Computer Networks

From **Andrew S. Tanenbaum**

Computer Networks

Latest Edition

Physical Layer

- Transmission Media
  - Twisted Pair
  - Coaxial Cable
  - Fiber Optic
- Wireless Transmission
  - Radio Transmission
  - Terrestrial Microwave
  - Satellites
- Multiplexing
- Modulation
- Switching (Circuit Switching & Packet Switching)

Transmission Media (1)

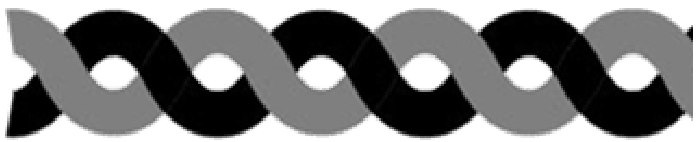
- **Twisted pair (1)**
  - Simply two wires twisted together – thickness=1mm
    The twisting cuts down on electrical interference.
  - Heavily used in the phone system
    Typical office has four pairs for phones.
  - Until some Kilometers/ Some Mbps
  - For Analog and Digital

Transmission Media (2)

- Twisted pair (2)
  - Bandwidth depends on thickness and distance

    Need repeater for long distances
  - Category 3 and 5 - with 5 having more twists and better insulation.
  - Popular by UTP (Unshielded Twisted Pair)

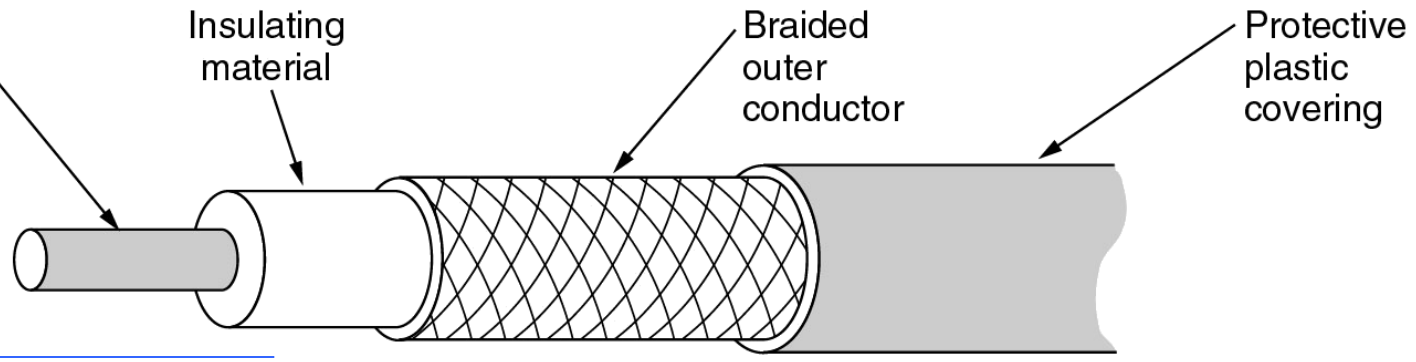
Cat3



Cat 5

Transmission Media (3)

- Baseband Coaxial cable
  - Used for digital transmissions (called baseband.)
  - Good noise immunity.
  - Data rates as high as 2 Gbps for 1 Km distance.
  - Now being replaced by fiber.
- Broadband Coaxial cable
  - Used for analog transmissions (called broadband.)
  - Can run 300 MHz for long distances.
  - Analog signaling has better S/N than digital signaling.
  - Interfaces must convert digital signals to analog and vice versa.
  - Designed for long distances - can use amplifiers.



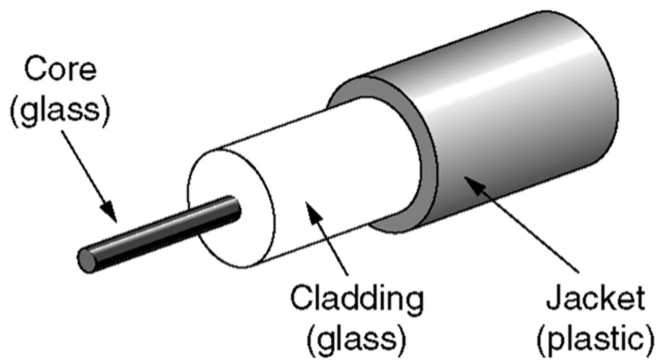
Transmission Media (4)

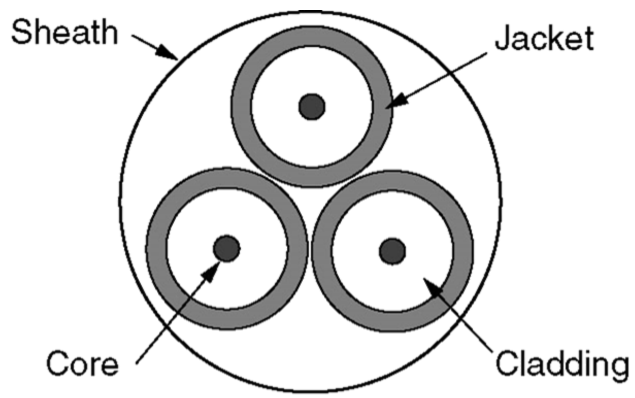
❑ Fiber Optic (1)

- Transmission of light through fiber
- Bandwidth more than 50,000 Gbps !

  But now restricted to 1Gbps!

  Reason: Electrical and optical signal conversion
- Including 3 components:
  1. Light source: Pulse of light=1, absence of light=0
  2. Transition medium: an ultra-thin fiber of glass
  3. detector: generate an electrical pulse when light falls on it
- Similar to coax (without braid)





Transmission Media (5)

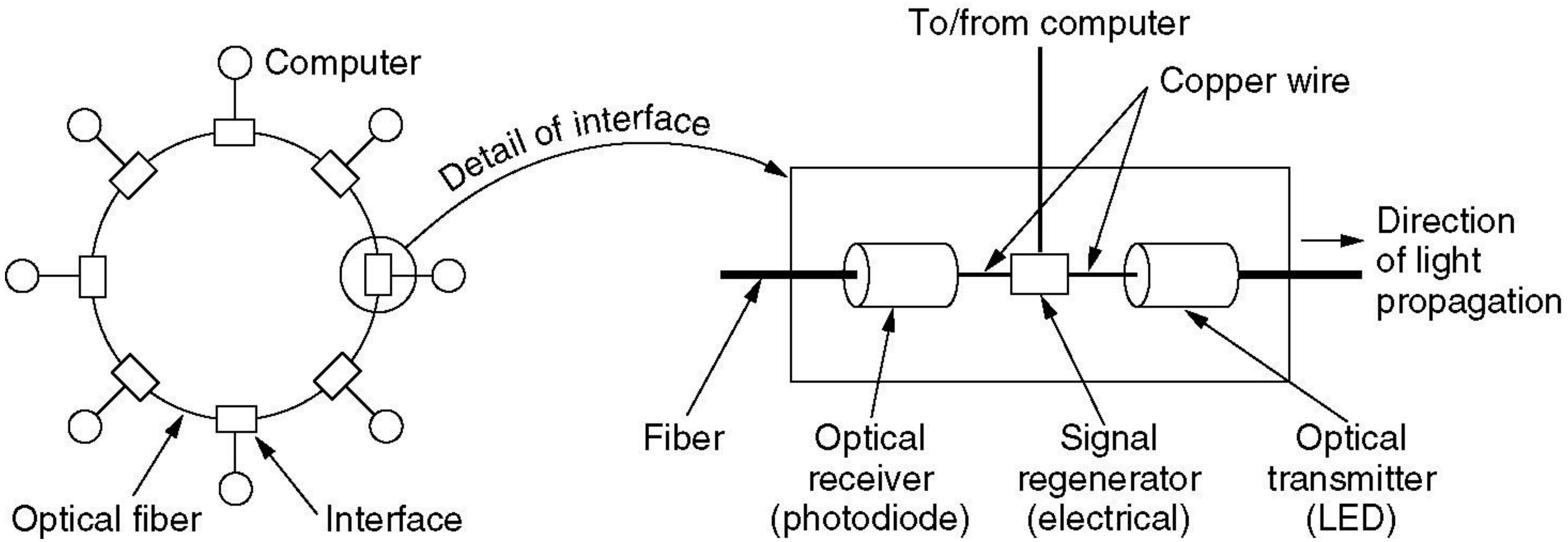
❑ Fiber Optic (2)

- Thickness of core: 8~10 microns or 50 microns
- Two typically light sources:
  1. LED (Light Emitting Diode)
     response time=1ns ➔ data rate = 1Gbps
  2. Semiconductor laser

Item	LED	Semiconductor laser
Data rate	Low	High
Fiber type	Multimode	Multimode or single mode
Distance	Short	Long
Lifetime	Long life	Short life
Temperature sensitivity	Minor	Substantial
Cost	Low cost	Expensive

Transmission Media (6)

- Fiber Optic (3)
  - Properties include total internal reflection and attenuation of particular frequencies.
  - Fiber Optic Networks - can be used for LANs and long-haul.
  - A fiber-optic LAN

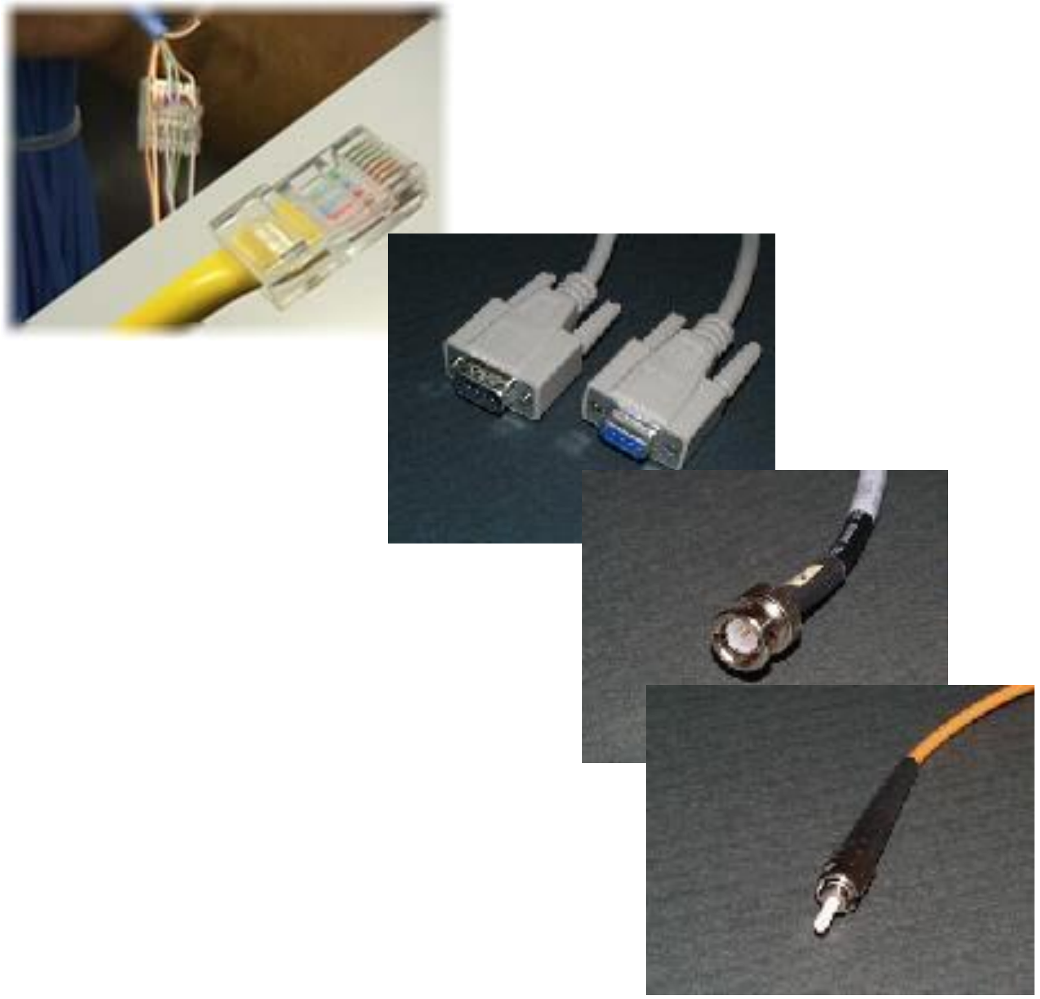


Transmission Media (7)

- Comparison of fiber optic and copper wire

	Fiber	Copper
Bandwidth	Higher	Lower
Distance between repeaters	30 KM	5 Km
Interference	Low	High
Physical	Smaller/Lighter	-
Flow	Uni-directional	Bi-directional

Transmission Media (8)



- Connector
- Repeater
  - Signal Regeneration
  - Clean up
  - Amplify
  - Distance Extension
- Hub
  - Repeater functionality, plus…
    - Concentration Point
    - Signal Distribution Device
    - Management Functions

Wireless transmission

- Radio transmission
- Microwave Transmission
- Lightwave Transmission
- Satellites

Public Switched Telephone System (PSTN) (1)

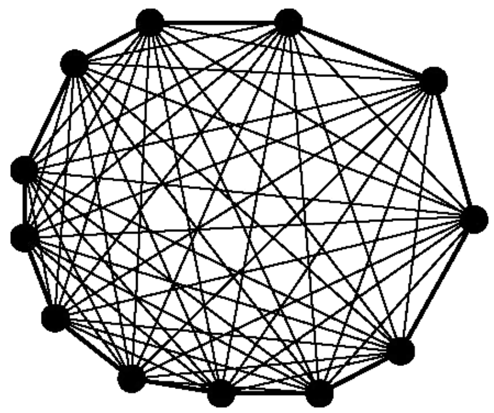
- For connecting computers in near distances (in a company) run a cable between them=LAN
- For long distances and more computers use existing telecommunication facilities = PSTN
  - A cable running ➔ faster than 10^9 bps
  - A dial-up line has max. 56 Kpds

    Difference factor = 20,000 !!
- Transmission of voice and data on system

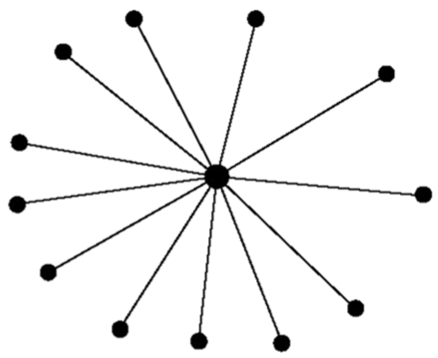
- Computer system designer try to figure out how to use PSTN efficiently

PSTN (2)

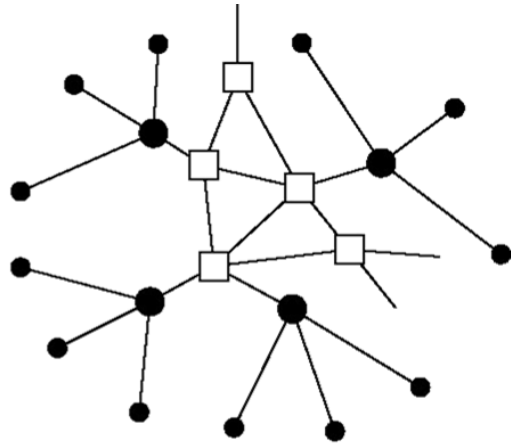
- Telephone structures
  - Fully interconnected



  - Centralized switch

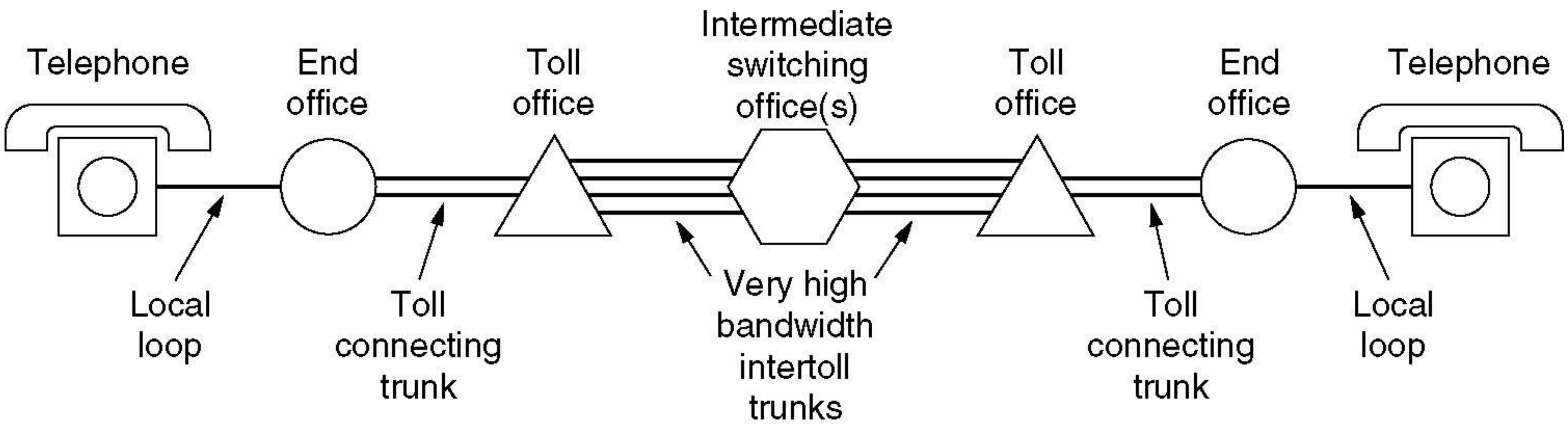


  - Two-level hierarchy



PSTN (3)

- A typical circuit route for a medium-distance call



- Major Components of the Telephone System
  - **Local loops:** Analog twisted pairs going to houses and businesses
  - **Trunks:** Digital fiber optics connecting the switching offices
  - **Switching offices:** Where calls are moved from one trunk to another

PSTN (5)

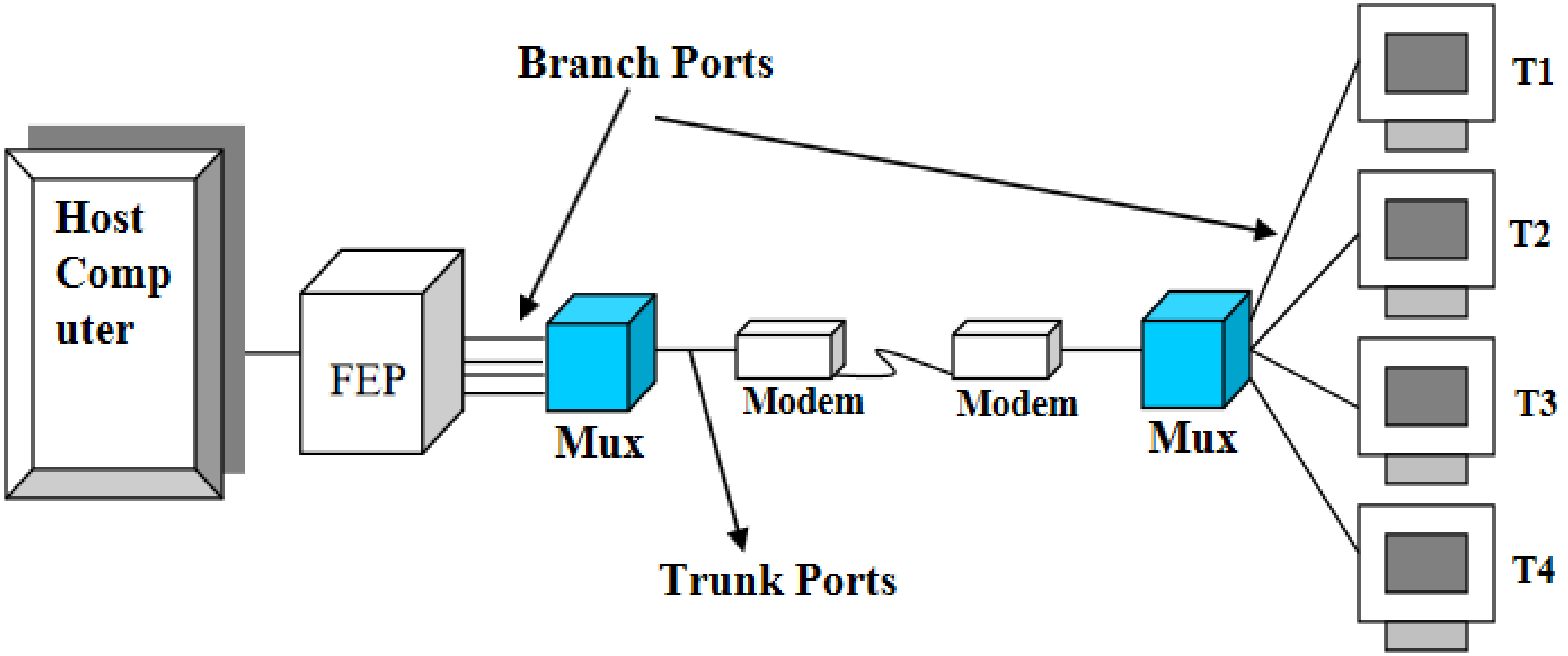
- Transmission Impairments:
  - Attenuation - the loss of energy as the signal propagates
  - Delay Distortion - different frequencies travel at different speeds so the wave form spreads out.
  - Noise - unwanted energy that combines with the signal - difficult to tell the signal from the noise.
- Modem
  - A device that converts digital data to and from an analog signal for transmission over phone lines.

Transmission Media

Multiplexing

- The method of dividing a physical channel into many logical channels so that a number of independent signals may be simultaneously transmitted on it is known as multiplexing.
- The electronic device that performs this task is known as a multiplexer (mux).
- A multiplexer takes several data communications lines or signals and converts them into one data communications line or signal at the sending location (as shown in figure).

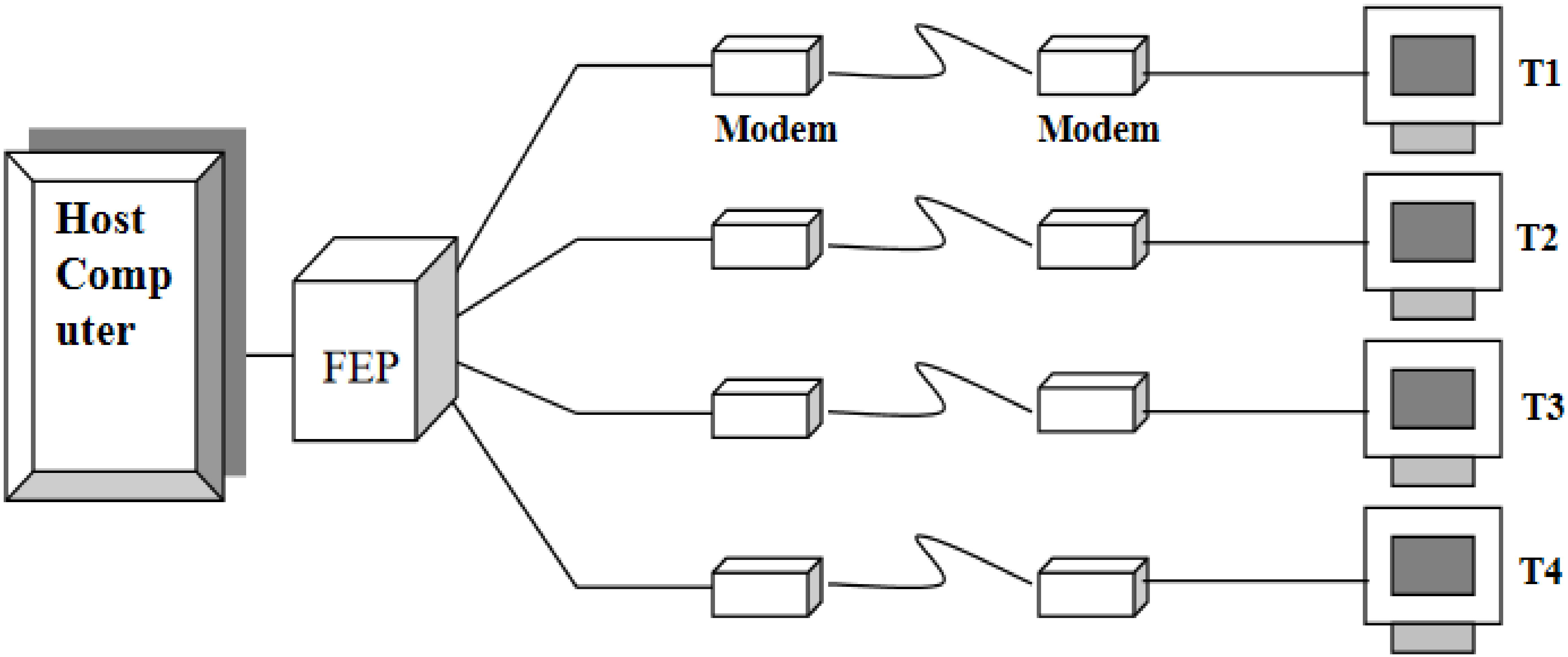
Multiplexing



Multiplexing

- There may be 4-terminals connected to a multiplexer. The multiplexer takes the signals from the 4-terminals and converts them into 1 large signal which can be transmitted over 1 communications line.
- Then, at the receiving location, a multiplexer takes the 1 large signal and breaks it into the original 4 signals.
- Without multiplexers, you would have 4 separate communications lines (as shown in figure).
- Thus, with multiplexing it is possible for a single transmission medium to concurrently transmit data between several transmitters and receivers. There are two basic methods of multiplexing channels.

Multiplexing

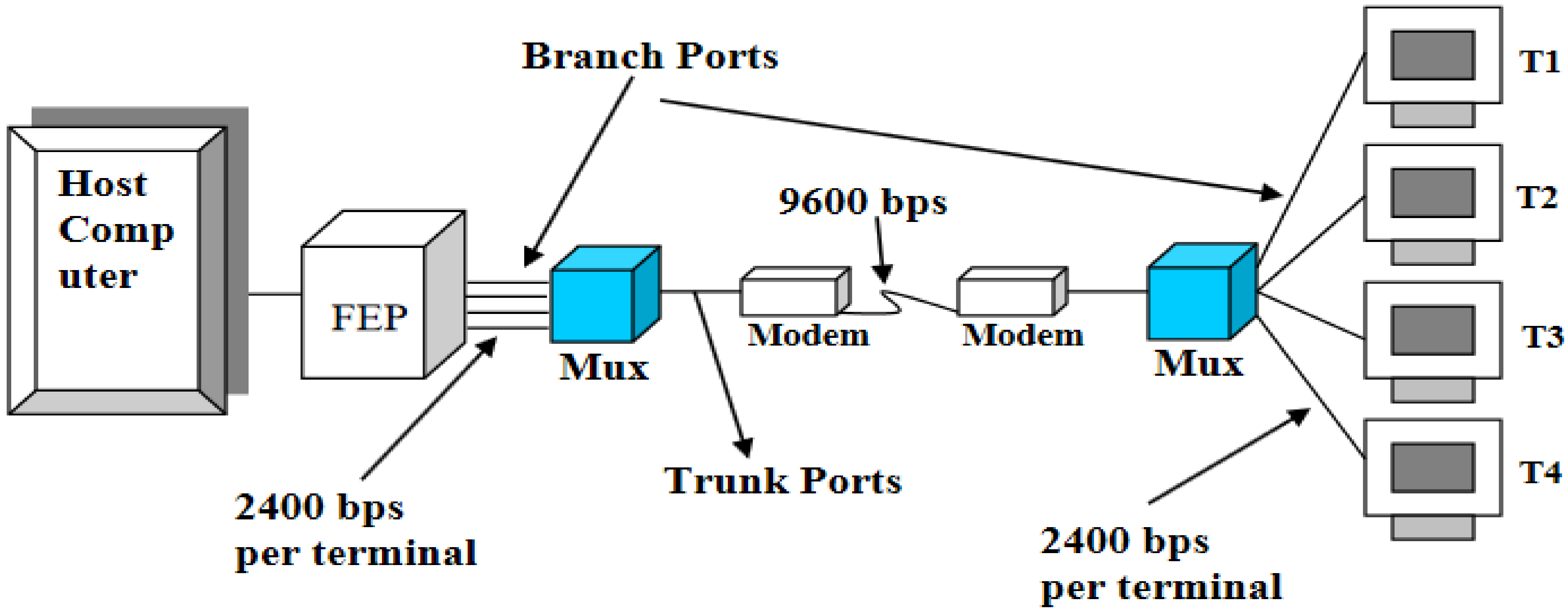


Time Division Multiplexing (TDM)

- The bit rate of a transmission medium always exceeds the required rate of the digital signal. This fact is utilized for time division multiplexing.
- In TDM, the total time available in the channel is divided between several users and each user of the channel is allotted a time slice (a small time interval) during which he may transmit a message.
- The channel capacity is fully utilized in TDM by interleaving a number of data streams belonging to different users into one data stream.

Time Division Multiplexing (TDM)

- In figure, the four terminals and front end ports each operate at 2400 bps. The pair of modems between the multiplexers operates at 9600 bps. The four terminals and front end ports actually share the modem's 9600 bps bandwidth.



Time Division Multiplexing (TDM)

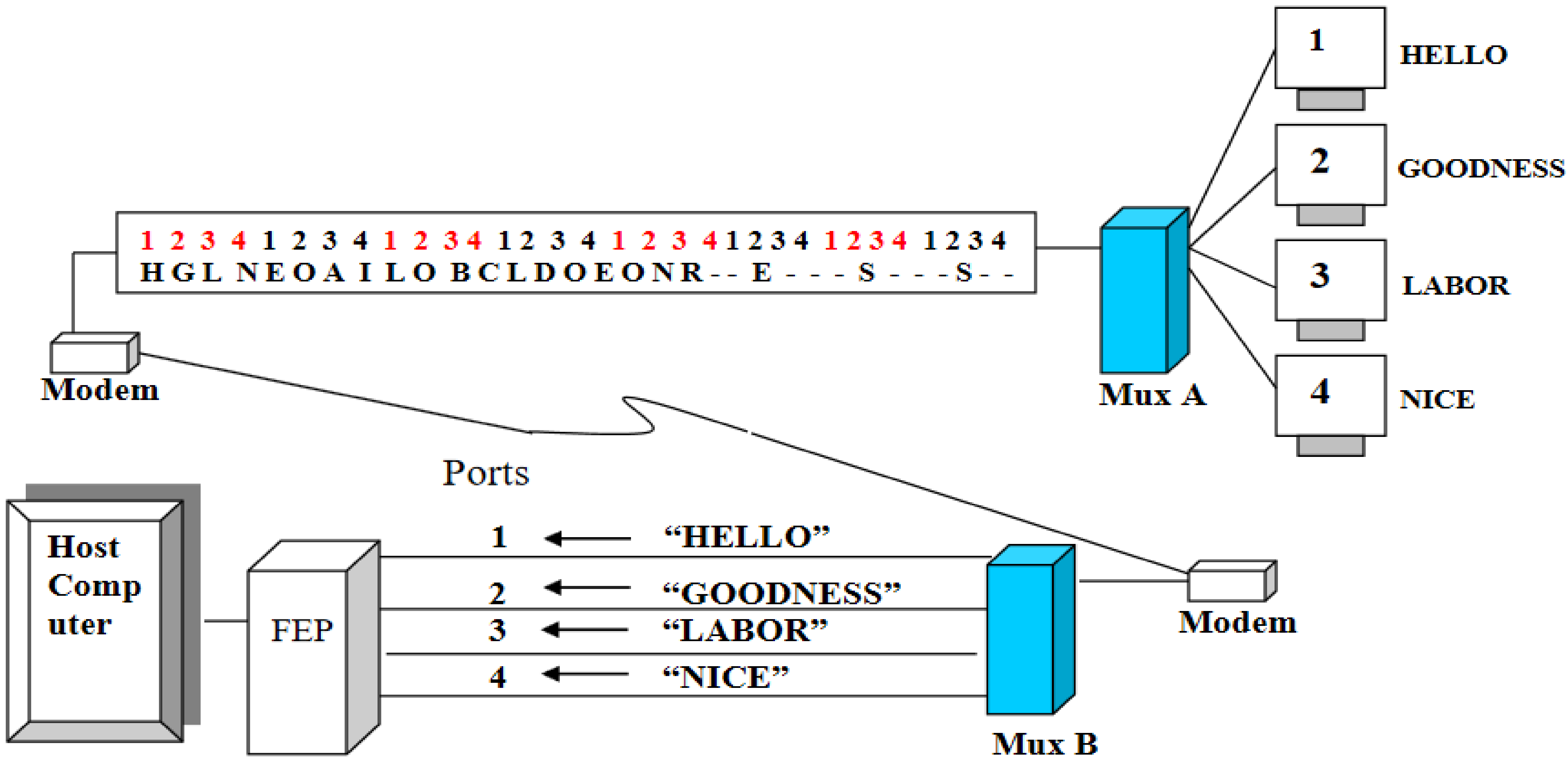
- Each of the terminals can transmit and receive at 2400 bps, so if all four are constantly transmitting and receiving data, there is a total of 9600 bps transmitted and received by the modems.
- Since all of the terminals are not transmitting all of the time. This technique is known as pure time division multiplexing (TDM).

How does TDM works?

- In character interleaving, multiplexing is performed one character (eight bits) at a time. As in fig, each of the terminals is sending a message; Terminal-1 sends “Hello”, terminal-2 sends “Goodness”, terminal-3 sends “Labor” and terminal-4 sends “Nice”. The terminals send these words one character at a time.
- Each of the terminals is allocated one fourth of the time on the modems in each direction is called a time slot. In our example, terminal-1 had the first time slot, terminal-2 the second, and so on.

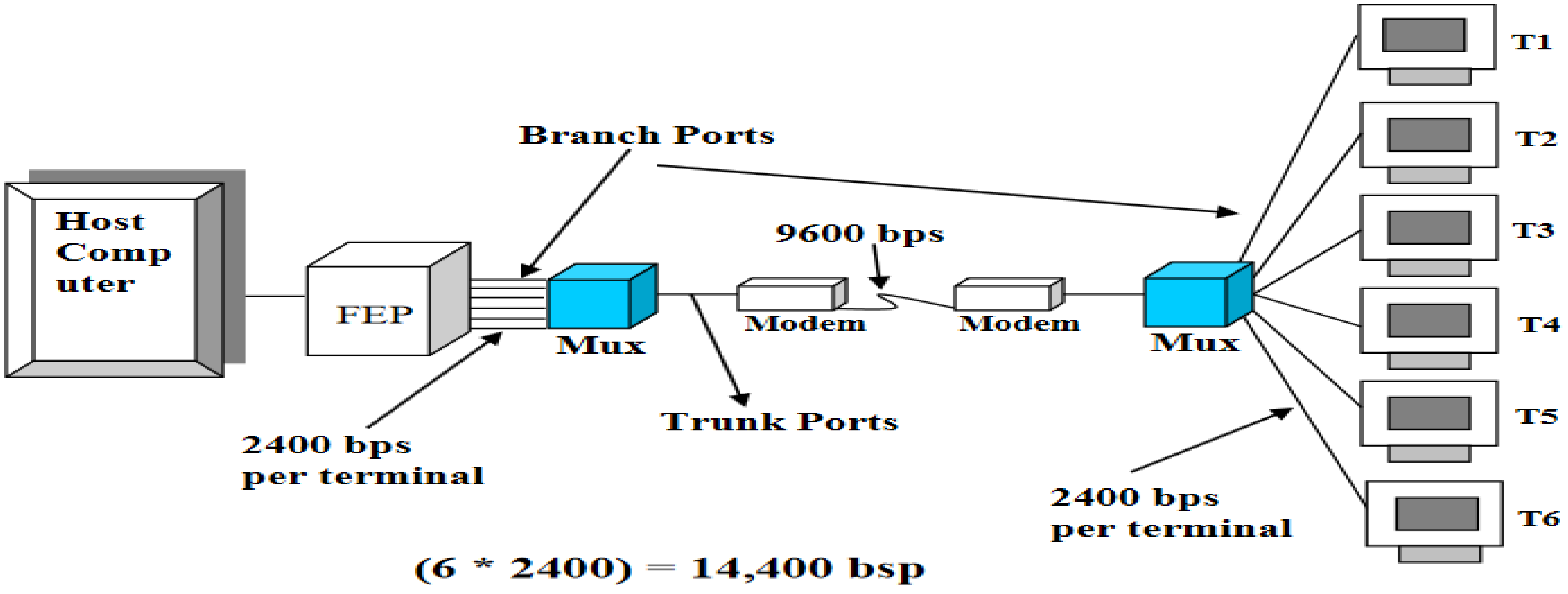
How does TDM works?

- Notice in our example that terminal-4, with the shortest message ("Nice"), does not use its time slot after it has sent the four characters. We could think of this as wasting a time slot, but the vacant time slot does have a purpose.



Statical Time Division Multiplexing (STDM)

- STDM allocates bandwidth to each terminal on the basis of demands and needs. For example, a multiplexer using STDM in figure can have a transmission speed in the trunk ports that is lower than the sum of the branch port speeds.
- In our example, six terminals, each at speeds of 2400 bps, are using a trunk port transmitting at 9600 bps. STDM assumes that not all of the devices are transmitting all the time.



Statical Time Division Multiplexing (STDM)

How does multiplexer B in fig, know which data goes to which front end port?

- Typically, a statistical multiplexer sends not only the data, but also an address, which indicates which of the ports the data is destined for. In our example a three bit address is used, which would allow for a maximum of eight ports;
- (000, 001, 010, 011, 100, 101, 110, and 111). In STDM, when a terminal is not sending data, no time slots are allocated to it, and other terminals that are sending data can use these time slots.

Statical Time Division Multiplexing (STDM)

What happens when all users try to transmit at the same time?

- Clearly the 9600 bps port cannot handle all 14,400 bps (6 * 2400 bps). Some multiplexers will buffer, or hold the data, until some of the users stop transmitting and there are extra time slots on the trunk port.

Frequency Division Multiplexing (FDM)

- An example of frequency division multiplexing can be found in cable television: a single coaxial cable carries all of the television channels simultaneously. Each channel is assigned a separate frequency, which the viewer selects by using the television's tuner.
- In data communications, frequency division multiplexing transmits the data from each terminal on a different frequency, as shown in fig.
- Terminal-A communicates with front end port A over multiplexer channel A, and so on.
- We choose 1000-1300 Hz for channel A, 1500-1800 Hz for channel B, 2000-2300 Hz for channel C, and 2500-2800 Hz for channel D, a 0 transmitted from terminal A to front end port A is sent between the multiplexers on channel A with a 1000 Hz tone; a 1 is sent with an 1100 Hz tone. And for other direction a 0 is sent with 1200 Hz tone, and a 1 with a 1300 Hz tone, and so on.

Frequency Division Multiplexing (FDM)

Frequency division multiplexing, like pure TDM, is transparent to the end user. Each user has a full bandwidth connection at all times. If a particular terminal does not transmit data, time on its channel is wasted.