SONET/SDH

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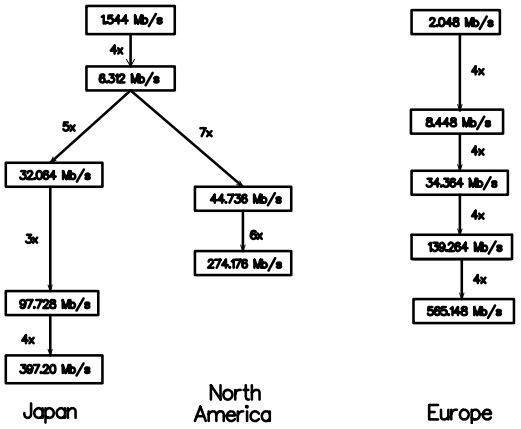
SONET/SDH

- **Synchronous Optical NETwork (*SONET*)**
- ***Synchronous Digital Hierarchy or SDH***
  - **ITU version for international standard**
- **Problems...**
  - **Need global telecommunications standard**
  - **Share signals between networks**
    - » **Ex., MCI to AT&T trunk without interface**
    - » **"Mid-fiber meet"**
  - **Standardize data rates**



SONET-2

- Synchronous network:
  - ☞ Has master clock
    - ✳ Controls timing of events all through network

SONET/SDH (cont.)

- Features...
  - Standardized digital interfaces for future data rates
  - Base rate: 51.84 Mb/s
    - » Frame format set so frame can carry...
      - DS3 signal (44.736 Mb/s) or...
      - Mixture of lower-rate signals (e.g., DS1, DS2)
  - Expandable to higher data rates
  - Use synchronous multiplexing and demulti-plexing
    - » Combine channels
    - » Simplify access to data payloads, and...
    - » Increase synchronization of network
  - Overhead channels for network maintenance

SONET-3

Optical Specifications

- Standard has several parts...
  - Optical interface
  - Operations specifications
  - Rates and formats specifications
- Optical specs
  - Wavelength: 1310 nm
    - 1280 $\rightarrow$ 1340 nm
    - Spectral width: $\leq$ 9 nm
  - Signal optical extinction ratio: 10:1
  - Coding: NRZ

Rates and Formats Specification

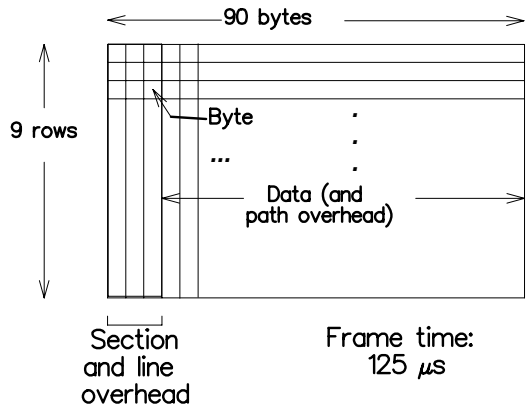
- **Key challenge:**
  - **Work with "pleisiochronous" signals (i.e., almost synchronous)**
  - ***Still* maintain synchronous network**
- **Solution**
  - **Incorporate feature giving high flexibility**
    - » **Payload "pointers"**
      - **Indicate location of data payload within SONET frame**

SONET-5

- Pleisiochronous:
  - ☞ Almost (but not quite) synchronous

Rates and Formats Specification (cont.): STS-1 Frame

- **Basic building block for US telcomm system**
  - **Synchronous Transport Signal-Level 1 (*STS-1*)**
- **Modeled as 90-column × 9-row structure of 8-bit bytes**
- **Transmitted at 51.84 Mb/s**
  - **One frame/125 μs**
- **First three columns...**
  - **Section overhead and line overhead bytes**
- **Remaining 87 columns... *Synchronous Payload Envelope* (SPE)**
  - **Data plus nine bytes of path overhead**

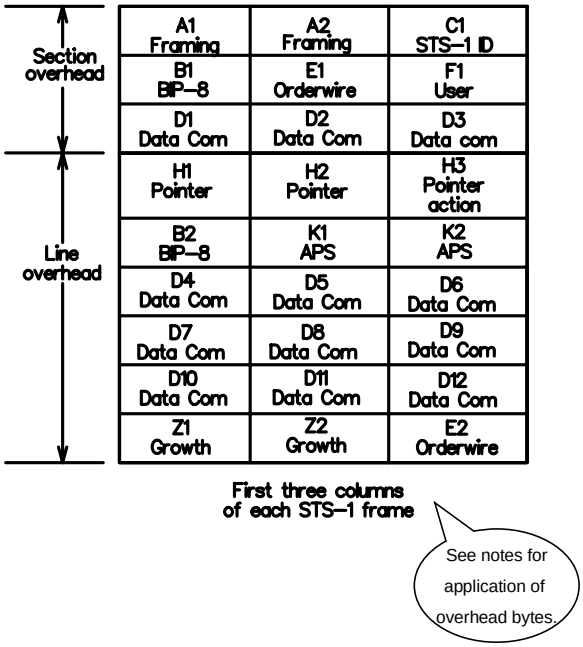


SONET-6

- One frame transmitted every 125 μs
  - ☞ Set by 64-kb/s voice sampling rate

Overhead Channels

- **Used to manage network**
- **Divided into**
  - **Section overhead**
  - **Line overhead**
  - **Path overhead**
- **Each overhead channel designed for different pieces of equipment in network**
- **Section overhead channel**
  - **Used by *all* SONET equipment**
- **Line overhead channel**
  - **Processed by all SONET equipment except repeaters**

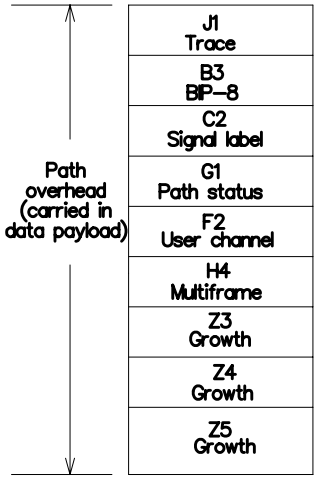


SONET-7

- Section overhead contents
  - ☞ Two framing bytes (A1 and A2): locates start of frame
  - ☞ STS-1 identification byte (C1)
  - ☞ 8-bit Bit-Interleaved-Parity (BIP-8) byte (B1); error check in section overhead
  - ☞ Orderwire byte (E1): sets up and takes down channel
  - ☞ Byte reserved for user applications (F1)
  - ☞ Three bytes for section overhead data (D1, D2, and D3) (e.g., maintenance or supply support data)
- Line overhead channel
  - ☞ STS-1 pointer (H1, H2, and H3); locates data relative to STS-1 frame (explained later)
  - ☞ 8-bit Bit-Interleaved-Parity (BIP-8) byte (B2); error check
  - ☞ 2-byte autoprotection switch (APS) message protection channel (K1 and K2); switch to backup components or implement user's protection scheme
  - ☞ 9 bytes of line overhead data (D4-D12)
  - ☞ 2 bytes reserved for future uses (Z1 and Z2)
  - ☞ Orderwire channel (E2): channel setup and takedown control messages

Overhead Channels (cont.): Path Overhead

- **Processed only by payload terminating equipment at destination**
  - **Located with data package**



SONET-8

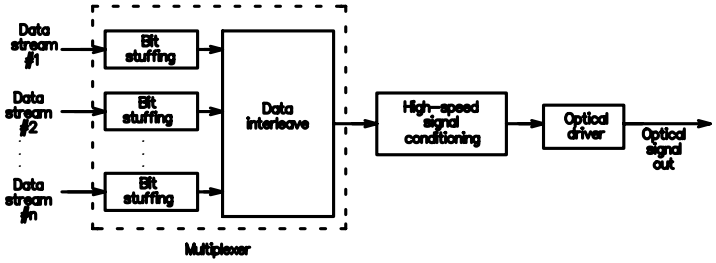
- Path overhead channel
  - ☞ Trace byte (J1); traces signal location through network elements
  - ☞ 8-bit Bit-Interleaved-Parity (BIP-8) byte (B3); error check
  - ☞ Signal-label byte (C2); identifies type of payload being carried
  - ☞ Path-status byte (G1); carries path maintenance signals
  - ☞ Byte reserved for user applications (F2)
  - ☞ Multiframe byte (H4); indicate DS0 signaling bit phase when carrying DS0 signals
  - ☞ 3 bytes (Z3, Z4, and Z5); reserved for future growth

Payload Pointer

- New feature introduced in SONET
  - Carried in line overhead
  - Provides multiplexing synchronization of pleisiochronous frames
  - Aligns frames in STS-N signals
- Low-data rate signals combined (multiplexed) into higher data rate signals for trunk transmission

Multiplexing Data Streams

- Usual multiplexing strategy
  - *Multiplexing*: interleave tributaries (Time-Domain Multiplexing - TDM)
  - Data streams already multiplexed; might be...
    - » US DS3 signal (44.736 Mb/s)
    - » European CEPT-4 signal (139.264 Mb/s)
    - » Japanese fifth-level signal (397.20 Mb/s)
- *Multiplexer* provides
  - Synchronization and
  - Addition of bits (*bit stuffing*)
    - » Performance monitoring and maintenance functions
- *High-speed signal conditioner* balances data
  - Avoid long strings of “0”s or “1”s
  - Inserts block codes



Bit Stuffing

- Two types of conventional multiplexing: *Bit-stuffing* and *Fixed-location mapping*

1. Bit-stuffing

- As signals are multiplexed together...
  - » Extra bits added to higher-speed channel to fill up capacity
  - » Ex., 4 1.544-Mb/s DS1 tributary channels multiplexed into 6.312 Mb/s DS2 stream
- Bit-stuffing indicators
  - » Included in frame at fixed positions
  - » Indicate whether stuffing bits contain
    - Useful system info or
    - Dummy bits
- Pro: accommodates signals with wide-varying clock speeds
- Con: requires de-stuffing at demultiplexer

SONET-11

Fixed-Location Mapping

2. *Fixed-Location Mapping*

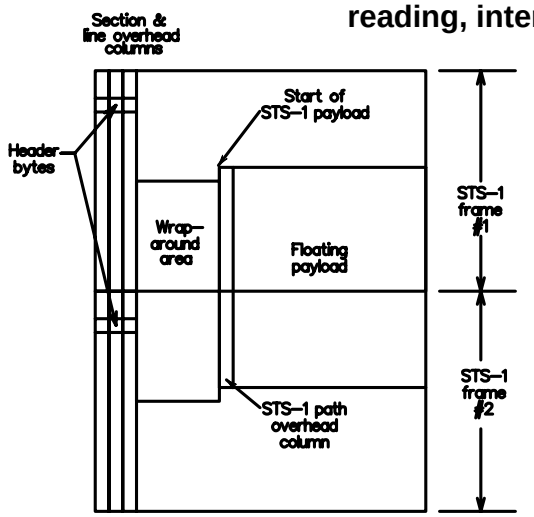
- **Tributaries mapped into fixed preassigned locations in main data stream**
- **Pro: easily multiplexed**
- **Con**
  - **Requires synchronized arrival at correct instant**
    - » **Highly synchronized networks (e.g., long-distance carriers), no problem**
      - **Misalignments due to propagation delays and other effects...**
        - **125 μs buffers ("slip buffers") in multiplexers**
        - **Aligns signals with respective slots**
  - ***Major* problem: multiplexing signals from sources with separate synchronizing clocks**
  - **Floating SONET payload potential solution**

Payload Alignment

- Two ways to align signal within STS-1 frame:
  - "Float" payload at arbitrary location within frame
    - Use payload pointer to indicate payload position
  - Rigidly fix location of payload
    - Require system timing meet requirements

Floating Payload

- SONET innovation: handles signals not synchronized by master clock
- "Payload pointer"
  - Contained in H1,H2 bytes of line overhead
  - Indicates starting-byte location of payload
- Payload floats vertically and horizontally within STS-1 frame
  - Late-starting payloads allowed to overlap into following STS-1 frame
- Disadvantage:
  - Requires pointer generation, reading, interpretation

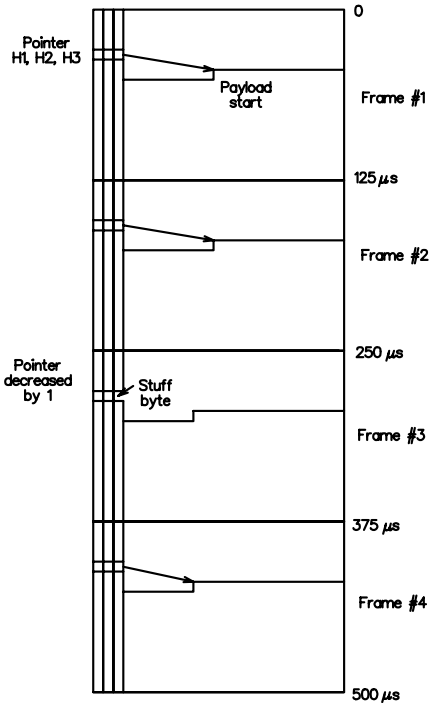


SONET-14

- In SONET, DS3 signal mapped into STS-1 frame directly
  - ☞ No data buffers or master synchronization of signals is required

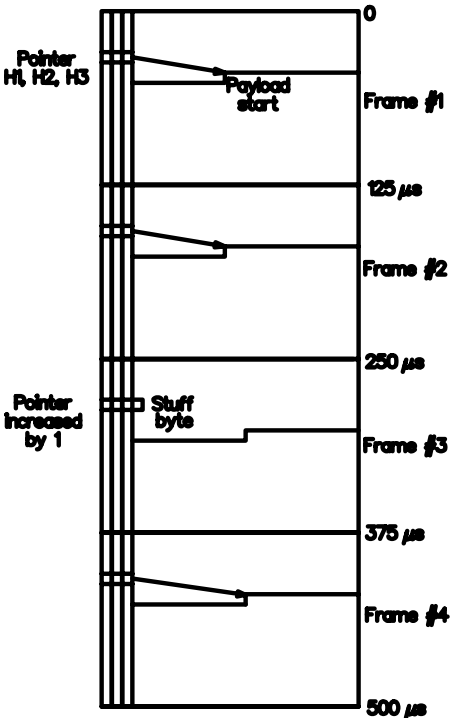
Floating Payload (cont.)

- **Accommodates data slippage due to slight differences in data and STS-1 clocks**
  - **Ex., data clock slightly faster than frame clock**



SONET-15

- Method of handling data slippage without lengthy data delays
  - ☞ One primary advantage of floating-payload structure
- Slower data handled in similar fashion...

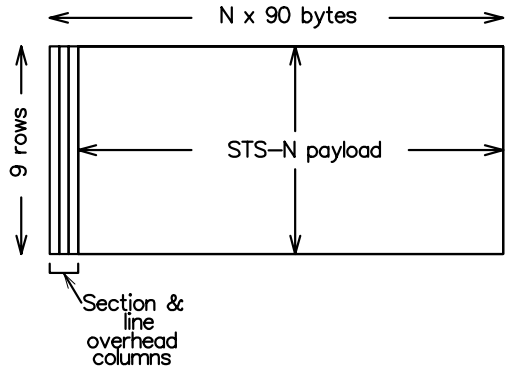


Fixed Payloads

- Alternative frame use
- Assign payload to rigidly-defined fixed location in STS-1 frame
  - Payload *not* allowed to float
    - » Fits into exactly same location in every frame
  - Accomplished by rigid synchronization of data clock with frame clock

Broadband Signal Handling

- One of SONET primary advantages
- Upward mobility to data-rates > DS3
  - Allowed SONET as international standard
  - European standard of 139.264 Mb/s
    - » Cannot use STS-1 frame alone for signals
- *STS-N frame:*
  - Byte interleave *N* STS-1 frames into larger frame
  - N $\times$ 90 columns (bytes) wide by 9 rows high
  - Duration: 155 μs; bit rate: N x 51.84 Mb/s
  - Ex., 3 STS-1 frames multiplexed for 139 Mb/s European rate



Broadband Signal Handling (cont.)

- **Payload pointers used to multiplex *N* STS-1 frames to STS-N levels**
  - **Section/line overhead bytes of first STS-1 frame used for overhead info**
  - **Overhead bytes in rest of frames not used**
- **STS-N frame scrambled**
  - **Avoid long strings of "0"s or "1"s**
- **Converted to *Optical Carrier-Level N (OC-N)* signal**
  - **Line rate: *N* times rate of OC-1 signal rate**

Level	Line rate (Mb/s)
OC-1	51.84
OC-3	**155.52**
OC-9	466.56
OC-12	**622.08**
OC-18	933.12
OC-24	1,244.16
OC-36	1,866.24
OC-48	**2,488.32**
OC-192	**9,953.28**
OC-768	**~40,000**

Compatibility

- **Proposed as method of ensuring compatibility of equipment, *BUT*….**
  - **SONET standard does not completely specify *all* possible permutations and combinations**
  - **e.g., some of overhead bytes are left for user applications**
    - » **Users ensure that applications do not conflict**
- **Needs to be done to ensure and demonstrate compatibility of SONET equipment**
- **Neutral test sites established**

SONET-19

SONET Summary

- Global telecommunications standard
- Common data rates
- Common transmission rates (OC-x)
- Inter-compatibility of equipment
- Standard wrapper for data (STS-1 frame)
- Multiple frames possible

SONET-20