Enabling Capabilities for Tactical Edge Networking

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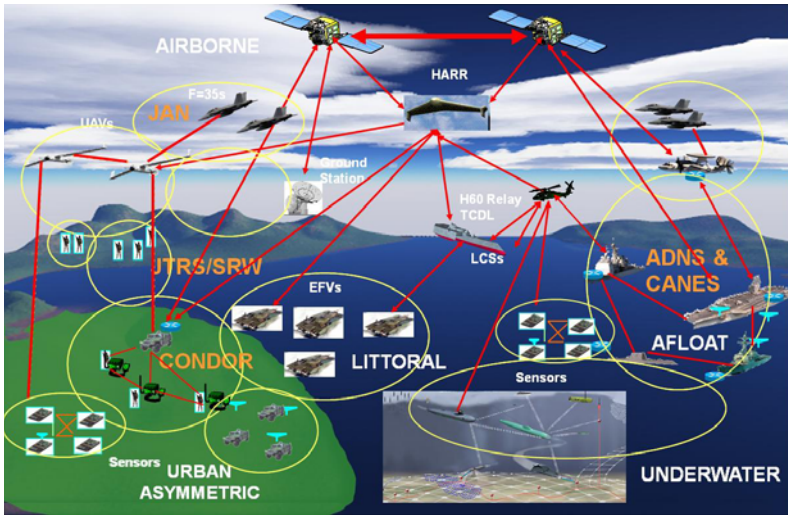
Problem

- **Future Navy systems supporting tactical edge communications and distributed operations will include a wide range of heterogeneous network technologies, including satellites, line-of-sight links, and edge networks.**
- **Mismatches in network characteristics such as data rate, error rate, and latency, coupled with changes in connectivity due to fading, platform motion, and obstruction severely impact end-to-end network performance.**
- **Can we extend recent work in Delay/Disruption Tolerant Networking (DTN) to support tactical environments with changing but predictable connectivity, limited per-node storage capabilities, and bandwidth restrictions requiring multicast applications?**

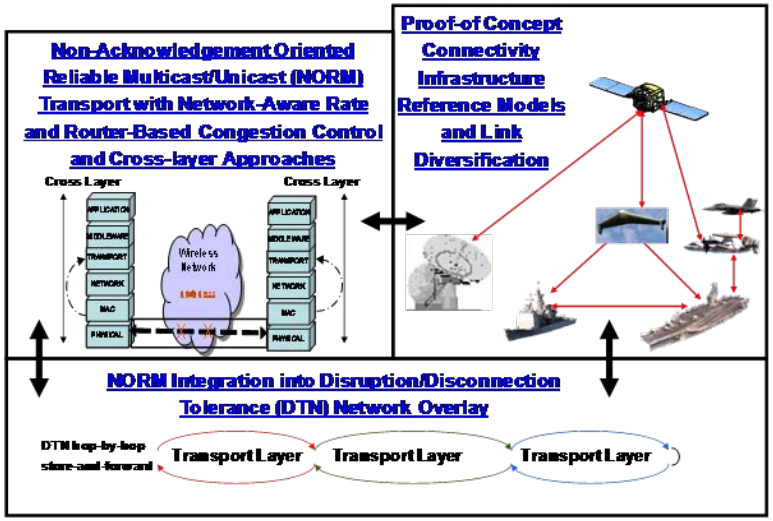
Background

MITRE Innovation Program

Heterogeneous Networks



DTN Store-and-Forward



- Navy plans for afloat networks with heterogeneous data links with vastly different characteristics
- Delay/Disruption Tolerant Networking can ‘impedance-match’ between networks and provide communications services with only intermittent connectivity among nodes

Objectives

- Extend DTN to support multicast
  - DTN custodial multicast that ‘checkpoints’ data in the network; re-transmissions use fewer resources than traditional reliable multicast
- Implement “environment-aware” routing at the DTN layer (above IP)
  - Develop routing cognizant of specifics of network behavior such as expected future connectivity (schedules), learned periodic intermittency, and node characteristics
- Develop congestion control (storage management) for DTN
  - Integrate storage management with DTN routing

Activities

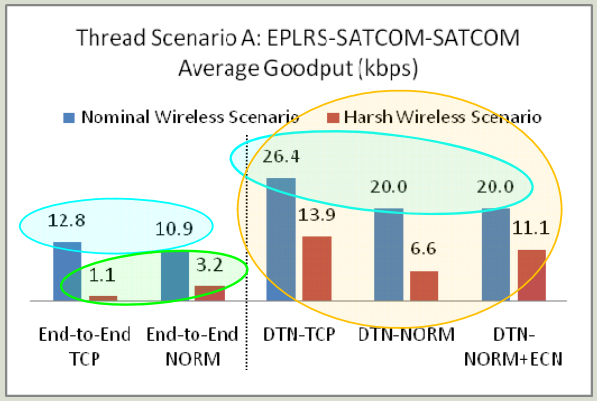
- **Multicast Routing – Examining extensions to PIM and exploring distribution models:**
  - **Examining extensions to Internet Protocol Independent Multicast (PIM) sparse and dense modes**
  - **Under separate funding, taking a broader look at what multicast models (source-driven, receiver-driven, pub/sub) are appropriate**
- **Unicast Routing – leveraging NASA work in scheduled routing:**
  - **NASA work in Contact Graph Routing (CGR) uses static contact schedules to route messages**
  - **MITRE will examine extending this work into a dynamic routing protocol capable of handing scheduled and unplanned connectivity changes**
- **Congestion Control – examining two mechanisms:**
  - **Short-range congestion control uses immediate feedback to suppress senders – akin to TCP congestion control in the Internet**
  - **Long-range congestion control integrated with DTN routing protocols to route around congestion**

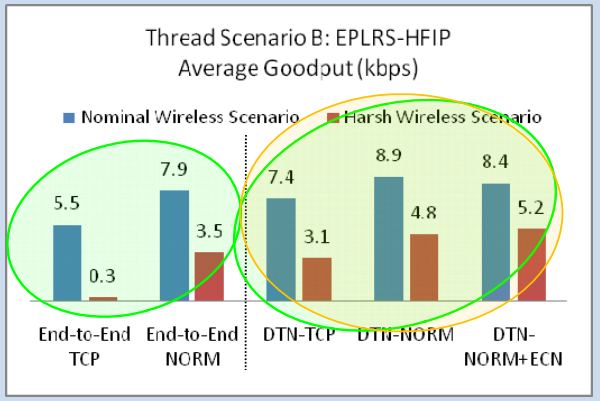
Hop-by-Hop vs. End-to-End Performance

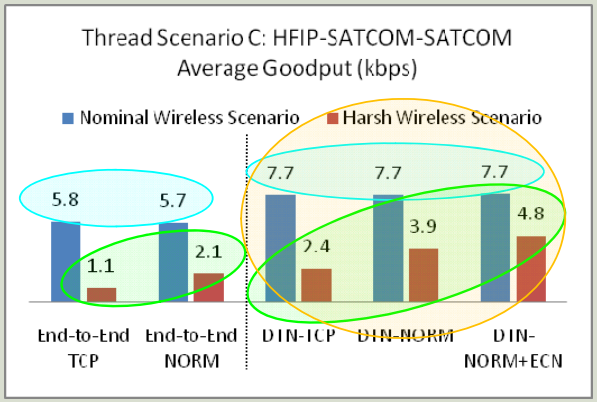
- As expected, goodput is better in the nominal environment.
- For the SATCOM nominal wireless environment, TCP performed as well as or better than NORM.
- Otherwise, NORM protocol variations generally performed better.
- DTN-based schemes typically outperform end-to-end schemes.

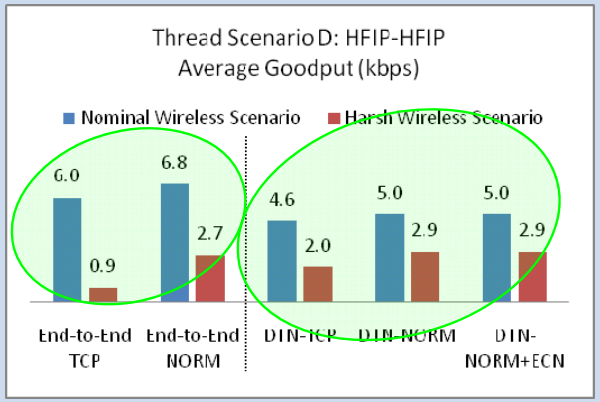
Nominal (w/SATCOM)

SATCOM-denied

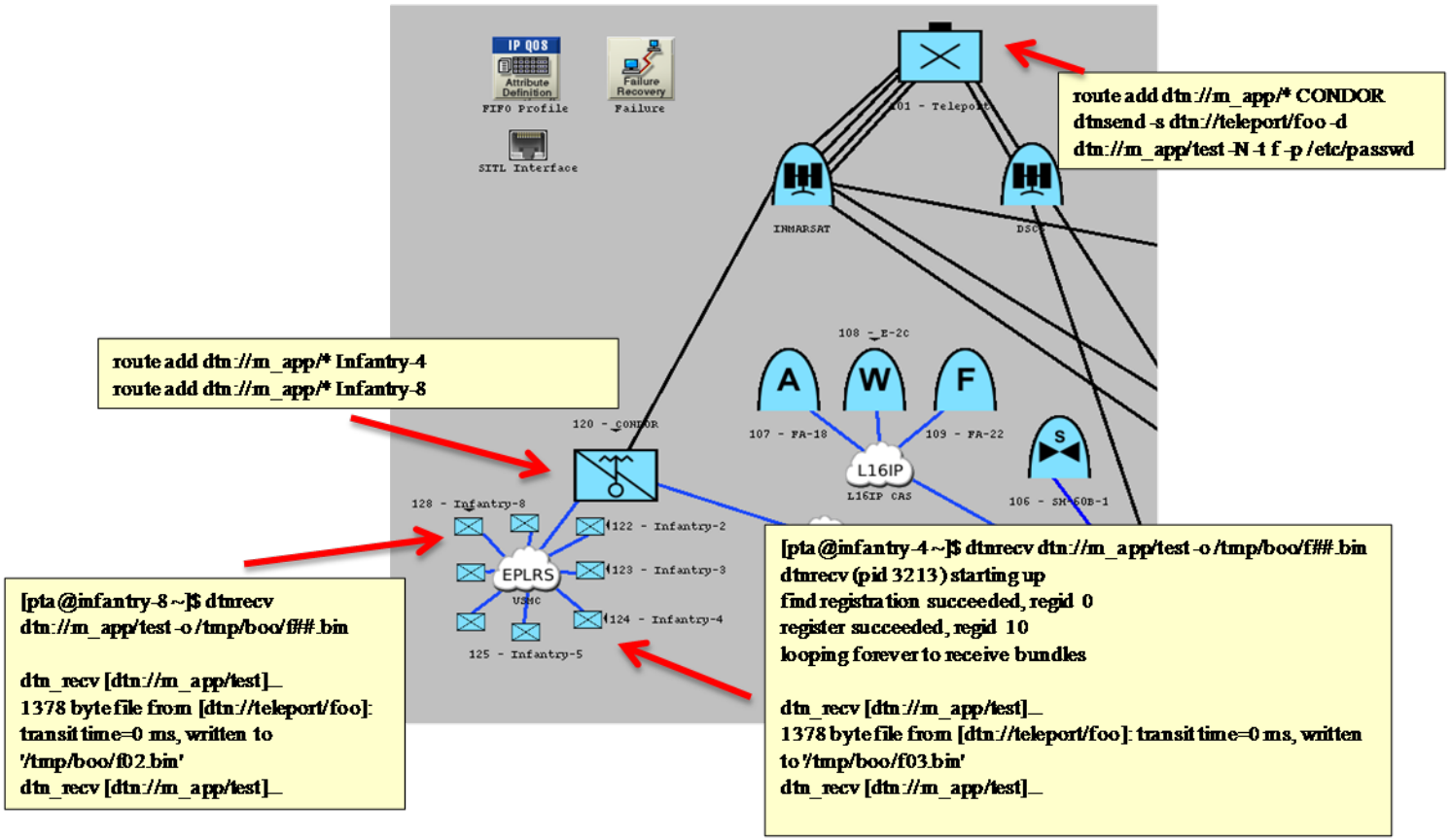








DTN Multicast Forwarding



- DTN Multicast *forwarding* (without a routing protocol) must be set up by hand

Impacts

- **This work will benefit all systems that connect heterogeneous tactical networks, allowing them to function reliably and efficiently despite inevitable network disruptions.**
- ***Near-term transition targets*: Communications Airborne Layer Expansion Joint Capability Demonstration (CABLE JCD), the Dynamic Tactical Communications Network Enabling Capability (DTCN EC).**
- ***Longer-term transition targets*: Capabilities developed for CABLE and DTCN will be picked up by Naval Tactical Networking (a POM-10 initiative) and will ultimately enhance CANES and MACTFC2. The results will also be made available to PMW160 and other efforts.**
- ***Collaboration* with the Naval Research Laboratory (NRL): Results of this project are being made available to NRL for use in their Mobile Ad-Hoc Network simulation testbed. This will allow NRL to apply the capabilities to the numerous tactical programs with which they are involved.**

Future Plans

- Transition DTN into programs such as the Communications Airborne Layer Expansion Joint Capability Demonstration (CABLE JCD), the Dynamic Tactical Communications Network Enabling Capability (DTCN EC), and Naval Tactical Networking (NTN)
- Continue integration of DTN capabilities with Naval Research Laboratory Mobile Ad-Hoc Network simulation/emulation testbed facilities