Cellular Networks
Introduction

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General Information

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Course Load

- Grading Policy
  - Assignments:/paper readings 10~15%
  - Project: 25~30%
  - Midterm:40%
  - Final: 2%

Roadmap

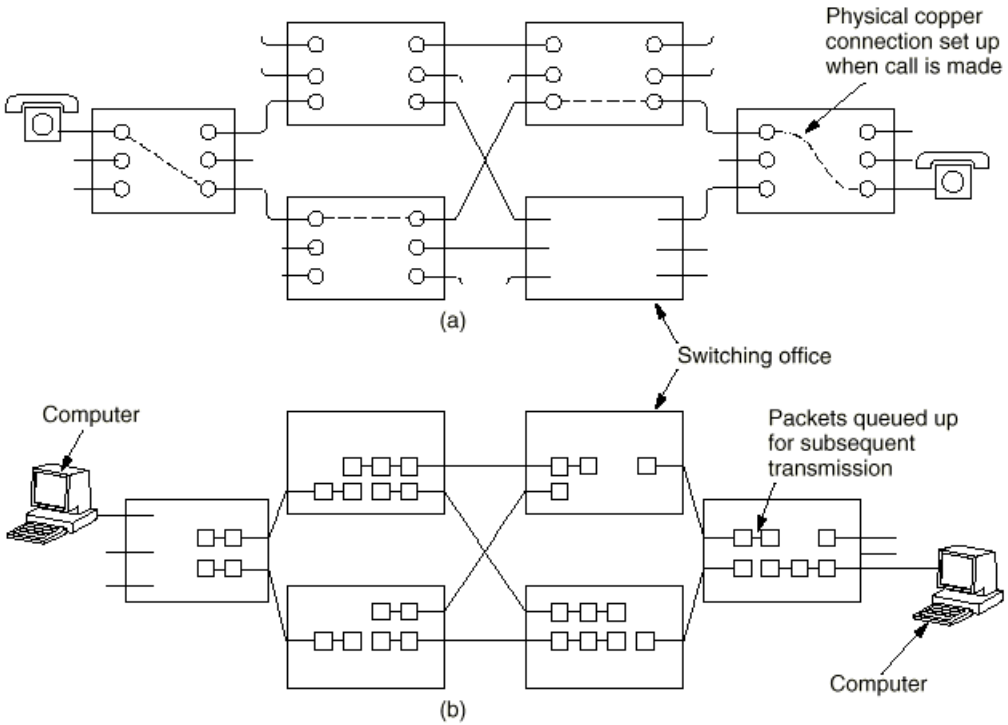
- Goal: Anything in cellular networks except physical layer.
  - Public Switched Telephony Network (PSTN)
  - Cellular Core Networks
    - GSM, GPRS, and EDGE,
    - 3GPP 3G (UMTS/HSPA)
    - 3GPP 4G (EPC)
  - Mobility models and managements, handoff, location management
  - 5G Technology

Network Types

- Telephone networks
  - Public switched networks for voice service.
- Computer networks
  - Mainly Internet.
  - Every Intranet employing packet switching concept.
  - Players:
    - User LANs
    - Server network LANs.
    - Internet service providers.
- Communication networks
  - Usually referred to wireless networks but not limited to.
  - Wireless ad-hoc/mesh networks are examples.
- Cellular networks:
  - Originally a wireless telephone network
  - Now, part of Internet.
  - Cellular service providers (operators)

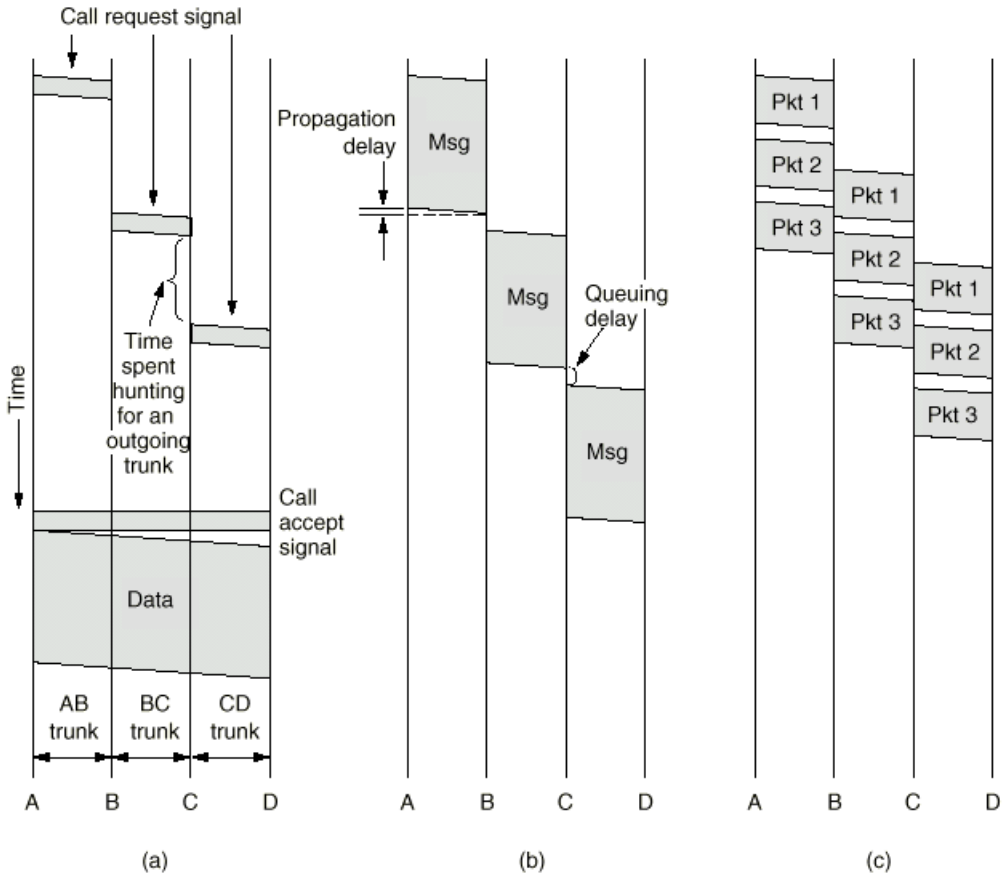
Switching

- **Circuit switching**
  - Dedicated (reserved) path established between source and destination
  - Long set-up time: O(10 sec)
  - No congestion change: guaranteed bandwidth
  - No extra random delay while call is established.
    Only transport delay
  - Unused bandwidth is wasted
  - Transparent to data
    format and framing
    mode. (road vs. railroad)



Switching

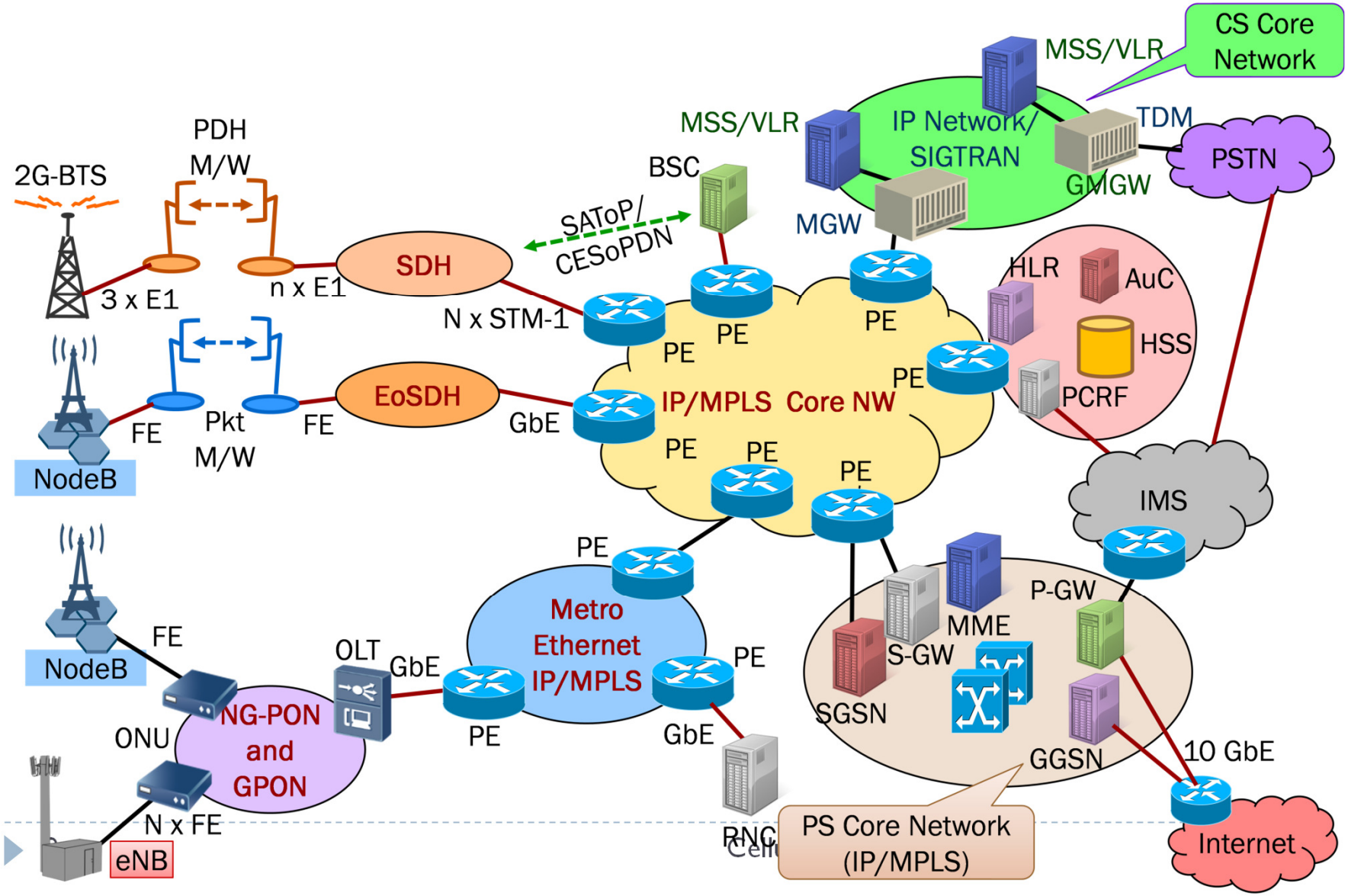
- **Packet switching**
  - Store-and-forward technique used
  - No dedicated path
  - Packet size should be limited in order not to block switches and/or overflow buffers
  - First packet is forwarded while second is received.
  - Rate conversion is easy
  - Delivery order may not be guaranteed



Cellular Networks

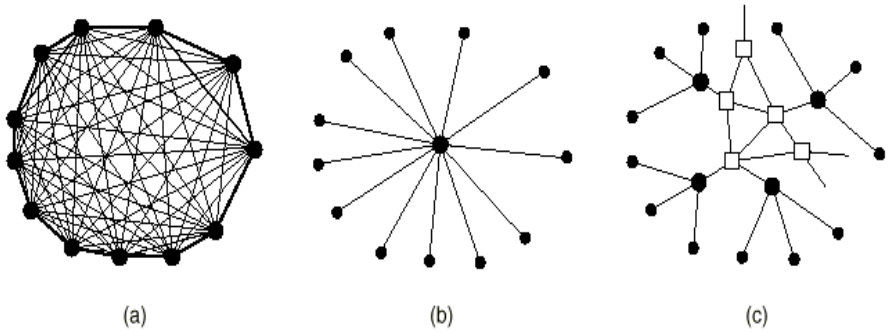
- Original providing voice service for fixed users.
- Service provisioning moved to mobile users.
- Data is added as the secondary service.
  - Connection to the Internet becomes necessary.
- Data becomes dominant in cellular networks.
- Voice moved as a secondary service.

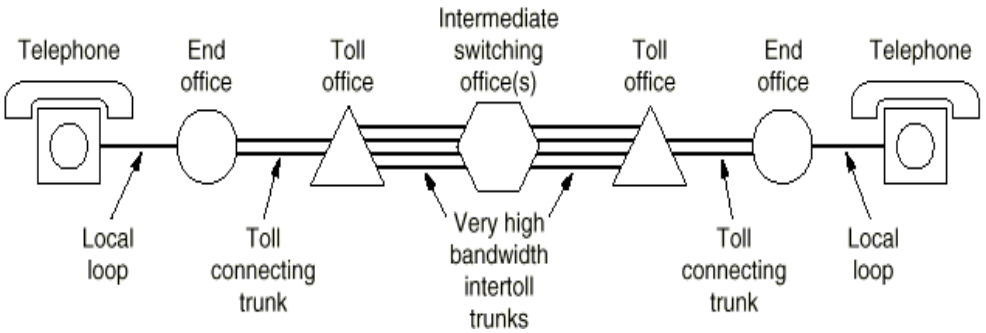
Cellular Networks



Telephone system

- Public Switched Telephone Network (PSTN)
  - Originally designed to transmit human voice
  - Loop plant with Limited bandwidth and complex interference environment
- Telephone system organization: hierarchical network with three important components:
  - Local loops:
  - Switching centers:
    - end office, local exchange, tandem, toll office
  - Trunks





Switch Hierarchy, an example

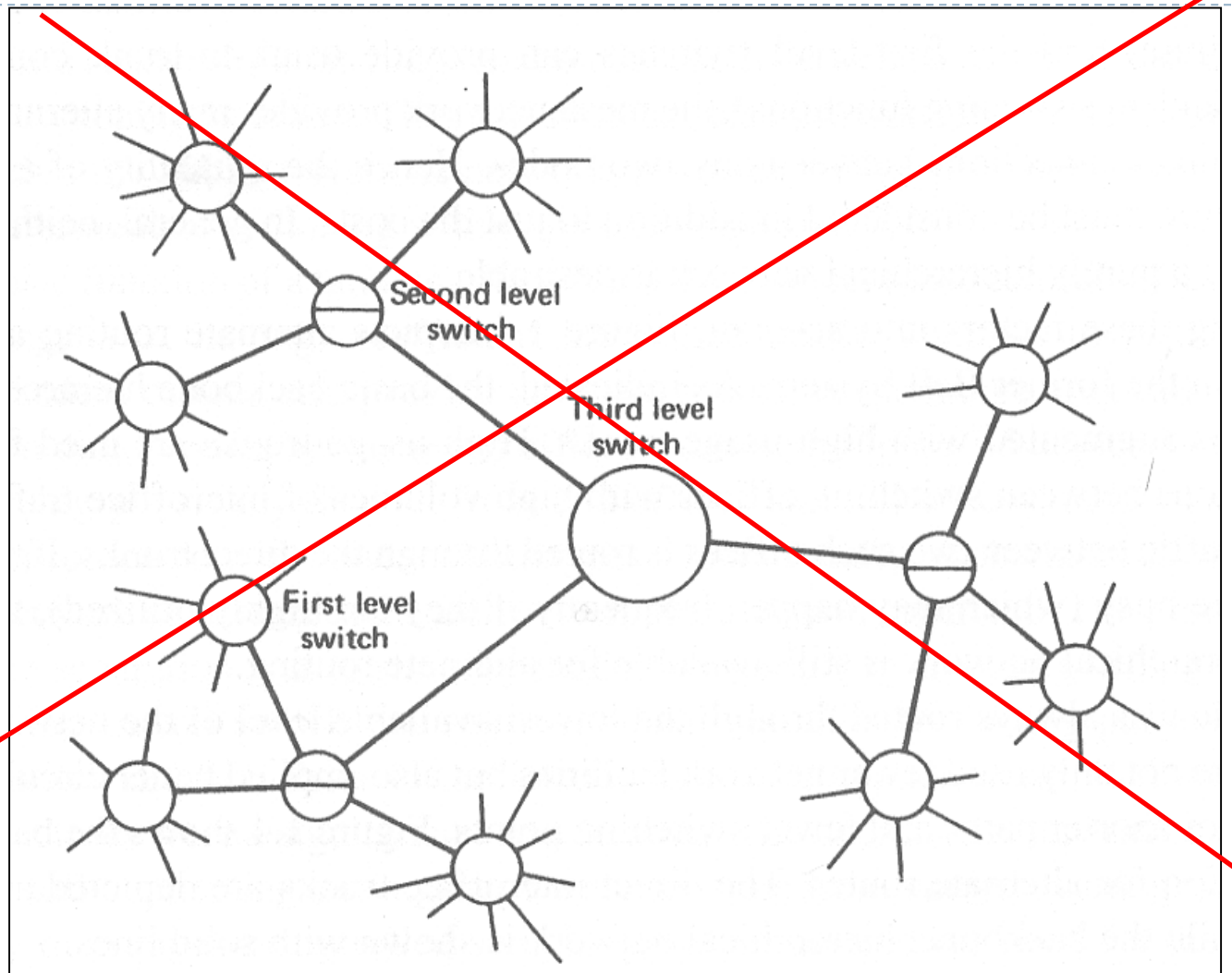


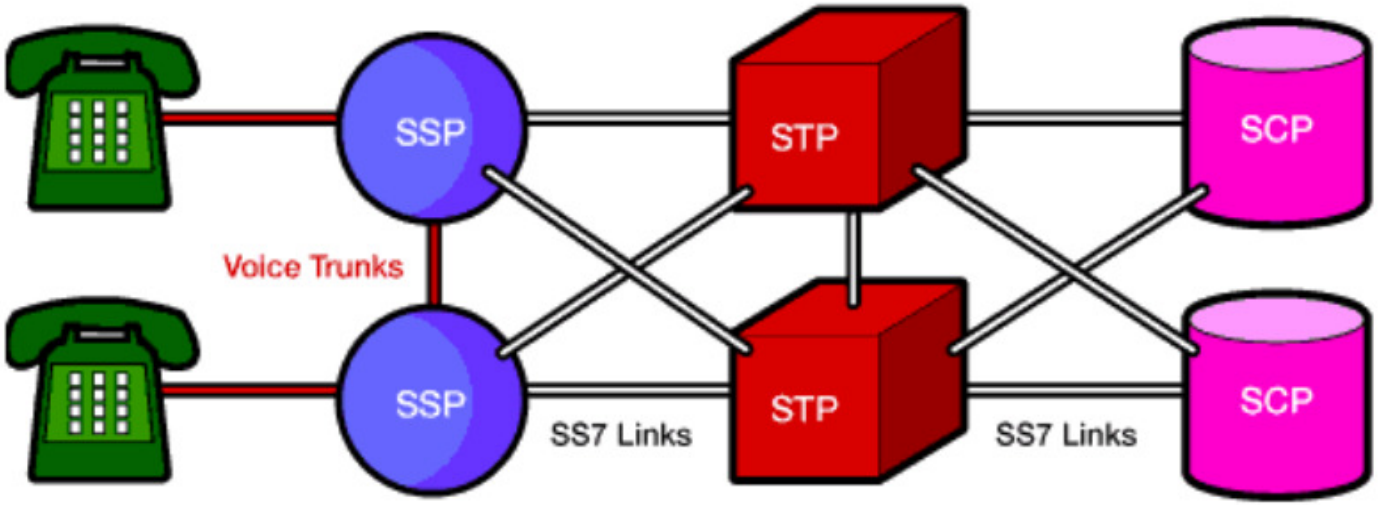
Figure 1.2 Three-level switching hierarchy.

ITU Signaling Systems Standards

- A set of telephony signaling protocols
- Signaling System No. 7 (SS7) is the most well known used to
  - set up and tear down telephone calls.
  - number translation,
  - local number portability,
  - prepaid billing mechanisms,
  - short message service (SMS),
  - and a variety of other mass market services.
  - enhanced call features such as call forwarding, calling party name/number display, and
  - three-way calling

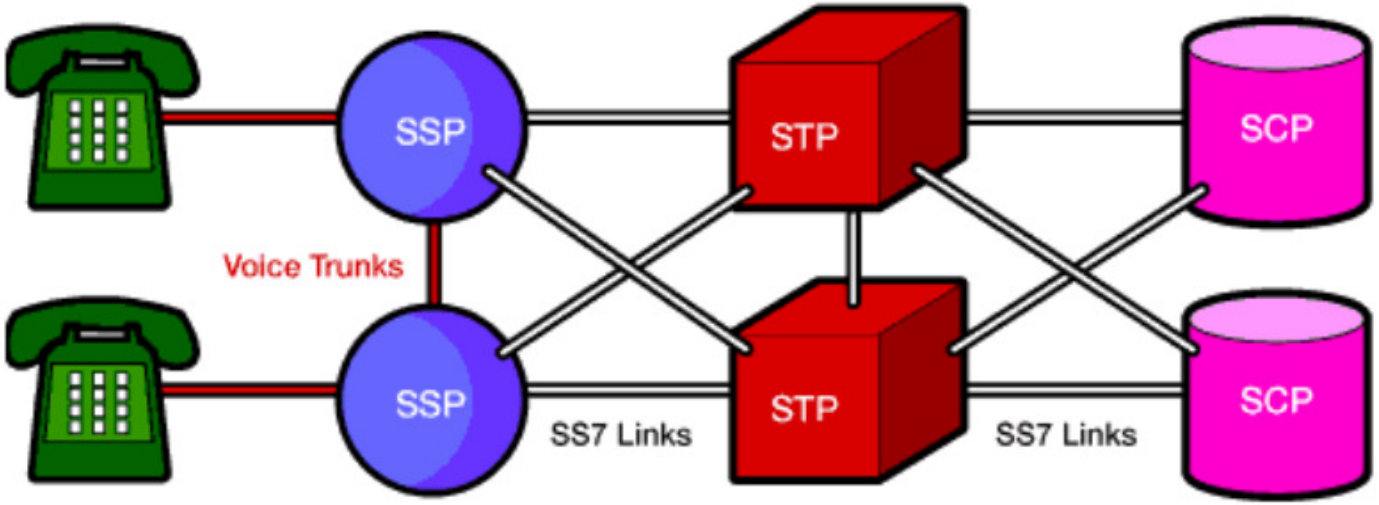
Signaling Points

- Each signaling point in the SS7 network is uniquely identified by a numeric point code.
- Point codes are carried in signaling messages exchanged between signaling points to identify the source and destination of each message. Each signaling point uses a routing table to select the appropriate signaling path for each message.



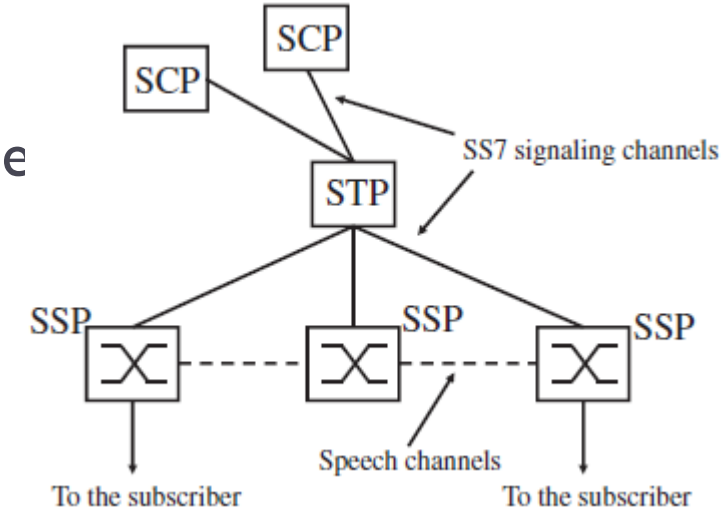
Signaling Points

- There are three kinds of signaling points in the SS7 network
  - SSP (Service Switching Point)
  - STP (Signal Transfer Point)
  - SCP (Service Control Point)



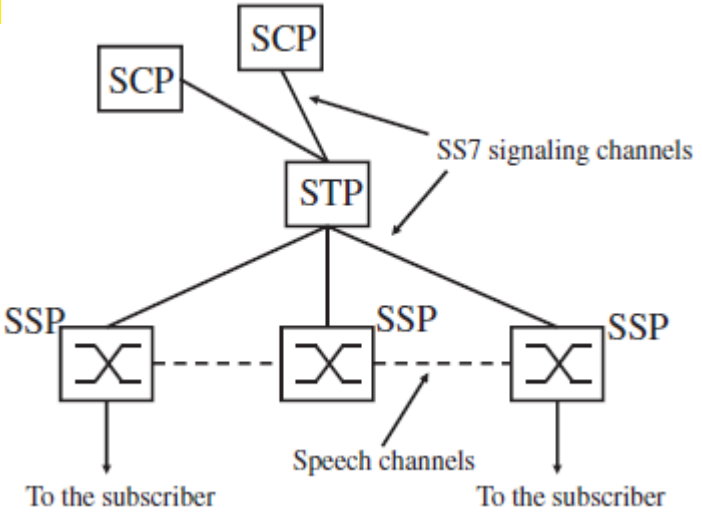
Network Structure

- Service Switching Points (SSPs)
  - SSPs are switches that originate, terminate, or tandem calls.
  - An SSP sends signaling messages to other SSPs to setup, manage, and release voice circuits required to complete a call.
  - An SSP may also send a query message to a centralized database (an SCP) to determine how to route a call.
- Service Control Points (SCPs)
  - databases and application software used by SSPs.

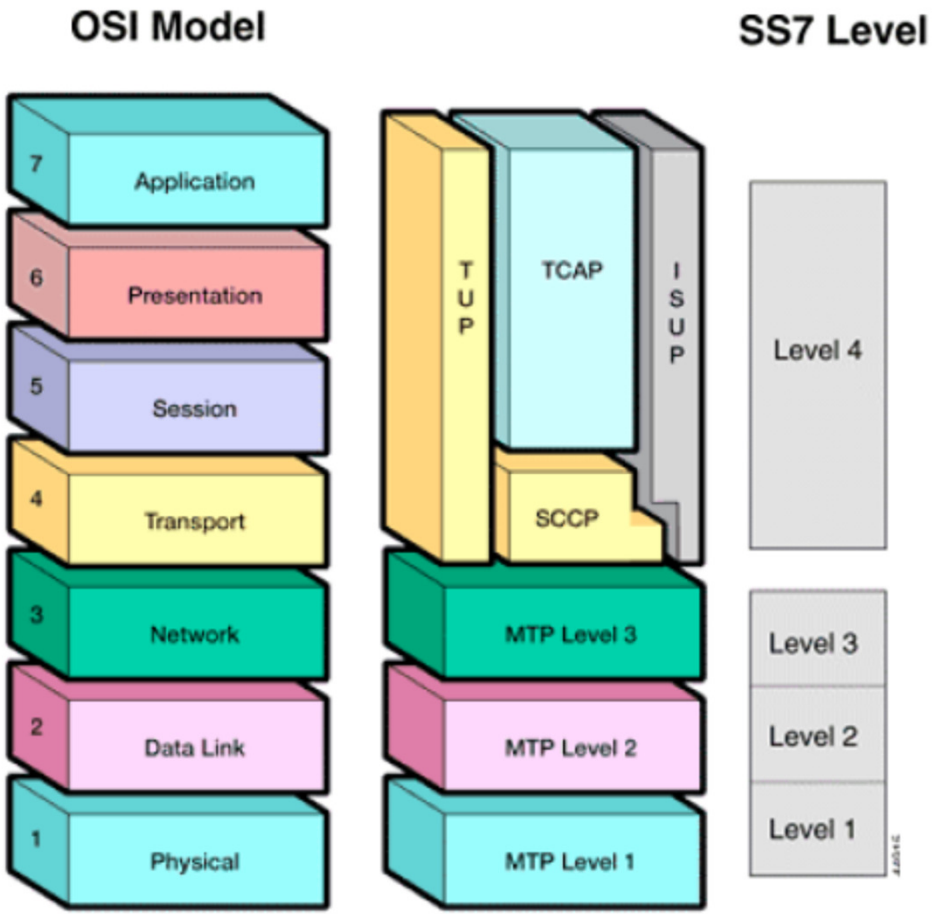


Network Structure

- Signaling Transfer Points (STPs)
  - Network traffic between signaling points may be routed via a packet switch called an STP
  - An STP routes each incoming message to an outgoing signaling link based on routing information contained in the SS7 message.



SS7 Protocol Stack



Message Transfer Part (MTP)

- It composes layers 1 to 3.
- MTP is responsible for reliable, unduplicated and in-sequence transport of SS7 messages between communication partners.
- Defined in ITU-T Recommendations Q.701, Q.702, Q.703, Q.704 and Q.705.
- MTP Level1
  - MTP Level 1 defines the physical, electrical, and functional characteristics of the digital signaling link.
- MTP Level 2
  - Ensures accurate end-to-end transmission of a message across a signaling link.
  - Level 2 implements flow control, message sequence validation, and error checking.
  - When an error occurs on a signaling link, the message (or set of messages) is retransmitted.
  - MTP Level 2 is equivalent to the OSI Data Link Layer.

Message Transfer Part (MTP)

- MTP Level 3
  - Provides message routing between signaling points in the SS7 network.
  - MTP Level 3 re-routes traffic away from failed links and signaling points and controls traffic when congestion occurs.
  - MTP Level 3 is equivalent to the OSI Network Layer.
- Each SS7 capable node has a unique identifying number called "Code Point" (24 bits in ANSI and 14 bits in ITU standard).
- MTP3 forwards messages based on their destination address point code.

SS7 Protocol Stack

- ISDN User Part (ISUP)
  - Used to create end-to-end connection between switching centers.
  - The ISDN User Part (ISUP) defines the protocol used to set-up, manage, and release trunk circuits that carry voice and data between terminating line exchanges (e.g., between a calling party and a called party).
  - ISUP is used for both ISDN and non-ISDN calls.
- Telephone User Part (TUP)
  - TUP handles analog circuits only.
  - In many countries, ISUP has replaced TUP for call management.

SS7 Protocol Stack

- Signaling Connection Control Part (SCCP)
  - SCCP provides connectionless and connection-oriented network services and global title translation (GTT) capabilities above MTP Level 3.
  - A global title is an address (e.g., a dialed number, calling card number, or mobile subscriber identification number) that is translated by SCCP into a destination point code and subsystem number.
  - A subsystem number uniquely identifies an application at the destination signaling point. SCCP is used as the transport layer for TCAP-based services.

Signaling Connection Control Part (SCCP)

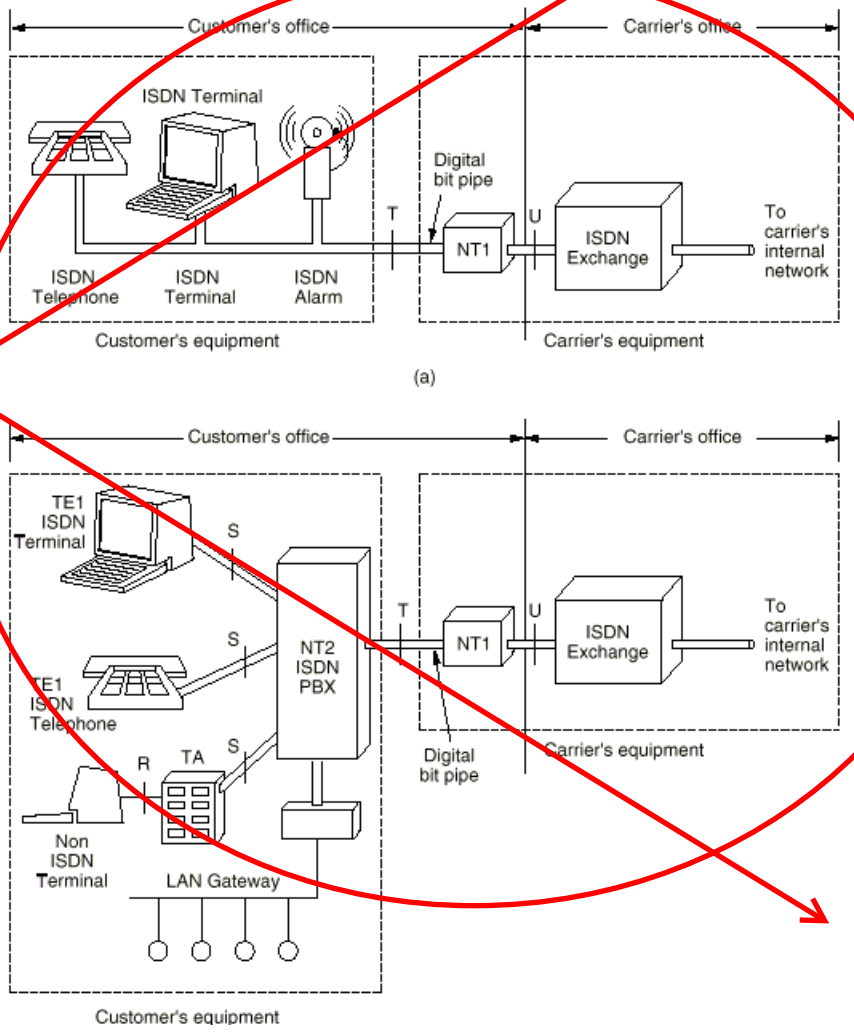
- SCCP provides 4 classes of protocol to its applications:
  - Class 0: Basic connectionless.
  - Class 1: Sequenced connectionless.
  - Class 2: Basic connection-oriented.
  - Class 3: Flow control connection oriented.

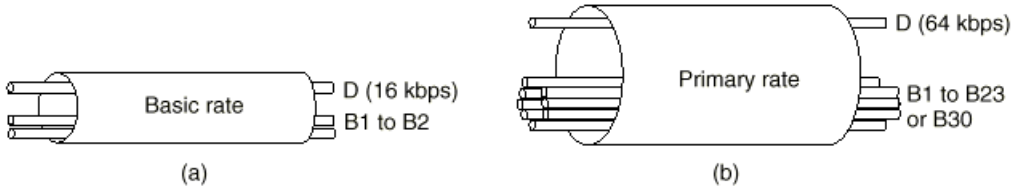
SS7 Protocol Stack

- Transaction Capabilities Applications Part (TCAP)
  - TCAP supports the exchange of non-circuit related data between applications across the SS7 network using the SCCP service.
  - For example, a switch sends a TCAP query to determine the routing number associated with a dialed 800/888 number and to check the personal identification number (PIN) of a calling card user.
  - In mobile networks (GSM), TCAP carries Mobile Application Part (MAP) messages sent between mobile switches and databases to support user authentication, equipment identification, and roaming.

Data in PSTN-ISDN

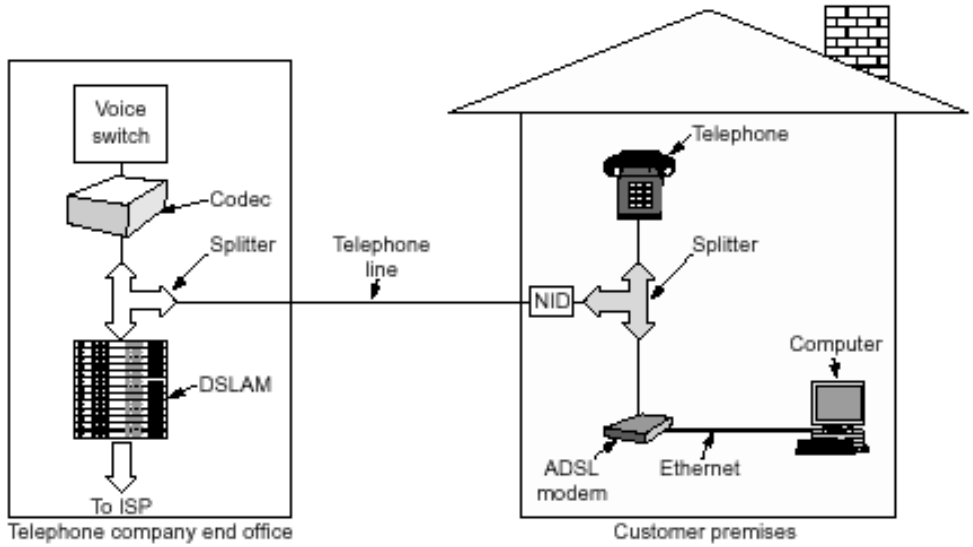
- ISDN *Integrated Services Digital Network* (1984)
- Goal: integration of voice and data communicatic and support all kinds of other services
- Architecture: digital bit pipe using TDM
- Channel types:
  - A: 4 kHz analog telephone channel
  - B: 64 kbps digital PCM
  - C: 8 or 16 kbps digital channel
  - D: 16 kbps channel for signaling
  - E: 64 kbps for internal ISDN signaling
  - H: 384, 1536 or 1920 kbps digital channel
- Mainly offered:
  - Basic Rate: 2B+D
  - Primary Rate: 23 B+ D US (~ 1.5 Mbps to fit in T1) 30B+1D (~2 Mbps to fit in E1)
  - Hybrid: 1A+1C





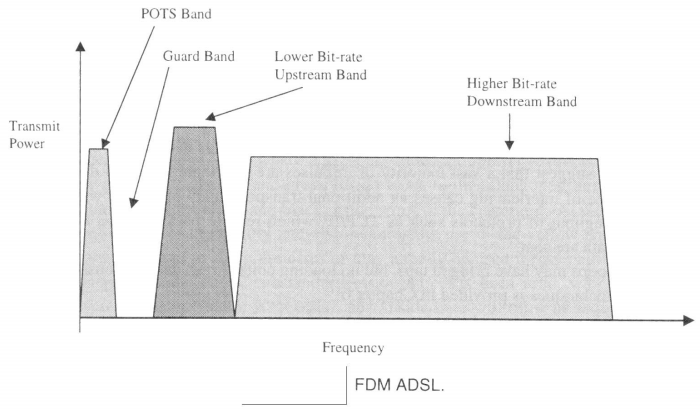
Data in PSTN-Broadband Access (ADSL)

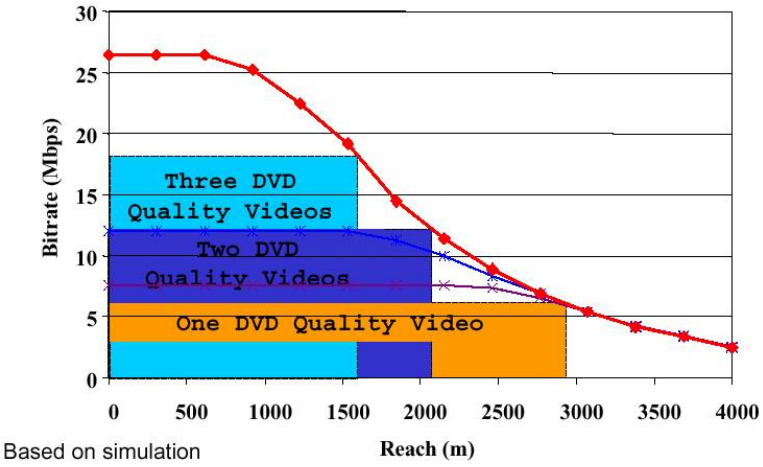
- Objective: Offering high rate data services without impacting the voice service on twisted pair
- Approach: splitting voice and data in frequency domain.
- Central Office (CO) side:
  - Use splitter to feed low pass part to the voice switch while the higher frequencies to the feed the DSLAM
- Customer Premise End (CPE)
  - Use splitter or in-line filters to feed the low pass part of the spectrum to the telephone and the high pass part to the CPE ADSL modem
- ADSL signal power spectrum is defined carefully to reduce cross talk into other services



Data in PSTN-Broadband Access (ADSL)

- Uses Discrete Multi tone technique (DMT) as the modulation scheme.
- Idea: Divide frequency into small bins each carrying a separate QAM constellation
  - Better use of channel capacity
  - More resistance to noise
  - Rate adaptability
- Most common mode of operation: Frequency Division Mode
  - Upstream (US) 25kHz to 130 KHz providing up to 1 Mbps
  - Downstream (D) 140 kHz to 1.1MHz providing up to 8Mbps
- New versions of ADSL (ADSL2+M) have improved the rate/reach curve by increasing the DS band to 2.2MHz. (24 Mbps DS, 3.5 Mbps US)





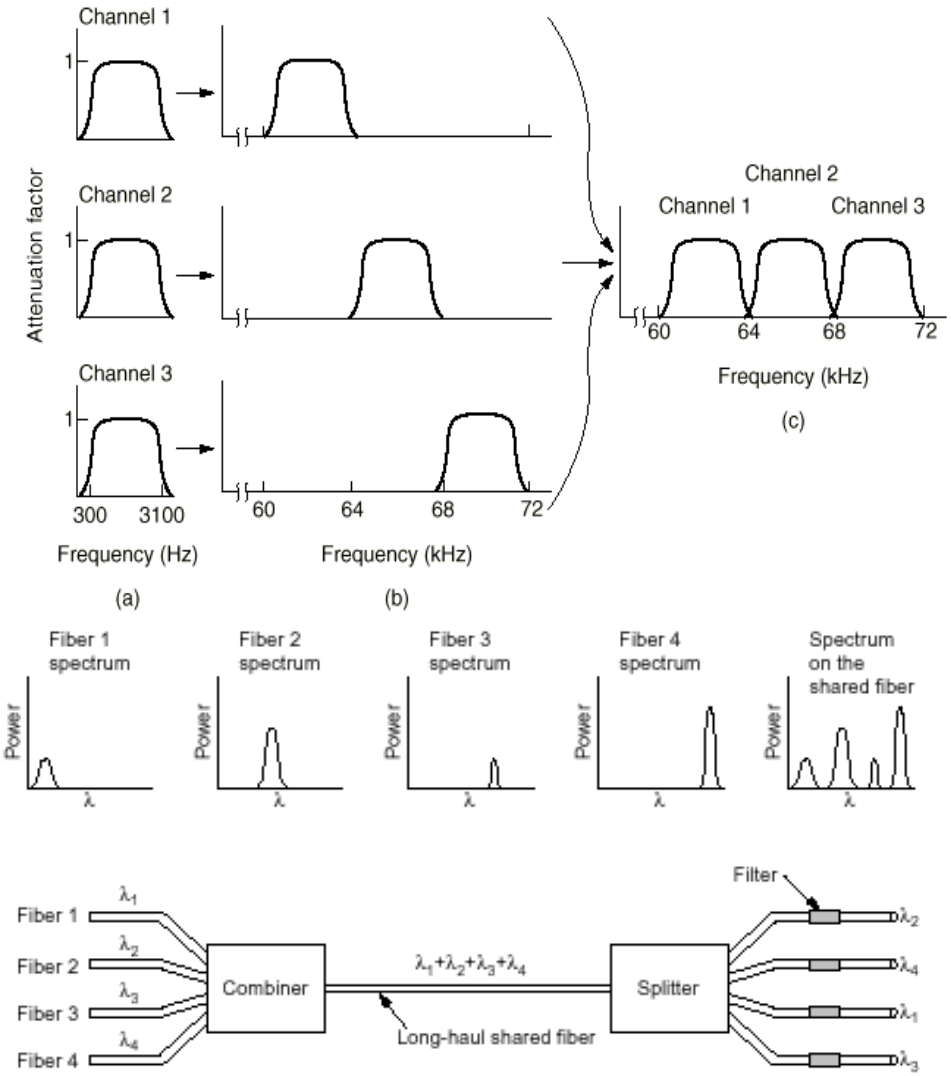
Based on simulation

Transmission Networks

- Various transmission networks are used nowadays in cellular networks.
- The medium is mainly fiber or microwave.
- Transmission networks cover layers 1, 2, and optionally 3 of ISO model.
- SDH/SONET
- Optical Transport networks (OTN)
- Carrier Ethenet
- ATM

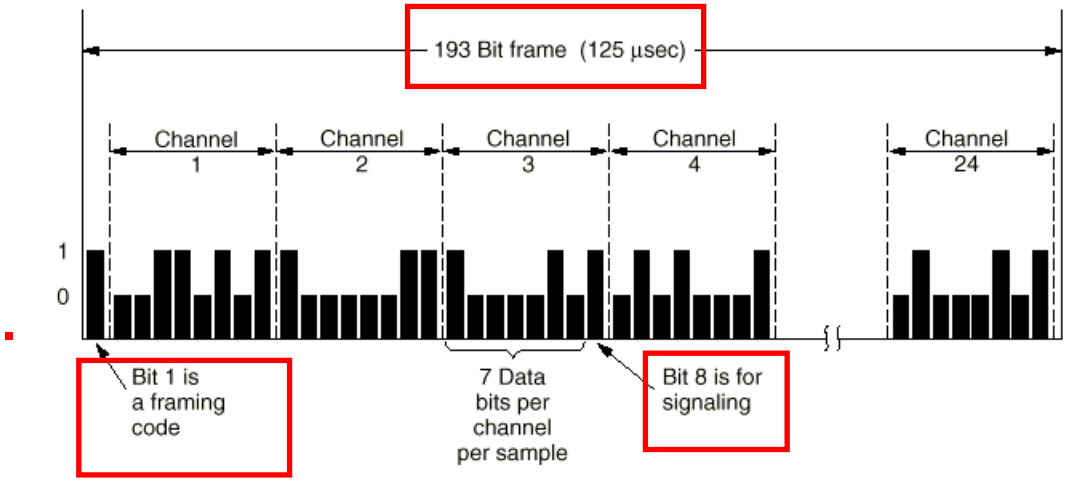
Trunks and Multiplexing

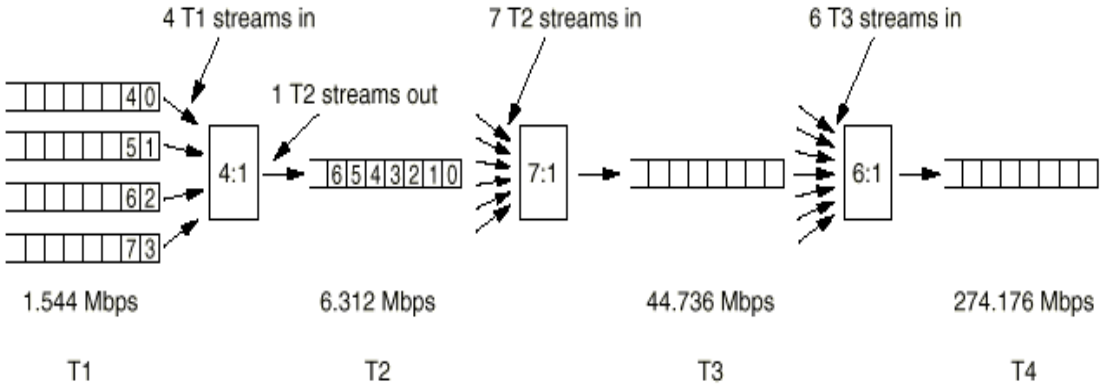
- Backhaul/core links in telephony systems are called trunks.
- FDM: frequency division multiplexing
- WDM: wavelength division multiplexing (just FDM for different optical wavelengths)
- TDM: time division multiplexing (can only be used in the digital domain)
  - Pulse Coded Modulation (PCM): Analog voice signals coming from local loop are sampled at 8000 samples/sec.
  - Each sample is represented by 8 bits. $\Rightarrow$ 64 kbps representation of the voice signal
  - Several voice channels can be multiplexed in time to carry voice info between Telco offices.



TDM carriers

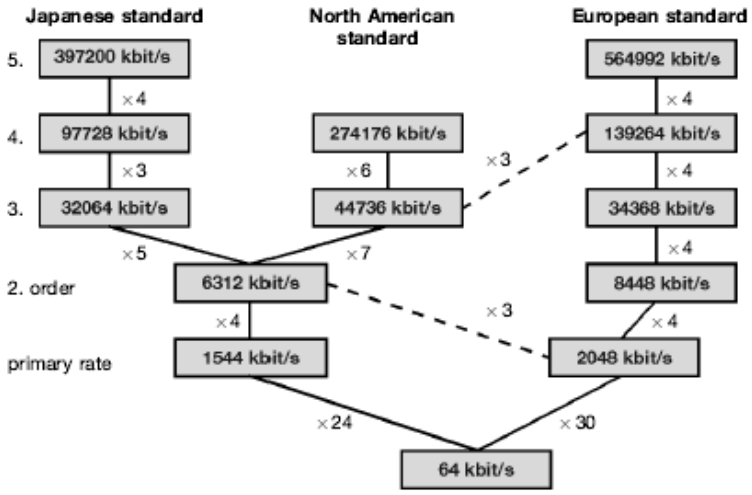
- N. America : T1 carrier
  - 8000 x 8 = 64 kbits/second per channel
  - 1 frame per 125 microseconds
  - 24 analog channels
  - 24 x 8 + 1 = 193 bits per frame
  - 1.544 Mbps
- Outside N. America : E1 carrier
  - 2.048 Mbps
  - 32 channels
  - 32 x 8 bits per frame
  - 30 data and 2 signaling channels
- Higher order rates are derived from multiplexing T1 or E1 signal streams





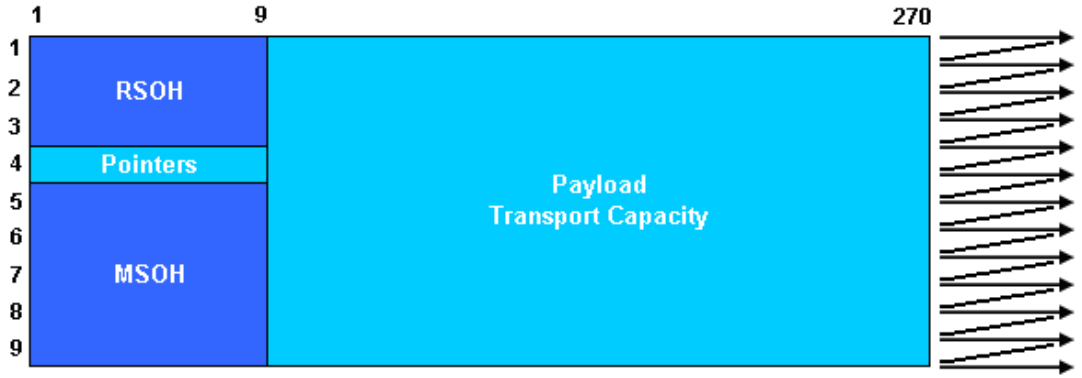
SONET/SDH

- SONET (Synchronous Optical Network) and SDH (Synchronous Digital Hierarchy) are the primary standards for all types of metro and long-haul transport of traffic over fiber networks.
- Design objectives:
  - Internetworking, unification
  - Provide a multiplexing scheme or digital hierarchy
  - Provide operations, administration, and maintenance (OAM) support
  - Direct access to low-level data without the need to de-multiplex the entire signal



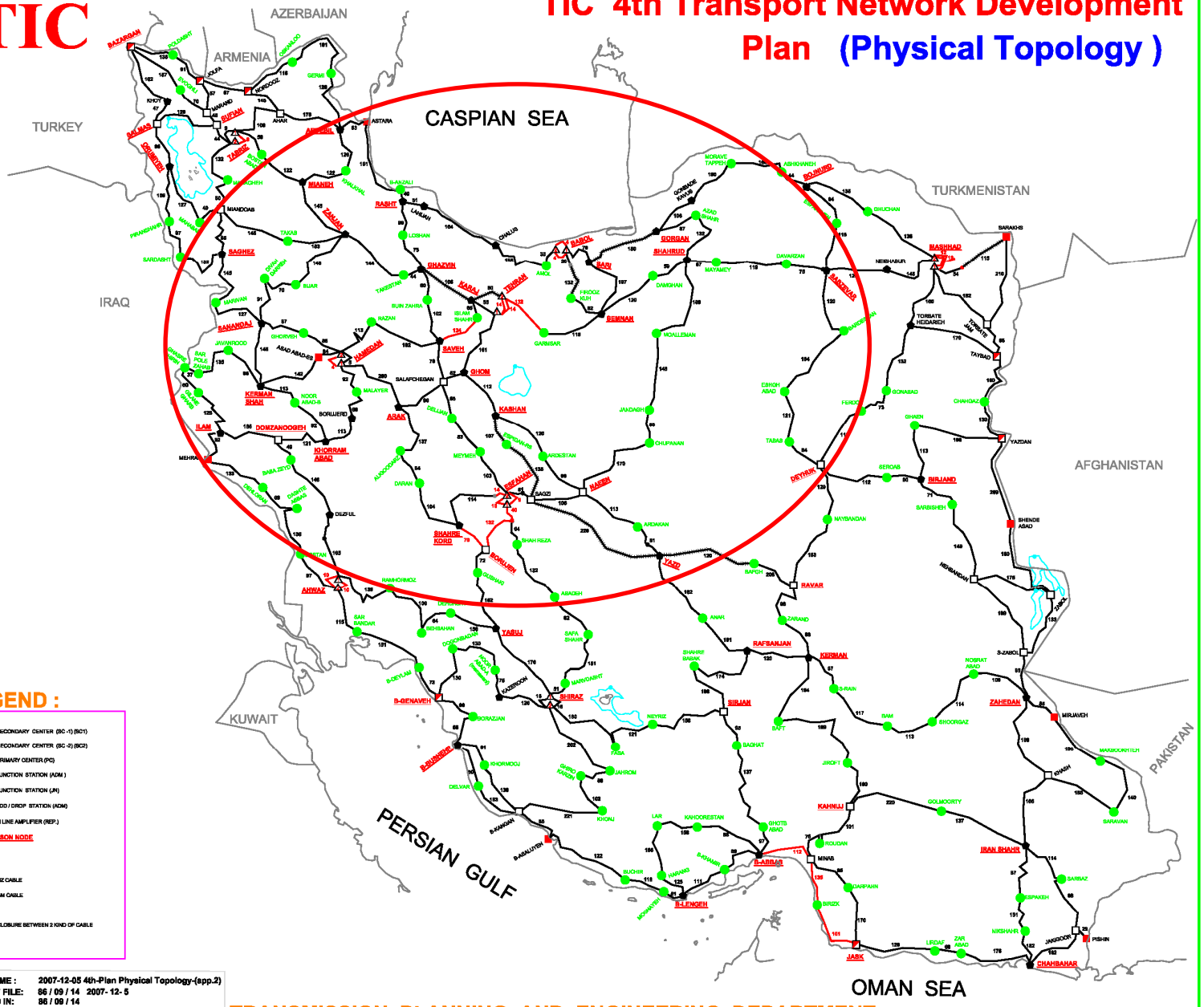
SONET/SDH

- SDH Rate and signaling
  - 155 Mbps or multiples
  - 270 x 9 x 8 bits per frame of 125 microseconds
- SDH multiplexing
  - 261 x 8 x 9 x 8 bits for synchronous payload envelope (SPE)
  - Payloads can carry many different types of traffic
  - Header bytes are used for framing, parity, voice channels, error monitoring, IDs, clocking and synchronization
- Standards: Multiples of 4nxSTM-1
  - STM-1: 155.52 Mbps
  - STM-4: 622.08 Mbps
  - STM-16: 2.5 Gbps
  - STM-64: 10 Gbps
  - STM-256: 40 Gbps



TIC

TIC 4th Transport Network Development Plan (Physical Topology)

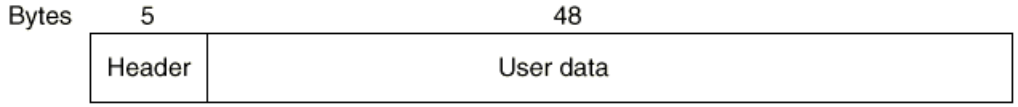


Asynchronous Transfer Mode (ATM)

- ATM is a transmission protocol used over the SONET/SDH backbone of the public switched telephone network (PSTN) and Integrated Services Digital Network (ISDN).
- Its use is declining in favour of all IP.
- ATM did not achieve all its objectives because of the same reasons: bad timing, bad technology, bad implementation, and bad politics.
- However, ATM is still used in the core of many modern packet based networks
- ATM development played a key role in development of fundamentals of today's modern packet networking concepts.
- ATM is replaced by a new generation of IP based networks using IPv4/6 and *MPLS*.

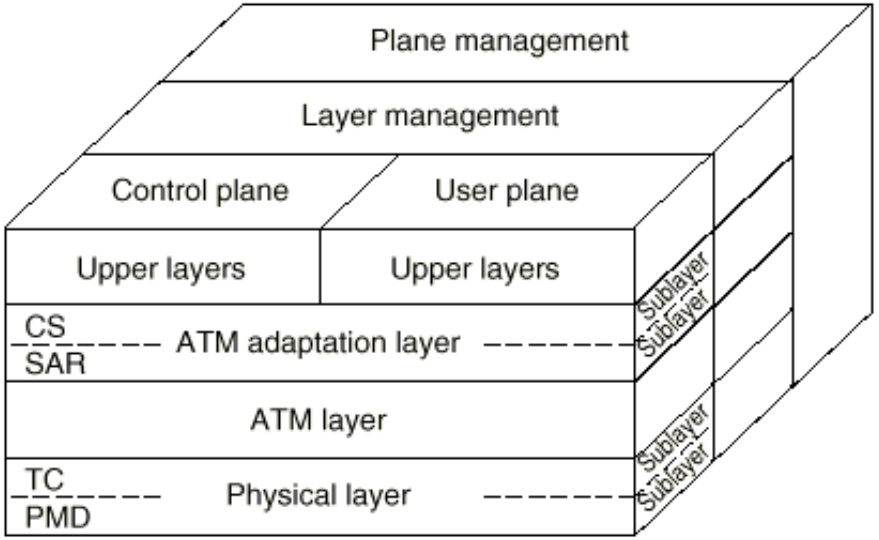
ATM

- ATM: Asynchronous transfer mode Cell based
  - Cell: Fixed size packet
  - Cell contains 5 byte header + 48 bytes data
- Why cell-switching?
  - Flexible, can handle all kinds of traffic
  - Allows high speed switching
  - Supports broadcasting
  - ATM networks are like WANs with lines & switches
  - In-order, unreliable delivery
  - Connection-oriented: virtual circuits



ATM Reference Model

- Physical layer
  - Deals with physical medium
  - Converting cells into bit stream
- ATM layer
  - Handling virtual circuits
  - Congestion control
  - Cell layout handling
- AAL: ATM Adaptation Layer
  - Segmentation and Re-assembly services
  - Providing different services to upper layers based on their required quality and type of service requirements.



CS: Convergence sublayer
SAR: Segmentation and reassembly sublayer
TC: Transmission convergence sublayer
PMD: Physical medium dependent sublayer