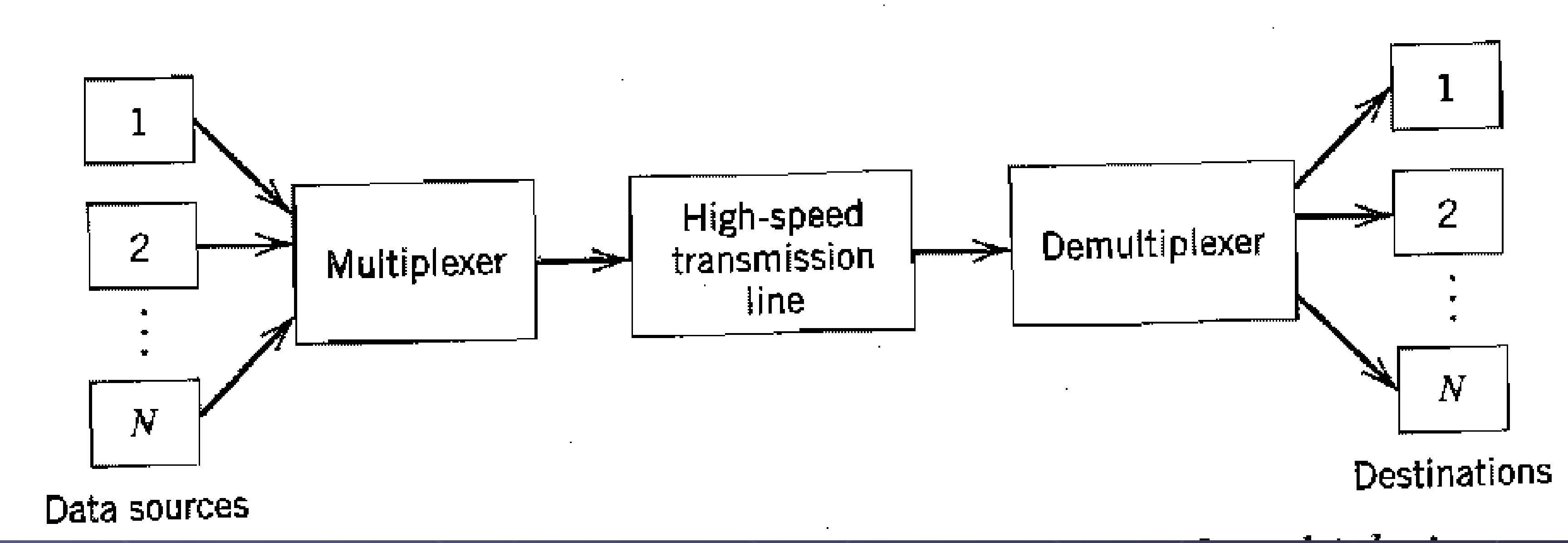
# Digital multiplexers

- In TDM a group of analog signals are sampled sequentially in time at a common sampling rate and then multiplexed for transmission over a common line
- In this section the multiplexing of digital signals at different rates will be considered
- Multiplexing of digital signals is accomplished by using a bit-by bit interleaving

# Digital multiplexers

- A selector switch is used sequentially takes a bit from each incoming line, then applies it to a high speed common line
- At the receiving end of the system the output of this common line is separated out into its low speed individual components and then delivered to their destination

# Digital multiplexers block diagram



# Digital multiplexers groups- group 1

- Digital multiplexers are divided into two major groups

1. One group is used to take relatively low bit-rate data streams originating from computers and multiplex them for TDM transmission over the public switched telephone network. This group requires the use of modulators and demodulators

# Digital multiplexers groups- group 2

2. The second group forms part of the data transmission services

- These multiplexers constitute a digital hierarchy that time division multiplexes low rate bit streams into much higher rate bit streams

# Digital signal zero (DS0) hierarchy

- The DS0 standard takes one voice signal, then samples it at a sampling frequency of 8 kHz/s, the samples are converted into PCM using 8-bit quantizer
- This means that the DS0 produces data at a rate of 64 kbit/s

# Digital signal one (DS1) hierarchy

- DS1 is the first level of the hierarchy
- DS1 combines 24 DS0 bit streams to obtain a digital signal one at 1.544 Mb/s
- The bandwidth of the DS1 is computed from the following equation
- $R_B = number\ of\ bits \times sampling\ rate$

$$R_B = (8 \times 24 + 1) \times 8000 = 1.544\ Mbit/second$$

# Digital signal two (DS2) hierarchy

- DS2 is the second level multiplexer
- DS2 combines 4 DS1 bit streams to obtain a digital signal one at 6.312 Mb/s
- The bandwidth of the DS2 is computed from the following equation

$$R_B = 4 \times DS1\left(\frac{49}{48}\right)\left(1+\frac{0.335}{288}\right)$$

$$R_B = 4 \times 1.544\left(\frac{49}{48}\right)\left(1+\frac{0.335}{288}\right) = 6.312\ \ Mbit/second$$

# Digital signal three (DS3) hierarchy

- DS3 is the third level multiplexer
- DS3 combines 7 DS2 bit streams to obtain a digital  signal one at 44.736 Mb/s

# Digital signal four (DS4) hierarchy

- DS4 is the fourth level multiplexer
- DS4 combines 6 DS3 bit streams to obtain a digital signal one at 274.176 Mb/s

# Digital signal five (DS5) hierarchy

- DS5 is the fifth level multiplexer
- DS5 combines 2 DS4 bit streams to obtain a digital  signal one at 560.16 Mb/s

# Problems involved in the design of a digital multiplexer

- Synchronization between receiver and receiver
- The multiplexed signal must include some form of framing so that its individual components can be identified at the receiver
- The multiplexer has to handle small variations in the bit rates of the incoming digital signals

A speech signal has a total duration of 10 s. It is sampled at the rate of 8 kHz and then encoded. The signal-to-(quantization) noise ratio is required to be 40 dB. Calculate the minimum storage capacity needed to accommodate this digitized speech signal.

The minimum number of bits per sample is 7 for a signal-to-quantization noise ratio of 40 dB. Hence,

$$\begin{pmatrix}\text{The number of samples} \\ \text{in a duration of } 10s\end{pmatrix} = 8000 \times 10 = 8 \times 10^4 \text{ samples}$$

The minimum storage is therefore

$$= 7 \text{ x } 8 \text{ x } 10^4$$

$$= 5.6 \text{ x } 10^5$$

$$= 560 \text{ kbits}$$

A PCM system uses a uniform quantizer followed by a 7-bit binary encoder. The bit rate of the system is equal to $50 \times 10^6$ b/s.

(a) What is the maximum message bandwidth for which the system operates satisfactorily?

(b) Determine the output signal-to-(quantization) noise ratio when a full-load sinusoidal modulating wave of frequency 1 MHz is applied to the input.

(a) Let the message bandwidth be W. Then, sampling the message signal at its Nyquist rate, and using an $R$-bit code to represent each sample of the message signal, we find that the bit duration is

$$T_b = \frac{T_s}{R} = \frac{1}{2WR}$$

The bit rate is

$$\frac{1}{T_b} = 2WR$$

The maximum value of message bandwidth is therefore

$$W_{max} = \frac{50 \times 10^6}{2 \times 7}$$

$$= 3.57 \times 10^6 \text{ Hz}$$

# Virtues, limitations and modifications of PCM

- Why someone use digital communications (PCM) even though it introduces complications in the design of communication system?
- PCM system has many advantages
- some of these advantages are

# Advantages of PCM

- Robustness to channel noise
- Efficient regeneration of the coded signal along the transmission path
- Efficient exchange of increased channel bandwidth for improved signal to noise ratio, obey an exponential law

# Advantages of PCM

- A uniform format for the transmission of different kinds of base band signals, hence their integration with other forms of digital data in a common network
- Comparative ease with which message sources may be dropped or reinserted in time division multiplex system
- Secure communication through the use of special modulation schemes or encryption