Chapter 7 - Multiplexing

Problem

> Consider 2 (or more) stations each is assigned a data link but does not use up its capacity. Thus a mean of sharing should be setup so that the capacity is properly shared between the 2 stations. This is Multiplexing.

1. Definition

> Multiplexing is a popular networking technique that integrates multiple analog and digital signals into a signal transmitted over a shared medium. Multiplexers and de-multiplexers are used to convert multiple signals into one signal.

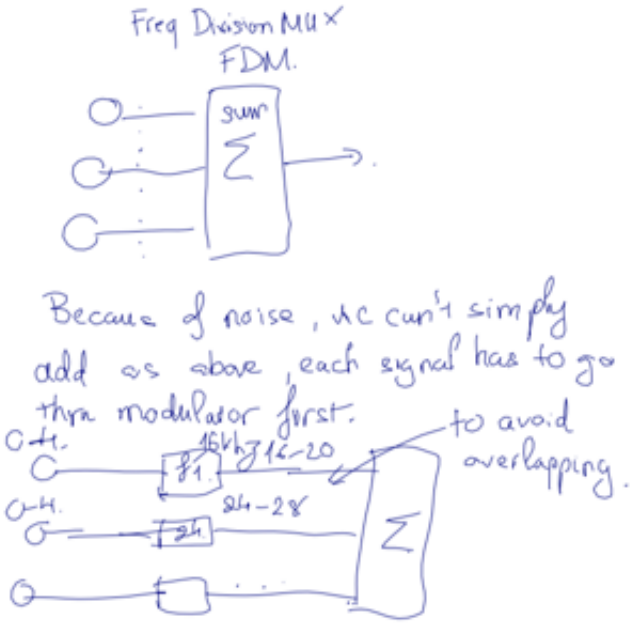
Figure 8.1 Multiplexing

There are 2 types of Multiplexing: **Time Division Multiplexing** (TDM) and **Frequency Division Multiplexing**

(FDM).

2. FDM

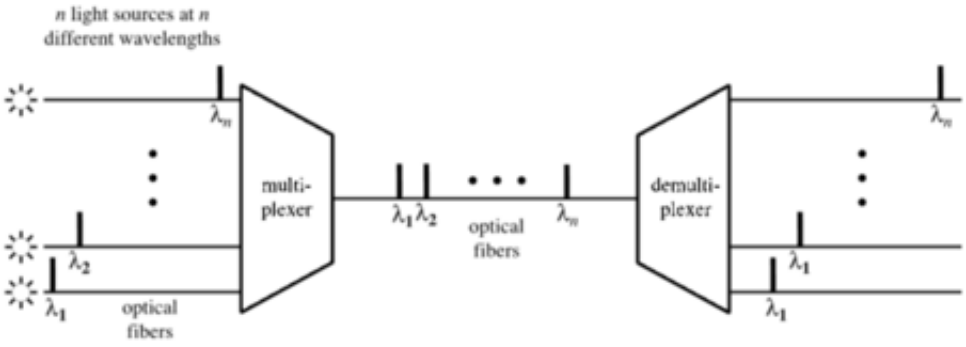
> **FDM** is possible when the useful bandwidth of the transmission medium exceeds the required b/w of signals to be transmitted. A number of signals can be carried simultaneously if each signal is modulated onto a different carrier frequency for trasmission.



- Modulation equipment is required to move each signal to the required frequency band (to avoid overlapping), and then use multiplexing equipment to combine the modulated signals, each called **subcarrier**.
- There are 2 problems the FDM system must cope:
  1. **Crosstalk**, this may happen since the component signals are close to each other.
  2. **Intermodulation noise**.
- Long-distance, high capacity links most likely use FDM hierarchy. (AT&T, ITU-T).

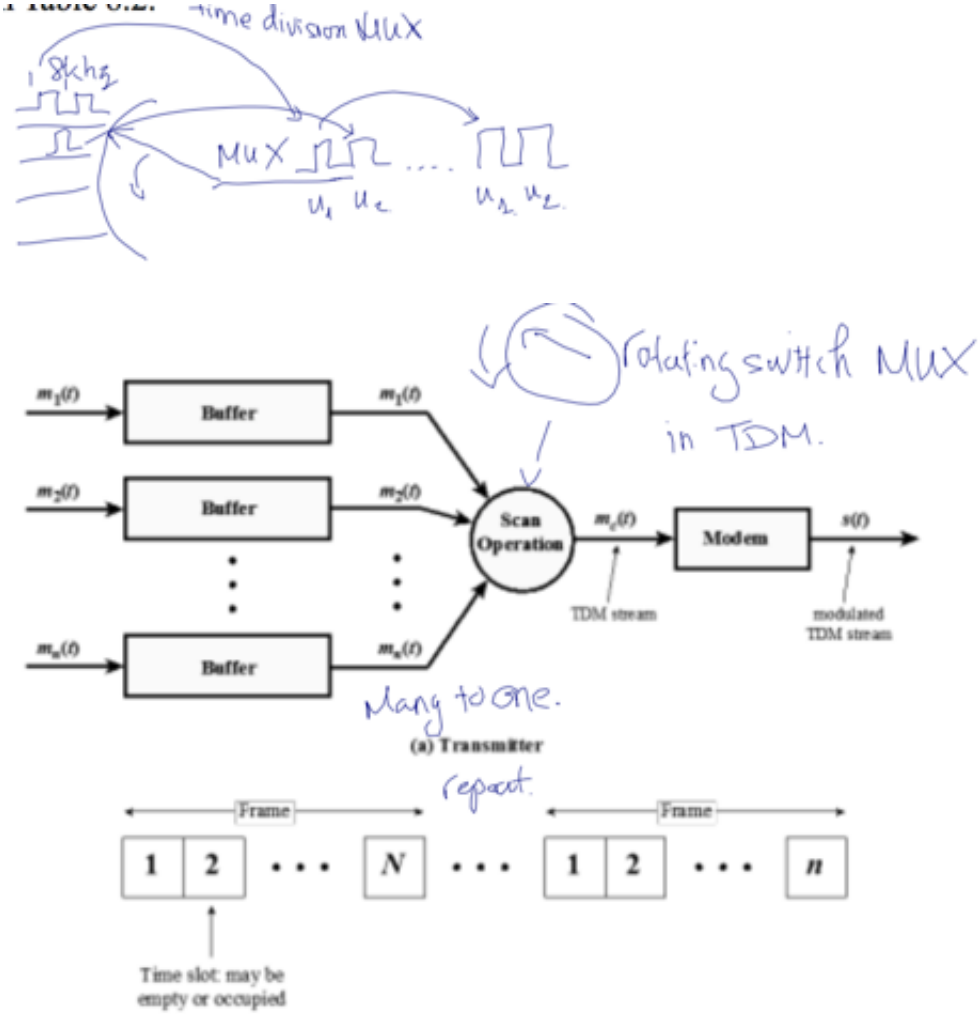
2.1. WDM - Wavelength Division Multiplexing

> **WDM** is a a derrived form of FDM, used in optical fiber where multiple beams of light are transmitted with different frequencies (thus, wavelength) on the same fiber cable.



3. TDM (Time Division Multiplexing)

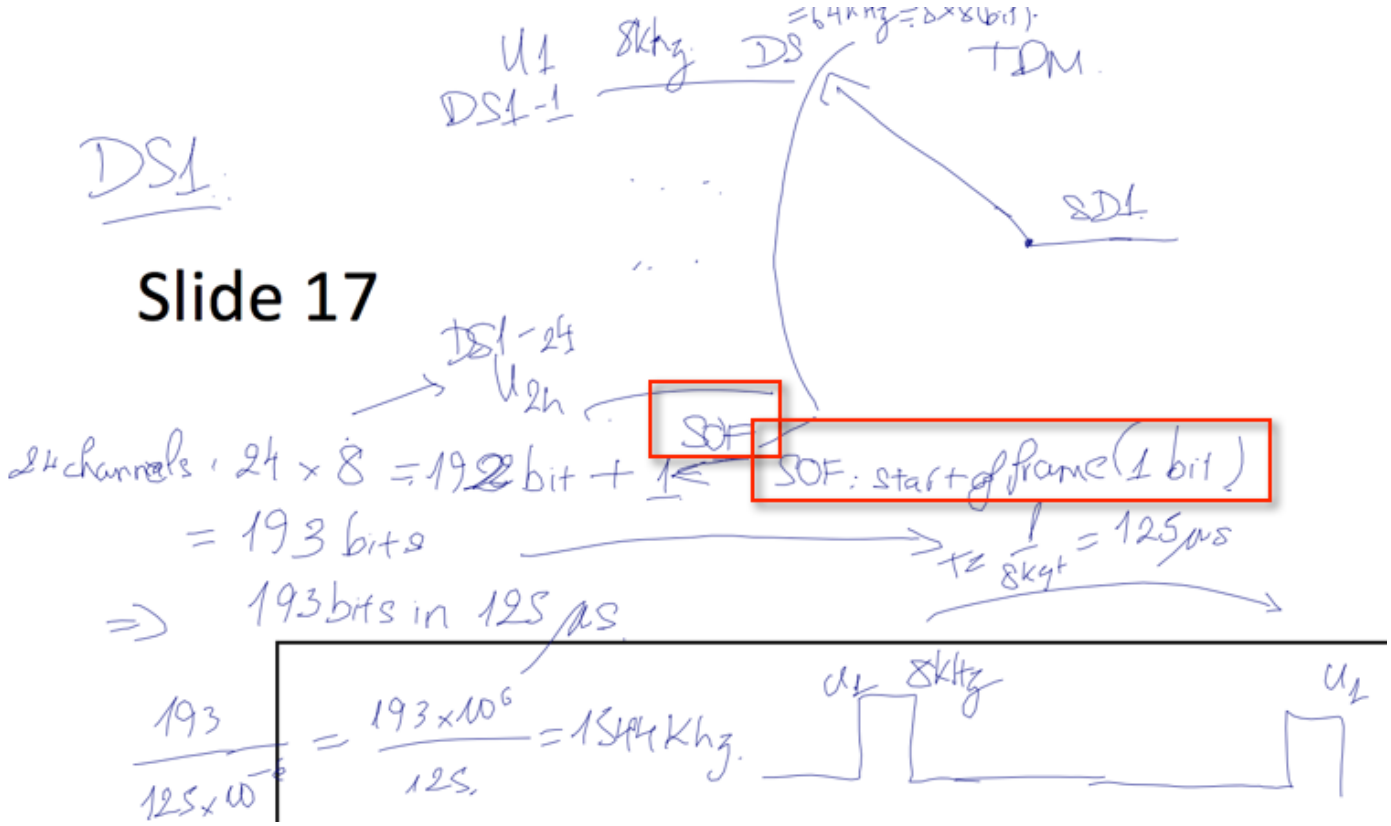
> **TDM** is a method of transmitting and receiving independent signals over a common signal path by letting each signal appears on the line only a fraction of time in an alternating pattern.



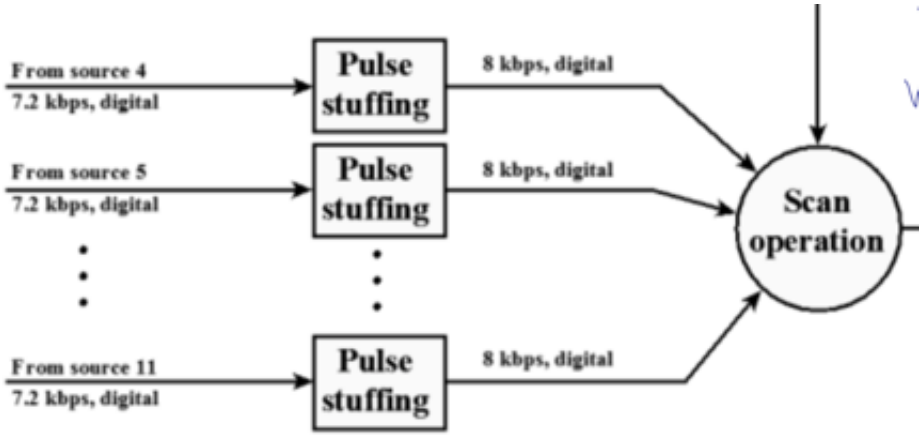
- **Synchronous TDM** is called synchronous not because of synchronous transmission, but because its time slots are already pre-assigned and fixed. A slower input will take less time slot than faster inputs.
- **Data Link Control**: TDM has no header nor trailer because the data link control protocol is not needed (i.e. no flow control and error control). The main reason is because TDM share transmission B/W with

among all channels so if one channel miss the bus it should not stop others from transmitting, same reason for error control. The error control should be applied to per-channel basis using HDLC.

- **Framing**: to maintain synchronization between source and destination, one control bit is added into each TDM frame.



- **Pulse Stuffing**: this technique stuffs extra dummy bits into each incoming signal until it matches the local clock (equalize the data rate among all sources that have different clock rates). The insertion is at fixed locations so the removal follows the same location.



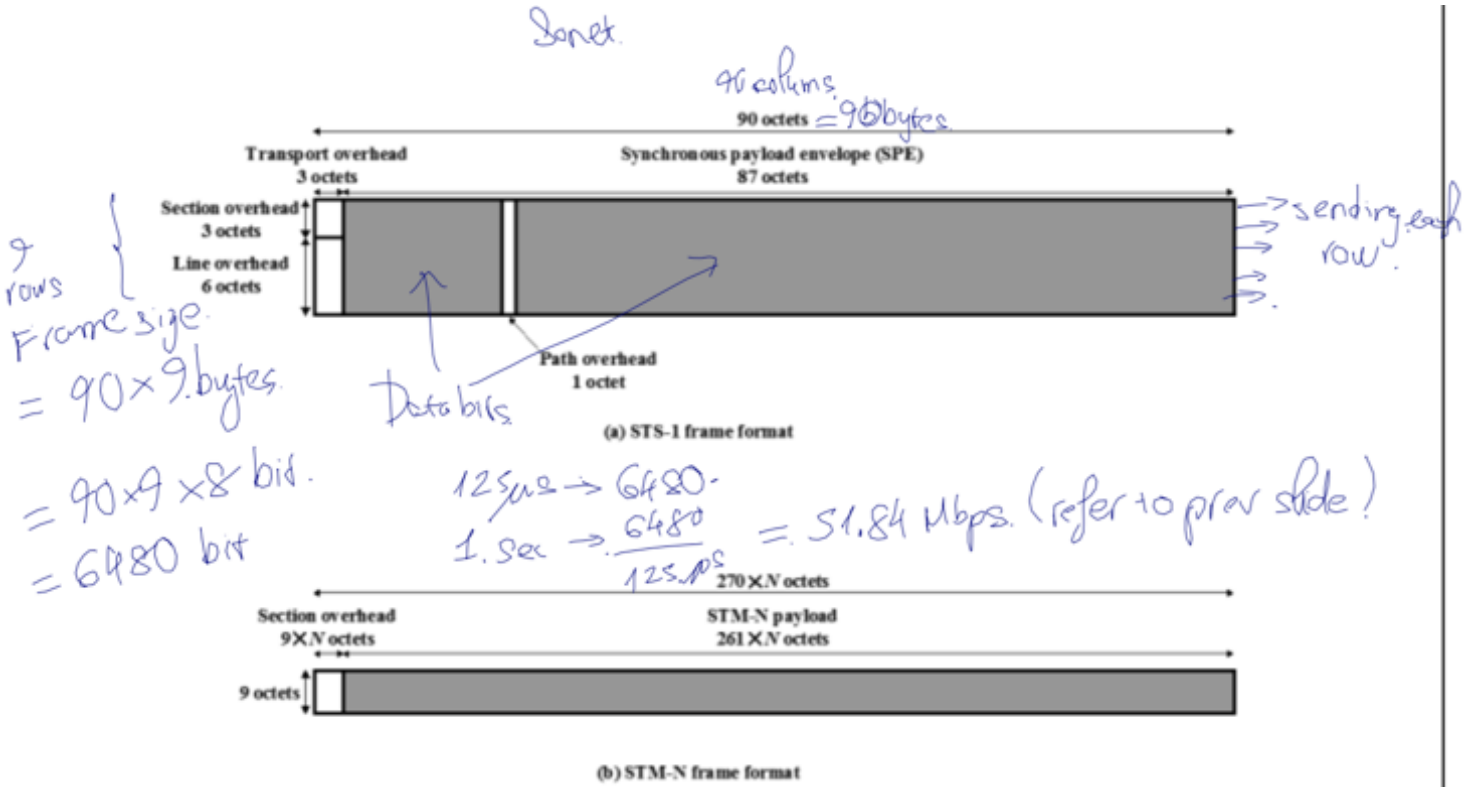
4. SONET / SDH

> Synchronous Optical Networking (SONET) and Synchronous Digital Hierarchy (SDH) are standardized

> multiplexing protocols that transfer multiple digital bit streams over optical fiber using lasers or light-emitting diodes (LEDs).

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

How to deduce the bandwidth of STS-1



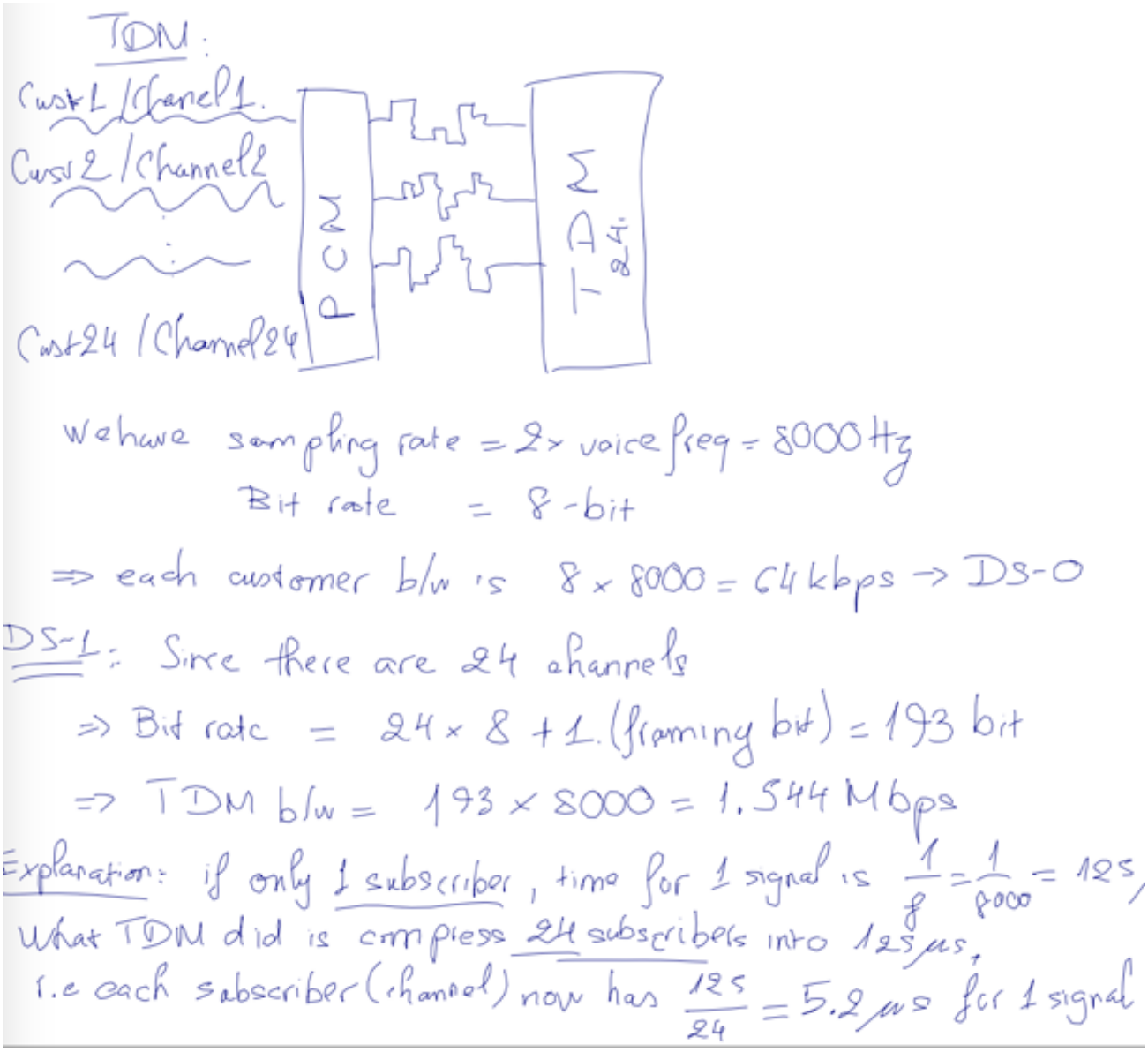
- Frame rate: 125μs

5. Questions

5.1. What is the freq of voice or telephone signal?

Ans: 4Khz

5.2. Prove why DS-1 = 1.544Mbps (1-bit stuffing)



We have sampling rate = 2× voice freq = 8000 Hz

Bit rate = 8-bit

⇒ each customer b/w is $8 \times 8000 = 64$ kbps → DS-0

DS-1: Since there are 24 channels

⇒ Bit rate = $24 \times 8 + 1$ (framing bit) = 193 bit

⇒ TDM b/w = $193 \times 8000 = 1.544$ Mbps

Explanation: if only 1 subscriber, time for 1 signal is $\frac{1}{8} = \frac{1}{8000} = 125\,\mu s$,

What TDM did is compress 24 subscribers into 125 μs,

i.e each subscriber (channel) now has $\frac{125}{24} = 5.2\,\mu s$ for 1 signal

5.3. Find out how many bits are stuffes for DS-2

DS-2 : 96 channels = 4 x DS-1

125μs : 193 x 4 + x

1s : 6.312 Mbps

(193 x 4 + x) x 8000 = 6312000

772 + x = 789

x = 17 bits

5.4. What is North American TDM Carrier Standards

North American and International TDM Carrier Standards

North American			International (ITU-T)		
Designation	**Number of Voice Channels**	**Data Rate (Mbps)**	**Level**	**Number of Voice Channels**	**Data Rate (Mbps)**
DS-1	24	1.544	1	30	2.048
DS-1C	48	3.152	2	120	8.448
DS-2	96	6.312	3	480	34.368
DS-3	672	44.736	4	1920	139.264
DS-4	4032	274.176	5	7680	565.148