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