Digital Video over Space Systems & Networks

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Introduction

◆ Space imagery started with film
  ♦ Public saw the footage after the mission
  ♦ Black & White and Color motion picture film
  ♦ Slow frame rates
  ♦ Had to get the film back!

◆ Live TV from space!
  ♦ Black & White
  ♦ Color via Black & White “color wheel” system
  ♦ Long term ground recording via film kinescopes
  ♦ Lots of unique video
    ♦ Field sequential
    ♦ ISS VBSP
Digital Video Parameters

- Analog video pretty simple
  - PAL, SECAM and NTSC
  - Interlace, frame rates and resolution differences

- Digital Video a bit more complicated
  - Horizontal/Vertical resolution options
    - 480, 720 and 1080
  - Scanning
    - Interlace
    - Progressive
  - Frame Rates
    - You name it
  - Aspect Ratios
    - 4:3
    - 16:9
    - 14:9
  - Color Sampling
    - 4:2:0
    - 4:2:2
    - And a bunch of other schemes
Video over IP

- Digital Video requires a lot of compression
  - SDTV is 270 Mbps uncompressed
  - HDTV is 1.485 Gbps uncompressed
  - MPEG-2
    - Groups of pictures
      - I, B and P frames
    - Frames divided into 8 x 8 pixel blocks
  - MPEG-4
    - MPEG-4 Part 10 = h.264
    - Compression between blocks and frames
  - Motion JPEG2000
    - Intraframe compression
Video over IP

- **Transport Stream**
  - Combines video, audio and other elements together
  - Typically used for real-time video applications such as terrestrial broadcasting or digital video satellite systems

- **Advantages**
  - Video & audio in sync
  - Common hardware solutions for encoding and decoding
  - Easy IP routing or video routing (using Asynchronous Serial Interface)

- **Dis-Advantages**
  - Added bandwidth overhead
  - Packetization stacks are common
  - Susceptible to packet-loss and jitter
Video over IP

♦ Program Element Stream
  ♦ Video and audio are separate
  ♦ Typically used for file-based playback, such as with DVD, or from computers

♦ Advantages
  ✈ Computer to computer friendly
  ✈ Flexibility with audio and video
  ✈ Less bandwidth overhead

♦ Dis-Advantages
  ✈ Re-synchronization of audio and video
  ✈ Hard to take out of the IP world and into the video world (ASI)
Video over IP

- Real-time Transport Protocol
  - Typically used for end-to-end multimedia applications like voice-over-IP or video teleconferencing
  - More tolerant of packet drops and jitter, but…
  - ….that requires end-to-end bi-directional links, or “handshakes”…. 
  - …which makes use of RTP for space links challenging
  - Also, most commercial decoders cannot recognize RTP streams
  - Best when used entirely within the computer domain, not a good candidate for use between computers and conventional video equipment
Link Integrity

- Encoded video creates a high bandwidth synchronous data stream, susceptible to packet loss and network jitter.
- Video is typically the largest data requirement for a spacecraft avionics system compared to telemetry, voice and other data streams.
- Therefore, video drives the link integrity requirements.
- MPEG-4 more susceptible to bit errors, packet loss and jitter problems than MPEG-2.
- Motion JPEG-2000 less susceptible because there is no interframe encoding.
Latency

- Compression creates latency
- Packetization of the data stream adds to that latency since the stream has to be de-packetized on the ground to get back to a signal that can be decoded
- Typically, the better the video quality, the longer the latency, since the encoder takes more time to analyze the incoming video for quality enhancement
- Real-time monitoring on spacecraft and the ground need to consider the latency vs. quality trade-off
  - Rendezvous
  - Interactive conversations
  - Time, voice and metadata synchronization with video
**Conclusion**

- Digital video provides many improvements but comes with new challenges
- Video as data allows for improved workflows and reusing data systems and avionics for routing of video
- Designers and System Engineers must consider impacts of compression, Video-over-IP options & trades, link integrity and latency on their video system
- End-to-end System Engineering is key!
  - Can’t treat digital video piece-meal and expect good results
  - The payoff can be some incredible imagery, useful for science, engineering, control center monitoring, and engaging the public