Delay / Disruption Tolerant Networking for the Internet -- Problem Statement

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Background

- **The Internet Protocols (TCP/IP) are ubiquitous:**
  - Most widely-deployed networking protocol suite in human history
  - Backbone for all data communications in the global Internet
  - Support wide diversity of applications (e.g., e-mail, file transfer, web browsing, social media, Internet telephony, streaming video, etc., etc.)
  - Connect billions of users worldwide
- **Best suited to "well behaved" paths:**
  - Low to moderate end-to-end delays (usec/msec/sec), packet loss, reordering, per-packet queuing delays in network middleboxes
  - "Conversational" data exchanges
  - Client/server architectures
  - Reactive congestion control
  - End-to-end flow control and retransmission
  - Data transmission order implicit in data arrival order – no need for explicit ordering markings

Emerging Paradigm Shift

- **New Requirements That Don't Fit the Mold:**
  - Moderate to long end-to-end delays (minutes/hours/days)
  - Moderate to high end-to-end packet loss (i.e., significant disruption)
  - Moderate to high queuing delays (store, carry, forward)
  - "Open Loop" data exchanges (bulk data transfers, public service bulletins, remote command and control messaging, situation awareness dissemination on scheduled/opportunistic contacts, etc.)
- **Use Cases Not Always Satisfied by TCP/IP:**
  - Space-based Communications (ISS, deep-space, etc.)
  - Satellite-Assisted Communications for Isolated Ground Systems
  - Civil Aviation (loss of comms; bulk transfers, etc.)
  - Unmanned Aerial Systems (UAS) operating in remote regions
  - Unmanned Underwater Vehicles (UUV)
  - Disaster Response and Humanitarian Aid
  - Expeditionary Units in Remote Deployments

Space Systems Communications

- **Customized (non-standard) Communications Between ISS; Ground Systems**
  - Custom SW required to overcome limitations of RF space links
    - ➢ Tracking and Data Relay Satellite (TDRS) Availability Issue (~30% outage)
    - ➢ Communications Latency in Ground/TDRSS/ISS RF Links
- **Deep Space Communications Incompatible With Traditional Methods**
    - ➢ One-Way Light Time (OWLT) from Earth to Mars ~4min minimum
    - ➢ Satellite Assist Not Always Available
- **Space System Support for Isolated Ground Systems**
    - ➢ Data Exchanges Only Possible During Satellite Over-Flights
- **Security Concerns:**
  - Current security based piecemeal solutions; local security schemes
    - ➢ Delay/Disruption-Tolerant Security Standards Needed

Unmanned Air Systems (UAS)

- **Unmanned Air Systems (UAS) in Civil Aviation**
  - UAS industry is exploding – unlimited applications
  - Technology that improves safety and reliability while reducing cost could find a large market.
  - FAA NextGen Program, and FAA Modernization and Reform Act of 2012
    - ➢ UAS integrated into the National Air Space (NAS) by 2015
- **Data Communications Crucial for UAS Command/Control/Situation-Awareness**
  - ➢ RF Communications Occasionally Subject to Disruption
  - ➢ Operation in Remote Regions can Result in Extended Outages
- **Traditional Internet Protocols Alone Insufficient to Assure Safety of Flight**
  - ➢ UAS Will Operate in the Same Airspace as Commercial Aviation
  - ➢ Need: DTN for Integrating Manned/Unmanned Aviation

Disaster Response and Humanitarian Aid

- **Communications Infrastructure Frequently Impaired or Decimated**
  - ➢ Need Comms in Intermittently-Connected and/or Disruptive Environments
- **Coordinated Response Teams Use Handheld/Portable Networking Gear**
  - Dismounted and/or vehicular radio systems
- **"Reachback" Supported by SATCOM and/or Terrestrial Links-of-Opportunity**
  - ➢ Long Delays when Connected
  - ➢ Extended Periods of Disconnection
- **Disruption as Important as Delays**
  - Loss due to attrition, battery lifetime, sensor network duty cycles, etc.
- **Standard Solutions Needed to Allow Natural Network Convergence**
  - ➢ Ad-hoc Approaches Often Result in Communication Failures

Unmanned Underwater Vehicles

- **Market for Underwater Sensors and Instrumentation Already $1B+**
- **Revenue in Autonomous Underwater Vehicle Industry Growing 14%/yr**
- **Internetworking Underwater Still in Exploratory Phase:**
  - Speed of sound underwater is 1.5 km/sec (1min round-trip time between two underwater entities separated by only 45km)
  - Data rates of acoustic modems are low
    - ➢ Delay-Tolerant Networking Needed to Support Underwater Comms
- **Long-endurance Underwater Operations**
  - UUVs can be underwater for days/weeks/months
- **Delay Tolerant Multi-Hopping Between Mobile Underwater Vehicles**
  - Message relaying based on scheduled or unplanned windows of opportunity
  - authentication, integrity and confidentiality are mandatory
    - ➢ Secure Store, Carry and Forward of Data Objects Larger than Packets

Summary

- **Satisfy Emerging Internetworking Needs**
  - Integration of delay/disruption-tolerant network architecture with the Internet already important
  - Integration will rapidly become much more important over the coming decade
- **Start With Well-Tested Technologies**
  - Community-developed advanced technologies with multiple interoperable implementations
  - Bundle Protocol ready for standards-track development
- **Mature Technologies to Product Readiness**
  - ➢ **Proposing formation of an IETF Working Group to establish DTN Internet standards**

Backups

- **1. The UAV industry is exploding. Nobody has any idea where the limits on applications of UAVs are, but what we do know is that the information that controls them is conveyed by radio, which is occasionally subject to disruption. Technology that could improve the safety and reliability of UAVs, while reducing cost, could find a large market.**
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- **2. The speed of sound underwater is 1.5 km/sec, so the round-trip time between two underwater entities communicating by acoustic modem and separated by a distance of 7.5 km is about equal to the round-trip time between Earth and the Earth/Sun L2 Lagrange point. Since the data rates of acoustic modems are low, efficient delay-tolerant networking is a pretty good way to establish underwater communication. The market for underwater sensors and instrumentation is already in the billions of dollars; revenue in the autonomous underwater vehicle manufacturing industry is growing at nearly 14% per year.**