HOMEWORK 1

1. Write the equivalent of 5Gbits in Kbits, Megabits and bits. Show the conversions clearly.

To convert **5 Gigabits (Gbits)** into **Kilobits (Kbits)**, **Megabits (Mbits)**, and **bits (b)**, we need to use the following conversions:

- **1 Gigabit (Gbit) = 1,000 Megabits (Mbits)**
- **1 Megabit (Mbit) = 1,000 Kilobits (Kbits)**
- **1 Kilobit (Kbit) = 1,000 bits (b)**

Step 1: Convert 5 Gbits to Megabits

$$5\,\text{Gbits} = 5 \times 1,000\,\text{Mbits} = 5,000\,\text{Mbits}$$

Step 2: Convert 5 Gbits to Kilobits

$$5\,\text{Gbits} = 5,000 \times 1,000\,\text{Kbits} = 5,000,000\,\text{Kbits}$$

Step 3: Convert 5 Gbits to bits

$$5\,\text{Gbits} = 5,000,000 \times 1,000\,\text{bits} = 5,000,000,000\,\text{bits}$$

Summary:

- 5 Gbits = 5,000 Megabits (Mbits)
- 5 Gbits = 5,000,000 Kilobits (Kbits)
- 5 Gbits = 5,000,000,000 bits (b)

2. Show the connection between Gigabyte, gigabits, Kilobyte, kilobits and bits.

To understand the connection between **Gigabyte (GB)**, **gigabits (Gb)**, **Kilobyte (KB)**, **kilobits (Kb)**, and **bits (b)**, we need to break down the relationships between these units and the common prefixes (Giga, Kilo) used in data measurement. Here's a detailed explanation:

1. Basic Unit: The Bit (b)

- A **bit** (b) is the smallest unit of digital data.
- It can have a value of either 0 or 1.

2. Byte (B)

- **1 Byte (B) = 8 bits (b)**.

- A **Byte** is often used as the basic unit for measuring the size of files or data storage.

3. Kilobyte (KB) and Kilobit (Kb)

- **Kilo-** means **1,000**, but in computing, it's often **1,024** because memory is often based on powers of 2. However, for simplicity:
    - **1 Kilobyte (KB) = 1,024 Bytes** (commonly rounded to **1,000 Bytes** in certain contexts like disk storage).
    - **1 Kilobit (Kb) = 1,000 bits** (typically used in networking to represent speed, such as **Kbps** for kilobits per second).

Relationship:

$$1\,\text{Kilobyte (KB)} = 1,024\,\text{Bytes} = 1,024 \times 8 = 8,192\,\text{bits (b)}$$

$$1\,\text{Kilobit (Kb)} = 1,000\,\text{bits (b)}$$

- **1 KB = 8 Kb** (since 1 KB is 8,192 bits and 1 Kb is 1,000 bits, you can approximate **1 KB = 8 Kb** in terms of data transmission).

4. Megabyte (MB) and Megabit (Mb)

- **Mega-** means **1 million**, or in some cases **1,024 Kilo-**.
    - **1 Megabyte (MB) = 1,024 KB = 1,048,576 Bytes**.
    - **1 Megabit (Mb) = 1,000,000 bits** (used for network speed, such as **Mbps** for megabits per second).

Relationship:

$$1\,\text{Megabyte (MB)} = 1,024\,\text{KB} = 1,048,576\,\text{Bytes} = 1,048,576 \times 8 = 8,388,608\,\text{bits}$$

$$1\,\text{Megabit (Mb)} = 1,000,000\,\text{bits}$$

- **1 MB = 8 Mb** (since **1 MB** is **8,388,608 bits** and **1 Mb** is **1,000,000 bits**, **1 MB** is approximately **8 Mb** for transmission rates).

5. Gigabyte (GB) and Gigabit (Gb)

- **Giga-** means **1 billion** (or **1,024 Megabytes** in binary computing).
    - **1 Gigabyte (GB) = 1,024 MB = 1,073,741,824 Bytes**.
    - **1 Gigabit (Gb) = 1,000,000,000 bits** (used for network speed, such as **Gbps** for gigabits per second).

Relationship:

$$1\,\text{Gigabyte (GB)} = 1,024\,\text{MB} = 1,073,741,824\,\text{Bytes} = 1,073,741,824 \times 8 = 8,589,934,592\,\text{bits}$$

$$1\,\text{Gigabit (Gb)} = 1,000,000,000\,\text{bits}$$

- **1 GB = 8 Gb** (since **1 GB** is **8,589,934,592 bits** and **1 Gb** is **1,000,000,000 bits**, **1 GB** is approximately **8 Gb** for transmission purposes).

Summary of Relationships:

Unit	Value in Bits	Relationship
1 bit (b)	1 bit	
1 Byte (B)	8 bits	1 B = 8 b
1 Kilobit (Kb)	1,000 bits	
1 Kilobyte (KB)	8,192 bits (1,024 Bytes)	1 KB = 8 Kb
1 Megabit (Mb)	1,000,000 bits	
1 Megabyte (MB)	8,388,608 bits (1,024 KB)	1 MB = 8 Mb
1 Gigabit (Gb)	1,000,000,000 bits	
1 Gigabyte (GB)	8,589,934,592 bits (1,024 MB)	1 GB = 8 Gb

Practical Uses:

- **File Sizes**: Typically measured in **Bytes** (KB, MB, GB).
- **Network Speeds**: Typically measured in **bits** (Kb, Mb, Gb), as in **Mbps** (megabits per second) or **Gbps** (gigabits per second).

Conclusion:

- **1 Byte (B) = 8 bits (b)**.
- **1 Kilobyte (KB) ≈ 8 Kilobits (Kb)**.
- **1 Megabyte (MB) ≈ 8 Megabits (Mb)**.
- **1 Gigabyte (GB) ≈ 8 Gigabits (Gb)**.

This relationship shows that file sizes are typically measured in Bytes, while network speeds are measured in bits.

3. Write equivalent of 5ms in seconds, microseconds. Show the conversions clearly.

To convert **5 milliseconds (ms)** into **seconds** and **microseconds**, we use the following conversions:

- **1 second (s) = 1,000 milliseconds (ms)**
- **1 millisecond (ms) = 1,000 microseconds (µs)**

Step 1: Convert 5 milliseconds to seconds

$$5\,\text{ms} = \frac{5}{1,000}\,\text{seconds} = 0.005\,\text{seconds}$$

Step 2: Convert 5 milliseconds to microseconds

$$5\,\text{ms} = 5 \times 1,000\,\text{microseconds} = 5,000\,\text{microseconds}$$

Summary:

- 5 milliseconds (ms) = 0.005 seconds (s)
- 5 milliseconds (ms) = 5,000 microseconds (µs)

4. Let us consider how long it takes to send a file of 640,000 bits from Host A to Host B over a circuit-switched network. Suppose that all links in the network use TDM with 24 slots and have a bit rate of 1.536 Mbps. Also suppose that it takes 500 msec to establish an end-to-end circuit before Host A can begin to transmit the file.
    a. How long does it take to send the file?

To calculate the total time taken to send a file of 640,000 bits from Host A to Host B over a circuit-switched network, we need to consider both the circuit establishment time and the data transmission time.

Step 1: Circuit Establishment Time

It is given that the circuit establishment takes 500 milliseconds (msec). This is the time required before any data can be transmitted.

Step 2: Data Transmission Time

The network uses **Time Division Multiplexing (TDM)** with **24 slots** and a link bit rate of **1.536 Mbps**. This means that each slot gets a portion of the total bit rate, and the data will be sent only during Host A's assigned slot.

Calculate the bit rate per slot:

The total bit rate is 1.536 Mbps (1.536 × 10^6 bits per second), and there are 24 slots. The bit rate available for each slot is:

$$\text{Bit Rate per Slot} = \frac{1.536 \times 10^6 \, \text{bits/sec}}{24} = 64,000 \, \text{bits/sec}$$

Host A can only transmit during its assigned slot, which means its effective bit rate is **64,000 bits/sec**.

Calculate the time to transmit the file:

The file size is **640,000 bits**, and the effective bit rate is **64,000 bits/sec**. The time to transmit the file is:

$$\text{Transmission Time} = \frac{\text{File Size}}{\text{Effective Bit Rate}} = \frac{640,000 \, \text{bits}}{64,000 \, \text{bits/sec}} = 10 \, \text{seconds}$$

Step 3: Total Time

The total time is the sum of the circuit establishment time and the data transmission time:

$$\text{Total Time} = \text{Circuit Establishment Time} + \text{Transmission Time}$$

$$\text{Total Time} = 500 \, \text{msec} + 10 \, \text{seconds} = 0.5 \, \text{seconds} + 10 \, \text{seconds} = 10.5 \, \text{seconds}$$

The total time to send the file from Host A to Host B, including the circuit establishment time and the file transmission time, is **10.5 seconds**.

b. What will the file transmission time be if packet switching is used? Let's assume that the entire file can be sent immediately once packet transmission starts. We can also assume no significant propagation delay or queuing delay in this simplified scenario.

If **packet switching** is used instead of circuit switching, we will need to calculate the transmission time based on how the file is broken into packets and transmitted through the network. In packet switching, there is no need to establish an end-to-end circuit beforehand, so the circuit establishment time of 500 msec is no longer relevant.

Here's how to calculate the transmission time for the file in a packet-switched network:

Info for Packet Switching:

1. The file size is **640,000 bits**.
2. The network bit rate is **1.536 Mbps** (same as before).

Step 1: Calculate the transmission time

The transmission time is the time required to push all the bits of the file through the network link at the available bit rate.

The formula to calculate transmission time is:

$$\text{Transmission Time} = \frac{\text{File Size}}{\text{Bit Rate}}$$

Where:

- File Size = **640,000 bits**
- Bit Rate = **1.536 Mbps = 1.536 × 10^6 bits/sec**

Now, plug in the values:

$$\text{Transmission Time} = \frac{640,000 \text{ bits}}{1.536 \times 10^6 \text{ bits/sec}} = 0.41667 \text{ seconds} \approx 417 \text{ milliseconds}$$

Since packet switching does not require an end-to-end circuit setup, the **total time is just the transmission time**. There is no 500 msec circuit establishment overhead.

If packet switching is used, the file transmission time will be **approximately 417 milliseconds**. This is significantly faster than the 10.5 seconds required in circuit switching due to the lack of a circuit establishment phase and more efficient use of the link's full bit rate.

c. Let's recalculate (b) by taking out the assumptions made. Let's assume that the file is transmitted in packets of 1,500 bytes, including the headers. Let's also assume that propagation delay from Host A to Host B is 5 milliseconds per packet, and processing and queuing delays are negligible.

Step-by-Step Calculation:

Step 1: Calculate the Number of Packets

The file size is 640,000 bits, and each packet is 1,500 bytes, which is 12,000 bits.

$$\text{Number of Packets} = \frac{\text{File Size}}{\text{Packet Size}} = \frac{640,000 \text{ bits}}{12,000 \text{ bits/packet}} = 53.33 \text{ packets}$$

We round this up, so we will need **54 packets**.

Step 2: Transmission Time per Packet

The bit rate of the link is **1.536 Mbps**, or **1.536 × 10^6 bits/sec**. The transmission time for one packet (1,500 bytes or 12,000 bits) is:

$$\text{Transmission Time per Packet} = \frac{\text{Packet Size}}{\text{Bit Rate}} = \frac{12,000\ \text{bits}}{1.536 \times 10^6\ \text{bits/sec}} = 0.00781\ \text{seconds} = 7.81\ \text{milliseconds}$$

Step 3: Total Transmission Time for All Packets

For 54 packets, the total transmission time is:

$$\text{Total Transmission Time} = 54 \times 7.81\ \text{milliseconds} = 421.74\ \text{milliseconds}$$

Step 4: Adding Propagation and Queuing Delays

If we add a propagation delay for each packet and assume a propagation delay of **5 milliseconds** per packet, the total propagation delay for 54 packets is:

$$\text{Total Propagation Delay} = 54 \times 5\ \text{milliseconds} = 270\ \text{milliseconds}$$

Step 5: Total Time

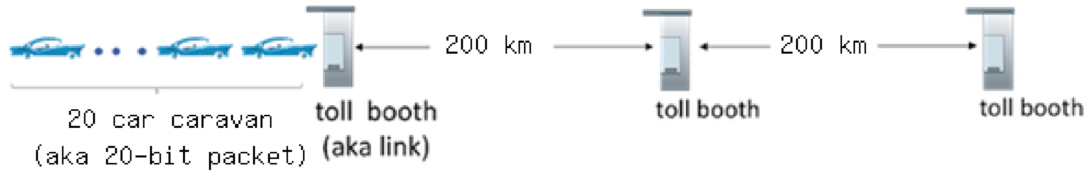
The total time is the sum of the transmission time for all packets and the total propagation delay:

$$\text{Total Time} = \text{Transmission Time} + \text{Propagation Delay} = 421.74\ \text{milliseconds} + 270\ \text{milliseconds} = 691.74\ \text{milliseconds}$$

Considering that the packet size already includes the header, the total time to send the file in a packet-switched network with packetization, transmission, and propagation delays would be approximately **692 milliseconds**.

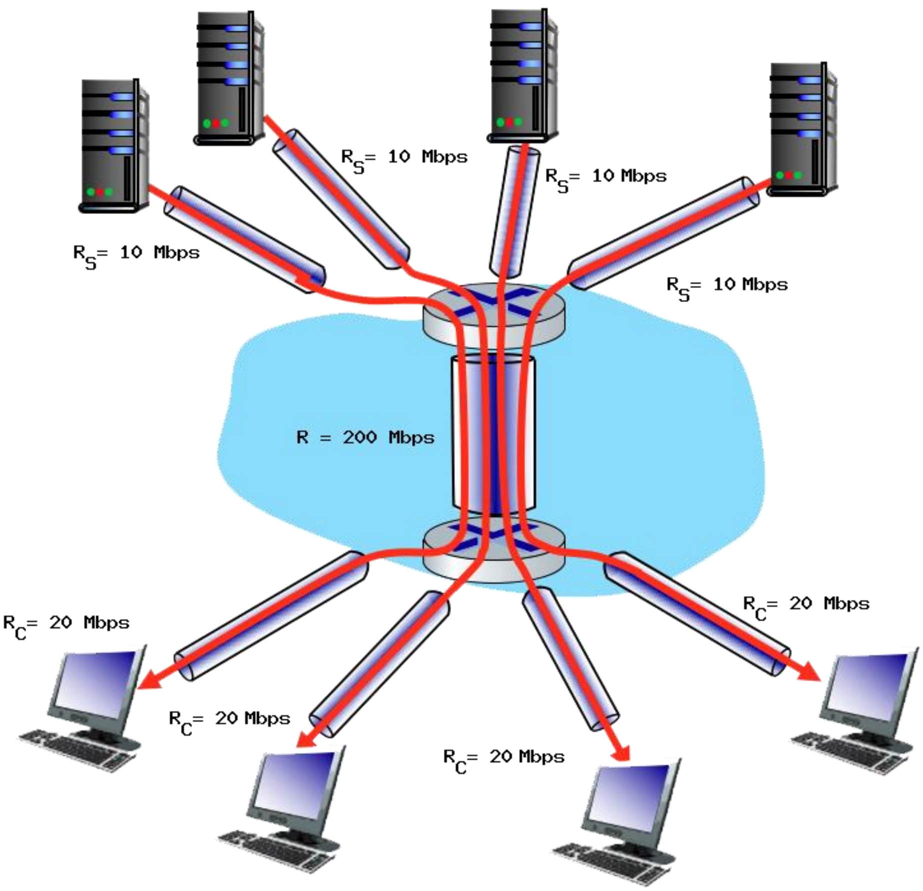
5. DSF Consider the figure below, which draws the analogy between store-and-forward link transmission and propagation of bits in packet along a link, and cars in a caravan being serviced at a toll booth and then driving along a road to the next tollbooth.

   Suppose the caravan has 20 cars, and that the tollbooth services (that is, transmits) a car at a rate of one car per 5 seconds. Once receiving serving a car proceeds to the next tool both, which is 200 kilometres away at a rate of 10 kilometres per second. Also assume that whenever the first car of the caravan arrives at a tollbooth, it must wait at the entrance to the tollbooth until all of the other cars in its caravan have arrived, and lined up behind it before being serviced at the toll booth. (That is, the entire caravan must be stored at the tollbooth before the first car in the caravan can pay its toll and begin driving towards the next tollbooth).



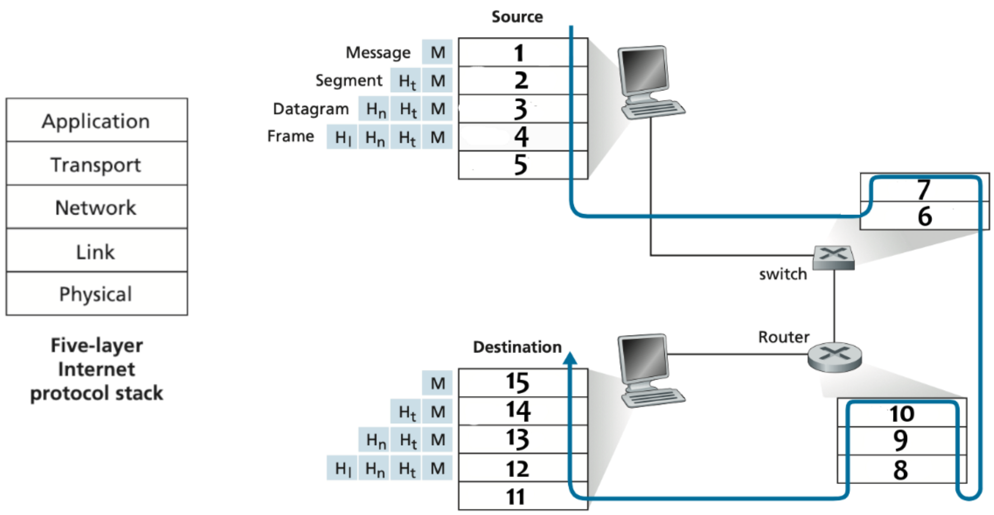
a. Once a car enters service at the tollbooth, how long does it take until it leaves service? Service time is 5 seconds
b. How long does it take for the entire caravan to receive service at the tollbooth (that is the time from when the first car enters service until the last car leaves the tollbooth)? It takes 100 seconds to service every car, (20 cars * 5 seconds per car)
c. Once the first car leaves the tollbooth, how long does it take until it arrives at the next tollbooth? It takes 20 seconds to travel to the next toll booth (200 km / 10 km/s)
d. Once the last car leaves the tollbooth, how long does it take until it arrives at the next tollbooth? Just like in the previous question, it takes 20 seconds, regardless of the car
e. Once the first car leaves the tollbooth, how long does it take until it enters service at the next tollbooth? It takes 115 seconds until the first car gets serviced at the next toll booth (20-1 cars * 5 seconds per car + 200 km / 10 km/s)
f. Are there ever two cars in service at the same time, one at the first toll booth and one at the second toll booth? Answer Yes or No No, because cars can't get service at the next tollbooth until all cars have arrived
g. Are there ever zero cars in service at the same time, i.e., the caravan of cars has finished at the first toll both but not yet arrived at the second tollbooth? Answer Yes or No Yes, one notable example is when the last car in the caravan is serviced but is still travelling to the next toll booth; all other cars have to wait until it arrives, thus no cars are being serviced

6. Consider this scenario, in which a single router is transmitting packets, each of length L bits, over a single link with transmission rate R Mbps to another router at the other end of the link. Suppose that the packet length is L= 16000 bits, and that the link transmission rate along the link to router on the right is R = 10 Mbps.
   a. What is the transmission delay? The transmission delay = L/R = 16000 bits / 10000000 bps = 0.0016 seconds
   b. What is the maximum number of packets per second that can be transmitted by this link? The number of packets that can be transmitted in a second into the link = R / L = 10000000 bps / 16000 bits = 625 packets
7. Consider the scenario where four different servers are connected to four different clients over four three-hop paths. The four pairs share a common middle hop with a transmission capacity of R = 200 Mbps. The four links from the servers to the shared link have a transmission capacity of R_S = 10 Mbps. Each of the four links from the shared middle link to a client has a transmission capacity of R_C = 20 Mbps.



a. What is the maximum achievable end-end throughput (in Mbps) for each of four client-to-server pairs, assuming that the middle link is fairly shared (divides its transmission rate equally)? The maximum achievable end-end throughput is the capacity of the link with the minimum capacity, which is 10 Mbps
b. Which link is the bottleneck link? Format as Rc, Rs, or R. The bottleneck link is the link with the smallest capacity between R_S, R_C, and R/4. The bottleneck link is Rs.
c. Assuming that the servers are sending at the maximum rate possible, what are the link utilizations for the server links (R_S)? Answer as a decimal. The server's utilization = $R_{bottleneck}$ / R_S = 10 / 10 = 1
d. Assuming that the servers are sending at the maximum rate possible, what are the link utilizations for the client links (R_C)? Answer as a decimal. The client's utilization = $R_{bottleneck}$ / R_C = 10 / 20 = 0.5
e. Assuming that the servers are sending at the maximum rate possible, what is the link utilizations for the shared link (R)? Answer as a decimal. The shared link's utilization = $R_{bottleneck}$ / (R / 4) = 10 / (200 / 4) = 0.2

8. In the scenario below, imagine that you're sending an http request to another machine somewhere on the network.



a. What layer in the IP stack best corresponds to the phrase: *'passes frames from one node to another across some medium'*. The given phrase corresponds to the Link Layer
b. What layer in the IP stack best corresponds to the phrase: *'bits live on the wire'*. The given phrase corresponds to the Physical Layer
c. What layer in the IP stack best corresponds to the phrase: *'moves datagrams from the source host to the destination host'*. The given phrase corresponds to the Network Layer.
d. What layer in the IP stack best corresponds to the phrase: 'handles messages from a variety of network applications'. The given phrase corresponds to the Application Layer.
e. What layer in the IP stack best corresponds to the phrase: 'handles the delivery of segments from the application layer, may be reliable or unreliable'. The given phrase corresponds to the Transport Layer.
f. What layer corresponds to box 1? APPLICATION LAYER
g. What layer corresponds to box 2? TRANSPORT LAYER
h. What layer corresponds to box 3? NETWORK LAYER
i. What layer corresponds to box 4? LINK LAYER
j. What layer corresponds to box 5? PHYSICAL LAYER
k. What layer corresponds to box 6? PHYSICAL LAYER
l. What layer corresponds to box 7? LINK LAYER
m. What layer corresponds to box 8? PHYSICAL LAYER
n. What layer corresponds to box 9? LINK LAYER
o. What layer corresponds to box 10? NETWORK LAYER
p. What layer corresponds to box 11? PHYSICAL LAYER
q. What layer corresponds to box 12? LINK LAYER
r. What layer corresponds to box 13? NETWORK LAYER
s. What layer corresponds to box 14? TRANSPORT LAYER
t. What layer corresponds to box 15? APPLICATION LAYER