SONET

By

Sadhish Prabhu

History

- Digital carrier systems
  - The hierarchy of digital signals that the telephone network uses.
  - Trunks and access links organized in **DS (digital signal) hierarchy**
  - Problem: rates are not multiples of each other.
- In the 1980's Bellcore developed the Synchronous Optical Network (SONET) standard.
- Previous efforts include: **ISDN** and **BISDN.**

SONET Overview

- The SONET specification defines:
  - standard optical signals, which permits the interoperation of equipment from different manufacturers
  - a synchronous frame structure for multiplexing digital traffic
- SONET includes:
  - support for broadband rates
    - base rate approximately 50 Mbps
    - hierarchical family of digital rates
    - defines data rates up to 2.4 Gbps
  - synchronous multiplexing
    - global timing structure at physical layer
    - synchronous implies simpler interface

Features of SONET

SONET:: encodes bit streams into optical signals propagated over optical fiber. SONET defines a technology for carrying many signals of different capacities through a synchronous, flexible, optical hierarchy.

- A bit-way implementation providing end-to-end transport of bit streams.
- All clocks in the network are locked to a common master clock so that simple TDM can be used.
- Multiplexing done by *byte interleaving.*
- *SONET* is backward compatible to DS-1 and E-1 and forward compatible to ATM cells.
- Demultiplexing is easy.

Comparing clocks

A clock is said to be isochronous (isos=equal, chronos=time)

if its *ticks* are equally spaced in time

2 clocks are said to be synchronous (syn=same chronos=time)

if they *tick in time*, i.e. have precisely the same frequency

2 clocks are said to be plesiochronous (plesio=near chronos=time)

if they are nominally in the same frequency

but are not *locked*

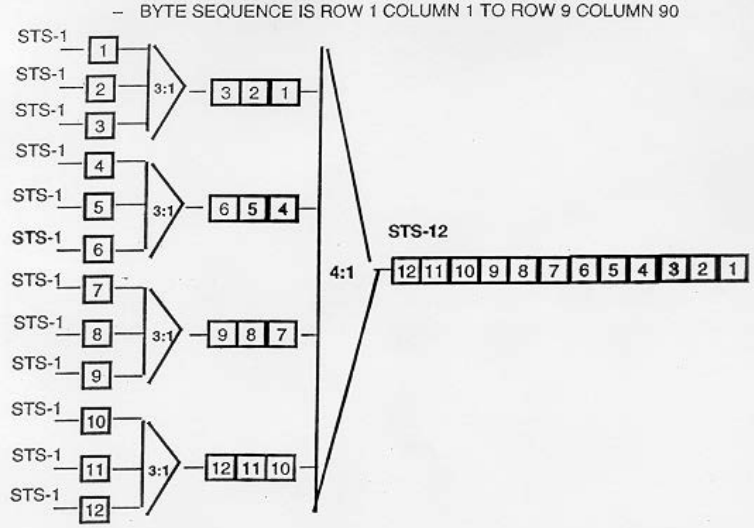
Byte Interleaving

INTERLEAVING

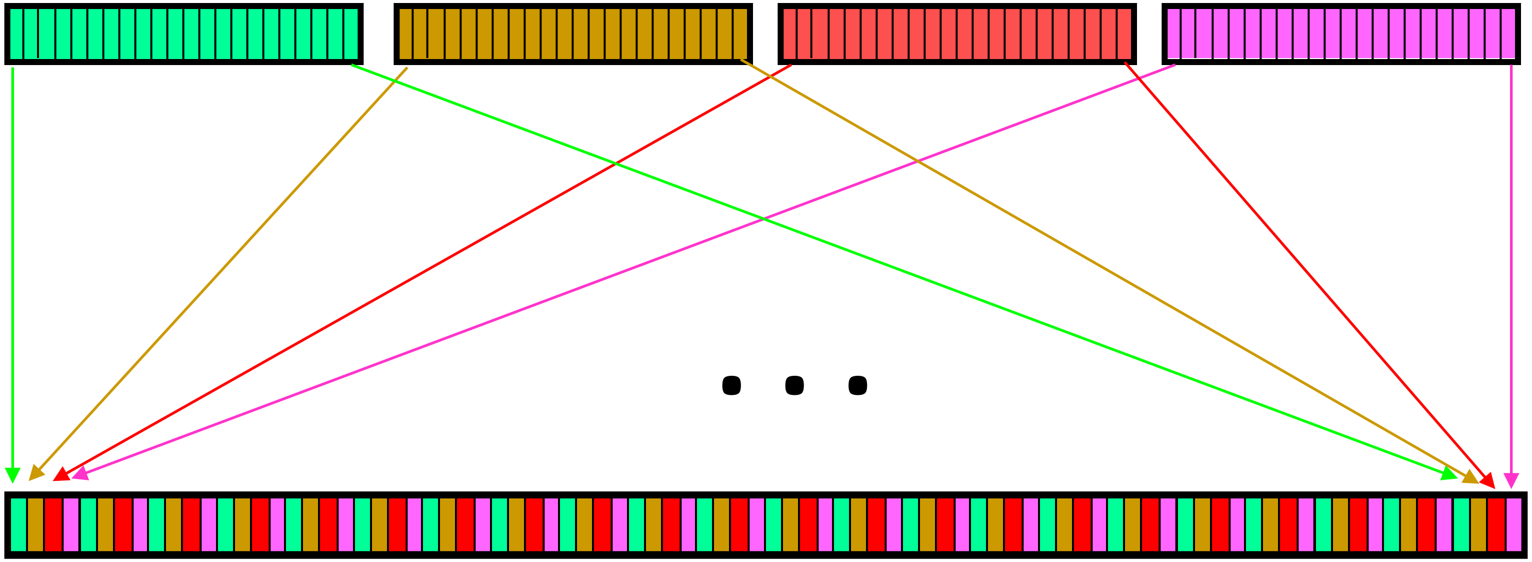
STS-1 SIGNALS ARE ***BYTE INTERLEAVED*** TO CREATE A **STS-N** SIGNAL BY COMBINING EACH BYTE IN THE VARIOUS DATA STREAMS IN A WAY SUCH THAT EACH BYTE IS IN A UNIQUELY SPECIFIED LOCATION FACILITATING DEMULTIPLEXING.

FIRST ALIGN STS-1 FRAMES

- NEXT BYTE INTERLEAVE TO FORM STS-N SIGNAL
- THE TRANSPORT OVERHEAD IS NOW 3 X N
- THE SPE (SYNCHRONOUS PAYLOAD ENVELOP - "DATA") IS NOW N X 87 COLUMNS
- BYTE SEQUENCE IS ROW 1 COLUMN 1 TO ROW 9 COLUMN 90

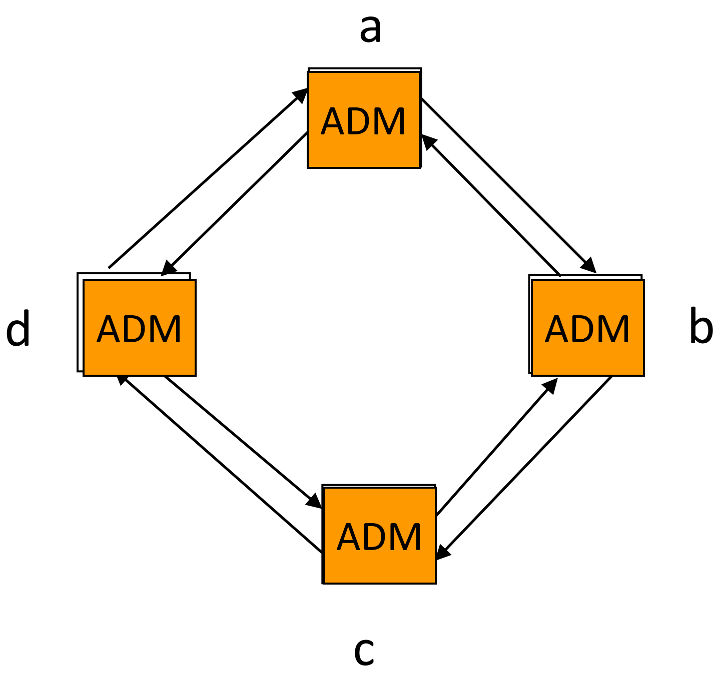


Byte-interleaving

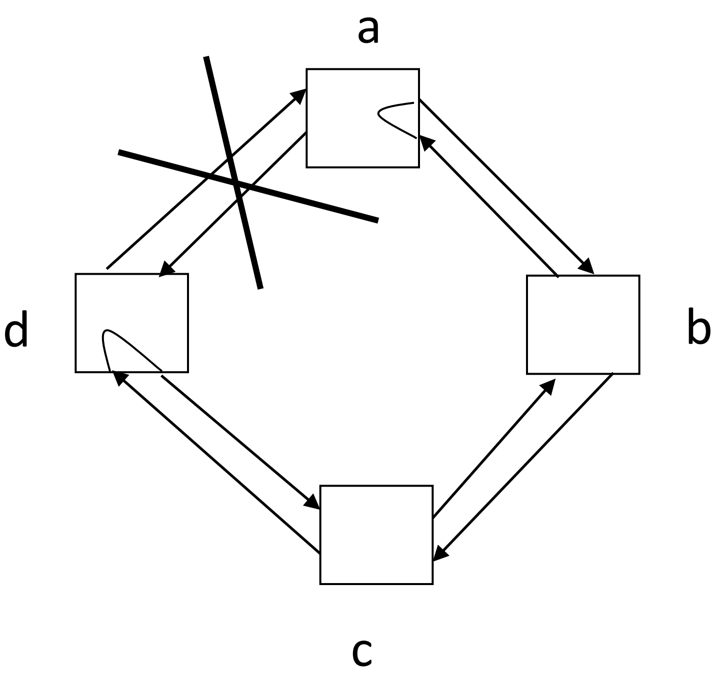


SONET Architecture

- SONET topology can be a mesh, but most often it is a dual ring.
- Standard component of SONET ring is an **ADM** (Add/Drop Multiplexer)
  - Drop one incoming multiplexed stream and replace it with another stream.
  - Used to make up bi-directional line switching rings.



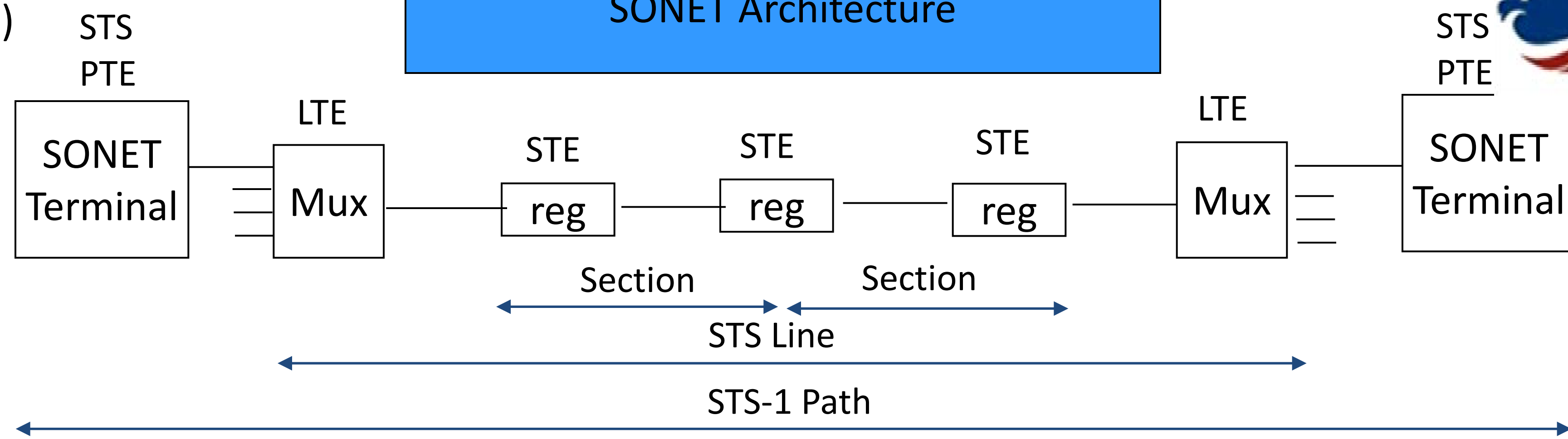
(a) Dual ring



(b) Loop-around in response to fault

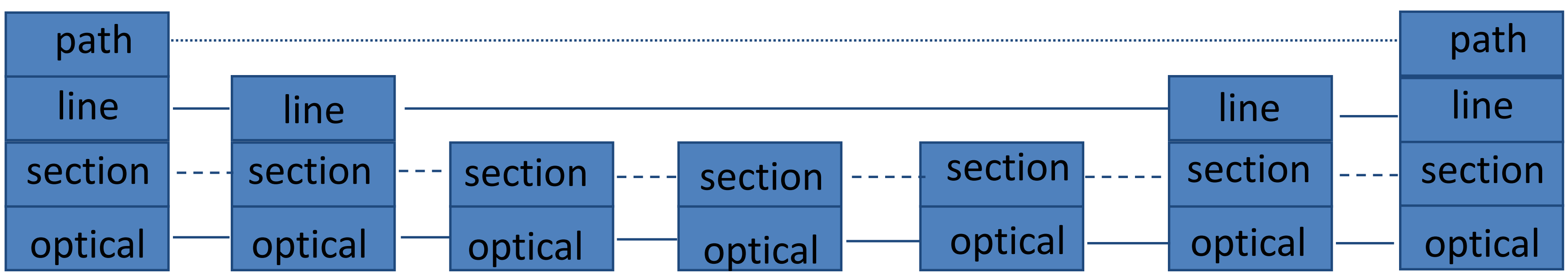
SONET Architecture

(a)



STE: Section Terminating Equipment, e.g. a regenerator
LTE: Line Terminating Equipment, e.g. a STS-1 to STS-3 multiplexer
PTE: Path Terminating Equipment, e.g. an STS-1 multiplexer

(b)



Layers

SONET was designed with definite layering concepts

Physical layer – optical fiber (linear or ring)

- when exceed fiber reach – regenerators
- regenerators are not mere amplifiers,
- regenerators use their own overhead
- fiber between regenerators called section (regenerator section)

Line layer – link between SONET muxes (Add/Drop Multiplexers)

- input and output at this level are Virtual Tributaries (VCs)
- actually 2 layers
  - lower order VC (for low bitrate payloads)
  - higher order VC (for high bitrate payloads)

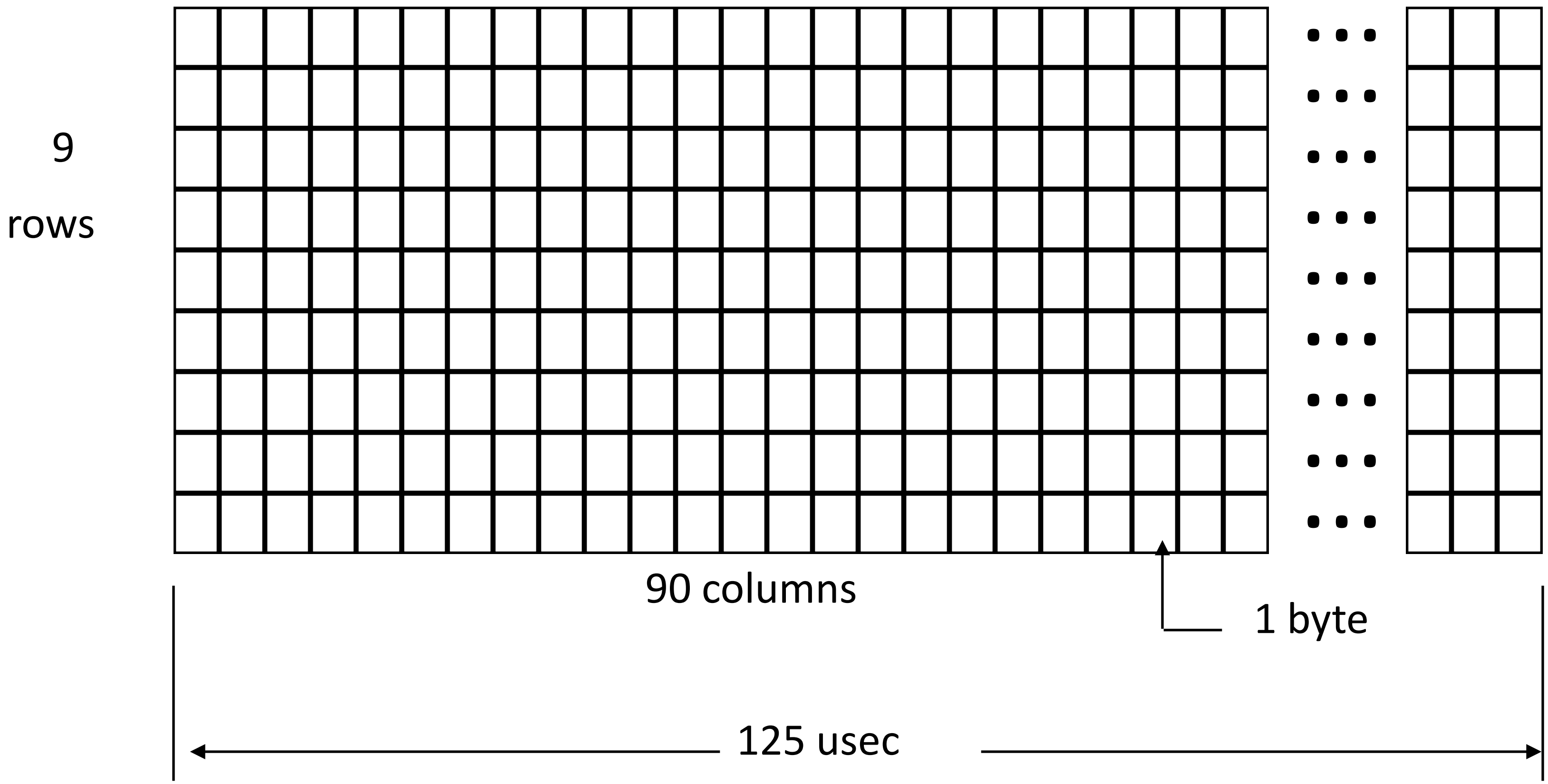
Path layer – end-to-end path of client data (tributaries)

- client data (payload) may be
  - PDH
  - ATM
  - packet data

SONET Framing Structure

- Basic module is STS-1 Synchronous Transport Signal, Level 1
- STS-1 corresponds to 51.84 Mbps
- Each STS-1 frame is 90 columns * 9 rows = 810 bytes
- There are 8000 STS-1 frames per second
- so each byte represents 64 kbps (each column is 576 kbps)

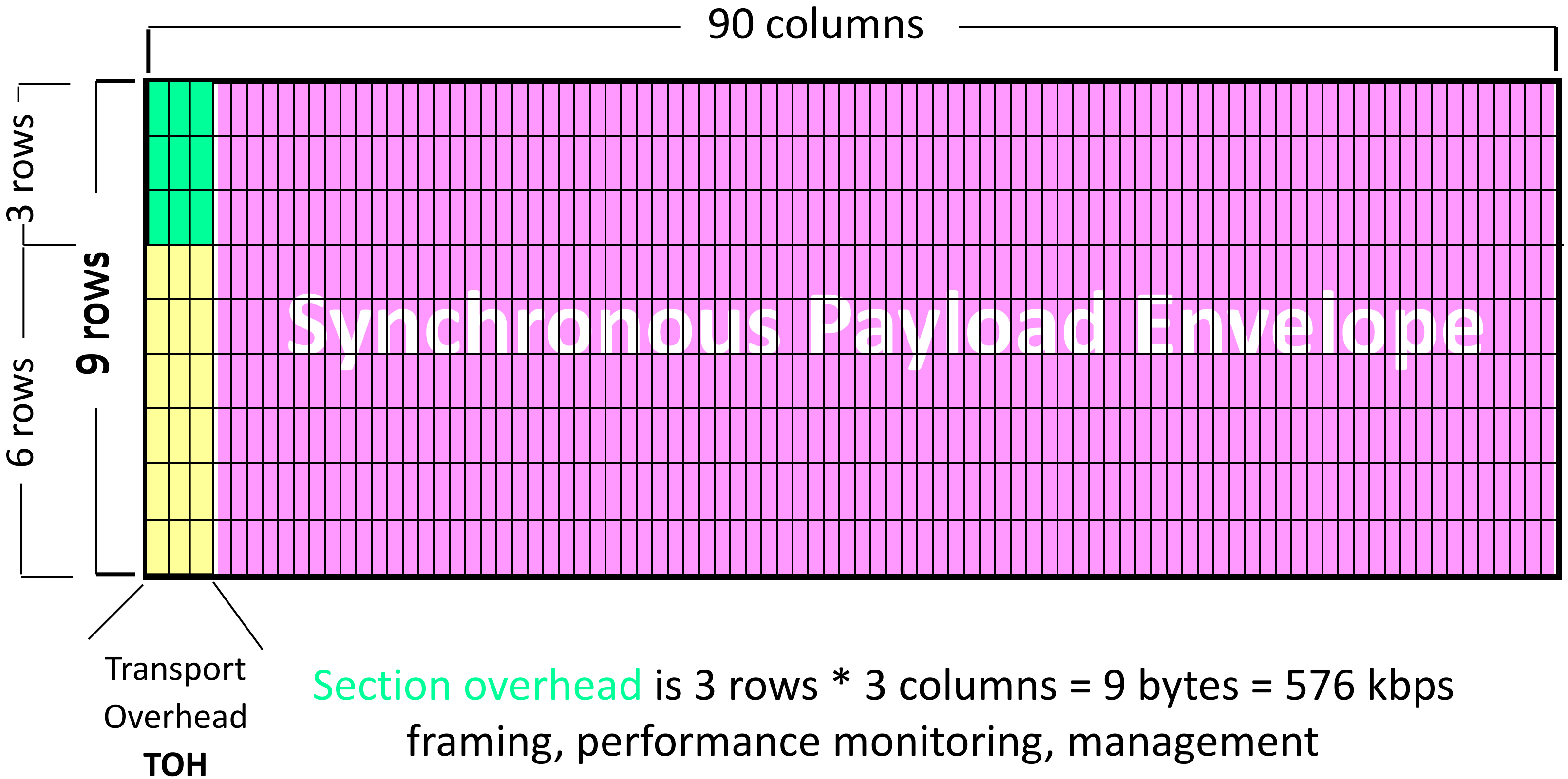
STS-1 Framing Structure



STS-1 Framing

- Bytes are transmitted one row at a time, from left to right
- Note: 1 byte/frame = 64 kbps
- First three columns of STS-1 frame are for section overhead and line overhead
- Remaining 87 columns are for the Synchronous Payload Envelope (SPE)

STS-1 frame structure



Section overhead is 3 rows * 3 columns = 9 bytes = 576 kbps
framing, performance monitoring, management

Line overhead is 6 rows * 3 columns = 18 bytes = 1152 kbps
protection switching, line maintenance, mux/concat, SPE pointer

SPE is 9 rows * 87 columns = 783 bytes = 50.112 Mbps

SONET Overhead

- Overhead bytes are used by SONET equipment (e.g., switches) for exchange of control and signalling information, and as a low bandwidth data channel
- Three types of overhead bytes
  - section
  - line
  - path

STS-1 Overhead

section overhead

A1	A2	J0
B1	E1	F1
D1	D2	D3
H1	H2	H3
B2	K1	K2
D4	D5	D6
D7	D8	D9
D10	D11	D12
S1	M0	E2

line overhead

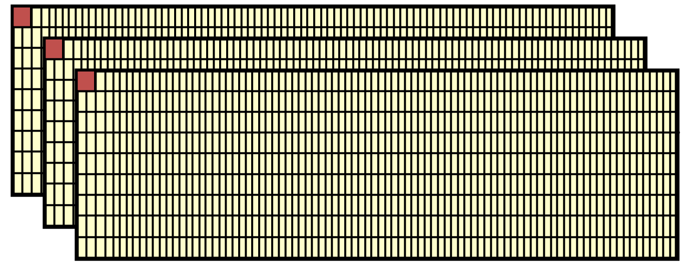
The STS-1 overhead consists of

- 3 rows of section overhead
  - frame sync (A1, A2)
  - section trace (J0)
  - error control (B1)
  - section orderwire (E1)
  - **E**mbedded **O**perations **C**hannel (Di)
- 6 rows of line overhead
  - pointer and pointer action (Hi)
  - error control (B2)
  - **A**utomatic **P**rotection **S**witching signaling (Ki)
  - Data Channel (Di)
  - **S**ynchronization **S**tatus **M**essage (S1)
  - **F**ar **E**nd **B**lock **E**rror (M0)
  - line orderwire (E2)

A1, A2, J0 (section overhead)

A1, A2 - framing bytes

- A1 = 11110110
- A2 = 00101000



SONET/SDH framing always uses equal numbers of A1 and A2 bytes

J0 - regenerator section trace (in early SONET - a counter called C1)

enables receiver to be sure that the section connection is still OK

enables identifying individual STS/STMs after muxing

J0 goes through a 16 byte sequence

MSBs are J0 framing (1000…00)

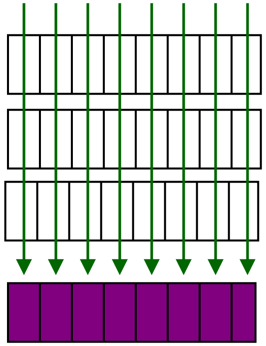
Cs are CRC-7 of previous frame

S are 15 7-bit characters

section access point identifier

1	C_1	C_2	C_3	C_4	C_5	C_6	C_7
0	S	S	S	S	S	S	S
…							
0	S	S	S	S	S	S	S

B1, E1, F1, D1-3 (section overhead)

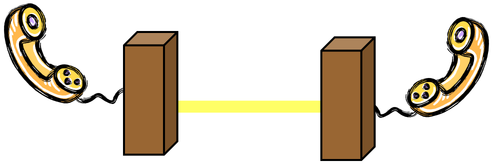


B1 – **B**yte **I**nterleaved **P**arity**-8** byte

even parity of bits of bytes of previous frame after scrambling

only 1 BIT-8 for multiplexed STS/STM

E1 – section orderwire



64 kbps voice link for technicians

from regenerator to regenerator

F1 – 64 kbps link for user purposes

D1 + D2 + D3 – 192 kbps messaging channel

used by section termination as **E**mbedded **O**perations **C**hannel (SONET)

or **D**ata **C**ommunications **C**hannel (SDH)

Pointers (line overhead)

In SONET, pointers are considered part of line overhead

For STS-1, H1+H2 is the pointer, H3 is the pointer action

H1+H2 indicates the offset (in bytes) from H3 to the SPE

To compensate for clock differences

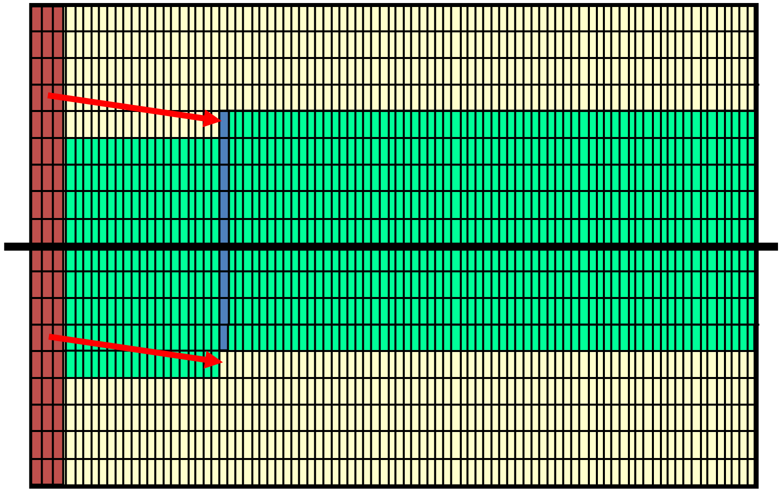
we have *pointer justification*

When *negative* justification

H3 carries the extra data

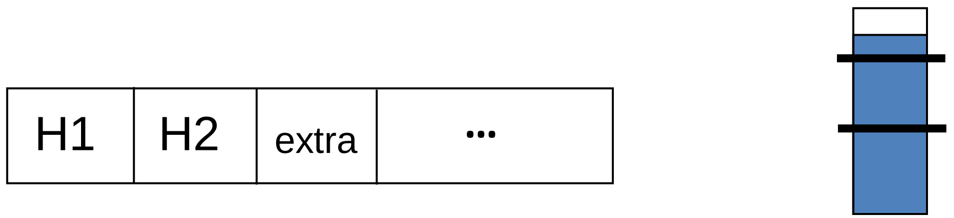
When *positive* justification

byte after H3 is stuffing byte

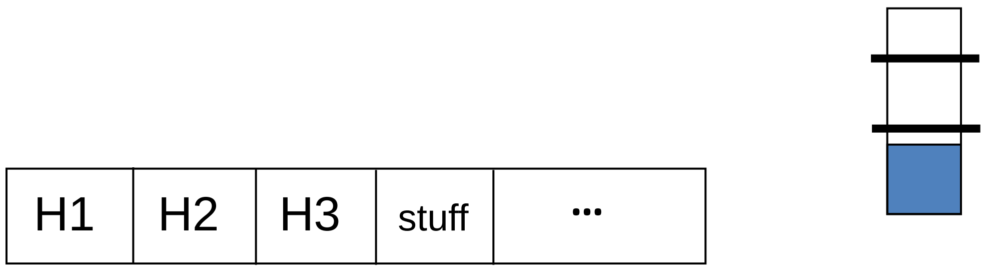


SONET Justification

If tributary rate is above nominal, negative justification is needed



If tributary rate is below nominal, positive justification is needed



B2, K1, K2, D4-D12 (line overhead)

B2 – BIP-8 of line overhead + previous envelope (w/o scrambling)

N B2s for muxed STM-N

K1 and K2 are used for Automatic Protection Switching (see later)

D4 – D12 are a 576 Kbps Data Communications Channel

between multiplexers

usually manufacturer specific

S1, M0, E2 (line overhead)

S1 – **S**ynchronization **S**tatus **M**essage

indicates stratum level (unknown, stratum 1, …, do not use)

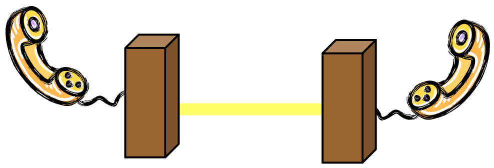
M0 – **F**ar **E**nd **B**lock **E**rror

indicates number of BIP violations detected

E2 – line orderwire

64 kbps voice link for technicians

from line mux to line mux



STS-1 Path overhead

J1
B3
C2
G1
F2
H4
F3
K3
N1

POH

1 column of overhead for path (576 Kbps)

POH is responsible for

- path type identification
- path performance monitoring
- status (including of mapped payloads)
- virtual concatenation
- path protection
- trace

J1, B3, C2 (path overhead)

J1 – path trace

enables receiver to be sure
that the path connection is still OK

B3 – BIP-8 even bit parity of bytes
(without scrambling)
of previous payload

C2 – path signal label

identifies the payload type
(examples in table)

C2 (hex)	Payload type
00	unequipped
01	nonspecific
02	LOP (TUG)
04	E3/T3
12	E4
13	ATM
16	PoS – RFC 1662
18	LAPS X.85
1A	10G Ethernet
1B	GFP
CF	PoS - RFC1619

G1, F2, H4, F3, K3, N1 (path overhead)

G1 – path status

conveys status and performance back to originator

4 MSBs are path FEBE, 1 bit RDI, 3 unused

F2 and F3 – user specific communications

H4 – used for LOP multiframe sync and VCAT (see later)

K3 (4 MSBs) – path APS

N1 – **T**andem **C**onnection **M**onitoring

Messaging channel for tandem connections

SONET/SDH rates

SONET	SDH	columns	rate
STS-1		90	51.84M
STS-3	STM-1	270	155.52M
STS-12	STM-4	1080	622.080M
STS-48	STM-16	4320	2488.32M
STS-192	STM-64	17280	9953.28M

STS-N has 90N columns   STM-M corresponds to STS-N with N = 3M

SDH rates increase by factors of 4 each time

STS/STM signals can carry PDH tributaries, for example:

- STS-1 can carry 1 T3 or 28 T1s or 1 E3 or 21 E1s
- STM-1 can carry 3 E3s or 63 E1s or 3 T3s or 84 T1s

- Next SDH……