1 Wireless

1. Consider five wireless stations: A, B, C, D, and E. Station A can communicate with all other stations. B can communicate with A, C and E. C can communicate with A, B and D. D can communicate with A, C and E. E can communicate with A, D and B.

(a) When A is sending to B, what other communications are possible?

**Solution:** Since all stations see A’s packets, it will interfere with receipt of any other packet by any other station. So, no other communication is possible in this case.

(b) When B is sending to A, what other communications are possible?

**Solution:** Although B’s packets are not be seen by D, other nodes cannot send to D because the packets from these nodes will interfere with the packets from B at A. Therefore, no other communication is possible at the same time.

(c) When B is sending to C, what other communications are possible?

**Solution:** B’s packets are be seen by E, A and C, but not by D. Thus, E can send to D at the same time.

2. The topology in Figure 1 consists of 6 wireless nodes, A through F, illustrated by the corresponding dots. The circle around each node illustrates its transmission range. For example, A’s transmission area is shown by the shaded circle. The transmissions of two nodes interfere if and only if they transmit at the same time and their transmission areas overlap.

(a) For the transmission from A to B, list the potential hidden terminals from A and the exposed terminals.
Solution: C, F are hidden terminals and E is an exposed terminal.

(b) Assume you are using an RTS/CTS protocol to reduce the hidden/exposed terminal problems.
   i. Explain what prevents a hidden terminal from interfering with a sender.

   Solution: Although the hidden terminal does not see the RTS of the sender, it sees the CTS of the receiver and infers that it should not transmit at the same time.

   ii. Explain how a terminal infers that it is exposed and can thus send to another destination.

   Solution: It sees the RTS of the sender, but not the CTS of the receiver. Thus, it knows it can send.

   iii. An exposed terminal in an RTS/CTS protocol may still be unsuccessful in sending. Explain how this is possible.

   Solution: Another simultaneous transmission may interfere with the receipt of a CTS or ACK.

2 Spanning Tree Algorithm

1. Consider the network shown in Figure 2, where the letters A to J represent LANs and the circles B1 to B7 represent switches.
   (a) Indicate which ports are not selected by the spanning tree algorithm.

   Solution: The spanning tree algorithm works as follows:

   1. Elect the bridge with the lowest ID as the root bridge (B1 in this case).
2. For each bridge, the port with the shortest path to the root becomes the root port (RP).

3. For each network segment, determine which bridge has the shortest path from this network segment to the root. The port connecting that bridge to the network segment is then the designated port (DP) for the segment.

4. Any port that is not a RP or a DP is a blocked port (BP).

The ports which are not selected by the spanning tree algorithm are shown as red dotted lines in Figure 3.

(b) Assume that switch B1 suffers catastrophic failure. Indicate which ports are not selected by the spanning tree algorithm after the recovery process when a new tree has been formed.

**Solution:** See blocked ports (BP) in Figure 4.

2. Consider hosts A, C, E and switches S1 to S6 with empty forwarding tables initially, connected as Figure 5 shows. The address of Sx is 00:00:00:00:00:0x.

(a) Which links are removed after the completion of the spanning tree? Mark the removed link(s) directly on Figure 5 Use the lowest switch address to break ties.
(b) Fill in the forwarding table at each switch after each transmission. Assume that each transmission starts after the previous has finished and the forwarding tables have been updated. In the forwarding table at each node, identify the port by the unique LAN segment (e.g., La, Lc) reachable using that port or the label of the link (e.g., \ell_{12}, \ell_{23}) that is connected to that port. In each cell, write only the forwarding information that gets updated and not the whole forwarding table.

3 Data transmission

1. How much bandwidth is needed to send computer screen images through an optical fiber? Assume the screen is 1920x1080 pixels, and each pixel carries 24 bits. The framerate is 60 images per second.
2. A direct Swiss flight between Zürich and New York takes 8h54m. You get on this flight, and take with you a 4 terabyte hard drive. Assume 4 terabytes is 32 terabits \((3.2 \cdot 10^{13} \text{ bits})\). Once you land in New York:

(a) What was the data transmission rate (in Gigabits/s)?

Solution: \((3.2 \cdot 10^{13} \text{ bits})/(3.204 \cdot 10^4 \text{ s}) \approx 1 \text{ Gbps.}\)

(b) What was the propagation delay?

Solution: \(3.204 \cdot 10^4 \text{ s}\)

(c) How long would it take to transfer the same amount of data on a typical home fiber connection (assume a data transfer rate of 100 megabits/s)?

Solution: \((3.2 \cdot 10^{13} \text{ bits})/(10^8 \text{ bit/s}) = 3.2 \cdot 10^5 \text{ s} = 3.7 \text{ days}\)

(d) Since the flight time is constant for any amount of data (1 byte or 100 terabytes), up to how much data does it make sense to transfer over the fiber connection?
Solution: The most data you can send in 32 000 seconds is 3.2 terabits, or 0.4 terabytes, or 400 gigabytes. More data than this would take longer than 8h54min, so you get a better transmission rate by flying.

3. Suppose a 100 Mbps point-to-point link is being set up between Earth and a new lunar colony. The distance from the moon to Earth is 385,000 km and data travels over the link at the speed of light \(3 \cdot 10^8 \text{ m/s}\)

(a) Calculate the minimum delay for the link.

Solution: Time for the data to travel from Earth to Moon:

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\frac{385,000 \text{ km}}{3 \cdot 10^8 \text{ m/s}} = 1.28333 \text{ s}
\]

(b) Calculate the bandwidth-delay product for the link.

Solution: \(1.28333 \text{ s} \times 100 \text{ Mbps} \approx 128 \text{ Mbit} = 16 \text{ MB}\)

(c) A camera on the lunar base takes pictures of Earth and saves them in digital format to disk. Suppose Mission Control on Earth wishes to download the most current image (25 MB). What is the minimum amount of time that will elapse between when the request for the data goes out and the transfer is finished?

Solution: The request will take 1.28333 seconds to reach the moon. The time to put the picture on the link is \(\frac{25 \text{ MB}}{100 \text{ Mbps}} = 2 \text{ s}\). It will take another 1.28333 seconds to return to Earth. So the total time is \(2 \times 1.28333 + 2 = 4.56666\) seconds.