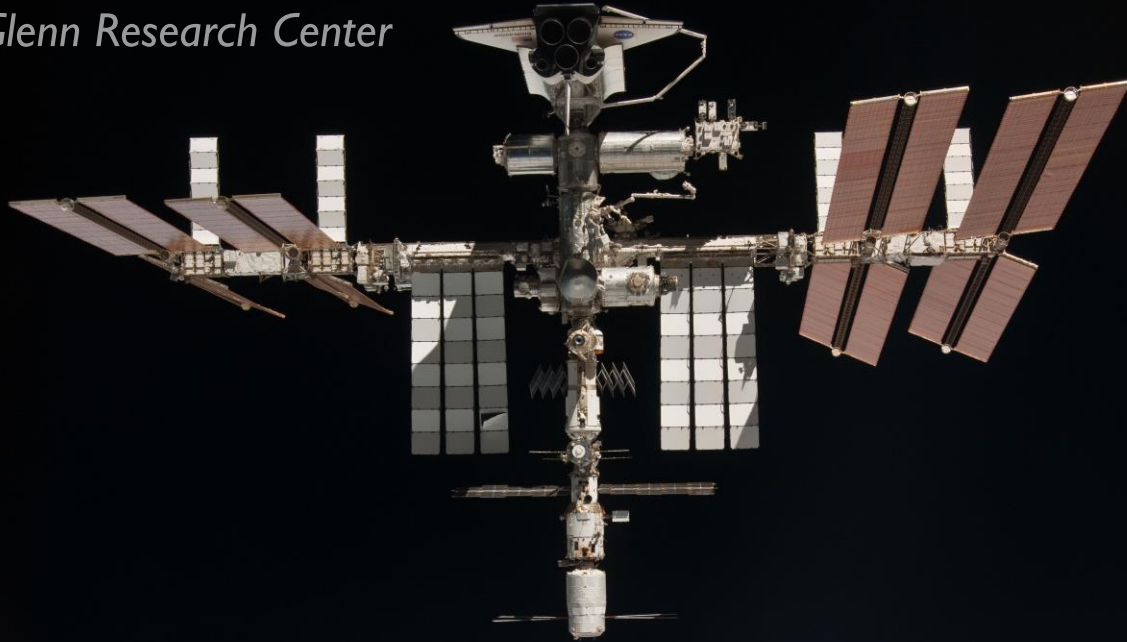


A Distributed Approach to High-Rate Delay Tolerant Networking Within a Virtualized Environment

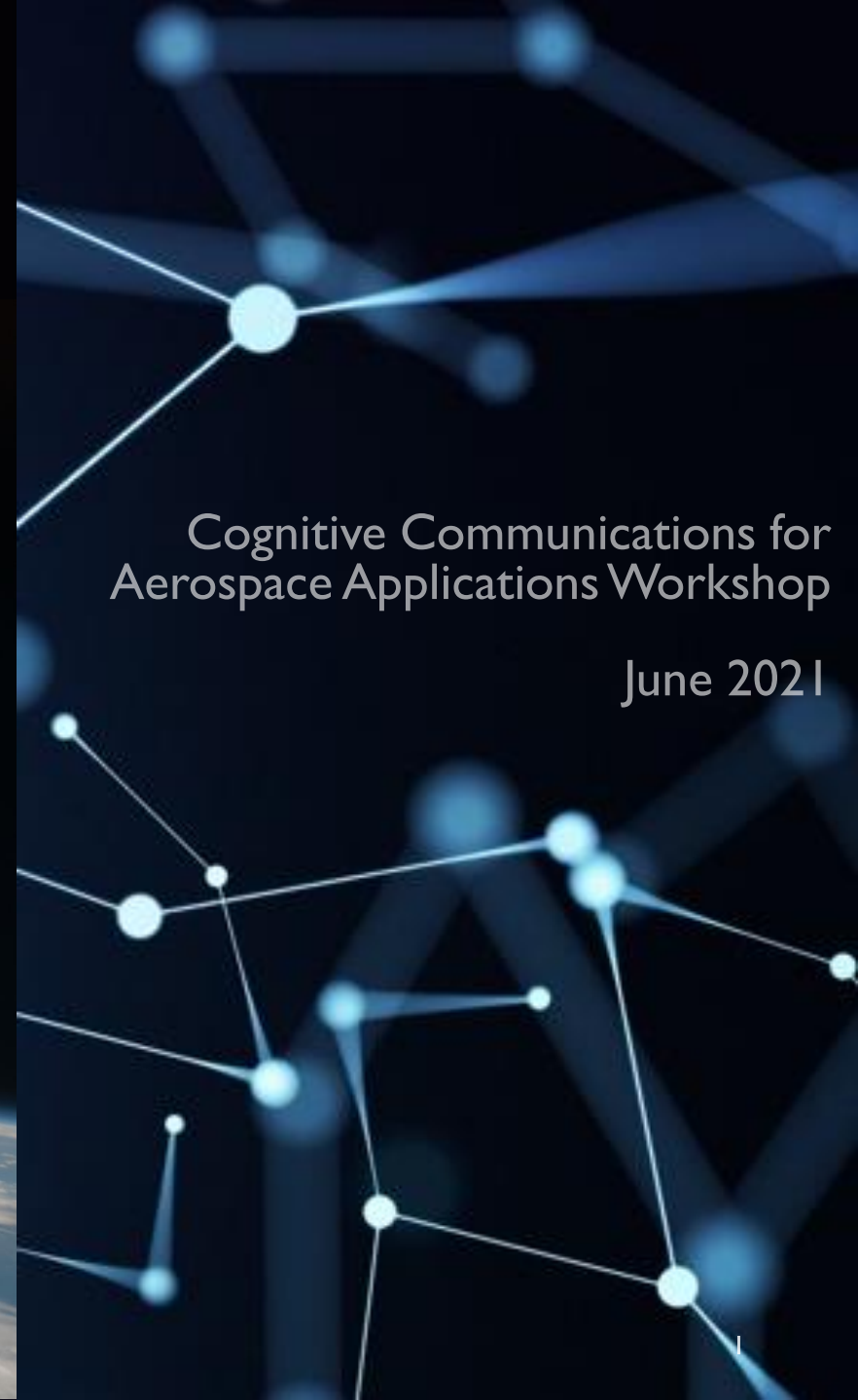
Rachel Dudukovich, Blake LaFuenta, Alan Hylton, Brian Tomko, Jeffrey Follo

NASA Glenn Research Center



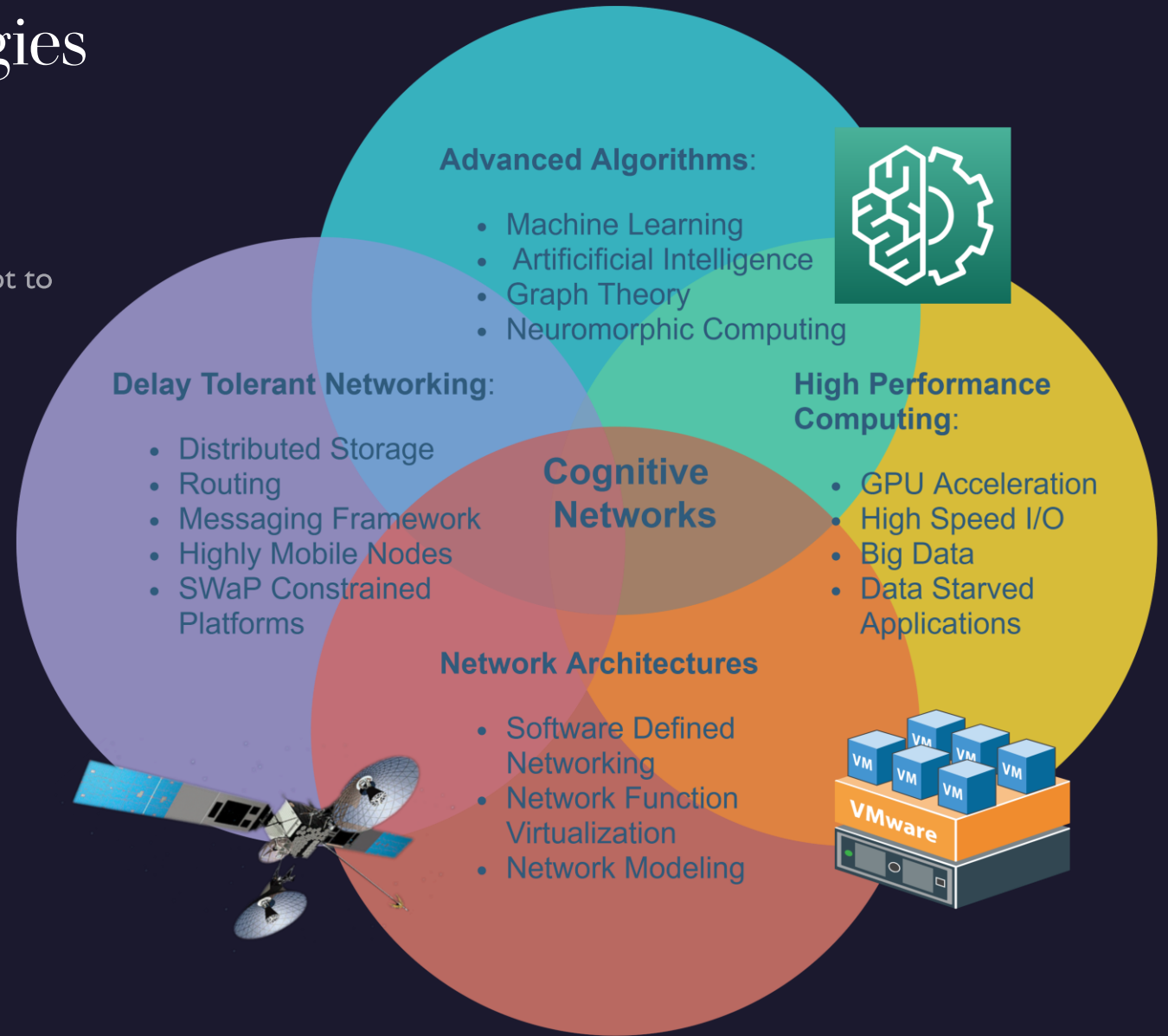
Cognitive Communications for
Aerospace Applications Workshop

June 2021



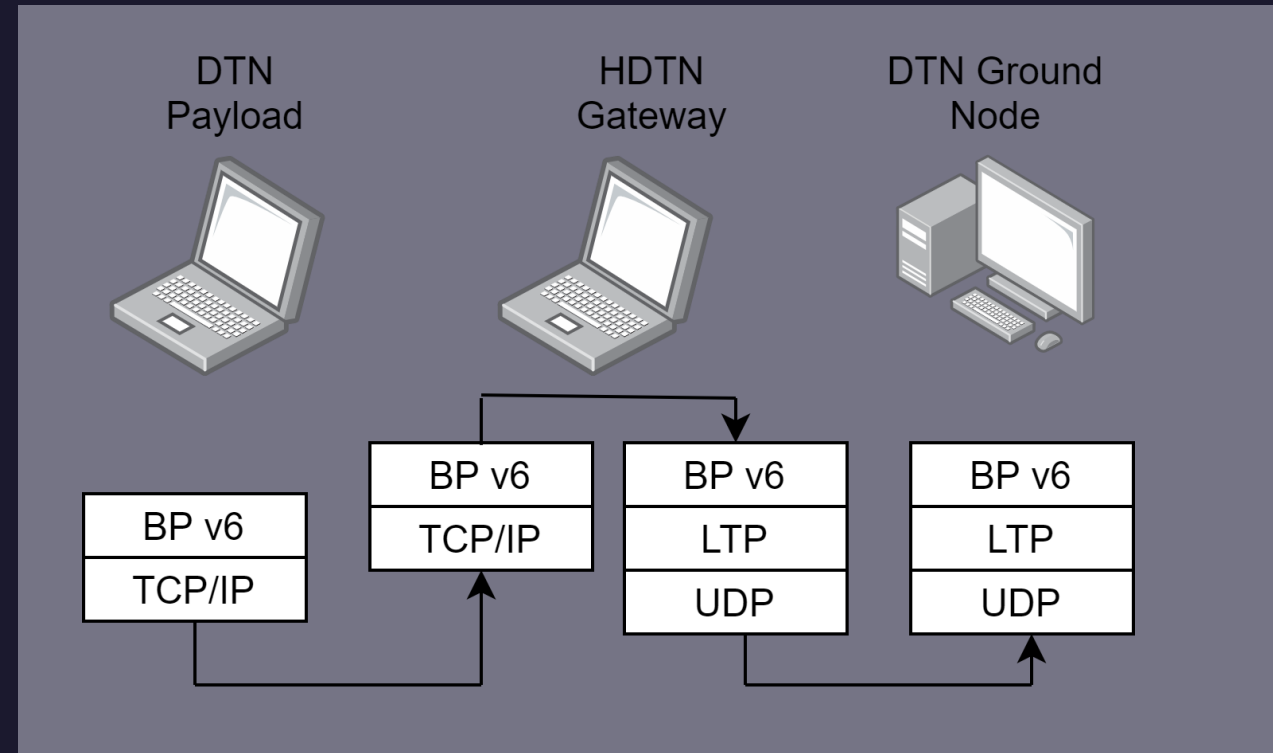
Cognitive Networking Technologies

- Cognitive networking encompasses several technology areas in an effort to develop:
 - Autonomous network implementations that sense and adapt to optimize network and system level performance
- Meet the challenges of:
 - Unlimited scalability of the network
 - Low Size, Weight, and Power (SWaP) platforms
 - Manage data storage, prioritization, custody, and security
 - Interoperability across heterogeneous protocols
 - Increased data return
 - Mobile, intermittently connected network
- Develop implementations beyond simulation
 - Realistic protocol stack
 - Hardware representative of flight systems



Delay Tolerant Networking

- Currently in use on-board ISS
- Considered a key technology for future Lunar architecture
- DTN architecture can serve as a framework to:
 - Mitigate link disruptions with store-and-forward capability
 - Address asymmetric data rates (forward vs. return rates)
 - Provide a common network layer among dissimilar nodes
 - Provide reliability
 - Provide a basis for routing in an intermittently connected network
- Continue to build upon and develop flight heritage



Advanced Algorithms and Decision-Making

Optimizations can be developed at the satellite system level and the network level

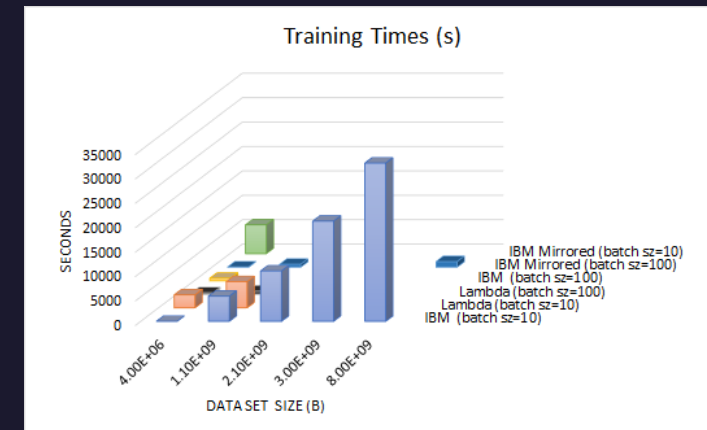
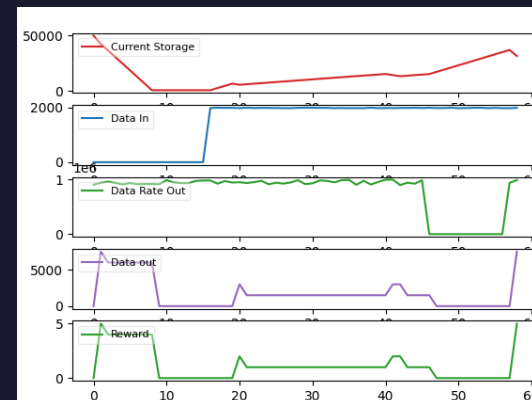
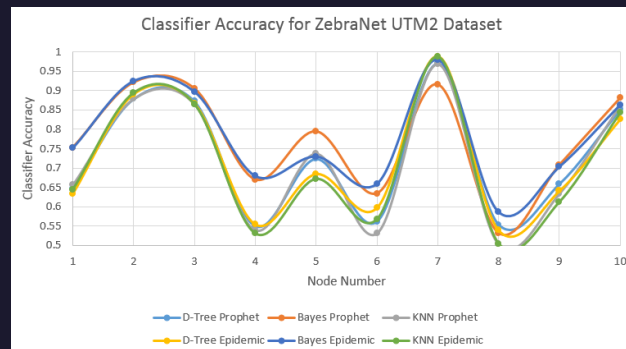
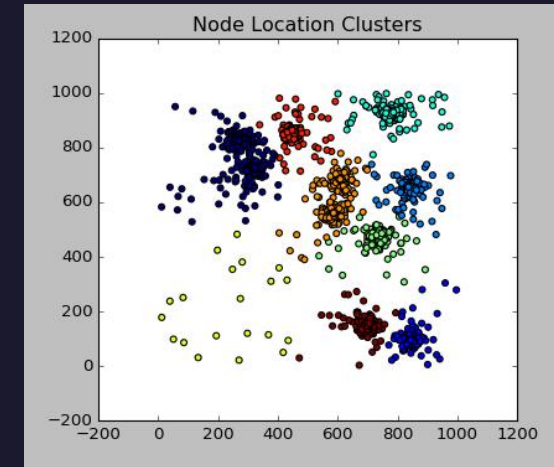
- An example of the Lunar network could be further divided into a network of networks
- Can be a mix of cognitive and conventional regions within the network
- Cognitive system may optimize both the physical and network layers
- Must account for constraints of link schedule and availability

Areas to apply decision-making:

- Determine and handle data priority, data management
- Optimize decisions related to fragmentation and reassembly
- Link Selection
- Routing (multi-hop)
- Neighbor discovery
- Scheduling
- Network management

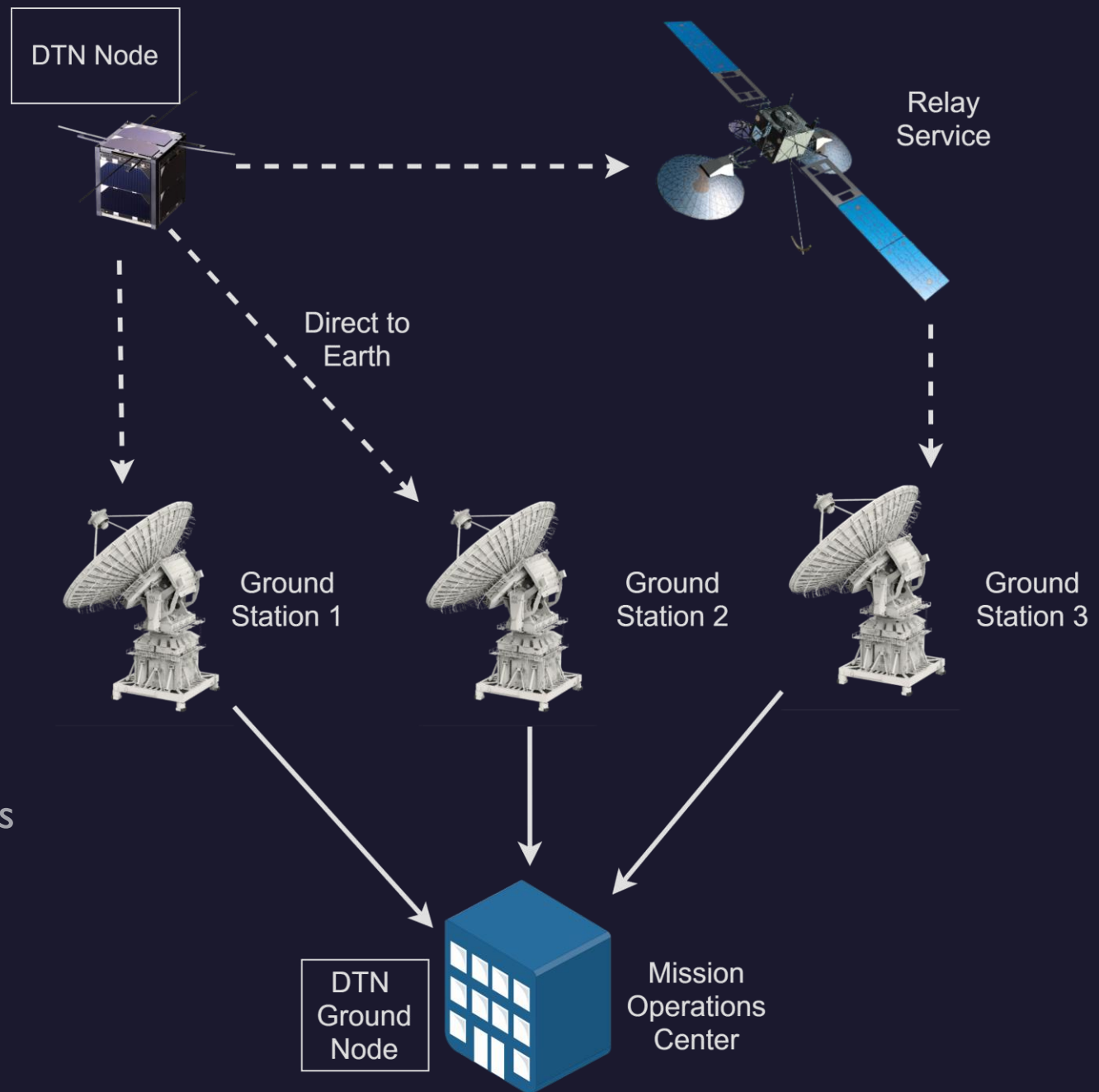
• Areas of interest include:

- Spiking neural networks and neuromorphic systems
- Deep learning
- Graph theory
- Reinforcement learning
- Multi-agent systems
- Multi-objective decision-making
- Clustering



Demonstrations and Infusion

- Cognitive Communications project must partner with missions that can provide opportunities to demonstrate cognitive technologies
 - Advance TRL
- Develop concept of operations for SmallSat and Lunar missions
- Build upon existing engineering efforts
- High-rate Delay Tolerant Networking project is developing a DTN bundle agent which can serve as a framework to implement a variety of cognitive processes



HDTN Software Development Timeline

Develop store-and-forward, UDP, TCP, STCP, LTP, logging and statistics, benchmark utilities. Spring 2021

Provide latest revision to ISS DTN team as experimental DTN gateway. Summer 2021

Enable nodes to share connectivity information with new neighbors. Winter 2021-22

HDTN Software

SDIL Testing

ISS Demo

Routing Interface

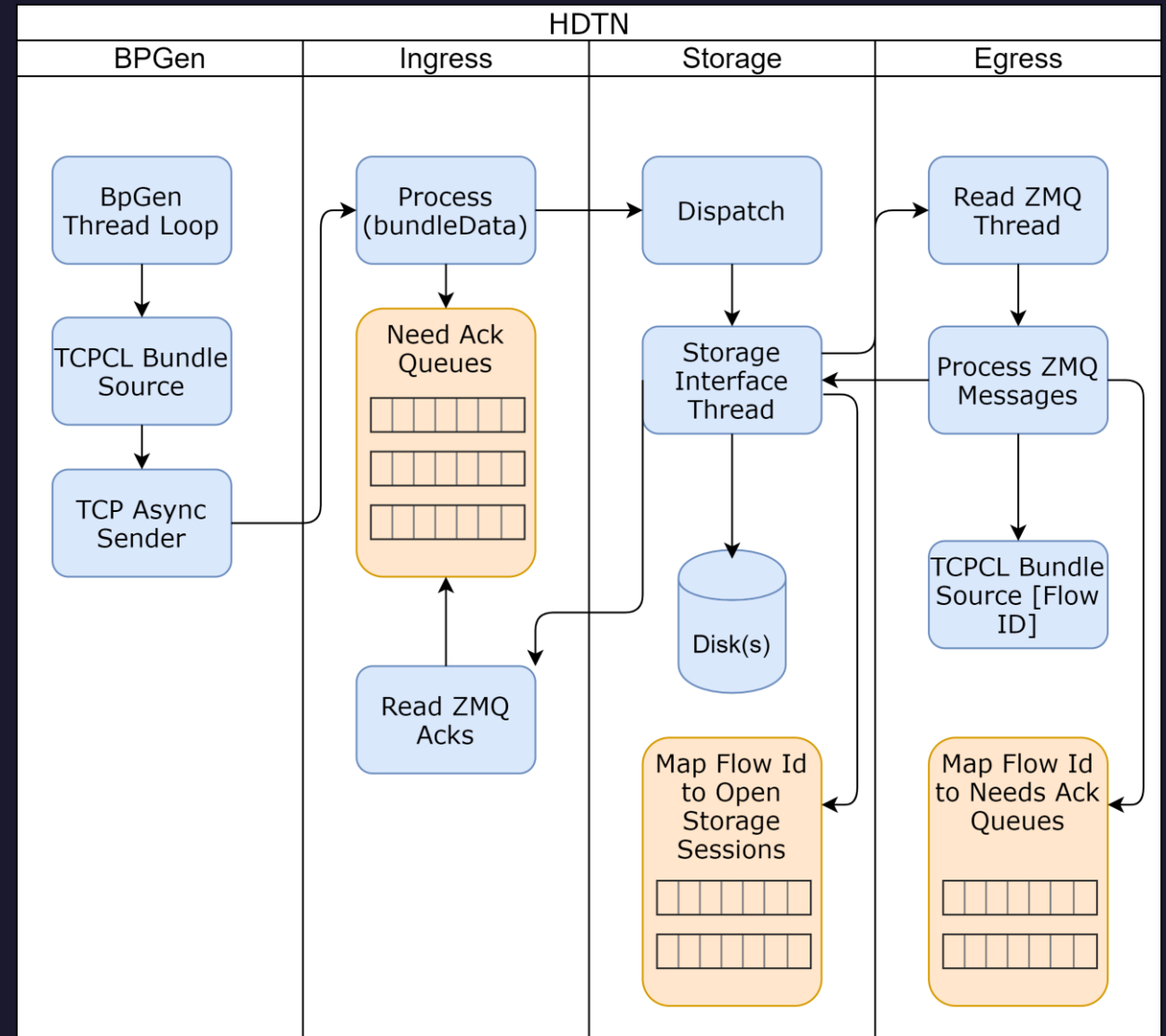
Discovery Interface

Test software with realistic environment similar to ISS DTN network. Summer 2021

Develop interface to allow various algorithms to trigger data storage and egress events. Fall 2021

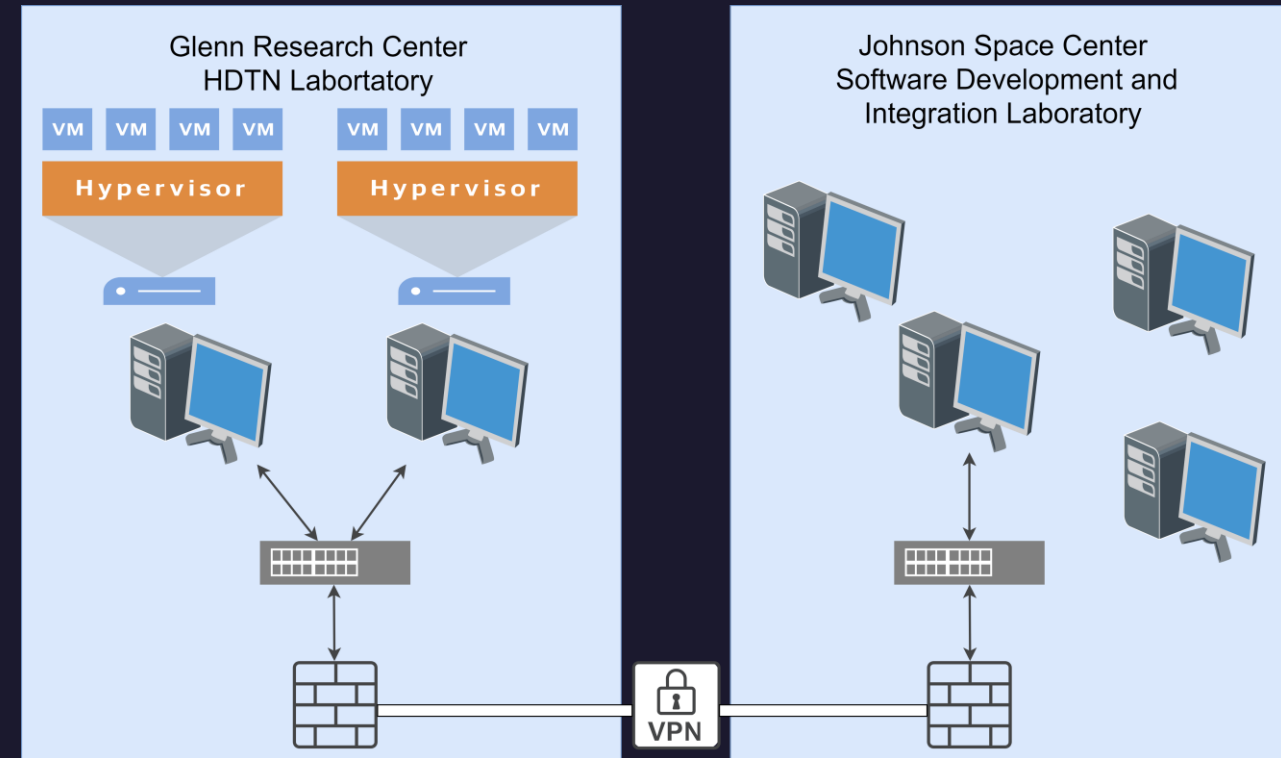
Software Development

- Initial version of bundle encoding/decoding and benchmarking utilities release through NASA Open Source Agreement
- <https://github.com/nasa/HDTN-BPCodec>
- Bundle storage completed
- Ingress and egress support UDP, TCP, STCP, and LTP
- Bundle agent uses message bus to share data between distributed processes
 - Could exist on separate physical machines or containers
- Bundle agent to be released tentatively summer 2021



Lab Environment

- HDTN gateway on ISS will run inside of a Kernel-based Virtual Machine (KVM)
- The software will be tested over a remote connection to the Johnson Space Center Software Development and Integration Laboratory (SDIL)
- The SDIL emulates the ISS DTN network and will flow realistic traffic through HDTN
- Network connection between labs has been established
- Testing to begin in end of June 2021
- Initial test will consist of ION payload node to generate data, HDTN gateway, and ION ground node
 - Nodes will use BPv6, TCP and LTP convergence layers

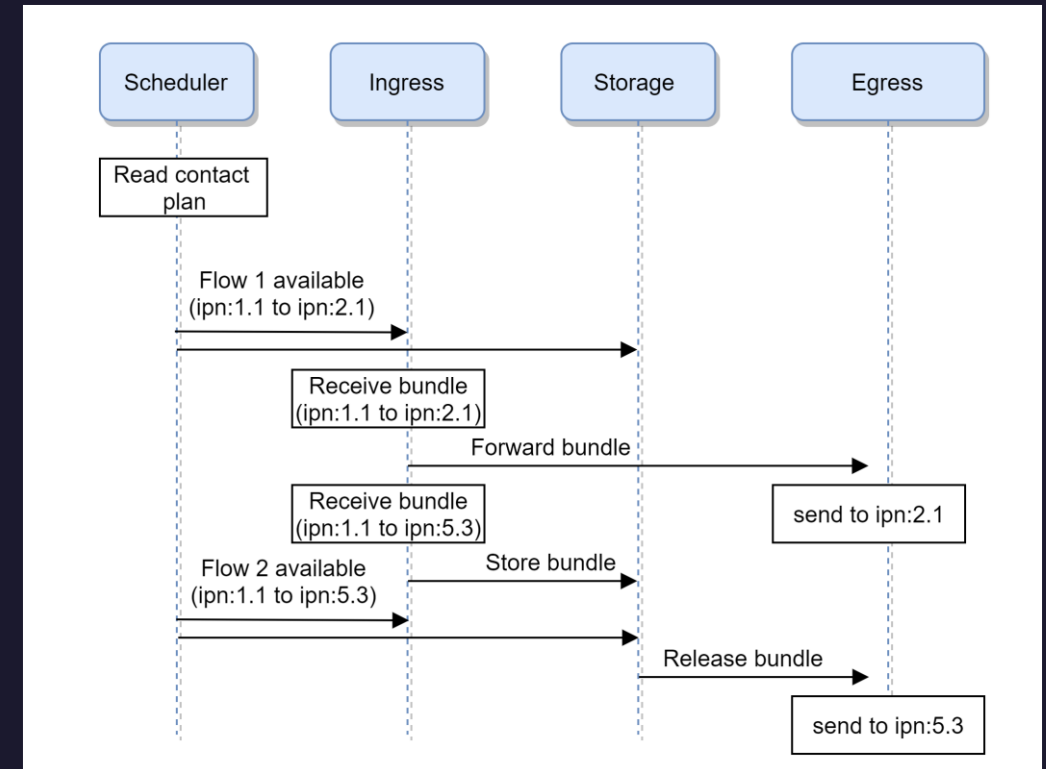


Event Scheduling and Routing Interface

- Event scheduler component has been developed to read contact plan information
 - Contact start and stop times, node numbers, data rate, and distance
- Functions a simple flow-based process to trigger the transmission, storage, and release of data
- ZMQ message bus shares events between modules
 - Supports Python and C/C++
- The basic mechanism will evolve into a routing interface to support contact graph routing and many other routing algorithms

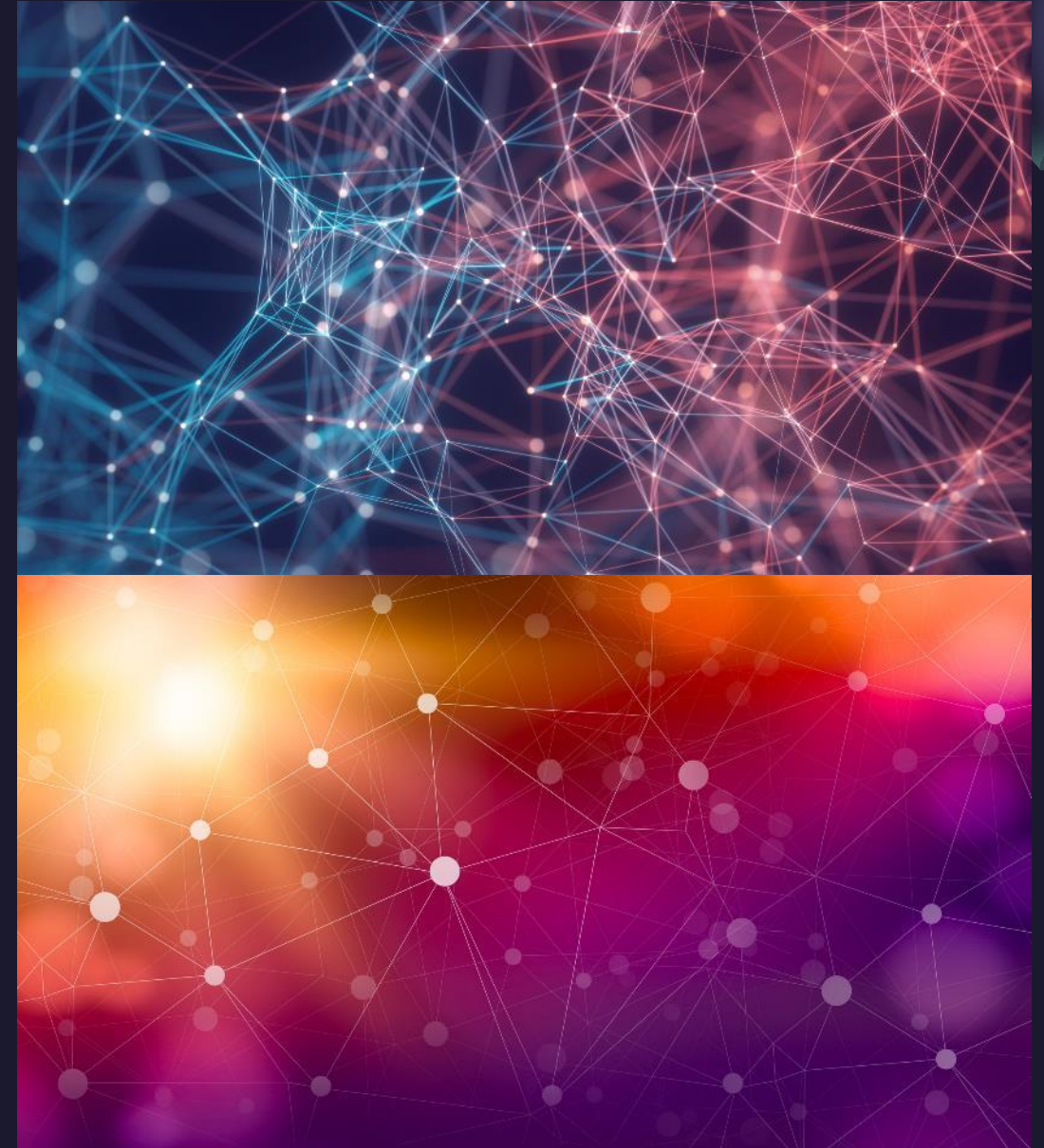
- Contact plan example (JSON):

```
{"contact plan": [  
  {"contact": "0", "source": "1", "dest": "4", "flow ID": "0", "start time": "0", "duration": "3600", "rate": "10000000"},  
  {"contact": "1", "source": "5", "dest": "2", "flow ID": "1", "start time": "0", "duration": "7200", "rate": "10000000"},  
  {"contact": "2", "source": "1", "dest": "3", "flow ID": "2", "start time": "10000", "duration": "7200", "rate": "10000000"},  
]}
```



Future Work

- Additional convergence layers can be developed to support software defined radios, other CubeSat/SmallSat radios
- Develop support for multicast and anycast
- Network statistics from HDTN tests can be used to develop a dataset that can serve as input for machine learning and artificial intelligence models
- Develop for support cognitive routing algorithms
- Develop neighbor discovery mechanism
- Test in multi-hop emulation





Thank You