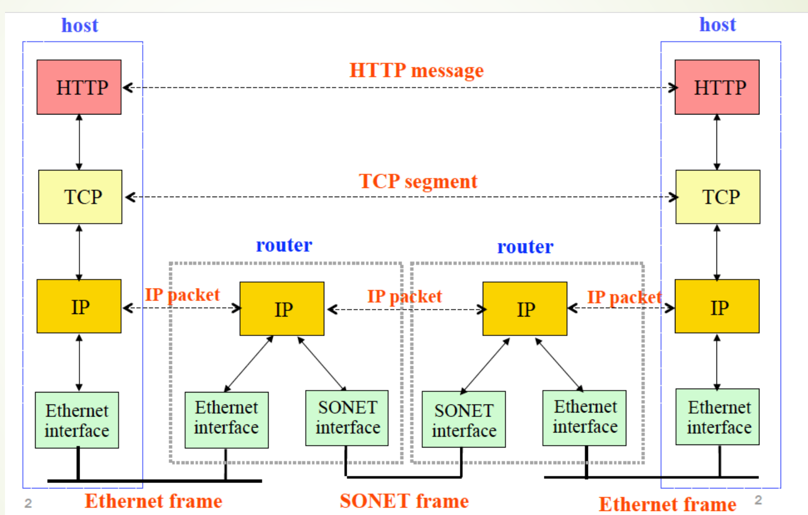
Finals Review

CSC 358 Principles of Computer Networks

2

Internet Layering: Message, Segment, Packet and Frame



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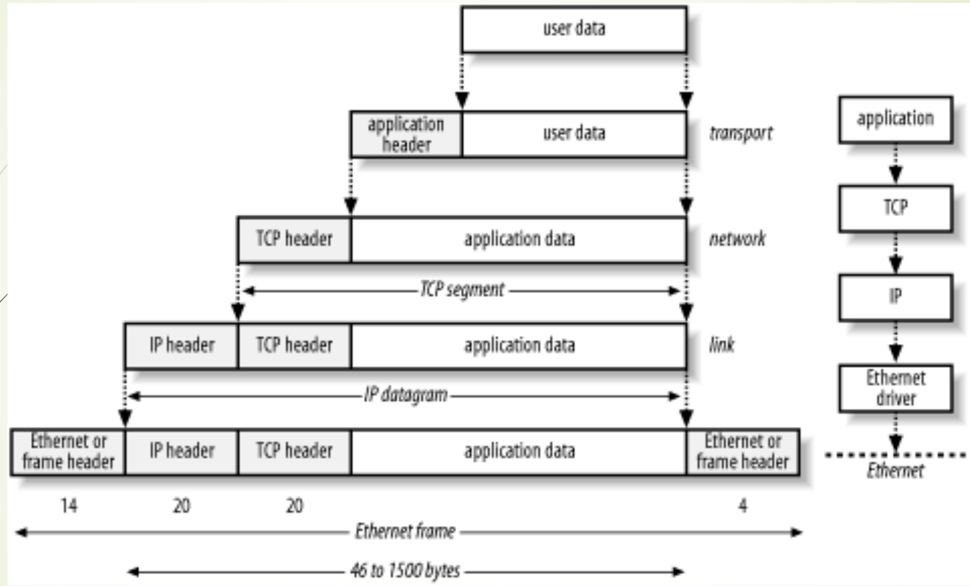


4

Topics

- Link Layer
  - Ethernet and CSMA/CD
  - Spanning Tree and Switching
  - DHCP and ARP
- Network Layer
  - IPv4 addressing, CIDR
  - IP Forwarding
  - Routing Protocols
  - Autonomous Systems
- Transport Layer
  - UDP
  - TCP
    - Reliability
    - Congestion Control
    - Queueing Management
- Application Layer
  - Middleboxes
- SDN

5

Which of the following is/are true about Address Resolution Protocol (ARP) and learning bridges?

a) A learning bridge maintains state that maps IP addresses to hardware (MAC) addresses.

b) A learning bridge maintains state that maps MAC addresses to IP addresses.

c) A host's ARP table maintains state that maps IP addresses to hardware (MAC) addresses.

d) A host's ARP table maintains state that maps hardware addresses to IP addresses.

6

Which one of the following is a true statement about TCP?

a) TCP is a routing protocol used throughout the Internet.

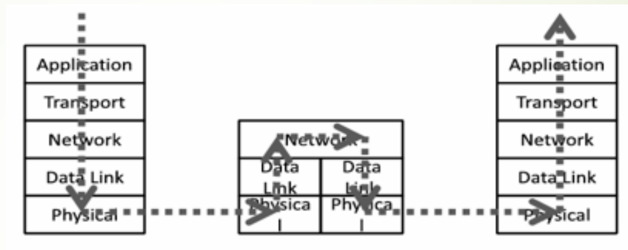
b) TCP establishes a connection between two end-hosts using a 2-way handshake scheme

c) TCP learns of congestion via packet loss or variations in delay.

d) If the SYN packet send by TCP source is lost, the connection is closed.

7

What is the name of the forwarding device in the middle of the diagram below?



a) Repeater
b) Switch
c) Hub
d) Router

8

Which are true about Ethernet protocols?

a) Ethernet is commonly used for the link-layer protocol for long-distance links (such as across a country).
b) The Ethernet spanning tree may take a longer path through a network than that which would be calculated by a link-state algorithm (assuming both have converged).
c) The Maximum Transmission Unit (MTU) of Ethernet is dictated by the buffer size of the link-layer endpoints.
d) CRC error detection cannot always detect if there is a frame error in Ethernet.

9

When a UDP segment arrives at a host, in order to direct the segment to the appropriate socket, the operating system's network stack uses the following fields:

a) the source IP address
b) the destination IP address
c) the source port number
d) the destination port number

10

Which of the following is/are true about web caches?

a) All HTTP objects are cacheable.
b) HTTP does not explicitly support caching or cache consistency.
c) A web cache, or proxy server, is a network entity that satisfies HTTP requests from clients.
d) A web cache is both a client and a server at the same time.

11

Suppose a 10Mb/s adapter uses Manchester encoding to send an infinite stream of 1's into a link. How many transitions per second will the signal emerging from this adapter have?

a) 5 million transitions per second.
b) 10 million transitions per second
c) 20 million transitions per second.
d) None of the above.

12

Which of the following is true about Random Early Detection (RED)?

a) RED is tolerant of bursts because when the average queue occupancy is close to the maximum threshold, there is still room in the queue to accept new burst of packets.
b) The possibility of RED dropping a packet belonging to a flow is proportional to the number of the flow's packets queued at the router.
c) RED drops packets with probability 1 when the router's queue length is greater than the maximum threshold value.
d) If two flows, one TCP and one UDP, share a "RED" router, the RED algorithm will ensure that both flows receive identical share of the outgoing link.

13

Which of the following statements is TRUE about TCP?

a) TCP Segments can only be lost when router queues overflow.

b) There is no performance benefit to having a window size larger than the receiver window size.

c) The received sees duplicate ACKs (with the same sequence number) only when a packet is lost

d) A receiver reduces the advertised window size in response to congestion

14

Consider an HTTP client that wants to retrieve a Web document at a given URL. The IP address of the HTTP server is initially unknown. What transport and application layer protocols besides HTTP are needed in this scenario?

- Application layer protocols: DNS and HTTP
- Transport layer protocols: UDP for DNS; TCP for HTTP

15

Why do HTTP, FTP and SMTP run on top of TCP rather than on UDP?

- The applications associated with those protocols require that all application data be received in the correct order and without gaps. TCP provides this service whereas UDP does not.

16

What is the difference between Distance Vector and Path Vector?

- DV – does not advertise entire network topology,
- None of the routers how the network looks like in its entirety
- Count to infinity problem
- PV/LS - Link state routing protocols allow a router to have a complete map of the network, and use specific algorithms to find shortest paths to every object in the network
- Link state protocols are much more complex and require more processing power and memory

17

Give two reasons why interdomain routing uses path-vector routing instead of distance vector routing.

- Faster convergence through loop detection, avoiding the "counting to infinity" problem
- Flexible routing policies that depend on the hops in the AS-PATH.

18

Give *one* reason why an Internet Service Provider (ISP) might select a route with a longer AS-PATH over a route with a shorter AS-PATH.

- Avoids an undesirable AS (e.g. that performs censorship or wire-tapping)
- Avoids an observed performance problem (e.g. high latency or low throughput)

19

A Network Address Translator (NAT) has a binding timer associated with each map entry. Why is this necessary?

- Eventually, the NAT box needs to reclaim memory and port numbers to use for new data transfers. Also, a stale map entry could be viewed as a security risk, as an attacker could send packets to the hosts behind the NAT box using a source address and port number of a past transfer.

20

How does the Border Gateway Protocol (BGP) avoid the count-to-infinity problem that plagues distance-vector protocols?

- BGP is a path-vector protocol. That is, BGP announcements include the entire path traversed by the message, not simply a total cost. A router, upon receiving a BGP announcement, can check for its own AS number in the path; if the AS number is present, the path has a loop and is immediately discarded.

21

Describe each of the following terms/concepts clearly and concisely. For each of these terms, explain the context they are defined at; which protocol(s) they are related to, when/where they are used, etc. and give examples if possible.

1. Fast Retransmission

Fast retransmission is used in TCP, to trigger the retransmission of a dropped packet sooner than the regular timeout mechanism. When the receiver receives an out-of-order packet, it resends the same acknowledgement it sent the last time. The sender who receives three duplicate ACKs then retransmit the dropped packet instead of waiting for the timeout of that packet. On page 511 of text.

22

2. Nagle's Algorithms

Nagle's algorithm is used by TCP senders to determine when to transmit a segment. The algorithm allows to send a full segment if the window permits. It also allows to send small amount of data if there are no segments in transit. Otherwise, if there is anything in flight, the TCP sender must wait for an ACK before transmitting the next segment. on Page 417 of text.

23

3. Maximum Segment Size (MSS)

MSS is a variable used by TCP to determine the size of the largest segment to send. TCP waits until having collected MSS bytes from the sending process and then sends a segment. MSS is usually set to the MTU of the directly connected network, minus the size of the TCP and IP headers. on Page 415 of text.

24

4. Stub Autonomous System (AS)

A group of networks and routers, subject to a common authority and using the same intra-domain routing protocol.

25

5. Interior Gateway Protocol (IGP)

The protocol used to exchange inter-domain routing information among routers in the same domain.

26

6. Distance Vector

A lowest-cost-path algorithm used in intra-domain routing. Each node advertises reachability information and associated costs to its immediate neighbors and uses the updates it receives to construct its forwarding table. The routing information protocol (RIP) uses a distance-vector algorithm. on Page 245 and Page 820 of text.

27

TCP

- Suppose Host A sends two TCP segments back to back to Host B over a TCP connection. The first segment has sequence number 90; the second has sequence number 110.

a) How much data is in the first segment?

20 Bytes

b) Suppose that the second segment is lost but the first segment arrives at B. In the acknowledgment that Host B sends to Host A, what will be the acknowledgment number?

ACK Number = 110

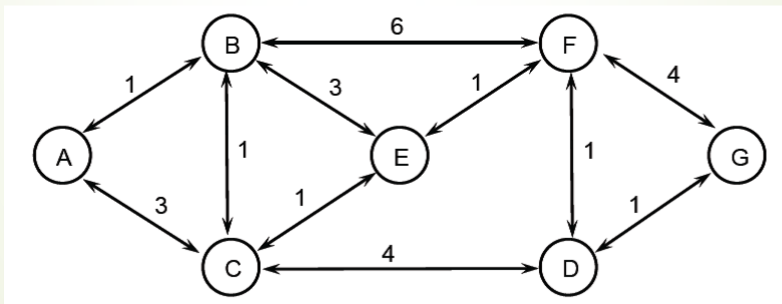
28

What is an autonomous system? List and explain two type of routing protocols used in the autonomous system.

- We use the term *Autonomous System* (*AS*) to capture the concept of groups of routers. An AS is a contiguous set of networks and routers all under control of one administrative authority. There is no exact meaning for *administrative authority* (the term is sufficiently flexible to accommodate many possibilities, but normally it means an organization, company or an ISP).
- Interior Gateway Protocols (IGPs): The routers within an AS use an *Interior Gateway Protocol* (*IGP*) to exchange routing information. Several IGPs are available; each AS is free to choose its own IGP. An IGP is easy to install and operate, but an IGP may limit the size or routing complexity of an AS.
- Exterior Gateway Protocols (EGPs): A router in one AS uses an *Exterior Gateway Protocol* (*EGP*) to exchange routing information with a router in another AS. EGPs are usually more complex to install and operate than IGPs, but EGPs offer more flexibility and lower overhead (i.e., less traffic). An EGP can implement *policy constraints* that allow a system manager to determine exactly what information is released outside the organization.

29

Consider the network topology shown below.
If we use Bellman-Ford's algorithm to find the shortest path between every pair of nodes, how many steps will it take for the algorithm to converge in the case? Explain



30

In general, if we have a network with N nodes, what is the maximum number of steps for the Bell-Ford algorithm to converge? Explain.

N-1 steps for the worse case.

31

Ethernet switches compute a spanning tree using the spanning tree protocol. Explain briefly how the spanning tree protocol works.

- The spanning tree protocol is designed to eliminate loops in the forwarding topology. It provides a distributed manner for individual switches to cooperatively form a spanning tree topology: each switch first declares itself as the root and passes the configuration messages out to each of its interfaces identifying itself as the root with distance 0. Switches periodically receive these messages from their neighbours and update their view of the root. Upon receiving a message, a switch checks the root id. If the new id is smaller than the recorded one, it starts viewing that switch as root.
- Switches compute their distance from he root. Also they add 1 to the distance received from a neighbour. Comparing these two values, they identify interfaces which are not on a shortest path to the root and exclude them from the spanning tree.

32

Do the switches learn the network topology (connecting the switches), like routers do in a link-state protocol? Does each pair of switches communicate over a shortest path, like routers do in link-state protocols?

- The spanning tree protocol is different from the link-state protocol. The first difference is the content exchanged between nodes - both the reachability and distance are exchanged in spanning tree configuration messages; only the reachability information is exchanged in link-state protocol.
- The second difference is that the shortest paths (from each switch to the root) are formed at the same time of forming the tree topology in Spanning tree protocol, whereas the shortest paths are calculated in the second stage after every node has learnt the network topology in the link-state protocol.
- The third difference is that the switches in spanning tree protocol only learn their paths to the root; but the routers learns their paths to all other routers in link-state protocol.

33

Consider a TCP flow over a 1-Gb/s link with a latency of 1 second that transfers a 10 MB file. The receiver advertises a window size of 1MB, and the sender has no limitation on its congestion window (i.e., it can go beyond 64 KB).

- How many RTTs does it take until slow-start opens the send window to 1 MB?
- Assuming TCP packet size is 1500 Bytes, 1MB is about 1000000/1500=667 packets.
- Starting from initial congestion window size of 1 packet, after each RTT the window size doubles. Therefore, we need to find the smallest n such that:
- 2^n>=667 => n=10
- After 10 RTTs the window size opens to 1Mb which equals to the advertised window size.

34

How many RTTs does it take to send the file?

- During the first 10 RTTs of slow-start, 1500B*(1+2+4+…+512) = 1534500B is transmitted. Starting from the 11th RTT, the sender will send 1MB to the network. Hence the remaining file takes (10MB-1.5345)/1MB = 8.4655 RTT to finish. Hence in total, it takes 10RTT + 9RTT = 19RTT to send the file.

35

If the time to send the file is given by the number of required RTTs multiplied by the link latency, what is the effective throughput of the transfer

- Throughput = Transfer Size / Transfer Time = 10 MB / 19*1 second = 0.5263 MB/s

(We assume that the ACKs are immediately received and so the latency is 1sec)

36

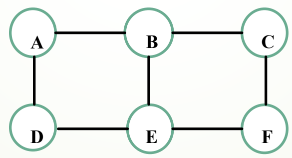
What percentage of the link bandwidth is utilized?

- Utilization = 0.5263*8 Mbps / 1000 Mbps = 0.42 %

37

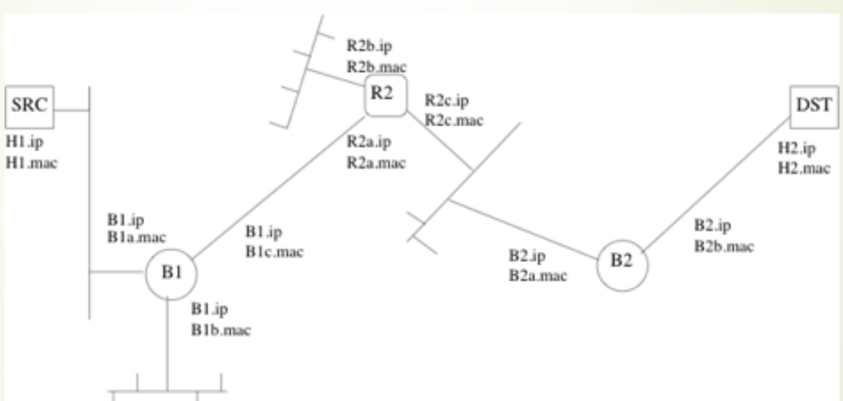
Suppose we have the forwarding tables shown below for nodes A and F, in a network where all links have cost 1. Give a diagram of the smallest network consistent with these tables.

NODE A				NODE F		
Node	Cost	Next Hop		Node	Cost	Next Hop
B	1	B		A	3	E
C	2	B		B	2	C
D	1	D		C	1	C
E	2	B		D	2	E
F	3	D		E	1	E



38

Below is a picture of a network with 2 bridges and 1 router. Each interface is labeled with both an IP address and a MAC address. Imagine that host H1 (SRC) is sending a packet to host H2 (DST). Answer the following questions:



39

- How many networks are shown above?

  3, the networks hanging off R2

- Just before the packet reaches bridge B1, what is its layer 2 (Link Layer) destination?

  R2a.mac

- Just before the packet reaches bridge B2, what is its layer 2 (Link Layer) source?

  R2c.mac

- Just before the packet leaves router R2, what is its layer 3 source?

  H1.ip

40

- When H1 sends out an ARP query, what is the reply to that query?

  R2a.mac has R2a.ip

- Does the entry B2a.mac appear in B1's forwarding table?

  NO, B2a is on a different network than B1

41

A “tier 1” ISP is an AS with no upstream providers of its own. Why do the tier-1 ASes form a clique (i.e., a fully-connected topology), where each tier-1 ISP connects directly to every other tier-1 ISP?

- A tier-1 ISP has no upstream providers of its own. As such, it cannot reach the (single-homed) customers of other tier-1 ISPs without peering with them.

42

Suppose AS 1 has an AS-PATH of “1 2 3 4” to reach prefixes in AS 4, and ASes 3 and 4 have a peer-peer relationship. Suppose that an AS does not export BGP routes learned from one peer/provider to another peer/provider. Is AS 2 a customer, peer, or provider of AS 1?

- AS3 would only announce customer-learned routes to AS4, implying that AS2 is a customer of AS3.
- Similarly, AS2 would only announce customer-learned routes to AS3, implying AS1 is a customer of AS2.
- As such, AS2 is a provider of AS1.

43

We have seen that TCP has a number of features that UDP does not. For each of the following problems that can occur in IP networks, explain how TCP supports reliable delivery.

a) Dropped packets

TCP detects packet drops and retransmits lost portions

b) Reordered packets

TCP's sliding window mechanism buffers out of order packets and delivers packets in-order to the application

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44

In TCP's congestion control mechanism, what is the purpose of 1) slow start and 2) congestion avoidance?

- Slow start's main purpose is to quickly get the window size up to the connection's capacity, so that the link's bandwidth is not wasted. As soon as a duplicate ACK is received, or the threshold size is reached, those are taken to be indicators that the window size is approaching capacity, and switches to congestion avoidance.
- Congestion avoidance tries to detect when the link quality is degrading, usually due to congestion (too many users trying to send too many packets), and quickly decreases the window size to decrease usage of it. It halves the window size to play it safe. Ideally, if all the users on the link do this, the link will be able to recover, and all the users will be back in slow start, trying to gauge the link's capacity.

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45

Using TCP, a sender has sent out packets 1 through 20. The sender receives an ACK for packet 10, then it receives three ACKS for packet 11 (i.e., if the final byte of packet 11 was byte no. 5000, then these ACKs were for byte 5001). Given this result:

Which of the 20 packets can the sender assume are lost?

- ***12***

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46

Which of the 20 packets can the sender assume were definitely received?

- ***1 - 11***

Now, the same sender resends the next missing packet and receives an ACK for packet 16 in response. Based on this information:

Which packets of the original 20 can the sender assume are still lost, if any?

- ***None***

Which of the original 20 can the sender assume were definitely received?

- ***1 - 16***

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