Chapter 8

Multiplexing

Reading Materials

- **Data and Computer Communications**, William Stallings

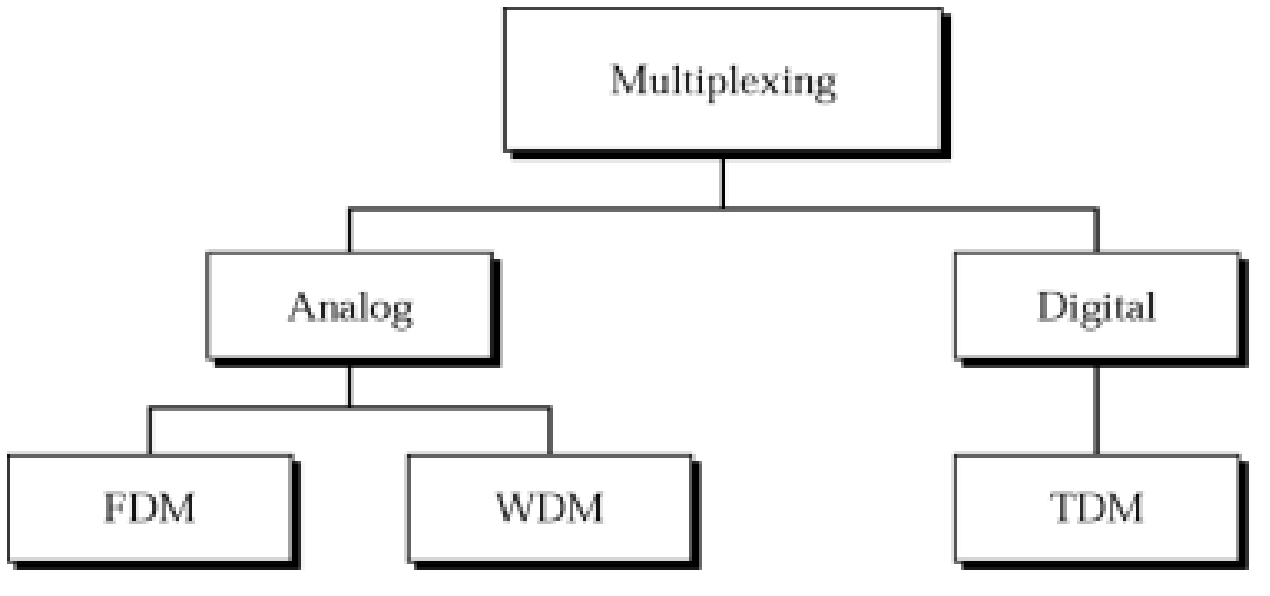
Contents

- Frequency division multiplexing
- Wavelength division multiplexing
- Synchronous time division multiplexing

Multiplexing

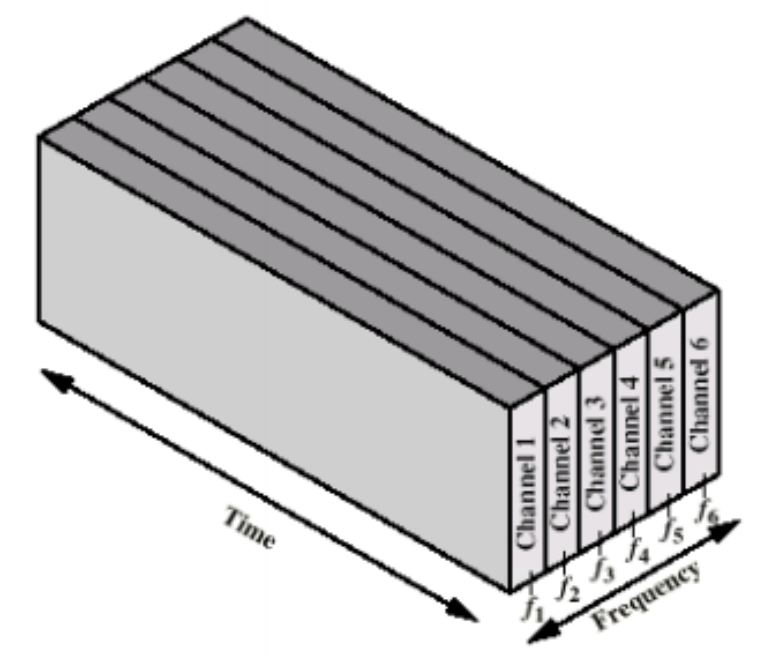
- To make efficient use of high-speed telecommunications lines, some form of multiplexing is used. Multiplexing allows several transmission sources to share a larger transmission capacity.
- The two common forms of multiplexing are frequency division multiplexing (FDM) and time division multiplexing (TDM).
- Typically, two communicating stations will not utilize the full capacity of a data link. For efficiency, it should be possible to share that capacity. A generic term for such sharing is **multiplexing**.
- A common application of multiplexing is in long-haul communications. Trunks on long-haul networks are high-capacity fiber, coaxial, or microwave links. These links can carry large numbers of voice and data transmissions simultaneously using multiplexing.

Multiplexing

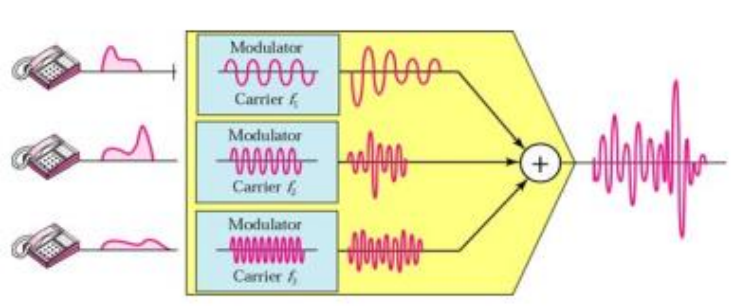


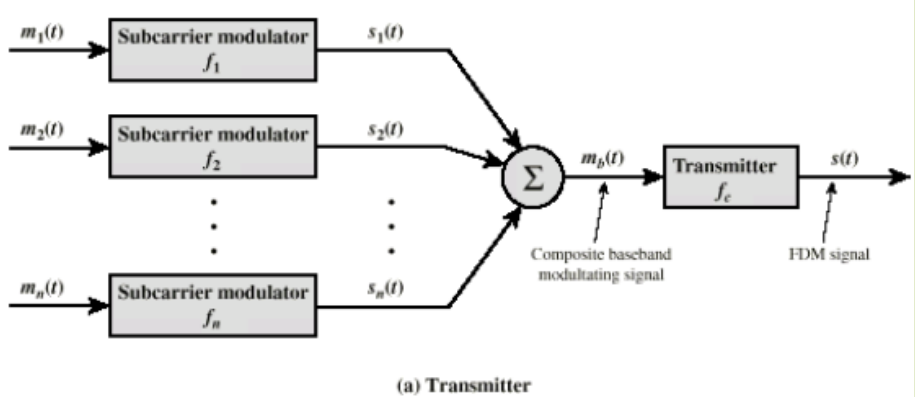
Frequency Division Multiplexing

- FDM
- Useful bandwidth of medium exceeds required bandwidth of channel
- Each signal is modulated to a different carrier frequency referred as channel.
- Carrier frequencies separated so signals do not overlap (guard bands)
- e.g. broadcast radio
- Channel allocated even if no data

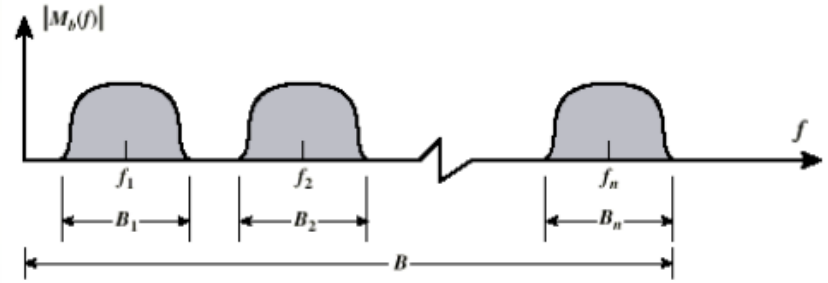


FDM System

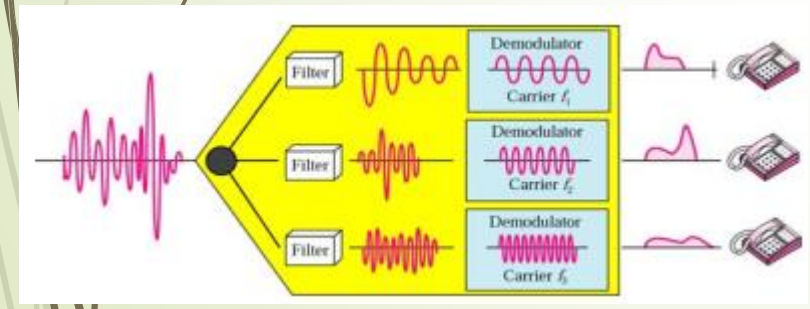


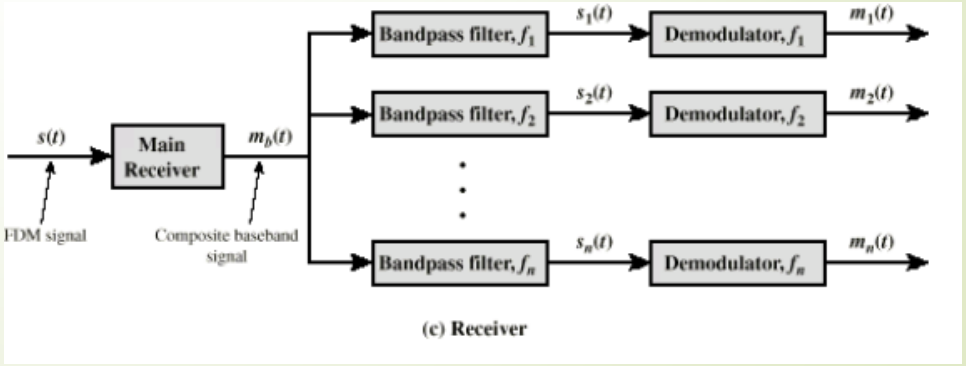


(a) Transmitter



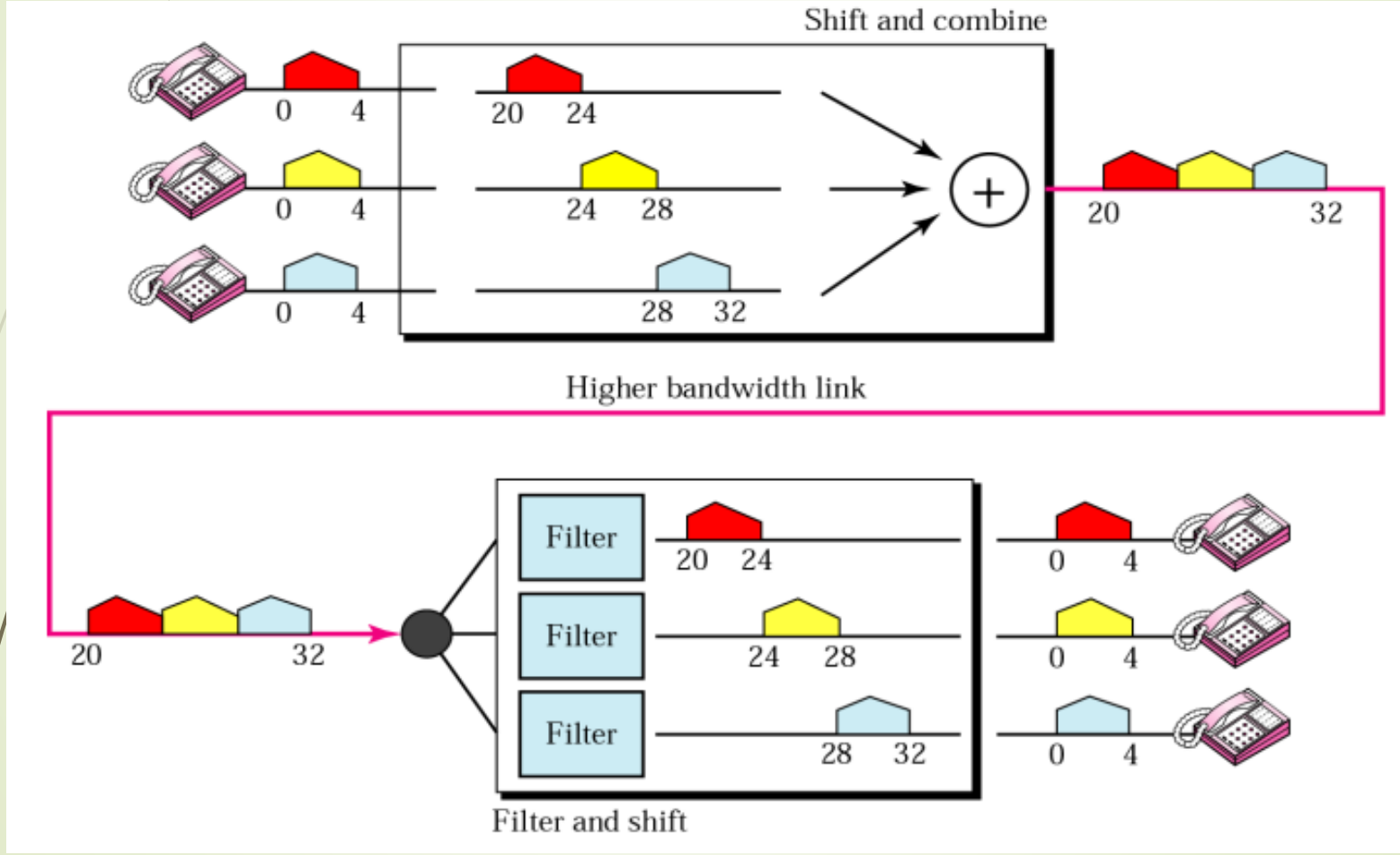
(b) Spectrum of composite baseband modulating signal





(c) Receiver

FDM Example

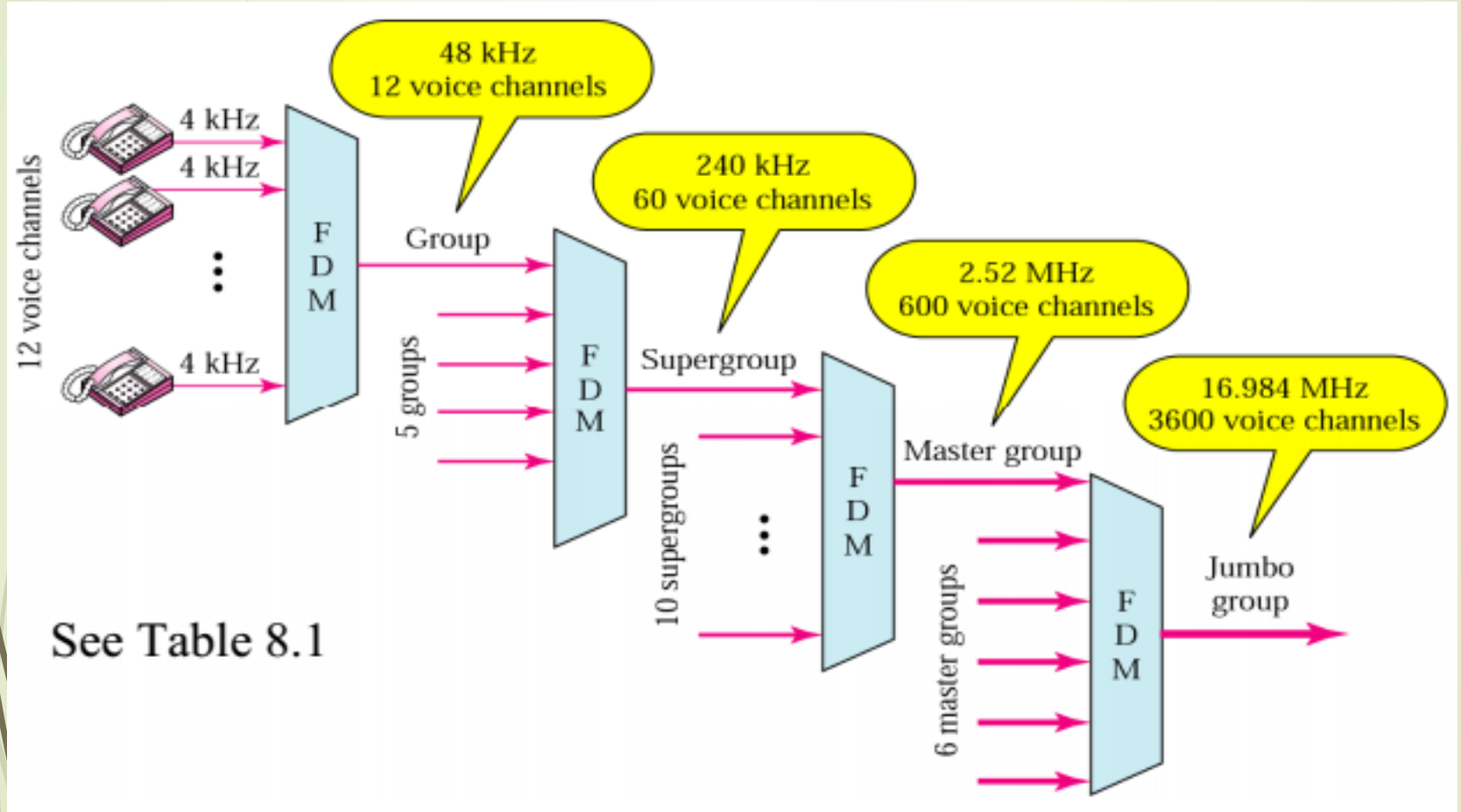

Shift and combine
0
4
20
24
0
4
24
28
0
4
28
32
20
32
Higher bandwidth link
20
32
Filter
Filter
Filter
20
24
24
28
28
32
0
4
0
4
0
4
Filter and shift

Analog Carrier Systems

Table 8.1 North American and International FDM Carrier Standards

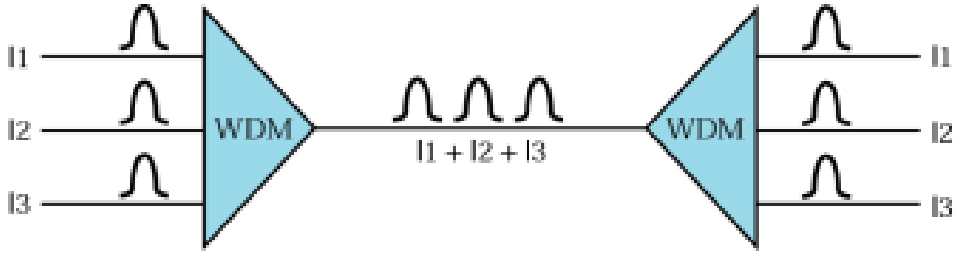
Number of Voice Channels	Bandwidth	Spectrum	AT&T	ITU-T
12	48 kHz	60–108 kHz	Group	Group
60	240 kHz	312–552 kHz	Supergroup	Supergroup
300	1.232 MHz	812–2044 kHz		Mastergroup
600	2.52 MHz	564–3084 kHz	Mastergroup	
900	3.872 MHz	8.516–12.388 MHz		Supermaster group
$N \times 600$			Mastergroup multiplex	
3,600	16.984 MHz	0.564–17.548 MHz	Jumbogroup	
10,800	57.442 MHz	3.124–60.566 MHz	Jumbogroup multiplex	

Analog Carrier Systems



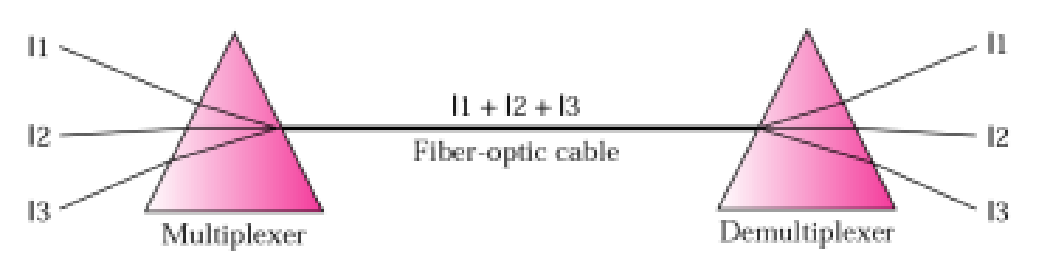
Wavelength Division Multiplexing

- Multiple beams of light at different frequency
- Carried by optical fibre
- A form of FDM
- Each colour of light (wavelength) carries separate data channel
- 1997 Bell Labs
  - 100 beams
  - Each at 10 Gbps
  - Giving 1 terabit per second (Tbps)
- Commercial systems of 160 channels of 10 Gbps now available
- Lab systems (Alcatel) 256 channels at 39.8 Gbps each
  - 10.1 Tbps
  - Over 100km



WDM Operation

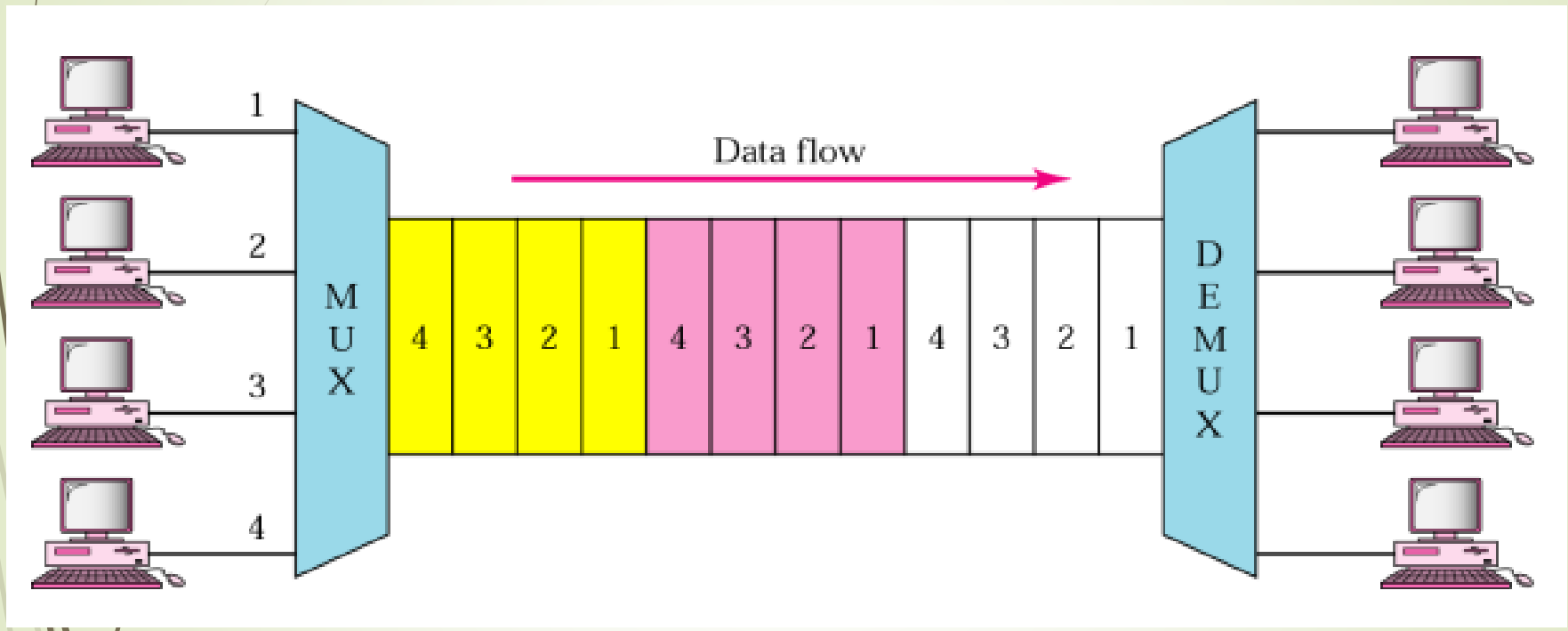
- Same general architecture as other FDM
- Number of sources generating laser beams at different frequencies
- Multiplexer consolidates sources for transmission over single fiber
- Optical amplifiers amplify all wavelengths
  - Typically tens of km apart
- Demux separates channels at the destination



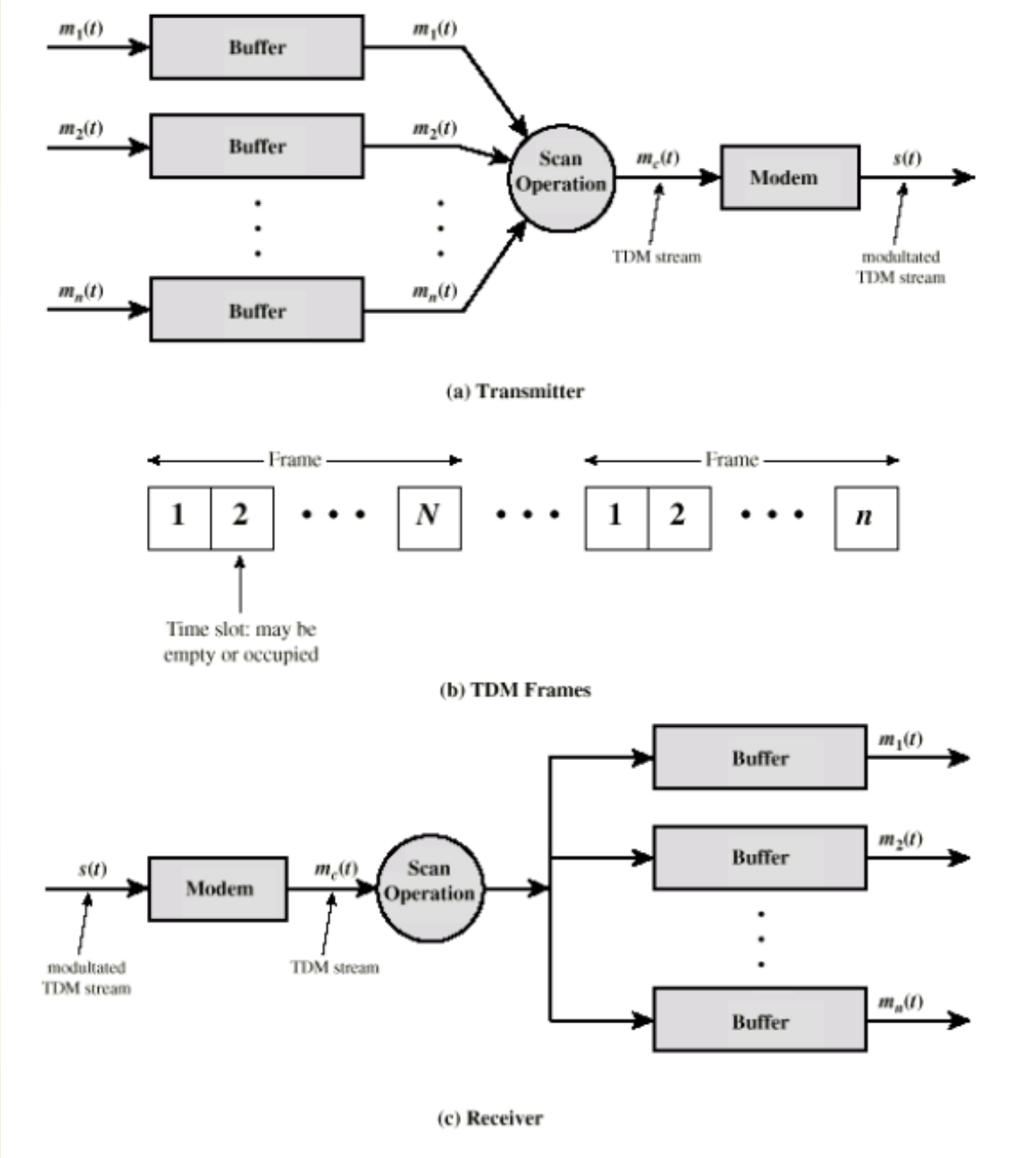
Synchronous Time Division Multiplexing

- Data rate of medium exceeds data rate of digital signal to be transmitted
- Multiple digital signals interleaved in time
- May be at bit level or in blocks of bytes
- Time slots pre-assigned to sources and fixed
- Time slots allocated even if no data
- Time slots do not have to be evenly distributed amongst sources

Time Division Multiplexing



TDM System


$m_1(t)$
Buffer
$m_1(t)$
$m_2(t)$
Buffer
$m_2(t)$
Scan Operation
$m_c(t)$
Modem
$s(t)$
$m_n(t)$
Buffer
$m_n(t)$
TDM stream
modultated TDM stream
(a) Transmitter
Frame
Frame
1
2
N
1
2
n
Time slot: may be empty or occupied
(b) TDM Frames
$s(t)$
Modem
$m_c(t)$
Scan Operation
Buffer
$m_1(t)$
Buffer
$m_2(t)$
Buffer
$m_n(t)$
modultated TDM stream
TDM stream
(c) Receiver

TDM Link Control

- No headers and trailers
- Data link control protocols not needed for multiplexer and demultiplexer
- Flow control
  - Data rate of multiplexed line is fixed
  - If one channel receiver cannot receive data, the others must carry on
  - The corresponding source must be quenched
  - This leaves empty slots
- Error control
  - Errors are detected and handled by individual channel systems

Thank You!

Courtesy

- Professor Jiying Zhao, University of Ottawa