# DATA LINK PROTOCOLS

1) Two stations communicate using a data link protocol based on the Go- Back- N ARQ. The channel capacity (in each direction ) is 2048 kbit /s , the distance between stations is 300 km, the propagation delay in the medium is 5 μs/km and the frames have a typical size of 256 octets . Assume that no errors occur and that the data frames are immediately confirmed by a supervisory frame (RR).
   a) Consider the particular case where N = 1 (Stop and Wait ) . Calculate the maximum efficiency of the protocol and the corresponding maximum bitrate (bit/s).
   b) Determine the minimum size of the transmission window that theoretically allows for a maximum utilization of the channel of 100%; in these conditions , what is the minimum number of bits needed to number the frames?
   c) Assume that the frames are numbered module 8 . For maximum window possible for this case, indicate the maximum number of consecutive Supervision frames that could be lost and still achieve a maximum usage of the channel of 100% .
   d) In the same conditions of the previous point, consider that an information frame is received in error (and discarded) and, subsequently, is sent one REJ frame. Indicate the number of frames that would be required to retransmit under these conditions . You can present the solution using a timing diagram , properly commented .

***Solution : See the lecture notes***

2) Two stations communicate using a data link connection based on Go- Back- N ARQ. Admit that Information frames are transmitted in only one direction (Supervision frames in the opposite direction). The channel capacity ( in each direction ) is 256 kbit /s , the propagation delay between stations (one-way ) is 270 ms (satellite transmission ) and the Information frames have a typical size of 2048 bits. In the calculations disregard the size of the Supervisison frames.
   a) Calculate the maximum bitrate of information ( bit/s) on the link , assuming that only 3 bits are used to number the Information frames. Calculate the minimum size of the transmission window that would allow full utilization of the channel and indicate how many bits would be needed in this case to number the frames.
      *Sol. Rmax = 26.2 kbit /s; Wmin = 69, k = 7 bits*
   b) Explain that in this case would be recommended to use the variant Selective Reject . In this case , assuming that 7 bits were used to number the frames of Information , calculate the maximum possible birate on the link in the absence of errors .
      *Sol. Rmax = 239 kbit /s*

3) We intend to examine the various alternatives of a data link protocol (Stop and Wait, Go- Back- N and Selective Reject) in the following cases :
   • Case A - channel capacity ( in each direction ) : 128 kbit/s ; distance between stations : 75 km
   • Case B - channel capacity ( in each direction ) : 640 kbit/s ; distance between stations : 750 km
   • Case C - channel capacity ( in each direction ) : 1920 kbit/s ; distance between stations : 2500 km
   The propagation delay in the medium is 5 μs/km . Consider that only Info frames are sent (with size 960 bits ) in one direction and Supervision frames in the opposite direction and neglect the size of the Supervision frames.
   a) Discuss , justifying , if it would be acceptable to use the option Stop and Wait in some of the cases .
      *Sol. Just in case A; S = 91%*
   b) Discuss in cases B and C which of the alternatives Go- Back- N and Selective Reject is advisable. Determine in each case , the minimum recommended size of window and the number of bits required to number the frames .
      *Sol. With errors, SR errors is more efficient ( SSR / SGBN = 1 +2ape ) but GBN is simpler . Case B : GBN ; Case C: SR*
      *Case B : GBN , Wmin = 6 , M = 8 , k = 3bit*
      *Case C: SR , Wmin = 51 , M = 128 , k = 7bit*

4) Two stations communicate using a protocol data link ARQ. The propagation delay between stations is 9 ms and the channel capacity is 10 Mbit / s ( in each direction) . Assume that the frames of information use 7 bits for numbering , have a typical size of 2000 bits and are instantly confirmed by frames of Supervision in the opposite direction . Neglect the size of the frames of Supervision.

a) Calculate the maximum efficiency of the protocol , considering the Stop- and-Wait , Go- Back- N and Selective Reject variants and calculate the corresponding maximum bitrates ( bit / s ) .
*Sol. SW : Smax = 1.1% , Rmax = 110 kbit / s ; GBN : Smax = 100 % , Rmax = 10 Mbit / s ; SR : Smax = 70.3 % , Rmax = 7.0 Mbit / s*

b) Calculate , for each of the variants, which would the limit of maximum bitrate, considering an arbitrarily high capacity for the channel. Interpret the results, taking into account the differences in the values previously calculated .
*Sol. SW : Rmax = 110 kbit / s ; GBN : Rmax = 14.0 Mbit / s , Rmax = 7.0 Mbit / s*

c) Calculate the maximum efficiency of the variants of Go- Back- N and Selective Reject , considering that the probability of a frame being received in error is 1 % . Repeat the calculations assuming frames with length 3000 bits , with a probability of error of 1.5 % . What conclusions can you draw regarding the influence of the size of the frames and the probability of error in the efficiency of these two variants of the protocol?
Sol. pe = 1 % - GBN : Smax = 52.1 % , SR : Smax = 69.6 %
pe = 1.5 % , L = 3000 bit - GBN : Smax = 51.8 % , SR : Smax = 98.5 %

## QUEUES

5) An output port of a router is served by a channel with capacity 256 kbit / s, with an expected average traffic intensity of 75%. Assume that the behavior of the port can be modeled by an M/M/1 queue and packets have an average size of 4000 bits.

a) Calculate the average delay of packets for that traffic intensity that. Discuss the influence of the size of the packets in the delay, assuming that the traffic intensity is the same - consider for example that the average packet size was, respectively, twice and half of the indicated.

b) Assume that the output port is configured with 24 buffers. Calculate the probability of packet loss for the indicated traffic and for an average traffic of 256 and 320 kbit / s, respectively. What is the impact of the packet size on these probabilities and the sizing of the buffers?

*Solution: See the lecture notes*

6) Two remote LANs communicate via a dedicated full-duplex link established between two routers. The link capacity is 512 kbit / s (in each direction). We would like to analyze the behavior of a router for an average traffic of 384 kbit / s submitted for transmission on the link, with the average packet size of 256 octets. Consider the behavior of the router can be modeled by a M/M/1 queue.

a) Calculate the traffic intensity on the link (utilization ratio), the average occupancy of the queue (in packets) and the mean packet delay (indicating the components of waiting and service).
Sol. $\rho$ = 0.75, Nw = 2.25, T = 16ms

b) Assume that the router is configured with 32 transmit buffers. Calculate the probability of packet loss for the indicated traffic (384 kbit / s) and for an average traffic of 512 kbit / s.
Sol. 384 kbit / s: $P_B = 25 * 10^{-6}$; 512 kbit / s: $P_B = 0.03$

7) An output port of a packet switch is served by a link with capacity 512 kbit / s . Assume that on average are transferred to that port 50 packets / s , with the average packet size 1024 octets . Consider the behavior of the port can be modeled by a M/M/1 queue .

a) Verify by calculating the traffic intensity on the link , the queue has a stable behavior. Calculate the average occupancy of queue and average delay and waiting packets .
*Sol. $\rho$ = 0.8 ( $\rho$ < 1 ) ; Nw = 3.2, T = 80 ms , Tw = 64 ms*

b) Assume that the output port is configured with 24 buffers . Calculate the probability of packet loss for the indicated traffic ( 50 packets / s ) and an average traffic of 75 packets / s . Calculate the

maximum number of packets that can be transmitted in a burst submitted at a constant rate and equal to 75 packets / s without causing any losses ( assume that the buffer is empty at the start of burst) ?
Sol. 50 pac / s : PB = 0.095 % ; 75 pac / s : PB = 16.7 % ;
burst = 144 packets

c) Assume that you want to redesign the system for a double of the traffic indicated ( 100 packets / s), maintaining the same nominal usage ratio. Consider two alternatives :
• establish a single link and double the initial capacity (1024 kbit / s ) ;
• establish a second link to the same initial capacity ( 512 kbit / s ) , distributing traffic across two channels with equal probability.
Which of the two solutions would be preferred from the point of view of the average packet delay? Justify qualitatively and quantitatively . What would be the impact on the average delay of packets if the volume of traffic (in bit / s ) remained , but the average size of the packets were half of the indicated ( 512 octets ) ?
*Sol. 1st case : T = 40 ms ; 2nd case : T = 80 ms, the first solution is preferable*
*L = 512 octets - average delay becomes half of the initial*

8) Through an output port of a packet switch is routed traffic received on 15 input ports. It is expected that each input stream contributes an average bitrate of 96 kbit/s . It is intended to dimension the channel capacity of the output port for an average use ( traffic intensity) of 75 % . Assume that the packets have an average size of 960 bits and that we can model the channel access by a M/M/1 queue .

a) Calculate the channel capacity (kbit /s) , the average delay packets, and the average occupancy of the queue.
*Sol. C = 1920 kbit/s , T = 2 ms ; Nw = 2.25*

b) Discuss how will vary the average delay of packets in the following two cases :
• Duplication of traffic on ports ( 192 kbit / s ) and doubling the capacity of the channel.
• Same traffic at input ports ( 96 kbit / s ) and half-length packets ( 480 bits) .
From the results, what conclusions can you extract. Characterize the sharing of resources in this scenario?
*Sol. 1st case : T = 1 ms ; 2nd case : T = 1 ms*

c) Dimension the number of buffers associated with the output port for a loss probability of less than 0.1 % of packets on the traffic conditions indicated . What is the probability of packet loss if the average traffic at each input port increases to 128 kbit/s ? And what is the number of buffers needed to ensure the probability of packet loss previously specified? Is this solution acceptable? Why?

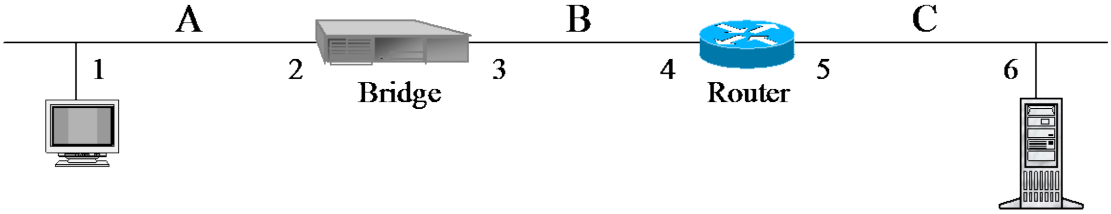
*Sun M = 20 , PB = 5 % , M = 999 - not acceptable , queue full , large delay*

## IP NETWORKS

9) A company has the IP network address 200.1.1.0 (class C) and intends to form subnets for four departments (A, B, C and D) with the following distribution of computers: 72, 35, 20 and 18 respectively.

a) Indicate a possible combination of addresses and subnet masks for resolving this situation.
b) Please provide a solution that could be adopted by the company in the case of D department grow to 34 computers.
*Solution: See the lecture notes*

10) Consider three segments (A, B and C) of an IEEE 802.3 LAN, connected by a bridge and a router, as shown. Six interfaces are indicated, corresponding a MAC address and an IP address to each of them.




Consider an IP packet sent from the computer in segment A to the server in segment in C. The packet is encapsulated in MAC frames for transmission in each segment. Identify, through the number of its interface, the source and destination addresses present in the frame and in the packet in each segment (admit that address resolution had been previously held). If address resolution is necessary indicate the station that initiates the process and the IP address it provides so that it can obtain the desired MAC address.

*Solution: See the 2nd laboratory work logs*