Chapter 2

Routing Algorithms

LEARNING OBJECTIVES

- *Routing algorithm basics*
- *Flooding*
- *Multipath routing*
- *Distance vector routing*
- *Link state routing*
- *Hierarchical routing*
- *Rip*
- *Ospf*
- *Congestion control techniques*
- *Traffic shaping*

Routing Algorithms Basics

The main function of network layer is routing packets from the source machine to the destination machine. The routing algorithms are part of the network layer software, responsible for deciding which output line an incoming packet should be transmitted on.

Routing algorithms can be grouped into two major classes: Non-adaptive and Adaptive.

1. Non-adaptive algorithms do not base their routing decisions on measurements or estimates of the current traffic and topology. Instead, the choice of the route to use is downloaded to the routers when the network is booted. This procedure is called static routing.
2. Adaptive algorithms, in contrast, change their routing decisions to reflect changes in the topology, and the traffic as well.

Store and Forward Packet Switching

In this Technique, the data packet will be stored at the node and it is forwarded to its next appropriate intermediate node. The next intermediate node will first store the packet in the buffer, based on the router decision, it selects an interface, and forwards to receiver.

The technique is most suitable for the networks with unsteady connectivity.

The length of the packet we take shows effect on the file transfer, if the data packet is small, in the store the forward, delay will be less at each node, but causes extra overhead with headers. So, the packet size selection should be done appropriately.

Flooding

Static algorithms, in which every incoming packet is sent out on every outgoing line except the one on which it is arrived. Header contains the hop count of each packet. Hop counter is decremented at each hop, with the packet being discarded when the counter reaches zero.

Another way for damming the flood is to keep track of which packets have been flooded, to avoid sending them out a second time. A variation of flooding that is slightly more practical is selective flooding. In this algorithm the routers do not send every incoming packet out on every line, only on those lines that are going approximately in the right direction.

Multipath Routing

Multipath routing is routing the packets from the source, on multiple paths to the destination. It is nothing but spreading the traffic.

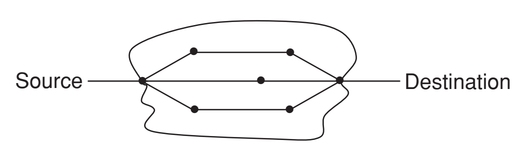


Figure 1 Multipath routing model

Single path routing causes QOS, throughput and delay problems, and multipath routing, improves network performance with sharing of available resources of network.

The components of multipath routing are

1. Multipath calculation algorithm
2. Multipath forwarding algorithm
3. End-Host protocol

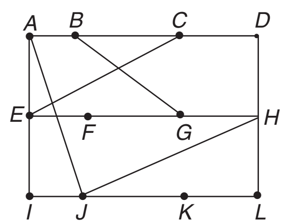
The algorithms specified above are based on Dijkstras shortest path algorithm they generate paths according to path characteristics and ensure path quality and path independence.

The end-host protocol uses the multipath (determined) effectively performance will be improved if end-users use the multiple paths effectively.

Distance Vector Routing

A dynamic routing algorithm, operates by having each router maintain a table (i.e., a vector) giving the best known distance to each destination and which line to use to get there. These tables are updated by exchanging information with the neighbors.

The Metric used might be number of hops, time delay in milliseconds, and total number of packets queued along the path or something similar.



(a)

New estimated	A	I	H	K	Delay from J	
A	0	24	20	21	8	A
B	12	36	31	28	20	A
C	25	18	19	36	28	I
D	40	27	8	24	20	H
E	14	7	30	22	17	I
F	23	20	19	40	30	I
G	18	31	6	31	18	H
H	17	20	0	19	12	H
I	21	0	14	22	10	I
J	9	11	7	10	0	-
K	24	22	22	0	6	K
L	29	33	9	9	15	k
	JA delay is 8	JI delay is 10	JH delay is 12	JK delay is 6	New routing table for J Vectors received from J's four neighbours.	

(b)

Figure 2 (a) Subnet, (b) Delay vectors of J

Figure 2(a) 'shows a subnet. The first 4 columns of figure 2(b) shows the delay vectors received from the neighbors of router *J*. A claims to have a 12 m sec delay to *B*, a 25 m sec delay to *C*, a 40 m sec delay to D, etc.

Suppose that *J* has estimated its delay to its neighbour, *A*, *J*, *H* and *K* as 8, 10, 12 and 6 m sec, respectively.

Now *J* computes its new route to router *G*. It knows that it can get to *A* in 8 m sec, and *A* claims to be able to get to *G* in 18 m sec, so *J* knows it can count on a delay of 26 m sec to *G* if it forwards packets bound for *G* to *A*, similarly, it computes the delay to *G* via *I*, *H* and *K* as 41 (31 + 10), 18 (6 + 12) and 37 (31 + 6) m sec, respectively.

The best of these values is 18, so it makes an entry in its routing table that the delay to *G* is 18 m sec and that the route to use is via *H*.

Count to Infinity Problem

It reacts rapidly to good news, but leisurely to bad news. Actual network may be down but routers will exchange routes with one another.

Following measures are taken to avoid count-to-infinity problem:

1. **Hop limit:** Limit number of hops normally 0 hops directly connected, hop 16 is (0 – 15), 16 hops unreachable.
2. **Split horizon:** Never send information back in direction where it came from.
3. Route poisoning and poison reverse, hold on timer trigger.
4. As soon as network goes down, make metric of root infinity to resolve the immediate instability created because of routing updates from neighbor.
5. When router sends update with infinite metric to neighbor, neighbor will make it down.
6. Now routers will initiate hold on time to learn alternate paths and send update in direction where it came (Poison reverse) from.
7. Routers will incorporate final roots in routing table.

Link State Routing

The idea behind link state routing is simple and can be stated as five parts. Each router must do the following:

1. Discover its neighbors and learn their network addresses.
2. Measure the delay or cost to each of its neighbors.
3. Construct a packet telling all it has just learned.
4. Send this packet to all other routers.
5. Compute the shortest path to every other router.

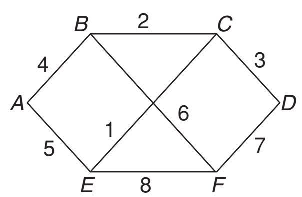
Learning about the neighbors When a router is booted, its first task is to learn who its neighbors are. It accomplishes this goal by sending a special HELLO packet on each point to point line. The router on the other end is expected to send back a reply telling who it is. These names must be globally unique.

Measuring the cost The link state routing algorithm requires each router to know, or at least have a reasonable estimate of, the delay to each of its neighbors.

The most direct way to determine this delay is to send over the line a special ECHO packet that the other side is required to send back immediately.

By measuring the round trip time and dividing it by two, the sending router can get a reasonable estimate of the delay. If two paths with same bandwidth exists and one path is heavily loaded then the path which is not heavily loaded is chosen. But this may oscillate in the choice of best path. So to avoid oscillation in the choice of best path, distribute the load over multiple lines with same known fraction going over each line.

Building link state packets Once the information needed for the exchange has been collected, the next step is, for each router to build a packet containing all the data. The packet starts with identity of the sender, followed by a sequence number and age, and a list of neighbors. For each neighbor, delay to that neighbor is given.



(a)

A	
Seq	
Age	
B	4
E	5

B	
Seq	
Age	
B	4
D	2
E	6

C	
Seq	
Age	
B	2
D	3
E	1

D	
Seq	
Age	
C	3
F	7

E	
Seq	
Age	
A	5
F	8
C	1

F	
Seq	
Age	
B	6
D	7
E	8

(b)

Figure 3 (a) Subnet5, (b) Link state packets for this subnet.

Distributing the link state packets As the packets are distributed and installed, the routers getting the routing packet first will change their routes.

Consequently, the different routers may be using different versions of the topology, which can lead to inconsistencies, loops, unreachable machines, and other problems. The fundamental idea is to use flooding to distribute the link state packets. To keep the flood in check, each packet contains a sequence number that is incremented for each new packet sent. Routers keep track of all the (source router, sequence) pairs they see.

When a new link state packet comes in, it is checked against the list of packets already seen. If it is new, it is forwarded on all lines except the one it arrived on. If it is a duplicate, it is discarded.

If a packet with a sequence number lower than the highest one seen so far ever arrives, it is rejected as being obsolete since the router has more recent data.

If a router ever crashes it will lose track of its sequence number. If its starts again at 0, the next packet will be rejected as a duplicate. Also due to bit error, packets may be rejected as obsolete. Solution to these problems is to include the age of each packet after the sequence number and decrement it once per second.

When the age hits zero, the information from that router is discarded.

Computing new routes Once a router has accumulated a full set of link state packets, it can construct the entire subnet graph because every link is represented. Every link is, in fact, represented twice, once for each direction. The two values can be averaged or used separately. Now dijkstra's algorithm can be run locally to construct the shortest path to all possible destinations.

Hierarchical Routing

Hierarchical Routing is mainly designed for large topologies. With increase in the topology there is proportionate increase in the routing tables, which consume more memory for maintaining tables and requires more bandwidth for the status reports.

In this routing, network topology is divided into hierarchies, these will reduce size of routing table. The node at each hierarchy will know about the nodes present in that level. It forwards the packet to its border router (at its level) if destination is not at its level. Hierarchical routing increases efficiency in routing, less traffic, reduction of table size in an order of about (log n).

RIP

1. It calculates best route based on hop count.
2. RIP cannot handle more than 15 hops, anything above 15 hops away is considered unsearchable by RIP. This fact is used by RIP to prevent routing loops.
3. RIP is a classful routing protocol.
4. Interval between route update advertisements: 30 sec. Time out/hold on times: 180 sec
5. RIP implements the split horizon, route isonning and hold down mechanisms to prevent looping.
6. It is a dynamic distance vector routing protocol.

OSPF

The open shortest path first is an adaptive routing protocol for IP networking. It uses a link state routing algorithm. OSPF keeps track of the state of all the various network connections between itself and a network it is trying to send data to. OSPF selects the best route by finding the lowest cost paths to a destination. All router interfaces are given a cost. Its domain is an autonomous system.

Backbone routers Backbone routers have one or more interfaces in Area 0 (the backbone area).

Area border router (ABR) Routers that belong to multiple areas, and connect these areas to the backbone area are called ABR. It has interfaces in multiple areas.

Autonomous system boundary router (ASBR) If the router connects the OSPF autonomous system to another autonomous system, it is called an autonomous system boundary router (ASBF).

OSPF elects two or more routers to manage the link state advertisements.

Designated router (DR) Every OSPF will have a DR, a backup DR. The DR is the route to which all other routers within the area, send their link state advertisements.

OSPF areas

OSPF areas are used to impose a hierarchical structure to the flow of data over the network. A network using OSPF will always have atleast one area and if there is more than one area, one of the two areas must be the backbone area. Areas are used to group routers into manageable groups that exchange routing information locally, but summarize the routing information, when advertising the routes externally, ABR's are used to connect the areas.

Congestion Control Techniques

Objective of congestion control technique is to limit queue lengths at the nodes, so as to avoid throughput collapse.

1. Send a control packet from a congested node to some or all source nodes to stop or slow the rate of transmission from source and thus limit the total number. of packets in the network.
2. Allow packet switching nodes to add congestion information to packets as they pass by. The packets carrying such information can go in both the directions i.e., opposite of the congestion and in the same direction of the congestion.

   Packets in the opposite direction of congestion quickly reache the source node which can reduce the flow of packets into the network.

   Packets going in the same direction as the congestion, reaches the destination. The destination asks the source to adjust the load by returning the signal back to the source in the packets.
3. Provides link delay information to other nodes. This information can be used to influence the rate at which new packets are produced. As these delays are influenced by the routing decision, they may vary too rapidly to use effectively for congestion control.

Congestion Control

Congestion control maintains the number of packets within the network below the level at which performance falls dramatically.

Every node has a queue of packets for each outgoing channel. If, rate at which packets arrive and queue up, exceeds the rate of packet transmission, then size of queue grows without bound and thus delay experienced by a packet goes to infinity.

When the packets arrive they are stored in the input buffer, of the corresponding link. The node examines each incoming packet to make a routing decision and then moves the packet to the appropriate output buffer. Packet queued up for output in output buffer is transmitted as soon as possible. When saturation point is reached, one can do any of the following:

1. Discard incoming packet for which there is no available buffer space.
2. Node should exercise some sort of flow control over its neighbors so that the traffic flow remains manageable.
3. Traffic shaping is about regulating the average rate of data transmission.

Leaky Bucket Algorithm

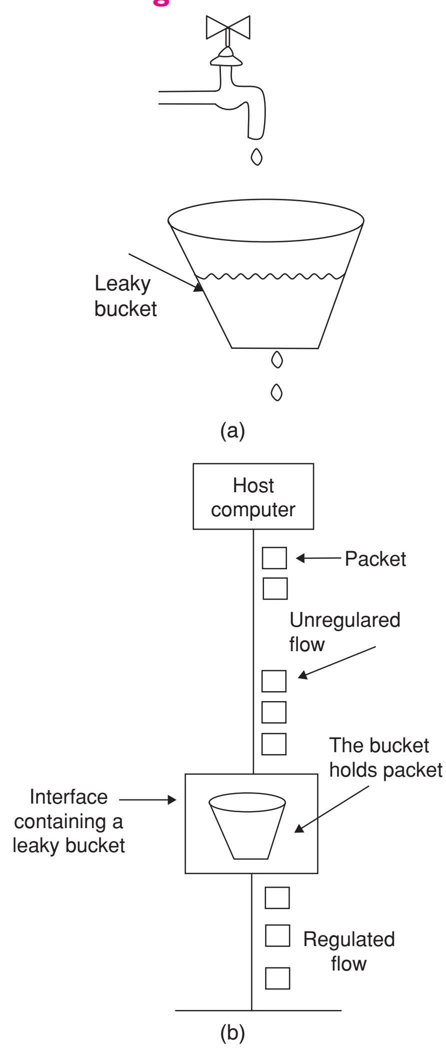
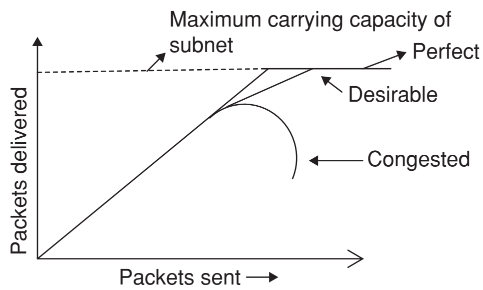


Figure 4 (a) A leaky bucket with water, (b) A leaky bucket with network

A leaky bucket is a bucket with a small hole. No matter at what rate water enters the bucket, the outflow is at constant rate, *S*, when there is any water in the bucket and zero when bucket is empty. Once the bucket is full, any additional water entering it, spills over the sides and it is lost. Each host is connected to the network by an interface containing a leaky bucket (i.e., a finite internal queue) congestion control algorithms.



When too many packets are present in the subnet, performance degrades. This situation is called congestion.

Causes of congestion

1. If all of a sudden, stream of packets are arriving on three or four input lines and all need same output line, a queue will build up.
2. Slow processor.
3. Low bandwidth line.

Token bucket

Tokens are added at a constant rate. For a packet to be transmitted, it must capture and destroy one token.

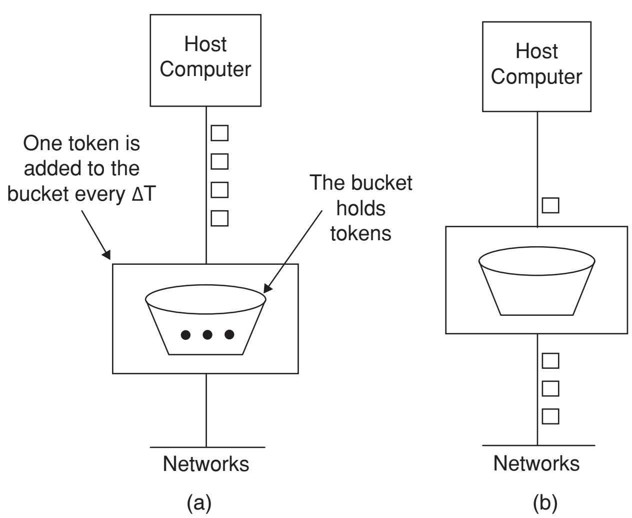


Figure 5 (a) shows that the bucket holds 3 tokens with 4 packets waiting to be transmitted, (b) shows that 3 packets have gotten through but the other one is stuck waiting for tokens to be generated.

Unlike leaky bucket, token bucket allows saving up to maximum size of bucket '*n*'.

The bursts of upto '*n*' packets can be sent at once, giving faster response to sudden bursts.

- Leaky bucket discards packets when the bucket is full, whereas token bucket throws away tokens when the bucket is full but never discards packets.
- Let Token bucket capacity be *c*(bits), token arrival rate ρ(bps), maximum output rate *M*(bps), and burst length *S*(*s*).
- During the burst length of *S*(*s*), tokens generated are ρS(bits), output burst contains a maximum of $C + \rho S$(bits)
- Output in a maximum burst of length *S*(*s*) is MS.
- $C + \rho S = MS \quad \text{(or)} \quad S = \dfrac{C}{M - P}$
- Token bucket still allows large bursts, even though the maximum burst length '*s*' can be regulated by selection of ρ and *M*.
- To reduce the peak rate, put a leaky bucket of a larger rate after the token bucket (To avoid discarding packets)

Traffic Shaping

1. One of the main causes of congestion is, that traffic is often burst.
2. If hosts could be made to transmit at uniform rate, congestion would be less.

This arrangement can be built into the network interface or simulated by the host OS. The host is allowed to put one packet per tick on the network.

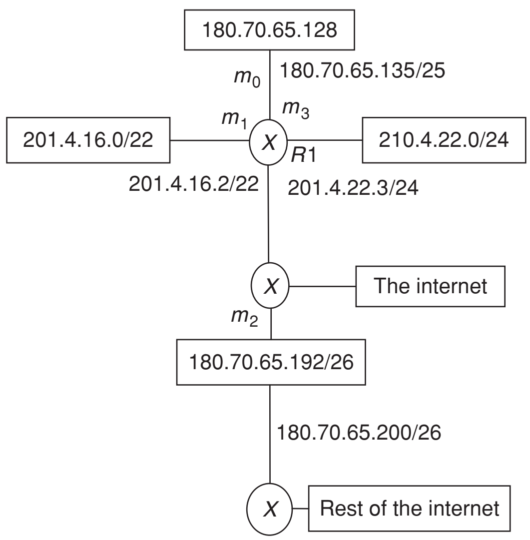
1. When the packets are all of the same size at every clock tick, one packet is transmitted.
2. When variable size packets are used.
   - (i) At every tick, a counter is initialized to *n*. If the first packet on the queue has fewer bytes than the current value of the counter, it is transmitted and counter is decremented by that number of bytes.
   - (ii) Additional packets may also be sent, as long as the counter is high enough.
   - (iii) When the counter drops below the length of the next packet on the queue, transmission stops until the next tick, at that time the residual byte count is overwritten and lost.

Exercises

Practice Problems I

Directions for questions 1 to 15: Select the correct alternative from the given choices.

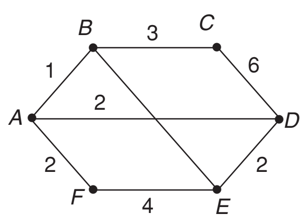
1. Consider below figure:



The network address, 180.70.65.130 goes through which of the following interface?

(A) m_0 (B) m_1
(C) m_2 (D) m_3

2. Consider below graphical representation of a subnet with each node denoting a router. If all the routers are booted at the same time, what is the number of link state packets that are generated having the cost/delay information?



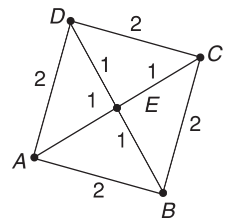
(A) 3 (B) 4
(C) 5 (D) 6

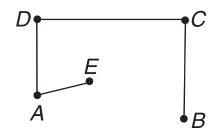
3. In a TCP connection it is found that burst size of 1024, 2048, 4096 have been transmitted while that of 8192 has resulted in a time out. The receiver has earlier set a window size of 4096. As per slow start algorithm which of the below statement is true?

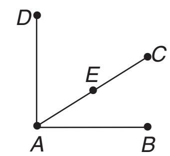
(i) Congestion window is set to 4096.
(ii) Maximum allowed burst size is 8192

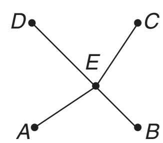
(A) (i) only
(B) (ii) only
(C) Both (i) and (ii)
(D) Neither (i) nor (ii)

4. From the below graph select the sink tree(s):



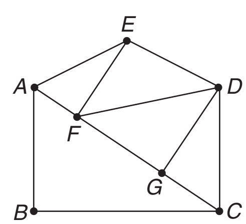
(i) 

(ii) 

(iii) 

(A) (i), (ii) (B) (ii), (iii)
(C) (i), (iii) (D) (i), (ii), (iii)

5. Consider the below graph.

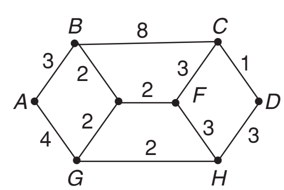


It is known that *D* is the optimal route from *A* to *C* and the optimal route from *A* to *C* has 3 hops. Which of the below statements is certainly true?

(i) *B* is not in the optimal route from *A* to *C*
(ii) *G* is not in the optimal route from *B* to *C*
(iii) Either *E* or *F* is in the optimal route from *A* to *C*
(iv) *ED*, *FD* are both optimal routes

(A) (i), (ii), (iii) (B) (ii), (iii), (iv)
(C) (i), (iii), (iv) (D) (i), (iv), (ii)

6. The shortest path using Dijkstra's algorithm after 3 iterations is



(A) A G (B) A B E
(C) A B C (D) A G H

7. There are totally 20 links among the routers of a subnet. How many rows are needed in all when link state packets combined together, which are used to notify each other about cost/delay in transmitting data to immediate neighbours. Assume 1 row is needed for each neighbour?

(A) 10 (B) 20
(C) 40 (D) 80

8. Below are the link state packets generated by routers in a subnet. What is the shortest distance between *A* and *D*?

A	
Seq	
Age	
B	4
E	5

B	
Seq	
Age	
A	4
C	2
F	6

C	
Seq	
Age	
B	2
D	3
E	1

D	
Seq	
Age	
C	3
F	7

E	
Seq	
Age	
A	5
C	1
F	8

F	
Seq	
Age	
B	6
D	7
E	8

(A) 6 (B) 9
(C) 10 (D) 11

9. What are the advantages of reverse path forwarding over other broadcasting algorithms like spanning trees, multidestination routing, broadcasting, and flooding?

(i) Route does not need to know information regarding spanning tree structures
(ii) Uses destination tables for further forwarding
(iii) Does not need a halt mechanism to stop packets from further getting routed

(A) (i), (ii) (B) (ii), (iii)
(C) (i), (iii) (D) (i), (ii), (iii)

10. Which of the following specifies the correct sequence of steps to route packets to mobile hosts?

(i) Sender is given foreign agent's address
(ii) Packet is sent to mobile host's home address
(iii) Packet is tunneled to foreign agent
(iv) Subsequent packets are tunneled to the foreign agent

(A) (i), (ii), (iii), (iv)
(B) (ii), (iii), (iv), (i)
(C) (ii), (iii), (i), (iv)
(D) (iii), (iv), (i), (ii)

11. What are the different parts of congestion control by closed loop methods?

(i) Design the system in advance to make sure congestion doesn't occur in first place
(ii) Monitor the system to detect when and where congestion occurs
(iii) Pass congestion information to places where action can be taken
(iv) Adjust system operation to correct the problem

(A) (i), (ii), (iii)
(B) (ii), (iii), (iv)
(C) (iii), (iv), (i)
(D) (i), (ii), (iv)

12. In Selective flooding

(A) Packets are sent in all outgoing lines.
(B) Packets are sent in only on those lines that are approximately in the right direction.
(C) Both (A) and (B)
(D) None of these

13. There are 5 routers and 6 networks in an inter-networking, using link state routing, how many routing tables are there?

(A) 1 (B) 5
(C) 6 (D) 11

14. Congestion control for multicasting flows from multiple sources to multiple destinations, the solution that can handle this is

(A) RSVP (Resource reSerVation Protocol)
(B) Load shedding
(C) Both (A) and (B)
(D) None of these.

15. Which of the below are part of backward learning algorithm?

(i) As the bridge starts operating, a hash table to map source addresses to corresponding LANs is constructed.
(ii) It dynamically updates the hash tables when machines are connected and re connected to the LAN.
(iii) It encrypts the frames for security reasons.

(A) (i), (ii)
(B) (ii), (iii)
(C) (i), (iii)
(D) (i), (ii), (iii)

Practice Problems 2

Directions for questions 1 to 15: Select the correct alternative from the given choices.

1. What does a routing algorithm perform?
(A) Decides if incoming packet should be further corrected for transmission errors
(B) Adds checksum bits to packets
(C) Encrypts the packets
(D) Decides the output line on which the incoming packet should be transmitted

2. What happens in session routing?
(A) User's session variables are managed by the network layer
(B) Route remains same throughout the user session
(C) Packets change their route for optimization sake during user session
(D) Provides special routes for important packets

3. What is the type of algorithm that changes their routing decision based on changes in topology and traffic?
(A) Adaptive routing
(B) Static routing
(C) Non-adaptive routing
(D) Network routing

4. Which of the below routing method always ensures the shortest path even though routers crash during course of routing?
(A) Dijkstra Routing
(B) Flooding
(C) Distance Vector Routing
(D) Link State Routing

5. What is the root cause for count-to-infinity problem?
(A) The routing tables are static and are not updated.
(B) The routing tables run out of space to accommodate more entries in table.
(C) When router *X* tells router *Y* that there is a path, it doesn't say if *Y* itself is in the path.
(D) When router *X* tells router *Y* that there is a path (to target route *Z*) it doesn't inform *Z* about the path.

6. In a strict sure security path ABCD, where A, B, C, D are routers, the maximum bandwidth is found to be 500 kbps, 700 kbps, 900 kbps, 300 kbps respectively. What is the effective bandwidth if no buffering is possible?
(A) 600 kbps (B) 900 kbps
(C) 300 kbps (D) 2400 kbps

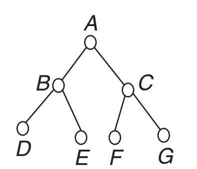
7. What is the characteristic of Distance Vector Routing?
(i) Time taken to reach other routers in the network is maintained in the routing tables.
(ii) Algorithm is susceptible to count-to-infinity problem.
(iii) The preferred outgoing line to be used for a particular destination is also stored in tables.
(A) (i), (ii) (B) (ii), (iii)
(C) (i), (iii) (D) (i), (ii), (iii)

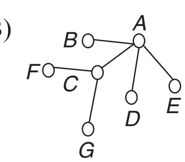
8. A subnet using link state algorithm has router, using link state packets with sequence of 16-bit fixed size. If a link state packet is sent every second, how long would it take before wrap around occurs. Assume starting sequence number is 0.
(A) 24.5 hours (B) 18.20 hours
(C) 17.5 hours (D) 16.4 hours

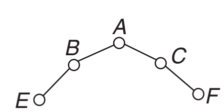
9. Which of the following are features of link state routing?
(i) In the first step discover all the routers in the subnet and find their network addresses.
(ii) Measure cost/delay to the neighbours.
(iii) Transmit the information as obtained in (ii) across the subnet.
(iv) Thus by pass the necessity for shortest path algorithm.
(A) (i), (ii) (B) (ii), (iii)
(C) (iii), (iv) (D) (i), (iv)

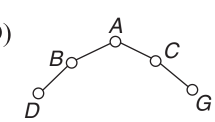
10. In multidestination routing,
(i) Each router makes new copies of the incoming packets.
(ii) It retains the same destination list in all copies.
(iii) It places them on appropriate outgoing lines.
(A) (i), (ii) (B) (ii), (iii)
(C) (iii), (i) (D) (i), (ii), (iii)

11. In a subnet which follows reverse path forwarding, routers *B* and *C* have received packets from *A* which have been further forwarded to *D* and *E* by *B* and to *F* and *G* by *C*. Of this *D*, *G* has always discarded the valid packets. Construct the preferred routing lines in the subnet.

(A)


(B)


(C)


(D)


12. Which of the following layers accept services from network layer and provides services to session layer?
(A) Data link layer
(B) Presentation layer
(C) Transport layer
(D) Physical layer.

13. Which of the below are different metrics for congestion?
(i) Packets discarded for lack of buffer space
(ii) Packets that are retransmitted
(iii) Average packet delay
(iv) Average queue length
(A) (i), (ii), (iii) (B) (ii), (iii), (iv)
(C) (iii), (iv), (i) (D) (i), (ii), (iii), (iv)

14. What are the ways to decrease congestion?
(i) Put spare routers to use
(ii) Increase bandwidth by routing on alternate lines
(iii) Increase the size of tables in the routers
(iv) Decrease the load
(A) (i), (ii), (iii) (B) (ii), (iii), (iv)
(C) (iii), (iv), (i) (D) (iv), (i), (ii)

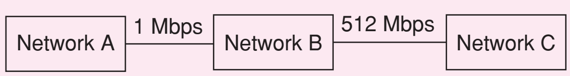
15. The algorithm which tells the routers to maintain certain data structures in their memories for congestion control is
(A) Resource Reservation Protocol.
(B) Fair queuing algorithm.
(C) Token bucket algorithm.
(D) None of these

Previous Years' Questions

Common data for questions 1 and 2: Consider three IP networks, *A*, *B* and *C*. Host H_A in network *A* sends messages each containing 180 bytes of application data to a host H_C in network *C*. The TCP layer prefixes a 20 byte header to the message. This passes through an intermediate network *B*. The maximum packet size, including 20 byte IP header, in each network is:

A: 1000 bytes
B: 100 bytes
C: 1000 bytes

The networks *A* and *B* are connected through a 1 Mbps link, while *B* and *C* are connected by a 512 Kbps link (bps = bits per second)



1. Assuming that the packets are correctly delivered, How many bytes, including headers, are delivered to the IP layer at the destination for one application message, in the best case? Consider only data packets. **[2004]**
(A) 200 (B) 220
(C) 240 (D) 260

2. What is the rate at which the application data is transferred to host H_C? Ignore errors, acknowledgements, and other over heads. **[2004]**
(A) 325.5 kbps (B) 354.5 kbps
(C) 409.6 kbps (D) 512.0 kbps

3. In a packet switching network, packets routed from source to destination along a single path having two intermediate nodes. If the message size is 24 bytes and each packet contains a header of 3 bytes, then the optimum packet size is: **[2005]**
(A) 4 (B) 6
(C) 7 (D) 9

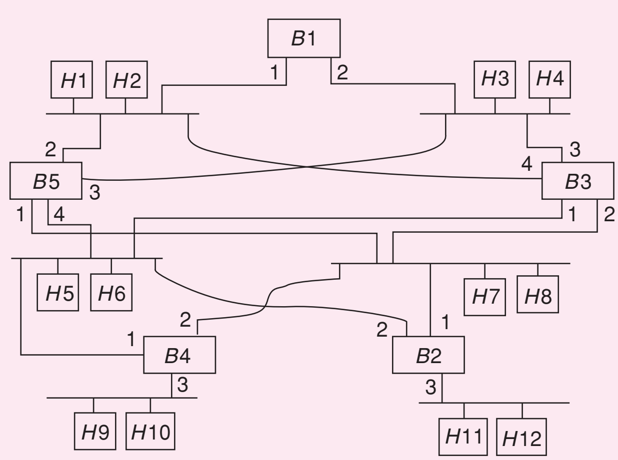
4. Suppose the round trip propagation delay for a 10 Mbps Ethernet having 48-bit jamming signal is 46.4 µs. The minimum frame size is: **[2005]**
(A) 94 (B) 416
(C) 464 (D) 512

5. Station *A* uses 32 byte packets to transmit messages to station *B* using a sliding window protocol. The round trip delay between *A* and *B* is 80 milliseconds and the bottleneck bandwidth on the path between *A* and *B* is 128 kbps. What is the optimal window size that *A* should use? **[2006]**
(A) 20 (B) 40
(C) 160 (D) 320

6. Station *A* needs to send a message consisting of 9 packets to station *B* using a sliding window (window size 3) and go-back-n error control strategy. All packets are ready and immediately available for transmission. If every 5th packet that *A* transmits gets lost (but no acks from *B* ever get lost), then what is the number of packets that *A* will transmit for sending the message to *B*? **[2006]**
(A) 12 (B) 14
(C) 16 (D) 18

Common data for questions 7 and 8: Consider the diagram shown, where a number of LANs are connected by (transparent) bridges. In order to avoid packets looping through circuits in the graph, the bridges organize themselves in a spanning tree. First, the root bridge is identified as the bridge with the least serial number. Next, the root sends out (one or more) data units to enable the setting up of shortest paths from the root bridge to each bridge.

Each bridge identifies a port (the root port) through which it will forward frames to the root bridge. Port conflicts are always resolved in favor of the port with the lower index value. When there is possibility of multiple bridges forwarding to the same LAN (But not through the root port), ties are broken as follows: bridges closest to the root get preference and between such bridges, the one with the lowest serial number is preferred.



7. For the given connection of LANs by bridges, which one of the following choices represents the depth first traversal of the spanning tree of bridges? **[2006]**
(A) B1, B5, B3, B4, B2 (B) B1, B3, B5, B2, B4
(C) B1, B5, B2, B3, B4 (D) B1, B3, B4, B5, B2

8. Consider the spanning tree for the previous question. let Host H1 send out a broadcast ping packet. Which of the following options represents the correct forwarding table on B3? **[2006]**

(A)

Hosts	Port
H1, H2, H3, H4	3
H5, H6, H9, H10	1
H7, H8, H11, H12	2

(B)

Hosts	Port
H1, H2	4
H3, H4	3
H5, H6	1
H7, H8, H10, H11, H12	2

(C)

Hosts	Port
H3, H4	3
H5, H6, H9, H10	1
H1, H2	4
H7, H8, H11, H12	2

(D)

Hosts	Port
H2, H2, H3, H4	3
H5, H7, H9, H10	1
H7, H8, 11, H12	4

9. In a token ring network the transmission speed is 10^7 bps and the propagation speed is 200 metres/μs. The 1-bit delay in this network is equivalent to: **[2007]**
(A) 500 metres of cable.
(B) 200 metres of cable.
(C) 20 metres of cable.
(D) 50 metres of cable.

10. In the slow start phase of the TCP congestion control algorithm, the size of the congestion window **[2008]**
(A) Does not increase
(B) Increases linearly
(C) Increases quadratically
(D) Increases exponentially

11. A computer on a 10 Mbps network is regulated by a token bucket. The token bucket is filled at a rate of 2 Mbps. It is initially filled to capacity with 16 Megabits. What is the maximum duration for which the computer can transmit at the full 10 Mbps? **[2008]**
(A) 1.6 seconds (B) 2 seconds
(C) 5 seconds (D) 8 seconds

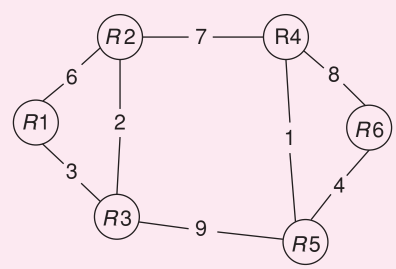
12. Let $G(x)$ be the generator polynomial used for CRC checking. What is the condition that should be satisfied by $G(x)$ to detect odd number of bits in error? **[2009]**
(A) $G(x)$ contains more than two terms
(B) $G(x)$ does not divide $1 + x^k$, for any k not exceeding the frame length
(C) $1 + x$ is a factor of $G(x)$
(D) $G(x)$ has an odd number of terms.

Common data for questions 13 and 14: Frames of 1000 bits are sent over a 10^6 bps duplex link between two hosts. The propagation time is 25 ms. Frames are to be transmitted into this link to maximally pack them in transit (within the link).

13. What is the minimum number of bits (l) that will be required to represent the sequence numbers distinctly? Assume that no time gap needs to be given between transmission of two frames. **[2009]**
(A) l = 2 (B) l = 3
(C) l = 4 (D) l = 5

14. Suppose that the sliding window protocol is used with the sender window size of 2^l, where l is the number of bits identified in the earlier part and acknowledgements are always piggy backed. After sending 2^l frames, what is the minimum time the sender will have to wait before starting transmission of the next frame? (Identify the closest choice ignoring the frame processing time.) **[2009]**
(A) 16 ms (B) 18 ms
(C) 20 ms (D) 22 ms

Common data for questions 15 and 16: Consider a network with 6 routers $R1$ to $R6$ connected with links having weights as shown in the following diagram

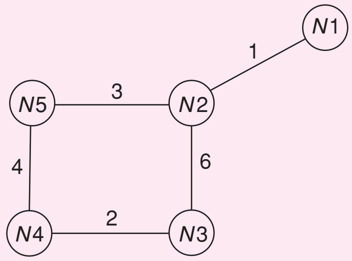


15. All the routers use the distance vector based routing algorithm to update their routing tables. Each router starts with its routing table initialized to contain an entry for each neighbour with the weight of the respective connecting link. After all the routing tables stabilize, how many links in the network will never be used for carrying any data? **[2010]**
(A) 4 (B) 3 (C) 2 (D) 1

16. Suppose the weights of all unused links in the previous question are changed to 2 and the distance vector algorithm is used again until all routing tables stabilize. How many links will now remain unused? **[2010]**

(A) 0 (B) 1 (C) 2 (D) 3

Common data for questions 17 and 18: Consider a network with five nodes, *N*1 to *N*5 as shown below.



The network uses a distance vector routing protocol. Once the routes have stabilized, the distance vectors at different nodes are as following.

*N*1 : (0, 1, 7, 8, 4)
*N*2 : (1, 0, 6, 7, 3)
*N*3 : (7, 6, 0, 2, 6)
*N*4 : (8, 7, 2, 0, 4)
*N*5 : (4, 3, 6, 4, 0)

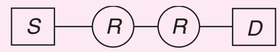
Each distance vector is the distance of the best known path at that instance to nodes, *N*1 to *N*5, where the distance to itself is 0. Also, all links are symmetric and the cost is identical in both directions. In each round, all nodes exchange their distance vectors with their respective neighbors. Then all nodes update their distance vectors. In between two rounds, any change in cost of a link will cause the two incident nodes to change only that entry in their distance vectors.

17. The cost of link *N*2-*N*3 reduces to 2 (in both directions). After the next round of updates, what will be the new distance vector at node, *N*3? **[2011]**
(A) (3, 2, 0, 2, 5) (B) (3, 2, 0, 2, 6)
(C) (7, 2, 0, 2, 5) (D) (7, 2, 0, 2, 6)

18. After the update in the previous question, the link *N*1-*N*2 goes down. *N*2 will reflect this change immediately in its distance vector as cost, ∞. After the NEXT ROUND of update, what will be the cost to *N*1 in the distance vector of *N*3? **[2011]**
(A) 3 (B) 9 (C) 10 (D) ∞

19. Consider an instance of TCP's Additive Increase Multiplicative Decrease (AIMD) algorithm where the window size at the start of the slow start phase is 2 MSS and the threshold at the start of the first transmission is 8 MSS. Assume that a timeout occurs during the fifth transmission. Find the congestion window size at the end of the tenth transmission. **[2012]**
(A) 8 MSS (B) 14 MSS
(C) 7 MSS (D) 12 MSS

20. Assume that source *S* and destination *D* are connected through two intermediate routers labeled *R*. Determine how many times each packet has to visit the network layer and the data link layer during a transmission from *S* to *D*. **[2013]**



(A) Network layer – 4 times and Data link layer – 4 times
(B) Network layer – 4 times and Data link layer – 3 times
(C) Network layer – 4 times and Data link layer – 6 times
(D) Network layer – 2 times and Data link layer – 6 times

21. Consider a selective repeat sliding window protocol that uses a frame size of 1 kB to send data on a 1.5 Mbps link with a one-way latency of 50 msec. To achieve a link utilization of 60%, the minimum number of bits required to represent the sequence number field is ______. **[2014]**

22. Consider the following three statements about link state and distance vector routing protocols, for a large network with 500 network nodes and 4000 links.
[*S*1] The computational overhead in link state protocols is higher than in distance vector protocols.
[*S*2] A distance vector protocol (with split horizon) avoids persistent routing loops, but not a link state protocol.
[*S*3] After a topology change, a link state protocol will converge faster than a distance vector protocol.
Which one of the following is correct about *S*1, *S*2 and *S*3? **[2014]**
(A) *S*1, *S*2 and *S*3 are all true
(B) *S*1, *S*2 and *S*3 are all false
(C) *S*1 and *S*2 are true, but *S*3 is false
(D) *S*1 and *S*3 are true, but *S*2 is false.

23. Let the size of congestion window of a TCP connection be 32 kB when a timeout occurs. The round trip time of the connection is 100 msec and the maximum segment size used is 2 kB. The time taken (in msec) by the TCP connection to get back to 32 kB congestion window is ______. **[2014]**

24. Which one of the following is TRUE about the interior gateway routing protocols-Routing information protocol (RIP) and Open Shortest Path First (OSPF)? **[2014]**
(A) RIP uses distance vector routing and OSPF uses link state routing
(B) OSPF uses distance vector routing and RIP uses link state routing
(C) Both RIP and OSPF use link state routing
(D) Both RIP and OSPF use distance vector routing

25. Consider the store and forward packet switched network given below. Assume that the bandwidth of each link is 10^6 bytes/sec. A user on host A sends a file of size 10^3 bytes to host B through routers R_1 and R_2 in three different ways. In the first case a single packet containing the complete file is transmitted from A to B. In the second case, the file is spilt into 10 equal parts, and these packets are transmitted from A to B. In the third case, the file is spilt into 20 equal parts, and these packets are sent from A to B. Each packet contains 100 bytes of header information along with the user data. Consider only transmission time and ignore processing, queuing and propagation delays. Also assume that there are no errors during transmissions. Let T_1, T_2 and T_3 be the times taken to transmit the file in the first, second and third case respectively. Which one of the following is CORRECT? **[2014]**

(A) $T_1 < T_2 < T_3$ (B) $T_1 > T_2 > T_3$
(C) $T_2 = T_3$, $T_3 < T_1$ (D) $T_1 = T_3$, $T_3 > T_2$

26. An IP machine Q has a path to another IP machine H via three IP routers R_1, R_2, and R_3.
$Q - R_1 - R_2 - R_3 - H$
H acts as an HTTP server, and Q connects to H via HTTP and downloads a file. Session layer encryption is used with DES as the shared key encryption protocol. Consider the following four pieces of information.
[*I*1] The URL of the file downloaded by Q
[*I*2] The TCP port numbers at Q and H
[*I*3] The IP addresses of Q and H
[*II*4] The link layer addresses of Q and H
Which of *I*1, *I*2, *I*3 and *I*4 can an intruder learn through sniffing at R_2 alone? **[2014]**
(A) Only *I*1 and *I*2 (B) Only *I*1
(C) Only *I*2 and *I*3 (D) Only *I*3 and *I*4

27. An IP router with a Maximum Transmission Unit (MTU) of 1500 bytes has received an IP packet of size 4404 bytes with an IP header of length 20 bytes. The values of the relevant fields in the header of the third IP fragment generated by the router for this packet are **[2014]**
(A) MF bit : 0, Datagram Length: 1444; Offset: 370
(B) MF bit: 1, Datagram Length : 1424; Offset: 185
(C) MF Bit: 1, Datagram Length: 1500; Offset: 370
(D) MF bit: 0, Datagram Length: 1424; Offset: 2960

28. Identify the correct order in which a server process must invoke the function calls accept, bind, listen, and recv according to UNIX socket API. **[2015]**
(A) listen, accept, bind, recv
(B) bind, listen, accept, recv
(C) bind, accept, listen, recv
(D) accept, listen, bind, recv

29. For a host machine that uses the token bucket algorithm for congestion control, the token bucket has a capacity of 1 megabyte and the maximum output rate is 20 megabytes per second. Token arrive at a rate to sustain output at a rate of 10 megabytes per second. The token bucket is currently full and the machine needs to send 12 megabytes of data. The minimum time required to transmit the data is _____ seconds. **[2016]**

30. Consider the following statements about the routing protocols. Routing Information Protocol (RIP) and Open Shortest Path First (OSPF) in an IPv4 network.
I: RIP uses distance vector routing
II: RIP packets are sent using UDP
III: OSPF packets are sent using TCP
IV: OSPF operation is based on link-state routing
Which of the statements above are CORRECT? **[2017]**
(A) I and IV only (B) I, II and III only
(C) I, II and IV only (D) II, III and IV only

Answer Keys

Exercises

Practice Problems 1

1. A **2.** D **3.** A **4.** B **5.** A **6.** A **7.** C **8.** B **9.** C **10.** C
11. B **12.** B **13.** B **14.** A **15.** A

Practice Problems 2

1. D **2.** B **3.** A **4.** B **5.** C **6.** C **7.** D **8.** B **9.** B **10.** C
11. C **12.** C **13.** D **14.** D **15.** A

Previous Years' Questions

1. D **2.** B **3.** D **4.** D **5.** B **6.** C **7.** C **8.** A **9.** C **10.** D
11. B **12.** C **13.** D **14.** B **15.** C **16.** B **17.** A **18.** C **19.** **20.** C
21. 5 **22.** D **23.** 1100 to 1300 **24.** A **25.** D **26.** C **27.** A **28.** B **29.** 1.1
30. C