# Multiplexing

## ITS323: Introduction to Data Communications

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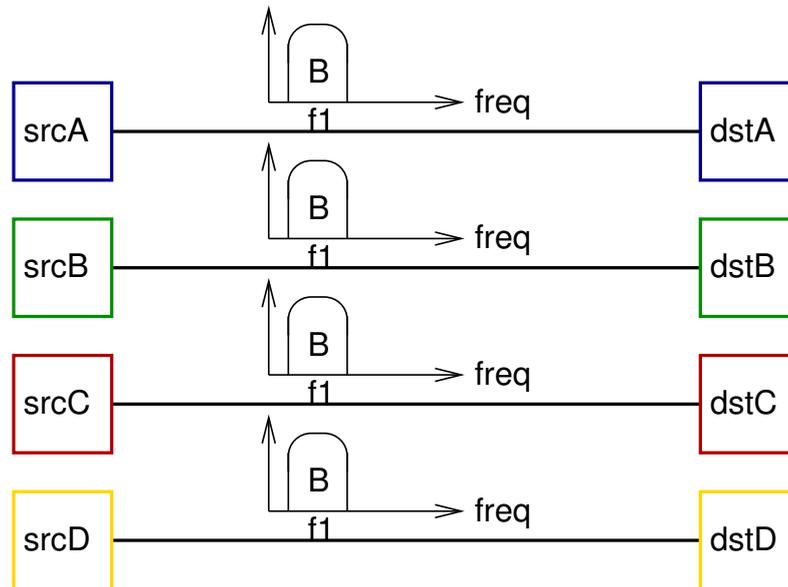# Contents

## Multiplexing

## Multiple Access

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# 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
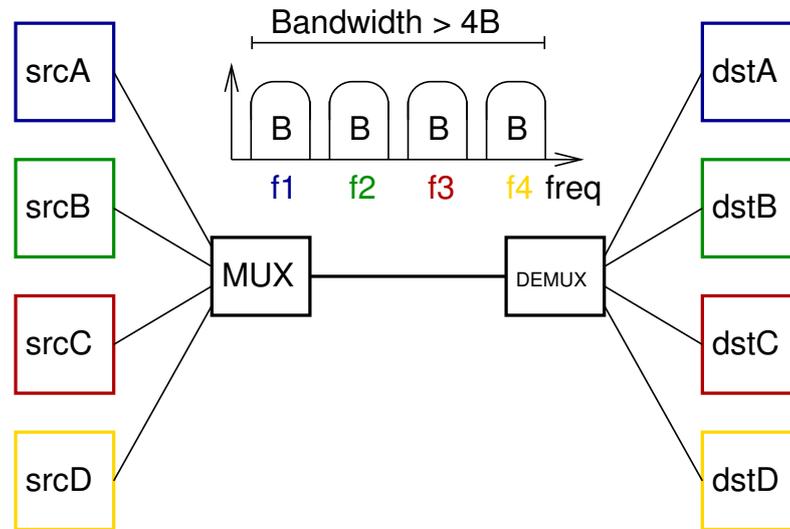
# Multiplexing

- ▶ 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?
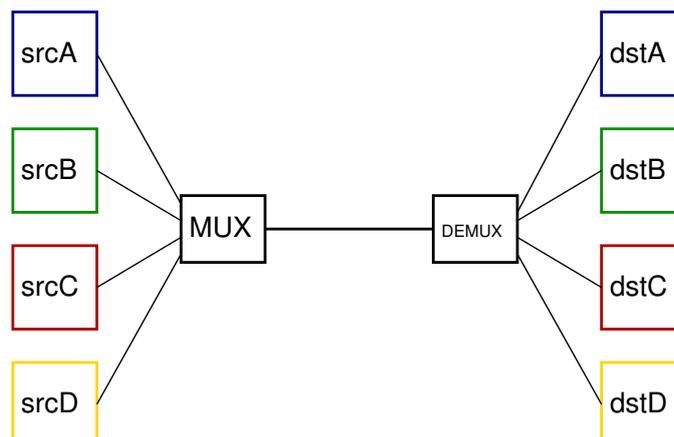
# Frequency Division Multiplexing

▶ Signals from each user are transmitted at same time, but different frequencies
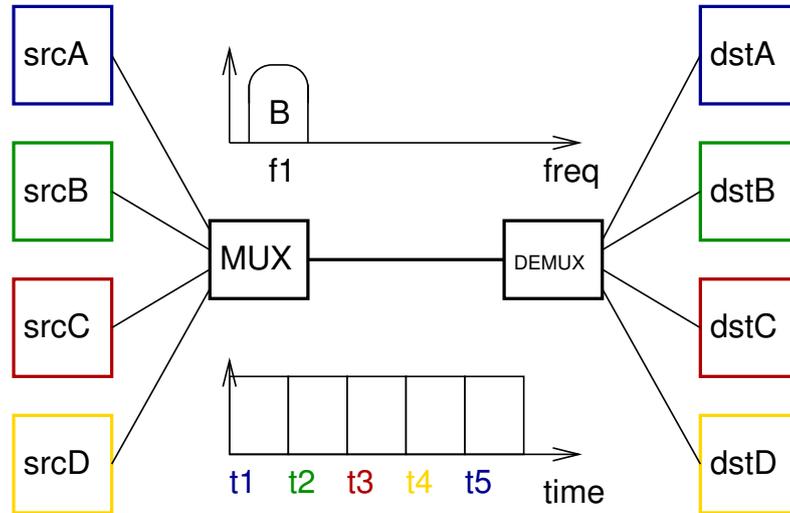
# Frequency Division Multiplexing

▶ 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
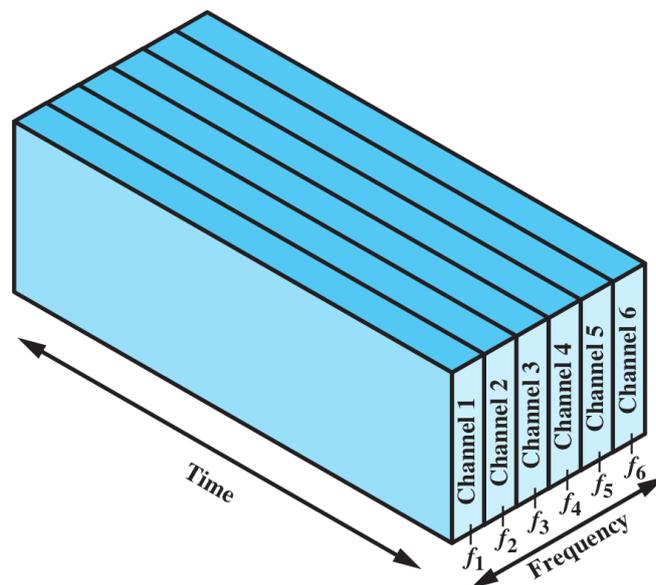
# Time Division Multiplexing

▶ Signals from each user are transmitted on same frequency, but at different times

# Time Division Multiplexing

▶ Multiple digital signals carried on single transmission path by transmitting portions of each signal one at a time
  ▶ Synchronous TDM
  ▶ Statistical TDM
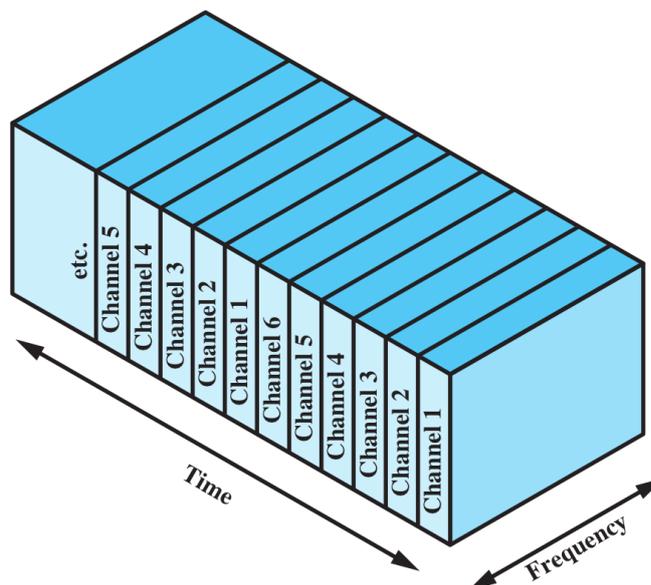
# Example Multiplexing Technologies

## FDM

- ▶ Broadcast and cable TV, radio
- ▶ Long-distance carrier system deployed by telecom operators
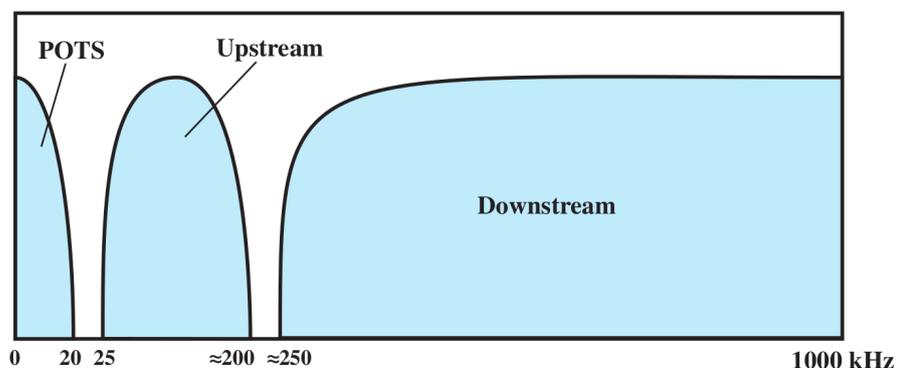- ▶ Optical fibre: Wavelength Division Multiplexing
- ▶ ADSL

## TDM

- ▶ Digital carrier systems to replace FDM carrier systems (T-hierarchy, PDH)
- ▶ SONET/SDH

# FDM Example: ADSL

- ▶ Plain Old Telephone Service (POTS), voice calls: 0—20 kHz
- ▶ Uplink data to ISP: 25—200 kHz
- ▶ Downlink data from 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 |

# Contents

Multiplexing

**Multiple Access**

# Supporting Multiple Users in Point-to-Multipoint Links

- ▶ Multiple users share a point-to-multipoint link
- ▶ Typical for wireless systems (WiFi, mobile phone) and some wired LANs
- ▶ Use multiple access schemes to determine who transmits and when

# Multiple Access: Fixed Assignment

A fixed assignment of transmission opportunities to users based on:

- ▶ Frequency Division Multiple Access (FDMA): users are assigned frequencies; transmit at same time
- ▶ Time Division Multiple Access (TDMA): users are assigned time slots; transmit on same frequency
- ▶ Code Division Multiple Access (CDMA): users are assigned codes, that allow receive to "separate" signals; transmit on same frequency, at same time
- ▶ Space Division Multiple Access (SDMA): transmissions in different physical areas, e.g. using directional antennas

# Multiple Access: Demand Assignment

Transmission opportunities are assigned to users on-demand:

- ▶ Reservation-based: users are assigned schedule of transmissions based on earlier reservations; use FDMA, TDMA, CDMA, SDMA
- ▶ Polling-based: users are asked if they want to transmit

# Multiple Access: Random Access

- ▶ Users transmit when desired, but after some random waiting time and as long as no-one else is transmitting
- ▶ The user that selects the smallest random waiting time will get to transmit first (and others will wait until they finish)
- ▶ Simple, can operate in distributed manner
- ▶ Used in wireless LANs (WiFi)