ELC 2080
Spring 2025
Network Communication Simulation Project

1 Objectives

Apply knowledge learned in the embedded programming part of the course and get hands on experience on RTOS concepts such as:

1- Tasks
2- Timers
3- Queues
4- Semaphores

2 Rules

1- Maximum two students per group.

2- Submission is via google classroom. Submission via any other means is rejected immediately.

3- Submit one file called main.c based on project template supplied for you by Eng. Hassan to work on.

4- Submit documentation in MS-WORD .docx format. Any other format including .doc and .PDF will be automatically rejected.

5- Documentation is to be submitted **using the provided .docx template** and should not exceed 5 pages. Other templates or longer reports will be penalized.

6- Name your report as Student1ID_Student2ID.docx where Student1ID and Studetn2ID are the IDs of the student according to the class list on the faculty web site. If only a single student is submitting then file name shall be Student1ID.docx.

   Use underscore _ not dash -

7- Copy your main.c and .docx into same folder say c:\temp

8- Go inside the folder created above and create a zip file containing the two files choose the option of using relative path name (not full path name). Adding full path name will need manual handling of the files and waste our time and thus you will be penalized.

   Relative path name is the default but you must make sure it is the case in your setup.

9- Name the zip file Student1ID_Student2ID.zip and submit it via the assignment created in google classroom.

10- Not following these instructions may cause huge penalty and might result (as in step 8) in your files be totally missing in the evaluation. So be careful.

11- Copying other groups code or document will result in all students in the two groups getting -10 grade.

Do not try to test this. If you copy, we will find that out and you will get a -10 grade.

12- Submission after deadline is penalized at -10% and keep increasing. Only 3 days after deadline is allowed.

3 Project Specifications

The project is implemented using FreeRTOS on the target emulation board provided via Eclipse CDT Embedded.

Part 1

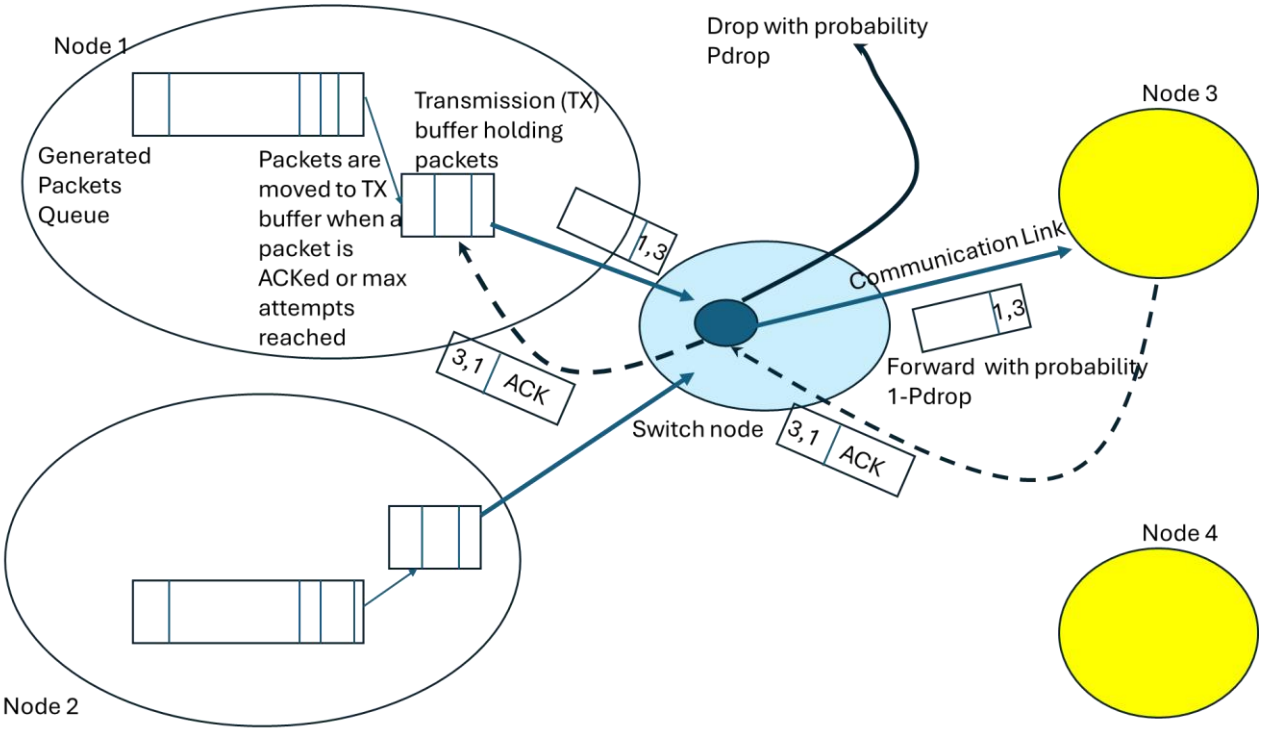

Fig. 1: System Model

i) Two senders (nodes 1 and 2) communicate with two receivers (nodes 3 and 4) over a lossy communication link. A sender generates a packet containing the data it wants to send to one of the receivers. A packet is described as follows:

1) It is a data structure comprised of a header containing control information and payload containing the data to be transmitted.
2) The header size H is constant.
3) The packets are of length L bytes and L is randomly distributed according to a uniform distribution [L1,L2]. The average packet length Lavg is equal to (L1+L2)/2 bytes.
4) Each packet has a sequence number starting from 0 and increments with each generated packet. The sequence number is large enough (32-bits).

A sender selects one of the receivers randomly and inserts information in the packet header indicating the following:

1) The sender
2) The destination
3) Packet Length L in bytes
4) Packet sequence number

The header size H should be carefully designed to carry the above information.

ii) Packets are generated according to a random process. The time between two packets generated is uniformly distributed and selected between [T1,T2] msec.

iii) The packets pass via the switch node and communication link which behaves as follows:

1) Drops packet with random probability P_drop selected from the set {P1, P2, P3, P4}. Acknowledgements (see below) are dropped with fixed probability P_ack. The values are provided in Part III.

2) The packet is subject to two types of delay:
    a. Propagation delay which is constat and equal to D
    b. Transmission delay which equal to (L*8)/C where C is the link capacity in bits/sec and L is packet length in bytes
3) The switch checks the packet to know its destination. It then forwards the packet to the proper receiver.

iv) Since the sender must make sure the data it sends is properly received by the receiver, it implements a data protection scheme. Each packet transmitted is placed in a transmission buffer and protected by a timer with period Tout. When the receiver receives a packet from a sender, it identifies the sending node from the packet header and sends an Acknowledgement packet (ACK) to the sender. The ACK is a packet of fixed length K bytes and thus may also be dropped by the link and is also subject to delay as described in bullet iii. The ACK must contain the following:

1) The node sending the ACK (the source)
2) The source node that sent the packet it is ACKing (the destination for the ACK)
3) The sequence number of the packet it is ACKing

v) If the ACK is received by the sender, then it removes the packet from its transmission buffer and proceeds with the transmission of the next packet. If no ACK is received, the packet timer will expire, and the sender will re-transmit the packet. The sender will try this 4 times, otherwise it will remove the packet from the transmission buffer and proceed with the next packet waiting in the generated packet queue.

The above-described protocol is known as the "Send and Wait" (S&W) protocol.

vi) Run the system till 2000 packets are received by the receiver. Evaluate the system performance by calculating the throughput in bytes/sec. The throughput is the properly received packets at the receiver over the whole period needed to receive 2000 packets. If a packet is received more than once due to retransmissions, it is only counted once in the throughput calculations. Plot the systems throughput:

1) as a function of Pdrop for different values of timeout period Tout
2) as a function of Tout for different values of Pdrop

Also, answer the following questions:

1) What is the average number of transmissions of a packet as function of Pdrop
2) How many packets were dropped due to being transmitted more than 4 times.

vii) Packets are dynamically allocated using malloc or new at creation time and deallocated (using free/delete) when either dropped by the switch, the sender, the receiver (when received out-of-sequence see part 3), or received properly by the receiver.

If you are able to understand till now, congratulations you are on track to become a brilliant communications/network/embedded engineer!

You start with the above model, once it is perfected proceed to Part 2. Part 1 counts towards 70% of the grade.

Parameter values are provided in Part 3

Part 2

i) The S&W protocol is known to result in the communication link becoming idle for long periods. A variation called Go-Back-N has much better performance. Here each packet is given a sequence 0,1,2,3, …. A sender can send a group of packets back-to-back upto a maximum of N packets. The receiver must receive packets in sequence. If it receives packet i but not i-1, packet i is dropped. It also sends ACKS for each received packet. An ACK for packet i implicitly acknowledges all previous packets i-1, i-2, ….. since the receiver will not process packet i unless it receives all previous packets.

ii) Similar to S&W, each packet is protected by a timer. So, when the timer associated with packet j expires, the sender will transmit packet j and all other packets waiting in its transmit buffer upto packet j+N-1 (note the sender can send upto N packets back-to-back).

Note that S&W protocol is a special case of Go-Back-N with N=1

iii) You need to find the throughput as functions of N where N is selected from the set {2,4,8,16} while varying Pdrop and Tout as in part 1.

Part 3: Parameters

[L1,L2]: [500,1500] bytes
[T1,T2]: [0.1,0.2] seconds
K: 40 bytes
C: 100 kbits/sec (100,000 bits/sec)
P_drop: {0.01, 0.02, 0.04, 0.08}
P_ack: 0.01
Tout: selected from the set {150, 175, 200, 225} msec
D: 5 msec

Documentation
The documentation needs to use the attached template and should contain the sections:

- System Design section: illustrating the overall flow of the program and how RTOS tasks model the senders, switch/communication link, and receivers. You can explain the logic of your program and can copy parts of the code as needed.
- Results section: The graphs requested and their interpretation (the insights from the results).
- References (if you used any)