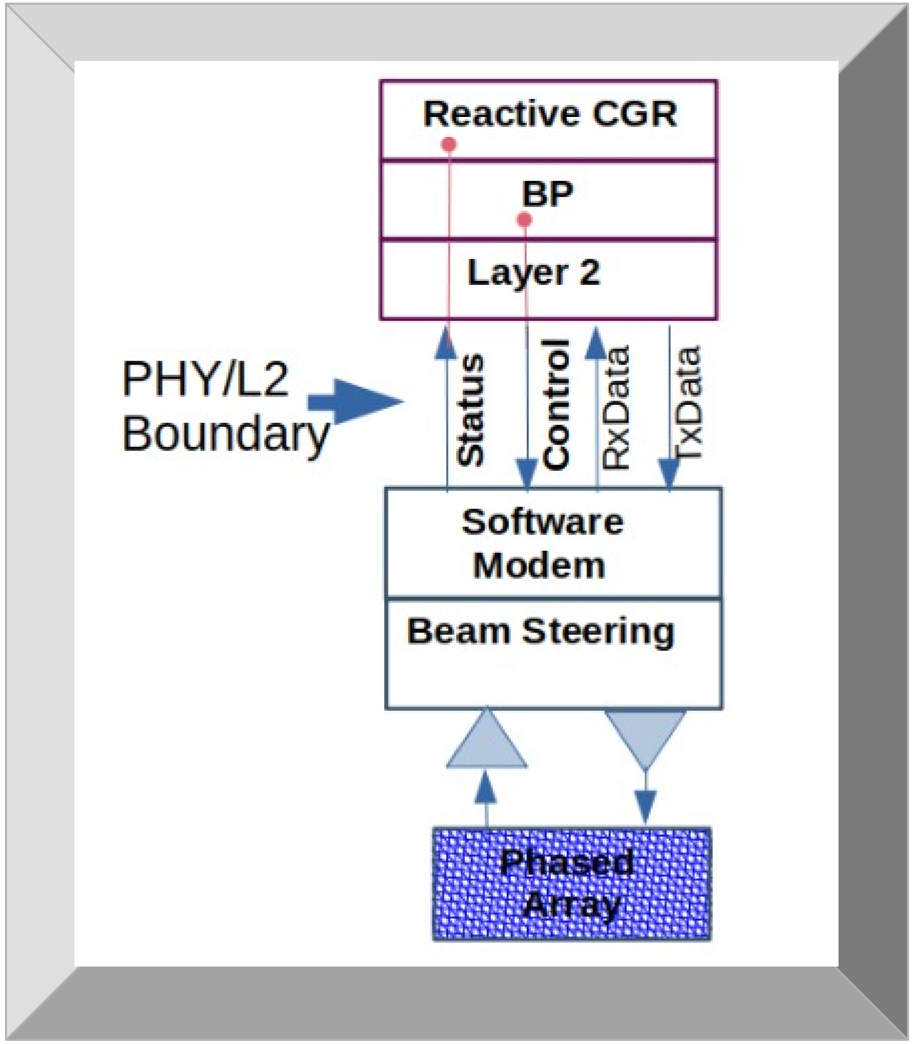
- An L2 Network can add more capability
  - Info about the other end of the link
  - L2 Network topology

DTN Reactive Routing can use some of this info to cause Contact Plan changes for mitigating unplanned issues.



Evolution of Software Radios: Next Decade

- High count SIMD multi-core chips will deliver the Gigaflops of performance needed for Gigabit link capacities.
- Conventional software on these platforms will offer significant flexibilities with waveforms.
- New waveforms will take advantage of the flexibilities.
- Network management will have new waveform features they can use for autonomous network management.

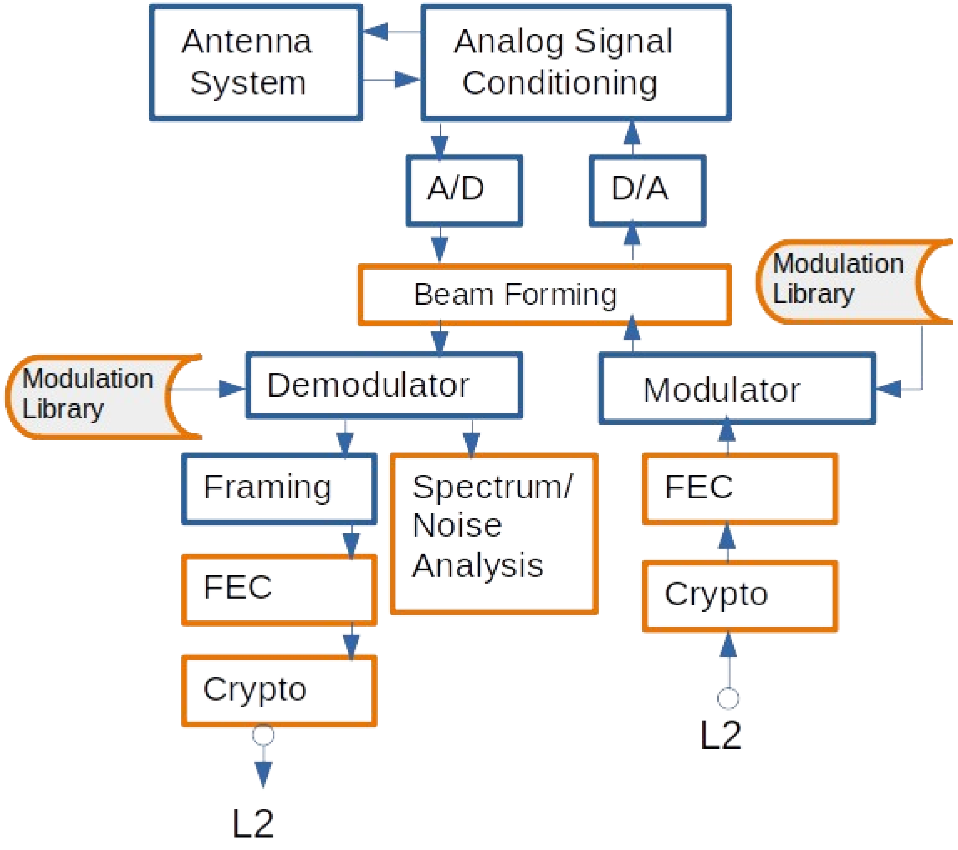


Our Focus: Harnessing Advanced Software Defined Radios

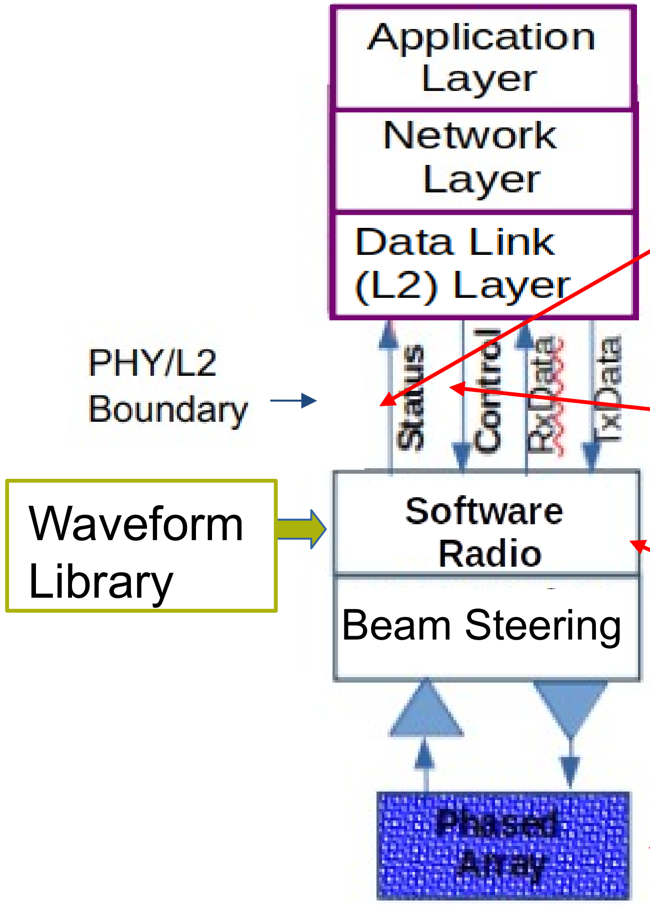
Advantages of Software Defined Radio
- Significant development cost reduction
- Malleable: Update through software change
- Flexible Wave-forms
- Cognitive Radio characteristics
- Configurations dynamically scheduled

SDR is more than 'Just a Digital Radio'
- Promotes spectrum sharing
- Promotes Efficiencies: via Waveforms, FEC
- Promotes Interoperability: dynamic adaptation
- Enables advanced network capabilities

Standards: Required for Optimal Utilization
- EDA-ETSI military SDR standardization
- VITA 49: interoperability metadata, control packets.



TCT's Focus: *Increasing computational capability & commercialization are driving development of advanced features, network operation opportunities..*



- Radio Control state and Metadata are increasingly feature packed as 'Waveforms' become more advanced. Upper Layers can exploit network control state & Metadata to optimize efficiencies.
  - FEC, SNR, PNT, Waveform, Congestion,...
- Phy Control is increasingly complex;
  - Modulations, link protocols, pointing, security, spectrum sensing & perception, …
- SDR Compute platform trending towards multi-core HPC; currently FPGA.
- Directional Antennas, Optical transducers.

Reactive Routing: A Beginning

Baseline Reactive Routing in ION

- ION insertion design
- Demo a build using emulated radios

Identify Advance Software Defined Radio Characteristics

- Expanded network role features achievable: Ten Year Vision
- Interactions needed between SDR and network layers (Phy Baseline)

Baseline a development environment

- Open source Common Open Research Emulator (CORE) / Extendable Mobile Ad-Hoc Network Emulator (EMANE) emulation software
- Linux™ virtual environment
- Test scenario scripts

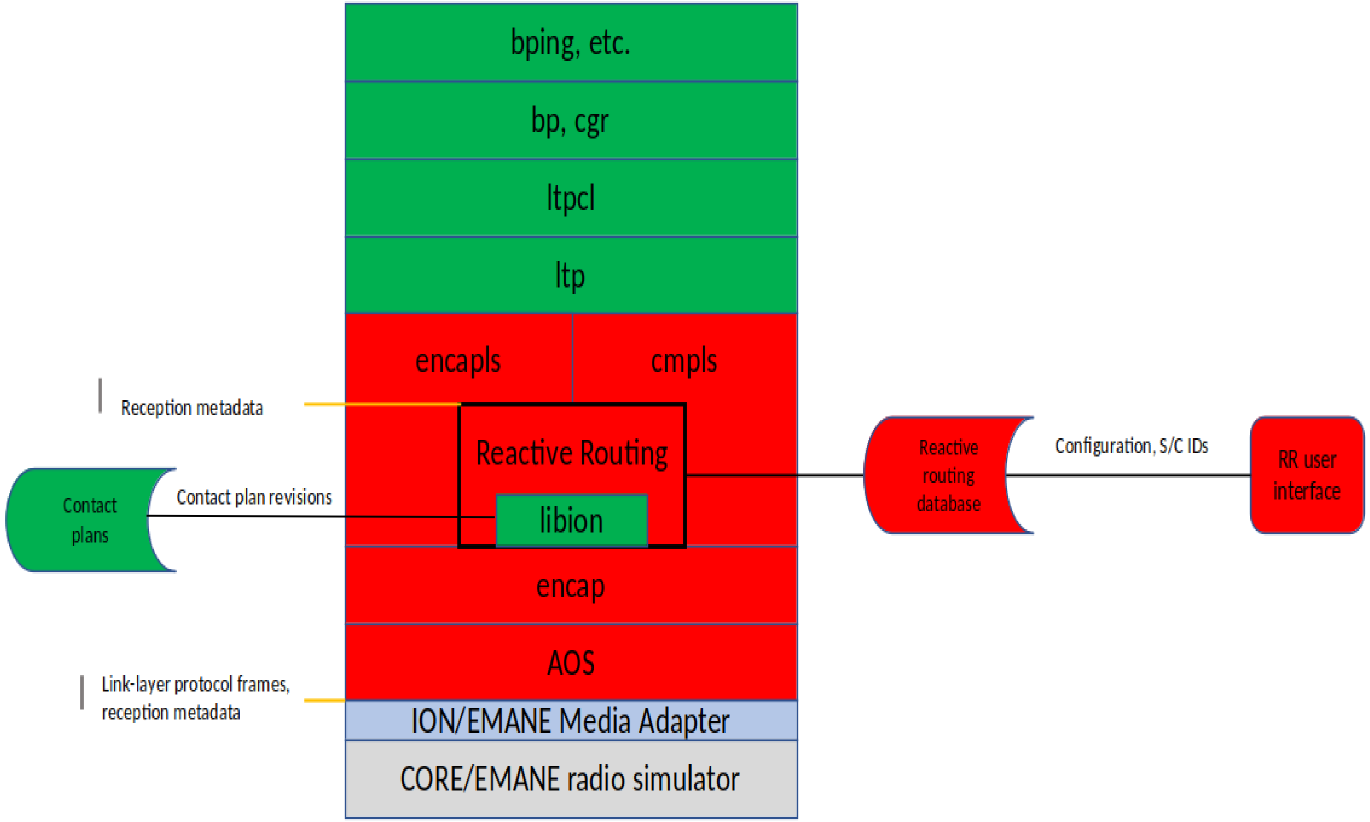
IONRR

Open source ION 4.1.1 was the basis of the IONRR Prototype.

Red modules correspond to modifications made during Phase I.

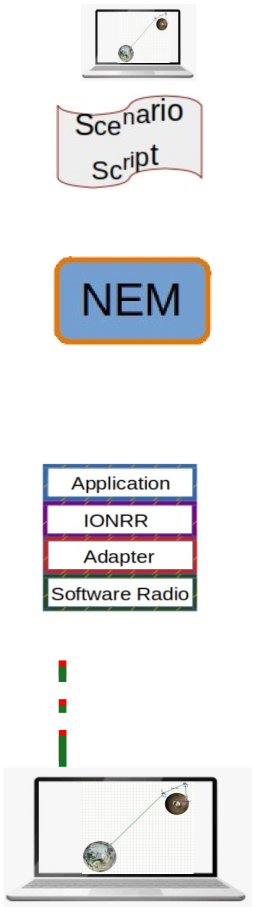
Green modules were untouched.

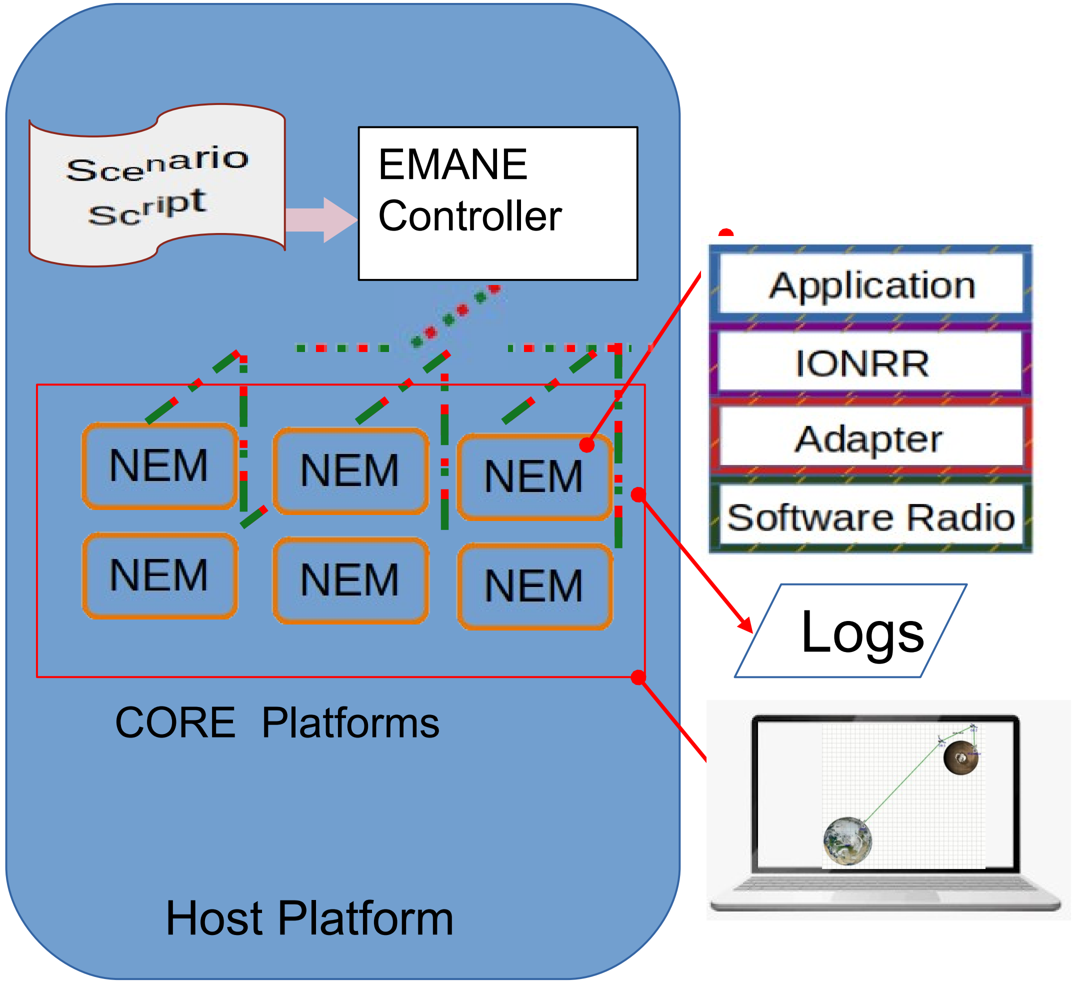
The pale blue “Media Adapter” corresponds to custom software developed by TCT Networks.



The Emulation System

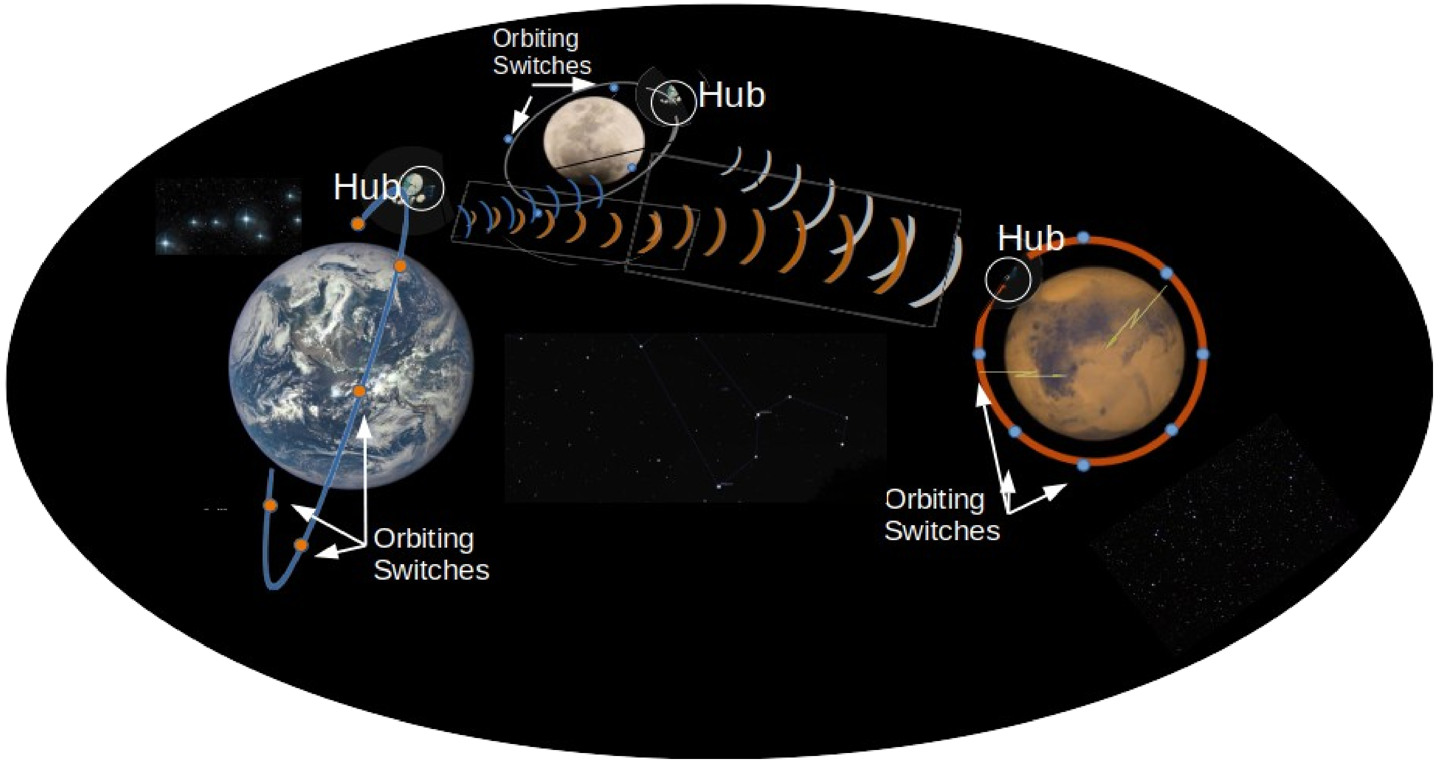
- A laptop can host entire emulation.
- Scenario script uses API to control & start CORE & EMANE processes.
- EMANE links CORE nodes as Network Emulation Modules (NEMs).
- CORE starts custom services to run IONRR and Adapter.
- Each CORE node is a vehicle with a full stack DTN.
- RF Comm emulated by EMANE via back-network.
- Animation on CORE canvas.



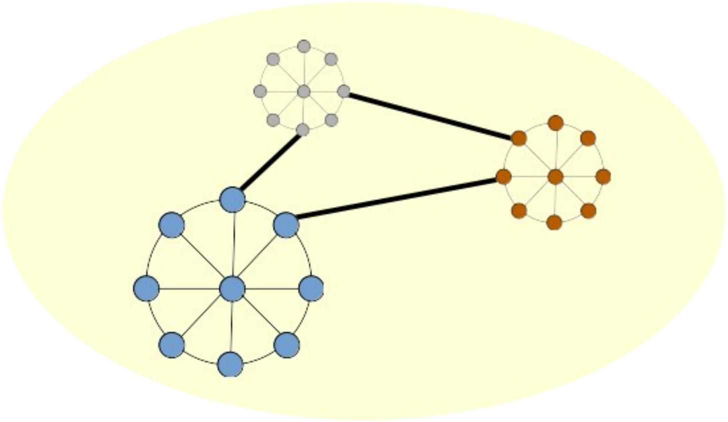


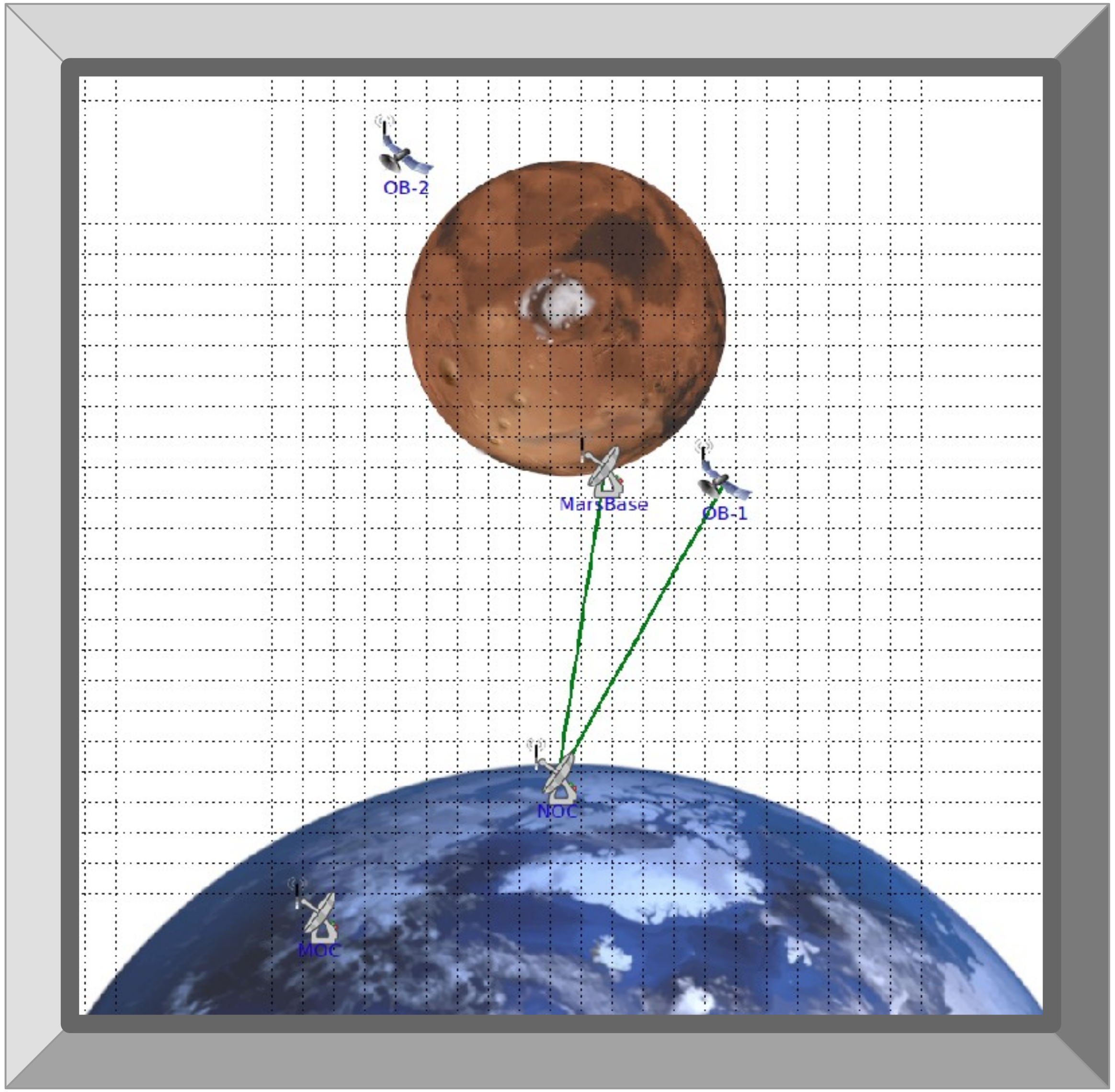
Scenario Concepts

Earth/Moon/Mars: Proximal and Distant Challenges.



Regional “Small-World Networks” connected by long haul trunks.

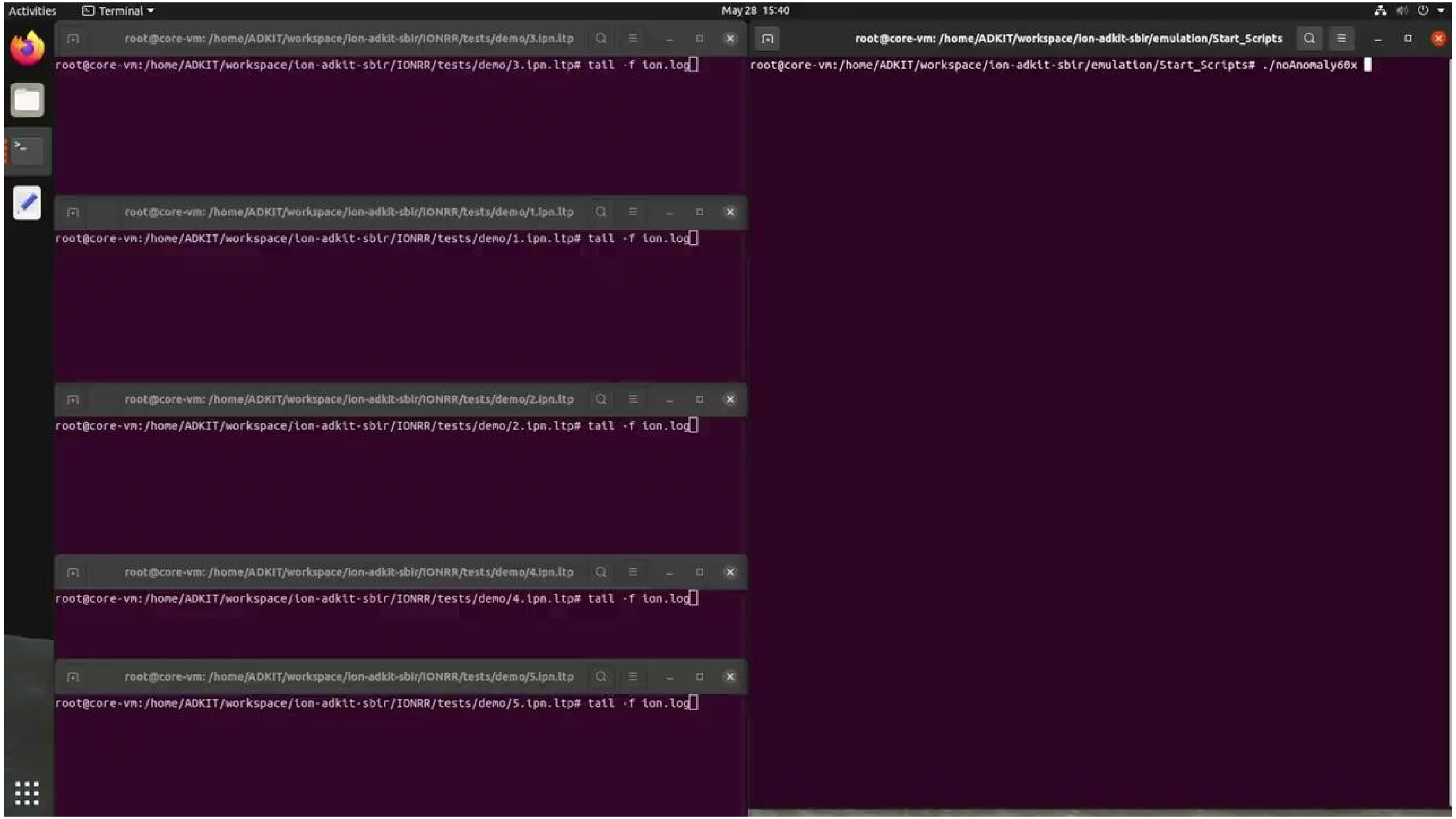




Parameters of Demonstration

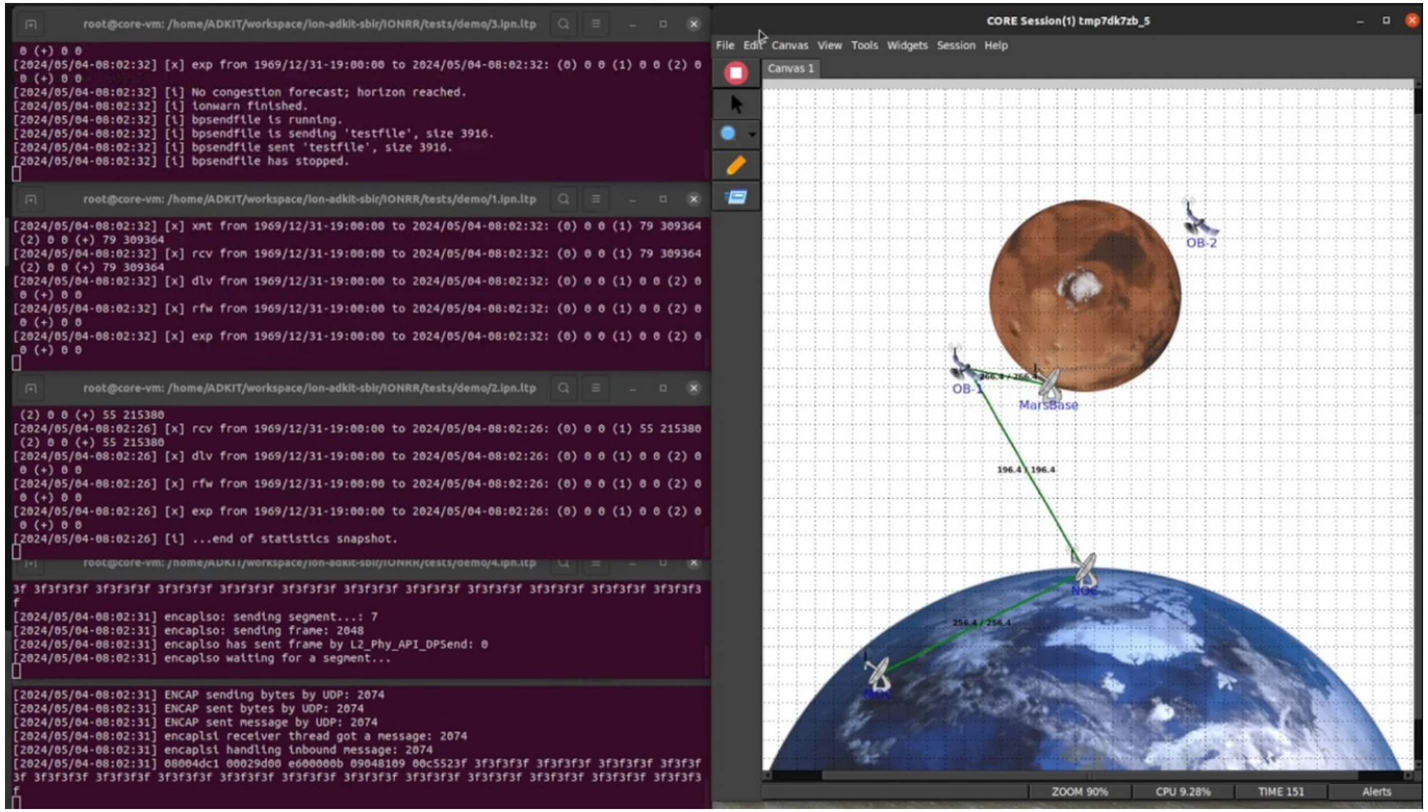
- SNR: Friis Equation
- Bit Errors: will be based on SNR (Phase I)
- Time: Real-Time X 20, mapped to Contact Plan
- 2 Mars orbiters: 180^o/1 Light Sec separation
- Mars surface base
- Mars-Earth Distance: 5 light minutes
- Mars base / orbiter contact: 20 minutes
- Mars orbiter period: 100 minutes
- *Scenario #1 AKA 'No Anomaly'*: Normal Operation as per Contact Plan.
- *Scenario #2 AKA 'Anomaly'*: Unexpected disruption between Mars Surface Base and an orbiter, mitigated by RR.

Scenario Demonstration



Scenario Summary

- What have we learned?
    - **Reactive Routing** is an effective method of tolerating delays / anomalies in networks - e.g. scenario log evidence.
- What will the future implementation of the scenario(s) look like?
    - Physical devices may be involved in communications as an adjunct to or replacement for emulated devices (in physical environments).



Frequently Asked Questions

What SDR does TCT Networks have in mind?

- None in particular. We are planning for a future where advanced SDRs are engineered to support DTN in challenging environments.

Are you targeting a specific computational platform?

- No. We are assuming space computational platforms will be capable of supporting high bandwidth comm, together with advanced network management.

Where does Cognitive Radio fit into this picture?

- Spectrum sensing features stay within the radio.
- Advanced network management, including use of machine learning, perception, analysis and decision making are things we see distributed within Network Management layers.

Thank you!

TCT NETWORKS