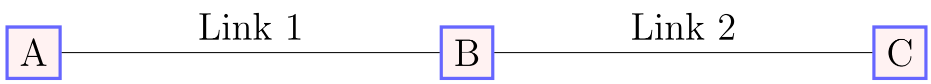
Intelligent Systems Engineering Department
The National School of Artificial Intelligence
3rd Year, Semester 1 — 2023/2024

NETWORKS AND PROTOCOLS

Exercise Sheet 1

Exercise 1

Consider the diagram below. Link 1 has length L_1 m (where m stands for meters) and allows packets to be propagated at speed S_1 (mps) , while Link 2 has length L_2 m but it only allows packets to be propagated at speed S_2 (mps) (because two links are made of different materials). Link 1 has transmission rate T_1 (bps) and Link 2 has transmission rate T_2 (bps).



Assuming nodes can send and receive bits at full rate and ignoring processing delay, consider the following scenarios:

(a) How long would it take to send a packet of 500 Bytes from Node A to Node B given $T_1 = 10000$, $L_1 = 100000$, and $S_1 = 2.5 \cdot 10^8$?

(b) Compute RTT (round trip time) for a packet of B Bytes sent from Node A to Node C (packet gets transmitted back from Node C immediately after Node C receives it).

(c) At time 0, Node A sends packet P_1 with D_1 Bytes and then it sends another packet P_2 with D_2 Bytes immediately after it pushes all bits of P_1 onto Link 1. When will Node C receive the last bit of P_2?

Exercise 2

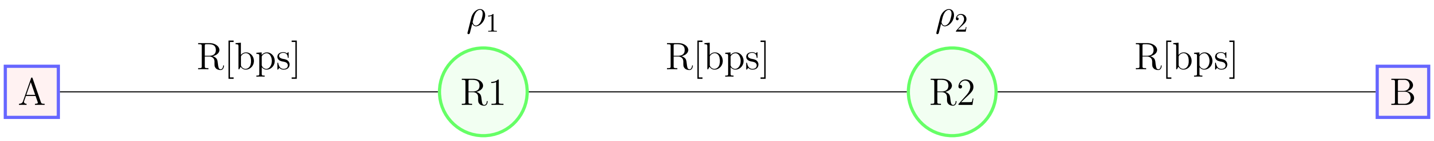
Consider a single link with bandwidth B and propagation delay L. It takes 1 ms for an entire 500 bytes packet to arrive at the other end of the link (that is, it takes 1 ms from the time the first bit starts being transmitted until the last bit arrives at the other end of the link). It takes 2 ms for an entire 1500 bytes packet to arrive at the other end of the link.

(a) What is the bandwidth B of the link? (in Mbps)

(b) What is the propagation delay L of the link? (in ms)

Exercise 3

Let us consider a simple packet-switching system as shown in the figure below. The path from sender A to receiver B passes through two intermediate routers. Each router has an input queue of size 1 [Mbit]. The three links support the same data rate R=10 [kbps].



(a) Assume the utilization of the first router (R1) is $\rho_1 = 0.2$, the utilization of the second router is $\rho_2 = 0.3$, and sender A generates and sends one packet of size 10 [kbit] every 3 seconds. What is the rate at which packets arrive at receiver B?

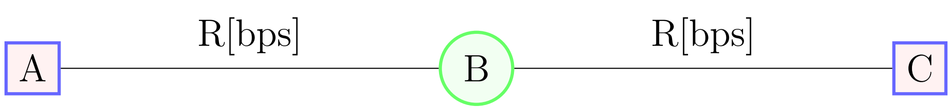
(b) The assumptions remain the same as in (a); except, sender A generates and sends only 3 packets in total. What is the overall time required to deliver these three packets to receiver B? (Propagation delay can be ignored on all three links.)

(c) The assumptions are the same as in (a); except, the utilization of the second router (R2) changes to $\rho_2 = 1.2$. What is the rate at which packets arrive at receiver B in this case?

(d) The assumptions remain the same as in (c). What are the maximum size to which queues in routers R1 and R2 grow? (Answer for each queue individually.)

Exercise 4

Suppose we would like to transfer a file of K bits from node A to node C using packet switching (see Figure below). The path from node A to node C passes through two links and one intermediate node, B, which is a store-and-forward device. The two links are of rate R [bps]. The packets contain P bits of data (P<K) and a 6-byte header. What value of P minimizes the time it takes to transfer the file from A to C? (You can assume: propagation delay on each link = 0, and K/P gives an integer number.)



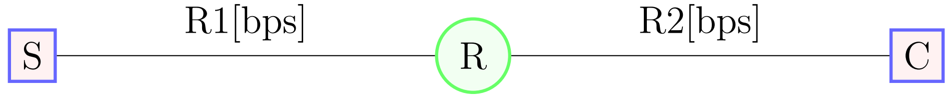
Exercise 5

Assume there is one router and two links between the file server (S) and client (C), as shown in the figure below. The first link has transmission rate R1 and the second link has transmission rate R2. Assume the file gets broken into three packets, each of size L. Ignore all propagation and processing delays. Answer the following three questions:

(a) How long does it take from when the server starts sending the file until the client has received the whole file if R1 $\leq$ R2?

(b) How long does it take from when the server starts sending the file until the client has received the whole file if R1 > R2?

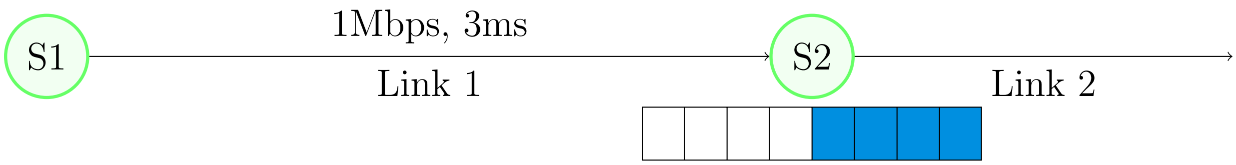
(c) In case (b), how long does the second packet spend in the router's queue?



Exercise 6

Consider two serially connected packet switches as shown in the figure below. The link connecting the two switches (Link 1) is full-duplex, with data rate of 1 Mbps and propagation delay of 3 ms (in each direction). The packets sent through the network are 1000 bits long. The input buffer/queue of Switch 2 can store at most 100 packets.

To control congestion and avoid packet loss, the switches employ the so-called 'back pressure' mechanism. According to this mechanism, whenever Switch 2 detects congestion on its outgoing link (i.e., no more packets can be sent over Link 2), Switch 2 sends a signal back to Switch 1 instructing Switch 1 to halt further packet transmission over Link 1. In this question, you are asked to determine how big Switch 2 should let its buffer grow (in case of congestion on Link 2), before sending a back pressure signal to Switch 1. Your answer should be in the units of 'packets'.



Additional assumptions:

- There is an unlimited number of packets at Switch 1; therefore, when active, Switch 1 sends packet continuously, back-to-back.
- Once detected, the congestion on Link 2 could be alleviated at any point in time. Hence, the back pressure signal should not be sent too early (unless there is a real risk of Switch 2 running out of buffer space), nor too late (no packet should ever be lost/dropped).

Exercise 7

Unlike store-and-forward, cut-through switching or forwarding allows a node inside a network to start forwarding a packet before it has been received in its entirety. Consider a path in a network that connects a host A to a host B via n links (1..n) through n-1 intermediate routers, each employing cut-through forwarding.

Ignore processing delay and assume that there is no queuing delay. Assume that all links have the same length d and that the speed of light in the link medium is s. Also, assume that each link has bandwidth R and that packets of length L bits are sent through the network. Each switch can start forwarding the packet after Lc bits have been received.

(a) What is the total latency for a single packet (counted from first bit sent at A until last bit received at B)?

(b) How much did cut-through switching reduce the latency for sending a single packet end-to-end, compared to store-and-forward?

(c) Now suppose a message of F bits is sent, which is sent as multiple packets. Will the latency savings increase, decrease, or stay the same as in the case of a single packet? Justify your answer.