SONET Technology Primer

by
Gary Nicholl
gnicholl@cisco.com

Gary Nicholl
613-271-3535

Agenda

- SONET Introduction
- SONET Framing and Signaling
- SONET Multiplexing
- SONET Overhead
- SONET OAM
- Summary

Introduction - What is SONET ?

- **SONET - Synchronous Optical NETwork (ANSI)**
- **SDH - Synchronous Digital Hierarchy (ITU)**
- **Set of physical layer standards for communication over fiber optic (and electrical) links.**

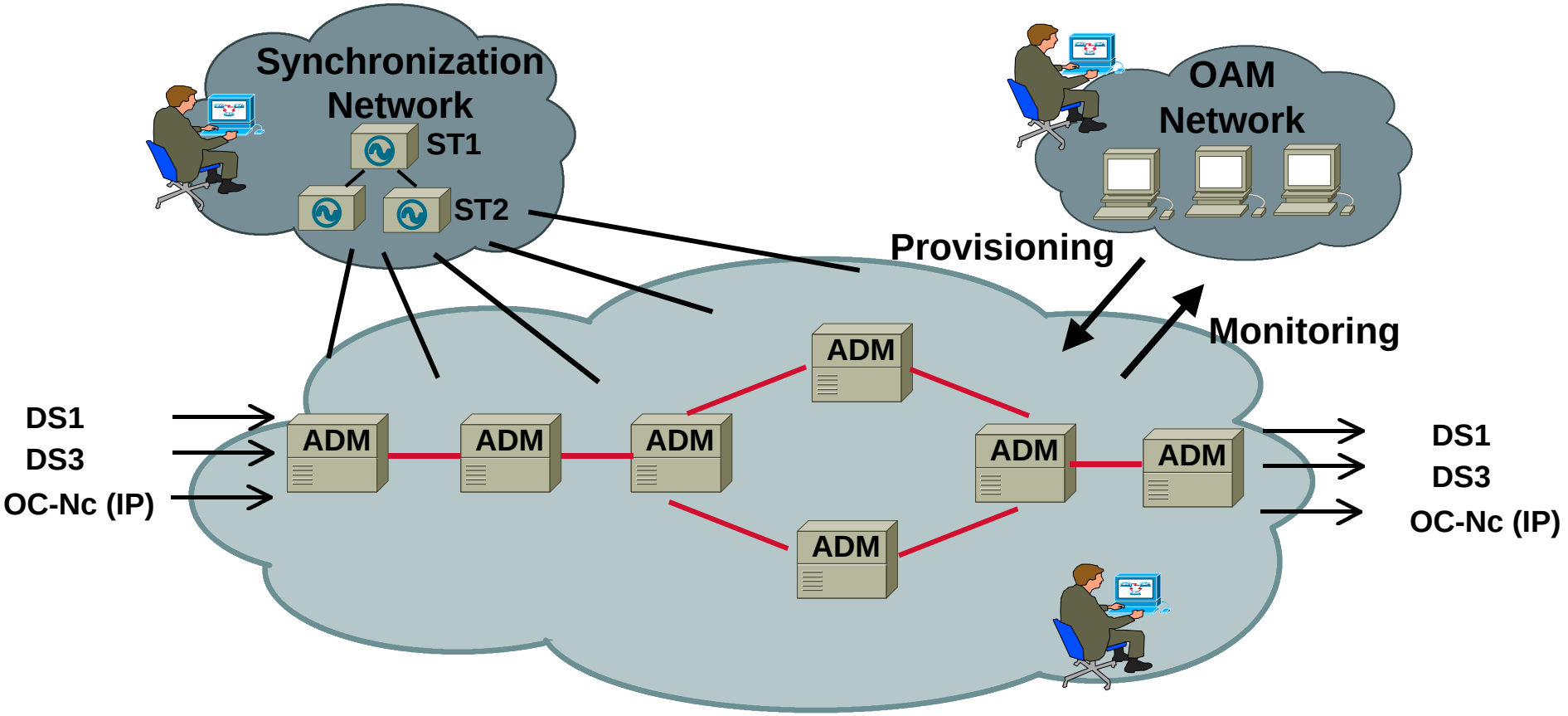
Note: The material in this presentation is applicable to both SONET and SDH, but for simplicity only SONET terminology is used.

What does SONET Provide ?

- **TDM multiplexing onto high capacity fiber systems.**
- **Standard bit rate, frame format, optical specifications to ensure multi-vendor interoperability.**
- **Fast restoration (50ms) schemes for both linear (pt-pt) and ring topologies.**
- **Operations, Administration, Maintenance & Provisioning (OAM&P)**

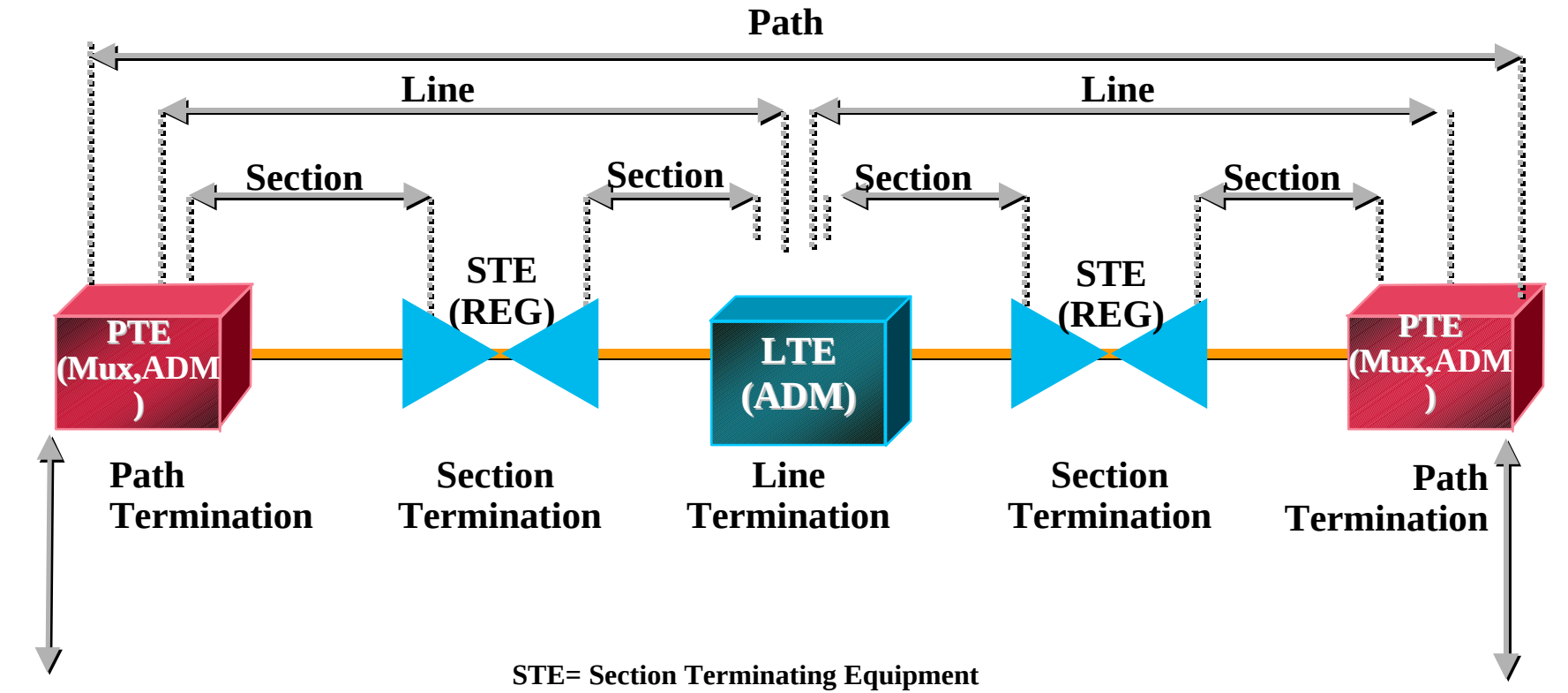
  - provision connections
  - performance monitoring
  - detect/isolate failures

SONET Network Overview



- SONET Transport Network
- Synchronization Network
- OAM&P Network

SONET Terminology

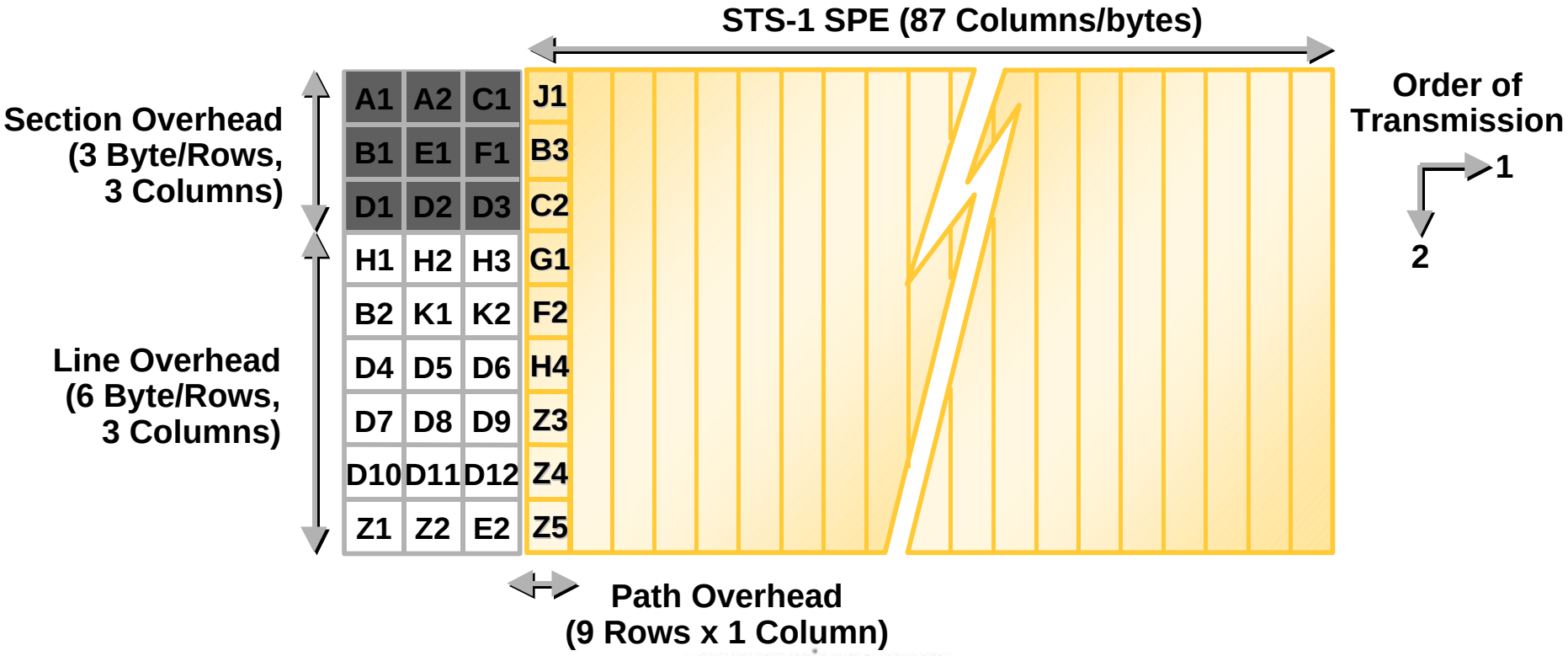


Signal Hierarchy and Line Rates

Synchronous Transport Signal	Line Rate Mbits/s	Optical Carrier
STS-1	51.84	OC-1
STS-3	155.52	OC-3
STS-12	622.08	OC-12
STS-48	2488.32	OC-48
STS-192	9953.28	OC-192

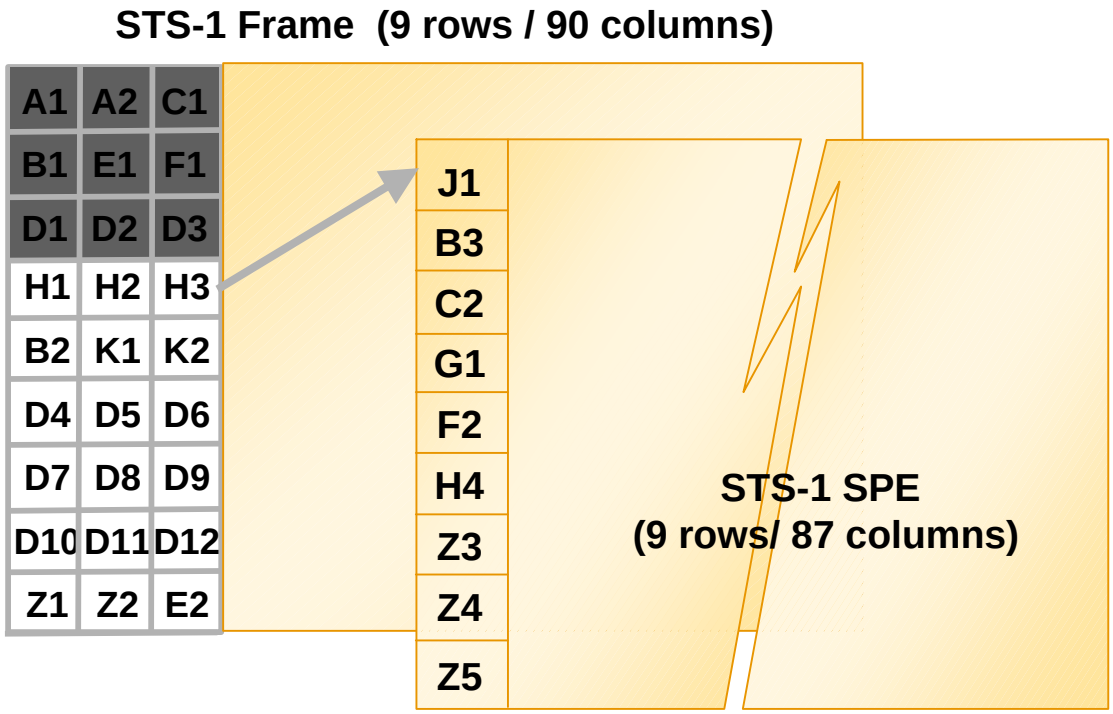
STS-1 Frame Format

- 9 rows x 90 columns
- Top row first, transmitted from from left to right
- 125 us frame
- 810 bytes / frame
- 51.84 Mb/s data rate (810 x 64 kb/s)



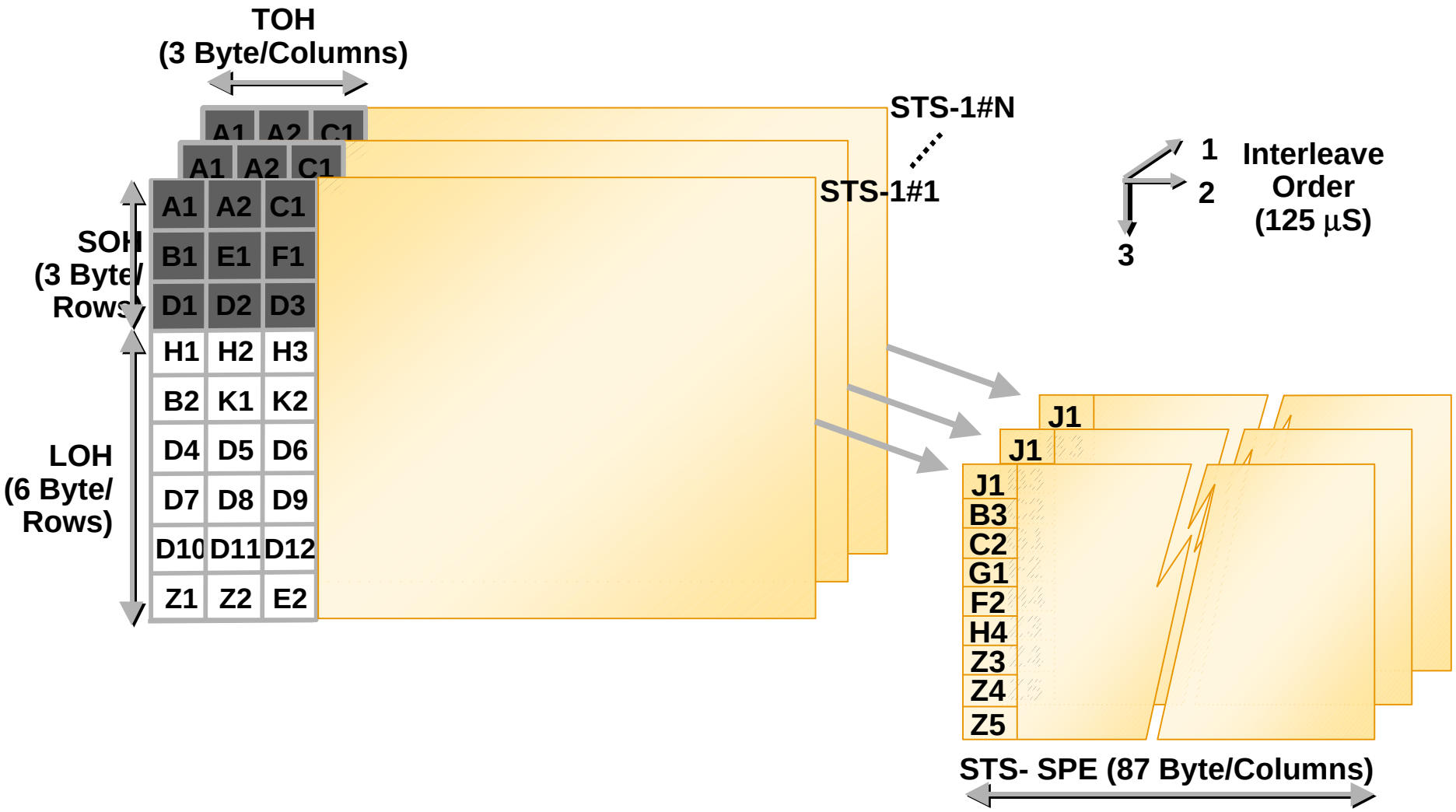
STS-1 Synchronization & Pointers

- STS-1 SPE ‘floats’ within STS-1 Frame
- Start of SPE (J1) indicated by pointer bytes (H1/H2)
- Accounts for difference between STS-1 SPE and STS-1 Frame rates
- Can tolerate up to 300ppm offset (1 pointer adjustment/4 frames)

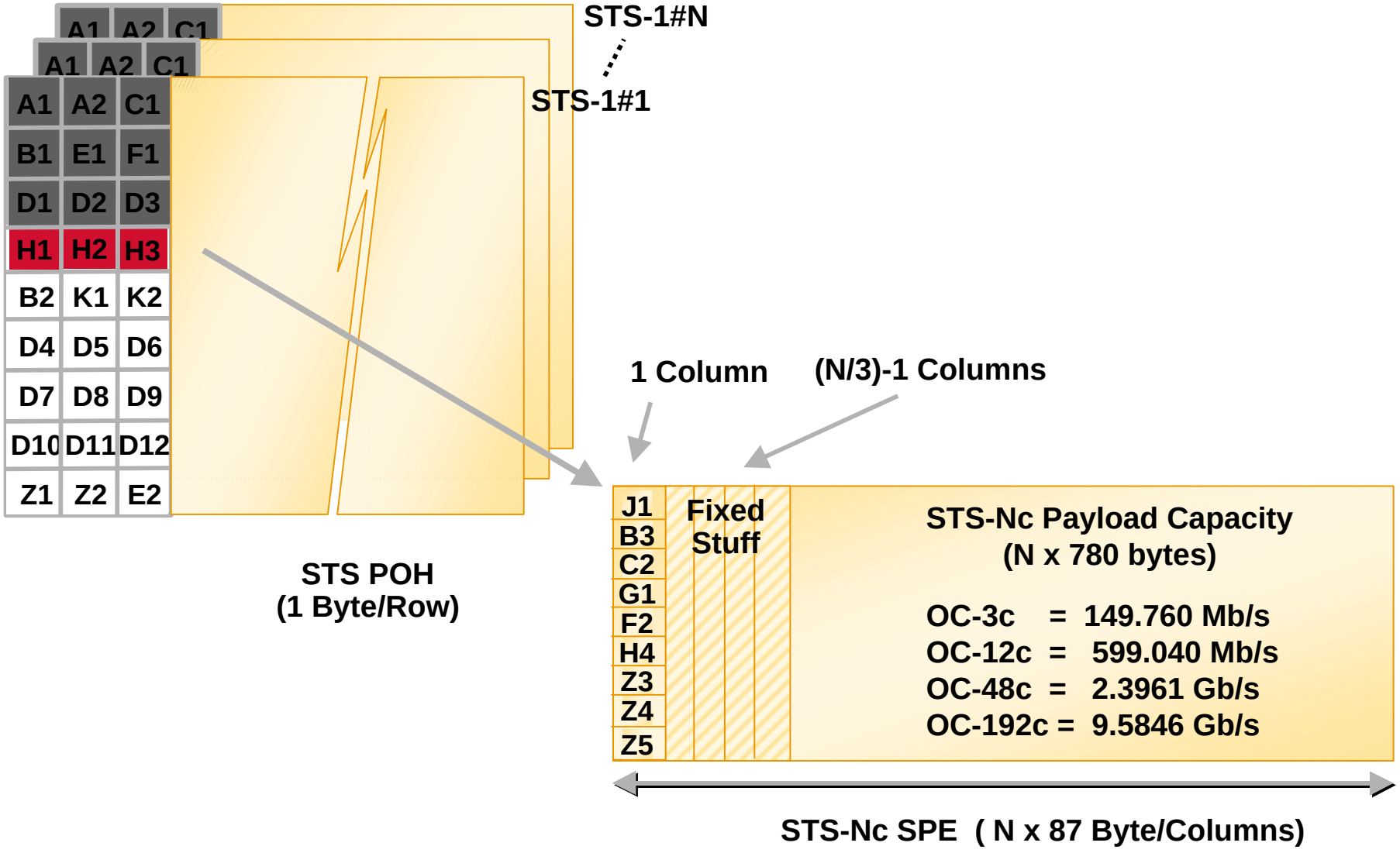


STS-N Frame Format

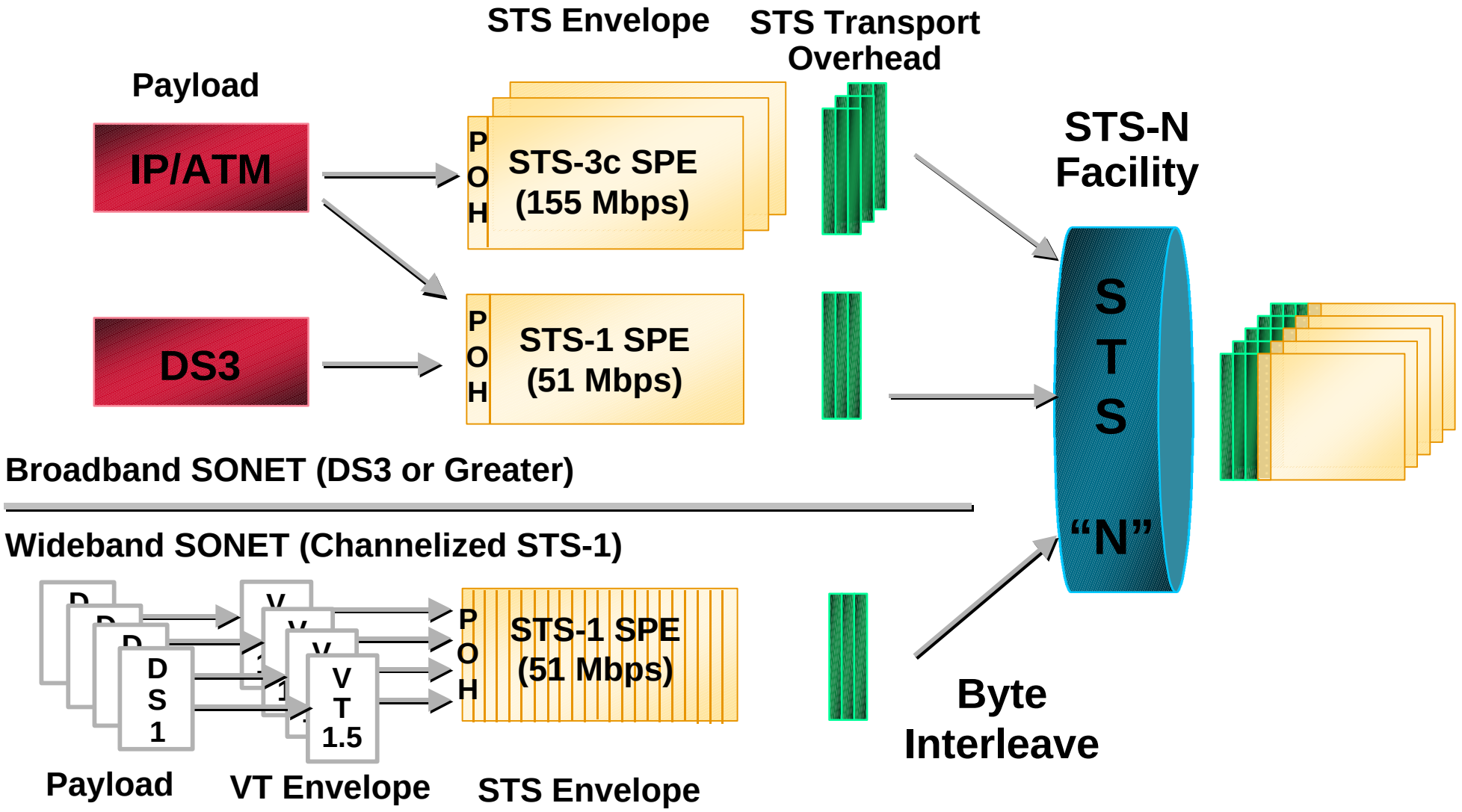
- **STS-N = N x byte interleaved STS-1s**



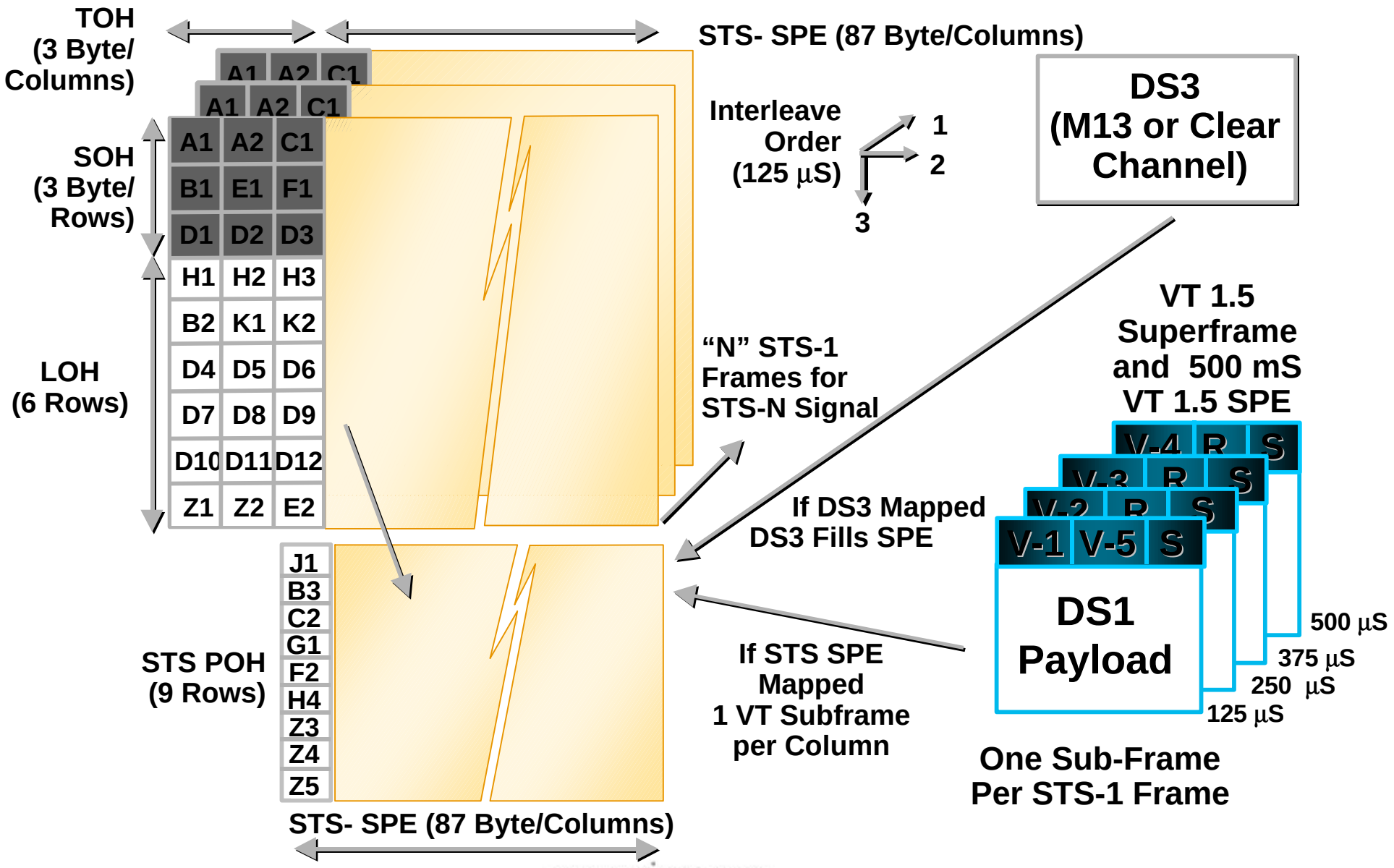
SONET Concatenation (STS-Nc)



SONET Multiplexing

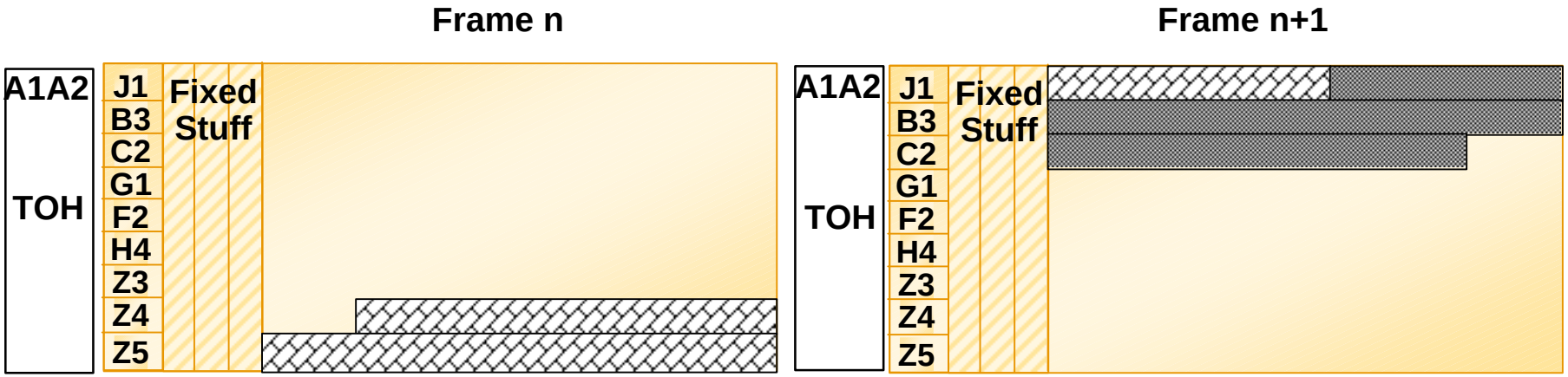


More SONET Multiplexing

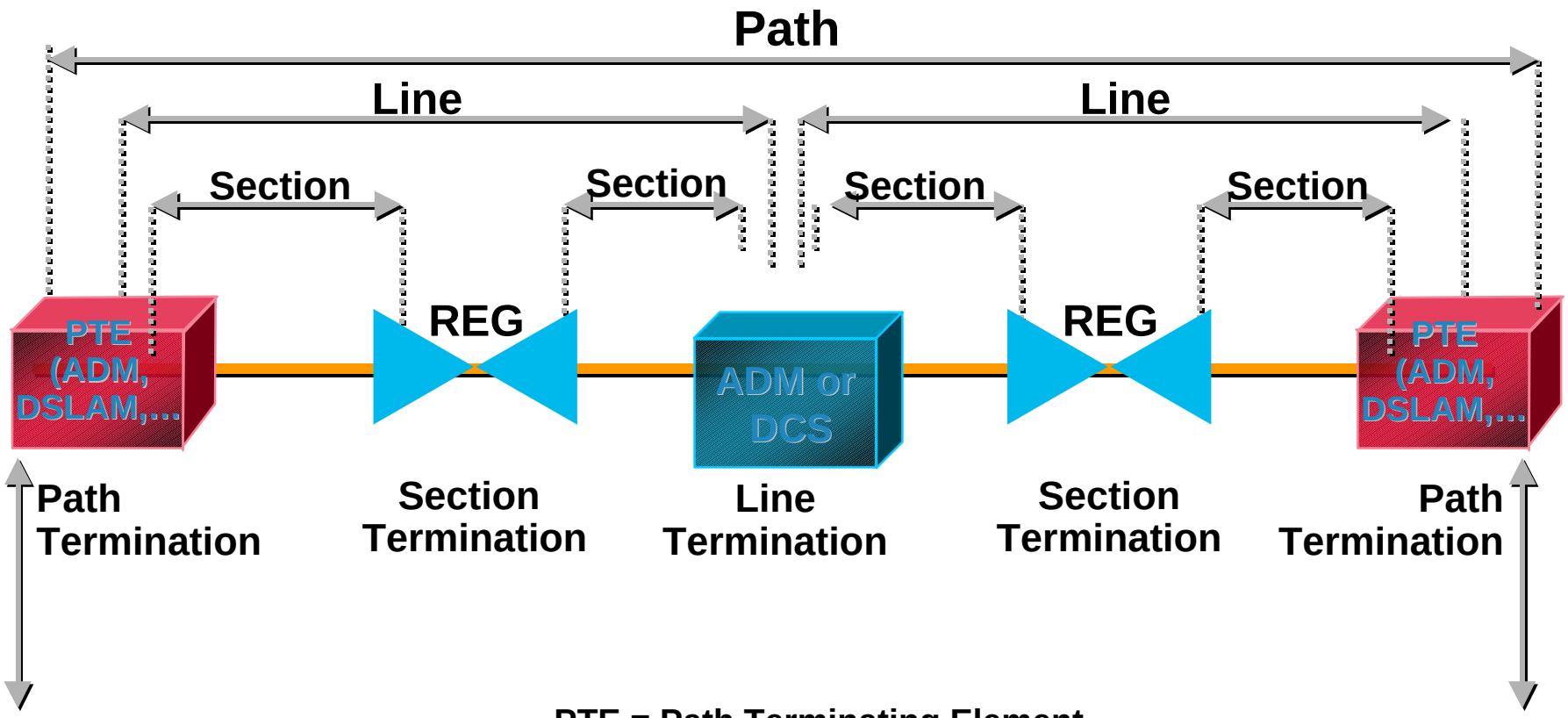


IP/ATM Mapping into SONET

- IP packets and ATM cells are mapped into SONET today !
- Packet/Cell octets aligned with SONET byte boundaries
- Cell/Packet boundaries can cross SONET STS-N frame boundaries



SONET Overhead Layers

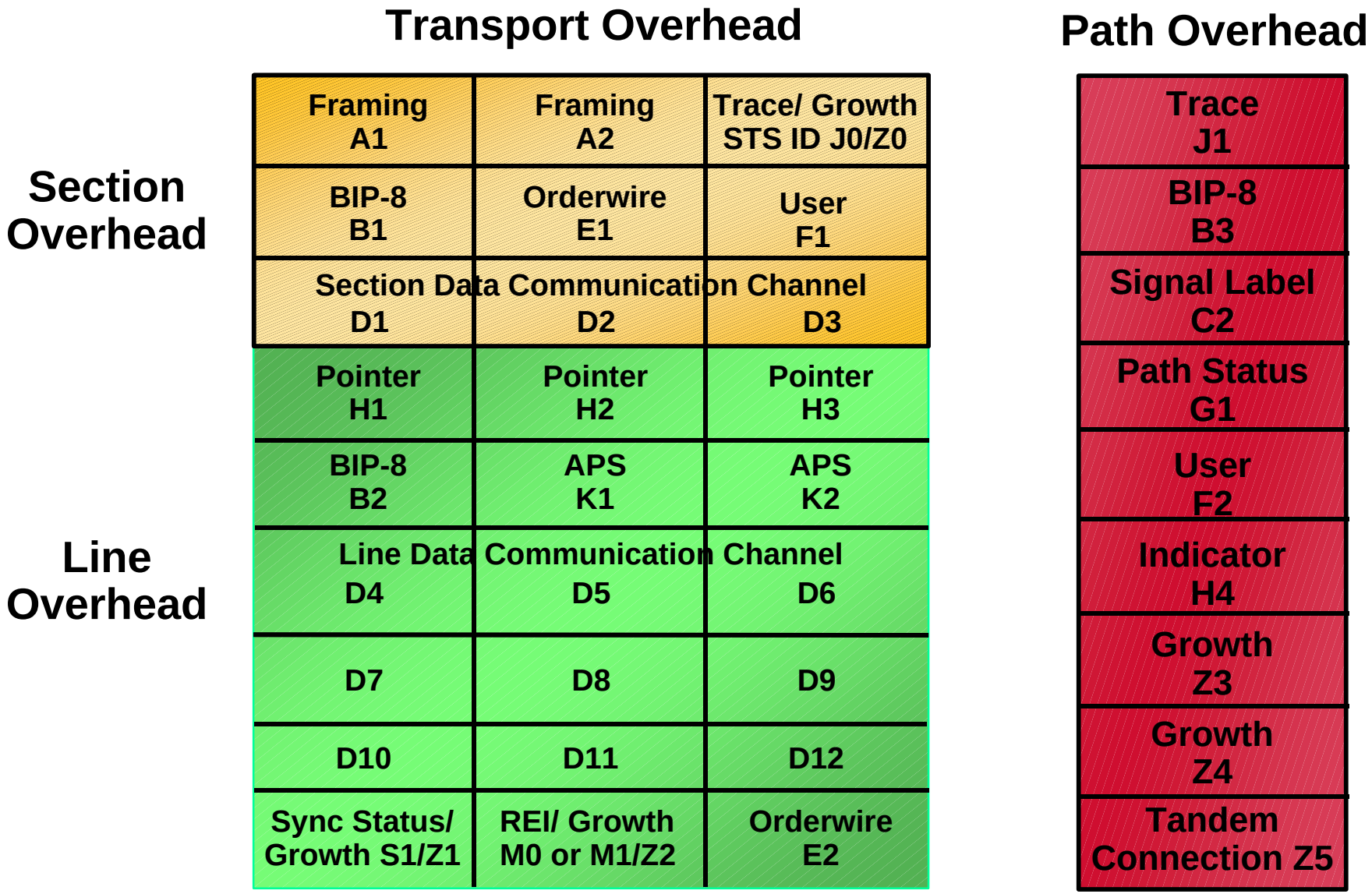


Service (DS1, DS3…)
Mapping
Demapping

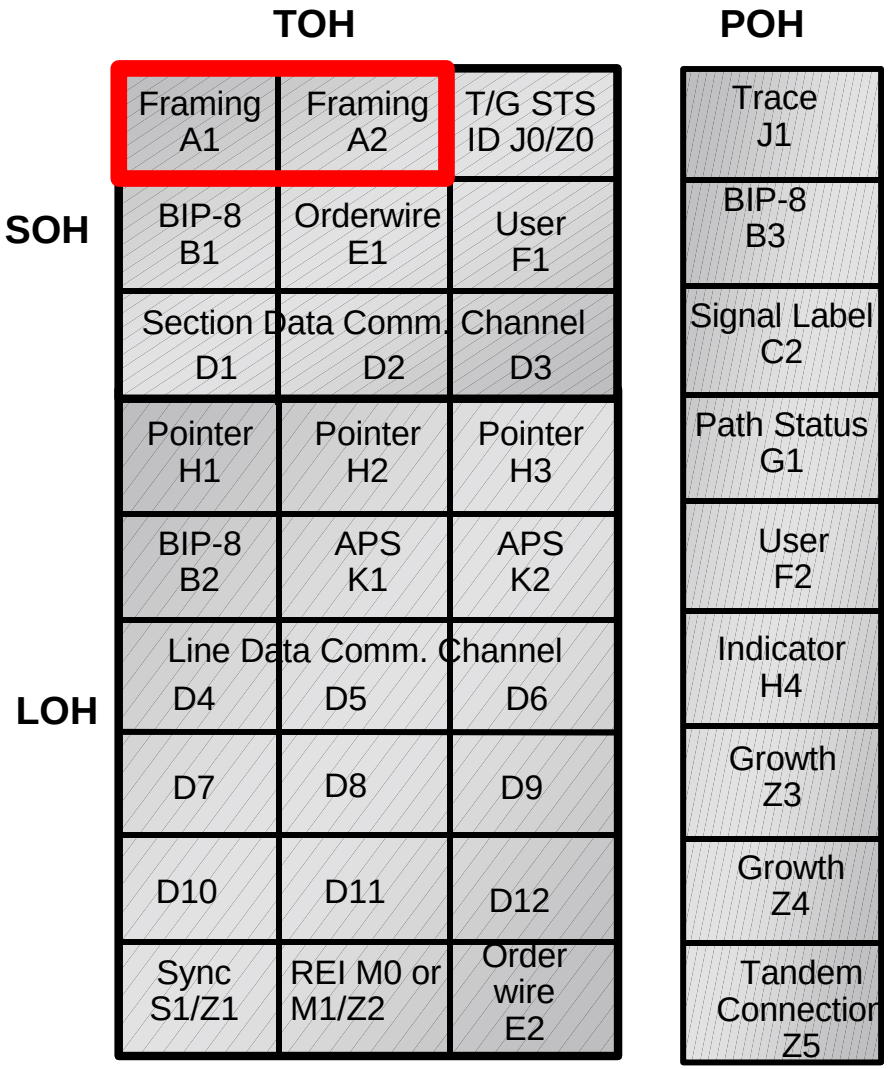
PTE = Path Terminating Element
MUX = Terminal Multiplexer
REG = Regenerator
ADM = Add/Drop Multiplexer
DCS = Digital Cross-Connect System

Service (DS1, DS3…)
Mapping
Demapping

SONET Overhead Byte Designations

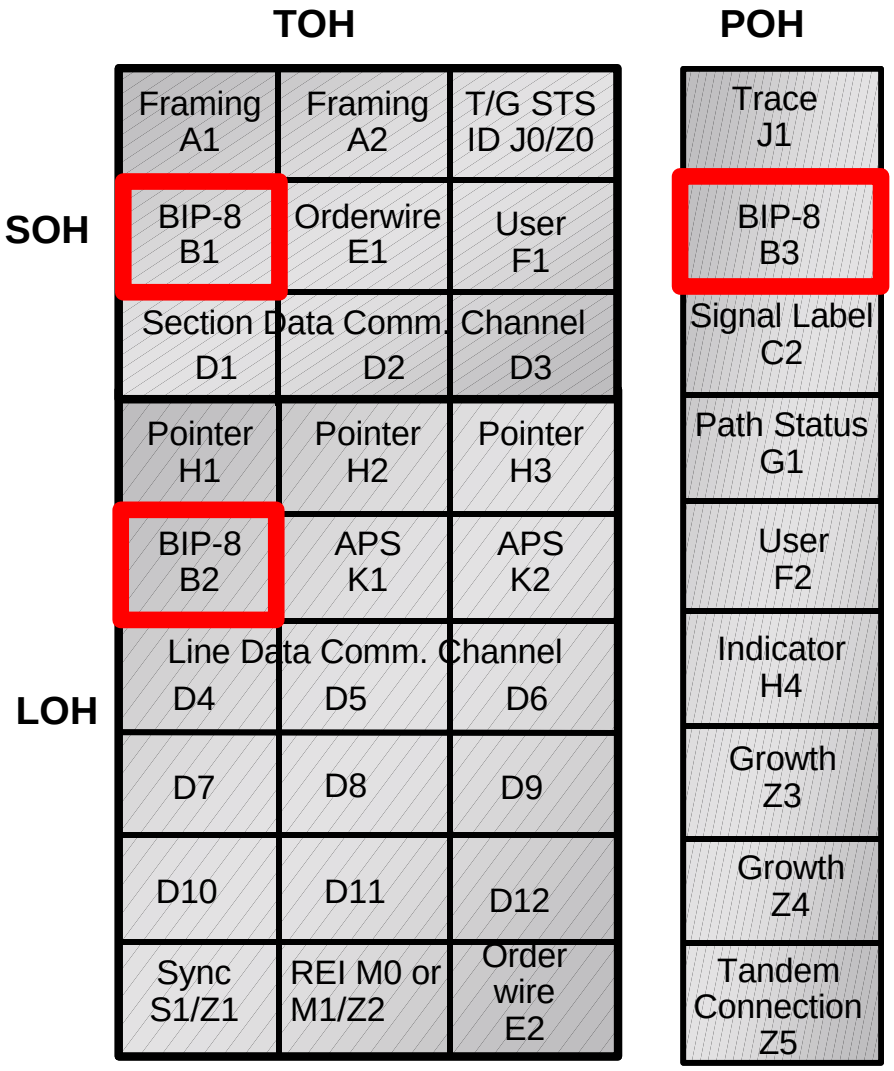


Framing Bytes



- **2 bytes for framing (F628)**
- **reside in all STS-1s**
- **framer typically searches for A1/A2 boundary**
- **set by h/w**

Performance Monitoring

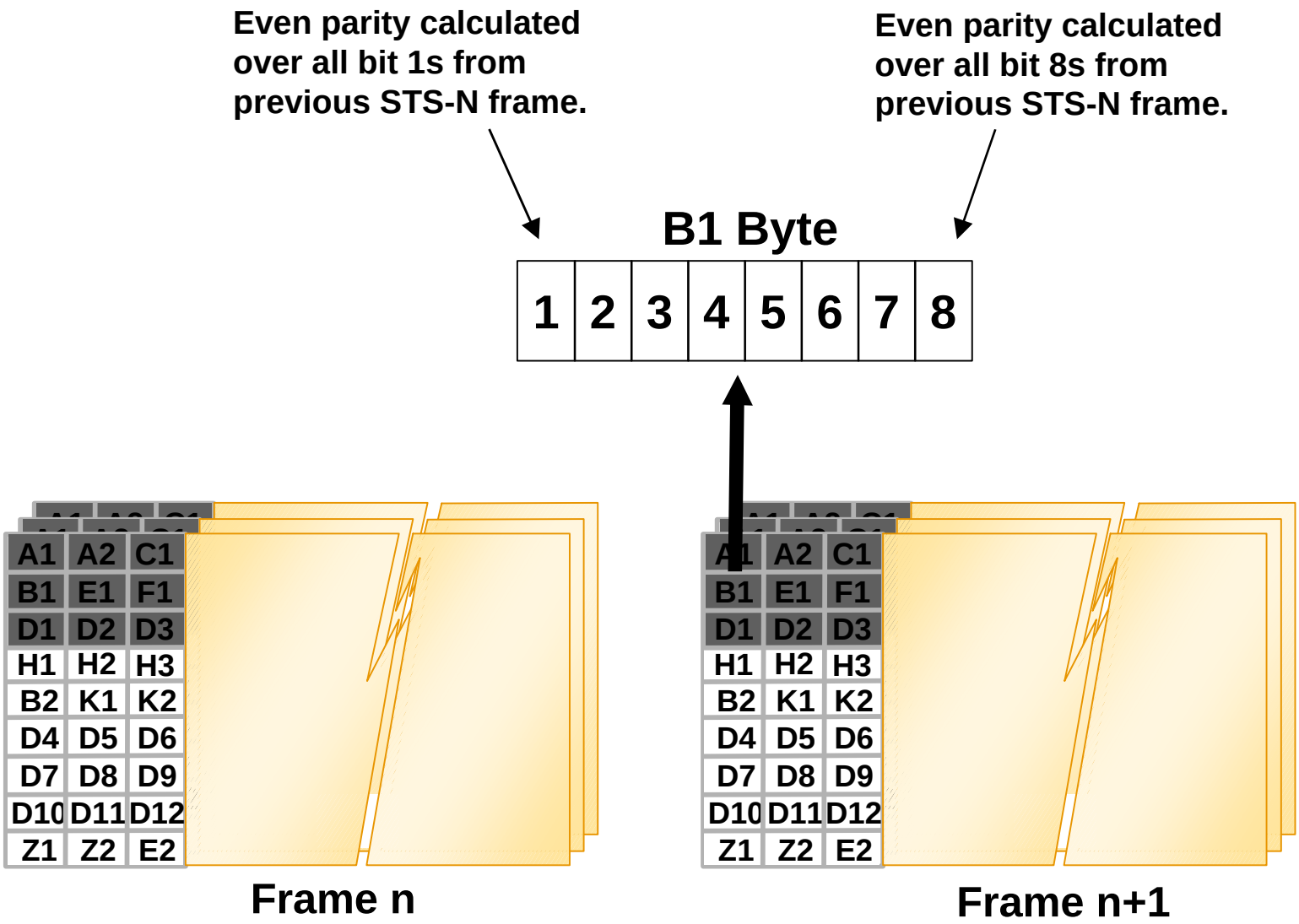


- **Separate checks for Section, Line and Path**
- **BIP = 'Bit Interleaved Parity'**
- **Simple 'even parity' scheme**
- **Parity calculated over all corresponding bit positions in previous frame.**
- **set by h/w**

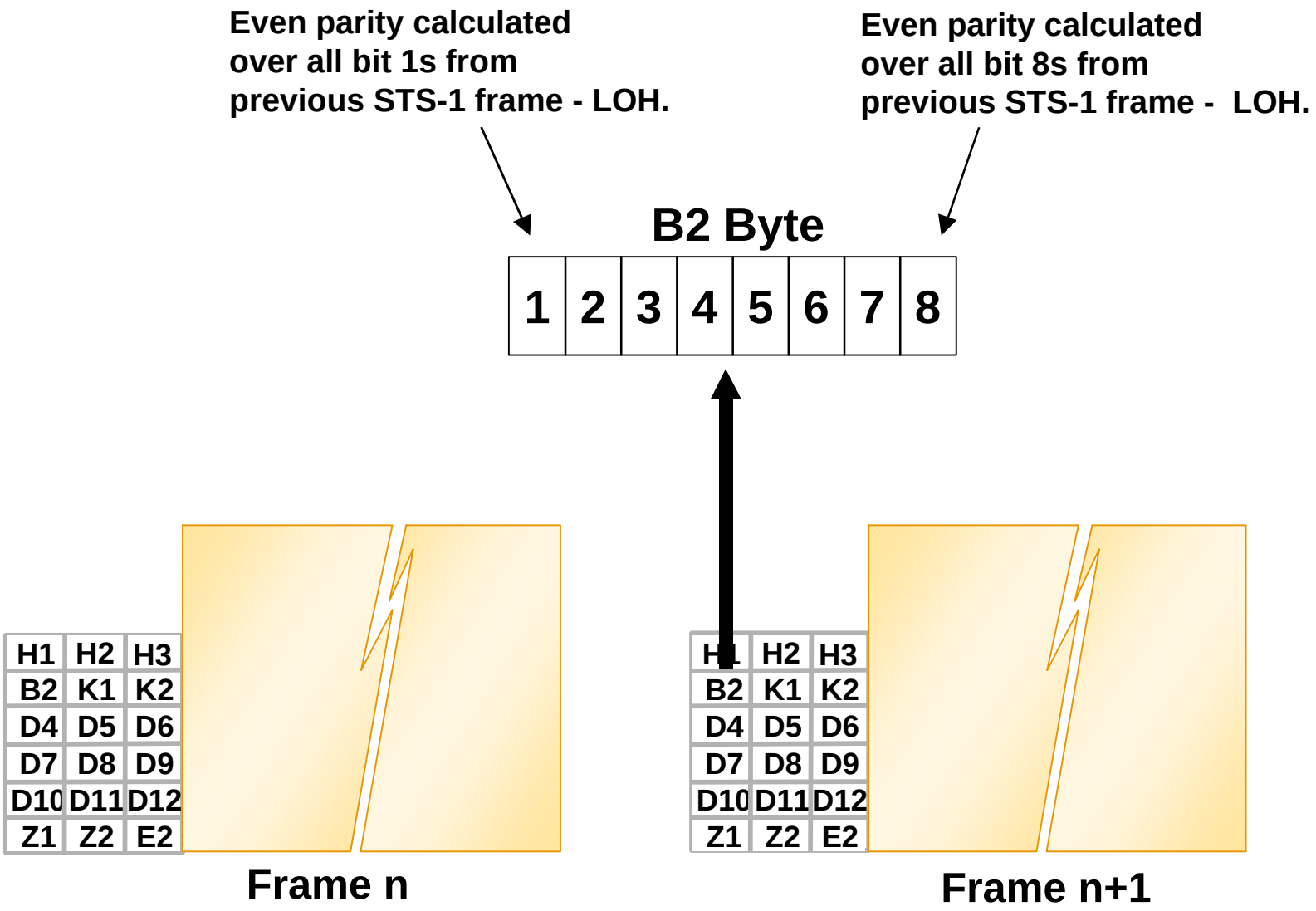
- **B1: 1 x BIP-8 byte / STS-N**
- **B2: N x BIP-8 bytes / STS-N**
- **B3: 1 x BIP-8 byte / SPE**

- **B1/B3 do not scale well with N!**

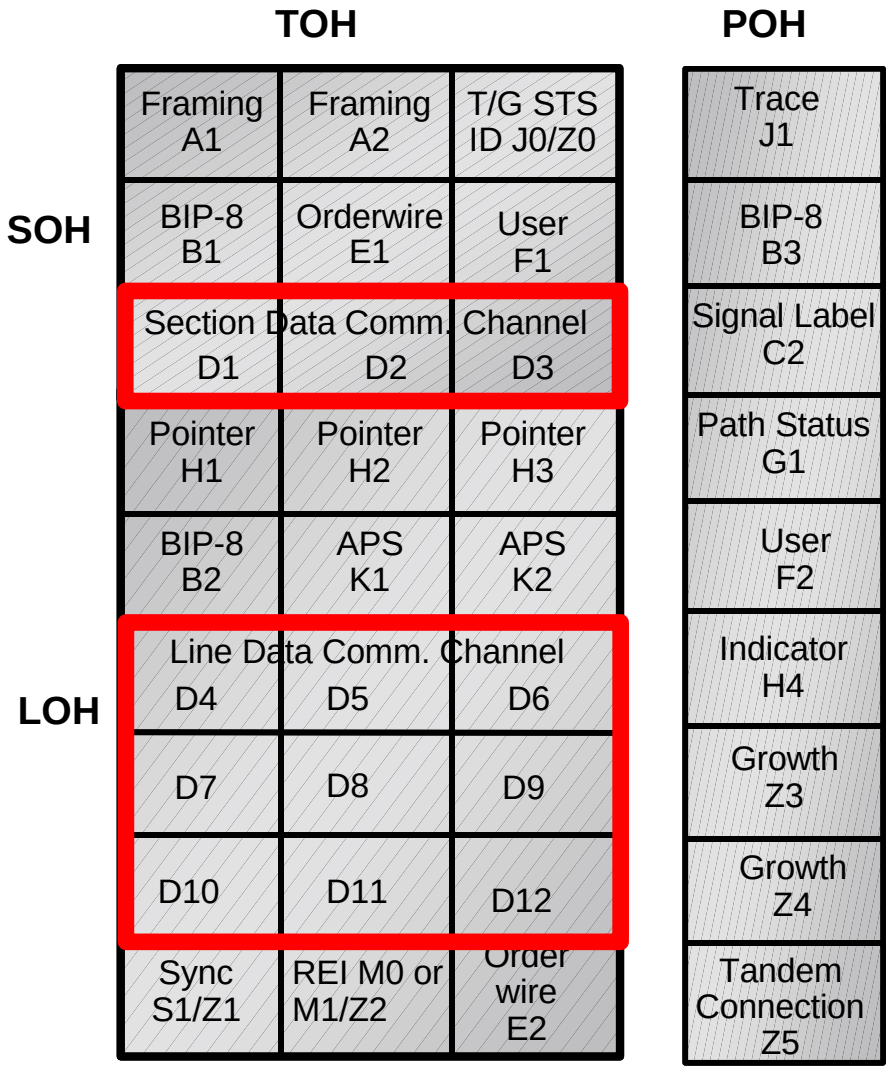
Section BIP-8 (B1) Example



Line BIP-8 (B2) Example

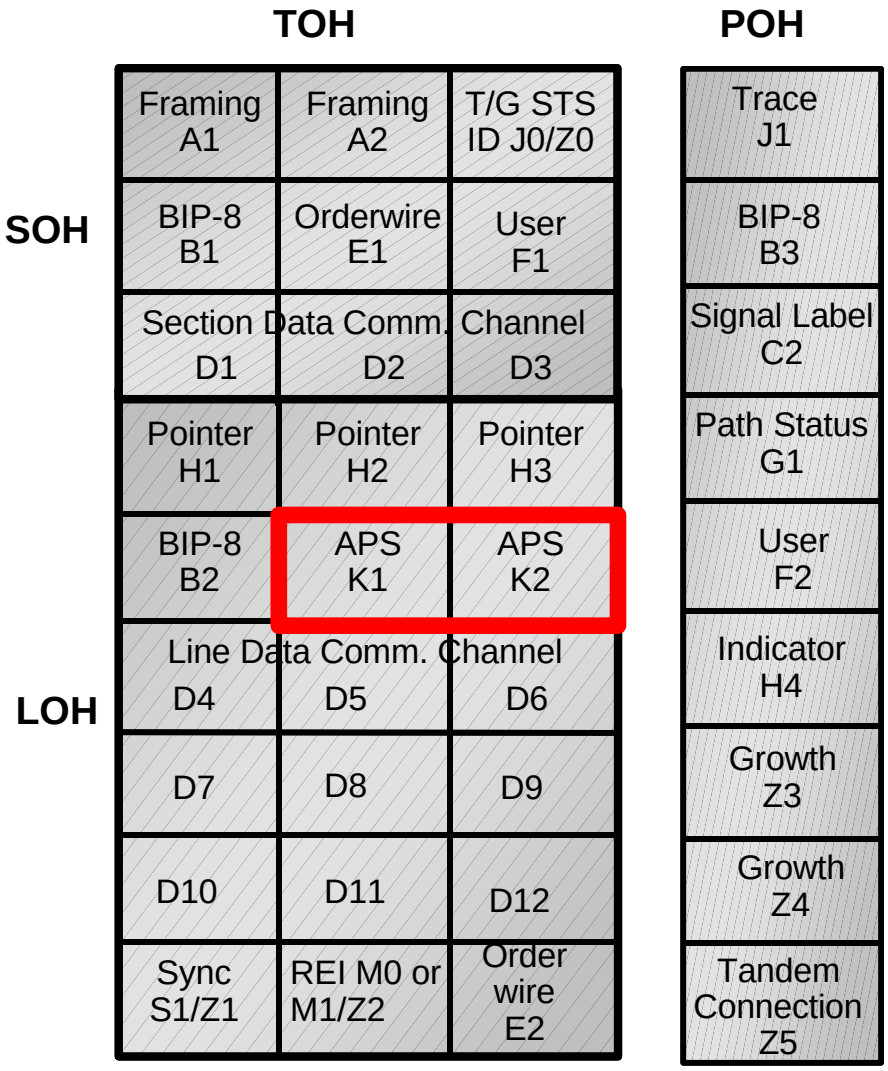


Data Communication Channel (DCC)

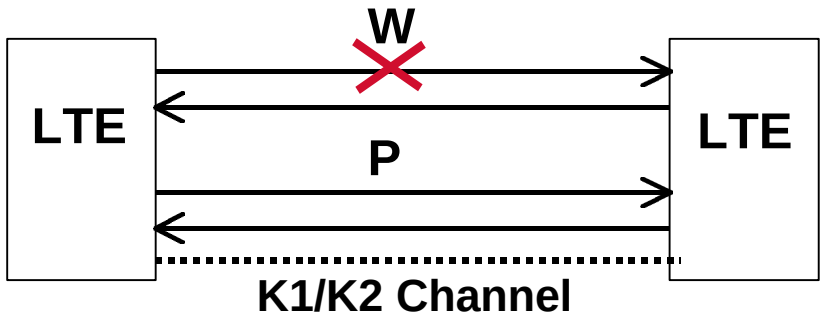


- **Out-of-Band communications channel**
- **Used to transmit OAM data to/from Network Management system**
- **Separate Section and Line channels**
- **D1-D3 - 192 kb/s OSI/CMIP**
- **D4-D12 - 576 kb/s OSI/CMIP**

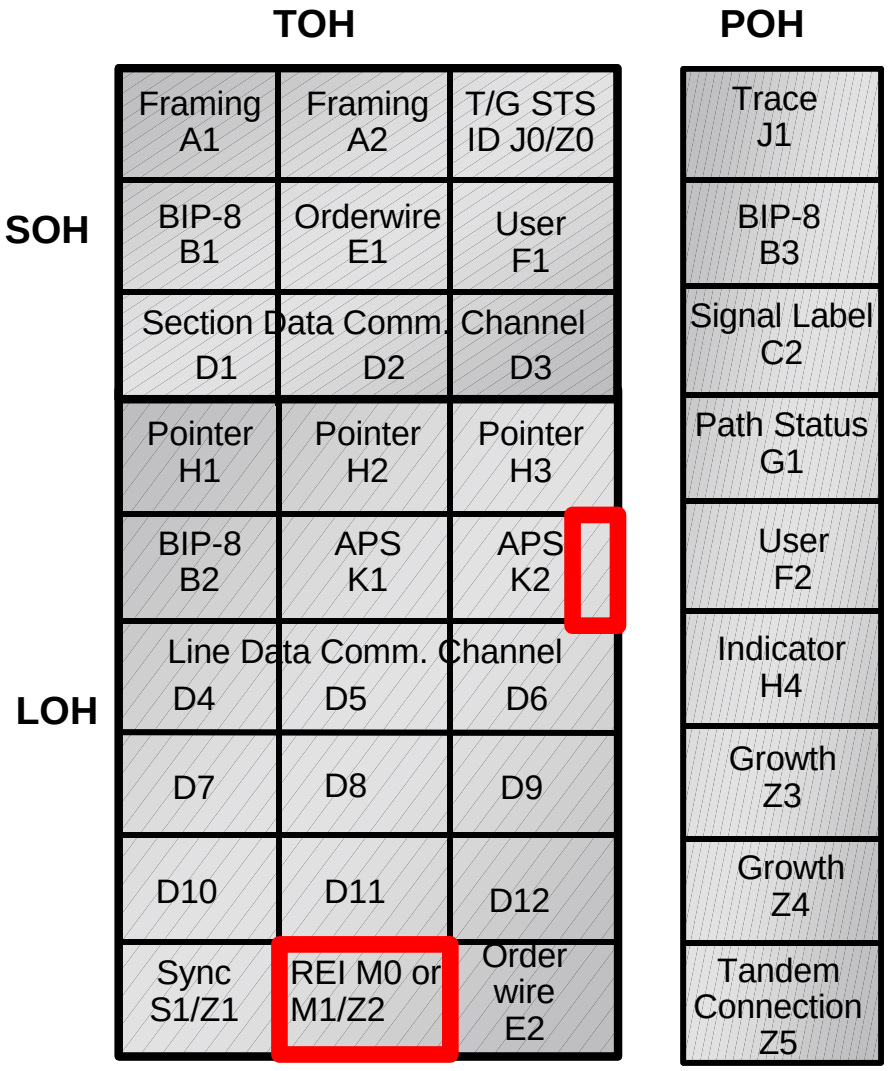
Automatic Protection Switching (APS)



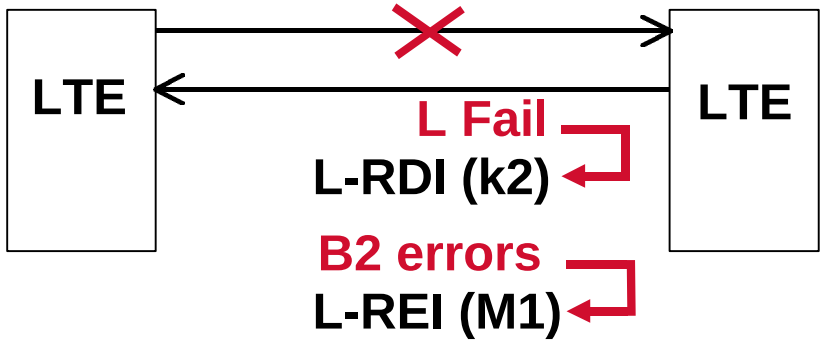
- **K1/K2 - Automatic Protection Switching (APS)**
- **Bit mapped communication channel between LTEs for controlling protection switching.**
- **Under control of APS s/w on line card**
- **Used on P link only**



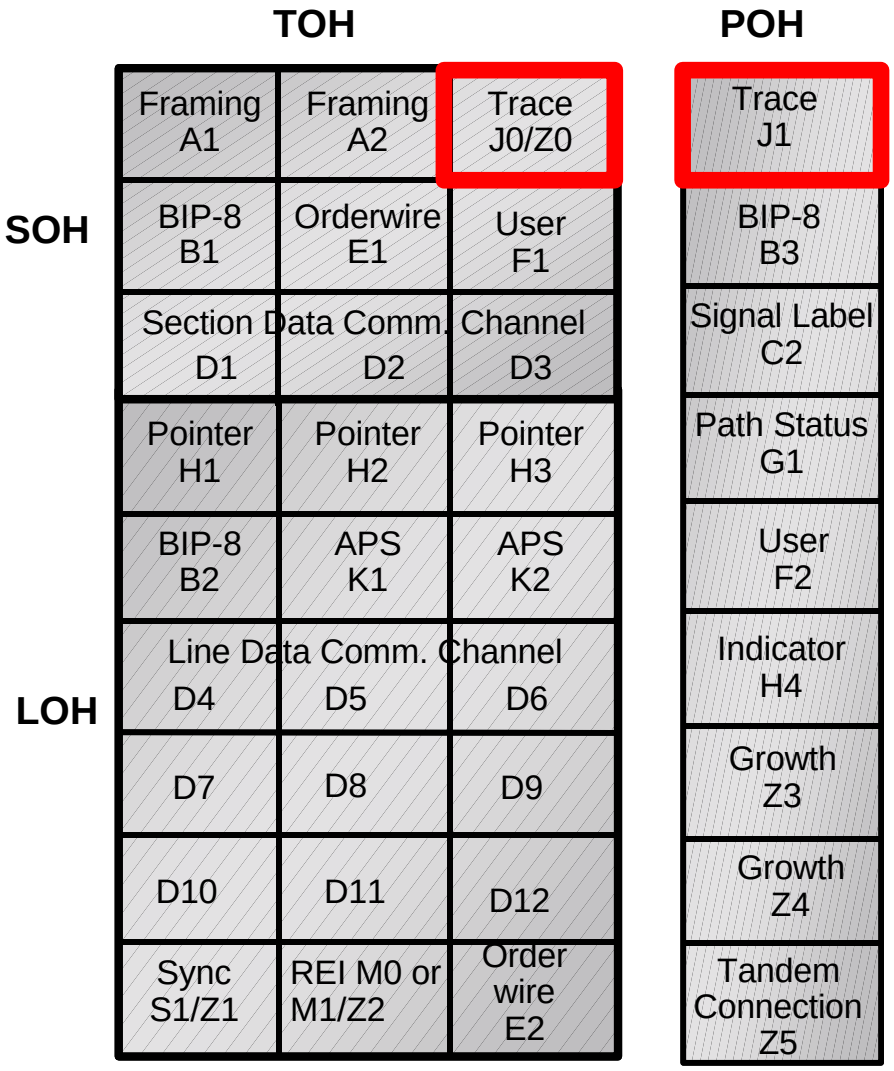
Reverse signaling



- **LTE-LTE Signaling**
- **Indicates to upstream LTE of downstream failure.**
- **RDI - Remote Defect Indicator (hard failure - K2)**
- **REI - Remote Error Indicator (B2 bit errors - M1)**
- **set by h/w**



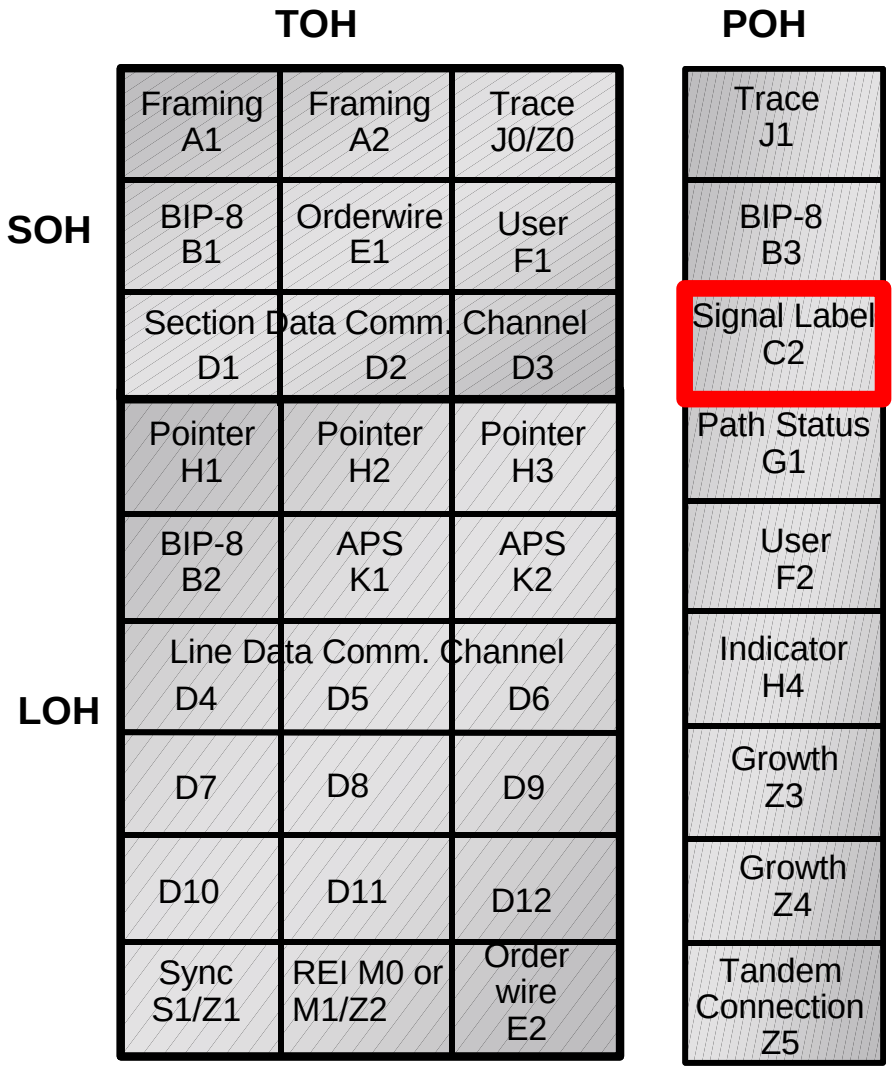
Path Trace



- **J1- Path Trace.**
- **End-End path connectivity check**
- **64 byte (SONET) or 16 byte (SDH) repeating message.**
- **Inserted continuously at source, checked against expected value by receiver**
- **message typically set by user**

- **J0 - Section Trace. Not defined yet (old STS ID byte)**

Signal Label



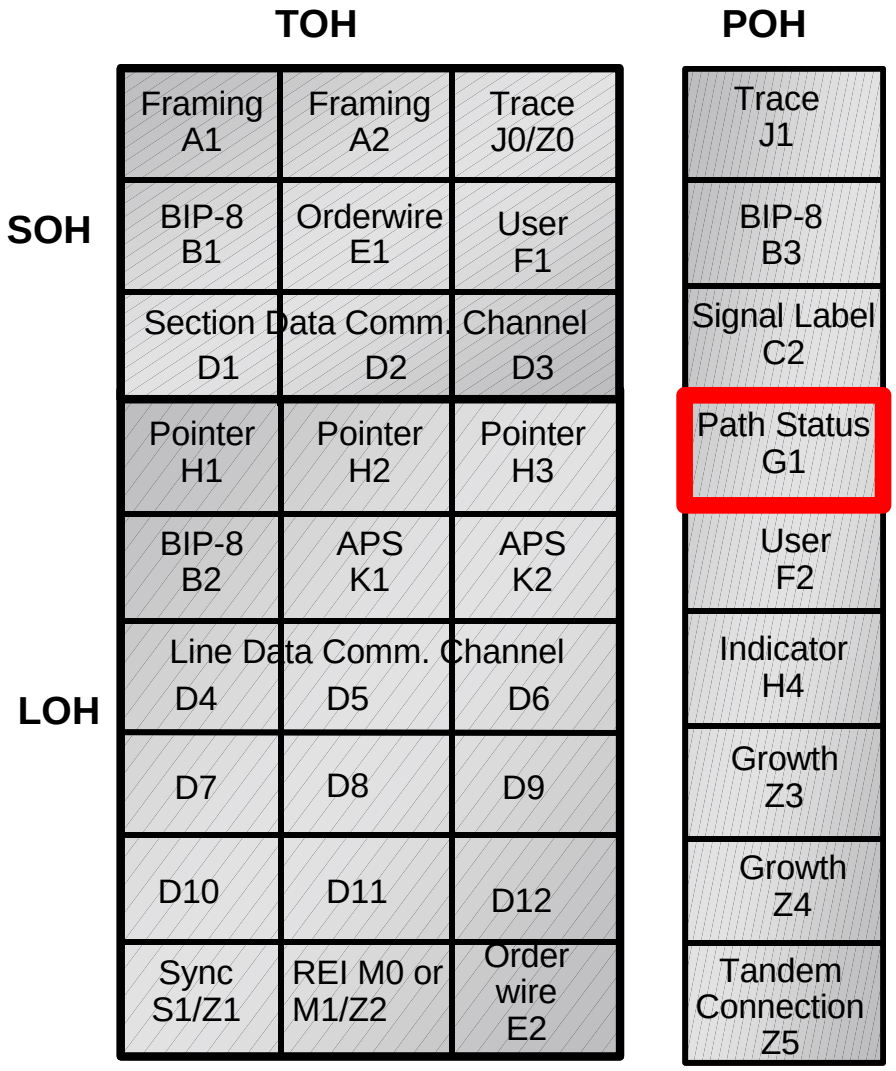
- **Describes contents of payload (e.g. DS1, ATM, FDDI etc.)**
- **fixed value, set by application**

C2 Byte

1	2	3	4	5	6	7	8

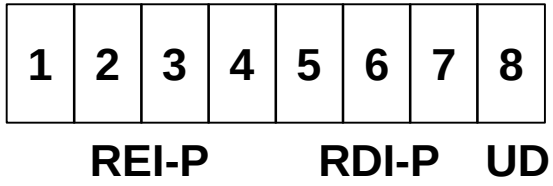
HEX VALUE	PAYLOAD
00	Unequipped
01	Equipped – Nonspecific payload
02	Virtual Tributaries
04	DS3
12	139.264Mb/s
13	ATM
14	DQDB
15	FDDI
16	Scrambled POS (Proposed)
CF	Unscrambled POS

Path Status



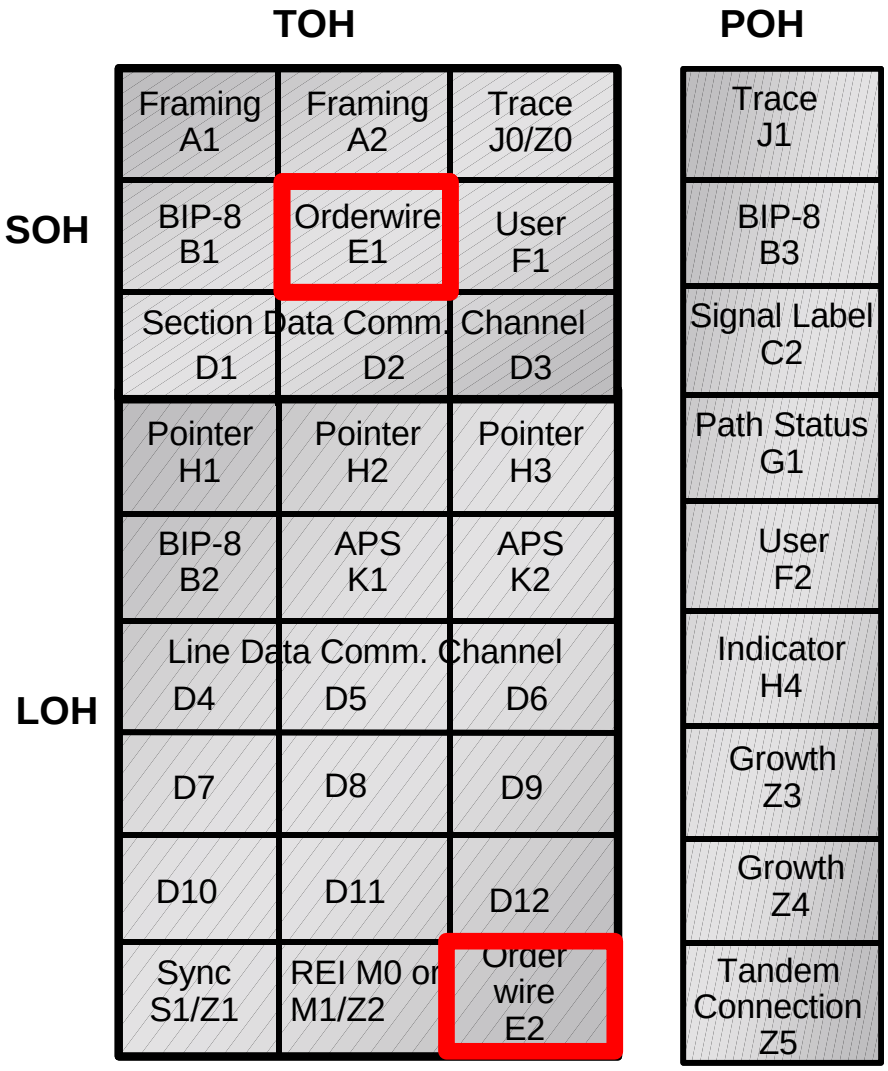
- **G1 Byte**
- **Performs function of REI & RDI for PTE**

G1 Byte



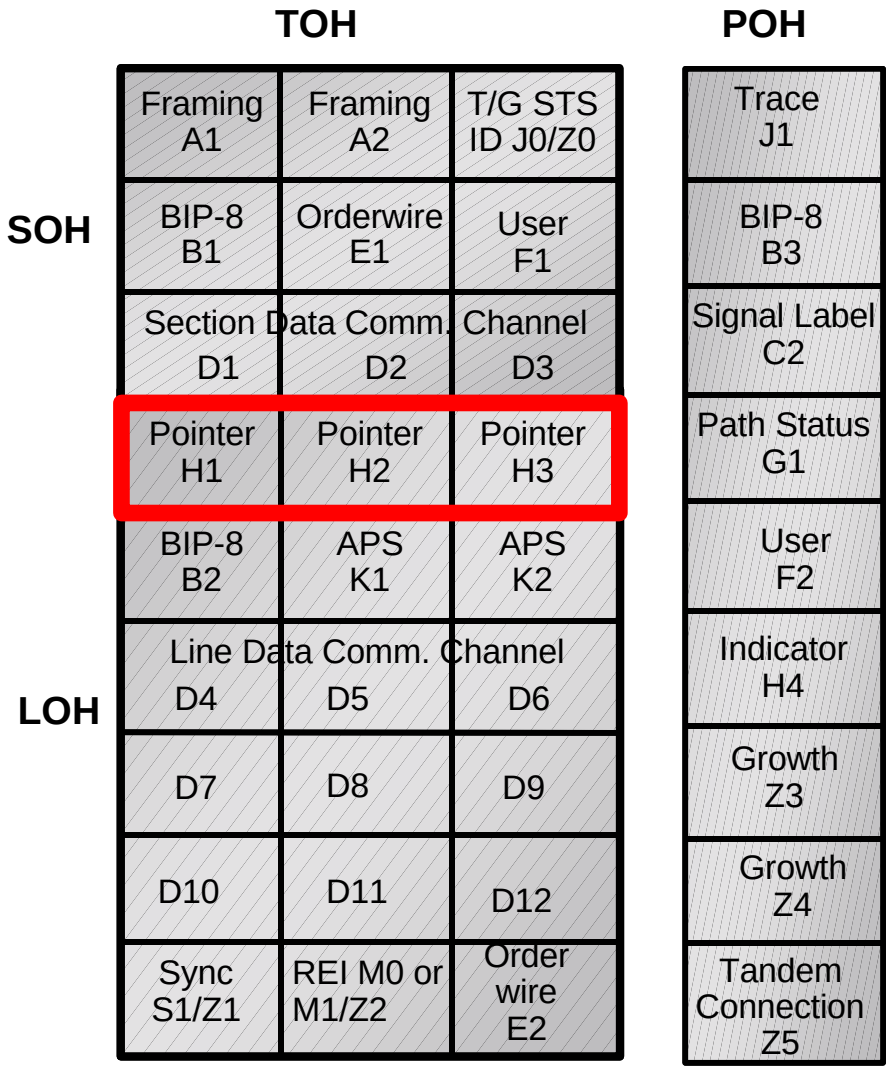
REI-P: G1 bits 1-4
RDI-P: G1 bits 5-7
Undefined: G1 bit 8

Order wire



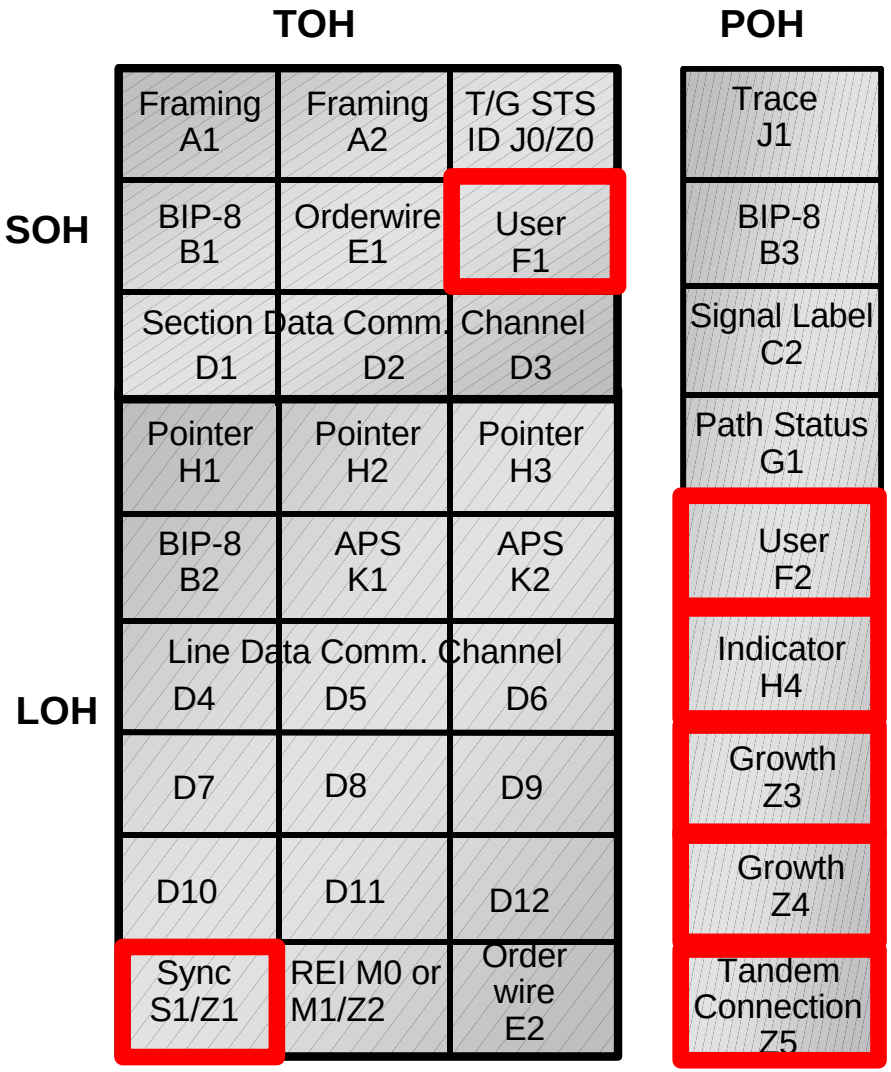
- **64kbps voice channels**
- **used for craftsperson communication between equipment locations**
- **mobile phones commonly used instead**

Pointers



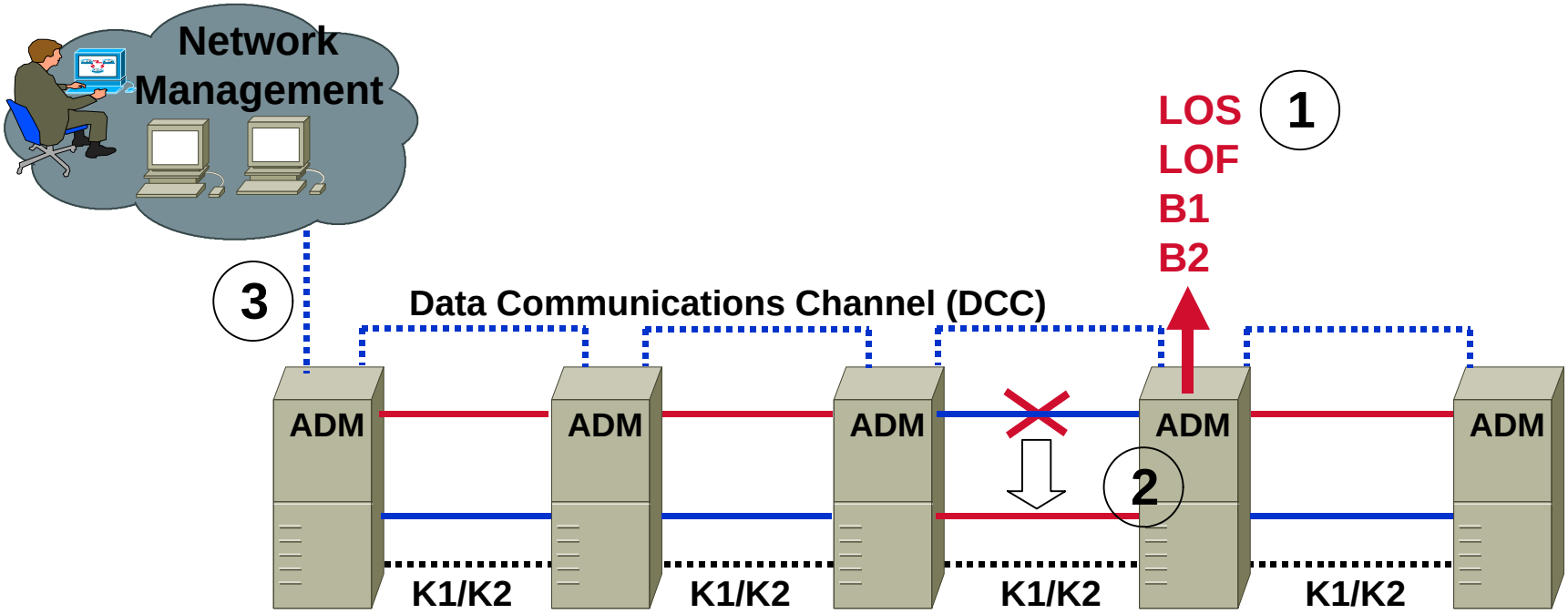
- **Payload Pointer bytes H1-H3**
- **Align SPE within STS frame**
- **set/controlled by h/w**

Misc Bytes



- **F1: Customer communications channel. Not used much.**
- **F2: same as F1.**
- **S1: Sync status byte. Indicates synchronization quality of OC-N signal.**
- **H4: Multi-frame byte. Only used for VT payloads.**
- **Z3/4: Growth bytes. Allocated for future undefined uses.**
- **Z5: Tandem connection. New function. Not used much.**

OAM - The Big Picture ?



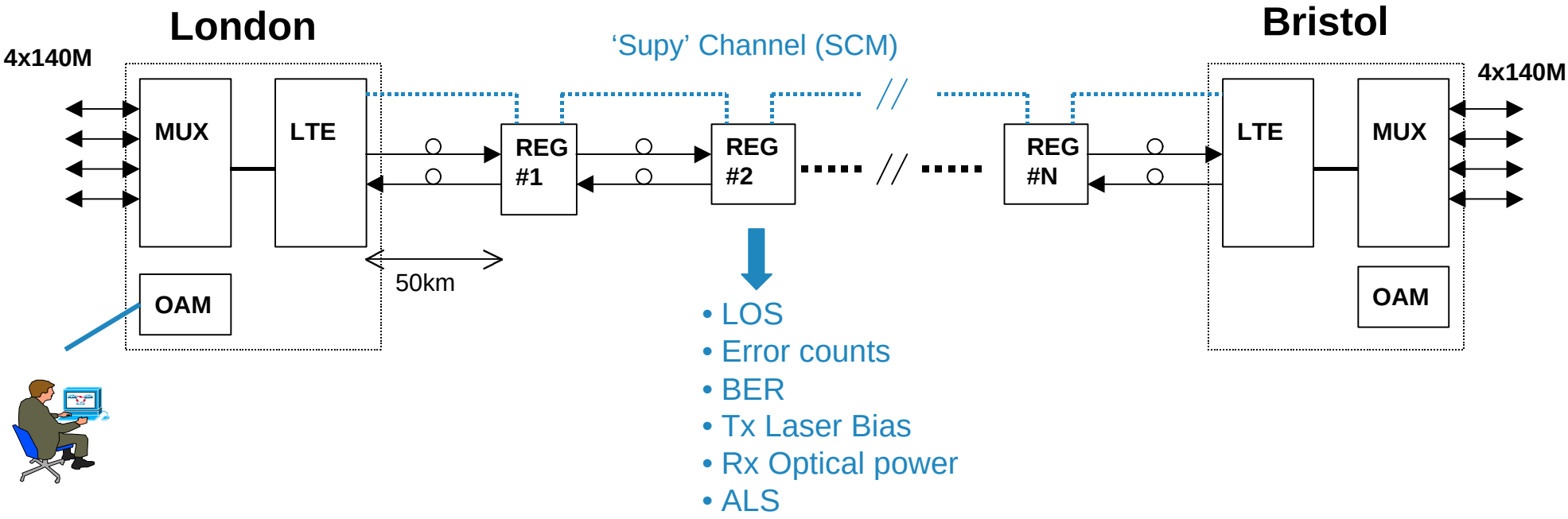
Three Steps:

1) Detect failure (BIP-8, B1, B2, B3)

2) Service restoration (50ms) - fast local signaling (K1/K2)

3) Fault isolation and repair - signaling to centralized network management location (DCC)

Is SONET the only way ?



- **565Mb/s Optical Line System**
- **Installed 1985, Mercury Communications, London-Bristol**
- **5B6B Block Coded - 678Mb/s line rate**
- **Sophisticated single-ended OAM features**

To Wrap Up !

- **TDM multiplexing onto high capacity fiber systems.**
- **Standard bit rate, frame format, optical specifications to ensure multi-vendor interoperability.**
- **Fast restoration (50ms) schemes for both linear (pt-pt) and ring topologies.**
- **Operations, Administration, Maintenance & Provisioning (OAM&P)**

  - provision connections
  - performance monitoring
  - detect/isolate failures

Summary

- SONET provides standardization, interoperability, and OAM
- SONET is complex to implement
  - largely due to requirement to support legacy traffic
- SONET is widely deployed
- However, there is no magic about SONET

Acronyms

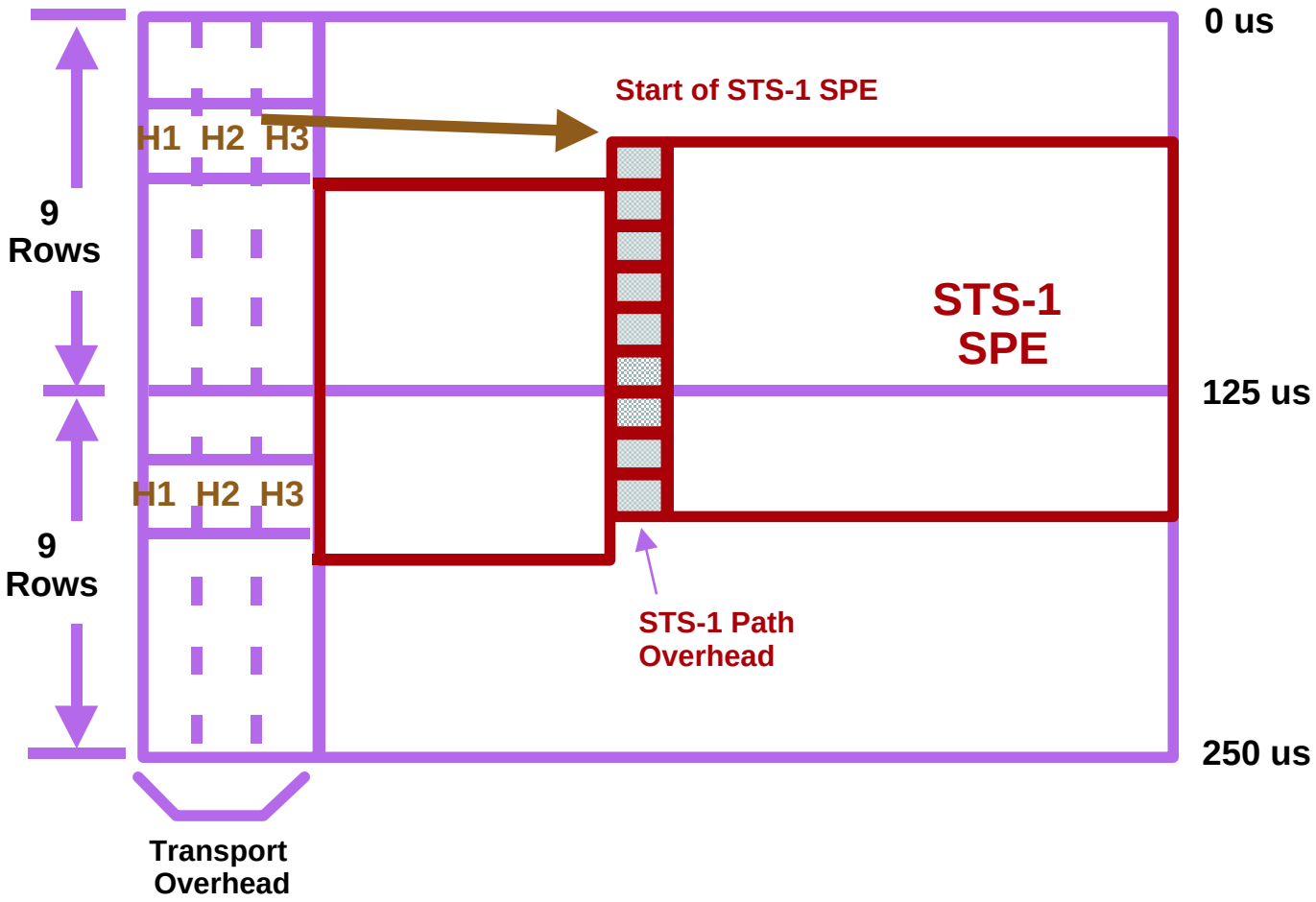
- ADM: Add-Drop Multiplex
- APS: Automatic Protection Switching
- BIP: Bit Interleaved Parity
- BITS: Building Integrated Timing Supply
- OC: Optical Carrier
- POH: Path Overhead
- POS: Packet Over SONET
- PTE: Path Terminating Entity
- SDH: Synchronous Digital Hierarchy
- SONET: Synchronous Optical Network
- SPE: Synchronous Payload Envelope
- STE: Section Terminating Entity
- STM: Synchronous Transport Module
- STS: Synchronous Transport Signal
- TOH: Transport Overhead
- VT: Virtual Tributary

References

- Telcordia (Bellcore) GR-253-CORE
- ANSI T1.105 and T1.106
- ITU-T G.707 and G.783
- SONET, Walter J. Goralski, McGraw-Hill Series on Computer Communications
- Broadband Networking, ATM, SDH, and SONET, Mike Sexton, Andy Reid, Artech House
- www.sonet.com

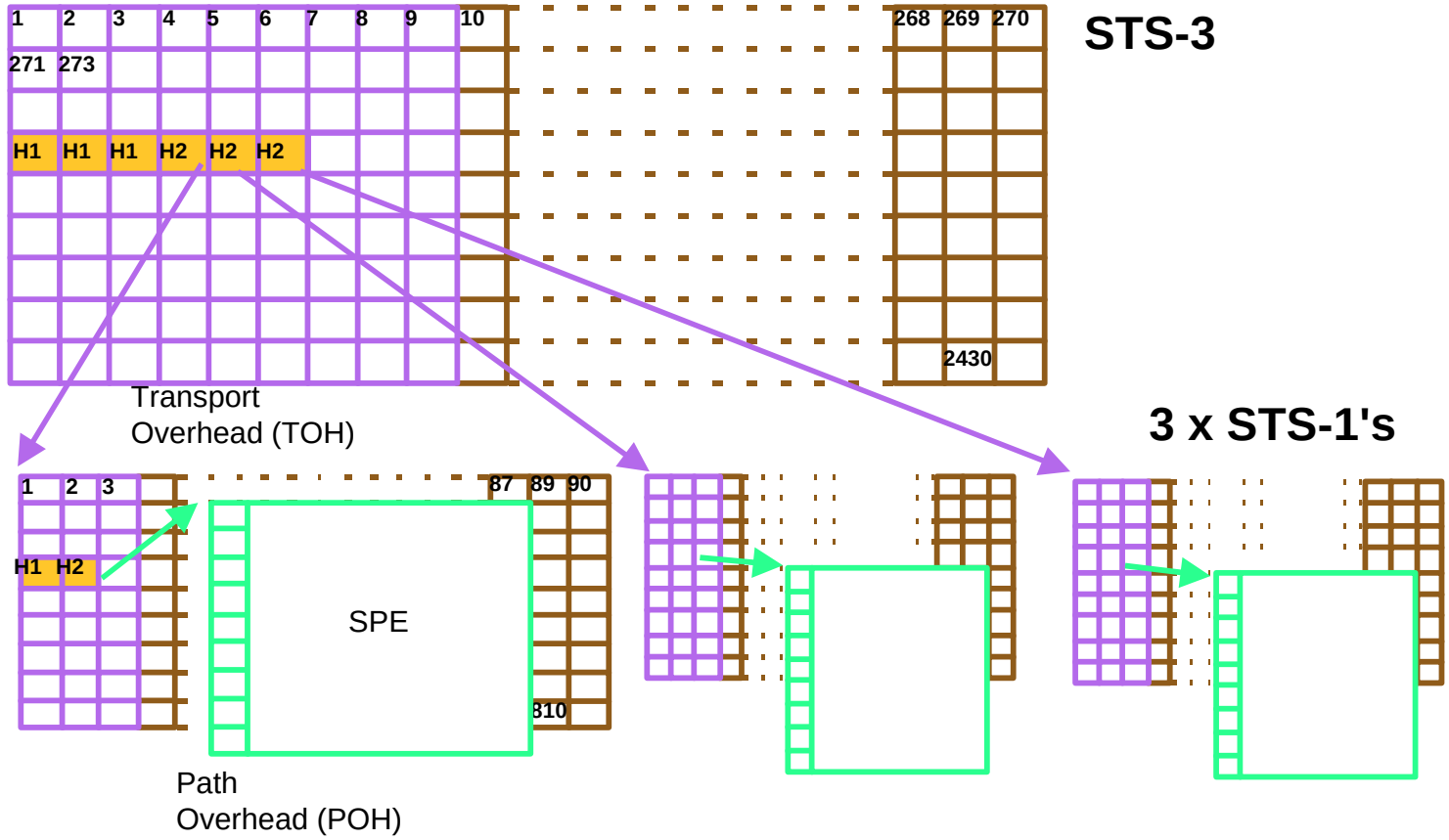
Backup Material

SONET STS-1 Pointers



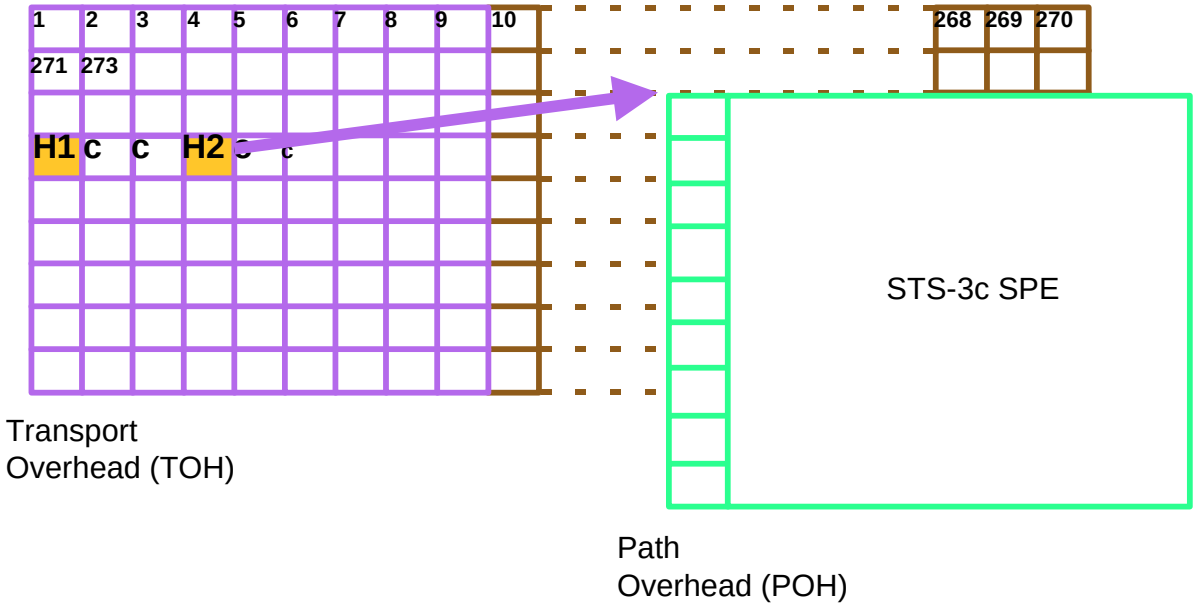
Pointer Bytes (H1, H2) - Channelized

- Consider STS-3
- 3 STS-1 bit steams of 51.84 Mbps



Pointer Bytes (H1, H2) - Concatenated (STS-Nc)

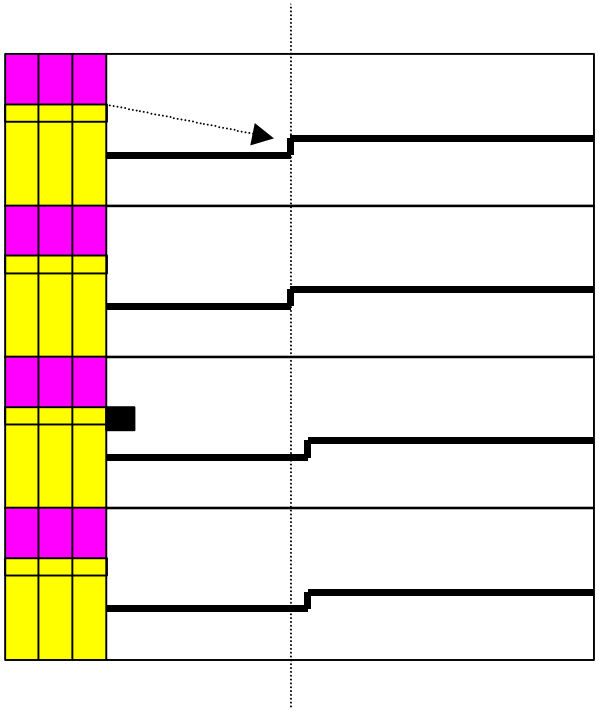
- Consider STS-3c (c = concatenated)
- Single bit stream of 155.52 Mbps



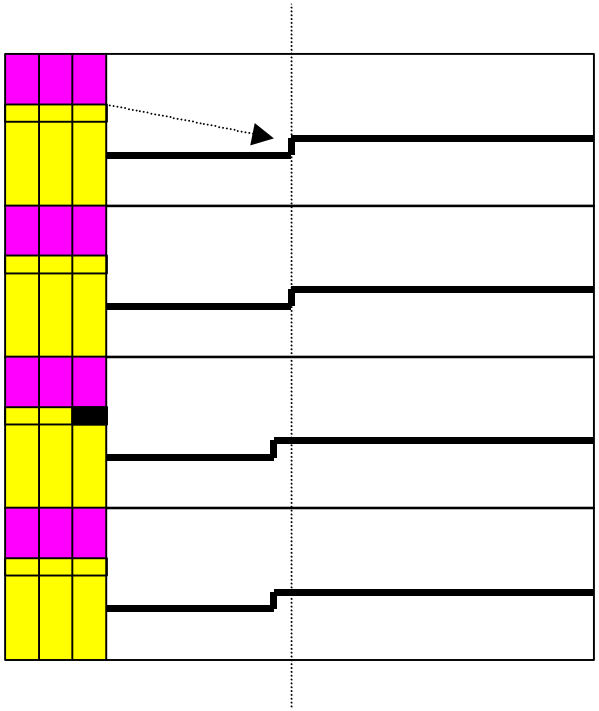
STS-3c SONET Frame

Using Pointers to Accommodate Timing Offsets/Jitter

Positive Stuff



Negative Stuff



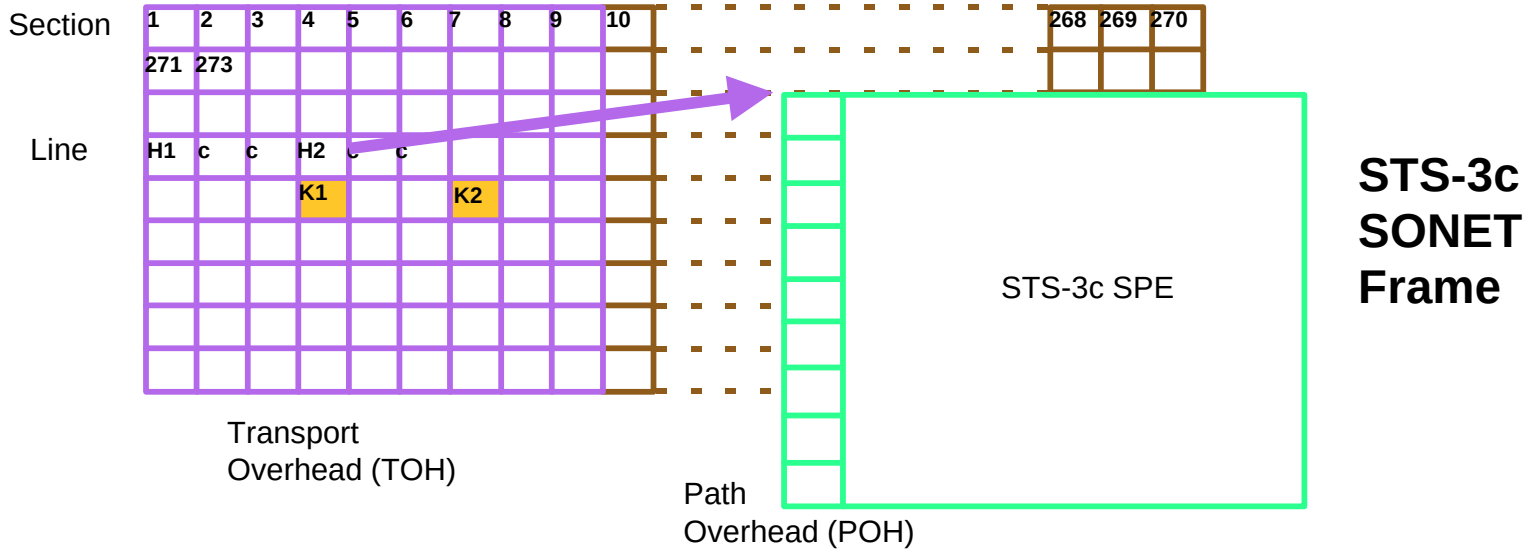
Byte After H3 Ignored, Or H3 Holds Extra Byte To Shorten/Lengthen Frame
H1, H2 Values Indicate Changes - Maximum Every 4 Frames
Requires Close (Not Exact - up to 300ppm offset) Clock Synchronization Among Elements

SONET Multiplexing Hierarchy

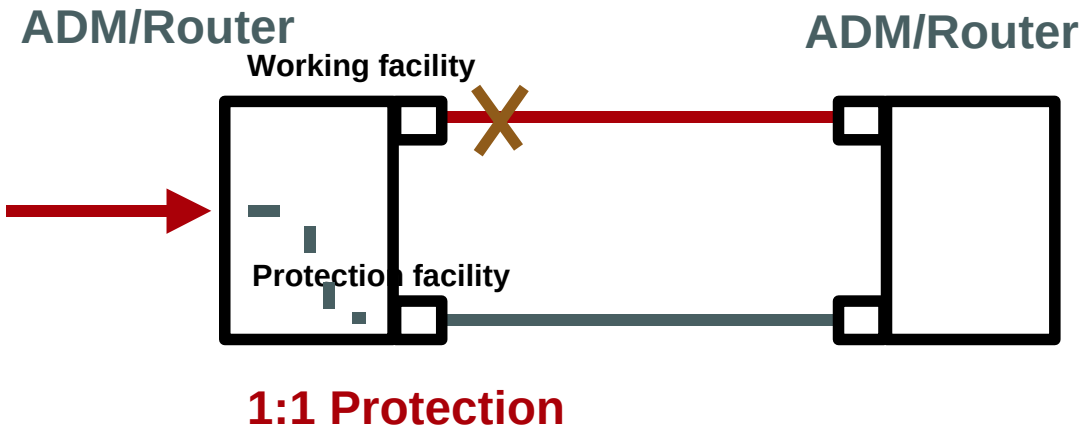
- **STS-1 signals can be wideband or broadband**
  - **Wideband = Channeled with VT 1.5s containing DS1s**
  - **Broadband = High rate DS3 and concatenated STS-1s**
- **VT mapped STS-1s are designed for transport and switching of sub-STS-1 rate payloads**
- **STS-1s can be concatenated to create higher speed payloads**
  - **STS-3c, STS-12c, STS-48c, STS-192c (future)**
  - **For data applications, etc..**
- **STS-1s are multiplexed together to create the transmitted payload**
  - **STS-N = N multiplexed STS-1s**
  - **Can intermix broadband and wideband STS-1s within STS-Ns**
  - **N is currently defined as 1, 3, 12, 48, 192….**

Automatic Protection Switching

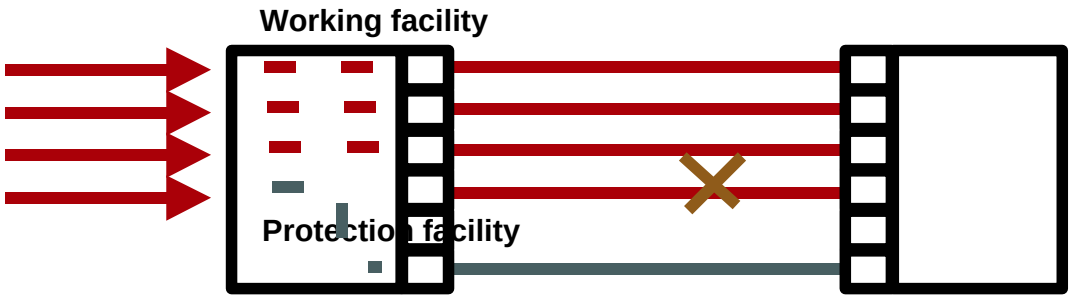
- Uses K1 and K2 bytes of Line Overhead
- Needs 2 or more fibers
- Allows network to react to failed lines, interfaces, or poor signal quality
- Can be provisioned for a 1:1 or 1:n facility
- For 1:1 each working facility is backed up or protected
- For 1:n one protection facility exists for n-working fibers



APS - Diagram



1:1 Protection



1:N Protection

Automatic Protection Switching - K1, K2

- APS - all bits of K1 + bits 1-5 or K2
- K1 byte:

  Switch priority - K1 bits 1-4

  Channel requesting switch action - K1 bits 5-8
- K2 byte:

  Carries the Line "Alarm Indication Signal" and

  Line "Remote Defect Indicator"