CCSDS: What’s New?

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• **Consultative Committee for Space Data Systems**
  – Key Members are the Major Space Agencies
  – Recommendations Span RF Links to Ground Transports
  – Related Areas for Ground Standards Include
    • Cross Support Services (SLE, Service Management)
    • Mission Operations and Information Management Services (MOIMS)
  – Recommendations can be Used Together or Separately

*James Afarin:*
CCSDS Secretariat and Chair, CCSDS Management Council
1981 – NASA and ESA met and formed a working group to address space data standards with particular interest in Packet Telemetry and Packet Telecommand

1982 – The CCSDS was officially formed

1991 – CCSDS joined the ISO Technical Committee 20, for Aircraft and Space Vehicles

2003 – CCSDS organized in the IETF Model with the following Working Group “Areas” of discipline

- Space Link Services
- Space Internetworking Services
- Spacecraft Onboard Interface Services
- Cross Support Services
- Mission Operations and Information Management Services
- System Engineering Services

2015 – CCSDS Runs out of “Space”

- Unified Space-Data Link Protocol
CCSDS Overview

- CCSDS Standards Span the Space and Ground Links
  - Define Telemetry & Command Formats
  - Define Ground Transport Protocols
  - Working on Control & Status Standards
CCSDS Benefits

- **Protocols Optimized for High-Latency, Error-Prone Links**
  - Command Structure
    - Frame and packets for complex payload
    - Onboard FEC decode with low processing power
  - Telemetry
    - Frame and packet structure for diverse payload functions and easy demux
    - Easy transition to IP on ground
    - Low spacecraft power requirement to encode data with strong FEC
      - RS, LDPC, Convolutional
    - Optimized file transport layer for on-board stored data transfer
    - Optimized IP packet encapsulation
    - COTS equipment for on-board and ground equipment
- **Standard Ground Protocol (SLE)**
  - Standard data encapsulation, timing, quality metrics, security, etc.
  - Standard commanding with scheduling, authentication, verification
Where do CCSDS Standards Apply?

Focus On The Data Formats

Focus On Key Interfaces Within The Architecture

Space Systems

Remote Ground Facility

Control Center

External User

RF/IF Equipment

Comm Equipment

Comm Equipment

TLM & CMD Front-Ends

TT&C Applications

Missions Applications

Missions Applications

RT Logic Proprietary as indicated on cover
CCSDDS Modeled After OSI

- Open Systems Interconnection (OSI)
- Utilize a Layered Approach
- Each Layer can be used Independently
- Each Layer Serves the Layer Above
• We will Touch on Many of these Through the Remainder of the Course

• We Encourage You to Learn More
Higher-Order, Variable, and Adaptive Modulations
Bit Mapping for Higher Order Modulation

(a) QPSK

(b) 8-PSK

(c) 16-APSK

(d) 32-APSK
6 Bits Per Symbol in 64 APSK

(e) 64-APSK
Variable and Adaptive Coded Modulations

• Variability in high-speed downlink conditions
  – Lower-rate coding, and lower-order modulations for challenged link
  – Higher-rate coding, and higher-order modulations for strong links

• Adaptive Coded Modulation
  – Measurement of computation of link quality
  – Feedback mechanism to vehicle to change rate and/or modulation
Variable and Adaptive Coded Modulations

- **VCM is a built-in feature of:**
- **VCM is not feature of**
- **Status of adaptive coded modulation (ACM):**
  - None of the three standards above specify an ACM protocol (although the term “ACM” is used in the Blue Books)
  - This is because these standards relate to downlink only. As such, they do not specify a protocol for estimating signal quality or feeding channel-state information back to the spacecraft for the purpose of selecting a new transmission mode.
  - The SCCC and DVB-S2 standards are compatible with ACM: the transmission modes may be modified and the slicer must be able to apply the change without losing Transfer Frames
• New Generation of Digital Video Broadcast coding
• Developed 2003 and ratified 2005

• A powerful coding scheme based on a modern LDPC code. For low encoding complexity, the LDPC codes chosen have a special structure, also known as Irregular Repeat-Accumulate codes.

• BCH Outer code for AWGN – simple decode

• Supports higher order modulations (e.g. 32APSK), IP transport, MPEG4

• VCM (Variable Coding and Modulation) and ACM (Adaptive Coding and Modulation) modes, which allow optimizing bandwidth utilization by dynamically changing transmission parameters.

• CCSDS Blue Book 131.3-B-1
## Telemetry Code Performance

<table>
<thead>
<tr>
<th>Code Type</th>
<th>Required Eb/No (dB) for 10E-05 BER</th>
</tr>
</thead>
<tbody>
<tr>
<td>PSK – No coding</td>
<td>9.6</td>
</tr>
<tr>
<td>Reed Solomon (255/223)</td>
<td>6</td>
</tr>
<tr>
<td>Conv. (R1/2,K=7)</td>
<td>4.1</td>
</tr>
<tr>
<td>RS + Conv</td>
<td>3.8</td>
</tr>
<tr>
<td>RS + Conv Interleaved</td>
<td>2.2</td>
</tr>
<tr>
<td>LDPC (8160/7136)</td>
<td>~0</td>
</tr>
</tbody>
</table>
Exclusive Internet Layer

- CCSDS Recommends IPE as the preferred (i.e., only) means for sending internet (IPv4/IPv6) packets over a CCSDS space link

IPE Packet

- Header identifying type of IP Packet in the payload
- Header based on a Cisco standard that supports header compression

<table>
<thead>
<tr>
<th>IPE Header Value</th>
<th>Protocol Encapsulated</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>IPv4 datagram</td>
</tr>
<tr>
<td>35</td>
<td>Frame Relay IP Header Compression Control Protocol (NOTE 1)</td>
</tr>
<tr>
<td>87</td>
<td>IPv6 datagram</td>
</tr>
<tr>
<td>97</td>
<td>FULL_HEADER</td>
</tr>
<tr>
<td>99</td>
<td>COMPRESSED_TCP</td>
</tr>
<tr>
<td>101</td>
<td>COMPRESSED_TCP_NO_DELTA</td>
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<tr>
<td>103</td>
<td>COMPRESSED_NON_TCP</td>
</tr>
<tr>
<td>105</td>
<td>COMPRESSED_RTP_8</td>
</tr>
<tr>
<td>107</td>
<td>COMPRESSED_RTP_16</td>
</tr>
<tr>
<td>109</td>
<td>COMPRESSED_UDP_8</td>
</tr>
<tr>
<td>111</td>
<td>COMPRESSED_UDP_16</td>
</tr>
<tr>
<td>113</td>
<td>CONTEXT_STATE</td>
</tr>
</tbody>
</table>
**IP Encapsulation with CCSDS**

- **ENCAP Header**
  - **Ver = 111**
  - **PID**
    - 000 = fill
    - 001 = IPv4 packets (removed)
    - 100 = IPE (IP Encapsulation) Packet
    - 011 = CFDP PDU
    - 111 = Arbitrary aggregation of bits
  - **Length of Length**
    - 00 = Single byte fill
    - 01 = 1 octet
    - 10 = 2 octets
    - 11 = 4 octets
  - **Length**

- **IPE Packet**
  - **IPE header multiplexes**
    - **IPv4 Uncompressed**
    - **IPv6 Uncompressed**
    - **Other header compression codes**
Transport Layer

- **Security**
- **Networking (Commercial)**
- **DTN**
IP Transport Protocols

- **UDP**
  - Constant data streaming
  - No acknowledgement required
  - No error control
  - Suitable for streaming voice and video (un-compressed), where timing is more critical than noise or dropout

- **TCP**
  - Guaranteed delivery and packet ordering
  - Acknowledgement required to advance the data window. When the data window is full, data flow stops
  - Susceptible to slow throughput due to high latency and errors in transmission
  - Multiple clients increase bandwidth and memory usage
Delay Tolerant Data Transport

• **SCPS-TP**
  - Point-to-point data transport
  - Continuous data streaming
  - Selective Negative Acknowledgement (SNAK)
  - Buffering to re-transmit only specific lost packet(s)
  - Packet re-ordering

• **Licklider Transmission Protocol (LTP) – CCSDS 734.1-R-2**
  - Based on RFC 5326
  - Provides reliable, single-hop transport over a non-reliable data links.
    - Uses proven concepts developed for CFDP, but implemented at the transport layer
  - CCSDS LTP PDUs are currently perceived to be delivered using either Space Packets or Encapsulation Packets

• **Bundle Protocol (BP) – CCSDS 734.1-R-2**
  - Based on RFC 5050
  - Sits just above Transport Layer (e.g., LTP)
  - Defines end-to-end, multi-hop (store-and-forward) transfer of application-addressed messages between ‘Bundle Nodes’
  - Intended to be used with LTP to create a Delay Tolerant Network (DTN)
Bundle Protocol

- Bundle Protocol (BP) sits above the Transport layer (e.g., LTP) and provides...
  - End-to-end, multi-hop, store-and-forward operation.
  - Application addressing using Uniform Resource Identifiers (URIs)
• [www.ccsds.org](http://www.ccsds.org) for all your needs!