Assignment2

Course: Computer Network

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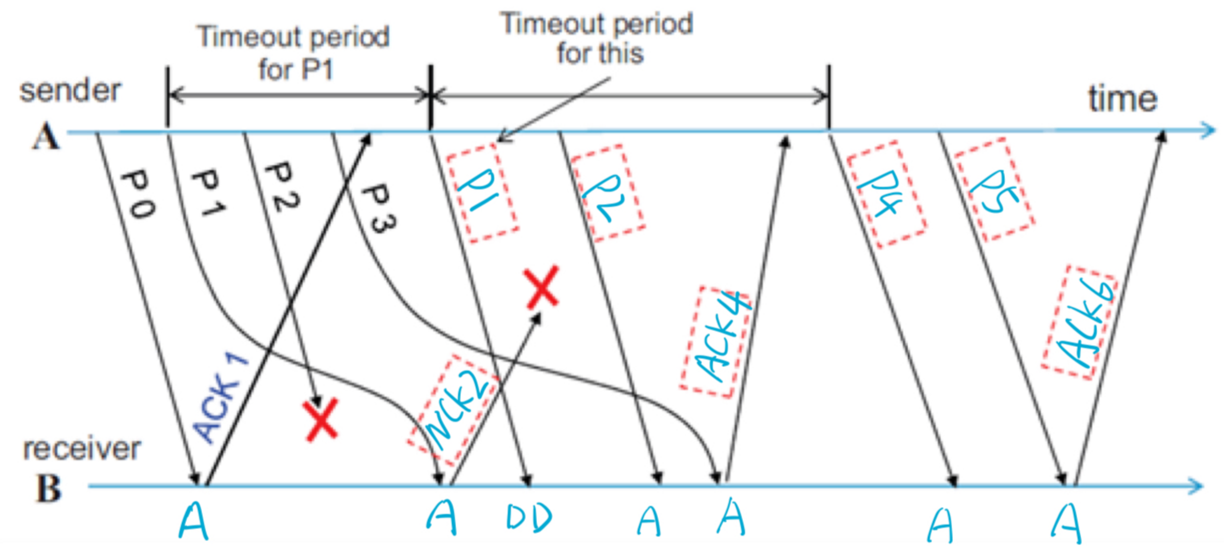
Q1. ARQ

Consider the data transmission from sender A to receiver B via the Go-Back-N (with NAK) protocol with a large window size N (so that packet transmissions will not be limited by the window size).

a) Fill in the boxes of the figure below. Write the packet number in the form of Px, and the response in the form of ACKx or NAKx. (14 points)

b) Write the corresponding actions (A for Accept, DD for discard as duplicates, DE for discard as error) for each packet at the receiver end. (6 points)

Ans.



Q2. Medium Access Control (25 points, 5 points each)

Briefly answer the following questions in your own words.

a) Describe the CSMA/CA mechanism used in IEEE 802.11 (WiFi). You may draw a diagram, describe in words, or write pseudo code for this.

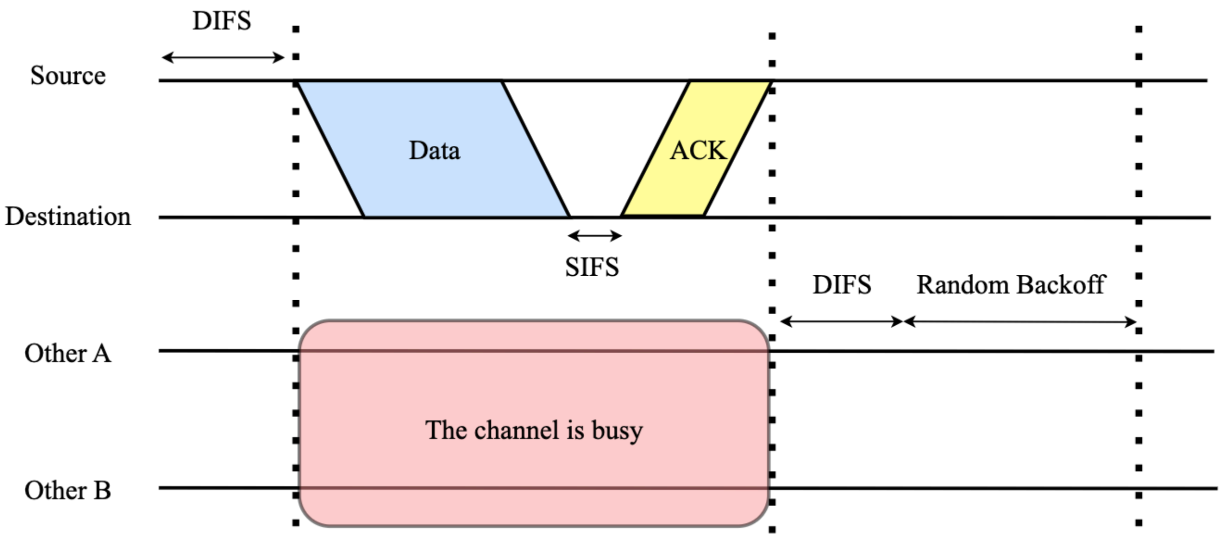
b) Why can’t we use CSMA/CD in wireless LAN?

c) Why do we need the RTS-CTS mechanism?

d) How does a bridge learn the hosts in a LAN? (Hint: Read Chapter 4.8.2 and 4.8.3 in the textbook)

e) What are the differences between a bridge/switch and a hub? (Hint: Read Chapter 4.8.4 in the textbook)

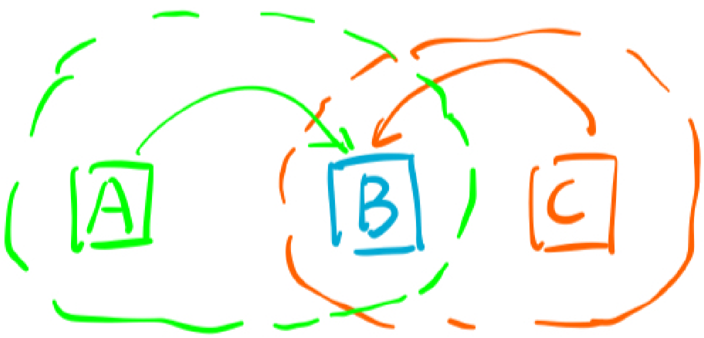
Ans. a) When a source station intends to transmit a data frame, it listens to the channel. If the channel is idle, it sends the data; otherwise, it waits until the channel becomes idle. When the channel transitions from busy to idle, any station intending to transmit a data frame not only needs to wait for a time interval but also enters a contention window. It calculates a random backoff time to attempt accessing the channel again.



b) Firstly, the received signal strength on wireless network cards is often much weaker than the transmitted signal strength. Achieving collision detection on wireless network cards requires high hardware demands.

Secondly, there is the hidden station problem in radio windows, making collision detection less meaningful.

c) RTS/CTS (Request to Send/Clear to Send) is primarily employed to address the hidden station problem. The fundamental idea behind the RTS/CTS mechanism is that, before transmitting data, the sending station first sends a short RTS frame to the receiving station. Upon receiving the RTS frame, if the channel is idle, the receiving station replies with a CTS (Clear to Send) frame to the sending station. Only after the sending station receives the CTS frame does it proceed to send the data frame.



d) The bridge creates a hash table entry for each machine, indicating the corresponding output port. Initially, when bridges are powered up and the hash tables are empty, they use a flooding algorithm. Incoming frames for unknown destinations are broadcast to all ports (except the incoming port). As bridges learn the locations of destinations over time, flooding is reduced, and frames are forwarded only to the proper port. To handle dynamic topologies, hash table entries include the arrival time of frames, enabling updates based on the last time a frame from a specific machine was seen. This ensures effective address learning and adaptation to changing network configurations.

e) **Operational Layer**

Bridge/Switch: Operates at the Data Link Layer (Layer 2) of the OSI model. Examines and makes decisions based on the MAC addresses in the frame headers.

Hub: Operates at the Physical Layer (Layer 1) of the OSI model. Functions as a simple repeater, broadcasting incoming frames to all connected devices.

Collision Domain

Bridge/Switch: Each port on a bridge/switch is typically its own collision domain, isolating traffic and reducing collisions. Full-duplex connections further eliminate collisions.

Hub: All devices connected to a hub share the same collision domain. If two devices transmit data simultaneously, a collision occurs, and CSMA/CD (Carrier Sense Multiple Access with Collision Detection) is used to handle collisions.

Performance

Bridge/Switch: Offers better performance compared to hubs. Bridges and switches can make intelligent forwarding decisions, reducing unnecessary traffic and collisions.

Hub: Can lead to network congestion and collisions, especially in larger networks, as all devices connected to the hub share the same bandwidth.

Use Cases

Bridge/Switch: Suitable for modern networks where performance and efficient use of bandwidth are essential. Commonly used in Ethernet networks.

Hub: Less common in modern networks due to performance limitations. Typically used in simpler, smaller-scale setups.

Q3. IP Addressing (10 points)

Briefly answer the following questions.

a) For a network with IP address 192.168.8.0/26, how many host IP addresses can be assigned in this network? (3 points)

b) With respect to the number of destinations, IP addresses can be categorized into three types. What are they? Give an example for each type of addresses. (4 points)

c) ARP is an aiding protocol for IP. Describe in your own words how ARP request and ARP reply works. (3 points)

Ans.

a) For IP address 192.168.8.0/26, there are 62 host IP addresses can be assigned in this network. The first 26 bits are network bits, and the last 6 bits are host bits. So the number of host IP addresses is $2^6 - 2 = 62$. (2 IP addresses are reserved for broadcast and network)

b) IP addresses can be categorized into three types: Unicast Address, Multicast Address, and Broadcast Address.

Unicast Address: Used to send a message to a single host. *e.g.* 192.168.1.1

Multicast Address: Used to send a message to a group of hosts. *e.g.* 224.0.0.1

Broadcast Address: Used to send a message to all hosts on a network. *e.g.* 192.168.1.255

c) ARP contains the mapping between each host's IP address and MAC address.

The ARP request and ARP reply works as follow:

ARP request: When a host wants to send a message to another host, it will first check the ARP cache to see if the MAC address of the destination host is in the cache. If the MAC address is in the cache, the host will send the message to the destination host directly. If the MAC address is not in the cache, the host will broadcast an ARP request message to all hosts on the network.

ARP reply: When a host receives an ARP request message, it will check if the IP address in the message is its own IP address. If the IP address is its own IP address, the host will send an ARP reply message to the sender of the ARP request message. Then the sender will add the IP address and MAC address in the ARP reply message to its ARP cache.

Q4. Routing: Dijkstra (20 points)

Consider the network topology as follow.

a) Describe the Dijkstra algorithm with pseudo code. (5 points)

b) Find the shortest path from node A to all the other nodes in the network with the Dijkstra algorithm. Make sure you show all your steps (with the table!). (10 points)

c) Consider a networking condition in which you are asked to write an algorithm to find the most reliable path, i.e., the path with the least Bit Error Rate (BER). Assume each link in the network has a BER (in the range of 0 and 1) that is independent of other links. Can we directly use Dijkstra algorithm? If not, how to change it to solve this problem? (5 points)

Ans. a)

```
function Dijkstra(G, s):
    """
    G: graph
    s: source node
    """
    for each vertex v in G: # Initialization
        dist[v] = infinity
        prev[v] = undefined

    dist[s] = 0
    Q = G.V

    while Q is not empty:
        # find dist[u] where u belongs to Q
        u = min(Q, key=lambda v: dist[v])
        Q.remove(u)

        for each neighbor v in u:
            item = dist[u] + length(u, v)
            if item < dist[v]:
                dist[v] = item
                prev[v] = u

    return dist, prev
```

b)

Step	set N	D(B), p(B)	D(C), p(C)	D(D), p(D)	D(E), p(E)	D(F), p(F)
0	A	4, A	1, A	∞	∞	∞
1	A, C	3, C	1, A	∞	4, C	∞
2	A, C, B	3, C	1, A	8, D	4, C	12, B
3	A, C, B, E	3, C	1, A	5, E	4, C	7, E
4	A, C, B, E, D	3, C	1, A	5, E	4, C	6, D
5	A, C, B, E, D, F	3, C	1, A	5, E	4, C	6, D

D(B) = 3, A -> C -> B

D(C) = 1, A -> C

D(D) = 5, A -> C -> E -> D

D(E) = 4, A -> C -> E

D(F) = 6, A -> C -> E -> D -> F

c) No, we can't directly use Dijkstra algorithm.

Dijkstra algorithm is used to find the shortest path in a graph where the weight of each edge is non-negative. The shortest path means the sum of the weights of the edges on the path is minimum. However, in this problem, we want to find the most reliable path, i.e., the path with the least Bit Error Rate (BER). The most reliable path means the product of the weights of the edges on the path is minimum. So we must change the algorithm to find the most reliable path.

```
function Dijkstra(G, s):
    """
    G: graph
    s: source node
    """
    for each vertex v in G: # Initialization
        M_UBER = 1 # bigger M_UBER -> better result
        prev[v] = undefined

    M_UBER[s] = 1
    Q = G.V

    while Q is not empty:
        # find M_UBER[u] where u belongs to Q
        u = max(Q, key=lambda v: M_UBER[v])
        Q.remove(u)
```

```
        for each neighbor v in u:
            item = M_UBER[u] * (1 - BER(u, v))
            if item > M_UBER[v]:
                M_UBER[v] = item
                prev[v] = u

    return dist, prev
```

Q5. Routing: Bellman-Ford (10 points)

Consider the same network topology as in Question 4, and find the shortest path to node A with the Bellman-Ford algorithm. Update Order B → C → D → E → F. Make sure you show all your steps (with the table!).

Ans.

Cycle	n(B), D(B)	n(C), D(C)	n(D), D(D)	n(E), D(E)	n(F), D(F)
0	·, ∞	·, ∞	·, ∞	·, ∞	·, ∞
1	A, 4	A, 1	B, 9	C, 4	E, 7
2	C, 3	A, 1	E, 5	C, 4	D, 6
3	C, 3	A, 1	E, 5	C, 4	D, 6

D(B) = 3, B -> C -> A

D(C) = 1, C -> A

D(D) = 5, D -> E -> C -> A

D(E) = 4, E -> C -> A

D(F) = 6, F -> D -> E -> C -> A

Q6. QoS (15 points)

Give real-world examples for the following scheduling schemes.

a) FIFO Queue (4 points)

b) Priority Queue (4 points)

c) Round Robin (4 points)

d) Weighted Fair Queue (WFQ) (3 points)

Ans.

a) Consider an university cafeteria. the first person who queued up will get the food first, the second person who queued up will get the food second, and so on.

b) Consider an hospital. The patient with serious illness will be treated first.

c) Consider a job interview. In the group interview, each person has an equal opportunity to speak. In computer networks, Round Robin is a fair scheduling algorithm. When multiple packets arrive at the router at the same time and need to be forwarded through the same output port, the Round Robin scheduling algorithm ensures that each packet has a chance to be forwarded, and each packet is forwarded at a relatively balanced interval

d) In Weighted Fair Queue (WFQ), the scheduling is based on bits. The bandwidth of each flow is allocated according to the queue weight. It prevents some flows from occupying too much bandwidth, which leads to insufficient bandwidth of other flows.