INTEGRATED TECHNICAL EDUCATION CLUSTER
AT ALAMEERIA

E-626-A
Data Communication and Industrial Networks (DC-IN)

Lecture #6
Multiplexing and Switching

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SPRING 2015

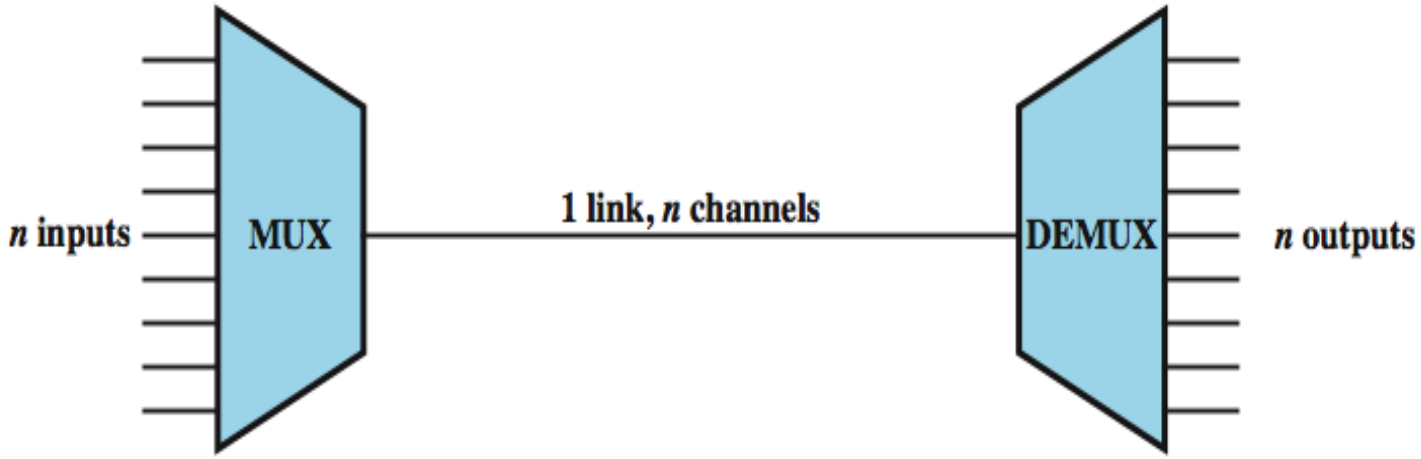
Agenda

- Multiplexing
- Circuit Switching
- Packet Switching

MULTIPLEXING

Multiplexing

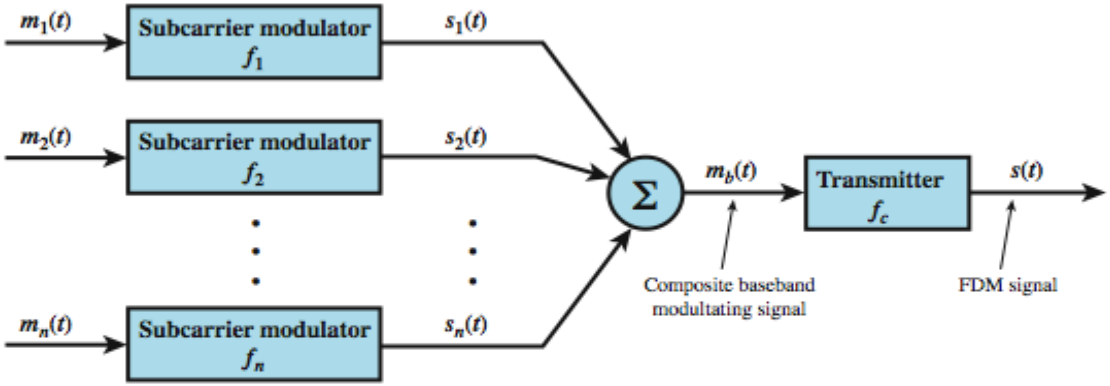
- Several data sources share a common medium, with each source having its own channel
- Line sharing saves transmission costs
- More cost-effective transmissions
- Common on long-haul, high capacity links



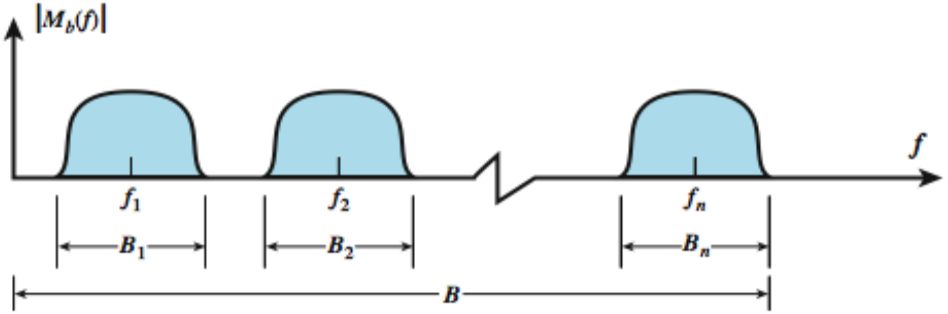
Frequency Division Multiplexing

- Requires analog signaling & transmission
- Bandwidth = sum of inputs + guardbands
- Modulates signals so that each occupies a different frequency band
- Standard for radio broadcasting, analog telephone network, and television
  (broadcast, cable, & satellite)

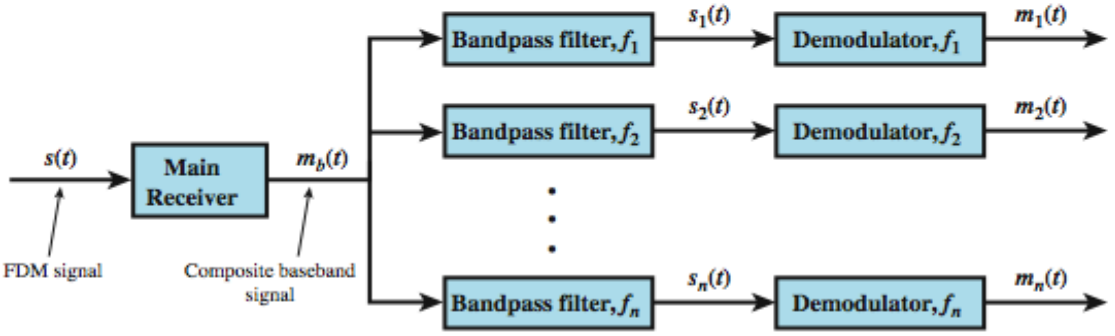
FDM System Overview



(a) Transmitter



(b) Spectrum of composite baseband modulating signal



(c) Receiver

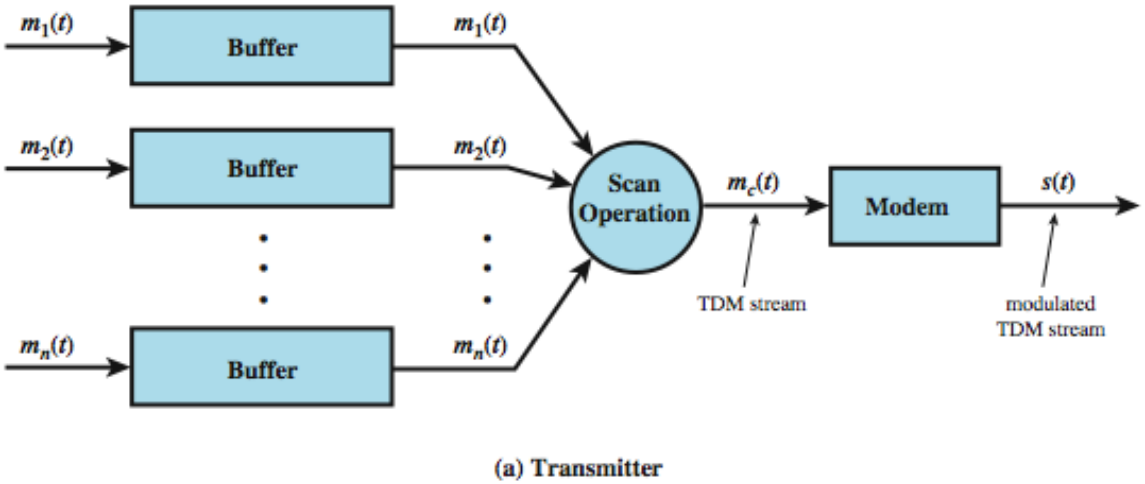
ADSL

- Asymmetric Digital Subscriber Line
- Uses FDM to exploit 1-MHz capacity
  - Reserves lowest 25 kHz for voice
  - Use either echo cancellation or FDM to allocate two bands, a smaller upstream and larger down
  - Use FDM within bands to split bit stream into multiple parallel bit streams - discrete multitone
- Range up to 5.5 km

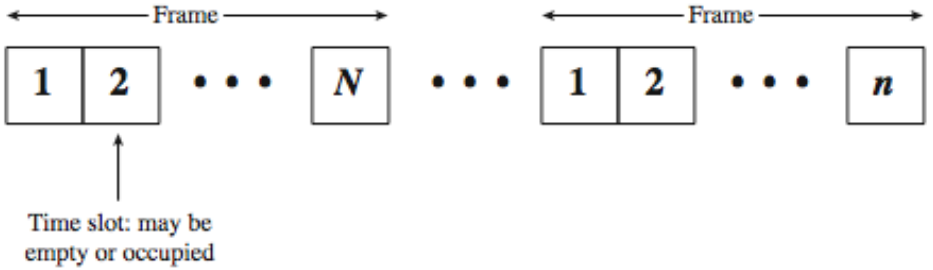
Synchronous TDM

- Synchronous Time Division Multiplexing
- Used in digital transmission
- Requires data rate of the medium to exceed data rate of signals to be transmitted
- Signals “take turns” over medium
- Slices of data are organized into frames

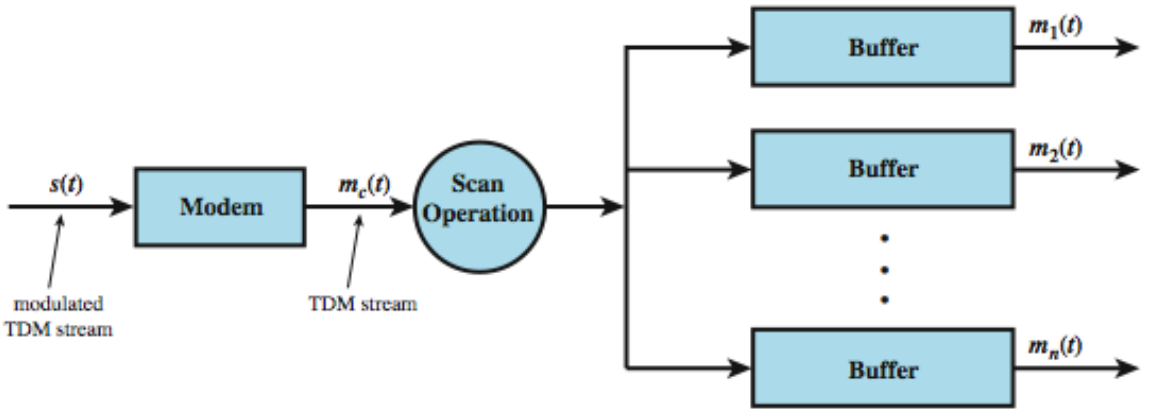
Synch. TDM System Overview



(a) Transmitter



(b) TDM Frames



(c) Receiver

Synchronous TDM and PSTN

- Used in modern digital telephone system
  - US, Canada, Japan: DS-1(T-1), DS-3(T-3), ...
  - Europe, elsewhere: E1, E3, ...
- DS-1: Data rate of 1.544 Mbps
- Uses PCM to digitize voice transmission at 8000 times/sec with 8 bits/sample = 64kbps
- 24 channels x 8 bits/channel + 1 frame bit = 193 bits/frame with 8000 frames/sec

Cable Modem & Cable Spectrum Division

- Two channels dedicated on cable,
  one for transmission in each direction
- Each channel shared by number of subscribers using statistical TDM

Cable Spectrum Division:

- to support both cable television programming and data channels, the cable spectrum is divided in to three ranges:
  - user-to-network data (upstream): 5 - 40 MHz
  - television delivery (downstream): 50 - 550 MHz
  - network to user data (downstream): 550 - 750 MHz

SWITCHING

Switching Techniques

- Transmission beyond local area requires intermediate switching nodes
- Nodes concerned not with content but with movement of data
- Two technologies of switching differ in way data is switched from one link to another
  - circuit switching versus packet switching

Circuit-Switching

- Definition:
  - Communication in which a dedicated communications path is established between two devices through one or more intermediate switching nodes
- Dominant in both voice and data today
  - e.g. PSTN is a circuit-switched network
- Relatively inefficient
  - 100% dedication even without 100% utilization

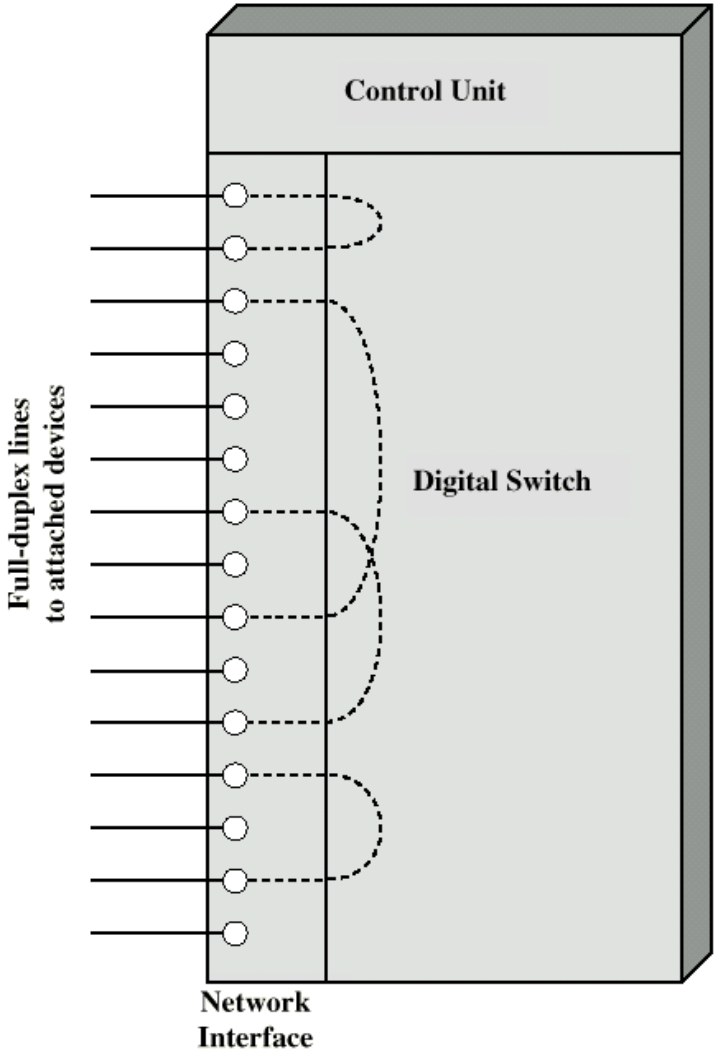
Circuit-Switching Stages

- Circuit establishment
  - end-to-end circuit established before any signals can be transmitted
- Data transfer
  - point-to-point from endpoints to nodes
  - internal switching/multiplexing among nodes
- Circuit disconnect
  - deallocate resources dedicated to circuit

PSTN

- Public Switched Telephone Network
- Four generic components
  - Subscribers - devices that attach to network
  - Local loop - link from subscriber to network
  - Exchanges - switching centers
    (end office - connected to subscribers)
  - Trunks - branches between exchanges
    (FDM or synchronous TDM)

Circuit-Switched Node



Circuit-Switching Node: Digital Switch

- Provides transparent signal path between any pair of attached devices
- Appears to devices as direct connection
- Typically full-duplex

Circuit-Switching Node: Network Interface

- Provides hardware and functions to connect digital devices to switch
- Analog devices can be connected if interface includes CODEC functions
- Typically full-duplex
- Trunks to other switches carry TDM signals to provide links for multiple node networks

Circuit-Switching Node: Control Unit

- Establishes on-demand connections
  - handle and acknowledge request
  - determine if destination is free
  - construct path through switch
- Maintains connection while needed
  - maintain time-division for connection
- Breaks down connection on completion

Blocking/Non-blocking Networks

- Blocking
  - network is unable to connect two stations because all possible paths are already in use (acceptable for voice only)
- Non-blocking:
  - permits all possible connection requests because any two stations can be connected (and may stay that way for a long time)

Switching Techniques

Space-Division Switching

- Developed for analog environment, but has been carried over into digital communication
- Requires separate physical paths for each signal connection
- Uses metallic or semiconductor “gates”

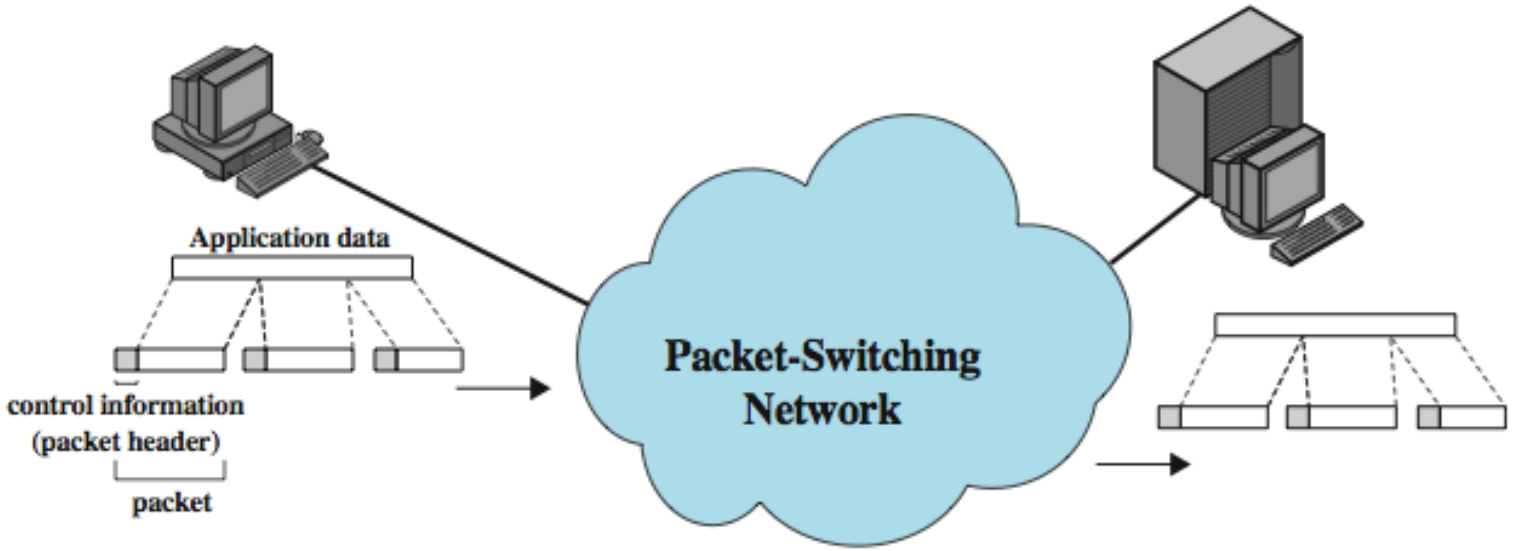
Time-Division Switching

- Used in digital transmission
- Utilizes multiplexing to place all signals onto common transmission path
- Bus must have higher data rate than the individual I/O lines

Packet Switching

- circuit switching designed for voice
- packet switching designed for data
- transmitted in small packets
  - packets contains user data and control info
  - user data may be part of a larger message
  - control information includes routing (addressing)
- packets are received, stored briefly (buffered) and passed on to the next node

Packet Switching (2)



Packet Switching (3)

- Advantages
  - Better line efficiency - shared by many
  - Can adjust data rates for different devices
  - Prioritization option - high priority packets first

- Disadvantages
  - Transmission delay in nodes - buffers & processing
  - Variable delays can cause jitter
  - Overhead for address and network status info

Packet Switching Techniques

- station breaks long message into packets
  - packets sent one at a time to the network
- packets can be handled in two ways:
  - datagram
    - each packet is treated independently with no reference to previous packets
  - virtual circuit
    - a preplanned route is established before any packets are sent

Circuit Switching	Datagram Packet Switching	Virtual Circuit Packet Switching
Dedicated transmission path	No dedicated path	No dedicated path
Continuous transmission of data	Transmission of packets	Transmission of packets
Fast enough for interactive	Fast enough for interactive	Fast enough for interactive
Messages are not stored	Packets may be stored until delivered	Packets stored until delivered
The path is established for entire conversation	Route established for each packet	Route established for entire conversation
Call setup delay; negligible transmission delay	Packet transmission delay	Call setup delay; packet transmission delay
Busy signal if called party busy	Sender may be notified if packet not delivered	Sender notified of connection denial
Overload may block call setup; no delay for established calls	Overload increases packet delay	Overload may block call setup; increases packet delay
Electromechanical or computerized switching nodes	Small switching nodes	Small switching nodes
User responsible for message loss protection	Network may be responsible for individual packets	Network may be responsible for packet sequences
Usually no speed or code conversion	Speed and code conversion	Speed and code conversion
Fixed bandwidth	Dynamic use of bandwidth	Dynamic use of bandwidth
No overhead bits after call	Overhead bits in each packet	Overhead bits in each packet

- For more details, refer to:
  - Chapters 8,10 , W. Stallings, **Data and Computer Communications**, 8th ed. .
- The lecture is available online at:
- Lecture notes are found at:
  - http://bu.edu.eg/staff/ahmad.elbanna-courses/12133
- For inquires, send to:
  - ahmad.elbanna@feng.bu.edu.eg