UNIVERSITY OF BIRMINGHAM

M.Sc. CS/AI & CS
Computer Systems

Threads & Introduction to Networks [Solutions]

Exercise #1: Suppose that two long-running processes, P1 and P2, are running in a system. Neither program performs any system calls that might cause it to block, and there are no other processes in the system. P1 has 3 threads and P2 has 2 threads. The system may use either kernel or user threads.

a) What percentage of CPU time will P1 get if the threads are kernel threads? Briefly Explain.

b) What percentage of CPU time will P1 get if the threads are user threads? Briefly Explain.

a) If the threads are kernel threads, they are independently scheduled and each of the five threads will get a share of the CPU. Thus, the 3 threads of P1 will get 3/5 of the CPU time. That is, P1 will get 60% of the CPU.

b) If the threads are user threads, the threads of each process map to one kernel thread, so each process will get a share of the CPU. The kernel is unaware that P1 has three threads. Thus, P1 will get 50% of the CPU.

Exercise #2: Suppose there is exactly one packet switch between a sending host and a receiving host. The transmission rates between the sending host and the switch and between the switch and the receiving host are R_1 and R_2, respectively. Assuming that the switch uses store-and-forward packet switching, what is the total end-to-end delay to send a packet of length L? (Ignore queuing, propagation delay, and processing delay).

At time t_0 the sending host begins to transmit. At time $t_1 = L/R_1$, the sending host completes transmission and the entire packet is received at the router (no propagation delay). Because the router has the entire packet at time t_1 , it can begin to transmit the packet to the receiving host at time t_1 . At time $t_2 = t_1 + L/R_2$, the router completes transmission and the entire packet is received at the receiving host (again, no propagation delay). Thus, the end-to-end delay is $L/R_1 + L/R_2$.

Exercise #3: Suppose users share a 2Mbps link. Also suppose each user transmits continuously at 1 Mbps when transmitting, but each user transmits only 20 percent of the time.

a) When circuit-switching is used, how many users can be supported?

2 users can be supported because each user requires half of the link bandwidth.

b) When packet-switching is used, why will there be essentially no queuing delay before the link if two or fewer users transmit at the same time? Why will there be a queuing delay if three users transmit at the same time?

Since each user requires 1Mbps when transmitting, if two or fewer users transmit simultaneously, a maximum of 2Mbps will be required. Since the available bandwidth of the shared link is 2Mbps, there will be no queuing delay before the link. Whereas, if three users transmit simultaneously, the bandwidth required will be 3Mbps which is more than the available bandwidth of the shared link. In this case, there will be queuing delay before the link.

Exercise #4: Consider an application that transmits data at a steady rate (for example, the sender generates an N-bit unit of data every k time units, where k is small and fixed). Also, when such an application starts, it will continue running for a relatively long period of time. Answer the following questions, briefly justifying your answers:

a) Would a packet-switched network or a circuit-switched network be more appropriate for this application? Why?

A circuit-switched network would be well suited to the application, because the application involves long sessions with predictable smooth bandwidth requirements. Since the transmission rate is known and not bursty, bandwidth can be reserved for each application session without significant waste. In addition, the overhead costs of setting up and tearing down connections are amortized over the lengthy duration of a typical application session.

b) Suppose that a packet-switched network is used and the only traffic in this network comes from such applications as described above. Furthermore, assume that the sum of the application data rates is less than the capacities of each and every link. Is some form of congestion control needed? Why?
In the worst case, all the applications simultaneously transmit over one or more network links. However, since each link has sufficient bandwidth to handle the sum of all of the applications' data rates, no congestion (very little queuing) will occur. Given such generous link capacities, the network does not need congestion control mechanisms.

Exercise #5: Suppose Host A wants to send a large file to Host B. The path from Host A to Host B has three links, of rates R_1 = 500 kbps, R_2 = 2 Mbps, and R_3 = 1 Mbps

a) Assuming no other traffic in the network, what is the throughput for the file transfer?
b) Suppose the file is 4 million bytes. Dividing the file size by the throughput, roughly how long will it take to transfer the file to Host B?
c) Repeat (a) and (b), but now with R_2 reduced to 100 kbps.

a) 500 kbps b) 64 seconds c) 100kbps; 320 seconds

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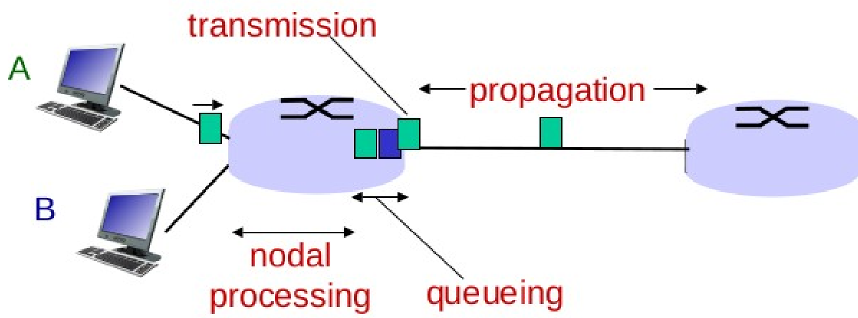
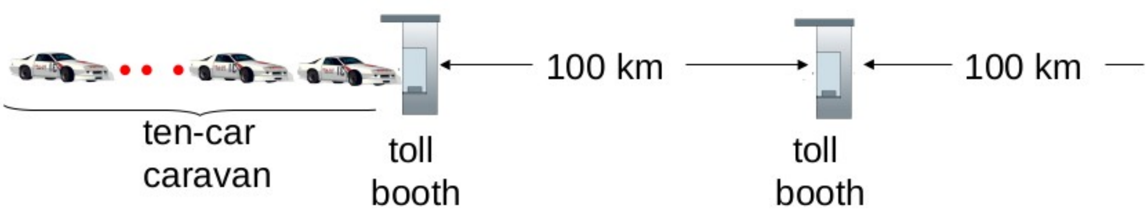
Exercise #6: There are actually four types of delays that can occur in networks:



$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$

1. d_{proc}: nodal processing (check bit errors, determine output link, typically < msec)
2. d_{queue}: queueing delay (time waiting at output link for transmission, depends on congestion level of router)
3. d_{trans}: transmission delay (L: packet length (bits), R: link bandwidth (bps), d_{trans} = L/R)
4. d_{prop}: propagation delay (d: length of physical link, s: propagation speed in medium (~2x10^8 m/sec), d_{prop} = d / s)

Consider the following Caravan Analogy:



The cars "propagate" at 100 km/h, and each toll booth takes 12 secs to service a car (bit transmission time).

a) How long it will take until the caravan is lined up before 2nd toll booth?

Time to "push" entire caravan through toll booth onto highway = 12*10 = 120 sec
Time for last car to propagate from 1st to 2nd toll both: 100km/(100km/hr)= 1 hr
Overall time needed = 62 minutes

b) Suppose cars now "propagate" at 1000 km/hr and suppose toll booth now takes one min to service a car. Will cars arrive to 2nd booth before all cars serviced at first booth?

Yes! after 7 min, 1st car arrives at second booth; three cars still at 1st booth.

c) Assume a propagation speed of 100 km/hour, toll booths are 75 km apart and it takes 12 secs to service a car at each toll booth. Suppose the caravan travels 150 km, beginning in front of one tollbooth, passing through a second tollbooth, and finishing just after a third tollbooth. What is the end-to-end delay?

There are ten cars. It takes 120 seconds, or 2 minutes, for the first tollbooth to service the 10 cars. Each of these cars has a propagation delay of 45 minutes (travel 75 km) before arriving at the second tollbooth. Thus, all the cars are lined up before the second tollbooth after 47 minutes. The whole process repeats itself for traveling between the second and third tollbooths. It also takes 2 minutes for the third tollbooth to service the 10 cars. Thus the total delay is 96 minutes.

Exercise #7: How long does it take a packet of length 1,000 bytes to propagate over a link of distance 2,500 km, propagation speed 2.5 x 10^8 m/s, and transmission rate 2 Mbps? More generally, how long does it take a packet of length L to propagate over a link of distance d, propagation speed s, and transmission rate R bps? Does this delay depend on packet length? Does this delay depend on transmission rate?

10msec; d/s; No; No

Exercise #8: In this problem, we consider sending real-time voice from Host A to Host B over a packet-switched network (VoIP). Host A converts analog voice to a digital 64 kbps bit stream on the fly. Host A then groups the bits into 56-byte packets. There is one link between Hosts A and B; its transmission rate is 2 Mbps and its propagation delay is 10 msec. As soon as Host A gathers a packet, it sends it to Host B. As soon as Host B receives an entire packet, it converts the packet's bits to an analog signal. How much time elapses from the time a bit is created (from the original analog signal at Host A) until the bit is decoded (as part of the analog signal at Host B)?

Consider the first bit in a packet. Before this bit can be transmitted, all of the bits in the packet must be generated. This requires

$\frac{56 \cdot 8}{64 \times 10^3}$sec=7msec.

The time required to transmit the packet is

$\frac{56 \cdot 8}{2 \times 10^6}$sec=224 μsec.

Propagation delay = 10 msec.

The delay until decoding is

7msec +224 μsec + 10msec = 17.224msec

A similar analysis shows that all bits experience a delay of 17.224 msec.