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CCSDS: What's New?

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CCSDS Overview

- **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

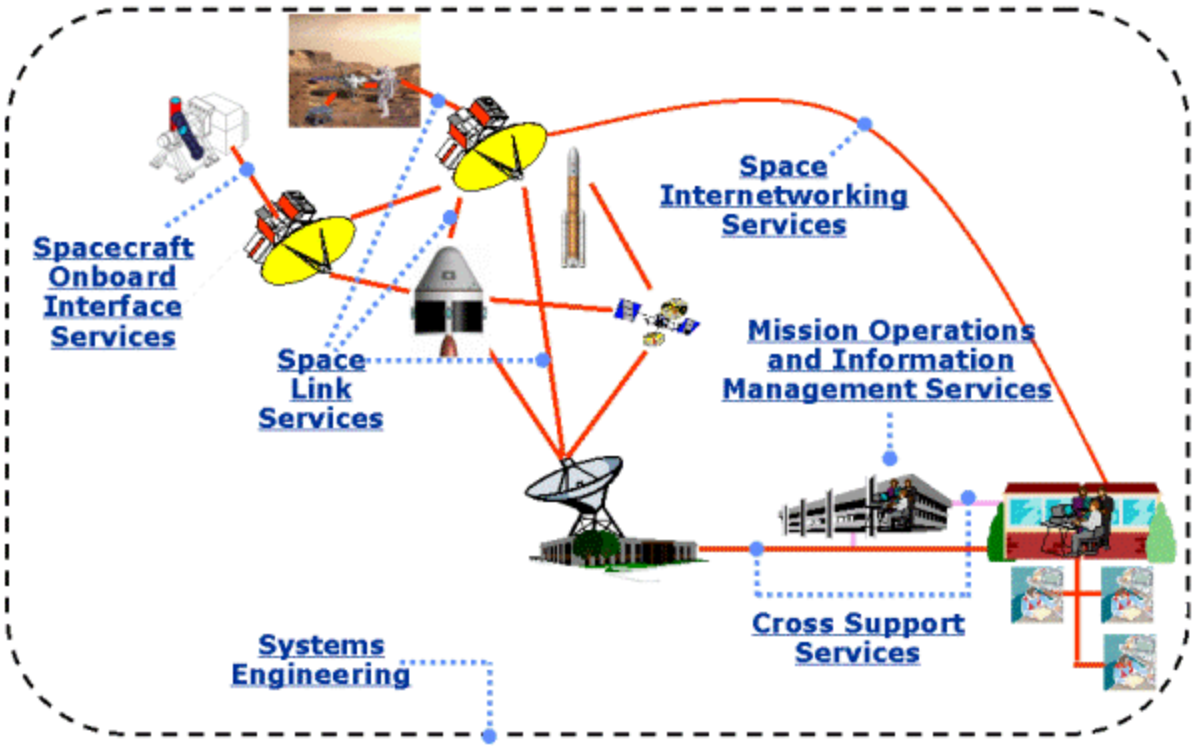
James Afarin:
CCSDS Secretariat and
Chair, CCSDS Management
Council

CCSDS History

- **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

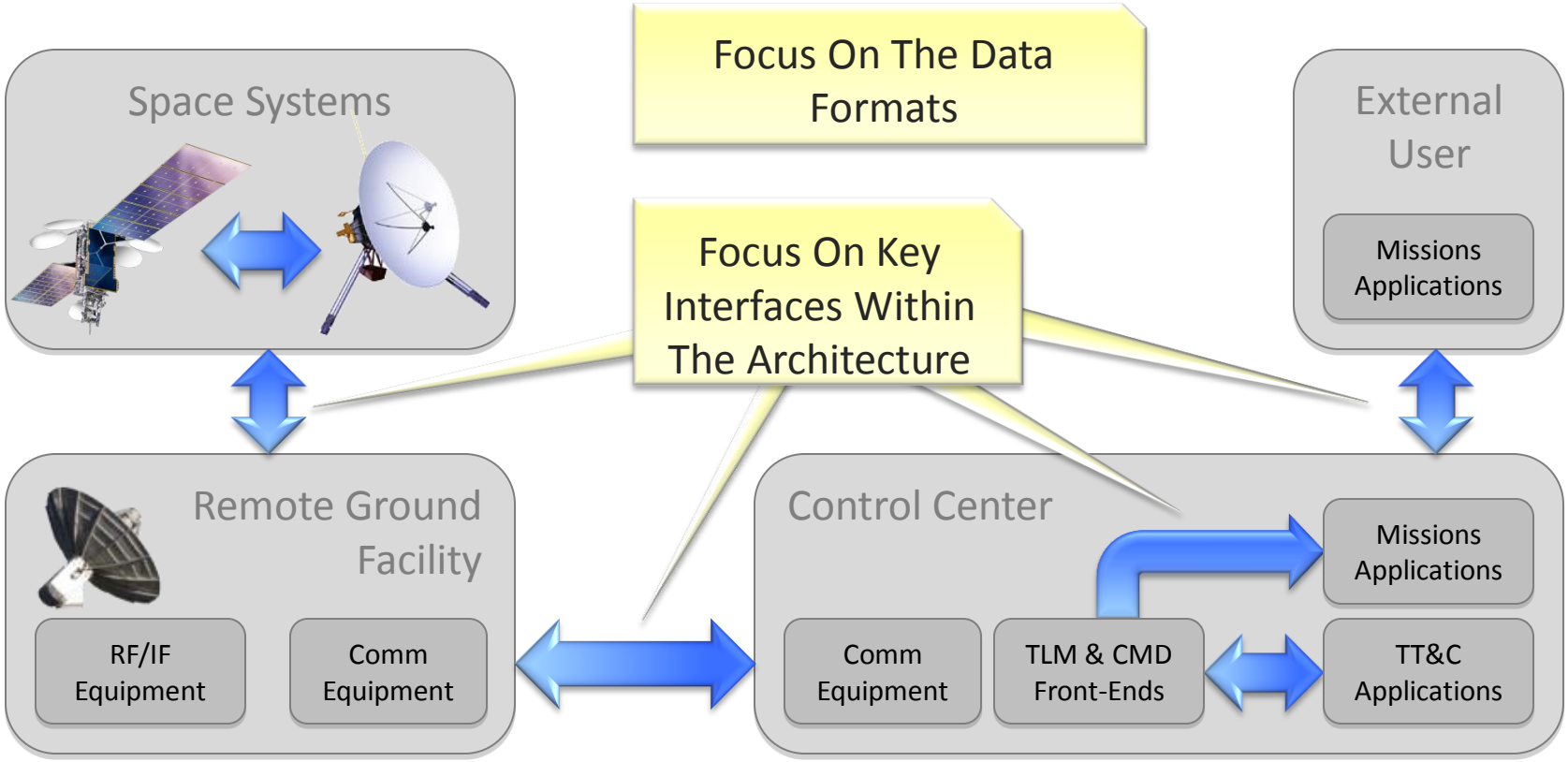
- **CCSDS Standards Span the Space and Ground Links**
  - Define Telemetry & Command Formats
  - Define Ground Transport Protocols
  - Working on Control & Status Standards



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

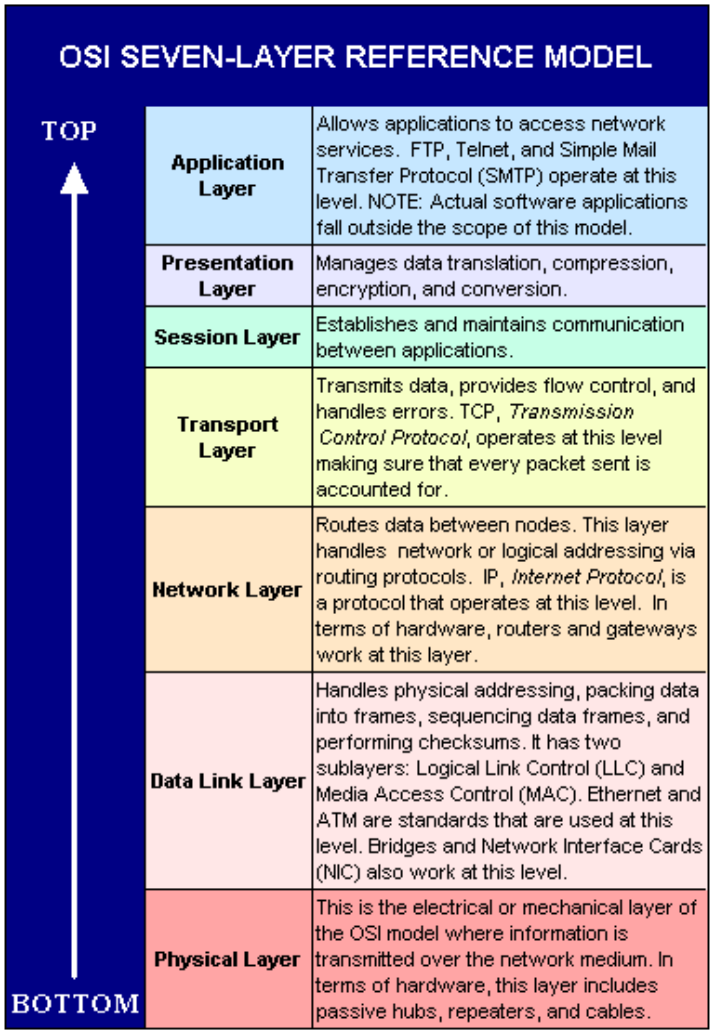
Where do CCSDS Standards Apply?



The OSI Stack

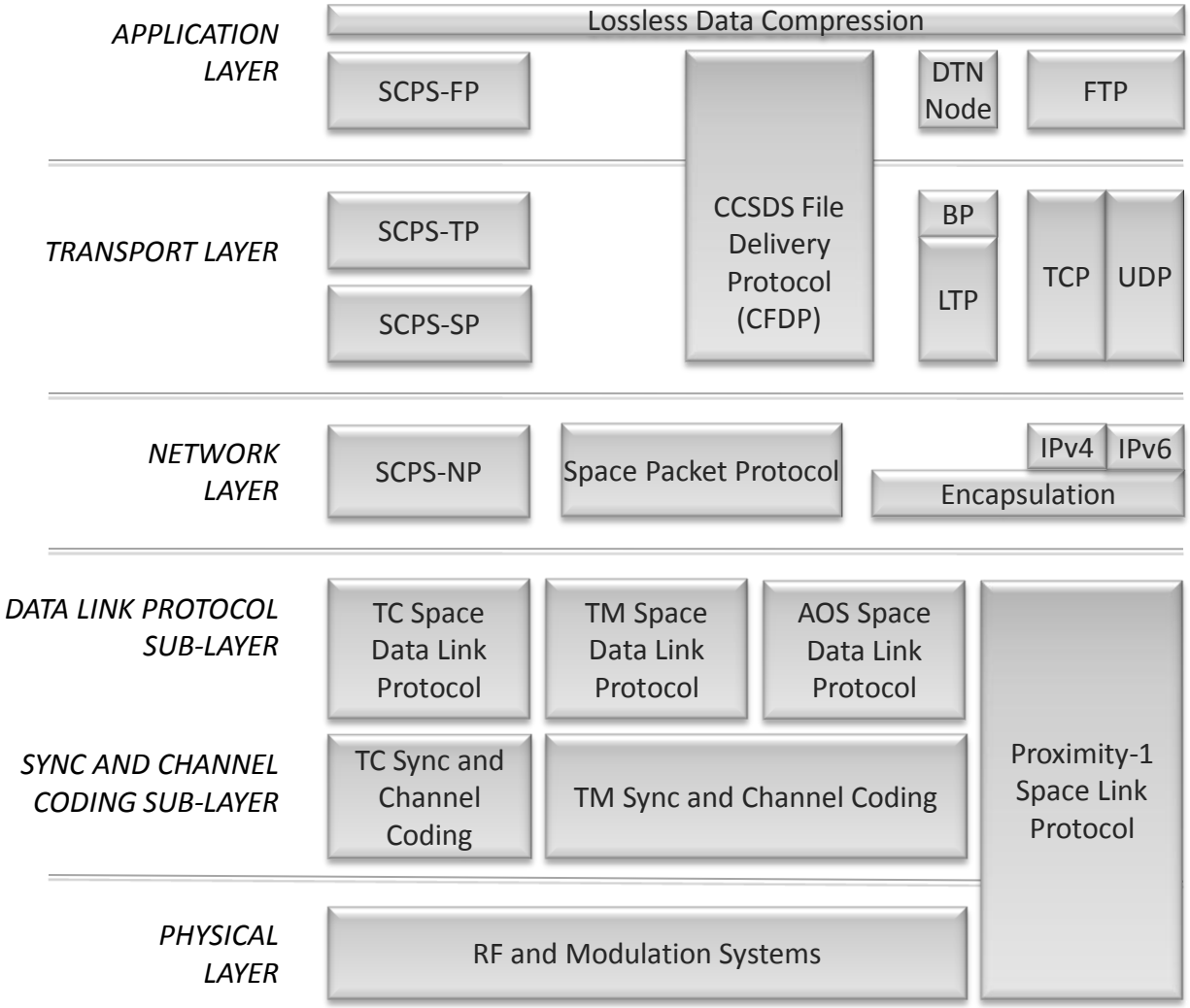
CCSDS Modeled After OSI

- Open Systems Interconnection (OSI)
- Utilize a Layered Approach
- Each Layer can be used Independently
- Each Layer Serves the Layer Above



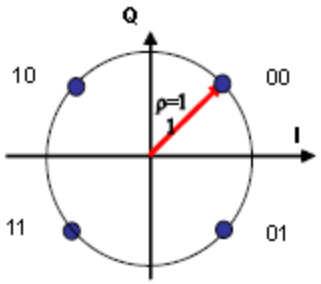
The CCSDS Stack

- **We will Touch on Many of these Through the Remainder of the Course**
- **We Encourage You to Learn More**

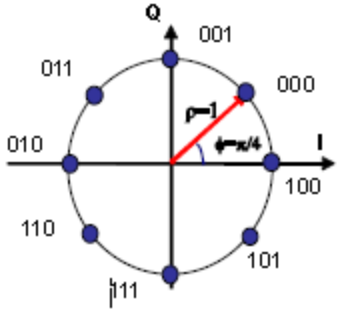


Higher-Order, Variable, and Adaptive Modulations

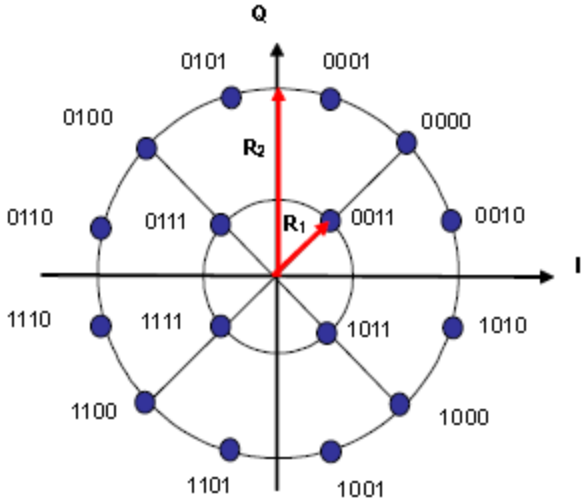
Bit Mapping for Higher Order Modulation



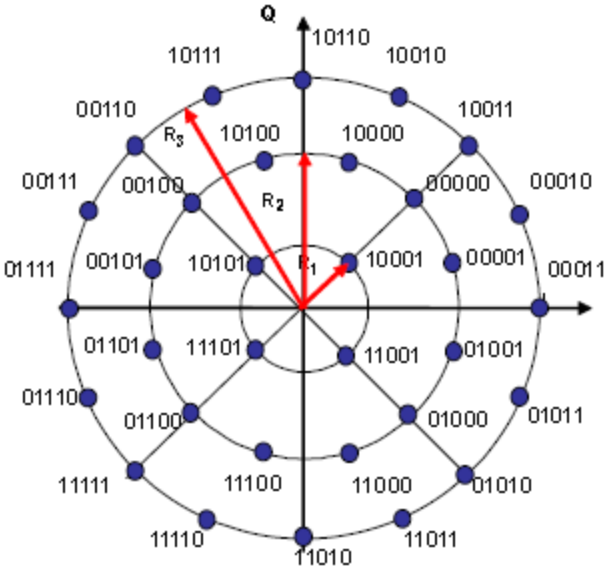
(a) QPSK



(b) 8-PSK

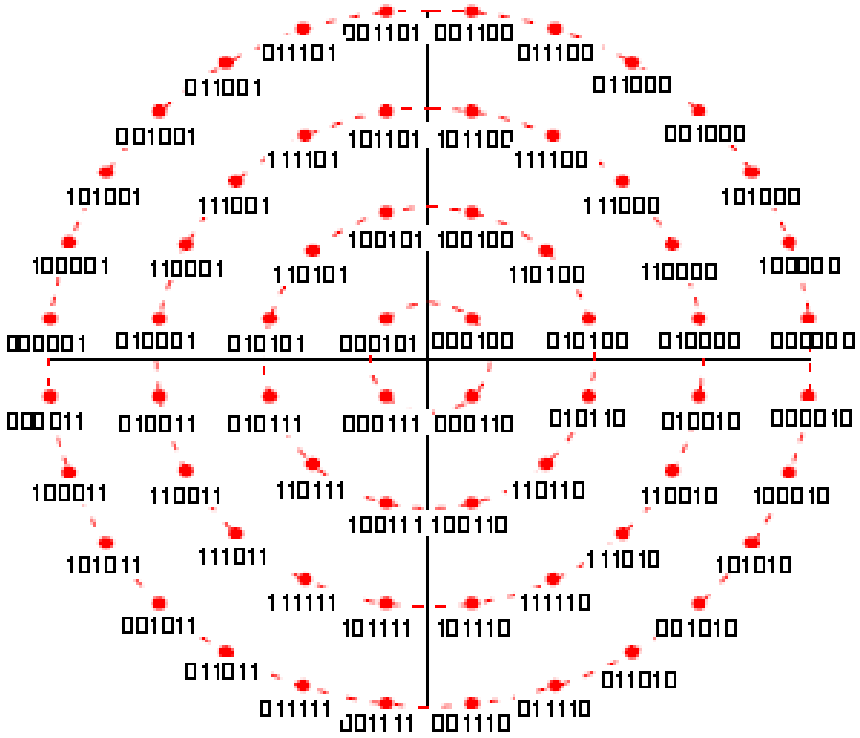


(c) 16-APSK



(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:
  - SCCC codes in CCSDS 131.2-B-1, "Flexible Advanced Coding and Modulation Scheme for High Rate Telemetry Applications," Blue Book. Issue 1. March 2012.
  - BCH+LDC codes in CCSDS 131.3-B-1, "CCSDS Space Link Protocols over ETSI DVB-S2 Standard," Blue Book. Issue 1. March 2013.
- VCM is not feature of
  - Convolutional, RS, concatenated, turbo, and AR4JA/C2 LDPC codes in CCSDS 131.0-B-2, "TM Synchronization and Channel Coding," Blue book. Issue 2. August 2011.
- 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

DVB-S2

- **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.

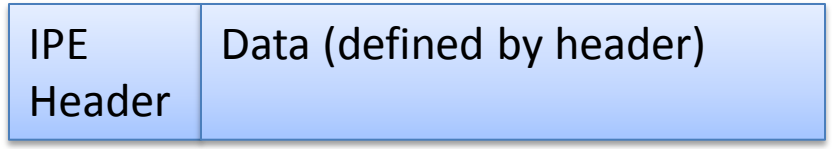
- CCSDS Blue Book 131.3-B-1

Telemetry Code Performance

Code Type	Required Eb/No (dB) for 10E-05 BER
PSK – No coding	9.6
Reed Solomon (255/223)	6
Conv. (R1/2,K=7)	4.1
RS + Conv	3.8
RS + Conv Interleaved	2.2
LDPC (8160/7136)	~0

IP Encapsulation (IPE) Packet

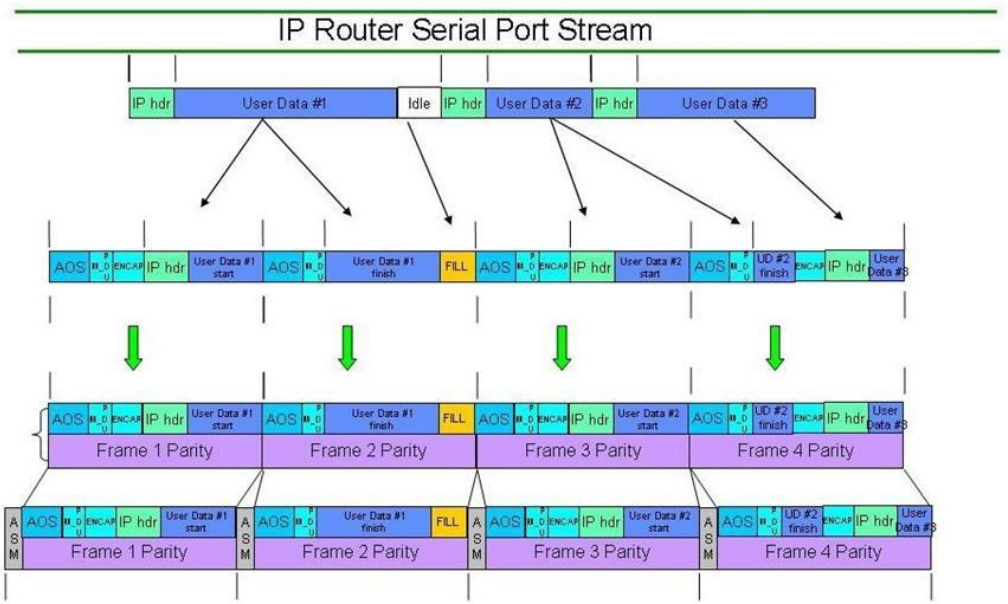
- **Exclusive Internet Layer**
  - CCSDS Recommends IPE as the preferred (i.e., only) means for sending internet (IPv4/IPv6) packets over a CCSDS space link
- **IPE Packet**
  - Header identifying type of IP Packet in the payload
  - Header based on a Cisco standard that supports header compression



IPE Header Value	Protocol Encapsulated
33	IPv4 datagram
35	Frame Relay IP Header Compression Control Protocol (NOTE 1)
87	IPv6 datagram
97	FULL_HEADER
99	COMPRESSED_TCP
101	COMPRESSED_TCP_NO_DELTA
103	COMPRESSED_NON_TCP
105	COMPRESSED_RTP_8
107	COMPRESSED_RTP_16
109	COMPRESSED_UDP_8
111	COMPRESSED_UDP_16
113	CONTEXT_STATE

IP Encapsulation with CCSDS

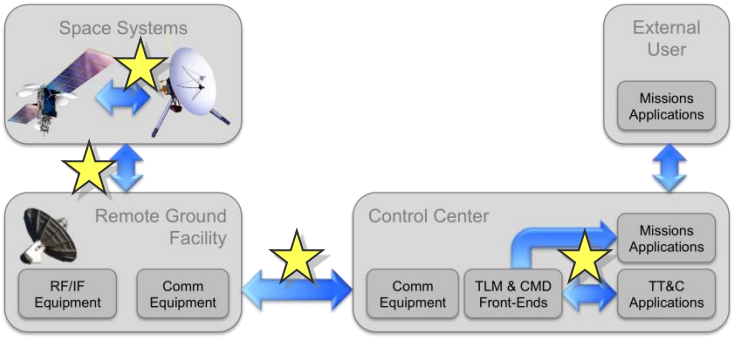
- **ENCAP Header**
  - **Ver = 111**
  - **PID**
    - 000 = fill
    - 001 = IPv4 packets (removed)
    - 100 = IPE (IP Encapsulation) Packet
    - 011 = CFDP PDU
    - 111 = Arbitrary aggregation of bits
  - **Length of Length**
    - 00 = Single byte fill
    - 01 = 1 octet
    - 10 = 2 octets
    - 11 = 4 octets
  - **Length**
- **IPE Packet**
  - **IPE header multiplexes**
    - **IPv4 Uncompressed**
    - **IPv6 Uncompressed**
    - **Other header compression codes**

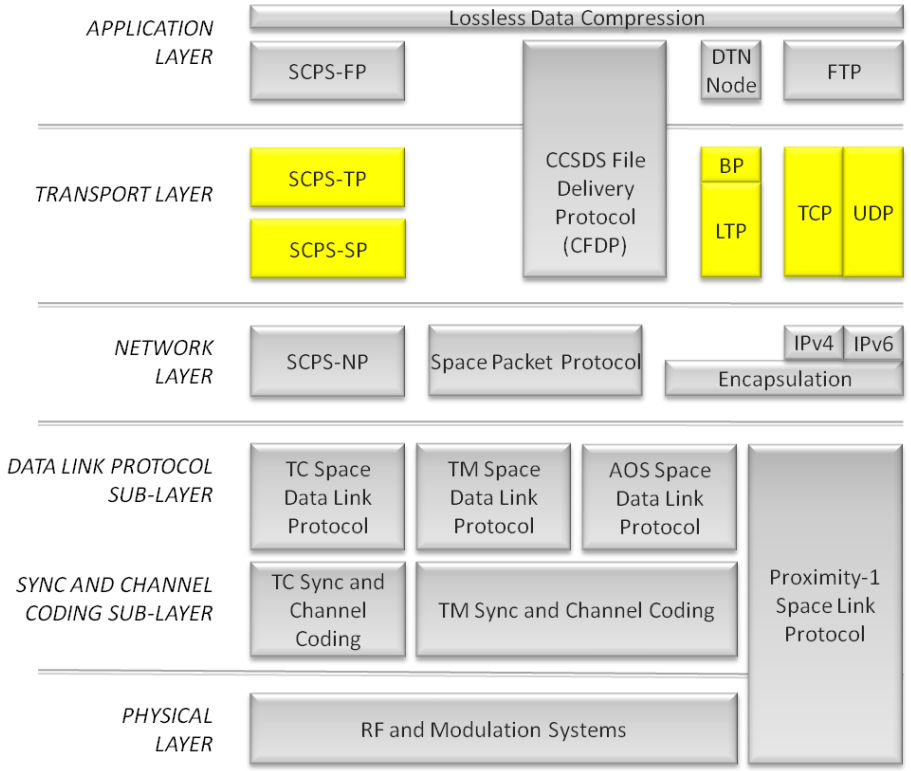


Transport Layer

Transport Layer

- **Security**
- **Networking (Commercial)**
- **DTN**





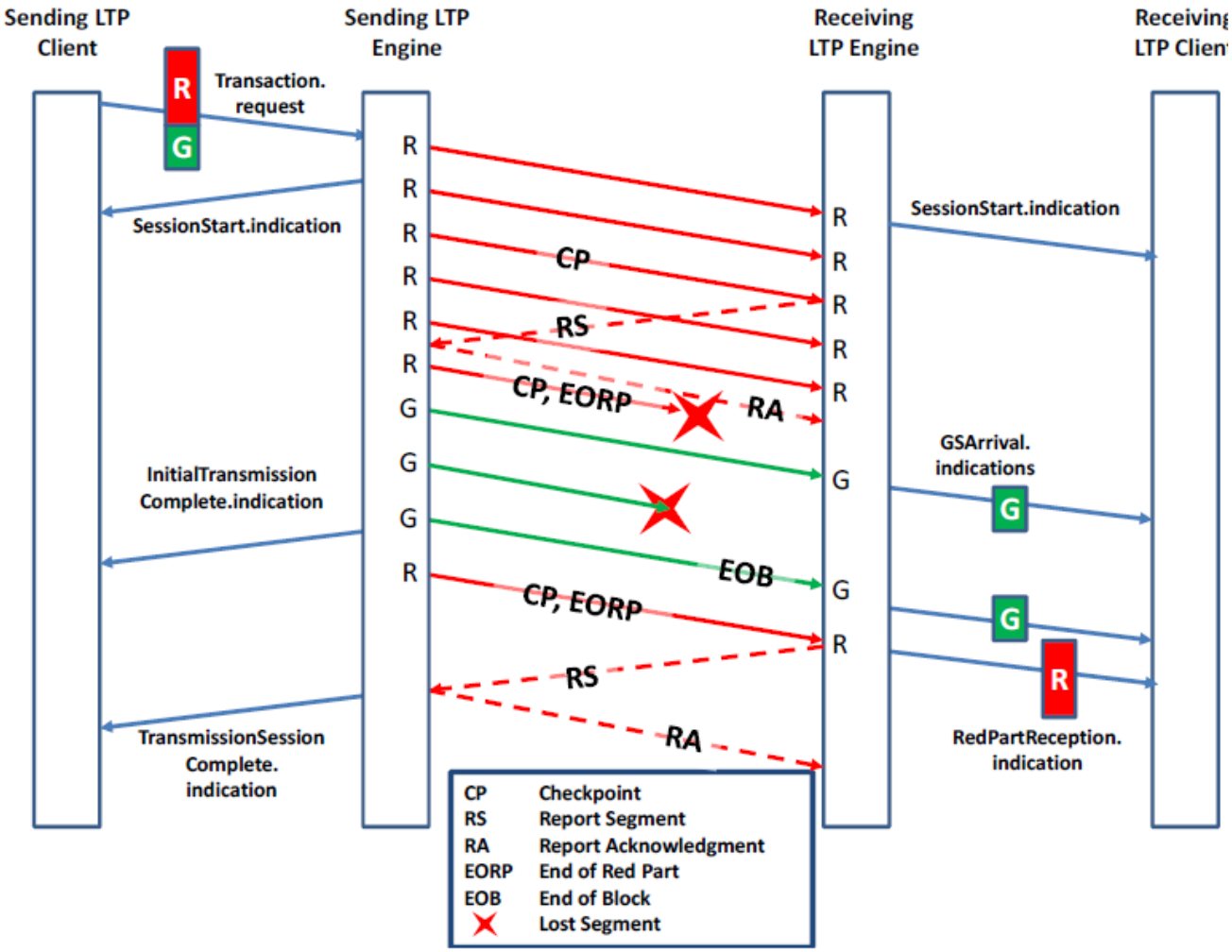
IP Transport Protocols

- **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

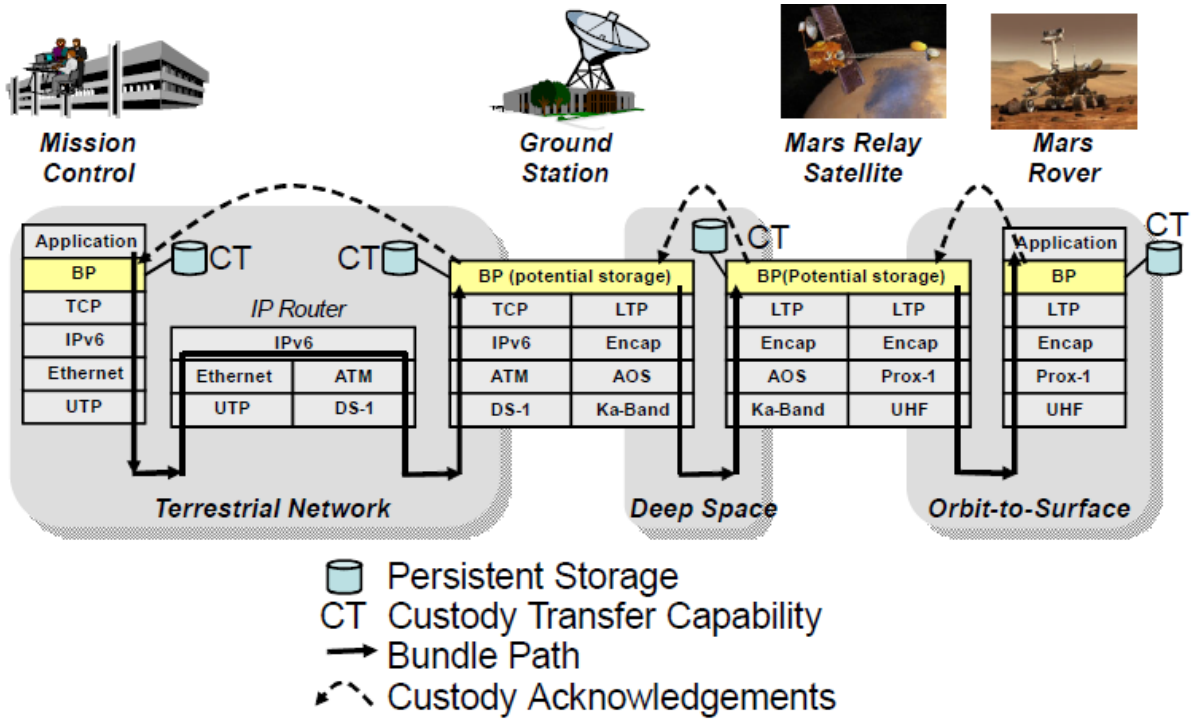
- **SCPS-TP**
  - Point-to-point data transport
  - Continuous data streaming
  - Selective Negative Acknowledgement (SNAK)
  - Buffering to re-transmit only specific lost packet(s)
  - Packet re-ordering
- **Licklider Transmission Protocol (LTP) – CCSDS 734.1-R-2**
  - Based on RFC 5326
  - Provides 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)

LTP Delivery Diagram



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)



References:

- www.ccsds.org for all your needs!