Telecom Basics

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Overview

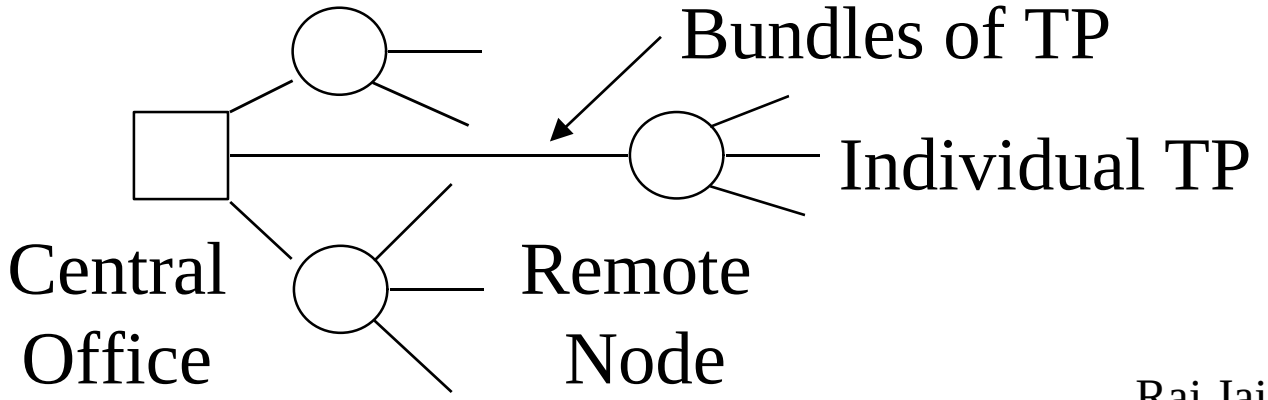
- Time Division Multiplexing
- T1, Digital TDM Hierarchy
- X.25
- Frame Relay
- ISDN
- SONET

Voice Sampling

- Voice signal has a bandwidth of 4 kHz
  (300 Hz to 3300 Hz is transmitted on phone systems)
- Nyquist sampling theorem:
  Sample at twice the highest signal frequency
  $\Rightarrow$ Sample at 8 kHz $\Rightarrow$ Sample every 125 μsec
- 256 levels $\Rightarrow$ 8 bits per sample $\times$ 8000 samples/sec
  = 64 kbps

Local Loop

- Distribution network uses a star topology
  ⇒ Hierarchical System: Subscribers are connected to local exchanges (or end offices), which are connected via trunks to other tandem or toll switching centers.
- Feeder cables connect central office to remote nodes. Can be replaced via fiber.
  May multiplex using TDM or WDM

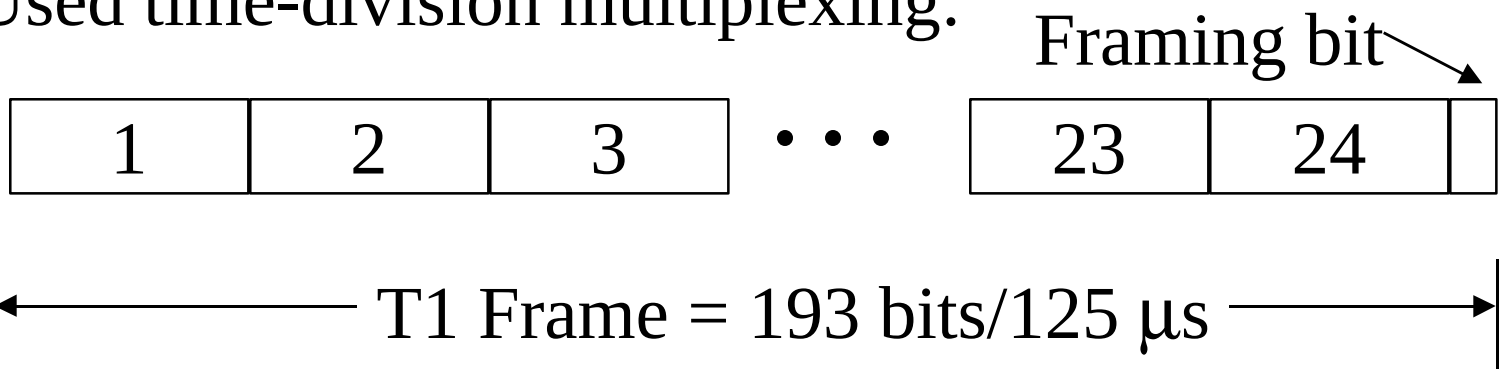


Multiplexing

- Multiple conversations ⇒ Multiple frequency bands
  Frequency division multiplexing (FDM)
  Useful for analog signals.
- In 1962, telephone carrier cable between Bell System offices could carry approx 1.5 Mbps over a mile
  = Distance between manholes in large cities
  = Distance between amplifiers
- 1500/64 ≈ 24 ⇒ Can multiplex approx.
  24 voice channels on that carrier
  ⇒ Telecommunication-1 carrier or T1 carrier.
  Named after the ANSI committee.

T1 Frame

- T1= 24 voice channels
  = Digital Service 1 = DS1
- Used time-division multiplexing:



  - Simple Framing: Add 101010 (1 bit per frame)

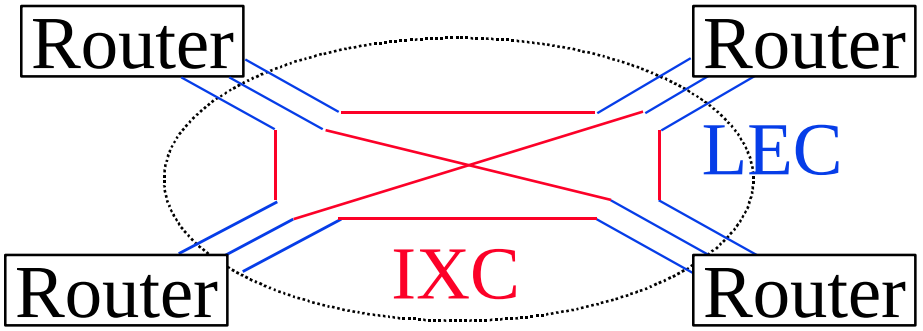
  - Any other sequence ⇒ Resynchronize

Digital TDM Hierarchy

	North America		Europe		Japan
DS0	64 kbps		64 kbps		64 kbps
DS1	1.544 Mbps	E1	2.048 Mbps	J1	1.544 Mbps
DS2	6.313 Mbps	E2	8.448 Mbps	J2	6.312 Mbps
DS3	44.736 Mbps	E3	34.368 Mbps	J3	32.064 Mbps
DS4	274.176 Mbps	E4	139.264 Mbps	J4	97.728 Mbps
DS1C	3.152 Mbps	E5	565.148 Mbps	J5	397.200 Mbps

Problems with Leased Lines

- Multiple logical links ⇒Multiple connections
- Four nodes ⇒12 ports,
  12 local exchange carrier (LEC) access lines,
  6 inter-exchange carrier (IXC) connections
- One more node ⇒8 more ports, 8 more LEC lines, 4 more IXC circuits



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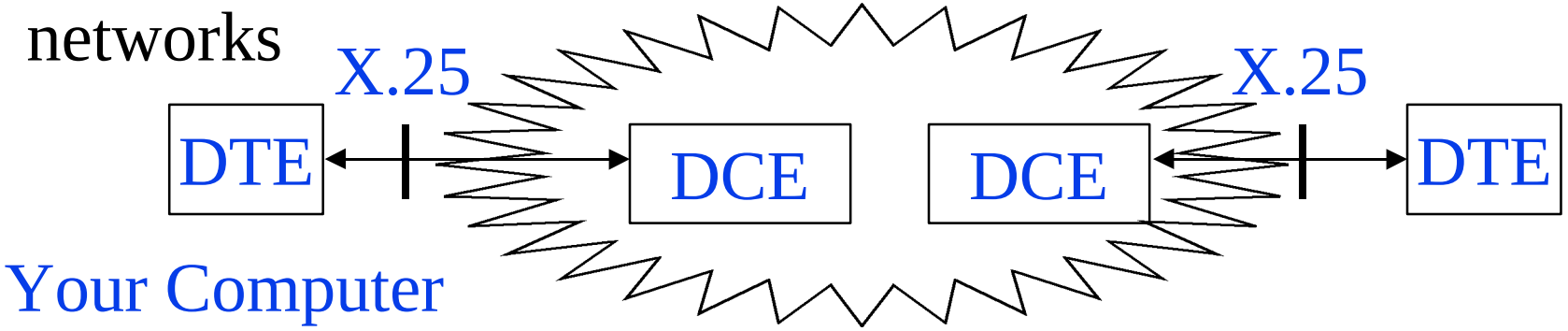
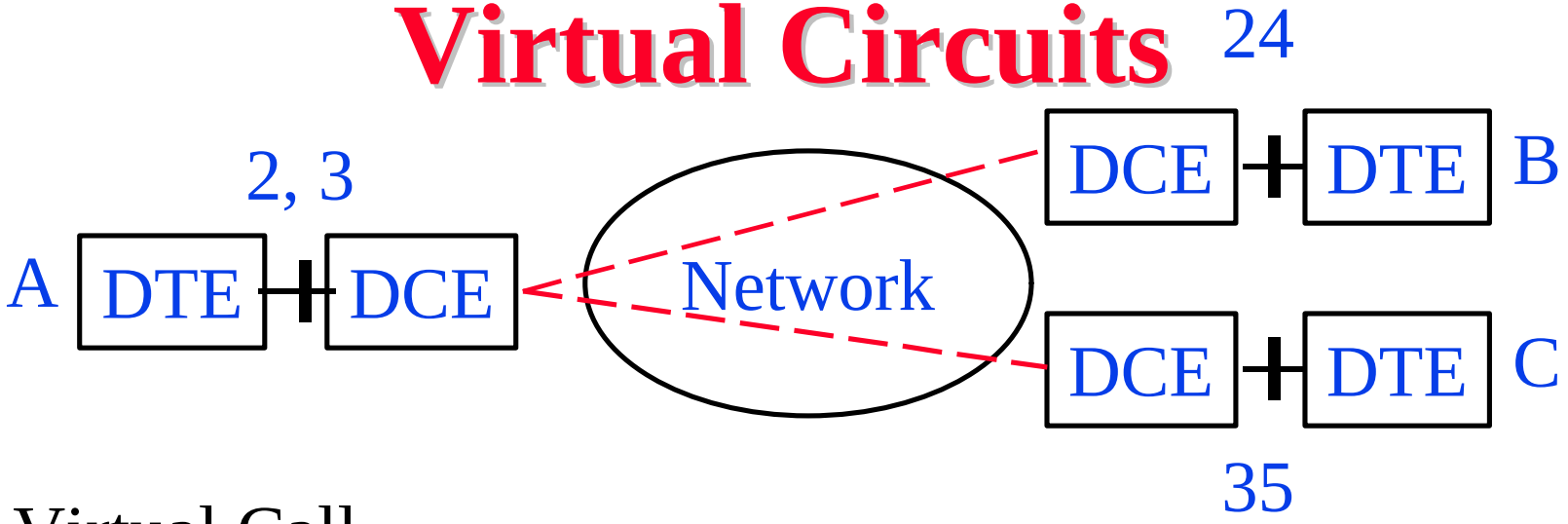
X.25 Overview

- First packet switching interface.
- Issued in 1976 and revised in 1980, 1984, 1988, and 1992.
- Data Terminal Equipment (DTE) to Data Communication Equipment (DCE) interface
  ⇒ User to network interface (UNI)
- Used universally for interfacing to packet switched networks



Virtual Circuits



- Virtual Call
- Two Types of Virtual Circuits:
  - Switched virtual circuit (SVC)
    Similar to phone call
  - Permanent virtual circuit (PVC)
    Similar to leased lines
- Up to 4095 VCs on one X.25 interface

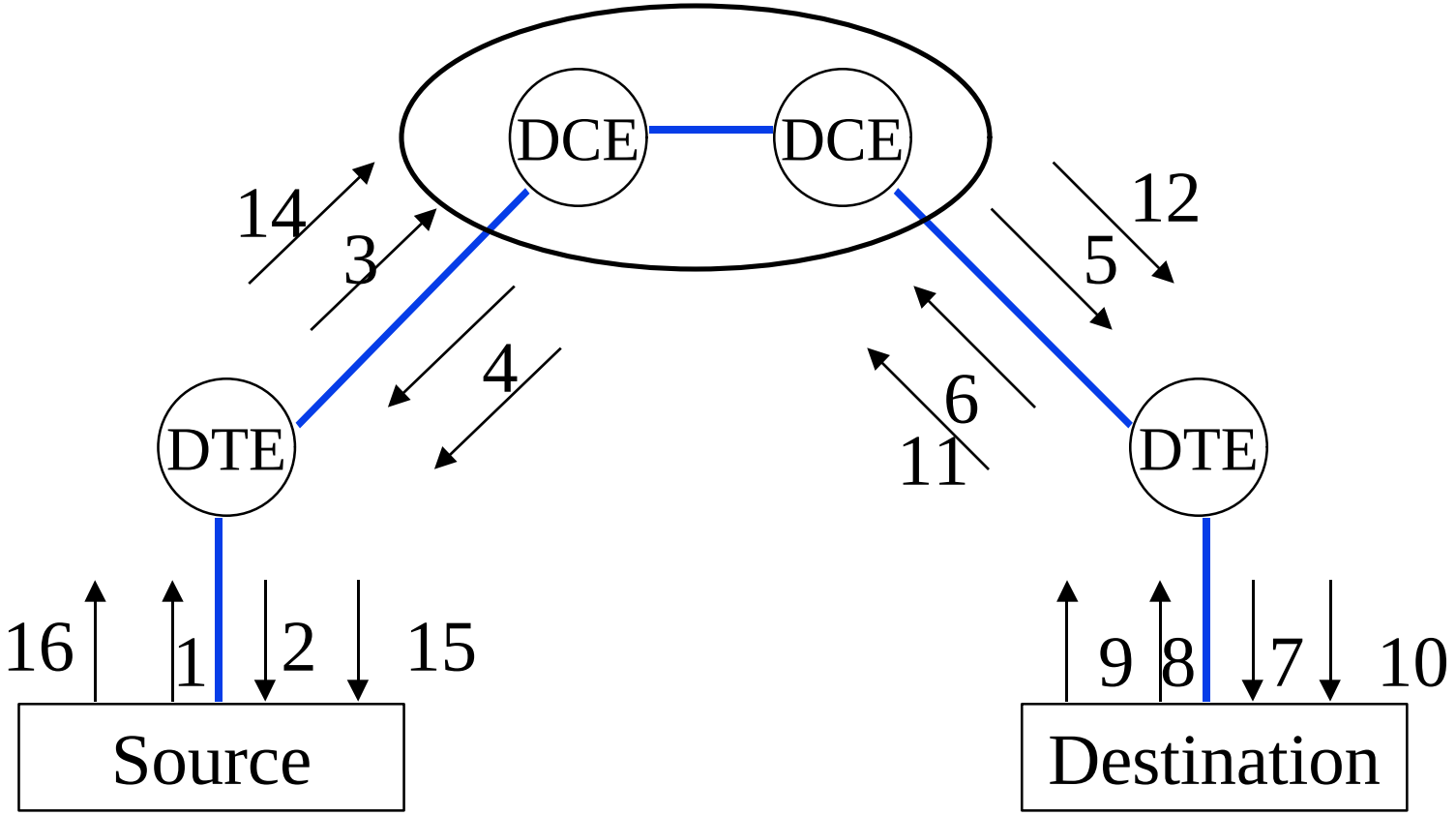
X.25

- Three layer protocol.
- Third layer for protocol multiplexing.
- Second layer = HDLC
- Per-Hop Flow control and Error control

$\Rightarrow$ 16 messages for one packet transfer

Only 8 messages without flow control and error control

X.25 Exchange



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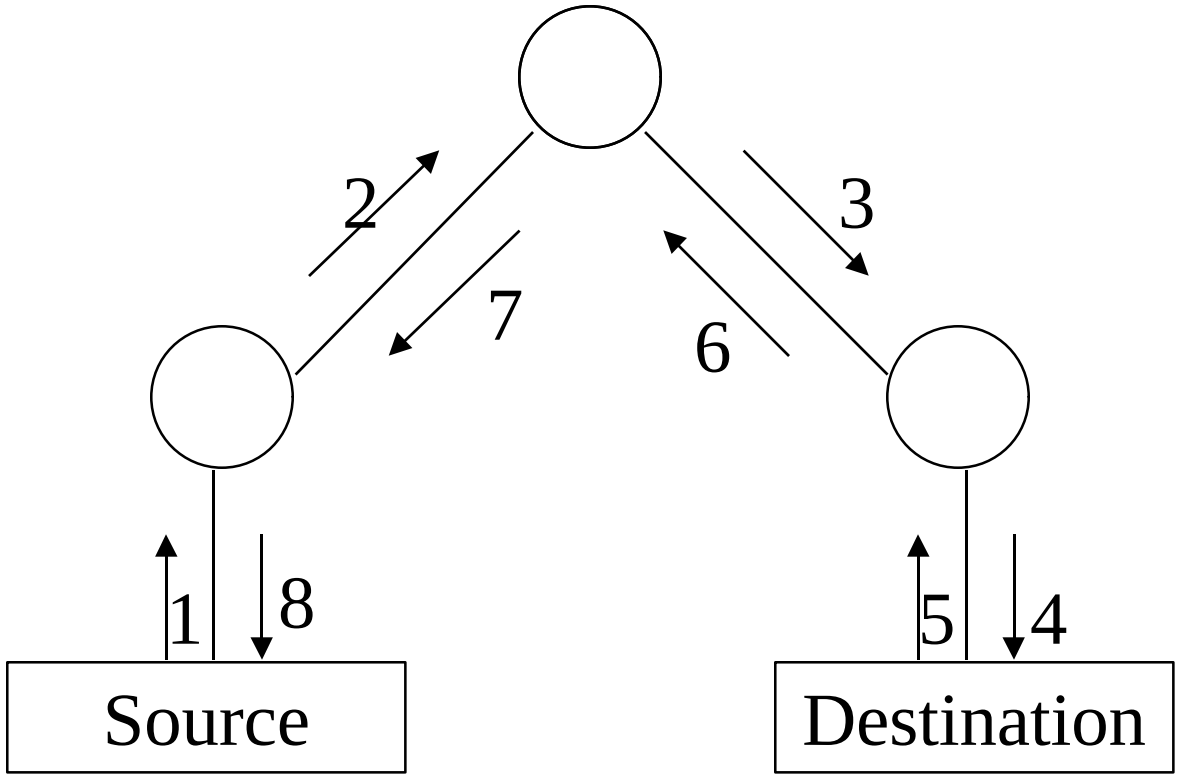
Frame Relay: Key Features

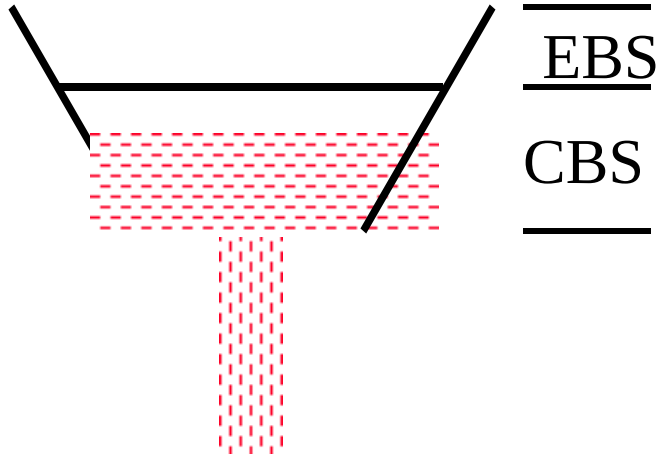
- X.25 simplified
- No flow and error control
- Out-of-band signaling
- Two layers
- Protocol multiplexing in the second layer
- Congestion control added
  $\Rightarrow$Higher speed possible.
  X.25 suitable to 200 kbps. Frame relay to 2.048 Mbps.

Frame Relay Exchange



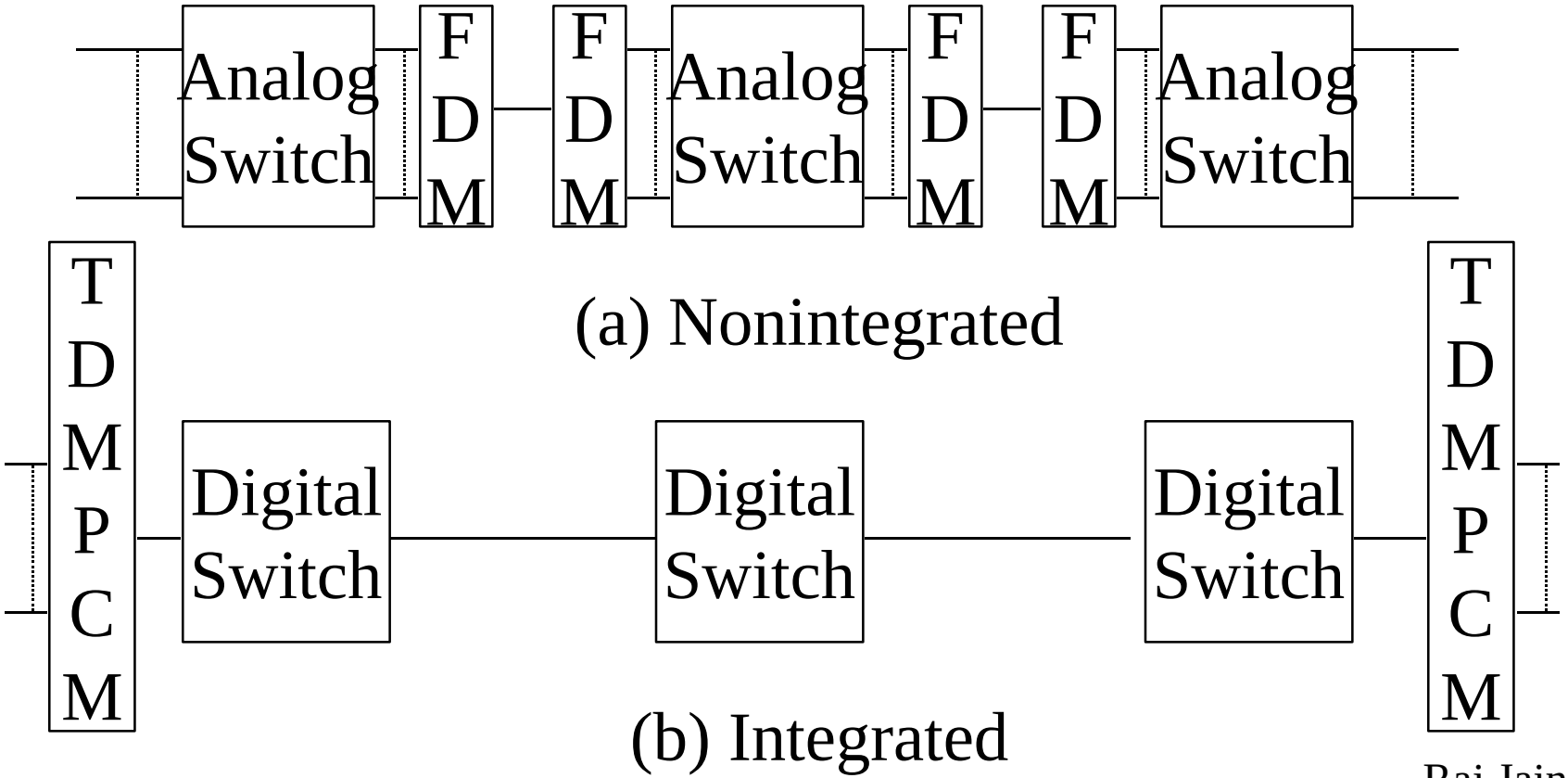
Discard Control

- Committed Information Rate (CIR)
- Committed Burst Size (CBS)
- Excess Burst Size (EBS)
- CBS to CBS+EBS: Mark Discard Eligibility bit
- Over CBS+EBS: Discard



Integrated Digital Networks

- Integrated ⇒ Both transmission and Switching
- Access was still analog

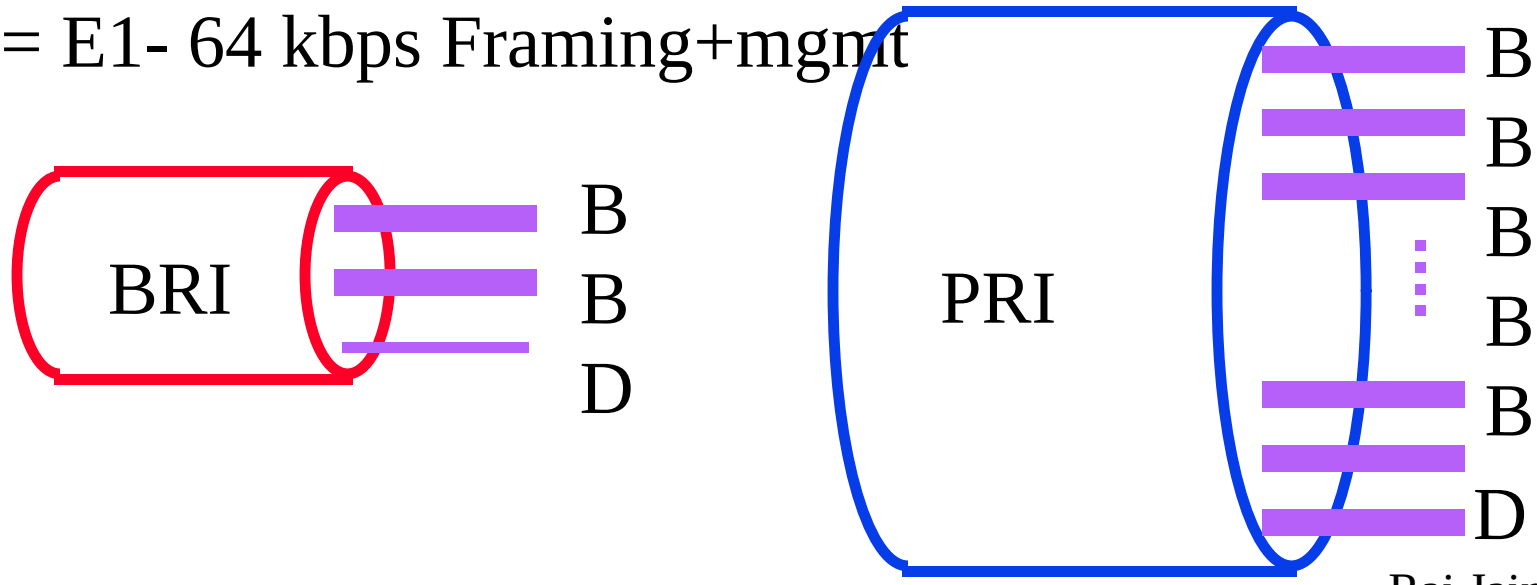


Int. Service Digital Network

- Past: IDN = Integrated Digital Network
  ⇒ Standardized digital techniques for switching and transmission (T1 etc)
- 1980: ISDN ⇒ Integrated access to all services
  ⇒ Digital end-to-end (Digital subscriber loop)
- One set of interfaces for all services at multiple speeds
- Supports both circuit switching and packet switching
- Out-of-band signaling. Sophisticated network management and maintenance using Signaling System 7 (SS7)
- Layered protocol architecture

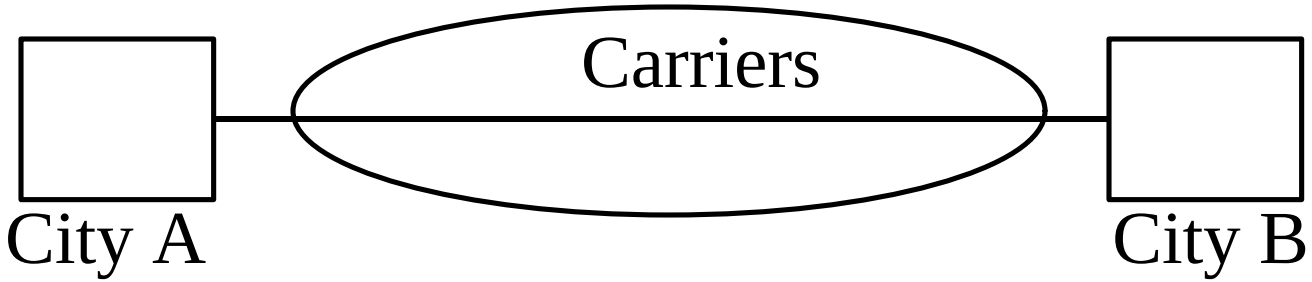
ISDN Access Interfaces

- Basic Rate Interface (BRI): 2B + D = 2 × 64 + 16 = 144 kbps (192 kbps total)
- Primary Rate Interface (PRI): For LANs or PBX
  - 23 B + D = 23 × 64 + 64 = 1.536 Mbps ≈ T1
  - 30 B+ D = 30 × 64 + 64 = 1.984 Mbps = 5H0+D = E1- 64 kbps Framing+mgmt



SONET

- Synchronous optical network
- Standard for digital optical transmission (bit pipe)
- Developed originally by Bellcore.
  Standardized by ANSI T1X1
  Standardized by CCITT
  $\Rightarrow$ Synchronous Digital Hierarchy (SDH)
- You can lease a SONET connection from carriers



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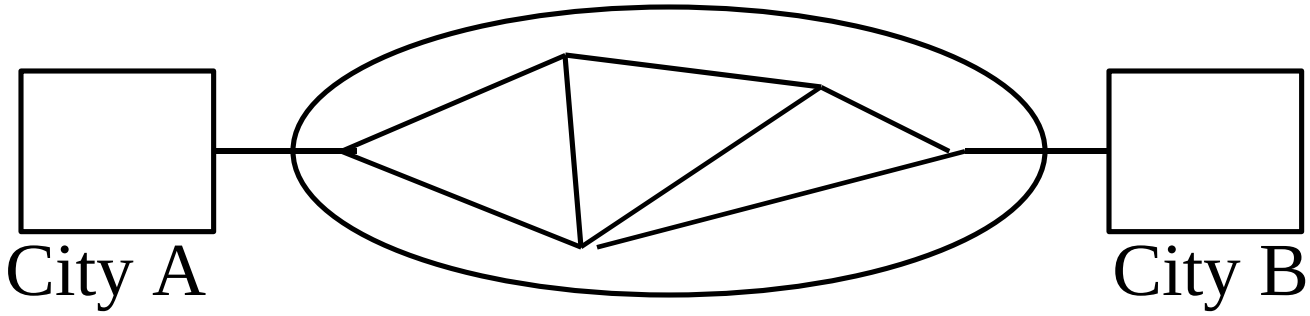
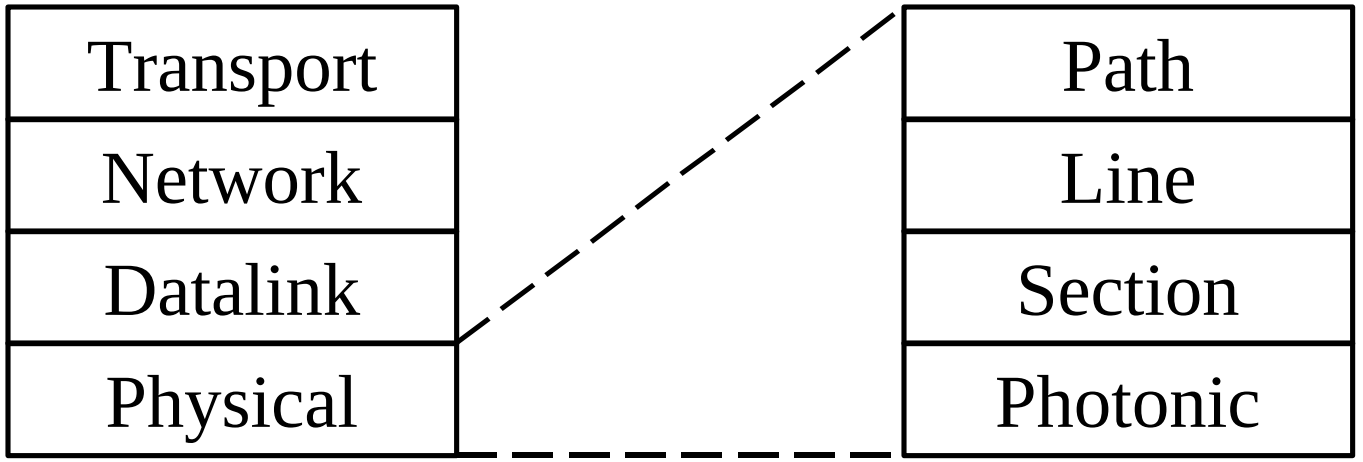
SONET Protocols

- Synchronous Optical **Network**





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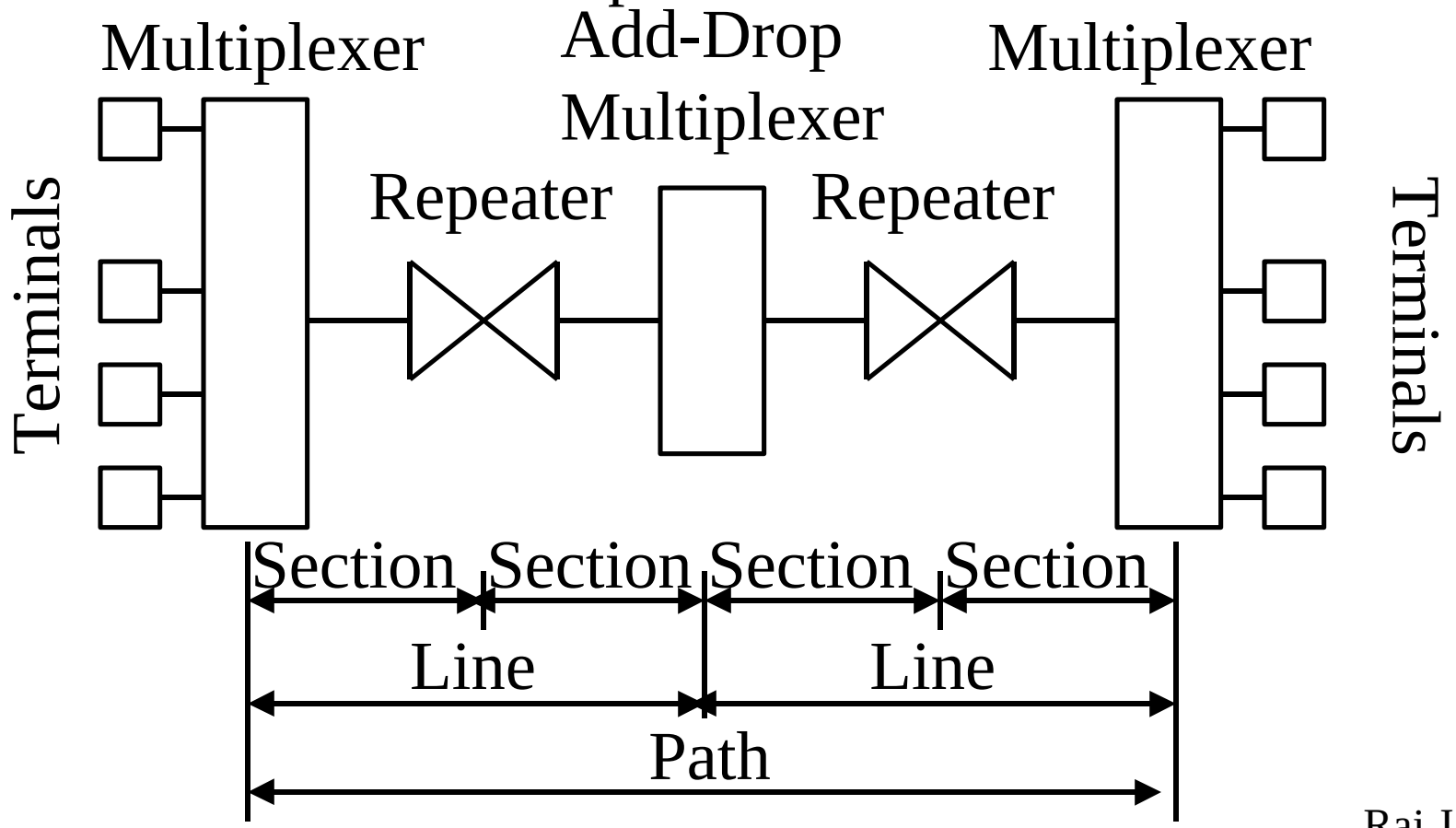
Physical Components

- Section = Single run of fiber
- Line = Between multiplexers



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Signal Hierarchy

Synchronous Transport Signal Level n = STS-n = $n \times 51.84$ Mbps
STM=Synchronous Transport Module, OC=Optical Carrier level

ANSI Designation	Optical Signal	CCITT Designation	Data Rate (Mbps)	Payload Rate (Mbps)
STS-1	OC-1		51.84	50.112
STS-3	OC-3	STM-1	155.52	150.336
STS-9	OC-9	STM-3	466.56	451.008
STS-12	OC-12	STM-4	622.08	601.344
STS-18	OC-18	STM-6	933.12	902.016
STS-24	OC-24	STM-8	1244.16	1202.688
STS-36	OC-36	STM-12	1866.24	1804.032
STS-48	OC-48	STM-16	2488.32	2405.376
STS-96	OC-96	STM-32	4976.64	4810.176
STS-192	OC-192	STM-64	9953.28	9620.928

Automatic Protection Switching

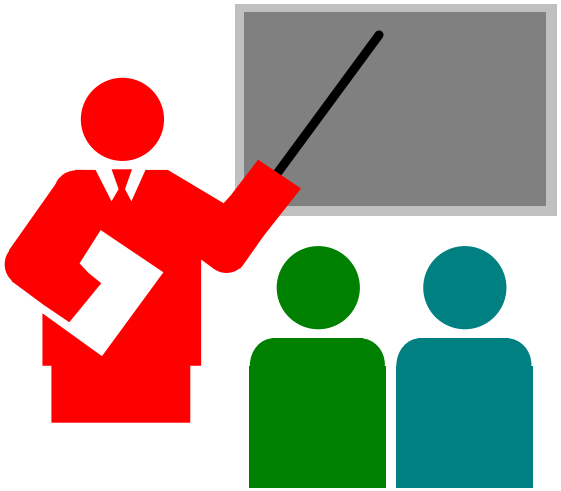
- 100 μs or more is "loss of signal"
  2.3 μs or less is not "loss of signal"
  In-between is up to implementations
- Most implementations use 13-27 μs
  ⇒ Higher speed lines ⇒ maintain sync for more bits
- APS allows switching circuits on fault
- May take up to 50 ms to complete
- Wastes entire links as standby.
- Protection by routers works faster than by SONET

Scrambling

- SONET uses NRZ coding.
  1 = Light On, 0 = Light Off.
- Too many 1's or 0's ⇒ Loss of bit clocking information
- All bytes (except some overhead bytes) are scrambled
- Polynomial $1 + x^6 + x^7$ with a seed of 1111111 is used to generate a pseudo-random sequence, which is XOR'ed to incoming bits.

  1111 1110-0000 0100-0001 … 010
- If user data is identical to (or complement of) the pseudo-random sequence, the result will be all 0's or 1's.

Summary



- T1 consists of 24 64-kbps TDM signals
- X.25 allows packet switching over telephone networks
- Frame relay is designed for more reliable networks with higher speeds
- ISDN Even the local loop is digital
- SONET is for high-speed optical fiber transmission

Telecom Basics: Key References

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