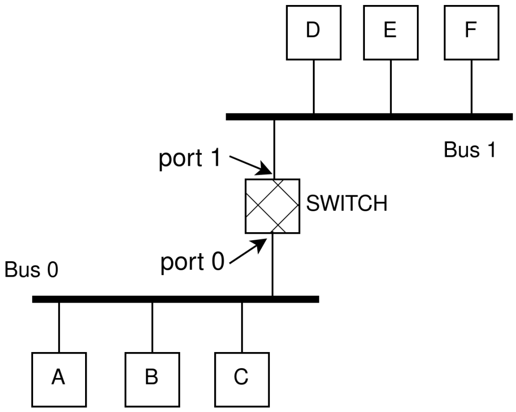
CS224M, Mid-Semester Exam

Duration: 2 hours; Max. Marks: 60

1. (10 marks) An Ethernet Switch connects two different Ethernet segments (each segment is a bus with nodes connected to it) as shown in the figure below. The switch has two ports: port 0 and port 1, as shown. At time t=0 seconds, the switch has an empty forwarding table. Suppose the forwarding table has columns (i) MAC address, (ii) Port number, (iii) Expiry time (expiry time is in absolute value in seconds, i.e. if the expiry time value is T, then that entry is slated to be removed at t=T seconds). Suppose every forwarding table entry has an expiry time of 15 seconds after it is created (**or renewed**) in the table. "Renewed" here means that if there is already an entry corresponding to a node in the table, and the switch hears another frame with that node as source at time "t", then the switch extends the expiry of that entry to "t+15" seconds. Let the MAC addresses of A,B,C etc. be represented by MAC(A), MAC(B), MAC(C) etc.

The following frames are transmitted by Ethernet nodes (other than the Switch). The time at which the frames are transmitted, and their source and destination MAC addresses are given below. Assume that no other frames are transmitted by the nodes A,B,C,D,E, F.



a) t=0 seconds; SRC MAC = MAC(A); DEST MAC=MAC(D)
b) t=10 seconds; SRC MAC = MAC(B); DEST MAC=MAC(D)
c) t=12 seconds; SRC MAC = MAC(D); DEST MAC=MAC(E)
d) t=18 seconds; SRC MAC = MAC(C); DEST MAC=MAC(D)
e) t=20 seconds; SRC MAC = MAC(B); DEST MAC=MAC(A)

Give the **contents of the <u>full forwarding table</u>** at the switch immediately **AFTER EACH** of the above frames are heard by the Switch, **and** state if the frame is forwarded by the Switch, **and if so**, onto which port. Explain why it forwards or does not forward the frame.

a)

MAC Addr	Port	Expiry
MAC(A)	0	15

Frame is forwarded to port 1 since table has no entry for MAC(D)

b) Frame is forwarded to port 1 since table has no entry for MAC(D)

MAC Add	Port	Expiry
MAC(A)	0	15
MAC(B)	0	25

c) Frame is forwarded to port 0, since table has no entry for MAC(E)

MAC Addr	Port	Expiry
MAC(A)	0	15
MAC(B)	0	25
MAC(D)	1	27

d) Frame is forwarded to port 1, since there is an entry in the table for MAC(D) corresponding to port 1

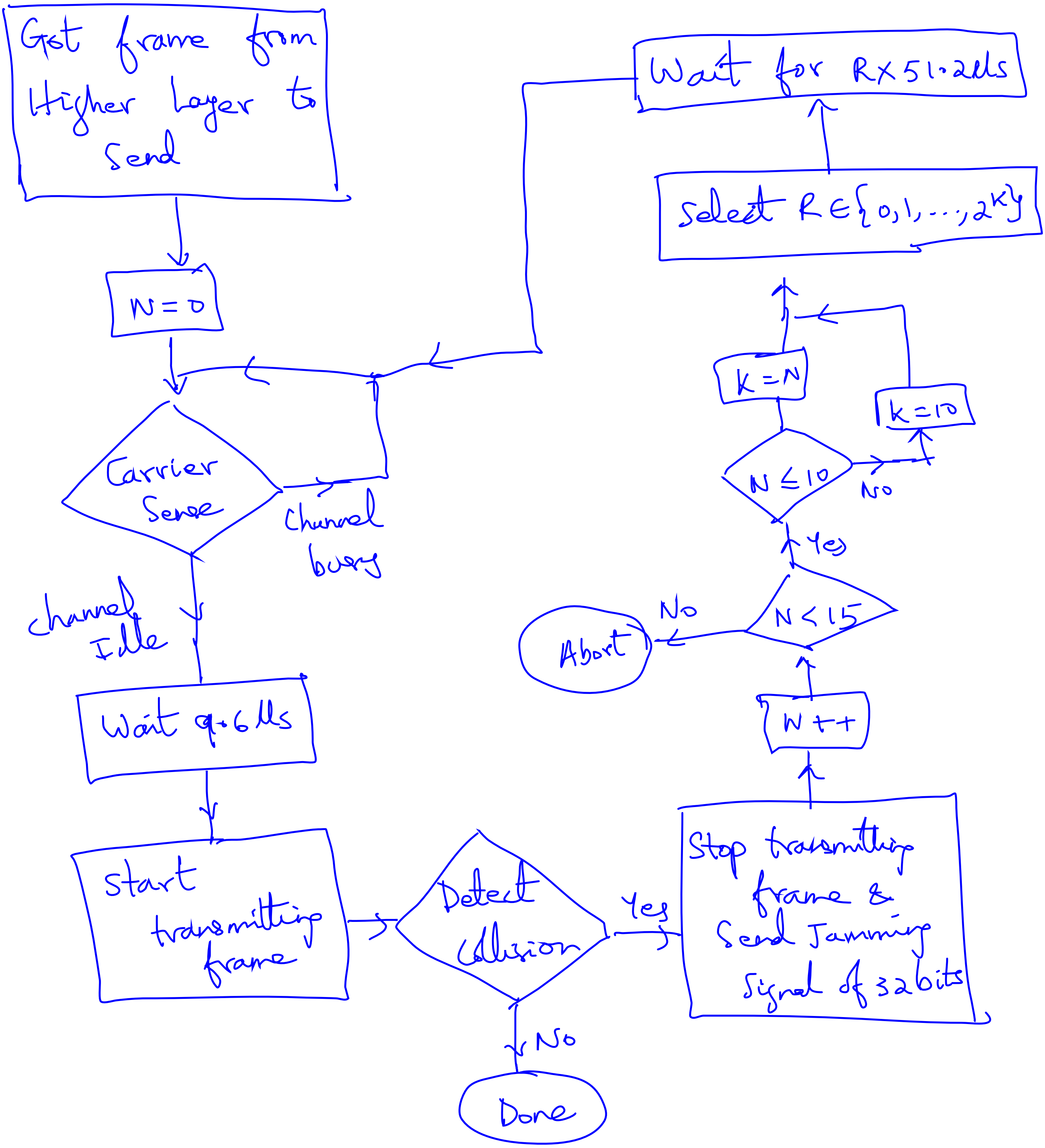
MAC Addr	Port	Expiry
MAC(B)	0	25
MAC (D)	1	27
MAC (C)	0	33

e) Frame is forwarded to port 1, as there is no entry for MAC(A) in table

MAC Addr	Port	Expiry
MAC(B)	0	35
MAC (D)	1	27
MAC(C)	0	33

2. (9 marks) Answer the following about Ethernet.

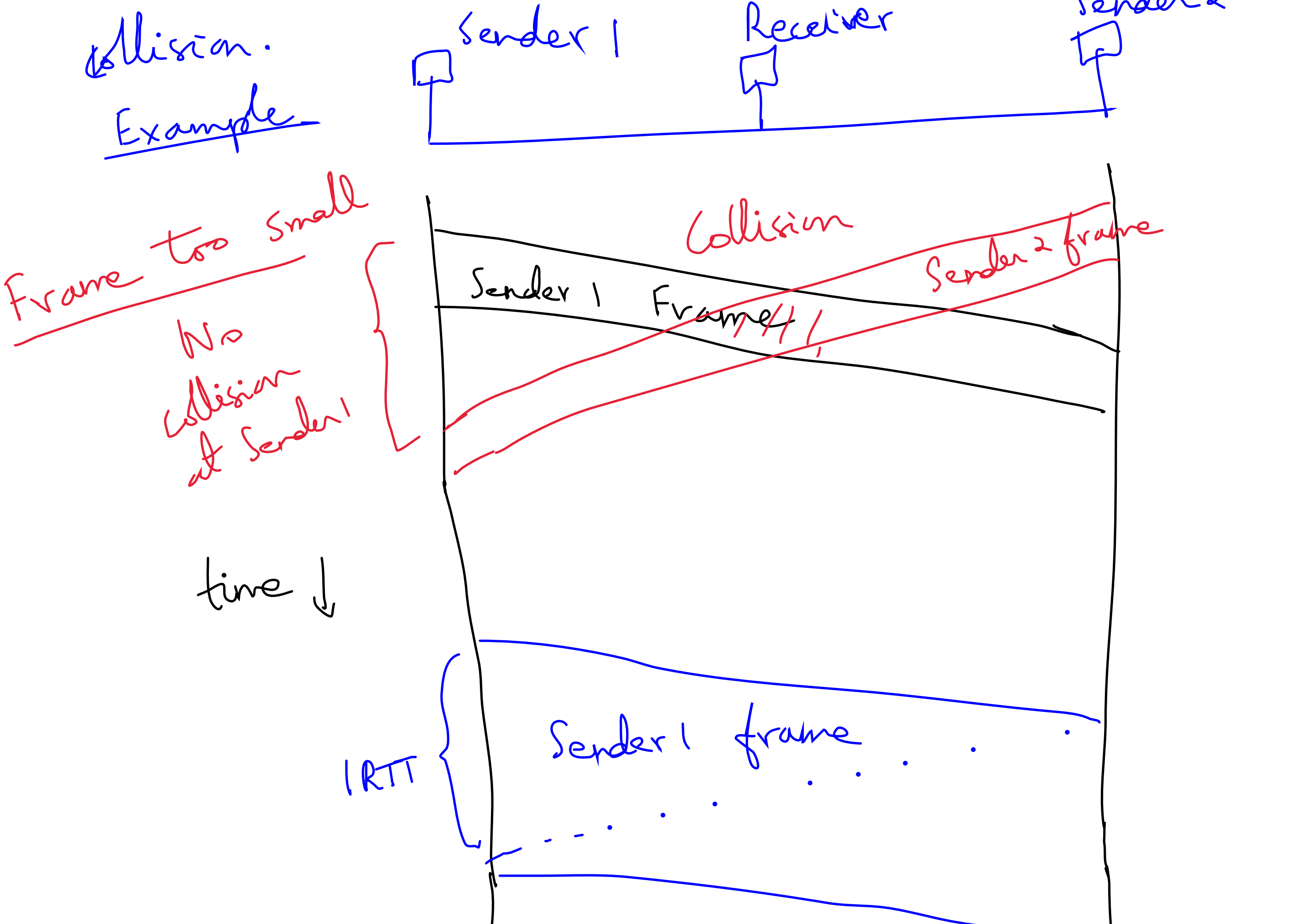
a) (6 marks) Draw the flow chart of the CSMA-CD protocol that an Ethernet node follows. You must include carrier sensing, exponential backoff, retransmissions etc. in this flow chart.



b) (3 marks) Explain why the IEEE 802.3 standard has a requirement for a minimum frame size of 64 bytes (i.e. 512 bits). You may use a diagram in your explanation.

In 802.3, a sender must detect collision while transmitting its frame. In case a frame is too small, it is possible that the sender does not experience a collision while transmitting, even though the receiver experiences collision.

Example



If frame duration is at least 1RTT in duration, then no matter where the receiver is located, the sender always detects collision while transmitting, if the receiver experiences collision.

Min. frame size = 10 Mbps × 51.2 μs = 512 bits

bit rate

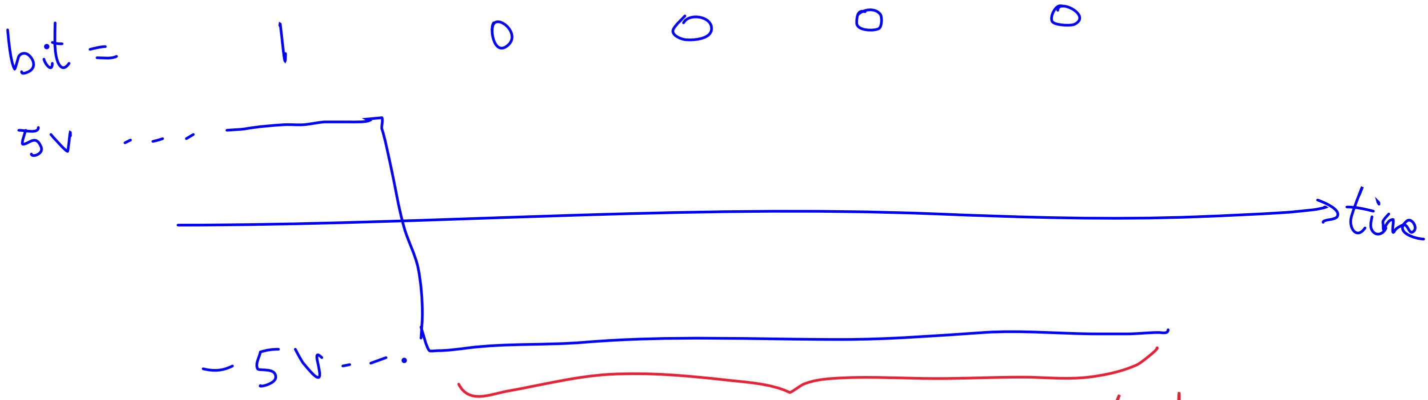
WORST CASE RTT

3. (9 marks) State whether the following are True or False. **Explain** briefly why.

a) (3 marks) With NRZ line coding, there may be scenarios where it is difficult for the receiver to recover the clock signal of the sender.

TRUE.

With NRZ, if the same bit is transmitted consecutively many times then there are no signal transitions, and so it is hard to recover the sender's clock at the receiver.

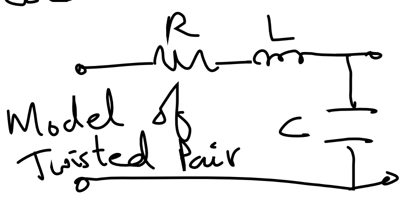


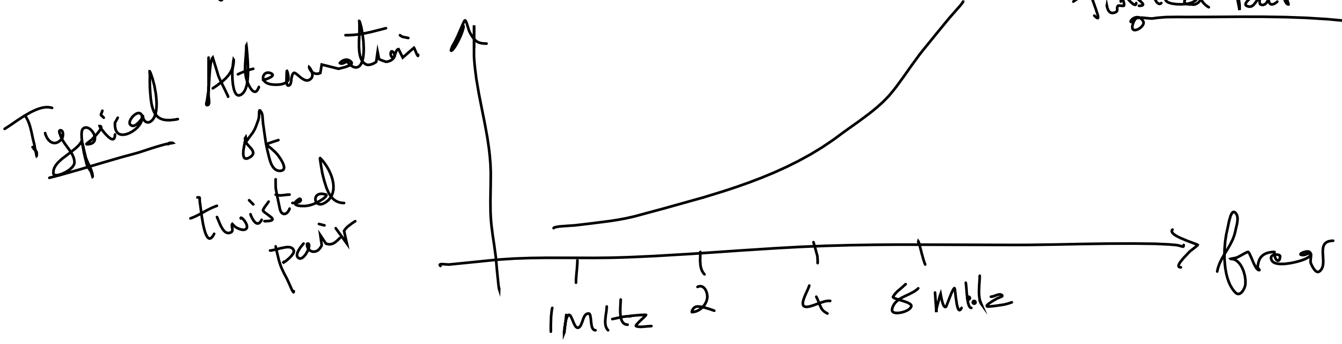
receiver does not know where the sender's clock transitions during this time

b) (3 marks) For a twisted pair wire the attenuation is constant with frequency of the input signal.

FALSE.

A twisted pair can be modeled as an R-L-C circuit. The L-C components are frequency dependent. Hence attenuation is also frequency dependent.

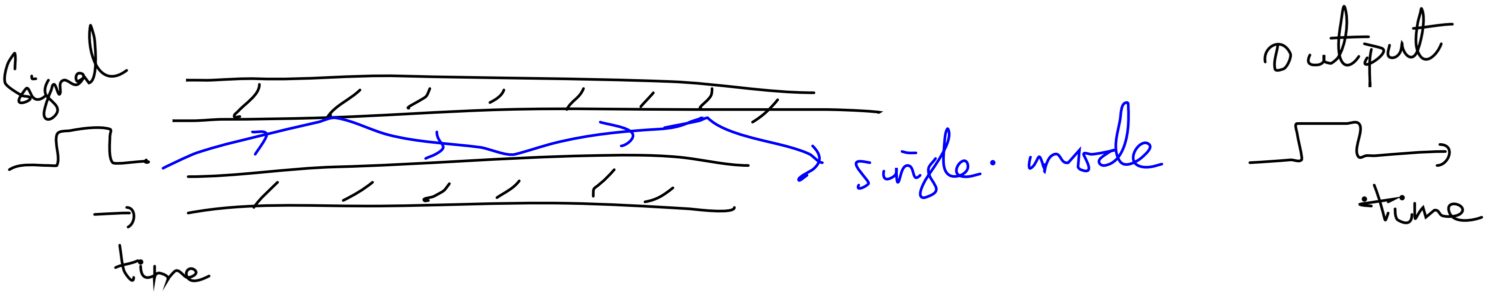


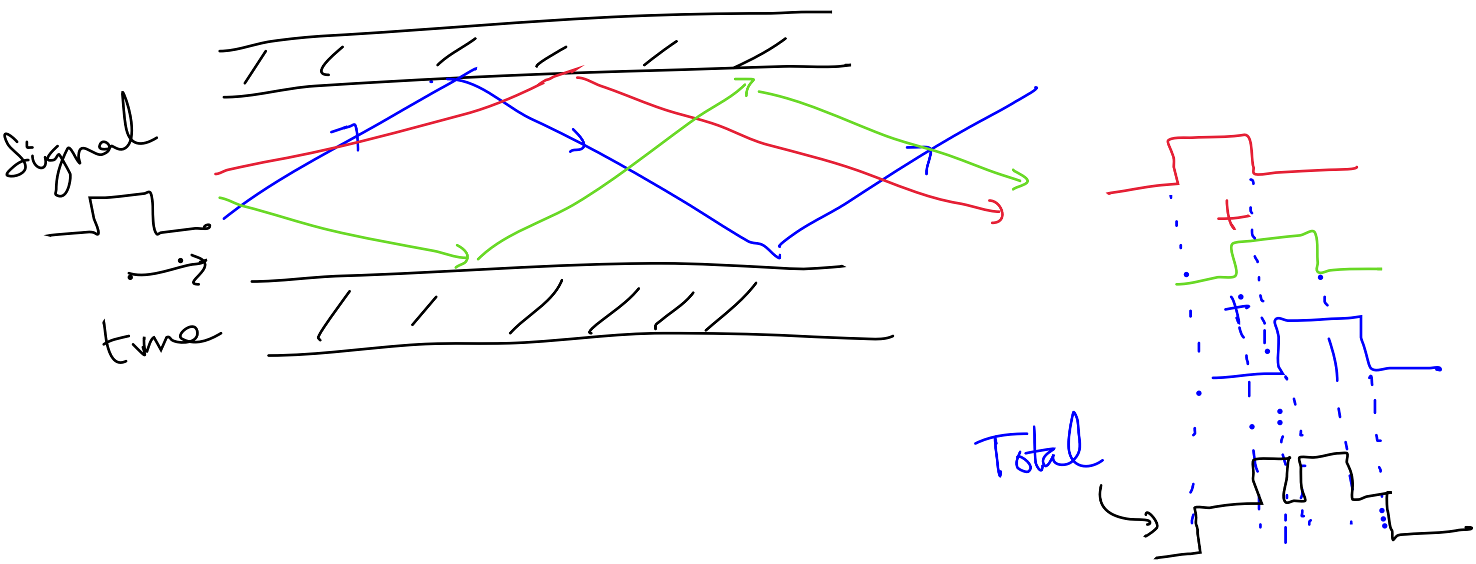


c) (3 marks) Single mode optic fibre causes less signal distortion than multi-mode fibers.

TRUE

In multi-mode, many "modes" of different lengths pass through the fibre, thus causing more distortion than a single-mode fibre which allows only a single mode to pass through.





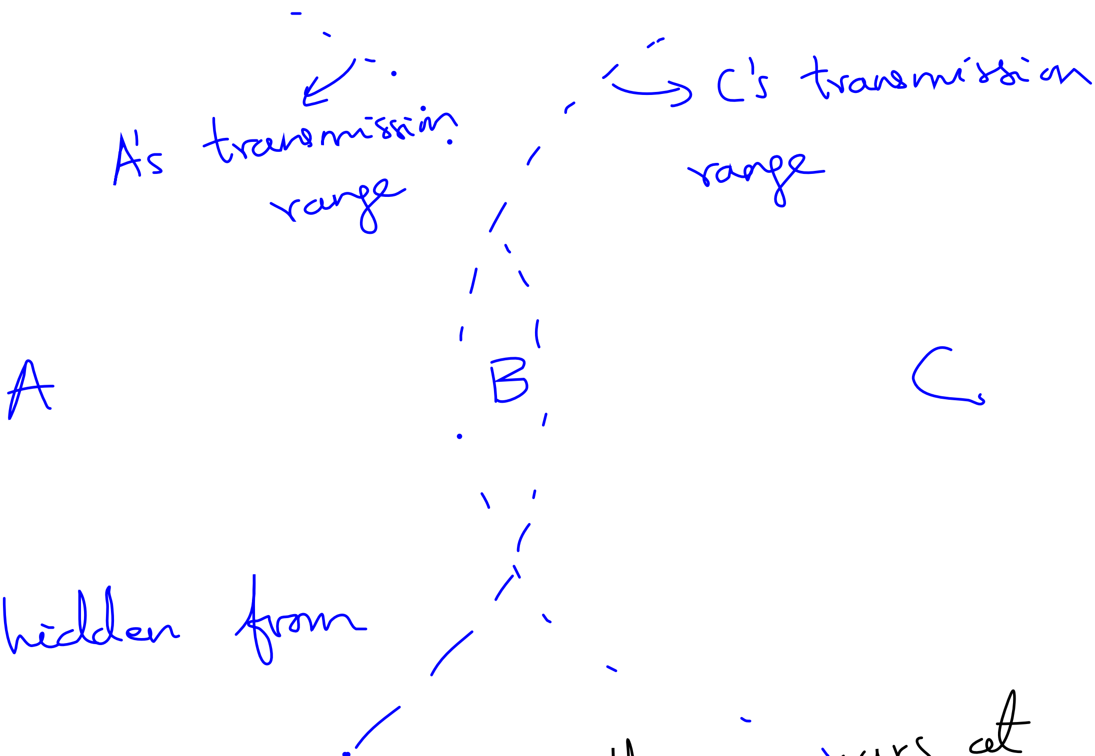
4. (10 marks) Explain the following in the context of WiFi.

a) (6 marks) What is the Hidden Terminal problem? Explain using a simple topology consisting of 3 nodes. State clearly which nodes are hidden from each other. For this part of the question (i.e. part (a)) assume that RTS/CTS are disabled.

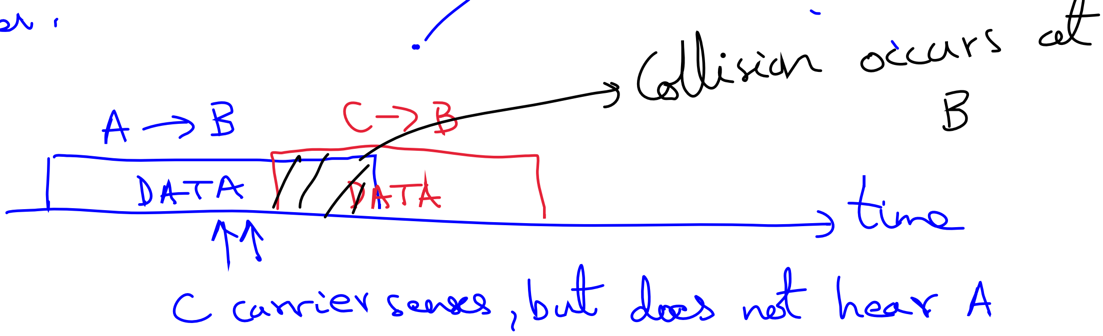
Two WiFi nodes which are too far from each other such that they cannot sense the carrier of each other are said to be "hidden" from each other.

The hidden terminal problem occurs when one node is transmitting to another, and a third node hidden from the sender starts transmitting, causing a collision at the receiver.

Example



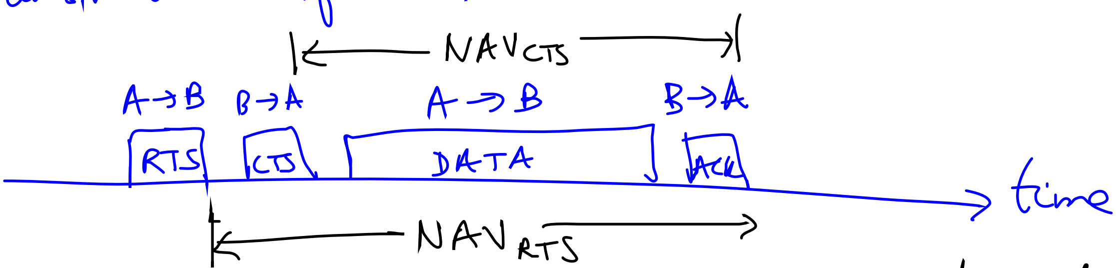
A & C are hidden from each other.



b) (4 marks) How does the WiFi MAC protocol address the Hidden Terminal problem using RTS and CTS frames? You must state clearly what information the RTS and CTS contain and the rule to be followed by any node (other than those nodes sending the RTS or CTS) on hearing an RTS or CTS.

In the above example, if C transmits at any time during DATA from A→B, there will be a collision. Since a DATA frame is large, the chances of this happening are high.

The solution of 802.11 is to send frames of short duration called RTS (by A) & CTS (by B) which are less likely to collide with a frame from C, and together they reserve the channel for the entire duration of DATA transmission from A→B.



RTS contains an NAV that specifies the time duration from after RTS till ACK completes

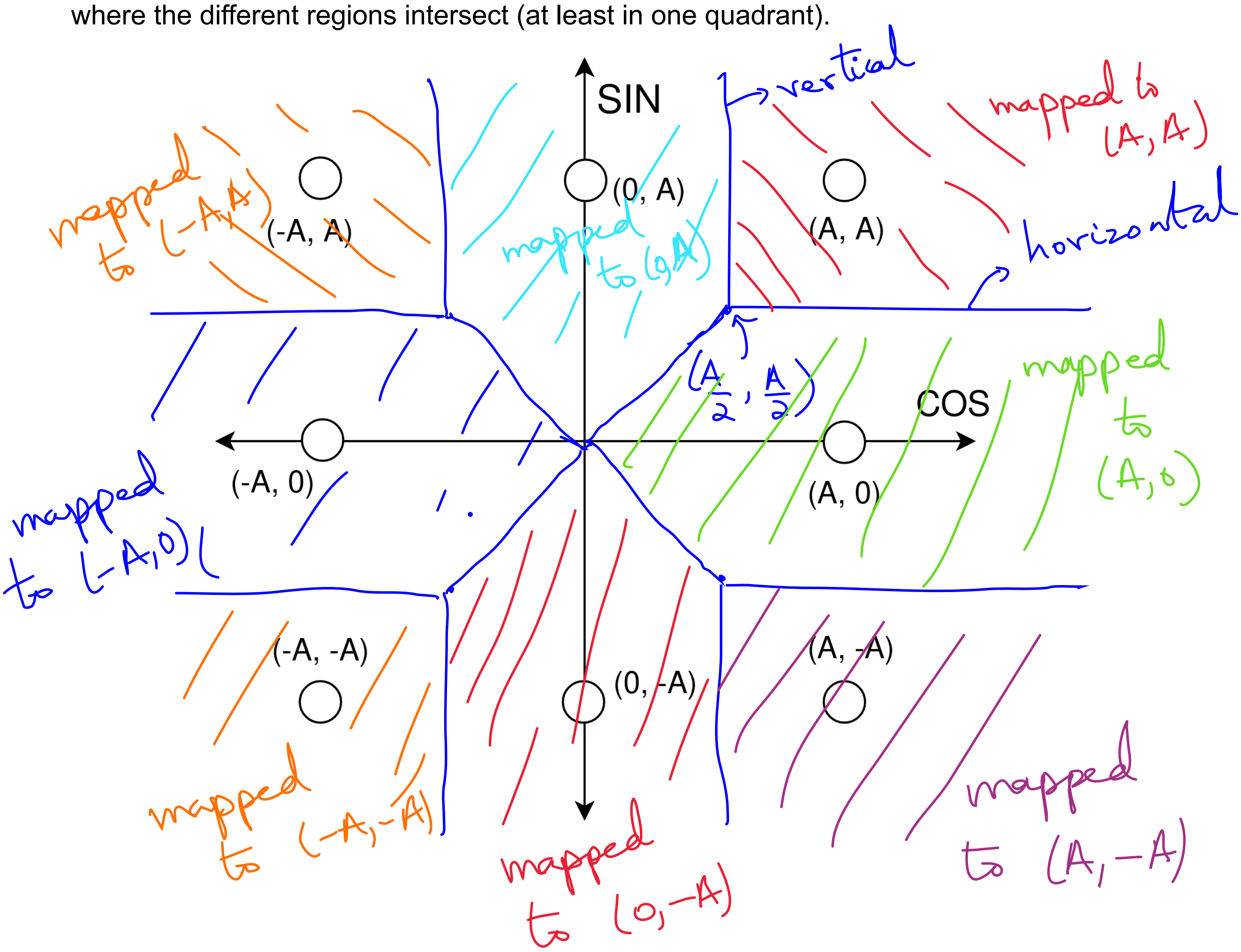
CTS contains an NAV specifying time from after CTS till ACK completes

Rule: All nodes hearing an RTS or CTS (except the nodes creating the RTS & CTS) must remain silent for the duration specified in the NAV.

Since C hears the CTS from B, it does not transmit during the DATA transmission from A→B.

5. (9 marks) The following figure shows an 8-QAM constellation diagram (with in-phase (Cos) and quadrature phase (Sin) on the X and Y axes respectively). The coordinates of each constellation point have been shown in the diagram. Ignore signal attenuation and assume that any transmitted constellation point is corrupted by additive white Gaussian noise at the receiver. Assume that all constellation points are equally likely to be transmitted.

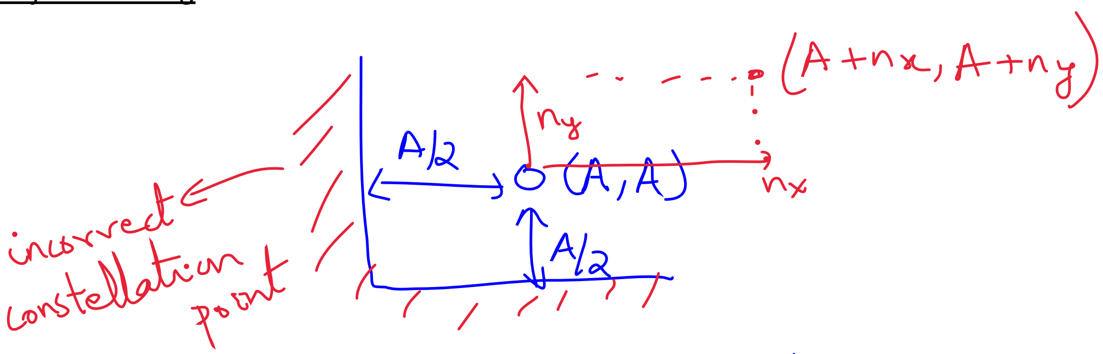
a) (4 marks) In a diagram, show the regions in the constellation diagram which are to be mapped to each of the 8 constellation points at the receiver. **Mention the coordinates** of important points where the different regions intersect (at least in one quadrant).



b) (5 marks) Suppose that the transmitted symbol is *(A,A)*. (In this question we are only interested in the case when this particular symbol is transmitted). Then the received constellation point is $r = (A + n_x, A + n_y)$, where n_x and n_y are i.i.d. Gaussian random variables with zero mean and variance $N_0/2$, where N_0 is the noise energy per symbol. Note that half the noise energy is in the X-axis direction and the other half in the Y-axis direction, which is why variance is $N_0/2$ in each direction. What is the probability that the receiver **correctly identifies** the transmitted constellation point as *(A,A)*? Write your answer in terms of the *Q(.)* function defined as

$$Q(z) = \frac{1}{\sqrt{2\pi}} \int_z^{\infty} exp(-x^2/2)\, dx$$

Show your working.



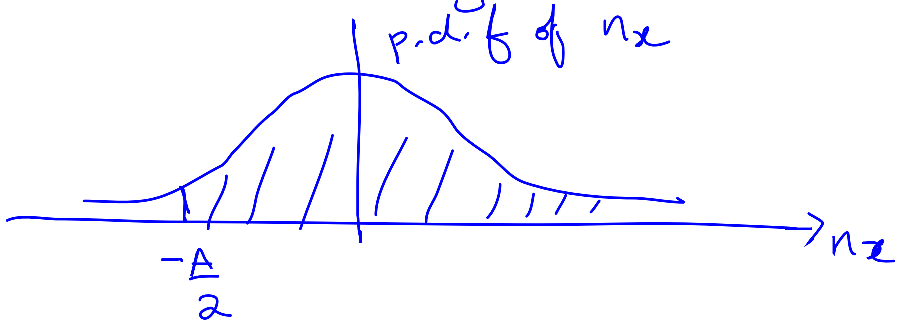
(A,A) is correctly detected if $n_x > -\frac{A}{2}$

and $n_y > -\frac{A}{2}$

Given n_x and n_y have distribution $\mathcal{N}(0, \frac{N_0}{2})$
and are independent Gaussian variance

$\left[\text{Prob}\left(n_x > -\frac{A}{2}\right)\right.$ is what we want
$\left.\times \Pr\left(n_y > -\frac{A}{2}\right)\right]$

$$= \left[\Pr\left(n_x > -\frac{A}{2}\right)\right]^2$$



$$\Pr\left[n_x > -\frac{A}{2}\right] = 1 - \Pr\left[n_x < -\frac{A}{2}\right]$$

$$= 1 - \Pr\left[n_x > \frac{A}{2}\right]$$

due to symmetry of Gaussian distrib.

Let $g = \dfrac{n_x}{\sqrt{N_0/2}}$. Then g is $\mathcal{N}(0,1)$

variance is 1

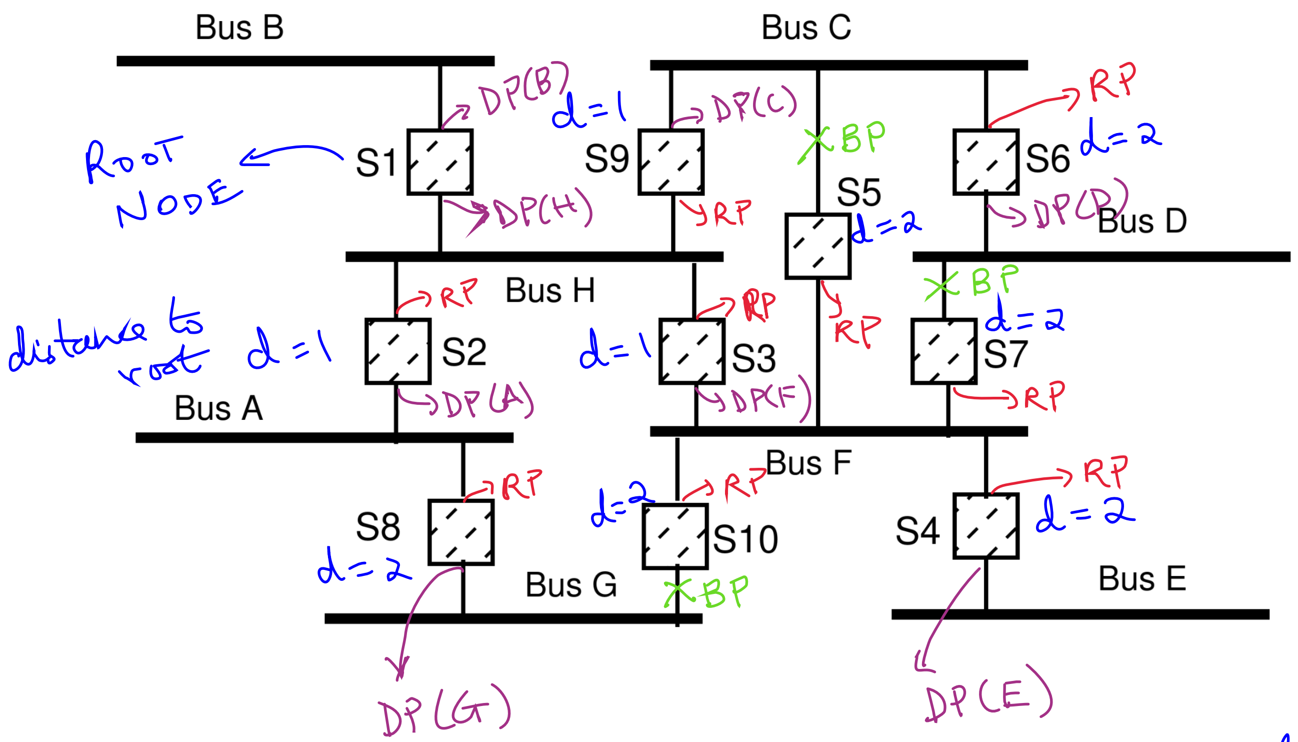
$$\Pr\left[n_x > \frac{A}{2}\right] = \Pr\left[g > \frac{A/2}{\sqrt{N_0/2}}\right]$$

$$= Q\left[\frac{A}{\sqrt{2N_0}}\right]$$

Hence prob. of correctly inferring (A, A) is $\left(1 - Q\left[\dfrac{A}{\sqrt{2N_0}}\right]\right)^2$

6. (13 marks) The following diagram shows several Ethernet Buses (Bus-A, Bus-B , etc.) connected by switches S1, S2, etc. Assume that the ID of S1 is smaller than that of S2, the ID of S2 is smaller than that of S3, and so on, with S10 having the largest ID. Suppose the switches finish running the spanning tree protocol discussed in class. Machines (other than the Switches) that are connected to various buses are not shown so as to make the figure less cluttered.

a) (1 marks) Indicate on a diagram which Switch is the root node and explain (in a few sentences) why.
b) (5 marks) Indicate which ports of each switch are root ports and briefly explain why.
c) (4 marks) Indicate which ports are Designated ports of each Bus and briefly explain why.
d) (3 marks) Indicate which ports are Blocked ports and briefly explain why.



a) S1 has smallest ID so it becomes the root

b) The distance of all switches to the root are shown

For most switches there is a unique closest port to the root which is marked RP.

S_5 has both ports equidistant to the root and so chooses the port connected to S_3

which has smaller ID than S_9.

c) The designated ports of most buses are the ports of uniquely closest switches, on that bus, to the root.

Bus G has two switches S8 and S10 equidistant to the root, so the port of S_8 (on Bus G) becomes its DP.

Similarly the port of S_6 on Bus-D becomes its DP, since S_6 has smaller ID than S_7 and both are equidistant from the root.

d) S_5, S_7 and S_{10} have one port each that are not RP or DP. These are hence blocked.