Delay / Disruption Tolerant Networking Enhancements for Streaming Data

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Delay / Disruption Tolerant Networking (DTN)

• DTN provides store-and-forward data transmission.
  – Missing data is automatically detected and re-transmitted.
  – Data is held at the origination node until receipt confirmation is received from the destination node.

• DTN is delay tolerant.
  – DTN is designed for transmission delays at interplanetary distances
    • Up to 20 minutes transmission delay for a Mars mission

• NASA’s Spacecraft Communications and Navigation (SCaN) Program Office has directed that DTN be incorporated into the Deep Space Network.

• Therefore, the MCC will need to account for the effects of DTN on data received from the DSN.

• This work addresses operational enhancements to the Interplanetary Overlay Network (ION).
Opportunities for DTN Enhancement

- Situation: An unconditioned DTN data stream produces out-of-order data, as missing data frames are re-transmitted and mixed in with the real-time data stream.
  - Out-of-order data would look like a transient glitch on a flight controller display.
  - A data gap would be preferable to out-of-order data.
  - This problem is addressed by the Bundle Streaming Service (BSS) bundled with ION.
  - However, the data samples are delivered in bursts due to DTN (LTP) aggregation.
    - This presents a problem for applications that rely on a steady stream of samples, such as voice and video.
    - A way to meter the data is needed.

- Situation: The user needs to know when 100% of the data has been received. Delay Tolerant Payload Conditioning (DTPC) does do this. This work uses a different approach.

- Situation: For timing sensitive applications, such as H.264 compressed video, the 100% complete received data stream timing should match the original timing, even though the original data samples may have been aggregated into larger blocks for space-to-ground transmission.

- All three of these streams are required simultaneously over the Licklider Transmission Protocol (LTP), which is DTN’s long haul space-to-ground (aggregating) protocol.

- All of these situations are addressed by DTN BSS Payload Conditioning.
DTN BSS Payload Conditioning

- DTN BSS Payload Conditioning provides:
  - A metered real-time data stream
    - Monotonically increasing time tags and sequence numbers, no out-of-order packets, may have gaps
    - Metering: timing of the output data stream matches the original, even though aggregation may have occurred during space-to-ground transmission.
      - Real-time metering will be important for transmission of voice over DTN.
  - A fully conditioned data stream
    - 100% confirmed reception; real-time data advancement when 100% is reached
  - A metered, fully conditioned data stream
    - Suitable for H.264 compressed video; lags behind real-time

- These capabilities require:
  - (Minimal) modification to the DTN bpsend() function to add a unique sequence number and a microsecond time tag to the DTN ECOS extension block
  - Modification to the ION DTN Bundle Streaming Service (BSS) library to add these two new parameters to the BSS database
  - The bss_player data stream control application
    - All three types of streams are available simultaneously
    - bss_player can distribute each stream independently over BP, UDP, or multicast
bss_player Stream Control Application
Demo Setup, Re-use Elements

- A DTN node in the iPAS lab, JSC Bldg. 29 simulates the vehicle transmission point.
- The simulated Deep Space Operations Center (DSOC) at JPL anchors the DTN LTP space-to-ground link.
- JPL models the space link with a 2 sec. one-way-light-time (OWLT) delay, and a 2% frame drop rate on the downlink.
- JPL provides the multi-center DTN distribution node.
- The OTF in JSC Bldg. 30 provides five independent DTN data reception nodes.
  - Their sole connectivity is through JPL
  - This configuration simulates geographically dispersed control centers
DTN / LTP
Command, Voice Uplink

Initial Cislunar Habitat
Software Defined Radio
iPAS Lab, JSC Bldg. 29

DTN / LTP
Telemetry, Voice, Video Downlink

Protocol Test Lab@JPL
DSN Operations Center Sim
Space-to-Ground Comm Link Sim
2 sec. one way light time delay
2% frame drop rate on the downlink
0.1% frame drop rate on the uplink
Available 24/7/365

UDP, STCP, DGR
DTN Convergence Layers

PTL@JPL
OTF@JSC Bldg. 30
DTN BSS Telemetry Demo

- bss_player, showing metered realtime, 100% conditioned, and metered replay data streams
- Sample telemetry display of metered realtime stream (red)
  - Skipped sequence numbers are evident, indicating missing data.
  - Sequence numbers monotonically increase
DTN BSS Video Demo

- bss_player, showing metered realtime, 100% conditioned, and replay data streams
- Video display of original low-def 4 fps Motion JPEG video signal, provided by an Axis 214 PTZ camera in the iPAS Pathfinder lab in Bldg. 29
- Video display of metered BSS realtime signal (red), propagated through the JSC / JPL DTN / DSN simulated space-to-ground and ground-to-ground network
  - Video glitches correspond to dropped MJPG frames.
  - Real-time received video lags the original by ~2 sec., the modeled OWLT
- Video display of real-time 100% conditioned DTN video signal (green)
  - Video freezes while bss_player waits for retransmission of missing data.
  - When all missing data are restored, the video jumps to the most current frame.
  - Intervening video is skipped; events will be missed.
- Video display of metered replay 100% conditioned DTN video signal (blue)
  - Smoothly displays the complete video signal
  - Lags behind real-time
Summary

• DTN Bundle Streaming Service (BSS) addresses the problem of out-of-order data in real-time displays.
  – DTN BSS Payload Conditioning includes this capability. Plus, it adds metering capability to the real-time stream, so that the output timing matches the input timing.

• DTN BSS Payload Conditioning addresses the need to confirm reception of 100% of the data transmitted over DTN, and to know real-time when 100% reception has occurred.

• DTN BSS Payload Conditioning addresses the need to match the output data timing to the input timing for the fully conditioned data stream.
  – Important for timing sensitive data streams such as H.264 compressed video
Questions?
DTN Voice Communication Architecture

ISS

DTN Node 1

BSS Player

BP-enabled Data Capture App

DTN Phone App

Astronaut Headset

Astronaut Voice

Flight Controller Voice

SPACE

BP Bundles over LTP

EARTH

DTN Node 2

LTP & BSSP Daemons

Controller Headset

Astronaut Voice

Flight Controller Voice

DTN Phone App

DTN Node 3

BP-enabled Data Capture App

BSS Player

BP Bundles over BSSP

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