

Report Concerning Space Data System Standards

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| Streaming Services over Bundle Protocol REquirements |

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[Foreword text specific to this document goes here. The text below is boilerplate.]

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# Introduction

## Purpose and scope

The purpose of this document is to record requirements for streaming services over Bundle Protocol, with particular emphasis on streaming digital video over Bundle Protocol. Previous testing of video streams over Bundle Protocol will be documented. A common test configuration for continued testing and benchmarking of video (and other streaming data) will also be documented.

## References

The following documents are referenced in this Report. At the time of publication, the editions indicated were valid. All documents are subject to revision, and users of this Report are encouraged to investigate the possibility of applying the most recent editions of the documents indicated below. The CCSDS Secretariat maintains a register of currently valid CCSDS documents.

[A list of documents referenced in the report goes here. See CCSDS A20.0-Y-4, *CCSDS Publications Manual* (Yellow Book, Issue 4, April 2014) for reference list format.]

# OVERVIEW

Previous testing and real-life experience with streaming video over networks indicates that video streams are particularly susceptible to network jitter and lost packets. Video decoders typically buffer the incoming data stream to reconstitute the frames of video that were encoding using “group of pictures” algorithms that combine frames or disassemble video frames into blocks of pixels. If enough data is missing, even with buffering, or the data arrives jumbled or out of order beyond what the decoder’s buffering can handle, the decoder will either freeze the last good frame video and present it as live video output, or will simply default to a blank or colored screen.

It is likely that as humans endeavor to explore space beyond low Earth orbit, video will be included as important data transmitted back to Earth. Whether it is used for situational awareness, such as proximity of approaching spacecraft during docking and rendezvous, or monitoring an Extra Vehicular Activity, or for public use to allow the rest of us on Earth to “go along for the ride,” successful transmission and reception of video will become an important requirement for mission success. As these missions move beyond the Earth-Moon system, it is very likely the data communications will be over delay tolerant networks.

This Green Book will explore the requirements for video over bundle streaming protocols and document prototyping and testing of video over these protocols.

# Use Case Scenarios

## Low earth orbit

*Describe here real-time and file based work flows including LOS scenarios, such as large RED camera file transfer.*

## Cis lunar

*Describe here likely scenarios including proximity operations (lander or robot plus orbiting spacecraft, rendezvous, EVA) over variable links from S-band to Ku, Ka & X.*

## mars campaign

*Describe here multiple scenarios, expanding on CIS Lunar, accounting for extended light time, priority of content (example of low quality imagery for situational awareness), optical links to S-band, and extended proximity operations.*

# Requirements

*List here requirements for streaming capability over bundle protocols, keeping in mind the use case scenarios outlines in section 3.*

# Methods for transmission of video over bundle streaming protocols

## DLR – ENCODING AND ENCAPSULATION

DLR has developed two systems for video transmission via DTN networks. The first is the transparent gateway which aims to provide a simple transport for UDP-based media protocols which is agnostic of the protocol running through it. The second is a more advanced native encoder which integrates directly with a H.264 video encoder and decoder and designed to natively function with DTN.

### Transparent Gateway

The transparent gateway is a set of applications which encapsulate UDP data into DTN bundles while maintaining the important timing information. This technique is primarily used for MPEG Transport Streams. The gateway will ingest a user-configurable number of UDP packets directed towards it and add additional metadata, comprised of a size and a nanosecond-resolution timestamp, generated as a delta between UDP packet reception at the gateway. Once the given number of packets have been received, they are serialized. A header containing a count of packets and a sequence number is prefixed to the serialized data. The gateway can be utilized as a drop-in replacement for existing link-layer protocols. Other multimedia protocols such as RTP have been successfully tested with the gateway.

The gateway implementation was complicated by the interleaving inherent in MPEG-TS data, as well as the 4-bit MPEG-TS sequence counter. The 4-bit counter overruns quickly, and will not typically (at higher bitrates) lend itself to the resequencing of data, even when that data is occurring within the same one-second DTN timestamp. The gateway receiver aims to prevent this by utilizing the sequence number to reorder packets into a buffer before outputting them based on the timestamp from the header. By tuning the input buffer size, a user can reduce the visual impact of out-of-order packets.

### Direct H.264 transmission

In the process of testing the transparent gateway, it was quickly discovered that DTN provides a greater advantage and requires less overhead when utilized with larger bundles, hence the addition of the multiple UDP packet encapsulation capability mentioned above. In addition, much of the robustness which MPEG-TS provides in terms of error-recovery and interleaving are inherent capabilities of a properly configured DTN link.

This encoder does not attempt to interleave data, instead relying on the underlying DTN stack to perform that task. Instead, the encoder outputs individual compressed frames as single bundles. Minimal metadata is added, comprised only of a width, height, and frame-rate, all of which are requirements for the initialization of the H.264 decoder. Frames are encoded in the packet-oriented H.264 Network Abstraction Layer (NAL) format. The decoder simply initializes a decoder, decodes the data provided in the bundles before finally displays them.

The native H.264 transmitter is extremely robust to interruption and packet loss. As LTP provides retransmission and fragmentation capability and will not present a bundle to the application layer before transmission has completed successfully, each bundle can be assumed to be intact. As such, each frame can be assumed to be intact as well. The order of packets is maintained via the timestamp from within the bundle protocol as well as a per-second count of frames. Any packet which contains a timestamp is less than the current “running” timestamp is assumed to have arrived out-of-order and is archived. Once the one-second frame count is equal to the framerate from the metadata, the video for that second is assumed to be 100% retrieved. The disadvantage of this system is the uniqueness of its implementation. The encoder and decoder are built using the FFMPEG libraries but are otherwise self-contained. It is technically possible to integrate it with other IP-based encoders and decoders by creating a new and functionally-identical MPEG TS output. It must be noted that the encoder must use a codec which supports frame-based output, such as H.264, motion JPEG2000, or H.265.

### Summary

Exhaustive in-house testing between both systems using MPEG-2, H.264, and H.265 has been performed. H.265 testing was ceased due to the high CPU requirements for software encoders. In general, it has been found that the native H.264 system provides higher video quality, although the integration between that system and the rest of a video pipeline is complex.

The gateway, running over LTP with a 2 second buffer have been shown to handle 8 mbps H.264 transport streams and allow for some packet loss with no visual degradation. Running with a smaller buffer demands a “perfect” connection, where even a small packet loss may cause a momentary disruption of audio or video.

The native transmission system running over LTP with a 25 frame buffer (one second at PAL rates), with an 8mbps encoding bitrate has been found to be resistant to a 10% bit error rate without visual degradation when running with a <1 second delay. If the delay is short enough, it is possible for any LTP retransmissions to occur before the next frame is due to be displayed. If the delay is longer than one second, then there may be some visual impact, but it will appear as dropped frames and eventually wind up in the archive. The time to archive can be shortened by using Bundle Streaming Service, though DLR has opted to not implement it.

## JPL (need a better title, JPL – BUNDLE STREAMING SERVICE)

*Here we describe and summarize Scott’s brilliant work thus far*

## common test scenarios for future study

*Here we outline common testing configurations for future trail blazers to allow them to add content to this book in the future*

1. [ANNEX TITLE]

[Annexes contain ancillary information. See CCSDS A20.0-Y-4, *CCSDS Publications Manual* (Yellow Book, Issue 4, April 2014) for discussion of the kinds of material contained in annexes.]