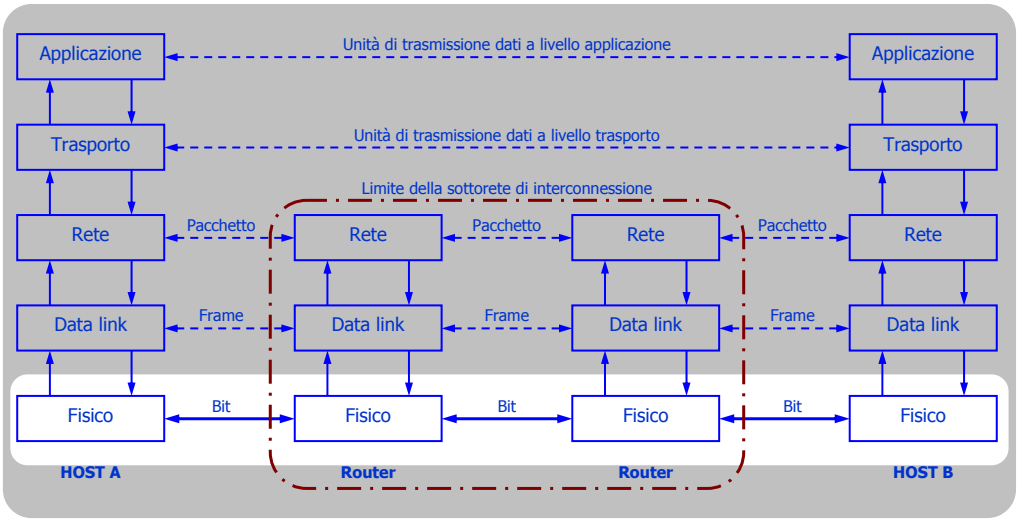
Livello Fisico



La condivizione dei mezzi

Trasmissione sincrona/asincrona

- Trasmettitore e ricevitore debbono cooperare:
  - i dati vengono tipicamente trasmessi un bit per volta lungo il canale (trasmissione seriale)
  - la temporizzazione di questi bit deve essere la stessa tra trasmettitore e ricevitore
- Trasmissione **sincrona**:
  - trasmettitore e ricevitore devono avere orologi sincronizzati per gestire la temporizzazione dei bit trasmessi;
  - l'informazione di sincronizzazione può essere contenuta nei dati mediante speciali codifiche.
- Trasmissione **asincrona:**
  - trasmissioni di breve durata, un carattere per volta (da 5 a 8 bit),
  - il ricevitore deve risincronizzarsi all'inizio di ogni nuovo carattere (segnalato mediante un bit di **start**),
  - la fine di un carattere è poi segnalata da un altro bit di controllo, il bit di **stop**.
- Direzione della trasmissione
  - **Simplex**: solo in una direzione (solo da A verso B)
  - **Full duplex**: contemporaneamente in entrambe le direzioni (da A a B e da B ad A contemporaneamente)
  - **Half duplex**: in entrambe le direzioni, ma non contemporaneamente (da A a B **xor** da B ad A)

Condivisione di un canale (multiplexing)

- Obiettivo: utilizzare un **canale fisico** come più **canali logici**, ognuno dei quali dedicato a una sorgente che trasmette lungo il canale fisico.
- FDM (**Frequency-Division Multiplexing**)
  - a ogni flusso di dati viene assegnato un diverso spettro di frequenze,
  - le diverse trasmissioni possono condividere il canale fisico nello stesso tempo.
- TDM (**Synchronous Time-Division Multiplexing**)
  - il tempo di trasmissione viene suddiviso in intervalli di uguale durata
  - ogni sorgente, a turno, ha la possibilità di inviare i propri dati sul canale
- Problemi (di entrambi)
  - Se una delle sorgenti non ha dati da inviare, la sua parte di canale (ossia il suo intervallo di tempo o la banda di frequenze assegnatagli) rimane inutilizzata, anche se esiste qualche altro flusso di dati che potrebbe sfruttare il canale.
  - Queste tecniche sono efficienti quando è noto e fissato il numero massimo di flussi.
- STDM (**Statistical Time-Division Multiplexing**)
  - il canale è condiviso nel tempo,
  - gli intervalli associati alle sorgenti dipendono dalle richieste di trasmissione: quando una sorgente intende inviare un flusso di dati non deve attendere il suo intervallo di tempo ma, se il canale è libero, può farlo immediatamente.

La condivisione dei mezzi

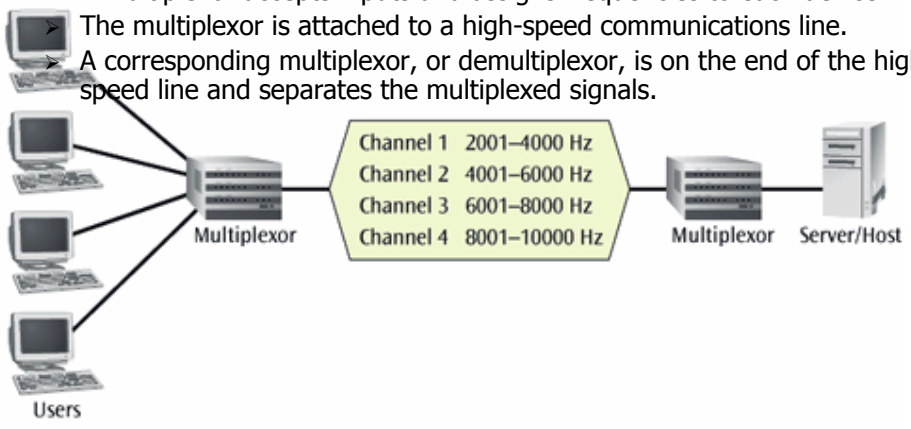
[White - Data Communications and Computer Networks - Chapter 5]

- Under the simplest conditions, a medium can carry only one signal at any moment in time.
- For multiple signals to share one medium, the medium must somehow be divided, giving each signal a portion of the total bandwidth.
- The current techniques that can accomplish this include
  - frequency division multiplexing,
  - time division multiplexing,
  - wavelength division multiplexing.

Frequency Division Multiplexing

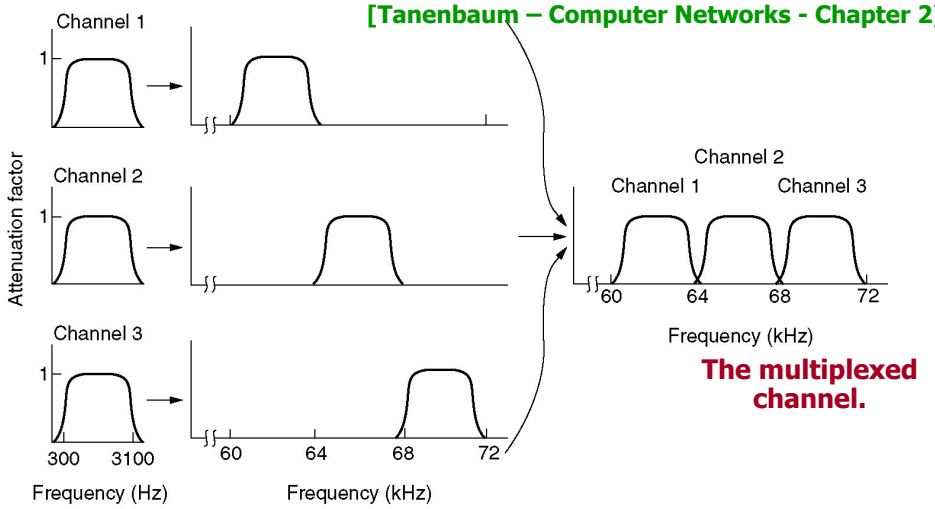
[White - Data Communications and Computer Networks - Chapter 5]

- Assignment of non-overlapping frequency ranges to each "user" or signal on a medium. Thus, all signals are transmitted at the same time, each using different frequencies.
- A multiplexor accepts inputs and assigns frequencies to each device.
- The multiplexor is attached to a high-speed communications line.
- A corresponding multiplexor, or demultiplexor, is on the end of the high-speed line and separates the multiplexed signals.



Frequency Division Multiplexing

[Tanenbaum – Computer Networks - Chapter 2]

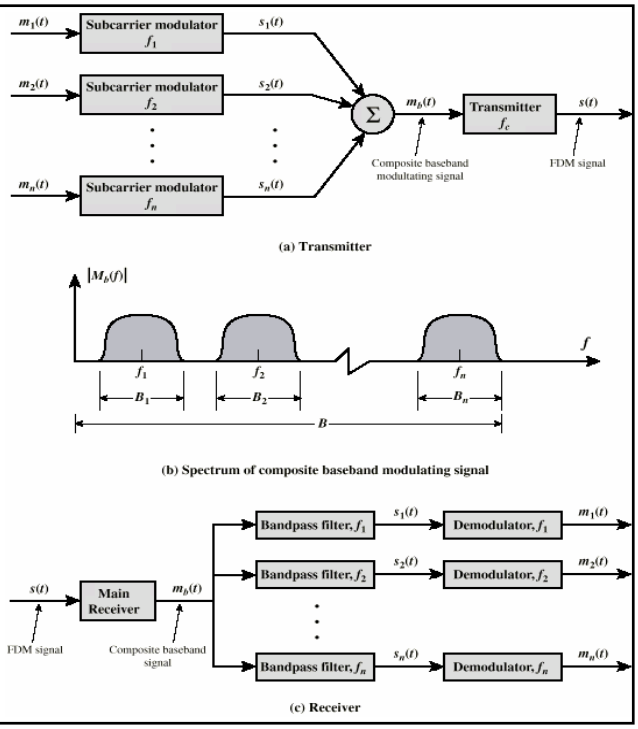


The original bandwidths

The bandwidths raised in frequency

The multiplexed channel.

Sistema FDM



Frequency Division Multiplexing

[White - Data Communications and Computer Networks - Chapter 5]

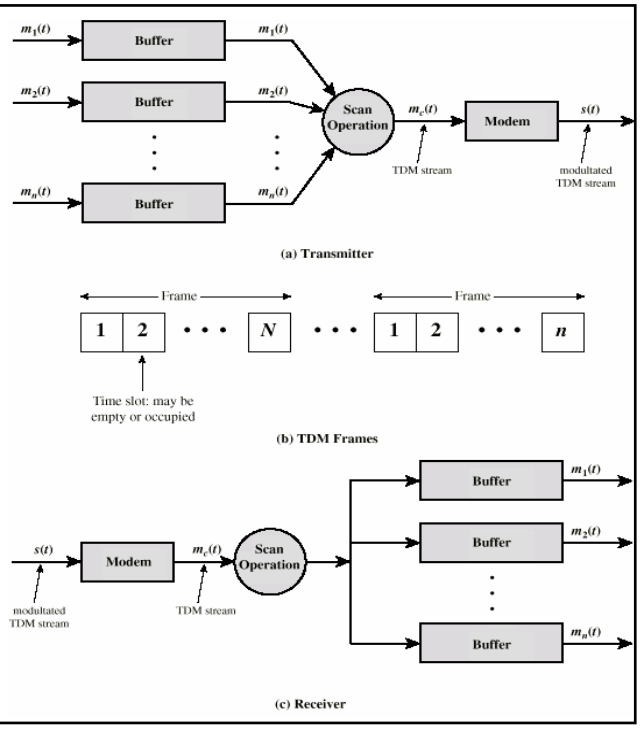
- **Analog signaling** is used to transmits the signals.
- Broadcast radio and television, cable television, and the AMPS cellular phone systems use frequency division multiplexing.
- This technique is the oldest multiplexing technique.
- Since it involves analog signaling, it is more susceptible to noise.

Time Division Multiplexing

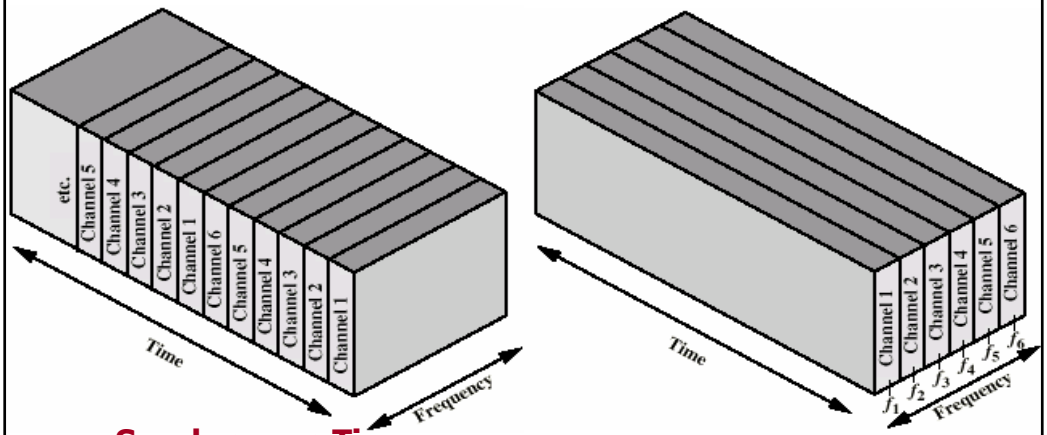
[White - Data Communications and Computer Networks - Chapter 5]

- Sharing of the signal is accomplished by dividing available transmission time on a medium among users.
- Digital signaling is used exclusively.
- Time division multiplexing comes in two basic forms:
  - Synchronous time division multiplexing, and
  - Statistical, or asynchronous time division multiplexing.

Sistema TDM



TDM vs FDM



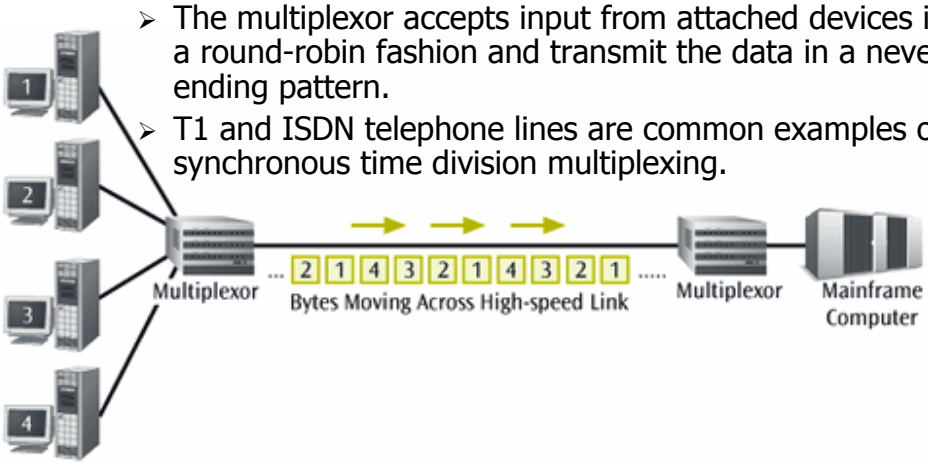
Synchronous Time Division Multiplexing

Frequency Division Multiplexing

Synchronous Time Division Multiplexing

[White - Data Communications and Computer Networks - Chapter 5]

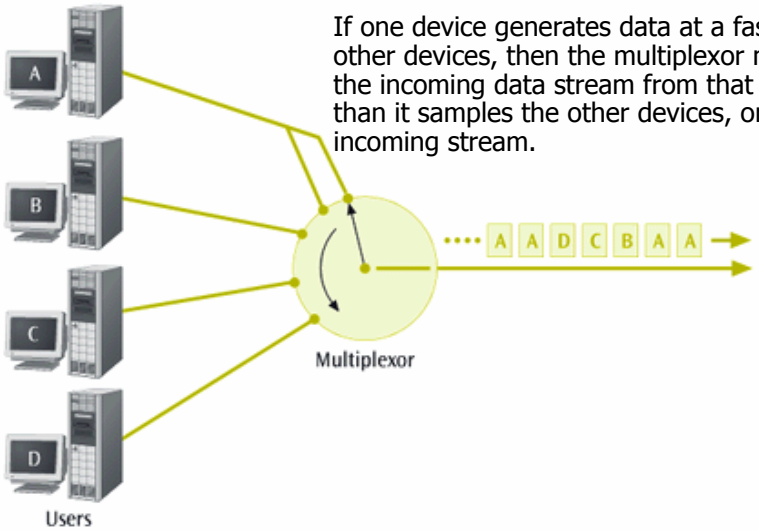
- The original time division multiplexing.
- The multiplexor accepts input from attached devices in a round-robin fashion and transmit the data in a never ending pattern.
- T1 and ISDN telephone lines are common examples of synchronous time division multiplexing.



Synchronous Time Division Multiplexing

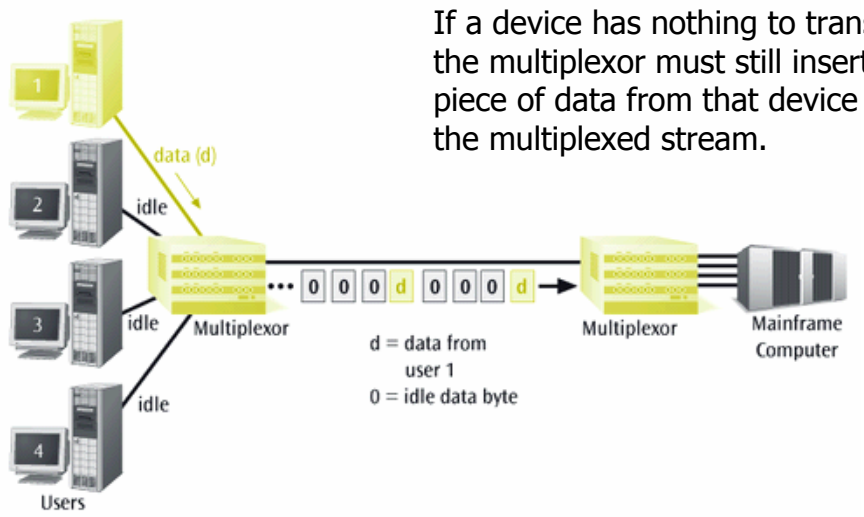
[White - Data Communications and Computer Networks - Chapter 5]

If one device generates data at a faster rate than other devices, then the multiplexor must either sample the incoming data stream from that device more often than it samples the other devices, or buffer the faster incoming stream.



Synchronous Time Division Multiplexing

[White - Data Communications and Computer Networks - Chapter 5]

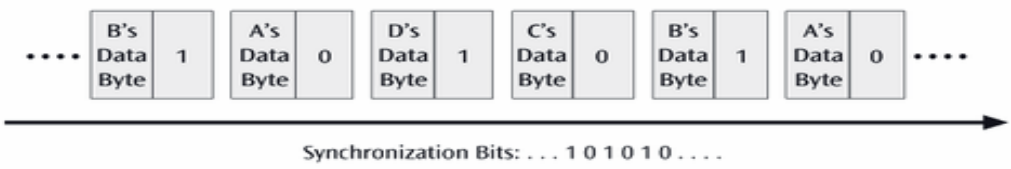


If a device has nothing to transmit, the multiplexor must still insert a piece of data from that device into the multiplexed stream.

Synchronous Time Division Multiplexing

[White - Data Communications and Computer Networks - Chapter 5]

So that the receiver may stay synchronized with the incoming data stream, the transmitting multiplexor can insert alternating 1s and 0s into the data stream.

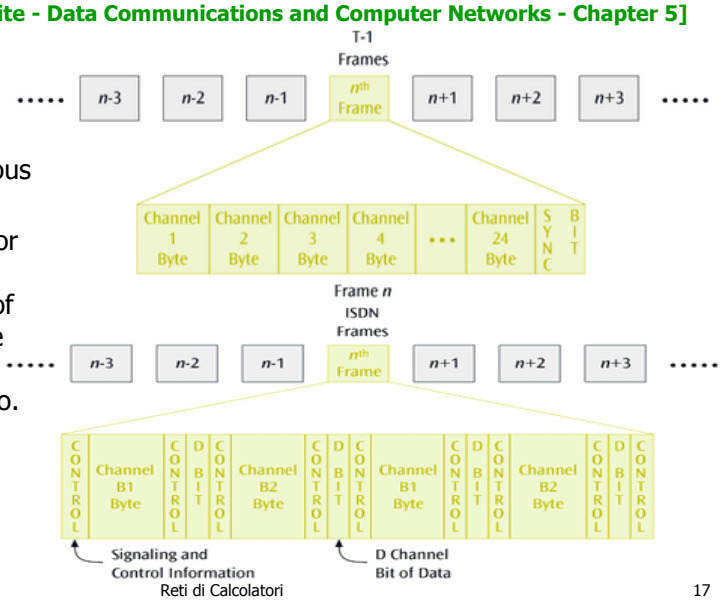


Synchronous Time Division Multiplexing

[White - Data Communications and Computer Networks - Chapter 5]

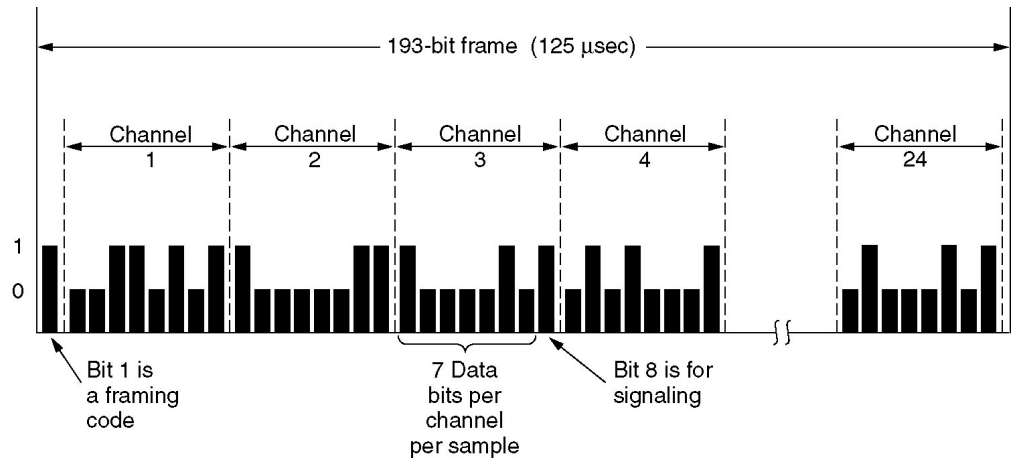
Examples

- The T-1 multiplexor stream is a continuous series of frames.
- The ISDN multiplexor stream is also a continuous stream of frames. Each frame contains various control and sync info.



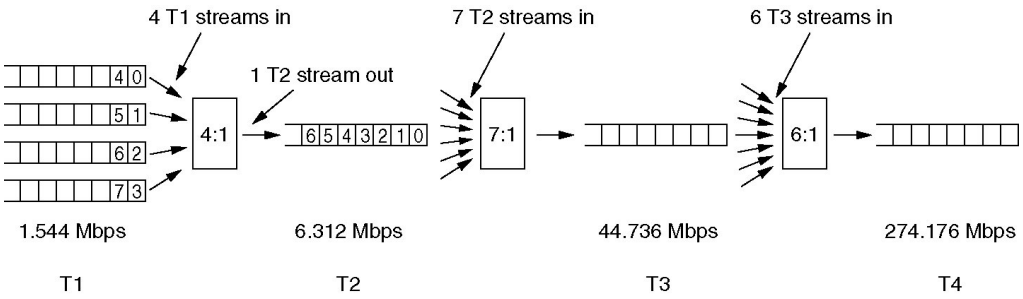
The T1 carrier (1.544 Mbps)

[Tanenbaum – Computer Networks - Chapter 2]



Multiplexing T1 streams into higher carriers

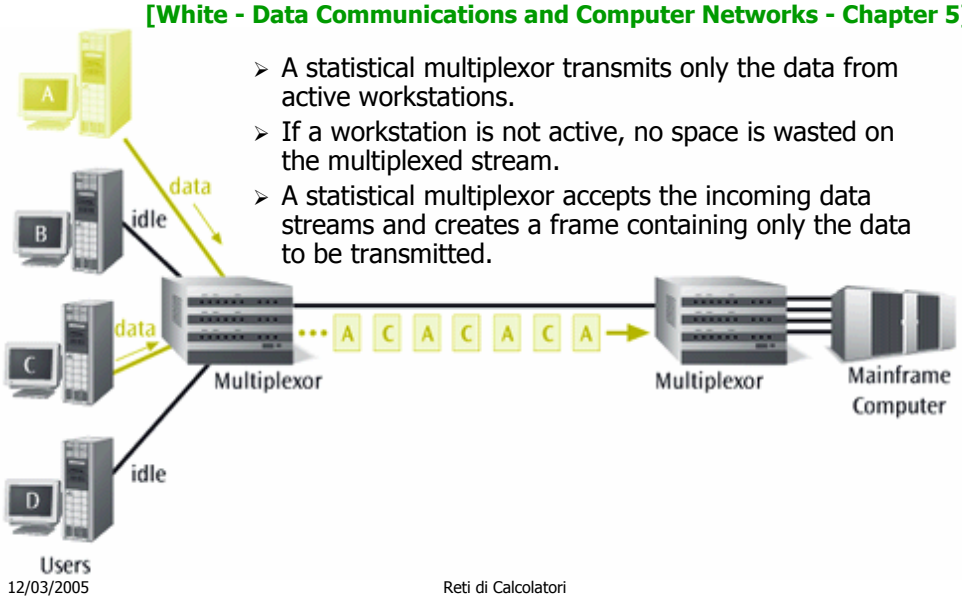
[Tanenbaum – Computer Networks - Chapter 2]



Statistical Time Division Multiplexing

[White - Data Communications and Computer Networks - Chapter 5]

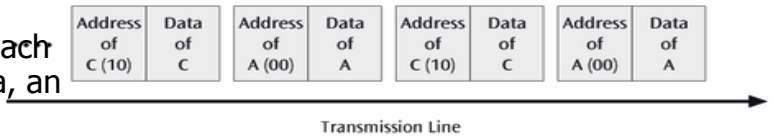
- A statistical multiplexor transmits only the data from active workstations.
- If a workstation is not active, no space is wasted on the multiplexed stream.
- A statistical multiplexor accepts the incoming data streams and creates a frame containing only the data to be transmitted.

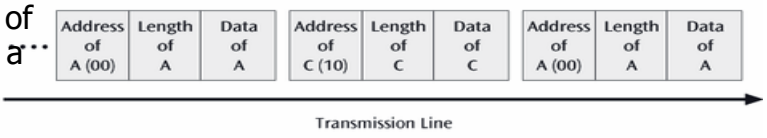


Statistical Time Division Multiplexing

[White - Data Communications and Computer Networks - Chapter 5]

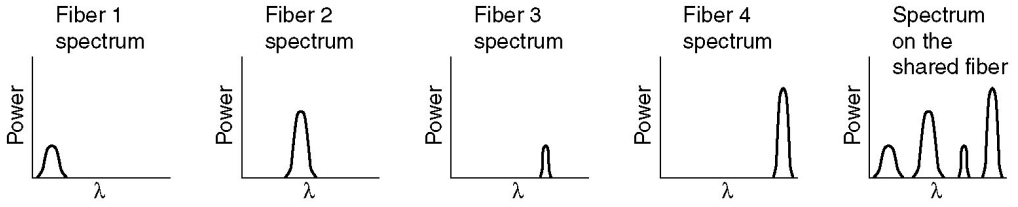
- To identify each piece of data, an address is included.
- If the data is of variable size, a length is also included.
- More precisely, the transmitted frame contains a collection of data groups.

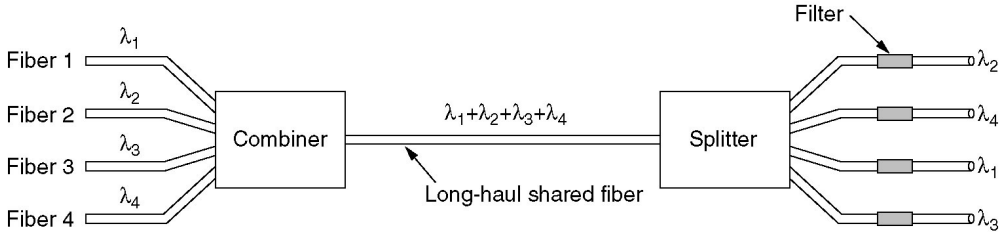




Wavelength Division Multiplexing

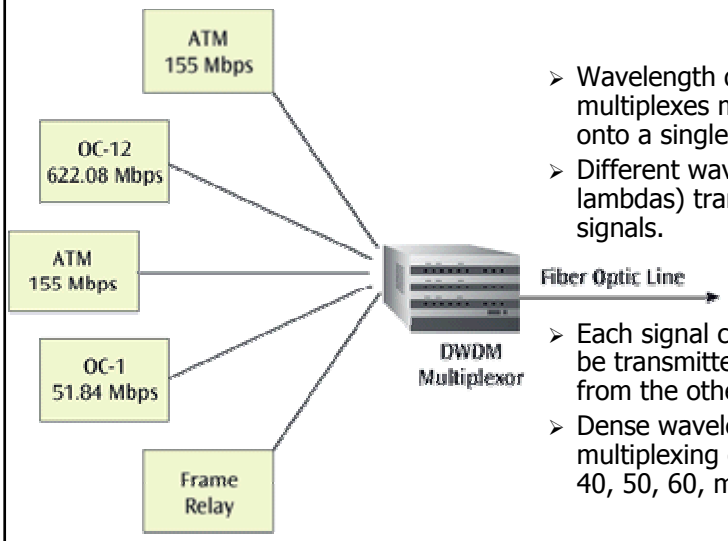
[Tanenbaum – Computer Networks - Chapter 2]





Wavelength Division Multiplexing

[White - Data Communications and Computer Networks - Chapter 5]



- Wavelength division multiplexing multiplexes multiple data streams onto a single fiber optic line.
- Different wavelength lasers (called lambdas) transmit the multiple signals.
- Each signal carried on the fiber can be transmitted at a different rate from the other signals.
- Dense wavelength division multiplexing combines many (30, 40, 50, 60, more?) onto one fiber.

Code Division Multiplexing

[White - Data Communications and Computer Networks - Chapter 5]

- Also known as **code division multiple access**
- An advanced technique that allows multiple devices to transmit on the **same** frequencies at the **same** time.
  - Each mobile device is assigned a unique 64-bit code (chip spreading code)
  - To send a binary 1, mobile device transmits the unique code
  - To send a binary 0, mobile device transmits the inverse of code
- Receiver gets summed signal, multiplies it by receiver code, adds up the resulting values
  - Interprets as a binary 1 if sum is near +64
  - Interprets as a binary 0 if sum is near –64

Code Division Multiplexing Example

[White - Data Communications and Computer Networks - Chapter 5]

- (for simplicity, assume 8-chip spreading codes) 3 different mobiles use the following codes:
  - Mobile A: 10111001
  - Mobile B: 01101110
  - Mobile C: 11001101
- Assume Mobile A sends a 1, B sends a 0, and C sends a 1
- Signal code: 1-chip = +N volt; 0-chip = -N volt; three signals transmitted:
  - Mobile A sends a 1, or **10111001**, or **+-+++--+**
  - Mobile B sends a 0, or **10010001**, or **+--+---+**
  - Mobile C sends a 1, or **11001101**, or **++--++-+**
- Summed signal received by base station: **+3, -1, -1, +1, +1, -1, -3, +3**
- Base station decode for Mobile A:
  - Signal received: **+3, -1, -1, +1, +1, -1, -3, +3**
  - Mobile A's code: **+1, -1, +1, +1, +1, -1, -1, +1**
  - Product result: **+3, +1, -1, +1, +1, +1, +3, +3**
  - Sum of Product results: **+12**
  - Decode rule: for result near **+8**, data is binary **1**
- Base station decode for Mobile B:
  - Signal received: **+3, -1, -1, +1, +1, -1, -3, +3**
  - Mobile B's code: **-1, +1, +1, -1, +1, +1, +1, -1**
  - Product result: **-3, -1, -1, -1, +1, -1, -3, -3**
  - Sum of Product results: **-12**
  - Decode rule: For result near **-8**, data is binary **0**

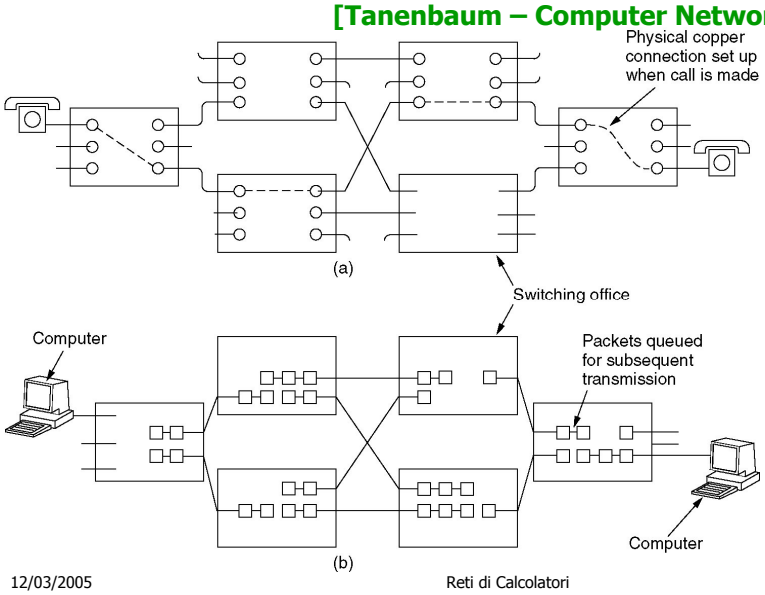
Multiplexing Techniques

[White - Data Communications and Computer Networks - Chapter 5]

Multiplexing Technique	Advantages	Disadvantages
Frequency Division Multiplexing	Simple	Analog signals only
	Popular with radio, TV, cable TV Relatively inexpensive All the receivers, such as cellular telephones, do not need to be at the same location	Limited by frequency ranges
Synchronous Time Division Multiplexing	Digital signals Relatively simple Commonly used with T-1 and ISDN	Wastes bandwidth
Statistical Time Division Multiplexing	More efficient use of bandwidth Packets can be various sizes Frame can contain control and error information	More complex than synchronous time division multiplexing
Dense Wavelength Division Multiplexing	Very high capacities over fiber Scalable Signals can have varying speeds	Cost Complexity
Code Division Multiplexing	Large capacities Scalable	Complexity

Circuit vs Packet Switching

[Tanenbaum – Computer Networks - Chapter 2]

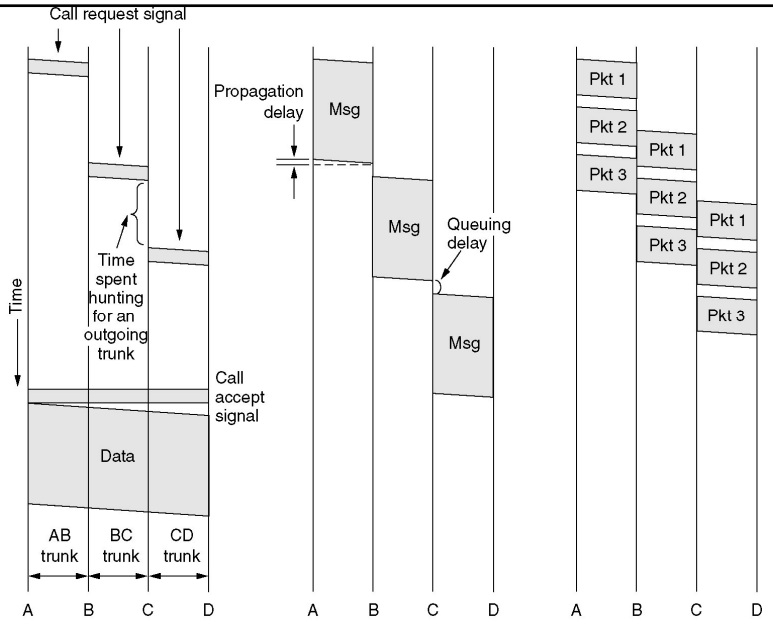


Circuit switching

Packet switching

Switching

[Tanenbaum – Computer Networks - Chapter 2]

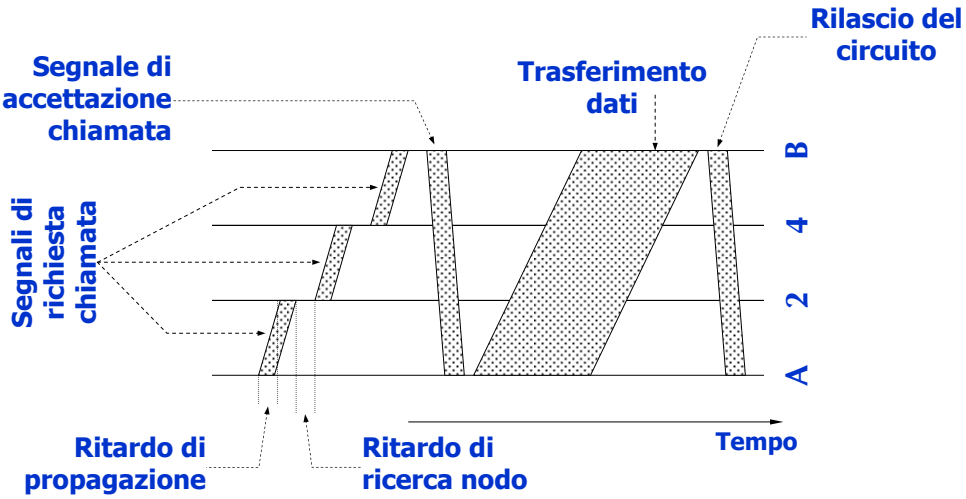


Circuit switching

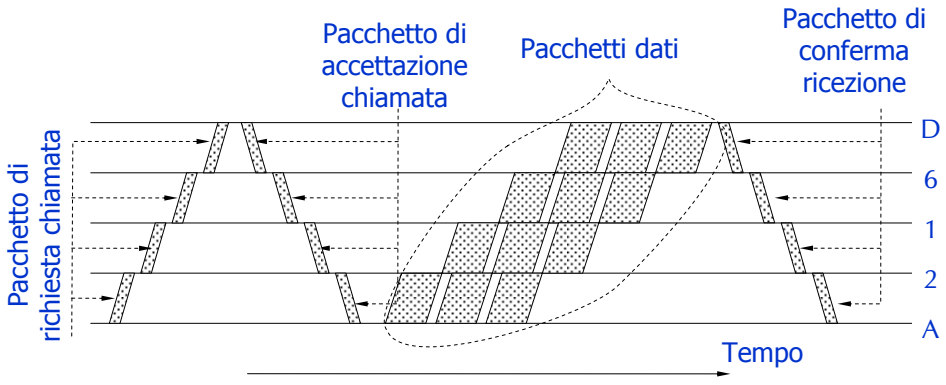
Message switching

Packet switching

Commutazione di circuito



Commutazione di pacchetto



Circuit vs Packet Switching

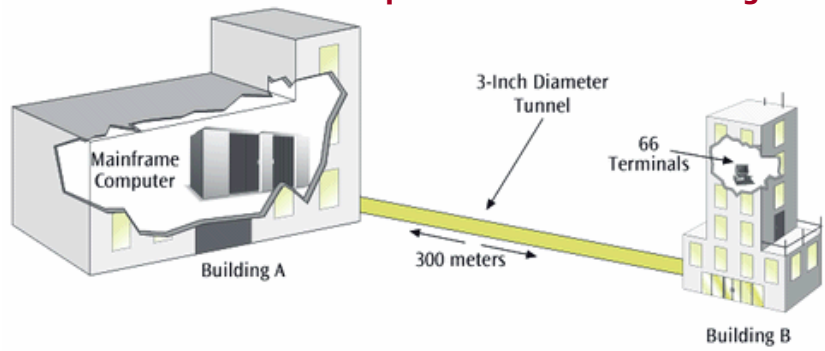
[Tanenbaum – Computer Networks - Chapter 2]

Item	Circuit-switched	Packet-switched
Call setup	Required	Not needed
Dedicated physical path	Yes	No
Each packet follows the same route	Yes	No
Packets arrive in order	Yes	No
Is a switch crash fatal	Yes	No
Bandwidth available	Fixed	Dynamic
When can congestion occur	At setup time	On every packet
Potentially wasted bandwidth	Yes	No
Store-and-forward transmission	No	Yes
Transparency	Yes	No
Charging	Per minute	Per packet

Business Multiplexing In Action

[White - Data Communications and Computer Networks - Chapter 5]

- XYZ Corporation has two buildings separated by a distance of 300 meters.
  - A 3-inch diameter tunnel extends underground between the two buildings.
  - Building A has a mainframe computer and Building B has 66 terminals.
- **List some efficient techniques to link the two buildings.**



Business Multiplexing In Action

[White - Data Communications and Computer Networks - Chapter 5]

- Possible Solutions
  - Connect each terminal to the mainframe computer using separate point-to-point lines.
  - Connect all the terminals to the mainframe computer using one multipoint line.
  - Connect all the terminal outputs and use microwave transmissions to send the data to the mainframe.
  - Collect all the terminal outputs using multiplexing and send the data to the mainframe computer using a conducted line.