

Circuit Switching

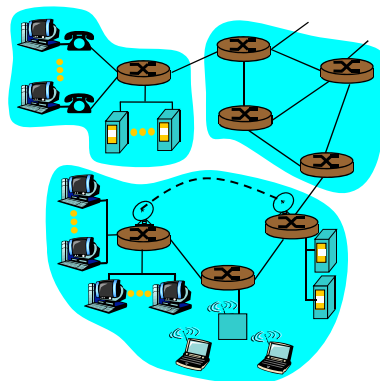
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Study: 10.1, 10.2,
8 .1, 8.2 (without SONET/SDH), 8.4

10-02-2012

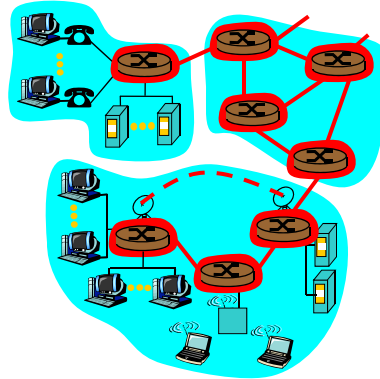
A Closer Look At Network Structure:

- **network edge:**
applications and hosts
- **network core:**
 - routers
 - network of networks
- **access networks,**
physical media:
communication links



The Network Core

- mesh of interconnected routers
- the fundamental question: how is data transferred through net?
 - circuit switching: dedicated circuit per call: telephone net
 - packet-switching: data sent thru net in discrete “chunks”

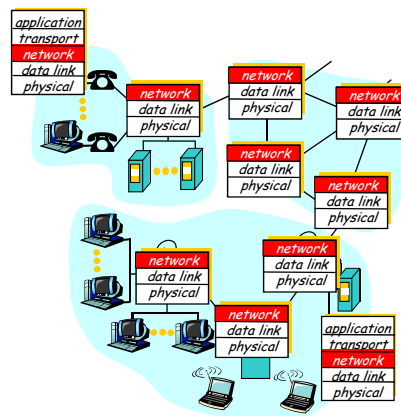


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Network Layer Functions

- transport packet from sending to receiving hosts
 - network layer protocols in every host, router
- three important functions:
- path determination: route taken by packets from source to dest. *Routing algorithms*
 - switching: move packets from router's input to appropriate router output
 - call setup: some network architectures require router call setup along path before data flows



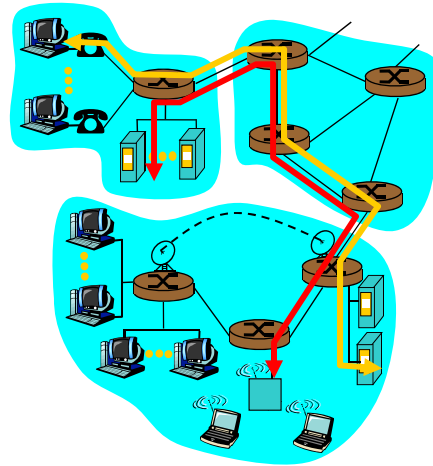
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Network Core: Circuit Switching

End-end resources reserved for "call"

- link bandwidth, switch capacity
- dedicated resources: no sharing
- circuit-like (guaranteed) performance
- call setup required



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Circuit Switching

- Dedicated communication path between two stations
- Three phases
 - Establish (set up connection)
 - Data Transfer
 - Disconnect
- Must have switching capacity and channel capacity to establish connection
- Must have intelligence to work out routing
- Inefficient
 - Channel capacity dedicated for duration of connection
 - If no data, capacity wasted
- Set up (connection) takes time
- Once connected, transfer is transparent
- Developed for voice traffic (phone)

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Public Circuit Switched Network

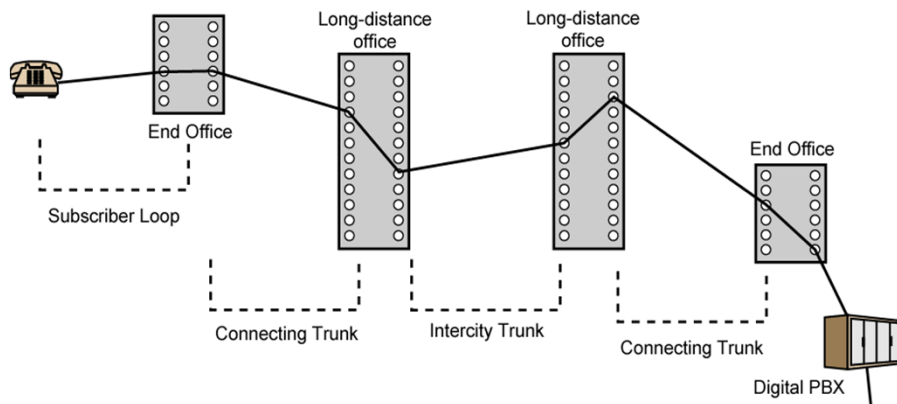


Figure 10.2

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Telecommunication Components

- Subscriber
 - Devices attached to network
- Subscriber line (also referred as subscriber loop)
 - Connection to network
 - Few km up to few tens of km
- Exchange
 - Switching centers
 - End office - supports subscribers
- Trunks
 - Branches between exchanges
 - Multiplexed, i.e. multiple links on 1 physical line

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Circuit Establishment

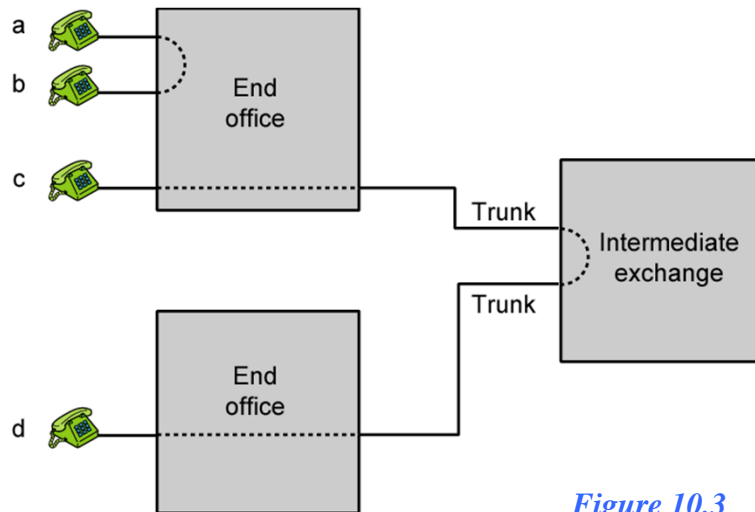


Figure 10.3

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Multiplexing

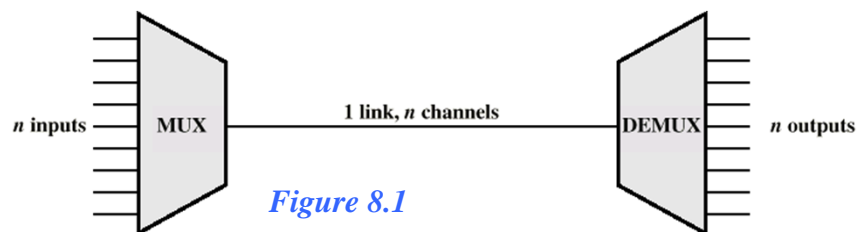


Figure 8.1

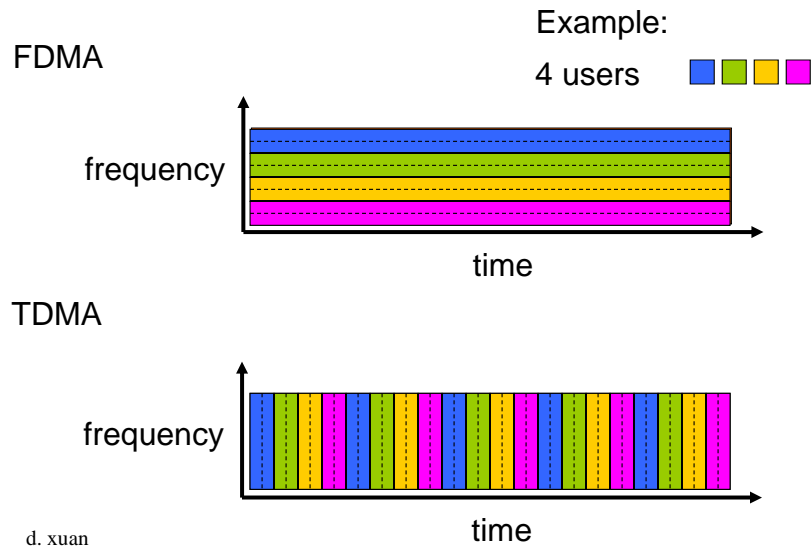
- **Frequency Division Multiplexing Access - FDMA**
 - Useful bandwidth of medium exceeds required bandwidth of channel
 - Each signal is modulated to a different carrier frequency
 - Carrier frequencies separated so signals do not overlap (guard bands)
 - Channel allocated even if no data
- **Time Division Multiplexing Access - TDMA**

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Circuit Switching: FDMA and TDMA



Frequency Division Multiplexing

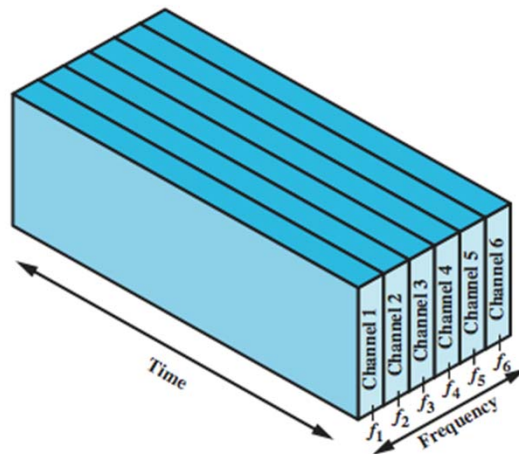


Figure 8.2 (a)

FDM System Overview

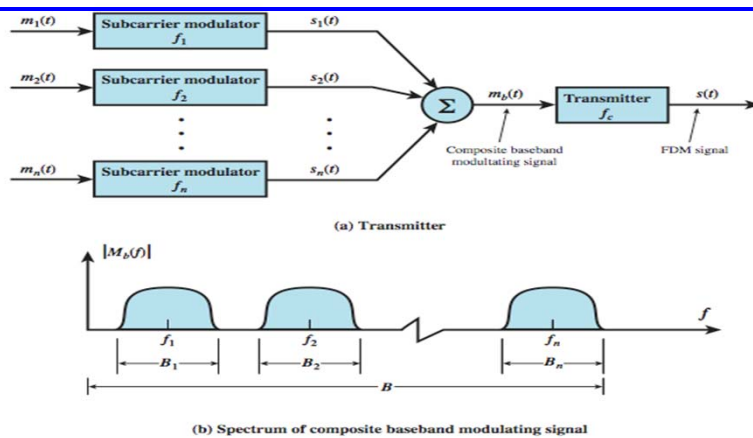
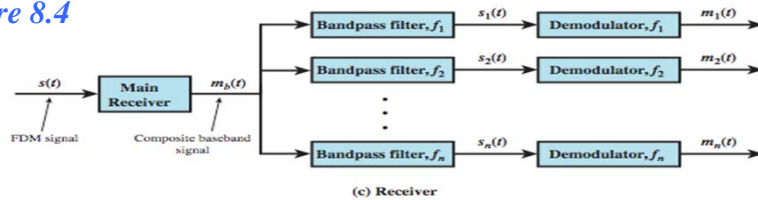


Figure 8.4



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FDM of Three Voiceband Signals

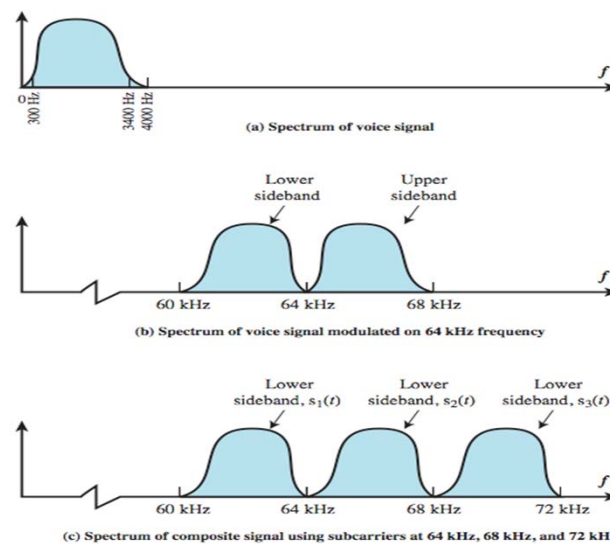


Figure 8.5

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Analog Carrier Systems

- long-distance links use an FDM hierarchy
- AT&T (USA) and ITU-T (International) variants
- Group
 - 12 voice channels (4kHz each) = 48kHz
 - in range 60kHz to 108kHz
- Supergroup
 - FDM of 5 group signals supports 60 channels
 - on carriers between 420kHz and 612 kHz
- Mastergroup
 - FDM of 10 supergroups supports 600 channels
- so original signal can be modulated many times

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Wavelength Division Multiplexing - WDM

- A form of frequency division multiplexing – FDM
- Number of sources generate laser beams at different frequencies and multiplexer consolidates sources for transmission over single optical fiber
- Each colour of light (wavelength) carries separate data channel; Mostly 1550nm wavelength range
- Optical amplifiers amplify all wavelengths
 - Typically tens of km apart
- De-multiplexer separates channels at the destination
- Lab systems (Alcatel): 256 channels at 39.8 Gbps each: 10.1 Tbps, over 100km
- Commercial systems of 160 channels with 10 Gbps each available
- **Dense Wavelength Division Multiplexing – DWDM:** Implies more channels more closely spaced than WDM

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Synchronous Time Division Multiplexing

- Multiple digital signals interleaved in time
- Time slots pre-assigned to sources and fixed

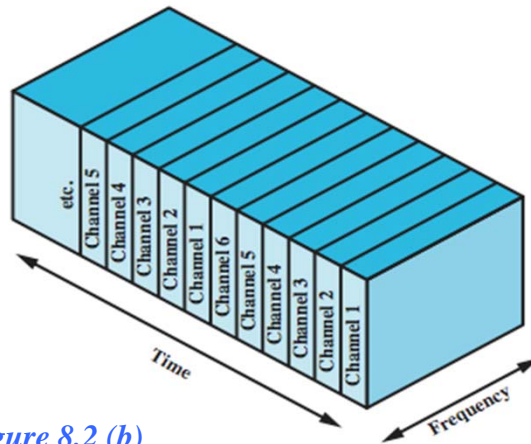
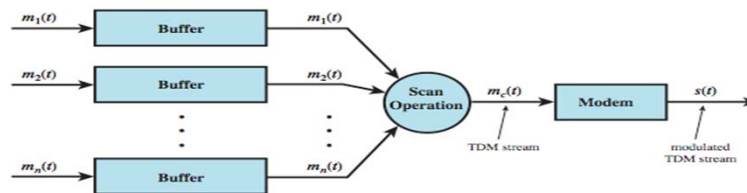


Figure 8.2 (b)

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Synchronous TDM System Overview

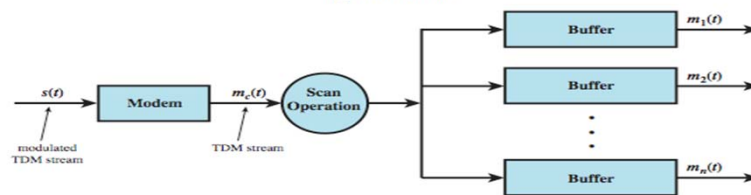


(a) Transmitter



Time slot: may be empty or occupied

(b) TDM Frames



(c) Receiver

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DS-1 Transmission Format

- In US digital carrier systems based on DS-1 format
- Multiplexes 24 channels
- Each frame has 8 bits per channel plus one framing bit
- 193 bits per frame
- Data rate $8000 \times 193 = 1.544\text{Mbps}$
 - Recall: $\text{PCM} = 8000\text{samples/sec} \times 7\text{bits}$

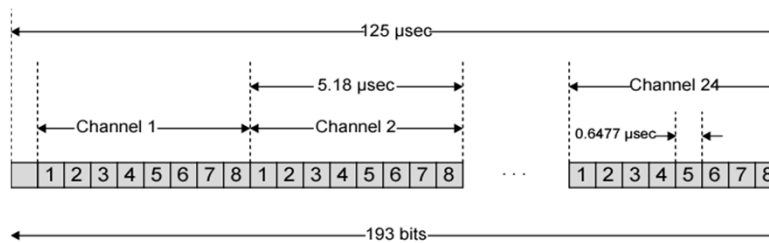


Figure 8.9
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Circuit Switching: Conclusion

- Circuit switching designed for voice
 - Resources dedicated to a particular call
 - Short duration calls assumed
- Much of the time a data connection may be idle
- Data rate is fixed
 - Both ends must operate at the same rate
- Blocking is possible
 - A network is unable to connect stations because all paths are in use

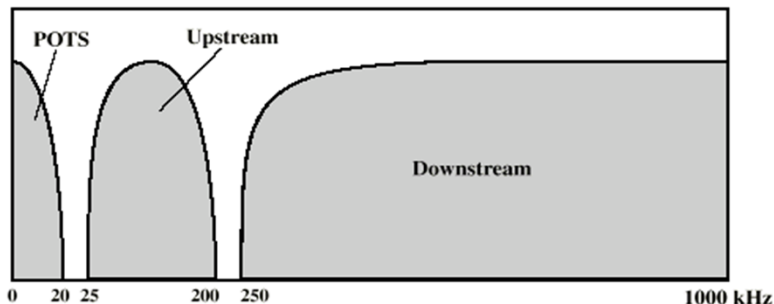
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ADSL Channel Configuration

- **ADSL (Asymmetric Digital Subscriber Line)** is a family of new modem technologies over ordinary telephone wire:
 - from 16 kbps to 640 kbps upstream
 - from 1.5 Mbps to 9 Mbps downstream
- **POTS**: plain old telephone service



- ADSL uses frequency division multiplexing

Figure 8.17

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Discrete Multitone (DMT)

- multiple carrier signals at different frequencies
- divide into 4kHz subchannels
- test and use subchannels with better SNR
- 256 downstream subchannels at 4kHz (60kbps)
 - in theory 15.36Mbps, in practice 1.5 - 9Mbps

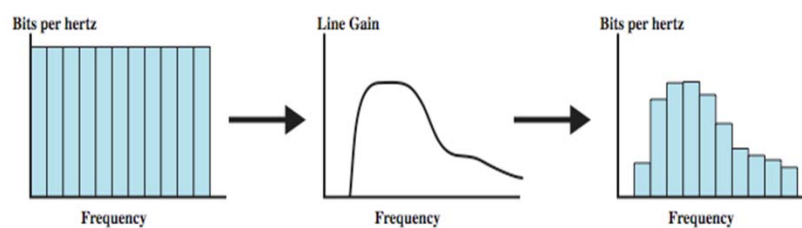


Figure 8.18

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DMT Transmitter

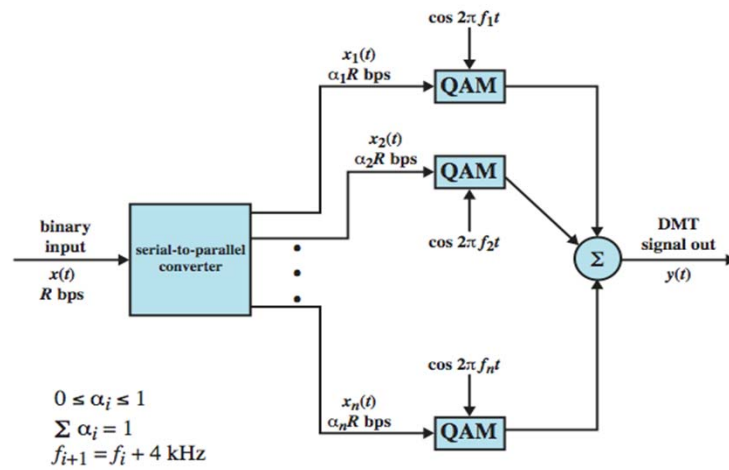


Figure 8.19