EEE 432 Introduction to Data Communications

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MULTIPLEXING

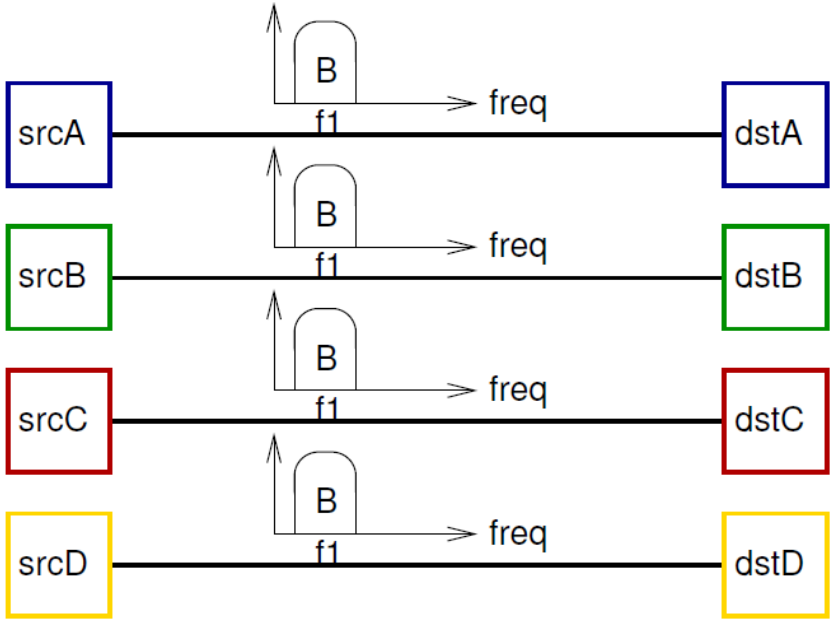
Course Information

1. Data Communications and Networks
2. Data Transmission
3. Transmission Media
4. Signal Encoding Techniques
5. Digital Data Communication Techniques
6. **Multiplexing**
7. Networking and Protocol Architectures
8. Switching
9. Routing in Switched Networks
10. LANs and WANs
11. Ethernet
12. The Internet

Supporting Multiple Users

- Multiple users in one location want to communicate with multiple users in another location
- Option 1: one link (line) per pair of users
- Each user has dedicated link, no interference
- Wasteful of resources; hard to expand
- But it comes with an advantage, since we have

4 cables for 4 links (for the figure given nearby), even though the frequency of the signals are equal, signals are not interfering each other.

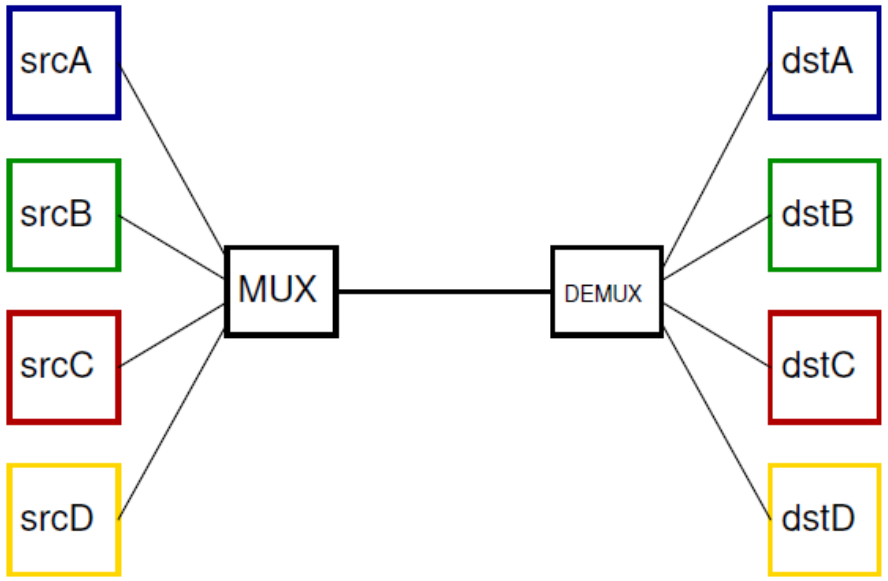


Multiplexing

- A single line connects two locations via special devices.
- **Multiplexer (MUX)** combines signals from each source user, and transmits one signal
- **Demultiplexer (DEMUX)** splits received signal into separate signals and sends to destination users
- How to combine signals from multiple users?
- There are two basic approaches, which are

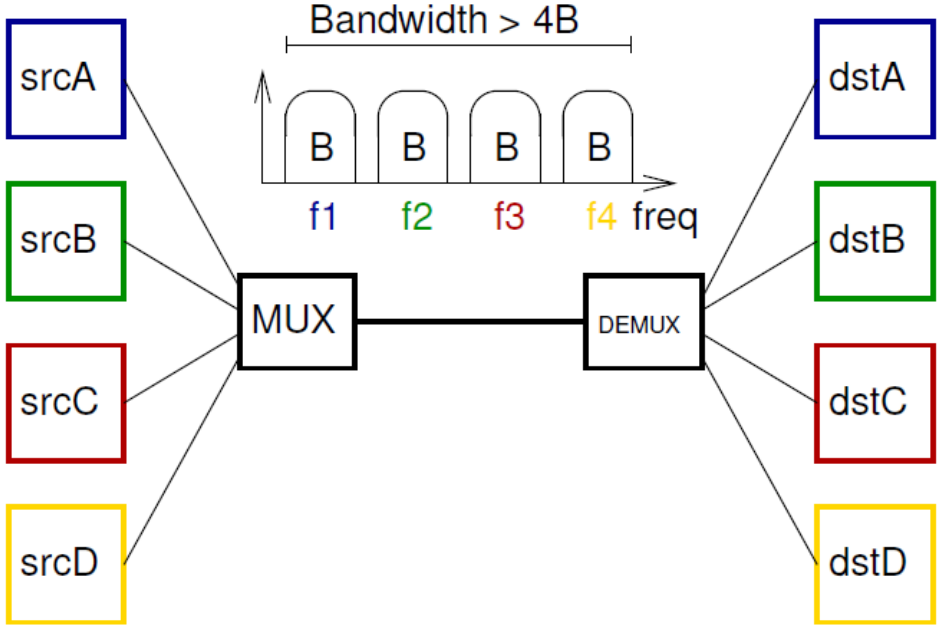
Frequency Division Multiplexing (FDM) and

Time Division Multiplexing (TDM)



Frequency Division Multiplexing (FDM)

- Signals from each user are transmitted at same time, but **different frequencies**
- f1, f2, f3 and f4 are center frequencies of the each signal.
- The idea is that we can transmit one signal but that signal actually contains the signals of those four different users. (f1≠ f2 ≠ f3≠ f4) For example; TV channels



Frequency Division Multiplexing (FDM)

- FDM possible when useful bandwidth of medium exceeds required bandwidth of signals
- Each signal modulated onto different carrier frequency, sufficiently separated so signals do not overlap
- As long as the channels use different center frequencies, it doesn't matter they are transmitted at the same time

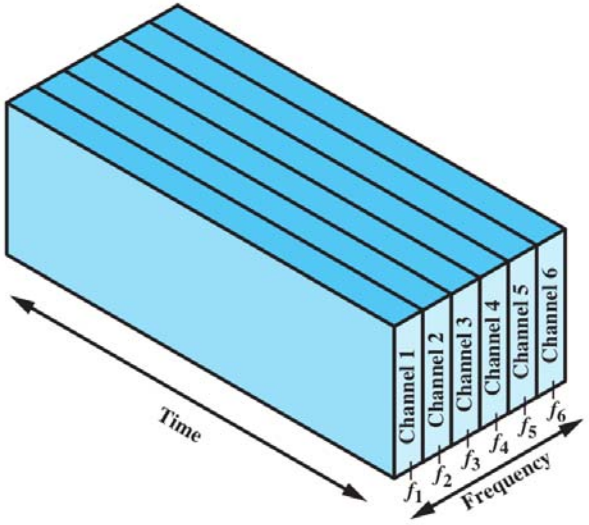
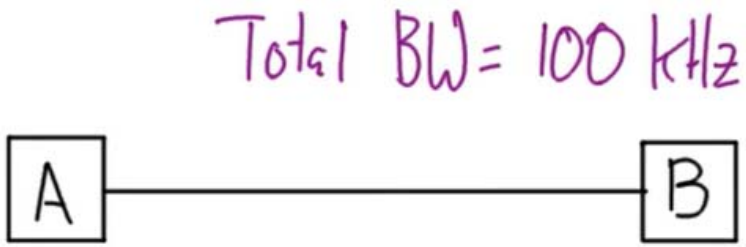


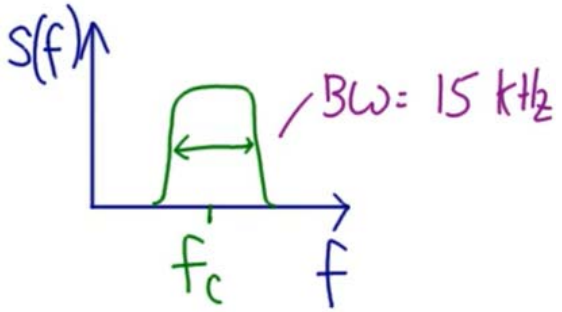
Fig. Another view of FDM

Remember the remote controller of a TV..
When we change the channel by using the remote controller, in fact, we tune the TV to the desired frequency of the TV station.

Frequency Division Multiplexing (FDM)

- **Ex:** Imagine we have a link between the points A and B and this link has a bandwidth of 100kHz. If the bandwidth for the per user is 15kHz. How many users can we support by using this link?

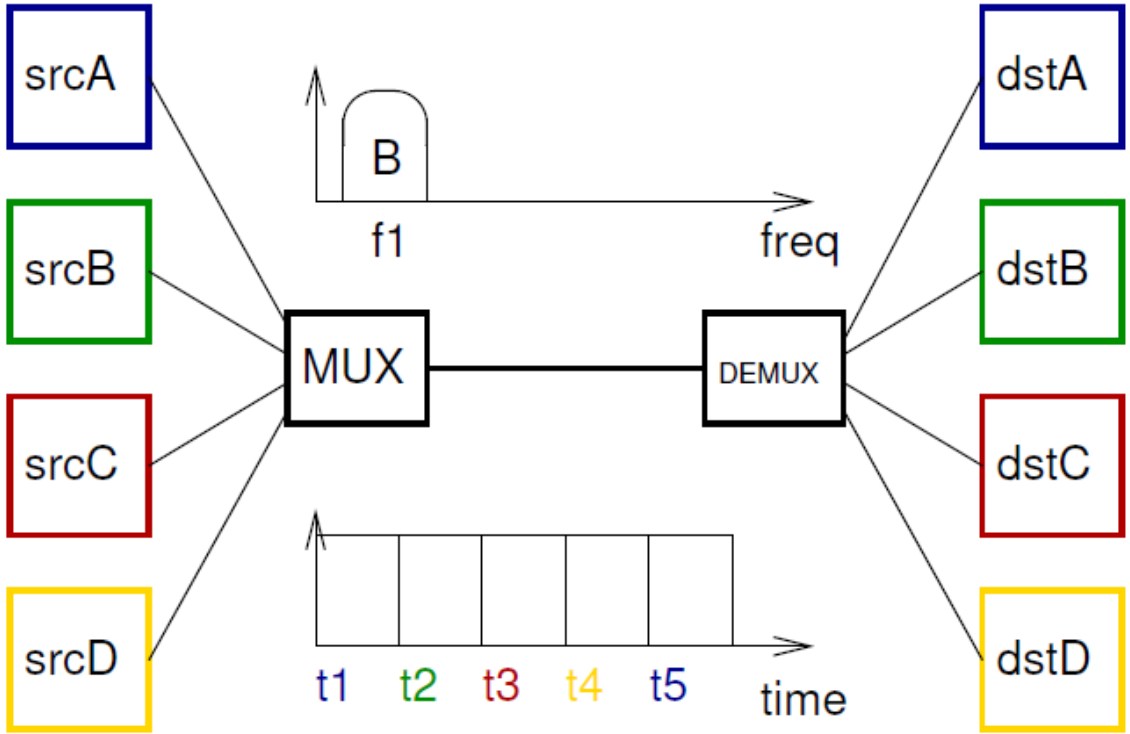




- If we try to insert 7 users, total bandwidth requirement will be 7*15= 105kHz and it is not possible to since we have totally 100kHz of bandwidth.
- If we try to insert 6 users, total bandwidth requirement will be 6*15= 90kHz and we can also insert 2kHz of space between the users (to prevent the interference).

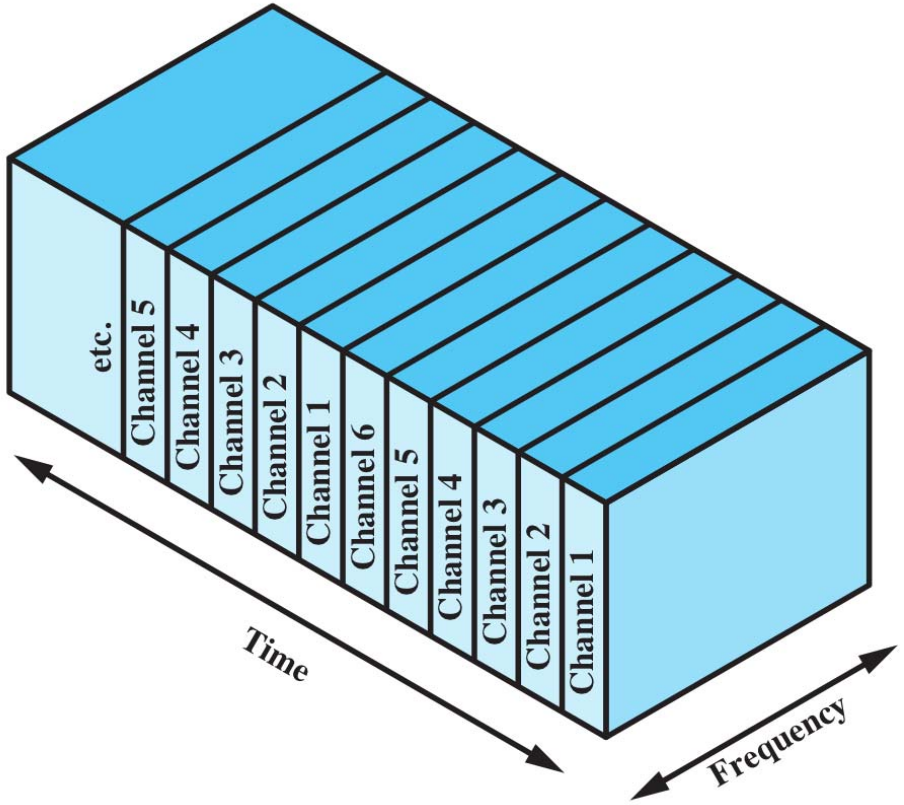
Time Division Multiplexing (TDM)

- Signals from each user are transmitted on same frequency, but at **different times.**



Time Division Multiplexing (TDM)

- Multiple digital signals carried on single transmission path by transmitting portions of each signal one at a time
  - Synchronous TDM
  - Statistical TDM

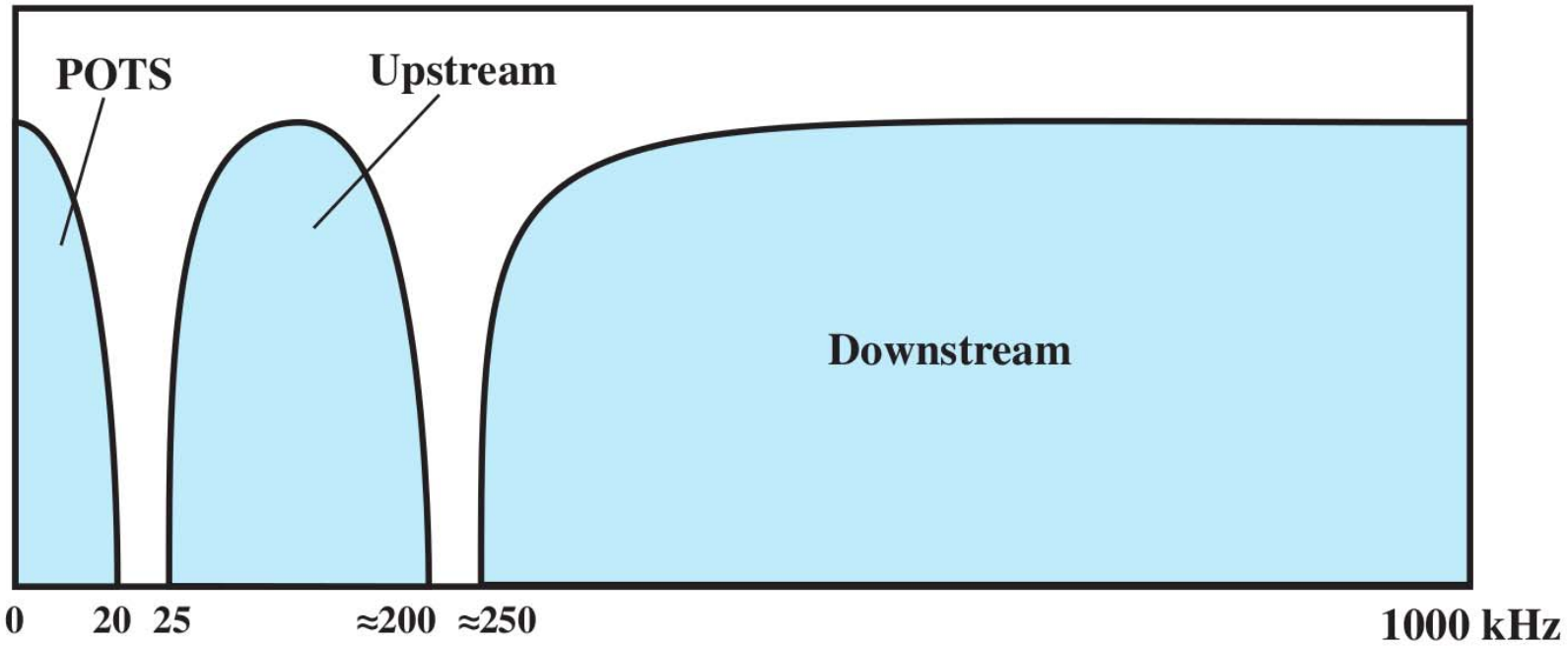


Example Multiplexing Technologies

- **FDM**
  - Broadcast and cable TV, radio
  - Long-distance carrier system deployed by telecom operators
  - Optical fibre: Wavelength Division Multiplexing
  - ADSL
- **TDM**
  - Digital carrier systems to replace FDM carrier systems (T-hierarchy, PDH)
  - SONET/SDH
- **Trade-off**
  - FDM requires larger bandwidth, therefore costs more. Higher performance
  - TDM requires narrower bandwidth, therefore costs less. Lower Performance

FDM Example: ADSL

- Plain Old Telephone Service (POTS), voice calls: 0 - 20 kHz
- Uplink data to Internet Service Provider (ISP): 25 - 200 kHz
- Downlink data from Internet Service Provider (ISP): 250 - 1000 kHz



TDM Example: SONET/SDH Signal Hierarchy

- PDH (T1, T2, E1, . . .) used electrical digital signals for connections between buildings, cities, countries: upto about 500 Mb/s
- Gradually replaced with SONET (US) and SDH (rest of world), which uses optical carrier (OC) signals.

SONET Designation	ITU-T Designation	Data Rate	Payload Rate (Mbps)
STS-1/OC-1		51.84 Mbps	50.112 Mbps
STS-3/OC-3	STM-1	155.52 Mbps	150.336 Mbps
STS-12/OC-12	STM-4	622.08 Mbps	601.344 Mbps
STS-48/OC-48	STM-16	2.48832 Gbps	2.405376 Gbps
STS-192/OC-192	STM-64	9.95328 Gbps	9.621504 Gbps
STS-768	STM-256	39.81312 Gbps	38.486016 Gbps
STS-3072		159.25248 Gbps	153.944064 Gbps