CS311 : Data Communication

Few Multiplexing Applications

by

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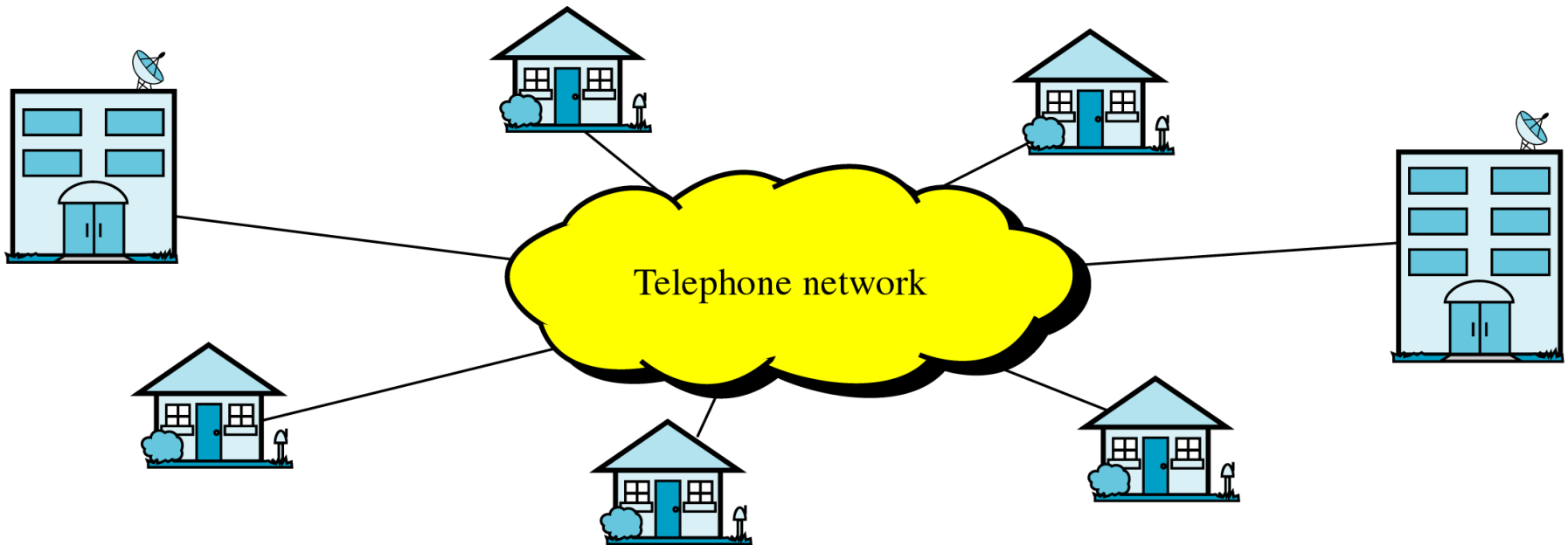http://manaskhatua.github.io/

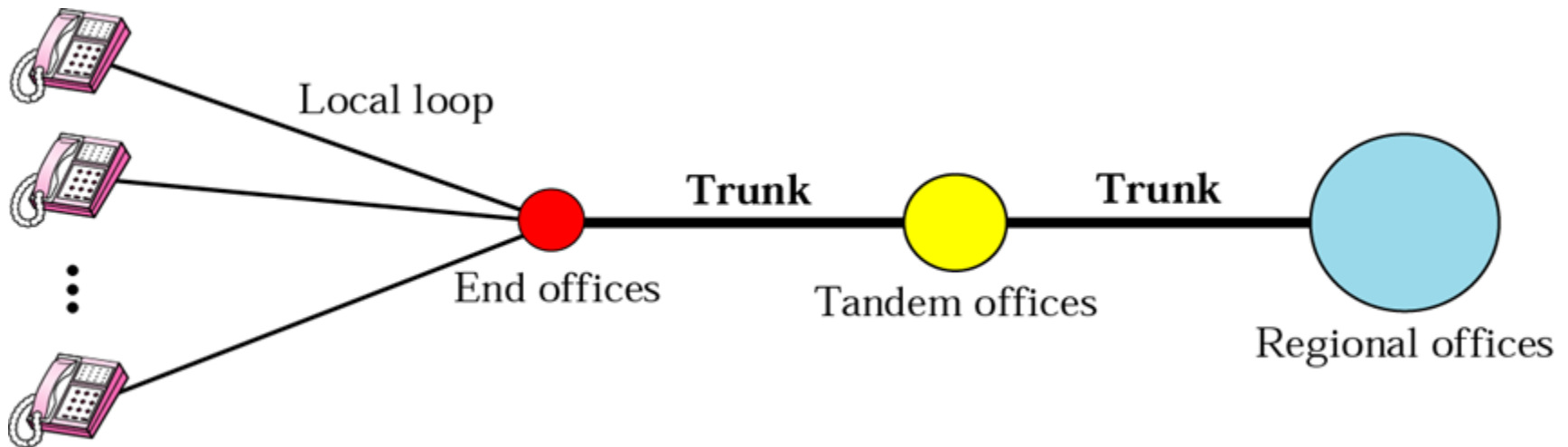# Outline of Lecture

- The Telephone System
    - Analog Services
    - Digtital Services

- DSL Technology
    - ADSL
    - SDSL
    - HDSL
    - VDSL

The Telephone System

One of the many applications of multiplexing is in the telephone network which makes use of both FDM and TDM.

The Telephone Network

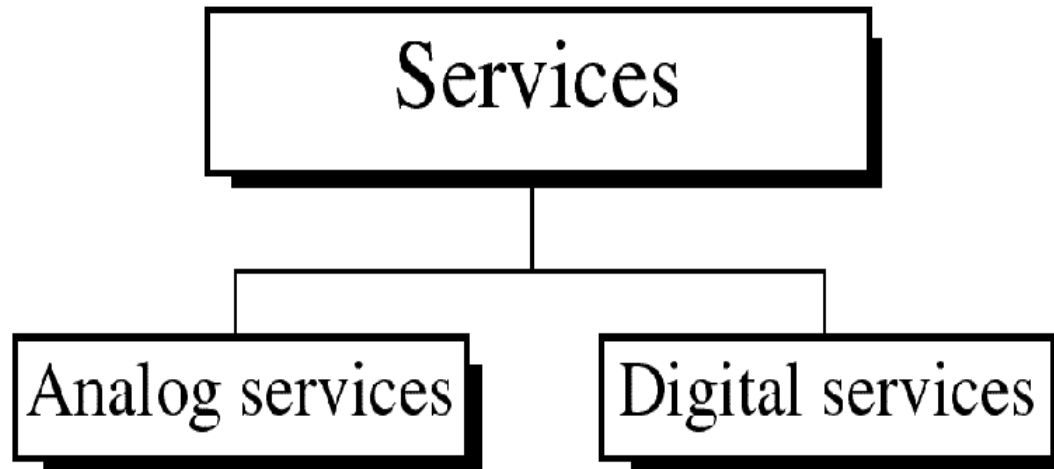Local Loop: Analog Line; Bandwidth 4kHz; Twisted-pair Cable

End Offices: Generally, Local Telephone Exchange

Trunk Lines: Coaxial Cable, Optical Fiber, Microwave, Satellite Link

Tandem Offices: used to interconnect local exchange offices for long distance communications
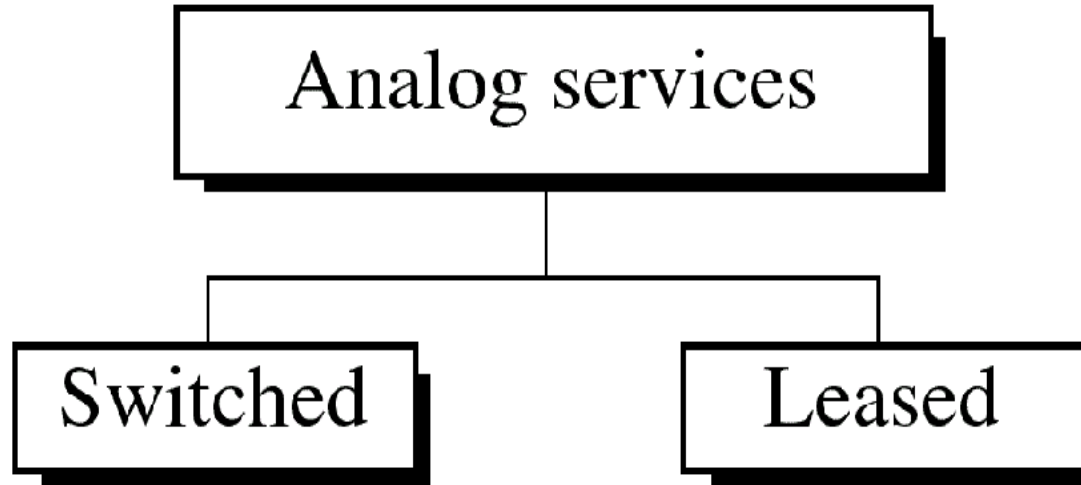
Regional Offices: used to interconnect tandem offices

Categories of Service

- Analog Services: Available from telephone companies for a long time
- Digital Services: Advances of technology has allowed the introduction of digital services

Categories of Analog Service

Analog services

Switched   Leased

- Analog Switched Service : familiar dial-up service most often encountered when using a home telephone.

- Analog Leased Service : dedicated line offers customers the opportunity to lease line (dedicated line), that is permanently connected to another customer.

Analog Switched Services

- Subscriber handest is connected to the telephone network by twisted-pair cable called local loop

- The Signal on the local loop is analog in nature having bandwidth 0 to 4 kHz

- A Switch in the exchange connects a subscriber to the subscriber of the dialed number of call

- The Network is referred to as Public Switched Telephone Network (PSTN)

Switched vs Leased Services

Telephone network
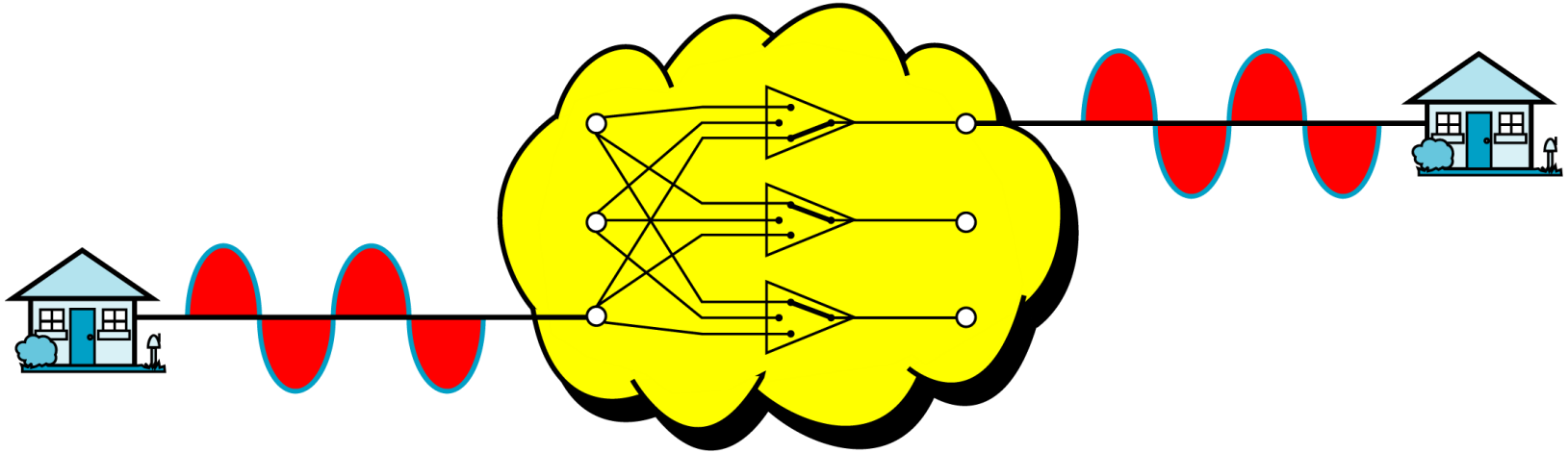
Telephone network
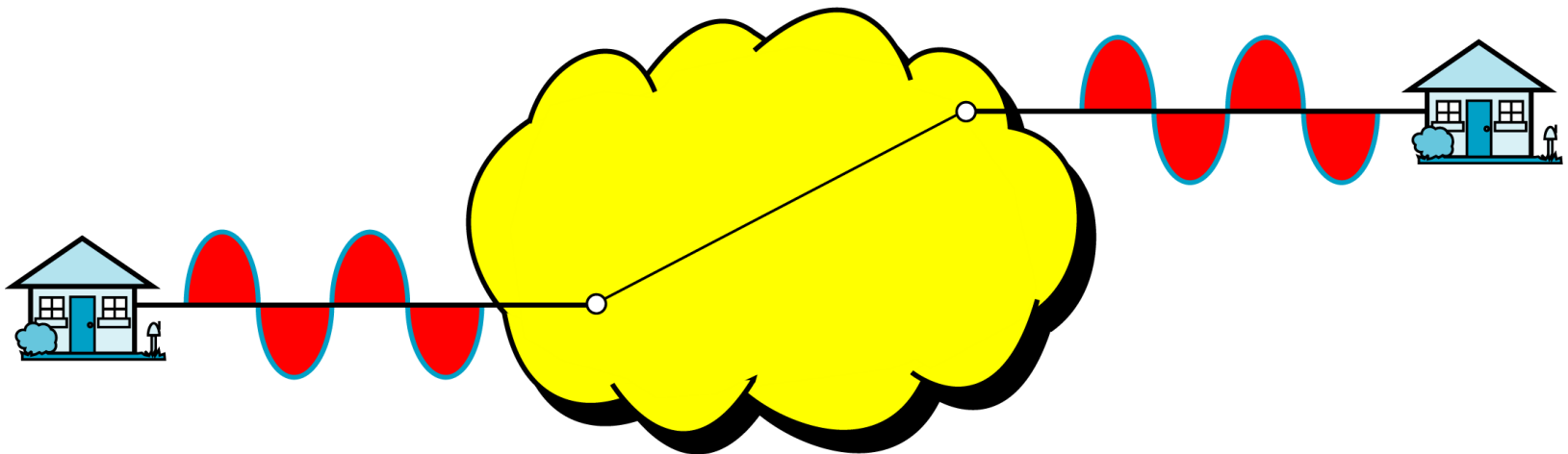
Analog Hierarchy

- For Better utilization of the infrastructure, analog services are multiplexed to provide lines of higher bandwidth.

- FDM is used to combine many lines into fewer lines in a hierarchical manner.

- The Hierarchical system used by AT&T comparises groups, supergroups, master groups and jumbo groups.
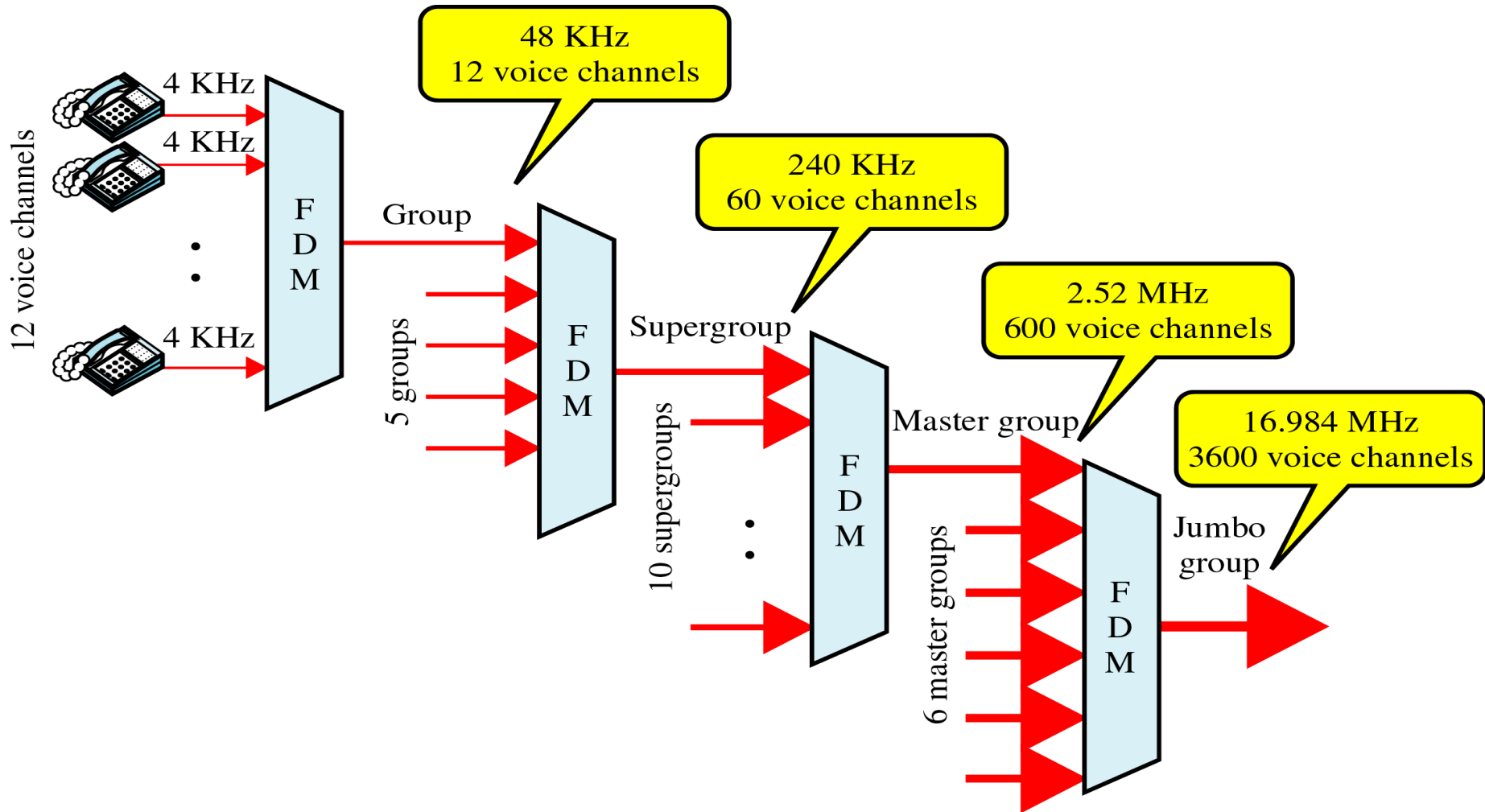
Digital Services

- The long-distance carrier system was designed to transmit voice signals over high-capacity transmission links, such as optical fiber, coaxial cable, and microwave. Part of this evolution was the adoption of digital technology.

- Digital Services are becoming increasingly popular because of higher immunity to noise and other interferences and lower cost.

- Categories of digital service:

```
                    Digital services
         ┌───────────────┼───────────────┐
    Switched/56         DDS              DS
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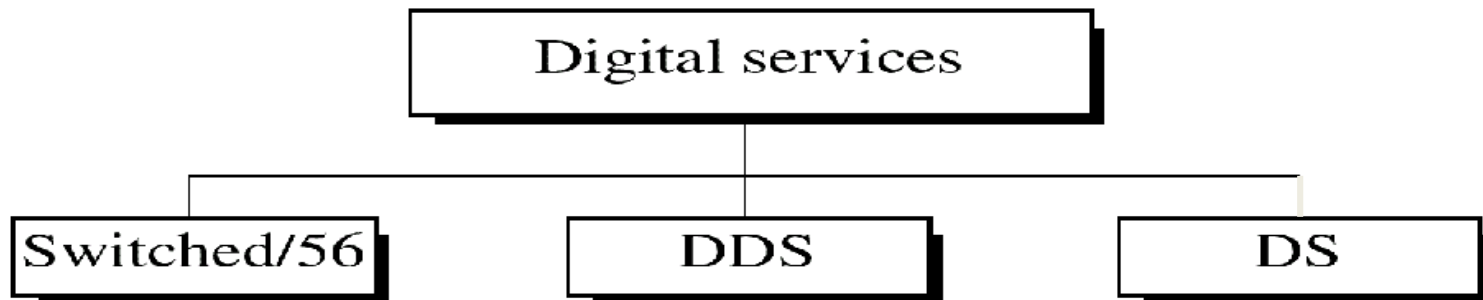
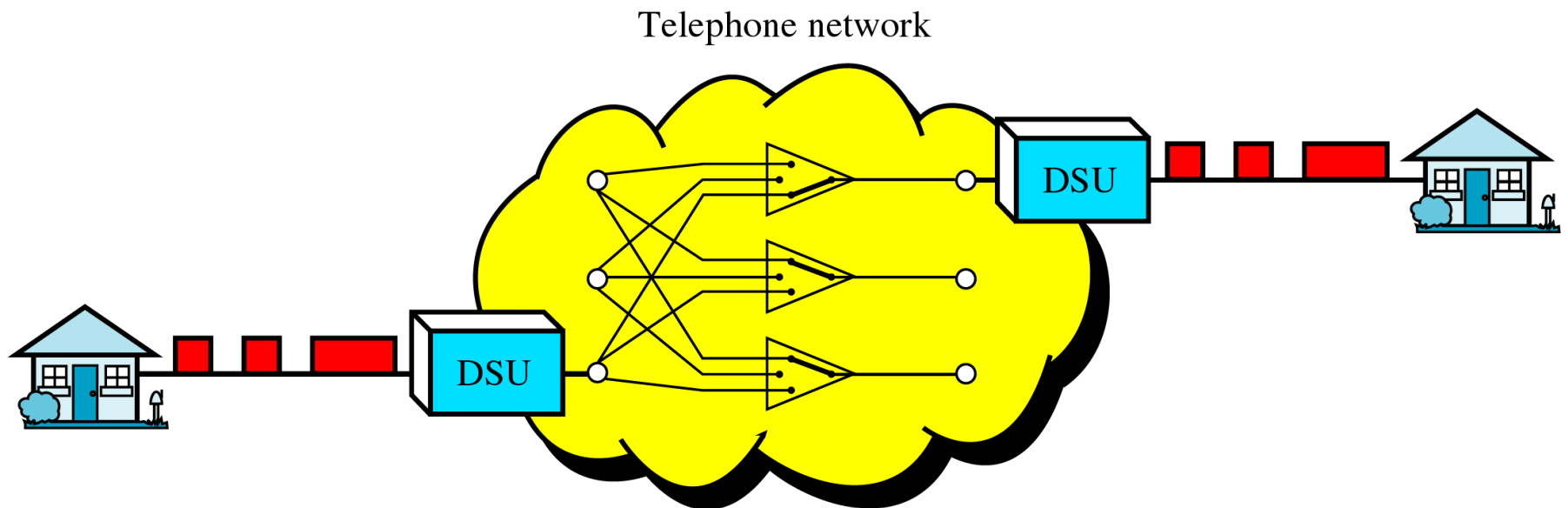# Switched 56 Services

- Digital version of the analog switched line.

- Allows data rate of up to 56 kbps.

- Althouth there is no need of modem, there is a need of another device known as Digital Service Unit (DSU).

- DSU provides better speed, less susceptibilty to noise and better quality.

- This Services provide bandwidth on demand.

Switched 56 Services

Telephone network
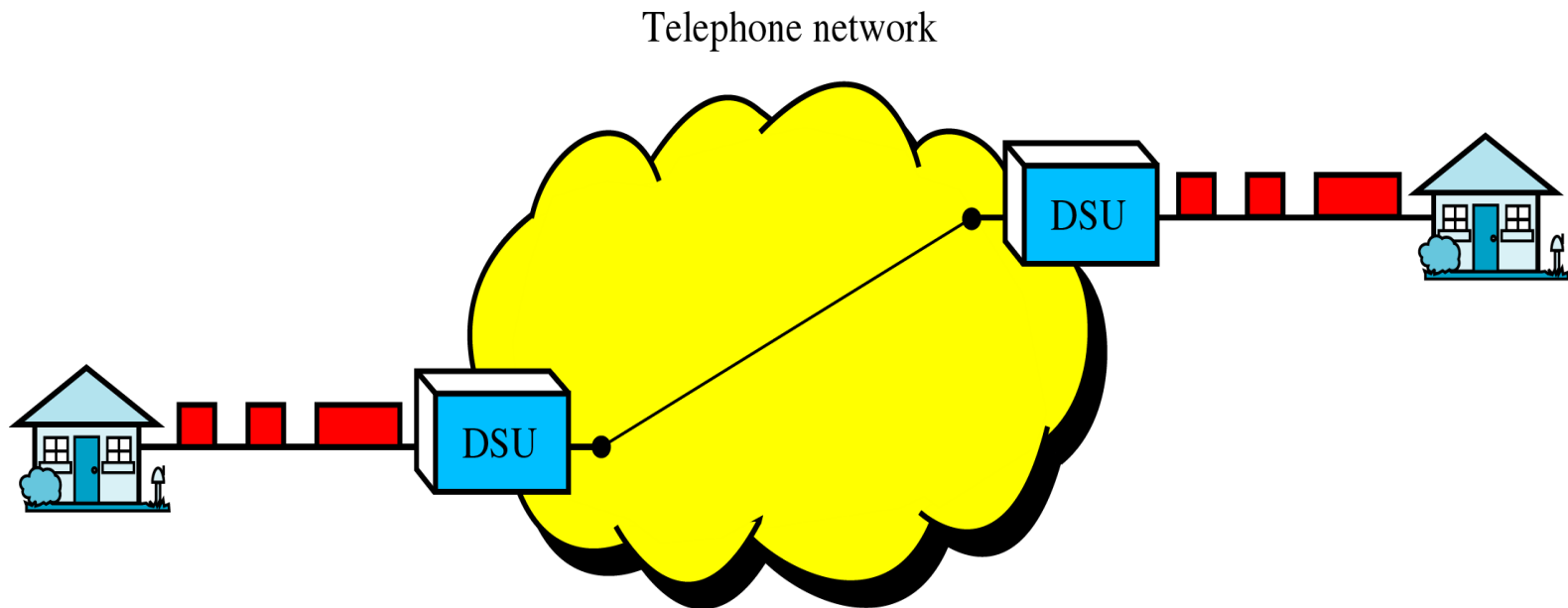
Digital Data Services (DDS)

- Digital version of analog leased line.

- Allows data rates of up to 56 kbps.

- Choice of lower data rates: 2.4, 4.8, 9.6, 19.2 or 56 kbps.

- Here also there is a need of DSU (digital service unit)

- DSU used in DDS is cheaper and simpler because it does not required keyboard.
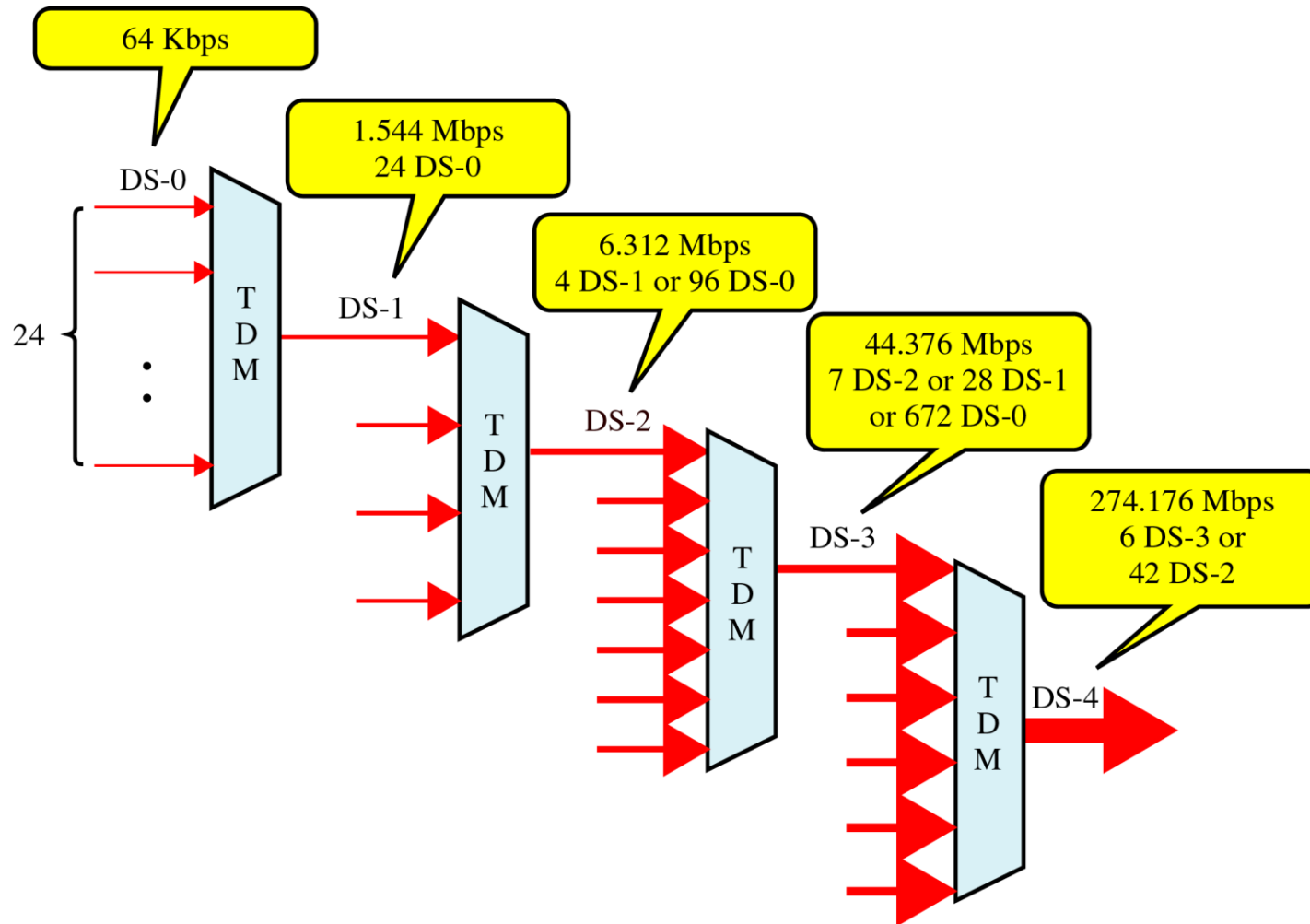
Digital Data Services (DDS)

Telephone network

Digital Signal (DS) Service

- Provides a hierarchy of digital services.

- DS-0 service is similar to DDS , a single digital channel of 64 kbps.
- DS-1 is 1.544 Mbps service.
- DS-2 is 6.312 Mbps service.
- DS-3 is 44.376 Mbps service.
- DS-4 is 274.176 Mbps service.

DS Hierarchy

USA Standard for DS

Table 8.3 North American and International TDM Carrier Standards

	North American			International (ITU-T)	
Designation	Number of Voice Channels	Data Rate (Mbps)	Level	Number of Voice Channels	Data Rate (Mbps)
DS-1	24	1.544	1	30	2.048
DS-1C	48	3.152	2	120	8.448
DS-2	96	6.312	3	480	34.368
DS-3	672	44.736	4	1920	139.264
DS-4	4032	274.176	5	7680	565.148

- **T1 lines are used** to implement these digital signal services.

Analog Transmission using T1 lines

- The basis of the TDM hierarchy is the DS-1 transmission format which multiplexes 24 channels.
- T1 lines can be used for analog transmission using PCM for conversion to digital signal.

Sampling at 8000 samples/second using 8 bits per sample

4 Khz

64,000 bps

PCM

PCM

PCM

24 voice channels

TDM

T-1 line 1.544 Mbps
24×64 Kbps + 8 Kbps overhead

T1 Frame Structure

Sample n

Channel 24	··	Channel 2	Channel 1
1 bit 8 bits		8 bits	8 bits

1 frame = 193 bits

Frame 8000	··	Frame n	··	Frame 2	Frame 1

T-1: 8000 frames/s = 8000 × 193 bps = 1.544 Mbps
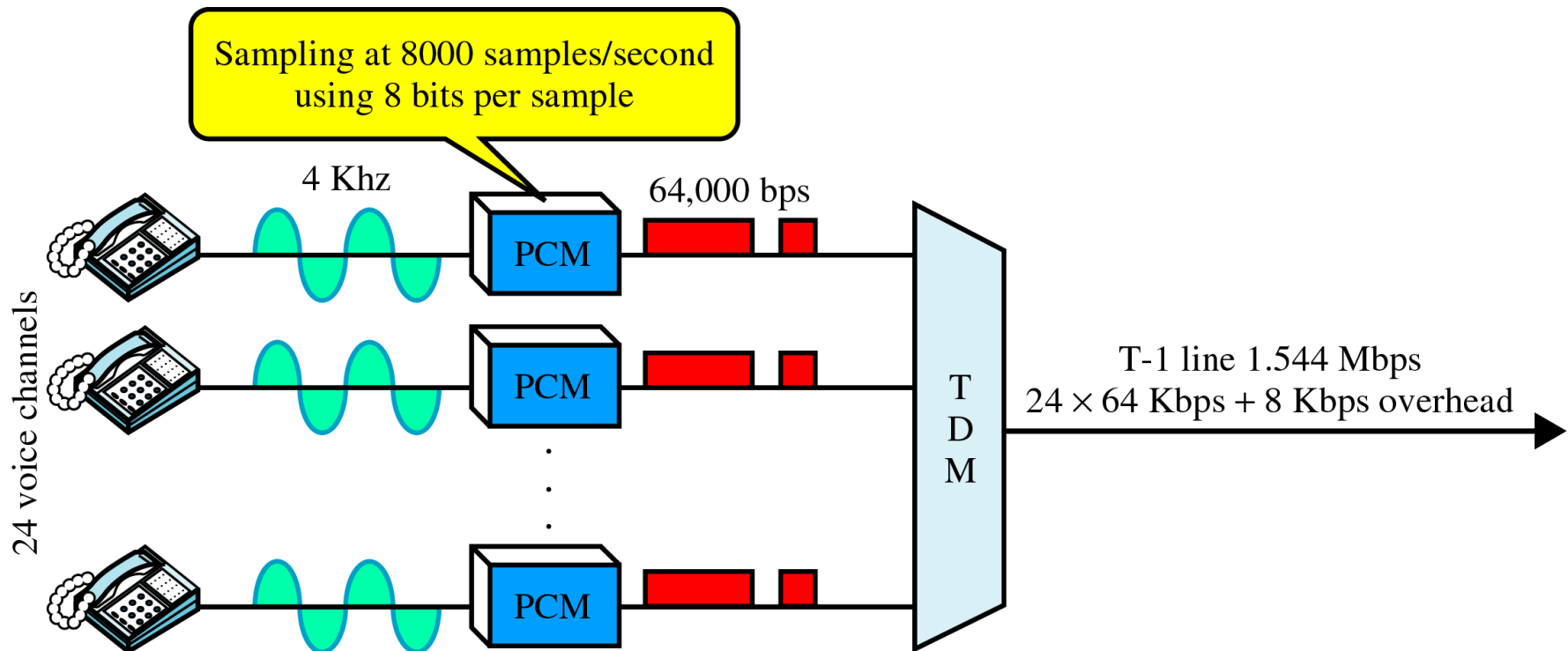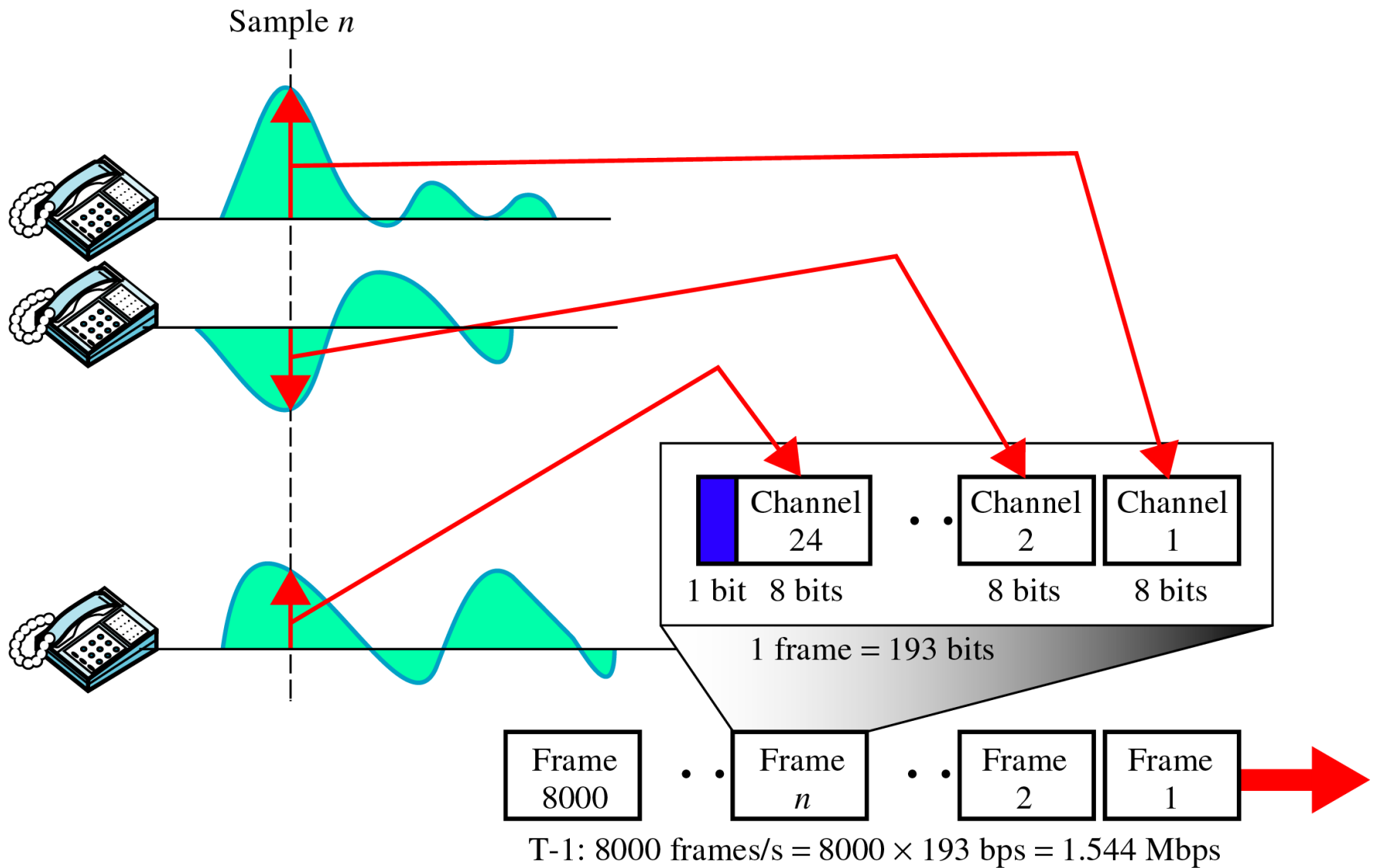
DS-1 Frame Format
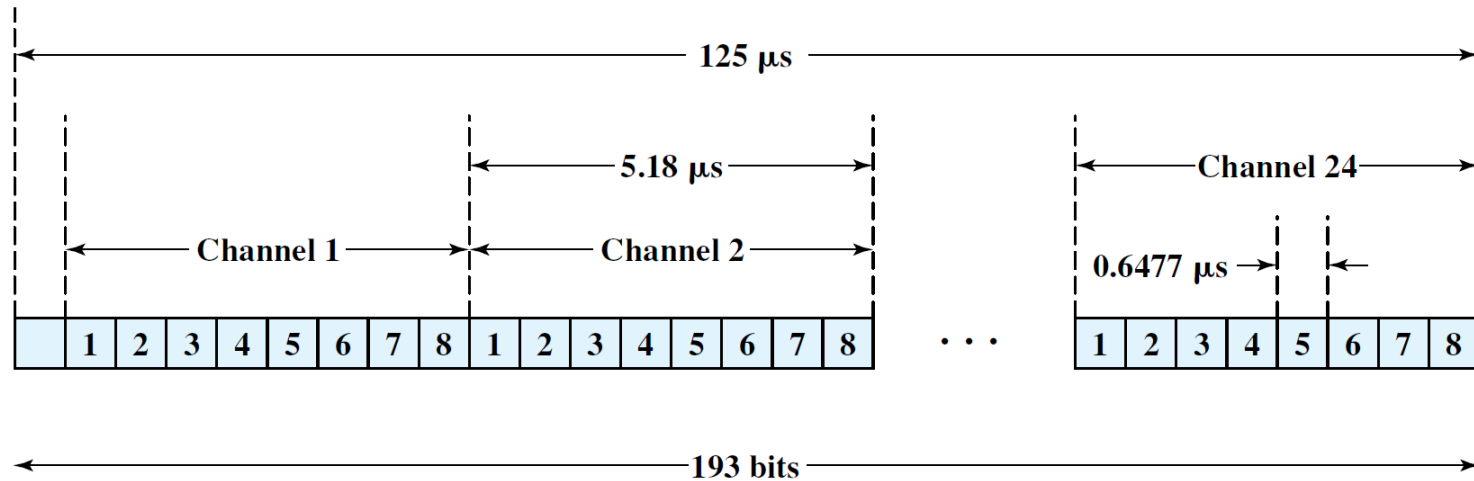
- The first bit is a framing bit, used for synchronization.
- Voice channels:
  - For five of every six frames, 8-bit PCM samples are used.
 - 7-bit PCM used on every sixth frame; bit 8 of each channel is a signaling bit.
- Data channels:
  - Channel 24 is used for signaling only in some schemes.
  - Bits 1–7 used for 56-kbps service
  - Bits 2–7 used for 9.6-, 4.8-, and 2.4-kbps service.

- Finally, the DS-1 format can be used to carry a mixture of voice and data channels. In this case, all 24 channels are utilized; no sync byte is provided.

DSL Technology

- Digital Subscriber Line (DSL) has been developed to facilitate high-speed digital communication over the existing local loops.

- Inherent bandwidth of 1.1 MHz of twisted pair cable used in local loops has been exploited.

- It uses suitable modulation as well as multiplexing techniques to achieve this.

- The DSL versions: ADSL, VDSL, HDSL and SDSL,often refered as xDSL.

Asymmetric DSL (ADSL)

- ADSL
  - provides higher bit rates in the downstream direction (from the telephone central office to the subscriber's site) than the upstream direction.
  - divides the bandwidth of a twisted-pair cable
  - Key underlying technology is DMT

POTS   Upstream   Downstream

0–25   25–200   250–1000
KHz   KHz   KHz
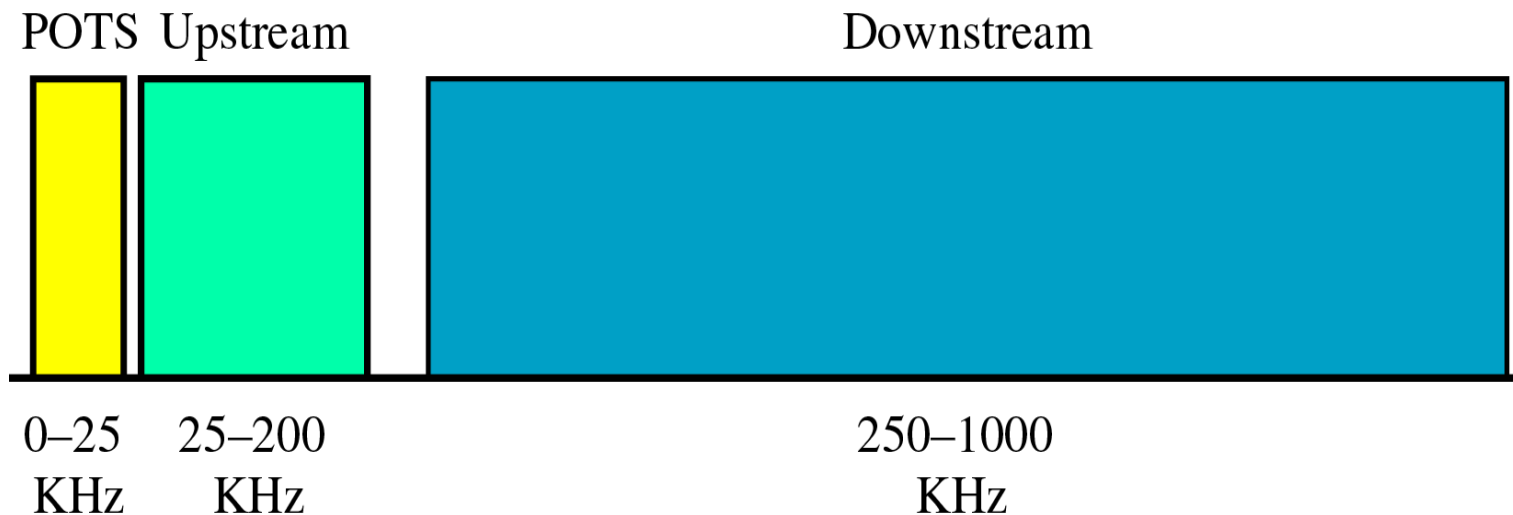
Discrete Multitone Technique (DMT)

- Discrete multitone (DMT) uses multiple carrier signals at different frequencies, sending some of the bits on each channel.
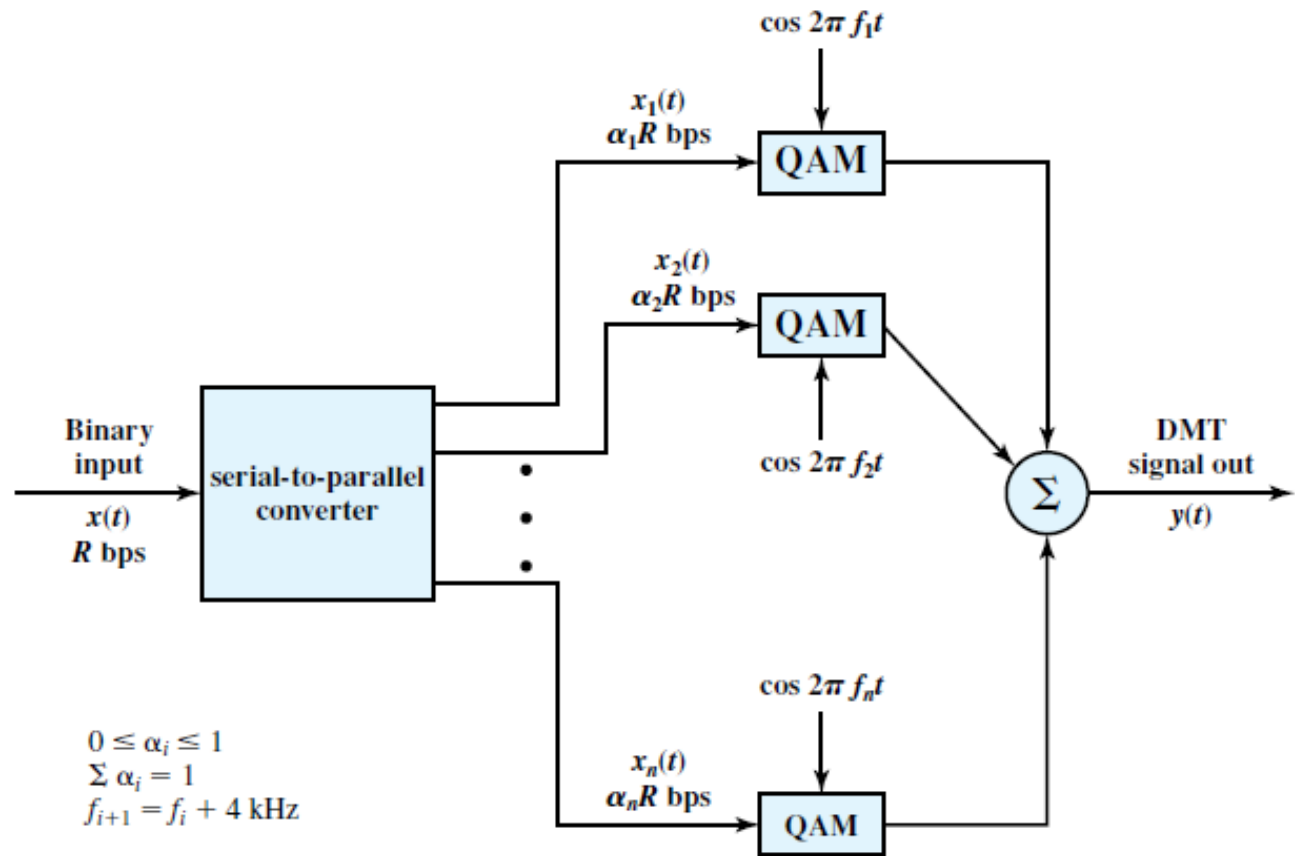

Figure 8.19 DMT Transmitter

Discrete Multitone Technique (DMT)

- voice: Channel 0 is reserved for voice.
- idle: channel 1-5 is not used.
- The available transmission band (upstream or downstream) is divided into a number of 4-kHz sub-channels

- Upstream Data and control: 24 channels for upstream data and control. one channel is used for control. Available bandwidth: 24*4000*15 = 1.44 Mbps

- Downstream Data and control: 224 channel for downstream data and control. Available bandwidth: 224*4000*15=13.4Mbps.

Others DSL Technique:

- Symmetric Digital Subscriber Line (SDSL): Divides the available bandwidth equally.

- High-bit-rate Digital Subscriber Line (HDSL): Designed as alternative to T1 line.
  - AMI encoding is used in T1 lines which is susceptible to attenuation at high frequencies.
  - HDSL uses 2B1Q encoding, which is less susceptible to attenuation.
  - Allows 2MBps over a distance of 3.6 km without repeater.
  - Uses two Pair of twisted pair wire for duplex communication.

Others DSL Technique:

- Very high bit rate Digital Subscriber Line (VDSL):

  - Similar to ADSL, but uses coaxial, fiber-optic or twisted-pair for shorter ditances.

  - Using DMT allows 1.5 to 2.5 Mbps for upstream and 50 to 55 downstream.

Comparison of xDSL

Table 8.8 Comparison of xDSL Alternatives

	ADSL	HDSL	SDSL	VDSL
Data rate	1.5 to 9 Mbps downstream 16 to 640 kbps upstream	1.544 or 2.048 Mbps	1.544 or 2.048 Mbps	13 to 52 Mbps downstream 1.5 to 2.3 Mbps upstream
Mode	Asymmetric	Symmetric	Symmetric	Asymmetric
Copper pairs	1	2	1	1
Range (24-gauge UTP)	3.7 to 5.5 km	3.7 km	3.0 km	1.4 km
Signaling	Analog	Digital	Digital	Analog
Line code	CAP/DMT	2B1Q	2B1Q	DMT
Frequency	1 to 5 MHz	196 kHz	196 kHz	≥ 10 MHz
Bits/cycle	Varies	4	4	Varies

UTP = unshielded twisted pair

Thanks!

Figure and slide materials are taken from the following sources:

1. W. Stallings, (2010), Data and Computer Communications
2. NPTL lecture on Data Communication, by Prof. A. K. Pal, IIT Kharagpur
3. B. A. Forouzan, (2013), Data Communication and Networking