Indian Institute of Technology Bombay

Department of Electrical Engineering

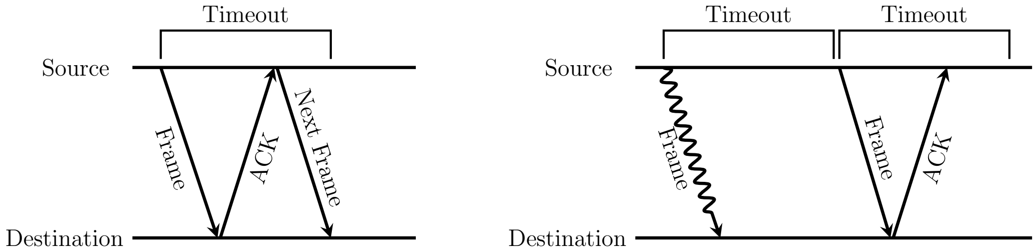
Handout 8 EE 706 Communication Networks
Solutions to Quiz 2 February 10, 2010

---

1. Using a two-node network consisting of a source S and a destination D with a noisy channel between them, explain how ARQ enables reliable communication. [2 points]
   Ans. Automatic Repeat Request (ARQ) principle works on following sequence of events,

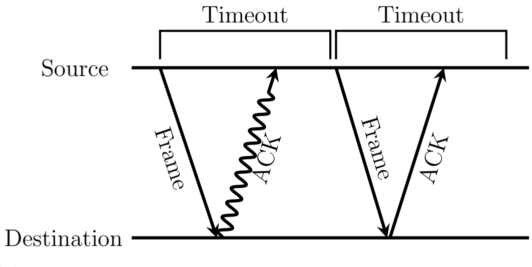
   - Source S sends a frame and after starting the timer, it waits for the ACK frame to be received from receiver.
   - At the destination D once the frame is received, it is checked for errors. If there are no errors, then destination sends ACK frame to the source. If there are errors in the frame, the destination does nothing.
   - If the source S receives the ACK frame before the timer exceeds a predetermined threshold, then it sends next frame. If the timer exceeds the threshold a timeout event is said to occur and the current frame is retransmitted.

   The following diagrams can also be used to illustrate ARQ operation.



(a) The ideal case: ACK is received before timeout occurs

(b) Error case: Frame errors are detected



(c) Error case: ACK errors are detected

Figure 1: Timing diagrams illustrating stop-and-wait ARQ operation

2. A single parity check is an error detection code which appends a single parity bit to an information bit string. The parity bit is set to 1 if the number of ones in the information bit string is odd and is set to 0 otherwise. Let the information bit string

be 0000. If a single parity check bit is added to it and the resulting bit string is sent over a noisy channel, list all possible received bit strings which are declared error free at the destination. [2 points]

Ans. Given that the information bit string is 0000, the parity check bit is 0 and so the transmitted bit string is 00000. The channel can introduce any number of errors and hence the received bit string can be any sequence of 5 bits. Let us denote them by $b_1 b_2 b_3 b_4 b_5$. There are $2^5 = 32$ possible received bit strings. The destination

Figure 2

recalculates the parity bit using the received information bits according the following formula.

$$\hat{b}_5 = \begin{cases} 1 & \text{Number of 1's is odd} \\ 0 & \text{otherwise} \end{cases}$$

It then checks whether the recalculated parity $\hat{b}_5$ is equal to the received parity bit b_5. If they are not equal, it declares an error. So the error free bit strings are such that $\hat{b}_5$ is equal to b_5. Since $\hat{b}_5$ is fixed once b_1, b_2, b_3, b_4 are fixed, we can only vary the latter. So there are 16 possible bit strings which are declared error-free.

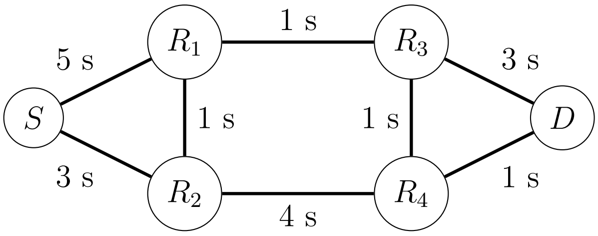
$b_1 b_2 b_3 b_4 b_5$	$\hat{b}_5$
00000	0
00011	1
00101	1
00110	0
01001	1
01010	0
01100	0
01111	1
10001	1
10010	0
10100	0
10111	1
11000	0
11011	1
11101	1
11110	0

3. Consider the six-node communication network shown in the below figure.

    (a) List all routes from node S to node D. [2 points]

(b) The number alongside a link indicates the packet delay incurred on that link in seconds. Taking the routing cost of a route to be the sum of the delays of the links which constitute the route, write down the minimum-delay routing tables for the nodes S, R_1, R_2 and R_3 in the format shown in the table below.

[4 points]



Routing table for S		
Reachable Node	Next Hop	Routing Cost

Ans.

(a) The loop-free routes are the following

S–R_1–R_3–D
S–R_1–R_3–R_4–D
S–R_1–R_2–R_4–D
S–R_1–R_2–R_4–R_3–D
S–R_2–R_4–D
S–R_2–R_4–R_3–D
S–R_2–R_1–R_3–D
S–R_2–R_1–R_3–R_4–D

If routes containing loops are allowed, then there are infinitely many routes. One example is S–R_1–R_2–R_4–R_3–R_1–R_2–R_4–D.

(b) The routing tables for S, R_1, R_2 and R_3 are given below.

Routing table for S		
Reachable Node	Next Hop	Routing Cost
R_1	R_2	4
R_2	R_2	3
R_3	R_2	5
R_4	R_2	6
D	R_2	7

Routing table for R_1		
Reachable Node	Next Hop	Routing Cost
S	R_2	4
R_2	R_2	1
R_3	R_3	1
R_4	R_3	2
D	R_3	3

Routing table for R_2		
Reachable Node	Next Hop	Routing Cost
S	S	3
R_1	R_1	1
R_4	R_1	3
R_3	R_1	2
D	R_1	4

Routing table for R_3		
Reachable Node	Next Hop	Routing Cost
S	R_1	5
R_1	R_1	1
R_2	R_1	2
R_4	R_4	1
D	R_4	2