

Introduction to Computer Networks



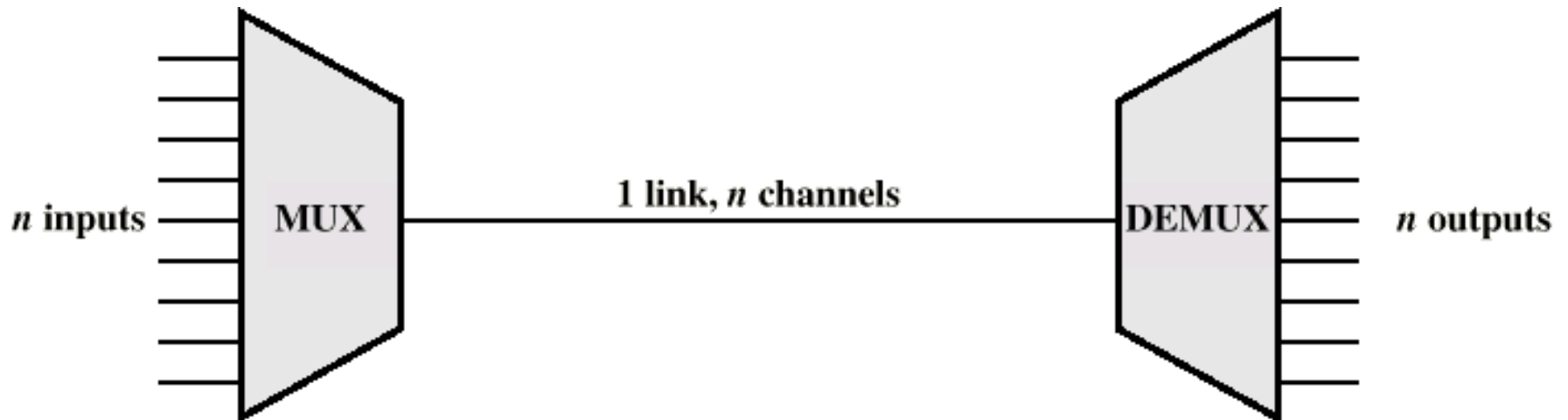
Lecture 4

Multiplexing

Multiplexor (MUX)

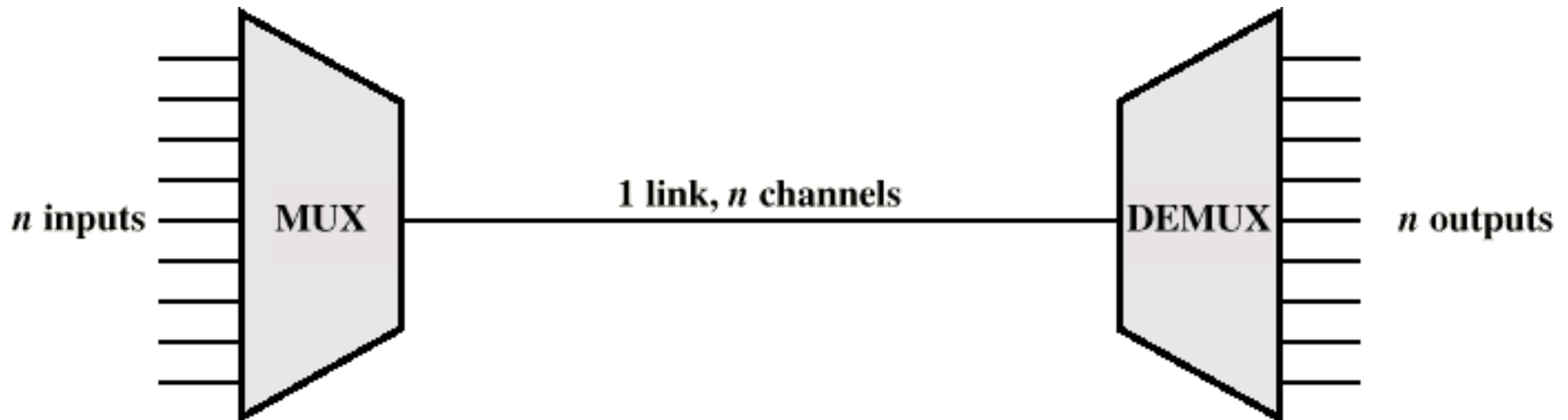
Demultiplexor (DEMUX)

Sometimes just called a MUX



Multiplexing

- Two or more simultaneous transmissions on a single circuit.
 - Transparent to end user.
- *Multiplexing costs less.*





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.

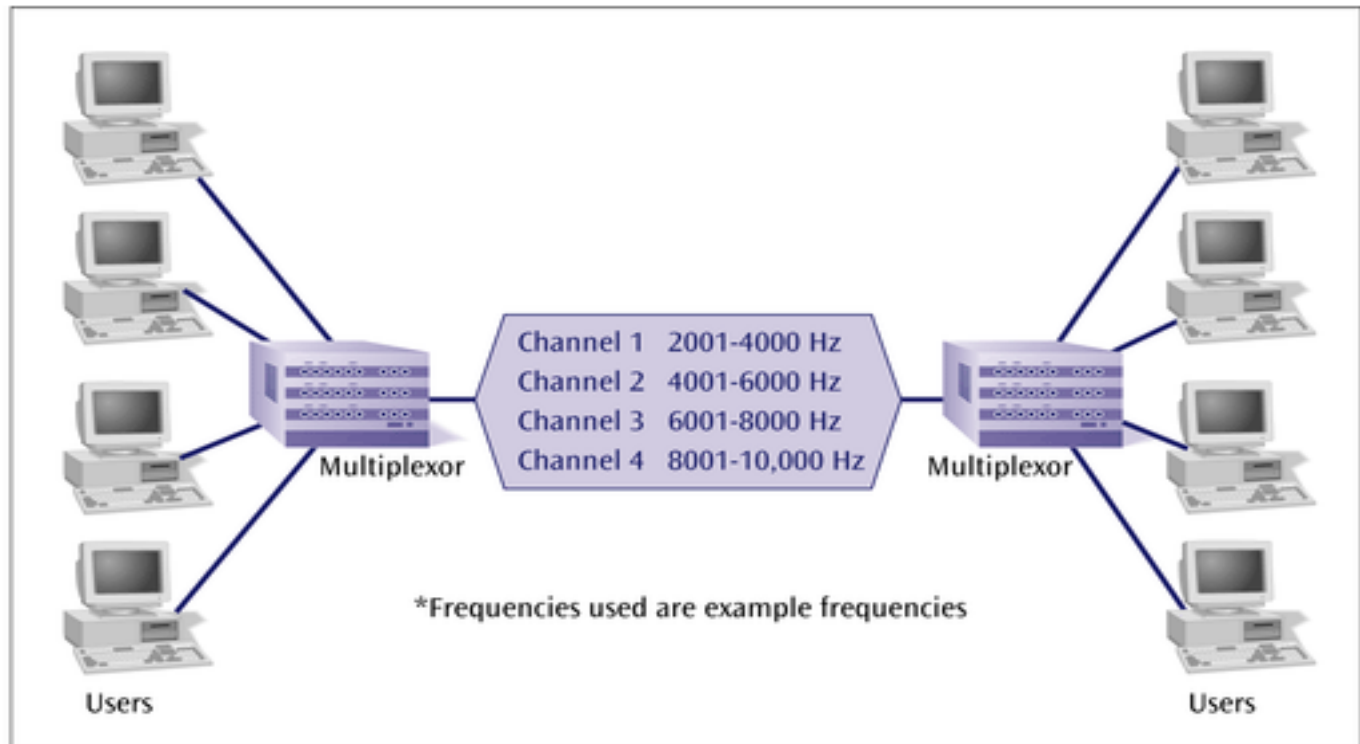
A multiplexor accepts inputs and assigns frequencies to each device.

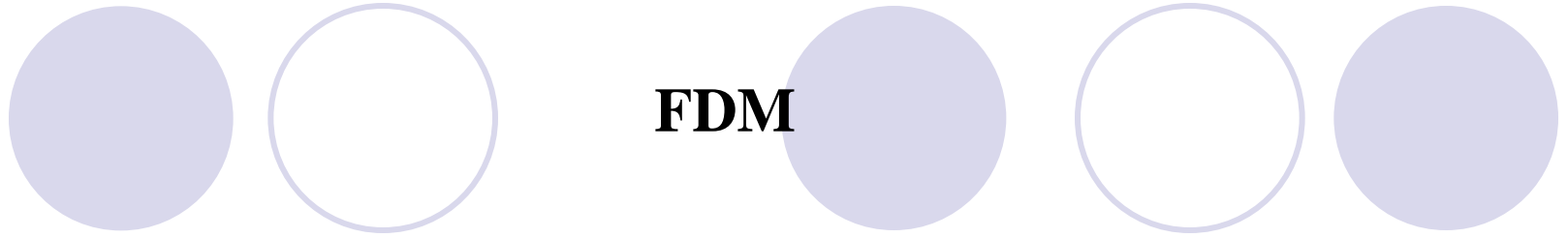
The multiplexor is attached to a high-speed communications line.

A corresponding multiplexor, or demultiplexor, is on the end of the high-speed line and separates the multiplexed signals.

FDM

Figure 5-1
*Simplified example of
frequency division
multiplexing*





Analog signaling is used to transmit the signals.

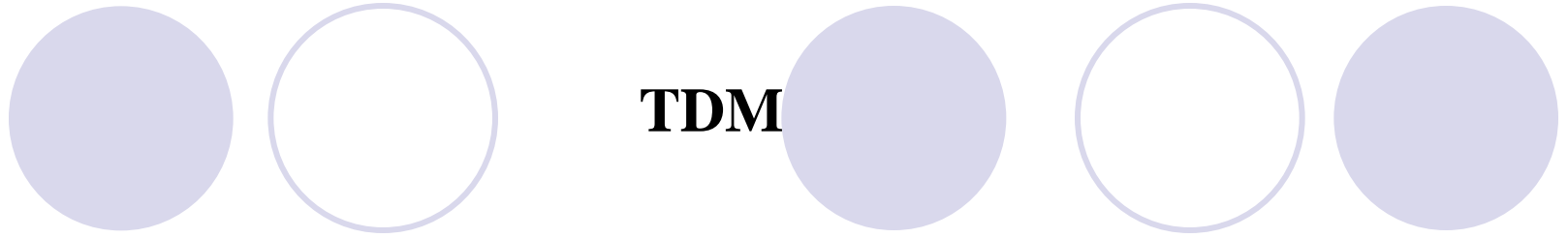
Broadcast radio and television, cable television, and the AMPS cellular phone systems use frequency division multiplexing.

This technique is the oldest multiplexing technique.

Since it involves analog signaling, it is more susceptible to noise.

Table 5-1*Assignment of frequencies for cable television channels*

	Channel	Frequency in MHz
Low-Band VHF and Cable	2	54–60
	3	60–66
	4	66–72
	5	76–82
	6	82–88
Mid-Band Cable	95	90–96
	96	96–102
	97	102–108
	98	108–114
	99	114–120
	14	120–126
	15	126–132
	16	132–138
	17	138–144
	18	144–150
	19	150–156
	20	156–162
	21	162–168
	22	168–174
High-Band VHF and Cable	7	174–180
	8	180–186
	9	186–192
	10	192–198
	11	198–204
	12	204–210
	13	210–216



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:

1. Synchronous time division multiplexing, and
2. Statistical, or asynchronous time division multiplexing.



Synchronous Time Division Multiplexing

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.

T-1 and ISDN telephone lines are common examples of synchronous time division multiplexing.

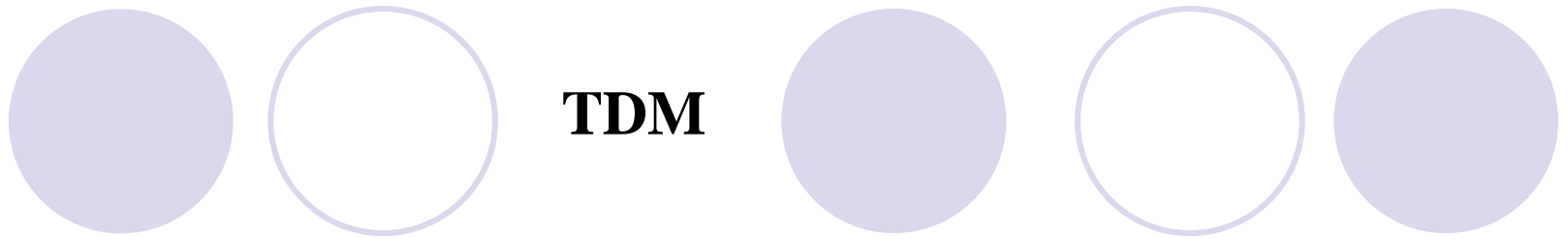
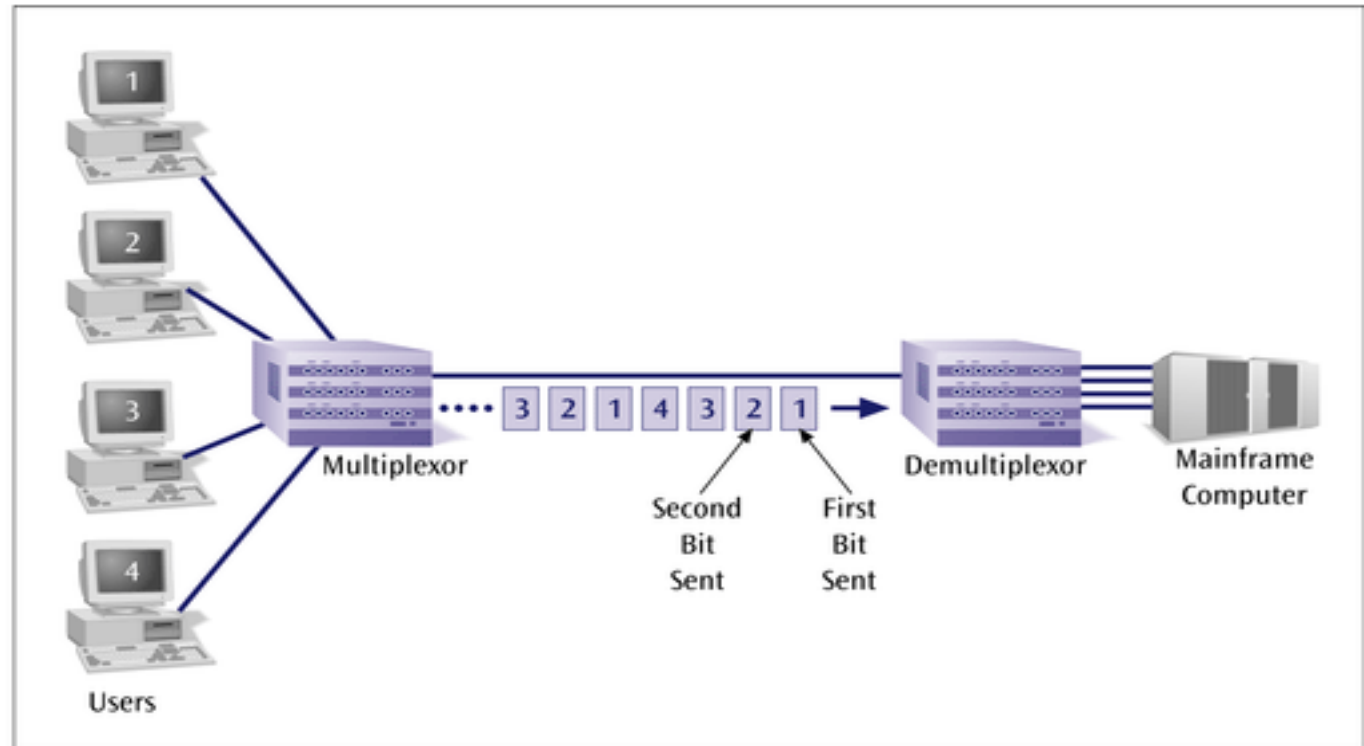


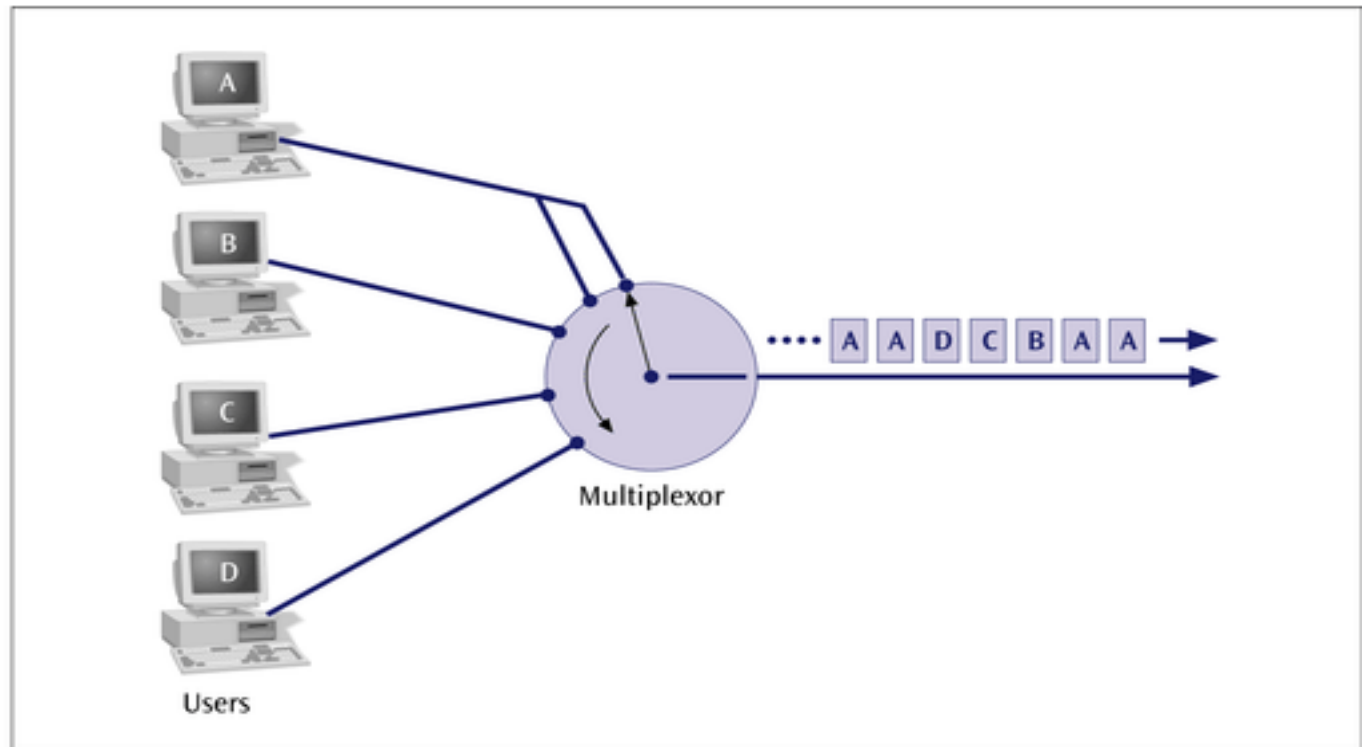
Figure 5-2
*Sample output stream
generated by a syn-
chronous time division
multiplexor*



TDM

Figure 5-3

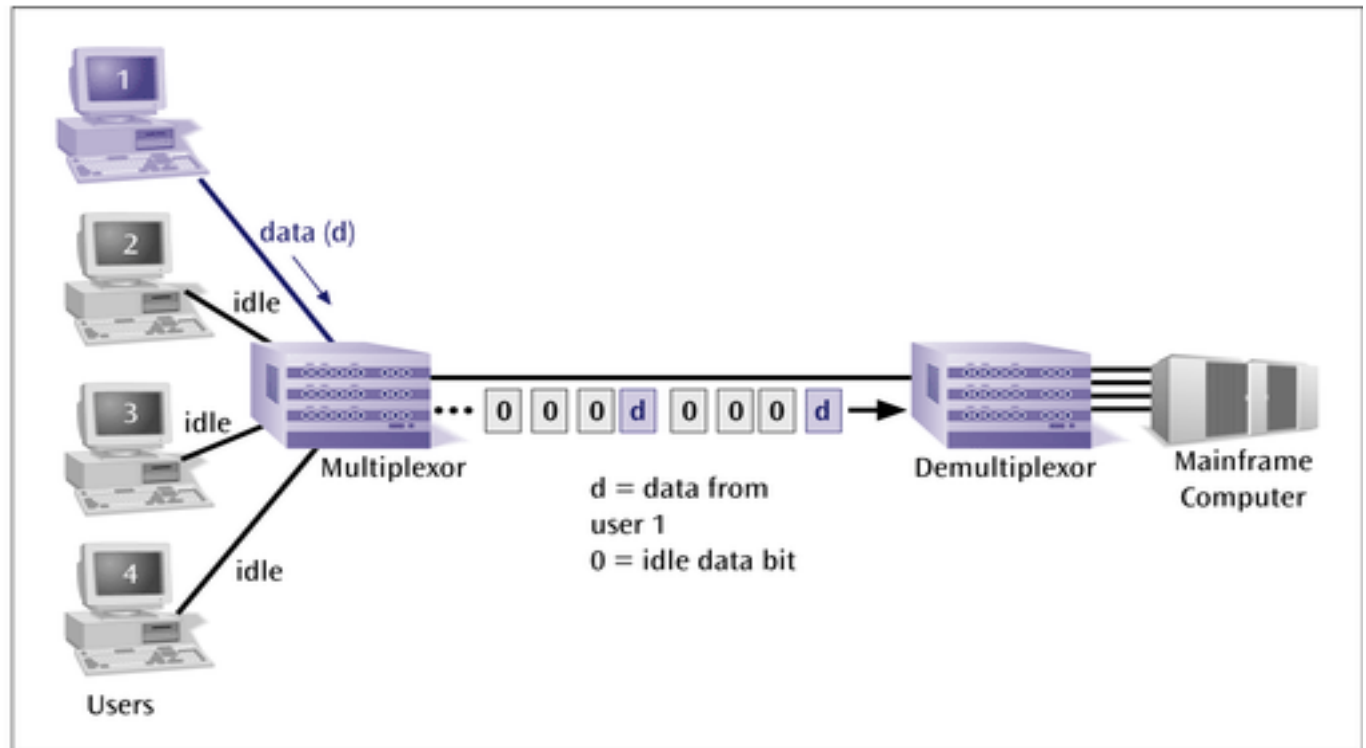
A synchronous time division multiplexor system which samples device A twice as fast as the other devices



TDM

Figure 5-4

Multiplexor transmission stream with only one input device transmitting data



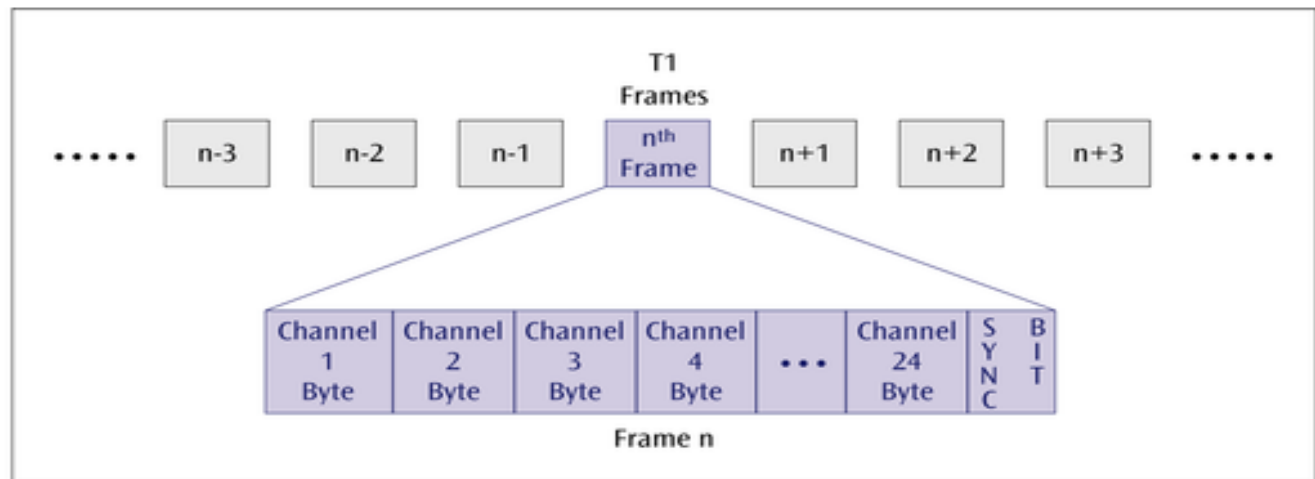


Three types popular today:

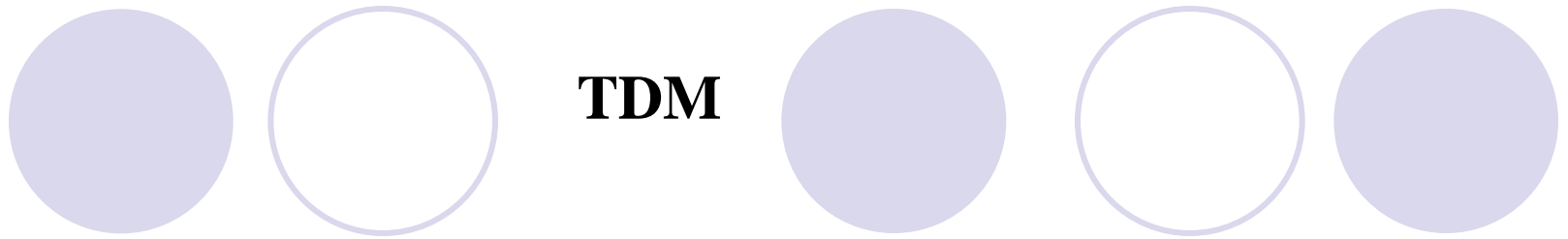
- T-1 multiplexing (the classic)
- ISDN multiplexing
- SONET (**S**ynchronous **O**ptical **NET**work)

The T1 (1.54 Mbps) multiplexor stream is a *continuous* series of frames of both digitized data and voice channels.

Figure 5-6
T1 multiplexed data stream

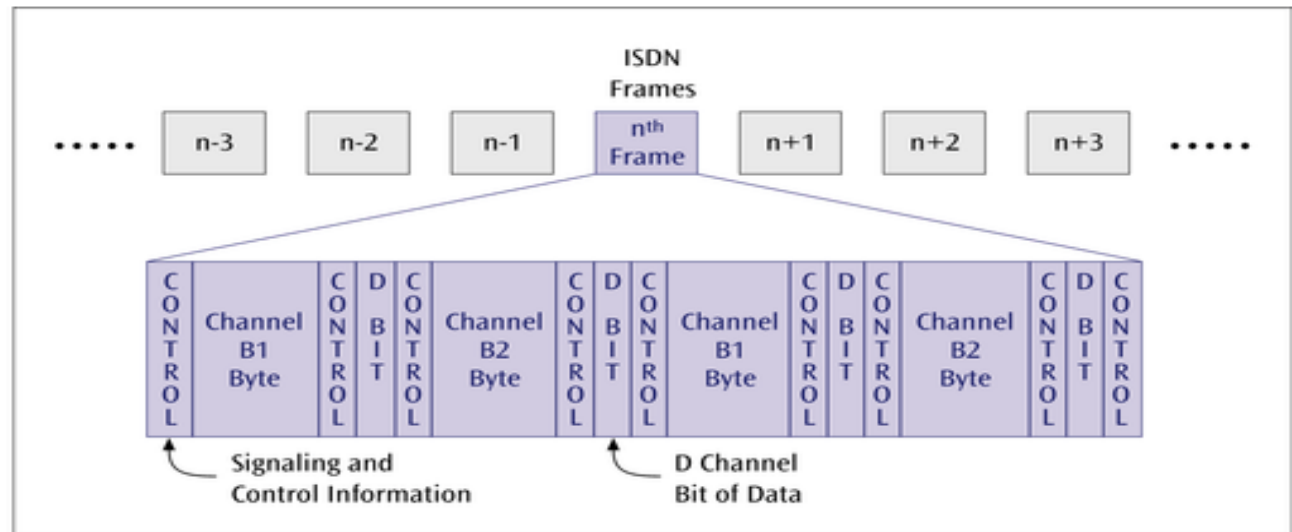


24 separate 64Kbps channels



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

Figure 5-8
ISDN frame layout
showing B channel bits
and signaling control
information bits



SONET

SONET – massive data rates

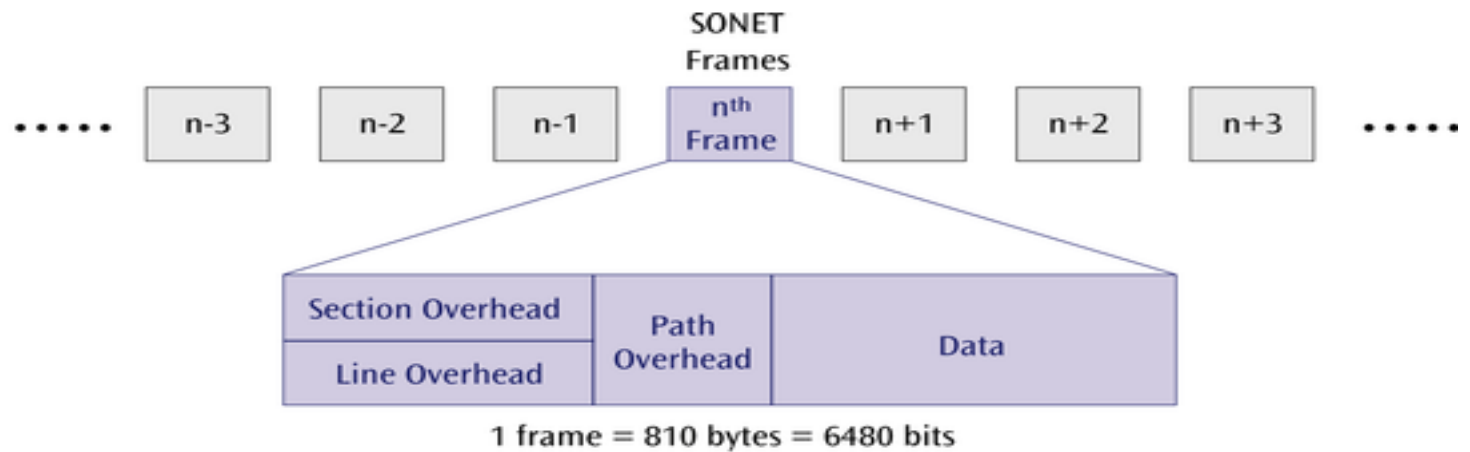
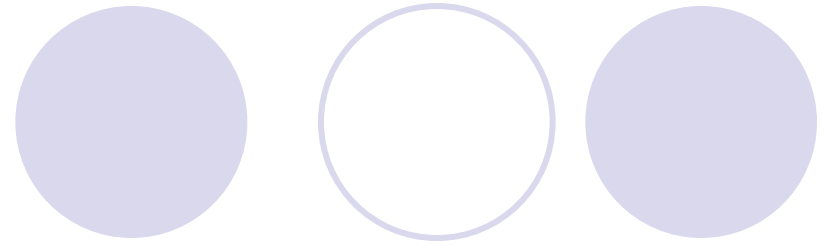


Figure 5-7 SONET STS-1 frame layout

Synchronous TDM



- Very popular
- Line will require as much bandwidth as all the bandwidths of the sources



Statistical Time Division Multiplexing

A statistical multiplexor transmits only the data from active workstations (*or why work when you don't have to*).

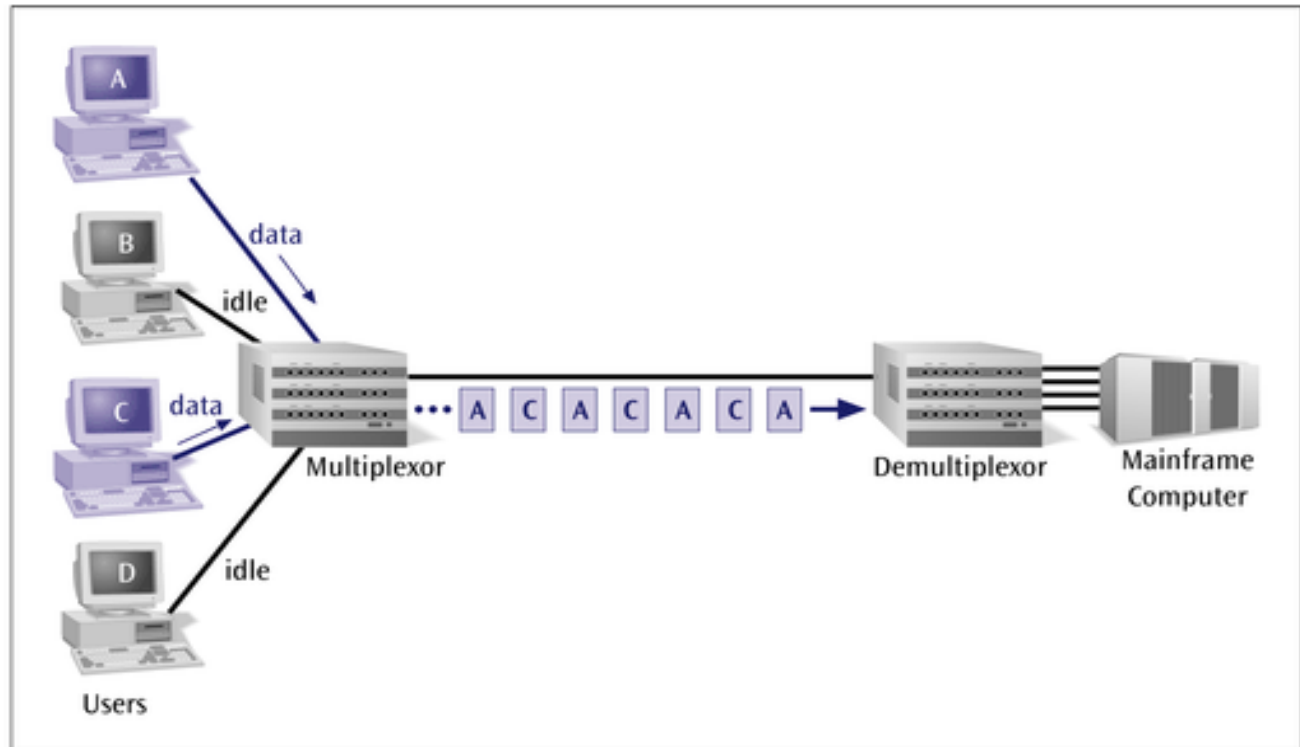
If a workstation is not active, no space is wasted on the multiplexed stream.

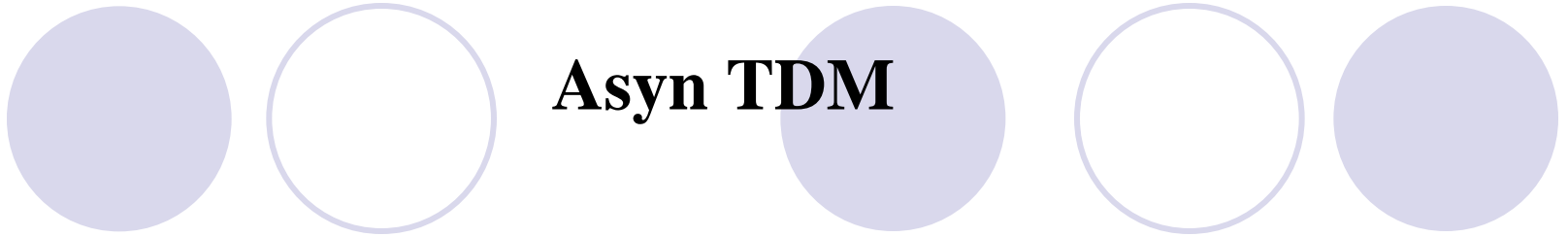
A statistical multiplexor accepts the incoming data streams and creates a frame containing only the data to be transmitted.

Asyn TDM

Figure 5-9

Two stations out of four transmitting via a statistical multiplexor



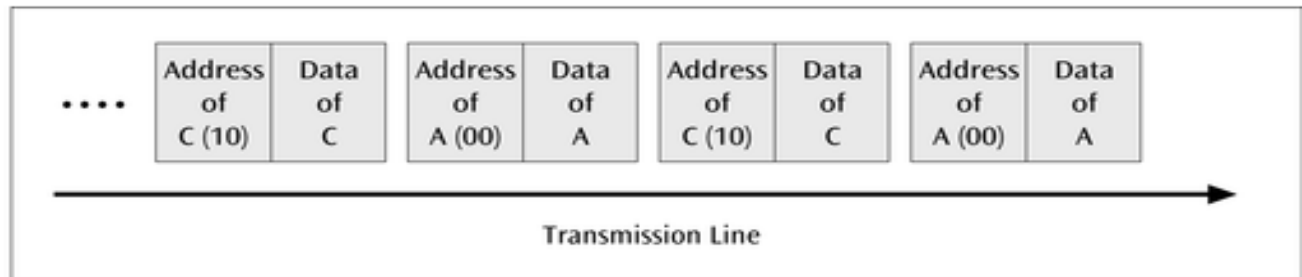


Asyn TDM

To identify each piece of data, an address is included.

Figure 5-10

Sample address and data in a statistical multiplexor output stream

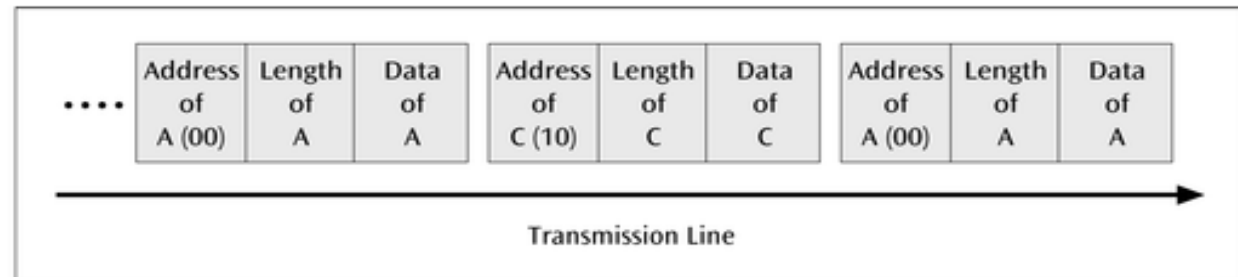


Asyn TDM

If the data is of variable size, a length is also included.

Figure 5-11

Packets of address and data fields in a statistical multiplexor output stream





Asyn TDM

A statistical multiplexor does not require a line over as high a speed line as synchronous time division multiplexing since STDM does not assume all sources will transmit all of the time!

Good for low bandwidth lines (used for LANs)

Much more efficient use of bandwidth!



Wavelength Division Multiplexing (WDM)

Give each message a different wavelength (frequency)

Easy to do with fiber optics and optical sources



Dense Wavelength Division Multiplexing (DWDM)

Dense wavelength division multiplexing is often called just wavelength division multiplexing

Dense wavelength division multiplexing multiplexes multiple data streams onto a single fiber optic line.

Different wavelength lasers (called lambdas) transmit the multiple signals.

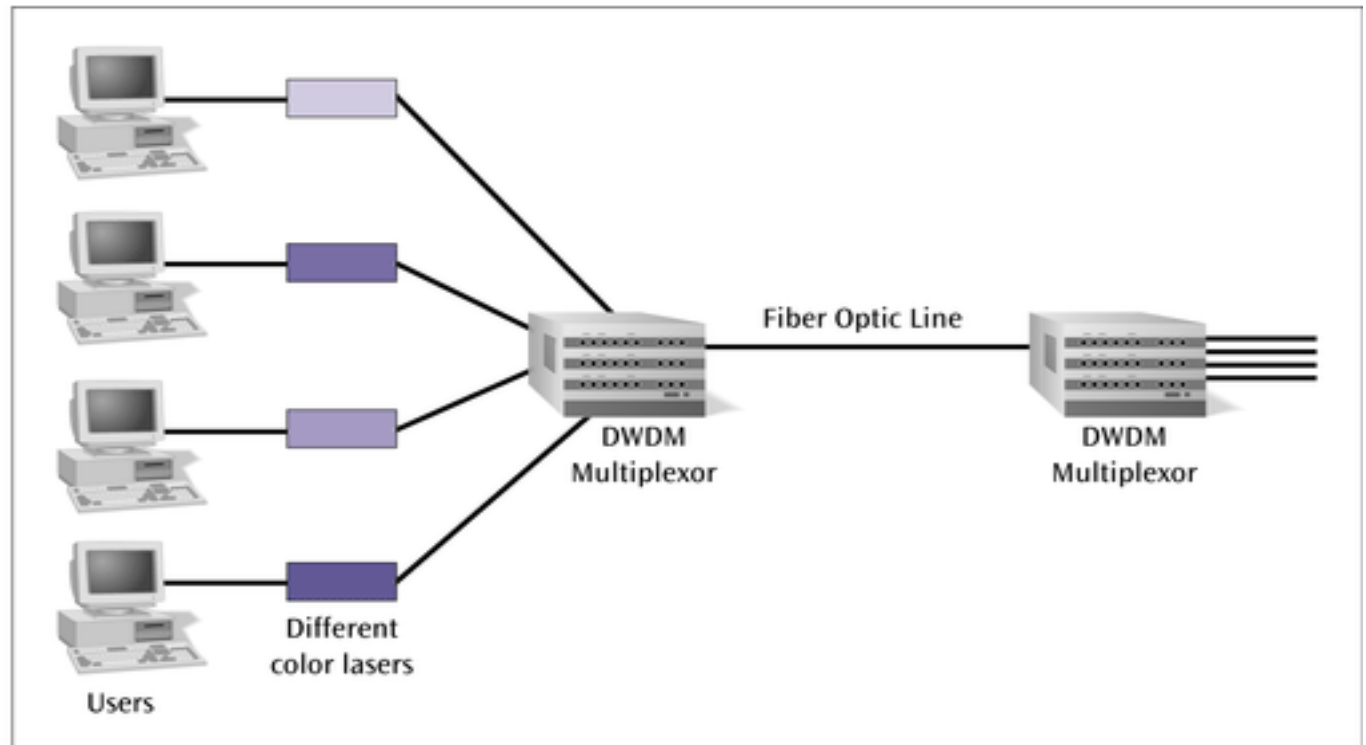
Each signal carried on the fiber can be transmitted at a different rate from the other signals.

Dense wavelength division multiplexing combines many (30, 40, 50, 60, more?) onto one fiber.

WDM

Figure 5-13

Multiple lasers transmitting data signals down a single fiber optic line



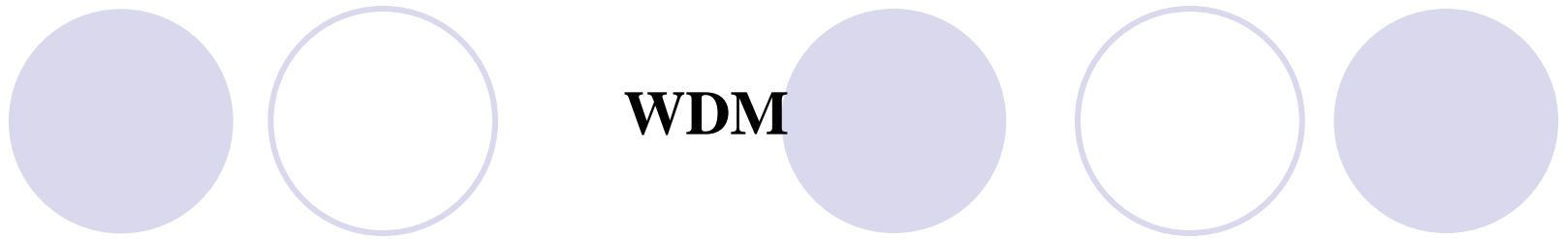
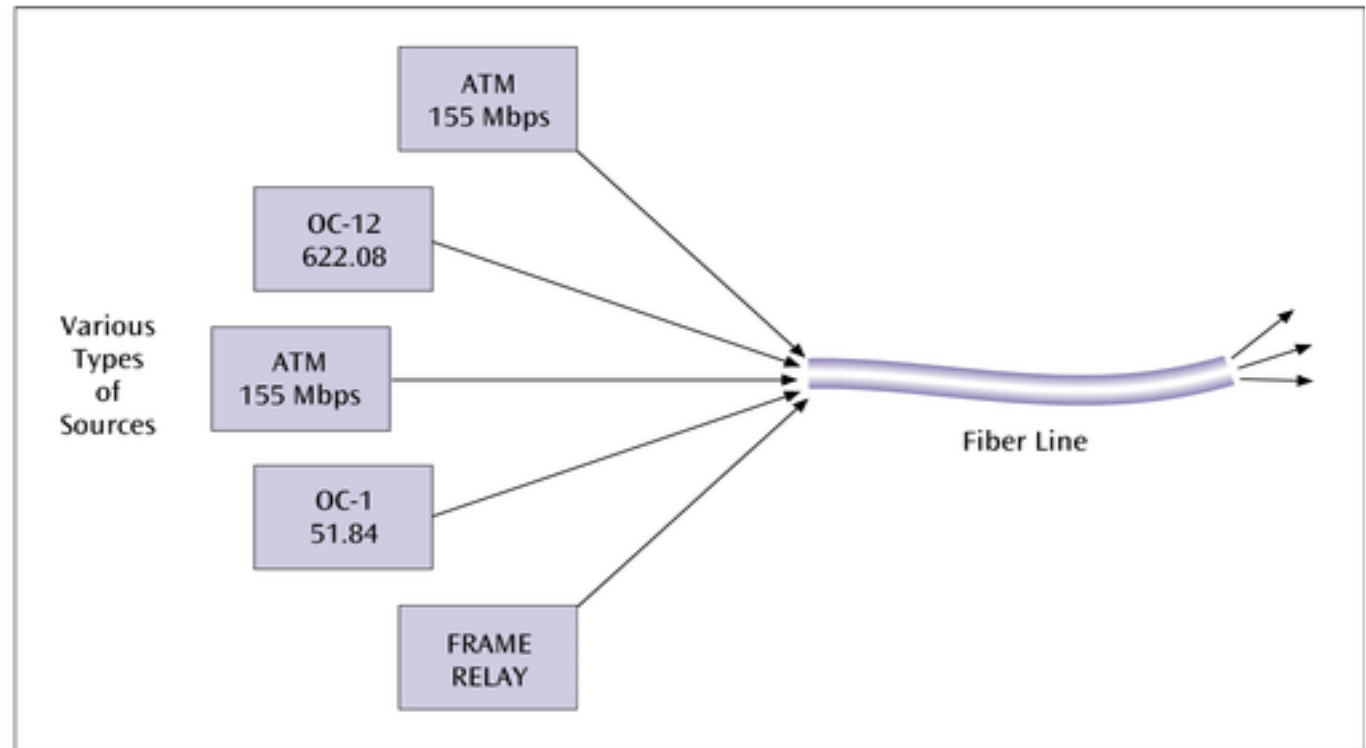


Figure 5-14

Fiber optic line using dense wavelength division multiplexing and supporting multiple-speed transmissions



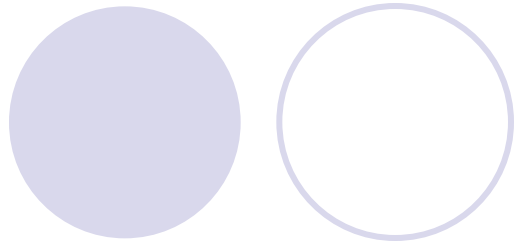


Code Division Multiplexing (CDM)

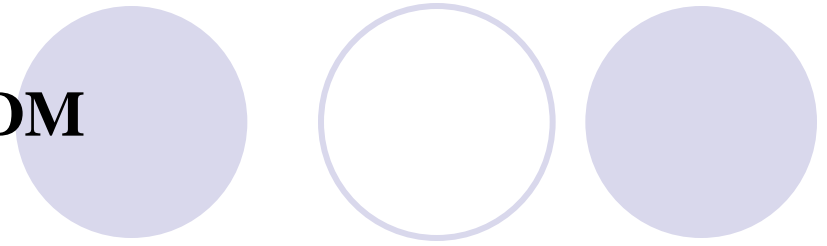
Also known as code division multiple access (CDMA)

An advanced technique that allows multiple devices to transmit on the *same* frequencies at the *same* time using different codes

Used for mobile communications



CDM



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



Code Division Multiplexing

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

Table 5-3*Advantages and disadvantages of multiplexing techniques*

Multiplexing Technique	Advantages	Disadvantages
Frequency Division Multiplexing	Simple Popular with radio, TV, cable TV Relatively inexpensive All the receivers, such as cellular telephones, do not need to be at the same location	Analog signals only 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