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PANEL #3

BARCELONA
May 2024

NexComm 2024 & DigitalWorld 2024

Theme: Complex Systems

Focus: Progress on Communications Networking and Data Storage/Processing

Moderator

Prof. Dr. Jin-Shyan Lee, National Taipei University of Technology (Taipei Tech.), Taiwan

Panelists

- Prof. Dr. Shintaro Mori, Fukuoka University, Japan
- Prof. Dr. Eugen Borcoci, National University of Science and Technology POLITEHNICA Bucharest, Romania
- Research Scientist Nadia Kortas, Space Communication and Navigation Program, National Aeronautics and Space Administration (NASA), USA
- President Emeritus, Dr. Robert Sundberg, Spectral Sciences, Inc., USA

Chair Introduction

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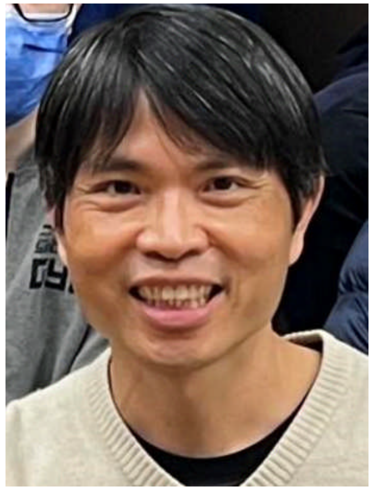
- **Complex Systems**
  - **SCAN: Sensing, Control/Computation/AI, and Networking**
- **Progress on Communications Networking and Data Storage/Processing**
  - **Hyperspectral imagers on satellites will require real-time onboard processing**
  - **Wireless communications/network technologies for future smart cities**
  - **Managing complexity in 5G networks and services**
  - **Solar System Internet (SSI)**



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TAIPEI TECH 國立臺北科技大學 National Taipei University of Technology

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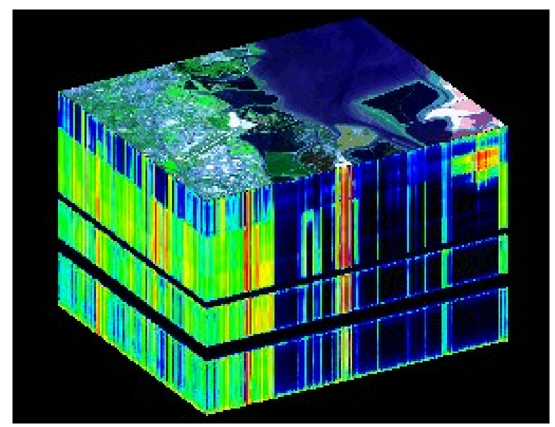
Robert Sundberg
Spectral Sciences, Inc.

- **Hyperspectral imagers on satellites will require real-time onboard processing**
  - **Landsat-8 example**
    - **384 Mbps X-band data downlink**
    - **~700 images a day**
    - **33,000 km^2 per image @ 30 m GSD**
    - **11 bands**
  - **Scale Landsat system to hyperspectral imager**
    - **~200-400 bands → 20-40 images (most planned systems will have 30 m GSD)**
    - **~200 bands & 3-5 m GSD → ~1 image**
  - **Onboard processing**
    - **Downlink data products**
    - **Small context image chips**
  - **Edge processing algorithms (classic & ML-based)**
    - **Atmospheric compensation**
    - **Anomaly identification**
    - **Object detection**
    - **Vegetation monitoring**
    - **…**



Courtesy NASA/JPL-Caltech

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- **Wireless communications/network technologies for future smart cities**
- **Wireless Information-Centric Networking (WICN)**
  - **ICN is a data-oriented network protocol focusing on content delivery.**
  - **Named data achieve abstraction, and caching schemes improve network performance, which is reasonable for dynamic wireless environments.**
- **Millimeter-wave (mmWave)-band communications**
  - **Exploitation of new higher frequencies is essential to deal with large-sized data transmissions.**
  - **MmWaves have different characteristics from the current mainstream radio frequencies, requiring new protocols to be considered.**
- **Non-terrestrial network (NTN) to complement ground networks**
  - **UAV-aided mmWave networks can provide a broadband wireless network, offering wide-area coverage even if a disaster strikes.**

Shintaro Mori
Fukuoka University

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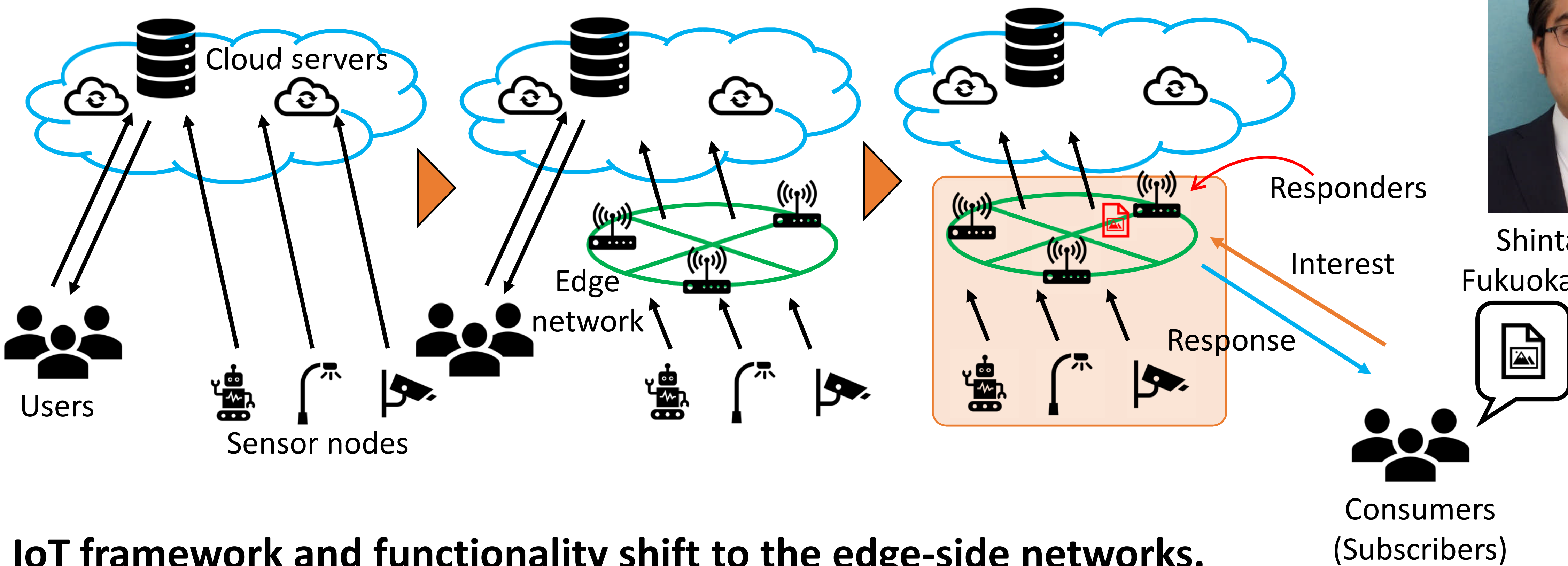
Shintaro Mori
Fukuoka University

Evolution of IoT platforms: Information-centric platform



- **IoT framework and functionality shift to the edge-side networks.**
- **Consumers post an interest packet with clues to find the data, and the responder replies with them, i.e., there is no need to distinguish between original or copy.**

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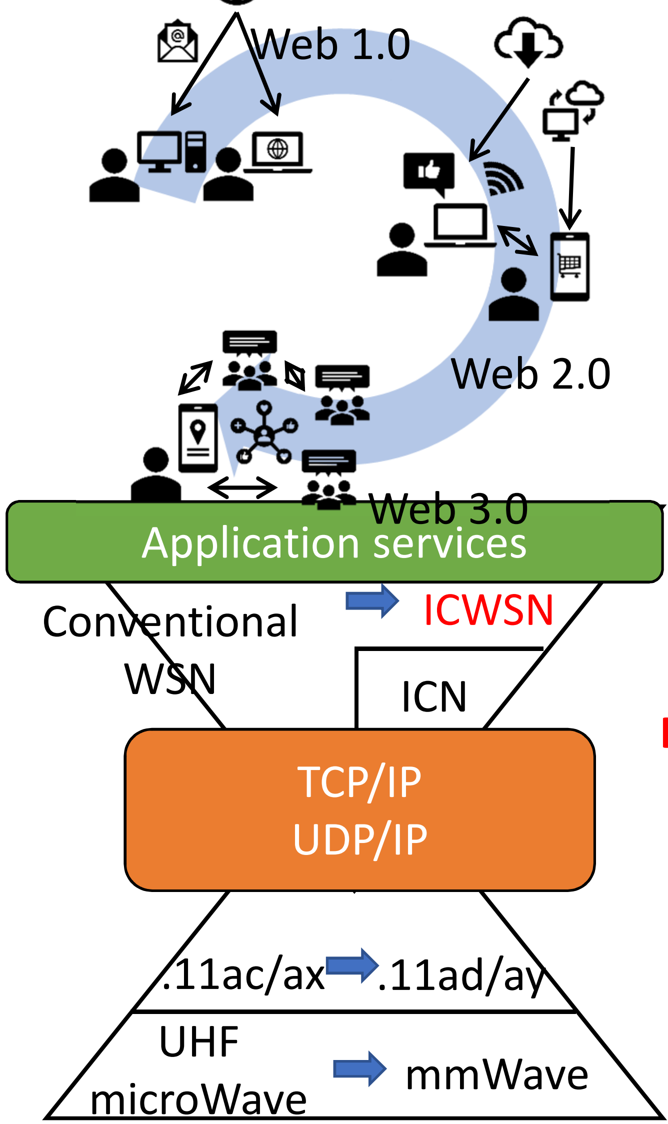

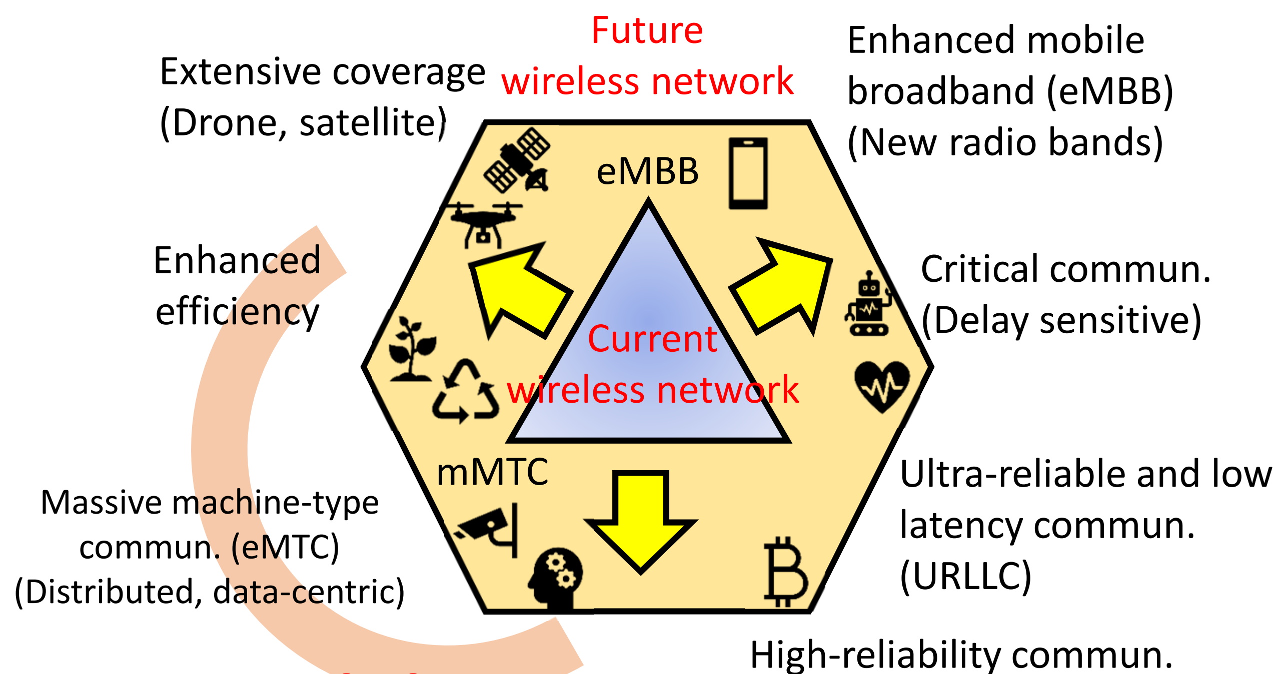

Shintaro Mori
Fukuoka University

mmWave UAV-aided WICNs

- **MmWave propagates straightforwardly.**
- **UAVs can establish reliable Line-of-Sight (LoS) links.**
- **UAV-aided networks can improve coverage areas as aerial nodes.**

- **PANELIST POSITION on**
  - **Managing complexity in 5G networks and services**

    - **5G general characteristics**
    - **Managing the complexity**
      - **The original-old, major idea : “divide et impera”- extended in 5G, 6G..**
      - **Splitting H/V**
      - **Defining hierarchies**

        - **Traditional architectural split and extensions**
        - **Vertical split (slicing)**
        - **Horizontal (spatial) split**
        - **Functional split**
        - **Programmability and virtualization**

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- **5G general characteristics**
  - **Significant higher performance** (versus 4G) :
    - **connectivity** : capacity, latency, spectral efficiency, mobility, number of supported user terminals, position accuracy, energy consumption, energy harvesting, etc.
    - more efficient hardware
    - reliability, availability, security and privacy
    - advanced architecture- E2E capabilities, multi-domain, multi-tenant, multi-operator
      - Compatibility with cloud/edge/fog computing, global internet
      - AI-based subsystems
    - large range of services supported: A/V, multimedia, (big) data, IoT, IoV/V2X, UAV, industrial, social networks, etc.
    - management of personal data by users, and control of exposure degree over public Internet domains
    - capability to integrate legacy technologies, flexible and interworking in heterogeneous environments
    - ...
  - **Challenges**
    - **High complexity - especially in 5G management and control**
    - **Complexity will be still higher in 6G…**

- **Managing complexity in 5G**
  - **Traditional architectural split and extensions**
    - Separation in architectural parallel planes: **Data/User, Control, Management**
      - in 5G **Orchestration plane** – added
    - Preserve the Internet good **functional layering** principle (**PHY, Data, Network, Transport Application**)
      - **5G macro-layers:**
        - **Network Domain:** ***Infrastructure, Network functions, Orchestration functions***
        - **Services and business domain :** ***Business functions, Services functions***
  - **Vertical split (slicing)**
    - **4G concept: one monolithic architecture to support all apps**
    - **5G slicing**: **logical separated networks- each slice can be dedicated to specific class of apps**
      - Each tenant/slice may have its own M&C – this will reduce the overall complexity
      - Main categories :
        - Enhanced mobile broadband (eMBB)
        - Ultra reliability low latency communication (URLLC)
        - Massive machine type communication (mMTC)
      - Sub-categories of slices can be defined : supporting IoT, IoV/V2X, smart cities, industrial, environment, etc.

- **Managing complexity in 5G**
  - **Horizontal (spatial) split**
    - **Separated domains (** belonging to different operators**)**
    - **Spatial segmentation of networks:** Radio Access Network (RAN), Backhaul, Edge, Transport, Core/Cloud
  - **Functional split**
    - Extending the traditional (FCAPS)management split
    - Defining functional hierarchies
    - Specific functions defined for: Orchestration, Management, Control, User plane
    - Specific sets of functions adapted to the spatial segments: RAN, Backhaul, ….
    - High level services split(graphs of VNFs) ; Microservices as building blocks
    - Delegating: optimizations, intelligent decisions, traffic-related, (dynamic) resource allocation, security, etc. to AI/ML adaptive subsystems
  - **Programmability and virtualization-** significant support to manage the complexity
    - **Support technologies – all based on virtualization; they cooperate**
      - Software Defined Networking
      - Network Function Virtualization
      - Edge computing/Fog computing
      - Central Cloud computing

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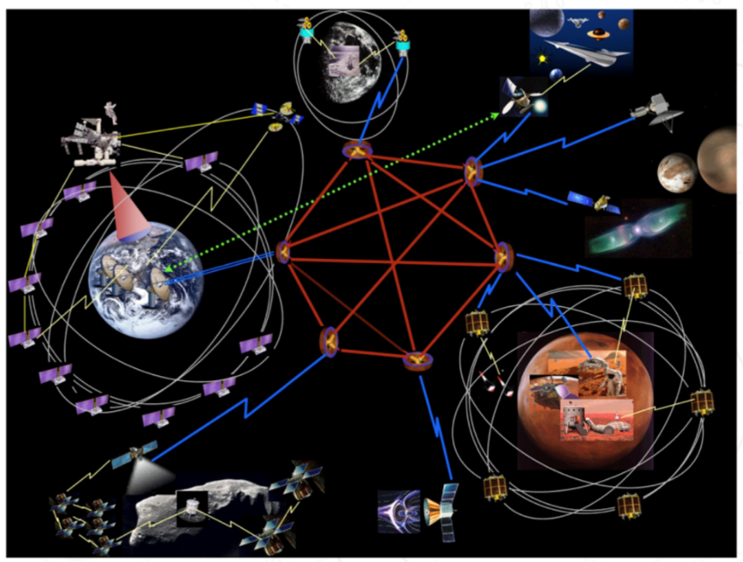
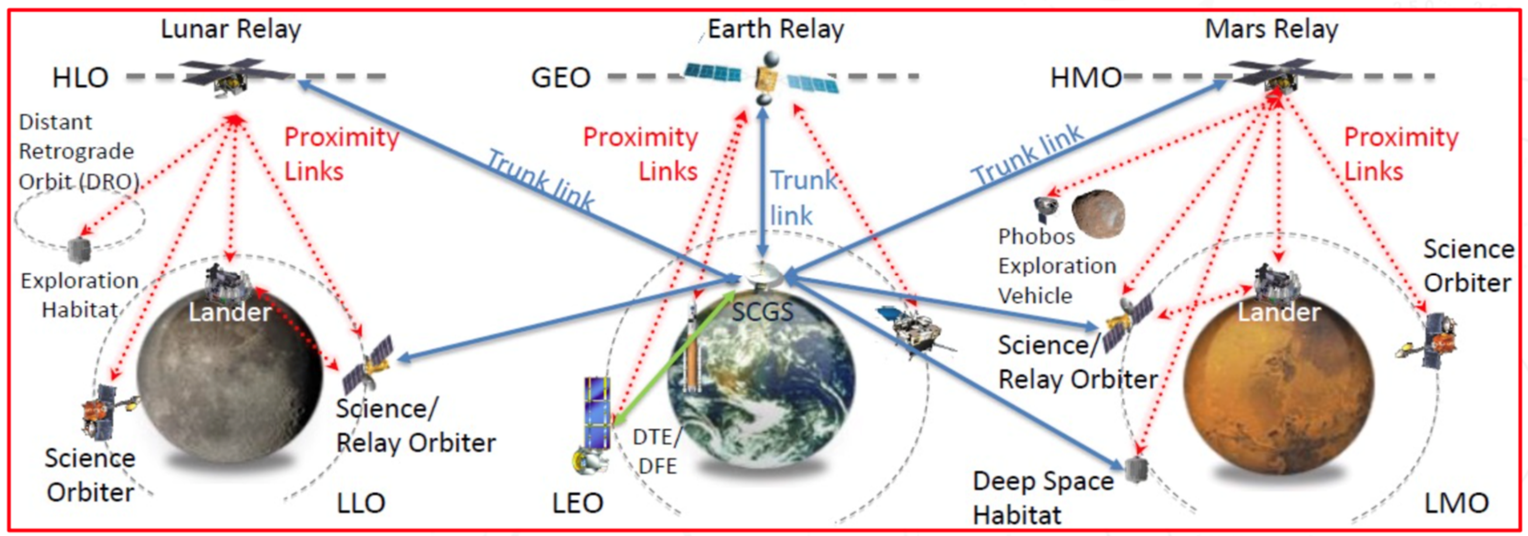
- Solar System Internet (SSI) : a variety of assets cooperate to relay information in both local networks and across long-haul interplanetary distances
- SSI challenges: Dispersed, sparse, and partitioned networks without end-to-end connectivity, and with very long delays
- Communications to Earth can happen even when orbits prevent line-of-sight communications: Spacecrafts acting as network relays and storage nodes
- Delay/Disruption Tolerant Networking (DTN) : NASA's solution for building interoperable, automated and reliable space communication networks
- DTN relies on a store-carry-forward transport approach where messages may remain at DTN nodes until a transmission opportunity arises or when transfer acknowledgment to a final recipient is received

Nadia Kortas
NASA





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- When using store-and-forward techniques, the network is considered available if there is enough local storage to hold a message until a future transmission opportunity arises
- Store-and-forward can add to the congestion in the network => exhaust local persistent storage on the node.
- Possible solutions:

1. A routing system equipped with knowledge of available storage and capable of pinning routes: linear computation approach, global knowledge required about the network, computational overhead
2. Slowing sources (flow control), using alternative routes, discarding traffic, migrating messages to alternative storage locations
3. Storage routing: employs nearby nodes with available storage to store data that would otherwise be lost
4. Predicting storage needs for satellites while taking throughput into consideration => optimize size, mass, and power needs of future satellites
5. Efficient use of networking resources: remove corrupted data early before it is allowed to consume network storage; Use of integrity verification with the intent of removing corrupted traffic.
6. Bundle processing, especially for larger bundles may require both large amounts of memory, bandwidth resources and storage, but also very efficient implementations of storage access and caching mechanisms => avoid storage quantity and storage speed becoming the bottleneck in the system.

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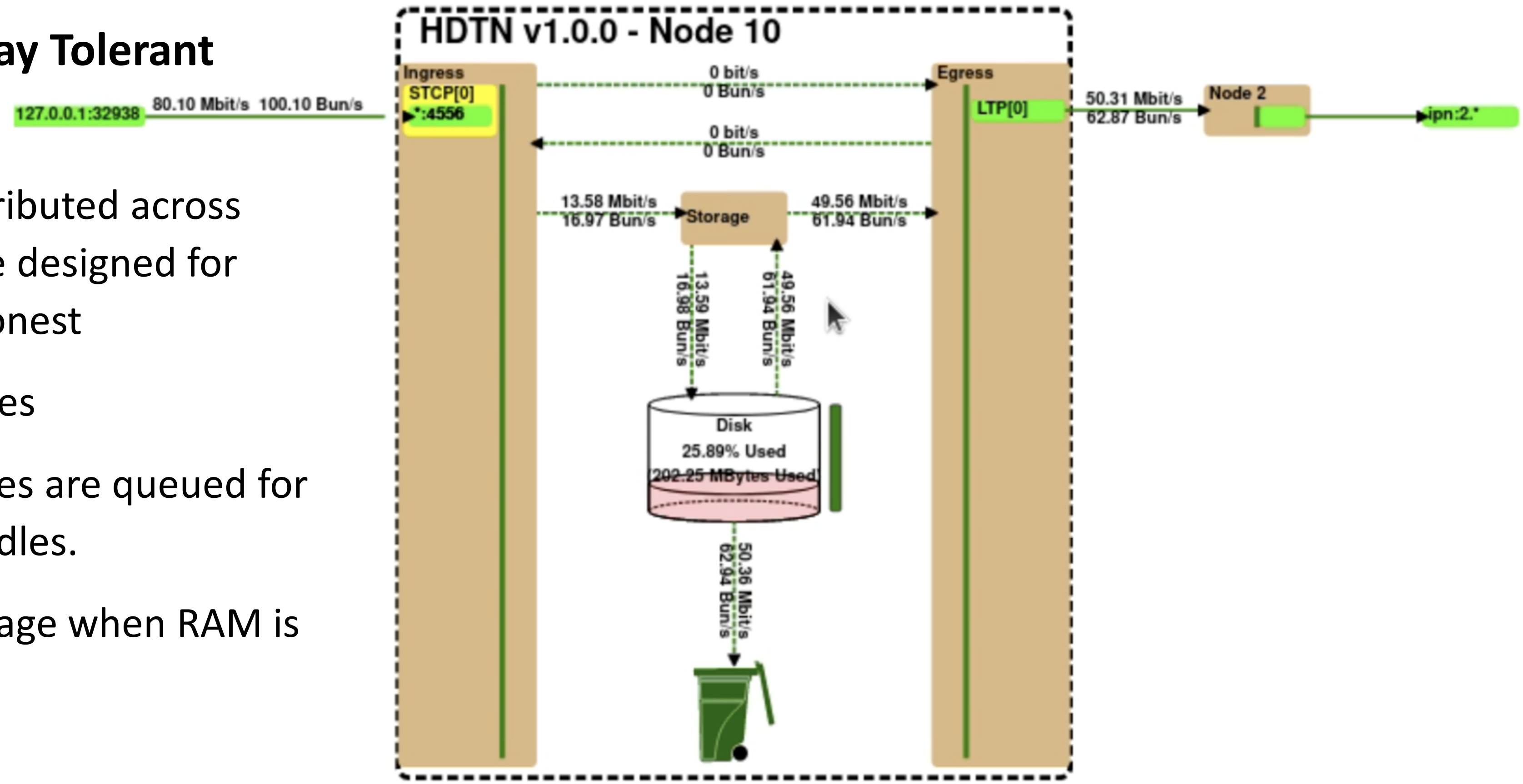
Storage module for High-rate Delay Tolerant Networking (HDTN) :

- Multi-threaded implementation distributed across multiple disks; custom data structure designed for releasing bundles that expire the soonest
- Storage can proactively delete bundles
- Must ensure that high priority bundles are queued for transmission before low priority bundles.
- Has the option to use persistent storage when RAM is constrained



Code available at https://github.com/nasa/HDTN

Q&A