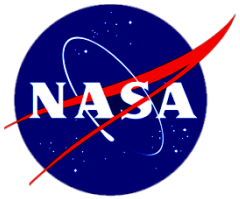

Delay / Disruption Tolerant Networking Enhancements for Streaming Data

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Agenda

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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).

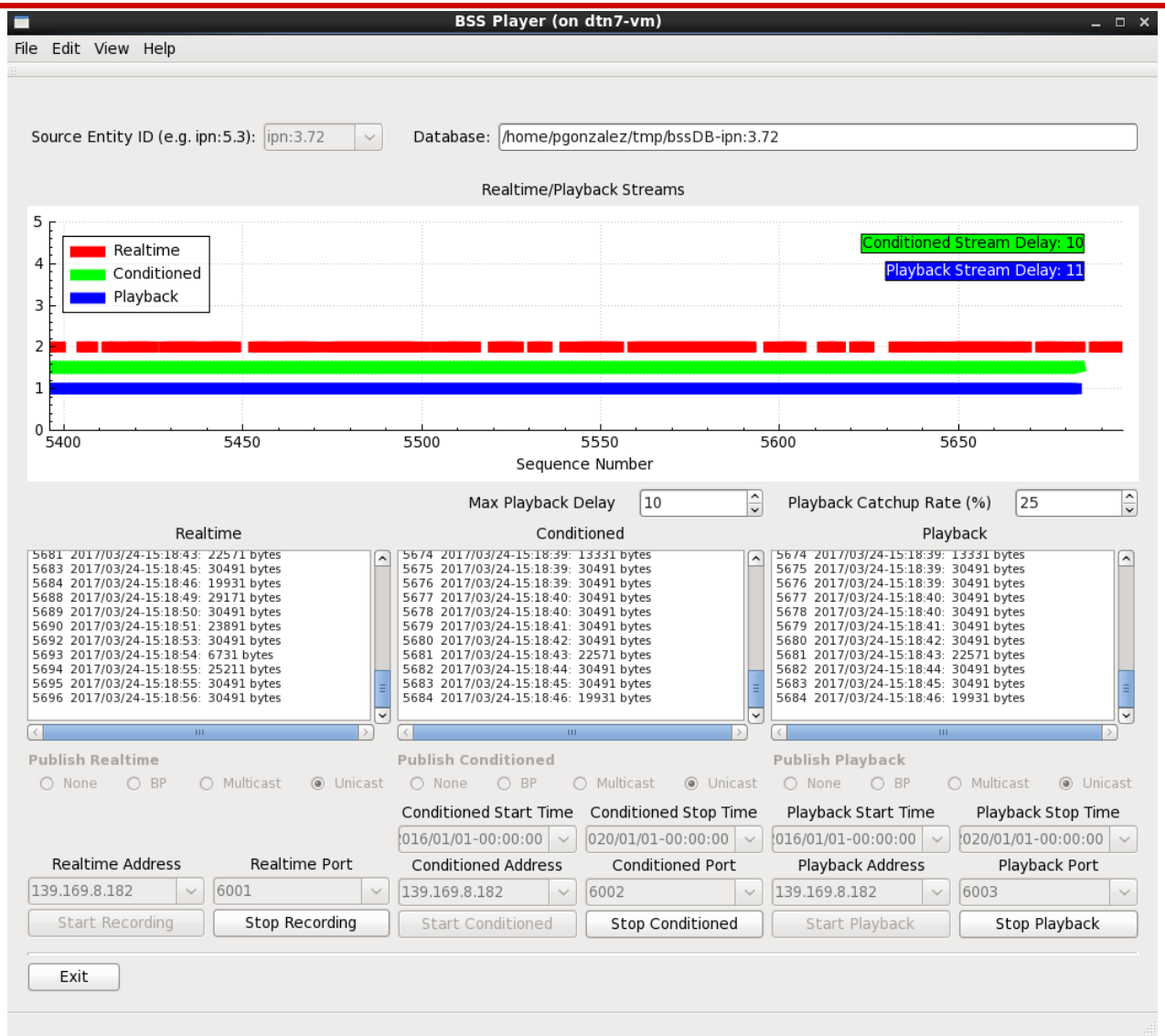
Opportunities for DTN Enhancement

- 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 occured 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

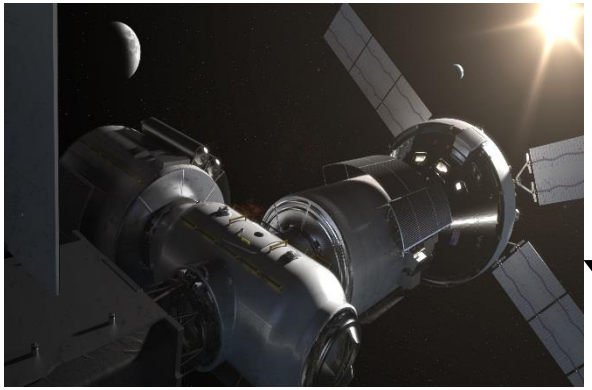
bss_player Stream Control Application



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

JSC / JPL DTN / DSN Overview



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

DTN / LTP
Command, Voice
Uplink

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

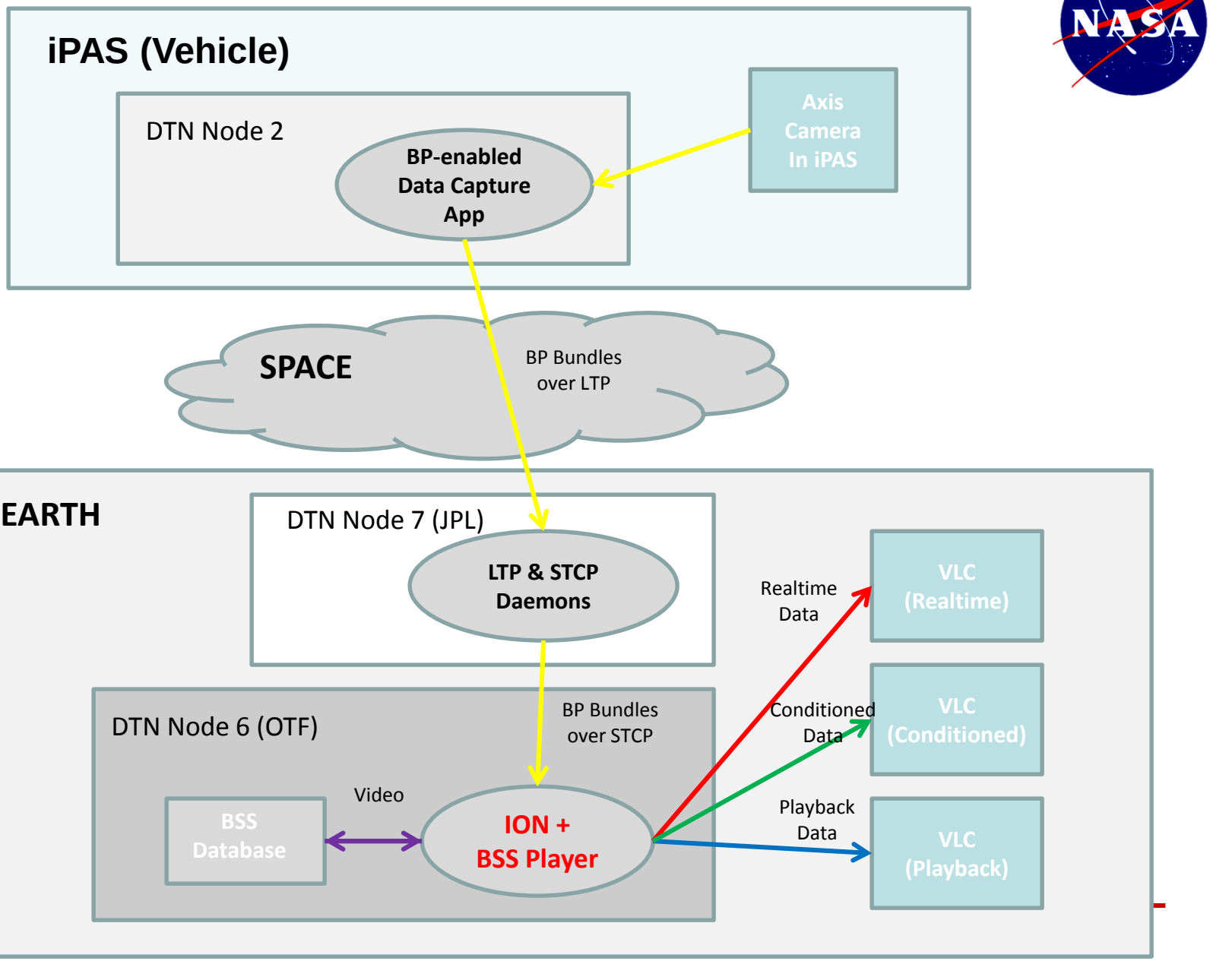
PTL@JPL

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

BSS Player Video Architecture



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?

Backup

DTN Voice Communication Architecture