EEEN 464 – DIGITAL COMMUNICATION

PLESIOCHRONOUS DIGITAL HIERARCHY (PDH) STUDY GUIDE

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1. CORE CONCEPT & DEFINITION:

1. **Plesiochronous:** From Greek "plesio" (near) + "chronos" (time). Clocks at different network nodes run at *almost* the same rate but not *exactly* synchronized. Slight variations (within tolerance) exist.
2. **Digital Hierarchy:** A standardized method for multiplexing (combining) lower-speed digital channels (like voice calls) into higher-speed aggregate signals for efficient transmission over cables (originally copper, later fiber).
3. **Goal:** Efficiently combine thousands of individual voice channels (64 kbps each - DS0) onto high-capacity trunk lines for long-distance telephony.

2. WHY PLESIOCHRONOUS DIGITAL HIERARCHY (PDH)?

- Replaced analogue carrier systems (like AM and FDM).
- Enabled digital switching and transmission advantages (better quality, regeneration, integration with digital switches).
- Provided a structured way to build higher capacity links from standardized lower-level building blocks.
- Solved the problem of aggregating streams from slightly different clocks.

3. KEY CHARACTERISTICS

- **Asynchronous Multiplexing:** Multiplexing signals derived from *independent* clocks (same nominal rate, slight variation).
- **Bit Stuffing (Justification):** The core technique to handle clock differences. Extra "stuffing" bits are inserted into the tributary streams *before* multiplexing to temporarily raise their rate to match the multiplexer's internal clock. Stuffing locations are indicated by control bits.
- **Layered Hierarchy:** Standardized rates build upon each other (e.g., E1 -> E2 -> E3 -> E4).
- **Regional Standards:** Three main "families":
    - **ITU:** Based on E1 (2.048 Mbps). Predominant in Europe, Africa, Asia-Pacific (mostly), South America.
    - **North American (ANSI):** Based on T1 (1.544 Mbps). Predominant in North America, Japan, South Korea.

- Japanese: Variant of the North American hierarchy.

- **Management Overhead:** Limited management capabilities embedded within the frame structure (alarm bits, error checking - CRC-4 in later E1 frames). Difficult to manage individual channels in higher aggregates.

4. THE BUILDING BLOCKS & HIERARCHY (FOCUS ON E1 & T1)

- **DS0 (Digital Signal Level 0):** The fundamental 64 kbps channel. Carries one digitized voice call (PCM) or data.
- **E1 (ITU 1st Level):**
    - **Rate:** 2.048 Mbps
    - **Structure:**

    a) 1 Frame = 32 Time Slots (TS).
    b) TS0 used for framing/alignment/synchronization.
    c) TS16 used for signalling (call setup/teardown) for the 30 voice channels (TS1-TS15 & TS17-TS31).
    d) 8000 frames/sec (125 μs/frame).

    - **Capacity:** 30 x 64 kbps voice channels + 1 x 64 kbps signaling + 1 x 64 kbps framing/management = 2.048 Mbps.

- **T1 (DS1 - North American 1st Level):**
    - **Rate:** 1.544 Mbps
    - **Structure:** 1 Frame = 24 DS0 channels + 1 framing bit (193 bits total). Superframe (SF - 12 frames) or Extended Superframe (ESF - 24 frames) structures used for synchronization and limited management/crc.
    - **Capacity:** 24 x 64 kbps voice channels = 1.536 Mbps + 8 kbps overhead = 1.544 Mbps. Signaling is often carried "in-band" (robbed bit signaling - 8th bit of every 6th frame per channel).
- **Higher Levels (Multiplexing):**
    - **European (E-Carrier):**
        - E1 = 2.048 Mbps (30 Ch)
        - E2 = 8.448 Mbps (4 x E1 + Stuffing Overhead)
        - E3 = 34.368 Mbps (4 x E2 + Stuffing Overhead)
        - E4 = 139.264 Mbps (4 x E3 + Stuffing Overhead)
        - E5 = 565.148 Mbps (4 x E4 + Stuffing Overhead - Less common)

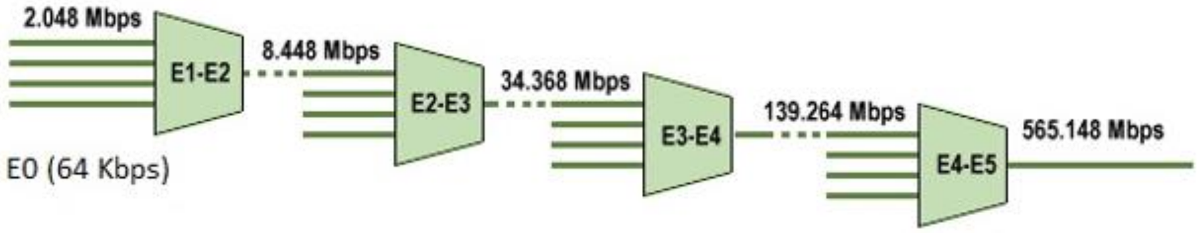

Figure x. Higher levels of PDH

- **North American (T/DS-Carrier):**
  - T1 (DS1) = 1.544 Mbps (24 Ch)
  - T2 (DS2) = 6.312 Mbps (4 x T1 + Stuffing Overhead)
  - T3 (DS3) = 44.736 Mbps (7 x T2 + Stuffing Overhead) OR (28 x T1 + Stuffing Overhead)
  - T4 (DS4) = 274.176 Mbps (6 x T3 + Stuffing Overhead) – Rare

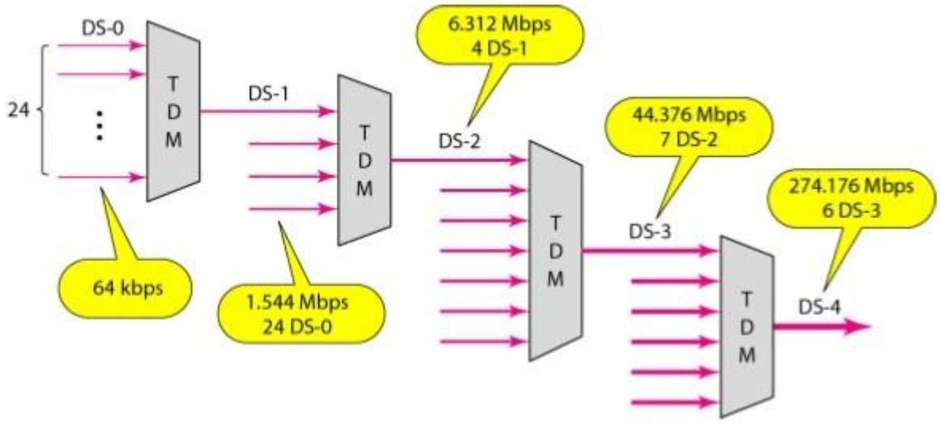

Figure x. Higher levels in North American (T/DS-Carrier)

- **Japanese (J-Carrier):**
  - J1 = 1.544 Mbps (Similar to T1)
  - J2 = 6.312 Mbps (Similar to T2)
  - J3 = 32.064 Mbps (5 x J2 + Stuffing)
  - J4 = 97.728 Mbps (3 x J3 + Stuffing) - Differs significantly from E3/T3.

5. FRAME STRUCTURE & BIT STUFFING (ILLUSTRATIVE - E1 FOCUS):

- **Frame:** 32 TS * 8 bits = 256 bits. Transmitted every 125 μs -> 2.048 Mbps.
- **TS0:** Carries alternating frame alignment word (FAW) in even frames (0011011) and alarm/management bits (e.g., CRC-4, Remote Alarm Indication - RAI) in odd frames.

- **TS16:** Carries signaling messages for the 30 voice channels (e.g., 4 bits per channel per frame, interleaved over multiple frames).
- **Bit Stuffing (Higher Levels):** Before combining four E1s into an E2:
    1. Each E1 input has a slightly different clock rate (within tolerance).
    2. The E2 multiplexer has its own master clock.
    3. The multiplexer adds extra "stuffing" bits into each E1 stream to temporarily increase its bit rate to match the internal rate needed for multiplexing.
    4. Control bits within the E2 frame overhead indicate *where* stuffing bits were inserted (so the demultiplexer can remove them).
    5. The four "justified" E1 streams + overhead bits are interleaved to form the E2 stream (8.448 Mbps).

6. LIMITATIONS OF PLESIOCHRONOUS DIGITAL HIERARCHY (PDH)

a) **Asynchronous Multiplexing Complexity**
   - Requires multi-stage multiplexing/demultiplexing (MUX/DEMUX) to access individual low-rate channels buried in high-rate streams (adding cost, delay, potential points of failure).
   - "Climbing the hierarchy" is inefficient and cumbersome.

b) **Limited Management Capabilities**
   - Poor Operations, Administration, and Maintenance (OAM) features.
   - Difficult to monitor performance, isolate faults, or reconfigure remotely.
   - Management bits are minimal and often tied to specific frame levels.

c) **Lack of Standardization**
   - Incompatible hierarchies (E1 vs T1 vs J1) make international interconnection complex and require expensive gateways.
   - No standard optical interface - vendor-specific.

d) **Inefficient Bandwidth Utilization:** Significant overhead required for stuffing, framing, and limited management.

e) **Scalability Issues:** Adding/dropping channels mid-stream ("Add-Drop") is very difficult and typically requires full demultiplexing to the lowest level (DS0).

7. WHY SDH/SONET REPLACED PDH

1. **Synchronous Operation:** All network elements locked to a highly stable Primary Reference Clock (PRC). Eliminates need for bit stuffing.

2. **Direct Access:** Allows direct Add/Drop of lower-rate channels from high-speed streams without full demultiplexing.
3. **Powerful OAM:** Extensive, standardized overhead bytes for monitoring, fault detection, performance reporting, and configuration.
4. **Global Standards:** SDH (ITU-T - Global) and SONET (ANSI - Primarily NA) are compatible, enabling seamless international networks. Defined optical interfaces.
5. **Higher Speeds & Scalability:** Supported much higher initial speeds (STM-1/OC-3 = 155.52 Mbps) and easier scaling.
6. **Resilience:** Built-in protection switching mechanisms (e.g., 1+1, 1:1).

8. IS PDH STILL USED?

a) Last-mile access connections (e.g., E1/T1 leased lines for business PBX connections, GSM base station backhaul in older sites).

b) Within older enterprise networks.

c) Remote locations where upgrading infrastructure is uneconomical.

d) As tributaries feeding into SDH/SONET or modern packet-based networks (via PDH interfaces on equipment).

9. KEY STUDY TOPICS & QUESTIONS

1. Define "plesiochronous" and explain why it was necessary.
2. Describe the core problem PDH solves (multiplexing async streams).
3. Explain **Bit Stuffing (Justification)** in detail - why, how, where indicated.
4. Draw/describe the **E1 frame structure** (TS0, TS16, payload).
5. Draw/describe the **T1 frame/Superframe/ESF** structure.
6. Memorize the **core rates** for E1, E2, E3, E4 and T1, T2, T3.
7. Understand the **multiplexing steps** (e.g., How many E1s make an E2? How many bits added?).
8. List and explain the **major limitations** of PDH (Management, Access, Standardization, Stuffing).
9. Contrast PDH with **SDH/SONET** (Synchronization, OAM, Add-Drop, Standards).
10. Explain **DS0** as the fundamental channel.
11. Understand the regional differences (E-carrier vs T-carrier).

10. VISUAL AIDS TO SEEK OUT:

- Diagrams of E1 and T1 frame structures.
- Diagrams illustrating the PDH multiplexing hierarchy (European & North American).
- Diagrams explaining bit stuffing in a multiplexer.

- Block diagrams showing the complexity of accessing a single DS0 within a high-level PDH stream vs. direct access in SDH.

11. STUDY TIPS

- **Start with E1/T1:** Master these fundamental building blocks first.
- **Focus on Bit Stuffing:** This is the key technical concept enabling PDH.
- **Compare & Contrast:** Constantly compare PDH limitations to SDH/SONET solutions.
- **Memorize Rates:** Know the key hierarchy levels (E1, E3, T1, T3 are most critical).
- **Understand the "Why":** PDH was revolutionary for its time; understand the problems it solved in the context of transitioning from analog to digital telephony.