EEEN 464 – DIGITAL COMMUNICATION

SYCHRONOUS OPTICAL NETWORK (SONET) - STUDY GUIDE/REVISION

OBJECTIVE

Understand SONET's role in optical transport networks, its frame structure, multiplexing, synchronization, and key advantages over Plesiochronous Digital Hierarchy (PDH).

1. CORE CONCEPTS & HISTORICAL CONTEXT

- **What is SONET?**
  Synchronous Optical Network: A standardized protocol for high-speed data transmission over fiber optics. Developed in the 1980s (ANSI standard) to replace PDH.
- **Why SONET?**
  - Solved PDH limitations:
    - Lack of synchronization → **Clocks locked to a Primary Reference Clock (PRC)**.
    - Poor management → **Embedded overhead bytes** for OAM.
    - Inefficient add/drop → **Direct access** to tributaries without full demux.
  - Enabled multi-vendor interoperability.
- **SDH vs. SONET**
  - **SONET** (North America/ANSI), **SDH** (Global/ITU-T).
  - Compatible: STS-3c = STM-1 (155.52 Mbps).

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2. SONET Layers & Architecture

- **Layered Model** (Bottom-up):
  1. **Photonic Layer**: Optical pulses (light wavelengths).
  2. **Section Layer**: Between repeaters/amplifiers (e.g., error monitoring).
  3. **Line Layer**: Between multiplexers (e.g., pointer adjustment, protection switching).
  4. **Path Layer**: End-to-end payload transport (e.g., virtual containers).

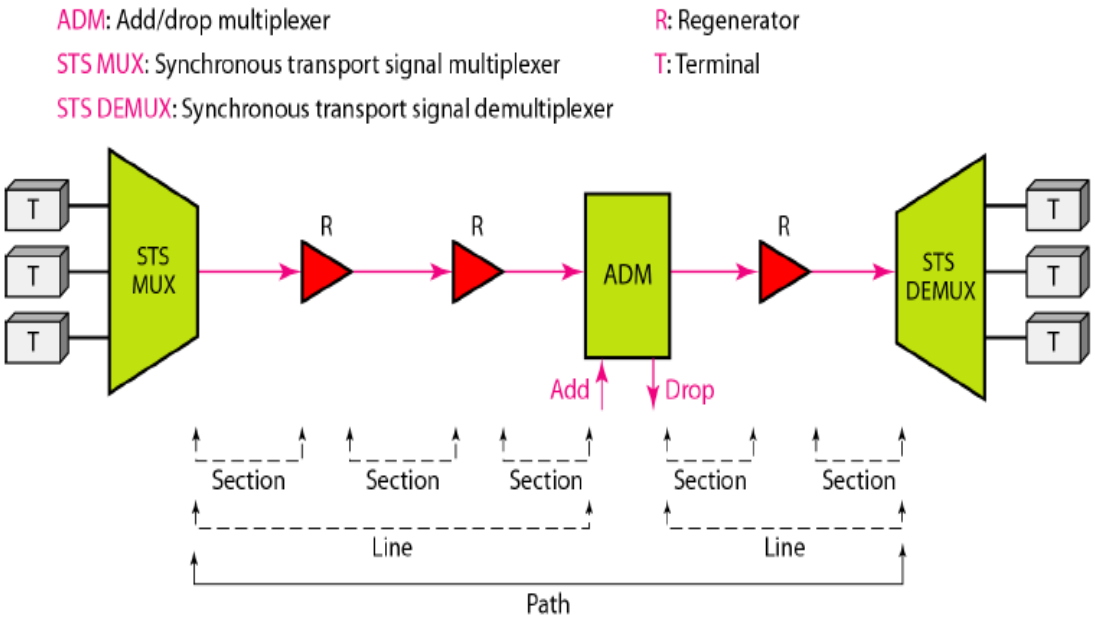

Figure 1. SONET architecture

- **Key Equipment**:
  - **Terminal Multiplexer (TM)**: Aggregates signals into STS-N.
  - **Add-Drop Multiplexer (ADM)**: Adds/drops tributaries mid-span.
  - **Digital Cross-Connect (DXC)**: Switches STS signals.
  - **Regenerator**: Amplifies optical signals.

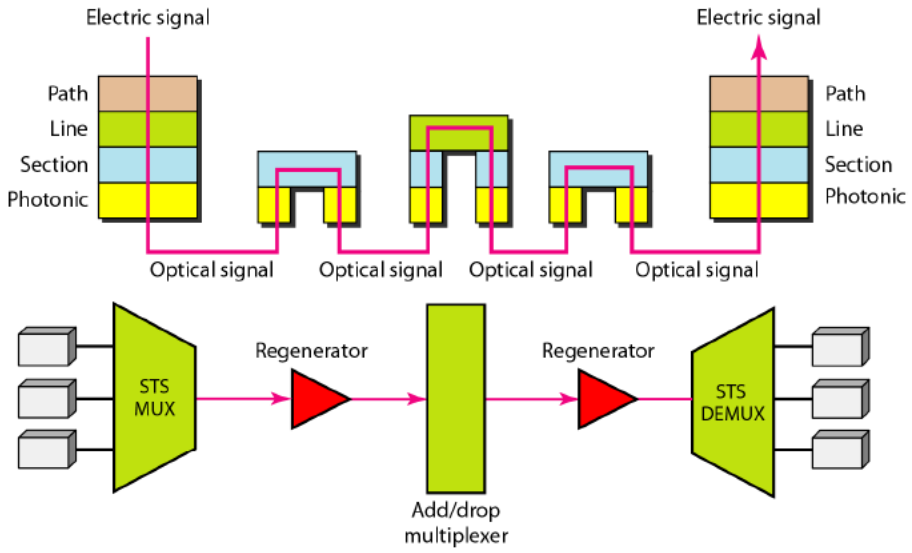

Figure 2. SONET architecture and layers

3. FRAME STRUCTURE & OVERHEAD BYTES

- **STS-1 Frame**:
  - **Size**: 9 rows × 90 columns = 810 bytes.

- **Duration**: 125 µs (8,000 frames/sec → matches voice sampling).
- **Structure**:
  - **Transport Overhead (TOH)**: First 3 columns (27 bytes).
  - **Synchronous Payload Envelope (SPE)**: 87 columns (payload + Path Overhead).

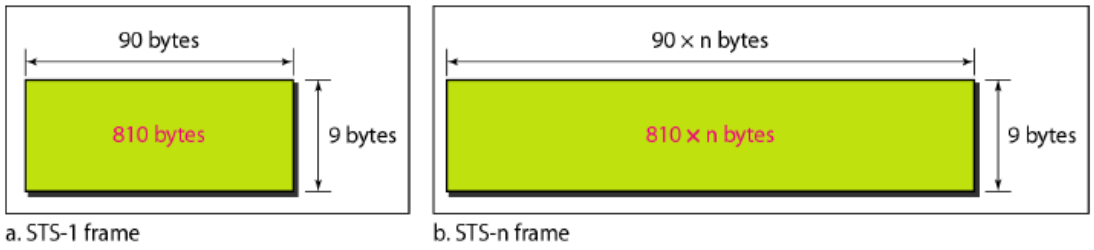

Figure 3. Frame structure

- **Overhead Functions**:

Layer	Key Bytes	Function
Section	A1/A2 (Framing)	Frame alignment
	B1 (BIP-8)	Section error check
Line	H1-H3 (Pointers)	SPE location
	K1/K2	Protection switching
Path	J1 (Trace)	Path ID verification
	B3 (BIP-8)	Path error check

4. KEY MECHANISMS

- **Synchronization**:
  - All nodes sync to a **PRC** (Stratum 1 clock, $\pm 1 \times 10^{-11}$ accuracy).
  - Eliminates bit stuffing; enables direct access to tributaries.
- **Pointers (H1-H3 Bytes)**:
  - Compensate for minor clock differences by **adjusting SPE start position**.
  - Allow "float" of payload within frame.
- **Concatenation**:
  - **STS-3c**: Fuses 3 STS-1s → single 155.52 Mbps payload (for ATM/IP).
  - Avoids fragmentation of large data streams.

5. SONET RATES & MULTIPLEXING

- **Hierarchy** (Common Rates):

SONET	SDH	Bit Rate	Payload Capacity
STS-1/OC-1	-	51.84 Mbps	50.112 Mbps
STS-3/OC-3	STM-1	155.52 Mbps	150.336 Mbps
STS-12/OC-12	STM-4	622.08 Mbps	601.344 Mbps
STS-48/OC-48	STM-16	2.488 Gbps	2.405 Gbps

- **Multiplexing Rules**:
    - **Byte-Interleaving**: STS-N combines *N* STS-1 frames (e.g., STS-3 = 3×STS-1).
    - **Payload Mapping**:
        - DS1 (1.544 Mbps) → VT1.5 → STS-1.
        - DS3 (44.736 Mbps) → STS-1 SPE.
        - ATM/IP → STS-3c/STM-1.

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6. PROTECTION & RESILIENCE

- **Automatic Protection Switching (APS)**:
    - Restores traffic in <50 ms after failure.
    - Uses K1/K2 bytes for signaling.
- **Ring Architectures**:
    - **UPSR (Unidirectional Path-Switched Ring)**:
        - 2 fibers, duplicates traffic on primary/backup paths.
        - Simple, used in access networks.
    - **BLSR (Bidirectional Line-Switched Ring)**:
        - 2 or 4 fibers, shares protection bandwidth.
        - Efficient, used in core networks.

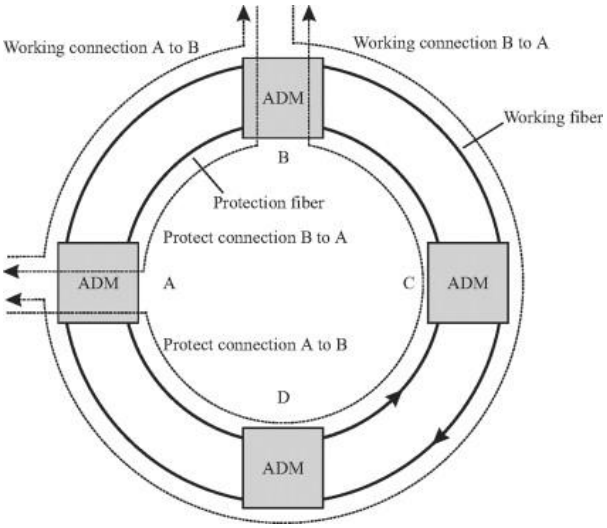

Figure 4. SONET Ring Protection

7. ADVANTAGES OVER PDH

1. **Synchronization**: No bit stuffing → simpler multiplexing.
2. **OAM Capabilities**: Embedded overhead → real-time monitoring.
3. **Direct Add/Drop**: Access tributaries without demuxing entire hierarchy.
4. **Scalability**: Smooth upgrade to higher rates (e.g., OC-192 to OC-768).
5. **Multi-Vendor Interoperability**: Standardized optical interfaces.

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8. LIMITATIONS & EVOLUTION

- **Limitations**:
  - Fixed frame size → inefficient for packet traffic.
  - Complexity for data-centric networks.
- **Evolution to Packet-Optical**:
  - **OTN (Optical Transport Network)**: Encapsulates SONET/SDH, Ethernet, IP.
  - **DWDM (Dense Wavelength Division Multiplexing)**: Boosts fiber capacity.

9. KEY STUDY TOPICS

- **Memorize**: STS-1 frame structure, overhead byte functions, common rates.
- **Explain**: Pointers, synchronization, ring protection (UPSR vs. BLSR).
- **Compare**: SONET vs. PDH, SONET vs. OTN.
- **Calculate**: Payload capacity (e.g., STS-1 = 87 cols × 9 rows × 8 bits × 8000 frames/sec).
- **Draw**: STS-1 frame, ring topologies, multiplexing hierarchy.

10. REAL-WORLD APPLICATIONS

- Legacy telecom backbone (still in use).
- Cellular backhaul (4G/LTE).
- Underlying transport for **MPLS** and **Ethernet** services.
- Migration path to **IP/MPLS** and **SDN**.

STUDY RESOURCES

- **Books**: *Optical Networks* (Rajiv Ramaswami), *SONET/SDH Demystified* (Steven Shepard).
- **RFCs**: RFC 1619 (PPP over SONET), RFC 3637 (SONET MIB).
- **Tools**: Wireshark (SONET decoding), OPNET/GNS3 for labs.
- **Videos**: IEEE ComSoc lectures on optical networking.

EXAM TIPS

Focus on **STS-1 structure**, **overhead byte roles**, and **how SONET solved PDH problems**. Practice mapping DS1/E1 into SONET frames!

Summary: SONET revolutionized optical transport via synchronization, embedded OAM, and efficient multiplexing. While newer technologies (OTN, DWDM) dominate, its principles underpin modern networks.