**Units**

1 byte = 8 bits

1 kilobyte = 1024 bits of storage

By convention, storage and data rate is different: 1kb/s 🡪 1,000bits/s

**Networking Questions and Activities**

**Q1. What is statistical Multiplexing?**

- Statistical multiplexing is a method used in Packet Switching, where communication links are shared by dynamically allocating bandwidth to each channel on an as-need basis.

- This is done by dividing communication channels into data streams, where each stream is divided into packets.

- Pipeline View: Packets get forwarded —> If there are back-to-back packets (Transient Overload), they are placed in a queue —> If the amount of packets exceed the size of the queue buffer, then packets will be lost (Persistent Overload) —> Packets are transmitted.

**Q2.) Sending Packets**

Two hosts separated by M meters. Propagation speed is S meters / sec. A —> B sending packet of size L. They are connected by a single link of rate R b.p.s

(note: propagation speed measures the speed at which a bit moves through a medium.)

(a)

- Propagation Delay: The amount of time for the head of the signal to travel from host A to Host B.

- d\_prop = M (link length) / S m.p.s (propagation speed)

(b)

- Transmission Delay: Time it takes to place the whole packet on the link / wire

- d\_trans = L (size of packet) / R (bps rate)

(c)

- End to End delay: Sending one packet from src to dest over a path with N links at rate R

- N = 1 link, R bps.

- End to End Delay = N \* (transmission delay + propagation delay)

= 1 \* (L/R + M/S)

(d) Host A transmits at t=0. At t=d\_trans, where is the last bit of the packet?

- At d\_trans, the entire packet should be on the link/wire. So the last bit would be on the link/wire, leaving Host A.

(e)

- If d\_prop > d\_trans —> at d\_trans, the first bit on the link would be between host A and B

- Even if entire packet is already on the link/wire, because propagation is longer than transmission, the first bit of the packet would NOT have reached host B / the next node yet.

(f)

- If d\_prop < d\_trans —> at d\_trans, the first bit on the link would be at host B.

- If the entire packet is / has already on the link/wire, because transmission is longer than propagation, the first bit of the packet would have already reached host B

**Q3.) Transmission**

Users share a 1mbps link. Suppose each user requires 100kbps when transmitting, but they only transmit 10% of the time.

(a) Circuit switching is used, how many users can be supported?

- 1mbps = 1000kbps and 100kbps bandwidth per user

- Therefore 1000/100 = 10 users can be supported

(b)

- The probability of a single user transmitting = 10%

(c)  
- 40 users, probability of n users transmitting simultaneously

- 0.940 – n \* 0.1n

**Q4.) Packet Switching**  
src 🡪 switch (transmission speed = R1)  
switch 🡪 dest (transmission speed = R2)

Transmission delay = size of packet L / R

End-to-end delay = R1/L + R2/L

**Q5.) Car-Caravan Analogy**

Propagation speed of 100 km/hr

(a)

In this example, we are looking only at Propagation Delay: d (length

end-to-end =

**Q6.) Sending a large file**

File size F / Sbits = # segments and 40 bits header \* # segments

Packet size L = 40bits header + S bit body

Transmission rate = R bps

What is the value of S that minimises delay of moving the file from A 🡪 B? Disregard propagation.

- Transmission delay = L (size of packet) / R ( bps)

- Therefore d\_trans = (40bits + S) / R

- To minimise delay of moving the file from A🡪B, maximise the use of the transmission rate of R. Therefore, optimal value of S would be: **40 + S = R 🡪 S = R -40**

**Q7.) Sending real-time voice**

64kbps bit stream

48-byte packets

One link between A🡪B, transmission rate is 1 mbps, propagation delay is 2ms

What is the End-to-End Delay? E-E = d\_proc + d\_queue + d\_trans + d\_prop

All bits in the packet must be generated before first bit in a packet is transmitted. The time to gather the first packet:

- Packet size = 48bytes \* 8 bits

- Conversion of each packet = (48 \* 8) bits / 64kbps **= (48 \* 8) bits / 64,000 bits** (change to same units)

- d\_gather first packet = **6ms**

Transmission Delay Per Packet = L / R

- d\_trans = (48 \* 8) bits / 1mbps = (48 \* 8) bits / 1,000kbps = **(48 \* 8) bits / 1,000,000bps**

- d\_trans = 384 / 1 million kbps = **384 microseconds**

End-to-End Delay = d\_proc + d\_queue + d\_trans + d\_prop

= d\_gather + d\_trans + d\_prop

= 6ms + 0.384ms + 2ms

= **8.384ms**

**Q8.) Sending packets over a computer network**

Bad things

**Q9.) Queueing delay in router buffer**

All packets are L bits, transmission rate is Rbps, N packets arrive simultaneously at the buffer every LN/R seconds.

Average queueing delay = **(N-1)L/R**

- The queue is empty when the first N packets arrive, therefore no queueing delay for them.

- The second packet has a queueing delay of L/R.

- The nth packet will have a queuing delay of (n-1)L/R seconds.