Information

- This exam is for course codes IK2215, IK2204, and 2G1701
- The duration of the exam is 4 hours (14.00-18.00).
- Answers should be well structured and readable.
- Write your name and personal-id/date-of-birth on each page.
- No help material is allowed.
- Answers will be posted on the course web within 3 weeks after the exam.
- Results will be published no later than November 15, 2017. Requests for grading re-evaluations should be made according to the routines specified by KTH School of Information and Communication Technology.
- The exam consists of 2 parts; Part A and Part B. Part A is a set of questions with short answers. **Respect the word limits!** Answers longer than the word limit will be truncated, meaning that we will disregard from the part of your answer that exceeds the word limit during the exam marking. Part B is a smaller set of questions that require more elaborative answers. To pass the exam you need to attain a certain number of points (preliminary 75%) on Part A. Higher grades (A-C or 4-5) will be based on the total score (Part A + Part B). **Part B will not be graded for those who do not pass Part A.**
- Preliminary grading is as follows:

Points	**Grade (A-F)**
23-30 points on Part A and 45-50 points in total	A
23-30 points on Part A and 40-44 points in total	B
23-30 points on Part A and 35-39 points in total	C
23-30 points on Part A and 23-34 points in total	D
21-22 points on Part A and passed complementary assignment	E
21-22 points on Part A (complementary assignment offered)	Fx
0-20 points on Part A	F (Fail)

Points	**Grade (U-5)**
23-30 points on Part A and 42-50 points in total	5
23-30 points on Part A and 37-41 points in total	4
23-30 points on Part A and 23-36 points in total	3
21-22 points on Part A (complementary assignment offered)	U
0-20 points on Part A	U (Fail)

Good Luck!

Exam Part A (30p) (Note the word limits)

1) Various true/false statements (10p)

Mark the following statements as **true** or **false**. Don’t write “t” or “f”, since indistinct hand-writing makes it hard to differ between the two.
Note:

- you will get 1p for each correct answer
- you will get -1p for each wrong answer
- you will get 0p for each “no answer”
- you will **not** get less than 0p in total on this question

A. In RIP, a node sends link state advertisements to all other nodes in the same subnet. (1p)
B. UDP has an optional MTU (maximum transmission unit) discovery function. (1p)
C. BGP can use AS prepending to affect the routing of outgoing traffic. (1p)
D. MSDP can be used to interconnect multiple IPv4 PIM-SM domains. (1p)
E. Greenhouse gas (GHG) emissions from ICT are far below the GHG emissions levels from the aviation industry. (1p)
F. To avoid maintaining flow state in routers, diff-serv (Differentiated Services) aggregates traffic flows into traffic classes and allocate resources on a per-class basis. (1p)
G. In IPv6, fragmentation can only occur in the sending host since routers are not allowed to fragment IPv6 datagrams. (1p)
H. IGMP is a multicast routing protocol used to build delivery trees for multicast packets in the Internet. (1p)
I. The main purpose of RTP (Real-time Transport Protocol) is to provide time-stamps and sequence numbers when sending real-time data. (1p)
J. 6LowPAN is an adaptation layer designed for making it possible to run IPv6 on low-power constrained devices. (1p)

Answer:

A. False
B. False
C. False
D. True
E. False
F. True
G. True
H. False
I. True
J. True

2) Various questions with short answers (10p)

Answer the following questions with short answers.
Note:

- You will get 1p for each entirely correct answer
- Word limit per question: 30 words

A. Place the following four protocols at the correct layer in the TCP/IP protocol stack: FTP, SCTP, IGMP, and RPL. (1p)

B. Assume you aggregate the prefixes 189.1.2.0/26 and 189.1.2.64/26, and 189.1.2.128/25 to one single subnet. Specify (in CIDR notation) the resulting aggregated prefix. (1p)
C. A TCP sender maintains both a receiver-advertized window and a congestion window. Assume that these two have different sizes. Which one will then be used as sender window?
D. What mechanism do CDNs typically use to allow users to find the most suitable server? (1p)
E. What type of data structure is used by BitTorrent (and other peer-to-peer applications) to map file IDs to locations? (1p)
F. An IP multicast packet arrives to a router and the router does reverse path forwarding. What address does the router then use for lookup in the forwarding table? (1p)
G. Is the EEE (Energy-Efficient Ethernet) standard based on rate switching (switch to lower tranimssion rate when possible) or low-power idle (sleep between packets when possible)? (1p)
H. Assume that a network uses OSPF and is divided into three areas (area 0, 1, and 2). An OSPF router in area 1 sends an LSA. To which routers will it send this LSA? (1p)
I. What was the main purpose with IPv6? (1p)
J. BGP uses a path vector when it advertizes routes. What does that mean? (1p)

Answers

A. FTP: Application layer, SCTP: Transport layer, IGMP: Network layer, RPL: Network layer.
B. 189.1.2.0/24.
C. The smallest of the two (swnd=min{rwnd,cwnd}).
D. DNS redirection.
E. A distributed hash table.
F. The source address of the multicast packet.
G. EEE uses low-power idle.
H. To all routers in OSPF area 1.
I. To increase the address space (moving from 32-bit addresses to 128-bit addresse).
J. BGP assigns a cost and a path to each route it advertizes.

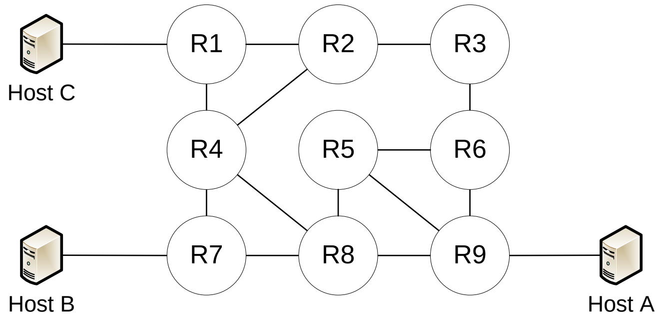
3) Internet-of-Things (2p) (Word limit: 120)

Explain what “constrained devices” means in the context of Internet-of-Things.

Answer:

Internet-of-Things is about connecting “non-computers” to the Internet. In contrast to regular computers, IoT devices are constrained in the sense that they are small units with very limited memory and CPU resources. IoT devices often have tiny operating systems with limited functionality and they need low-power communication technology.

4) Multicast Routing (2p) (Word limit: 50)



In the topology above, host A is multicasting a video stream to two receivers: host B and host C. Assume that the cost is 1 for each of all the links. Identify the path that multicast packets will take from node A to each receiver in scenarios when the following multicast trees are used:

A. A source based tree.
B. A group shared tree with R3 as a rendezvous point.

Example answer:

Host A -> Rx -> Ry -> Host B

Answer:

A. Host A -> R9 -> R8 -> R7 -> Host B
   Host A -> R9 -> R8 -> R4 -> R1 -> Host C
B. Host A -> R9 -> R6 -> R3 -> R2 -> R4 -> R7 -> Host B
   Host A -> R9 -> R6 -> R3 -> R2 -> R1 -> Host C

5) Interdomain routing (2p) (Word limit: 50)

Compare RIP and OSPF when it comes their different properties. Use the table below and identify which of the protools (RIP or OSPF) that best matches the given property. Redraw the table on your answer sheet and fill in the protocol column.

Property	**Protocol**
Has very limited scalability	
Uses flooding	
Uses only hop count metric	
Has network topology knowledge	
Has shortest convergence time	

Answer:

Property	**Protocol**
Has very limited scalability	RIP
Uses flooding	OSPF
Uses only hop count metric	RIP
Has network topology knowledge	OSPF
Has shortest convergence time	OSPF

6) Multimedia networking (2p) (Word limit: 60)

a) A programmer is about to implement an application for streaming of stored multimedia content. She selects TCP as the transport protocol. Explain why that might be a good choice. (1p)
b) Her application includes both a web client and a media player. What is the purpose with each of these parts? (1p)

Answer:

a) Firewalls often block UDP traffic. TCP will ensure that the complete file is downloaded without errors and it can then be cached locally at the receiver.
b) The web client is used to request information and the media player is for display and control of the audio/video.

7) Peer-to-peer networking (2p) (Word limit: 100)

Kazaa (and several other peer-to-peer applications) uses a distributed hash table (DHT). What is the DHT used for and why should the hash table be distributed?

Answer:

The DHT is used for mapping file identifiers (names) to locations (IP addresses). By making the hash table distributed, the method scales very well with an increasing number of users and single point of failures are avoided.

Exam Part B (20p)

8) Internet-of-Things (5p)

Make a detailed comparison between CoAP and MQTT and point out similarities and differences between these two protocols. You should consider things like overall purpose, message formats, transport protocol used, communication models, etc.

Answer:

MQTT and CoAP are both application layer protocols designed for IoT devices. They are both supposed to be suitable for implementations in tiny operating systems for IoT devices. CoAP implementations in particular can have a very small memory footprint.

MQTT uses TCP as transport protocol (a variant of called MQTT-SN using UDP also exists) and is based on a publish-subscribe model. With publish-subscribe, the sensors can publish data to a broker whenever they wake up and have some data to share. The users will interact with the broker, which can be hosted on a server-like machine capable of serving large amounts of user requests.

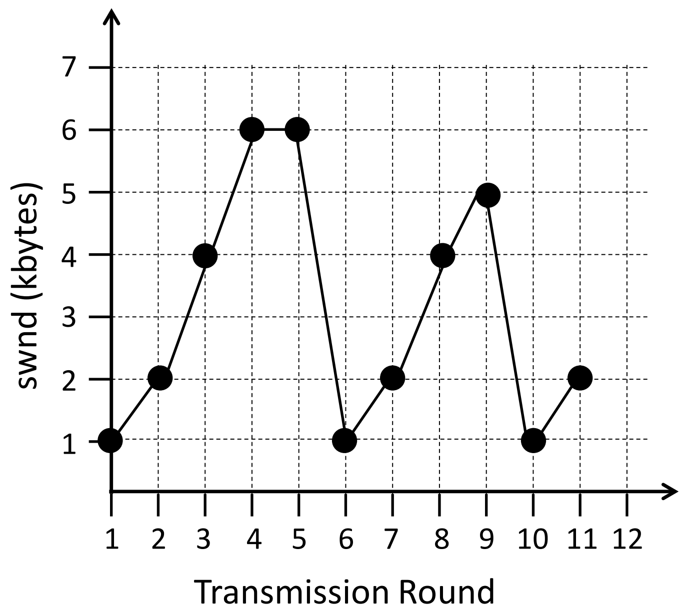
CoAP uses UDP as transport protocol and is originally designed more like a client-server model using URI:s (such as coap://example.se:5683/~sensors./temp1.xml) to access the sensor data. As of last year a publish-subscribe communication model for CoAP has been suggested and is on its way to be standardized in IETF. CoAP has a small message size to fit in a minimum IPv6 MTU size.

9) Transport layer (5p)

A user opens up an FTP session against a file server to download a file of size 31 kB (31 000 bytes). The file server has a receive window (rwnd) of 6 kB, and the maximum segment size (MSS) is 1 kB. Both the client host and the file server use the Tahoe version of TCP, i.e., neither fast retransmit nor fast recovery is supported. The FTP session experiences two packet losses: The first packet loss happens during the fifth transmission round, and the second packet loss during the ninth round. Draw a graph that shows the size of the send window (swnd) as a function of transmission round. And, on the basis of your graph, calculate how many transmission rounds it takes to download the file.

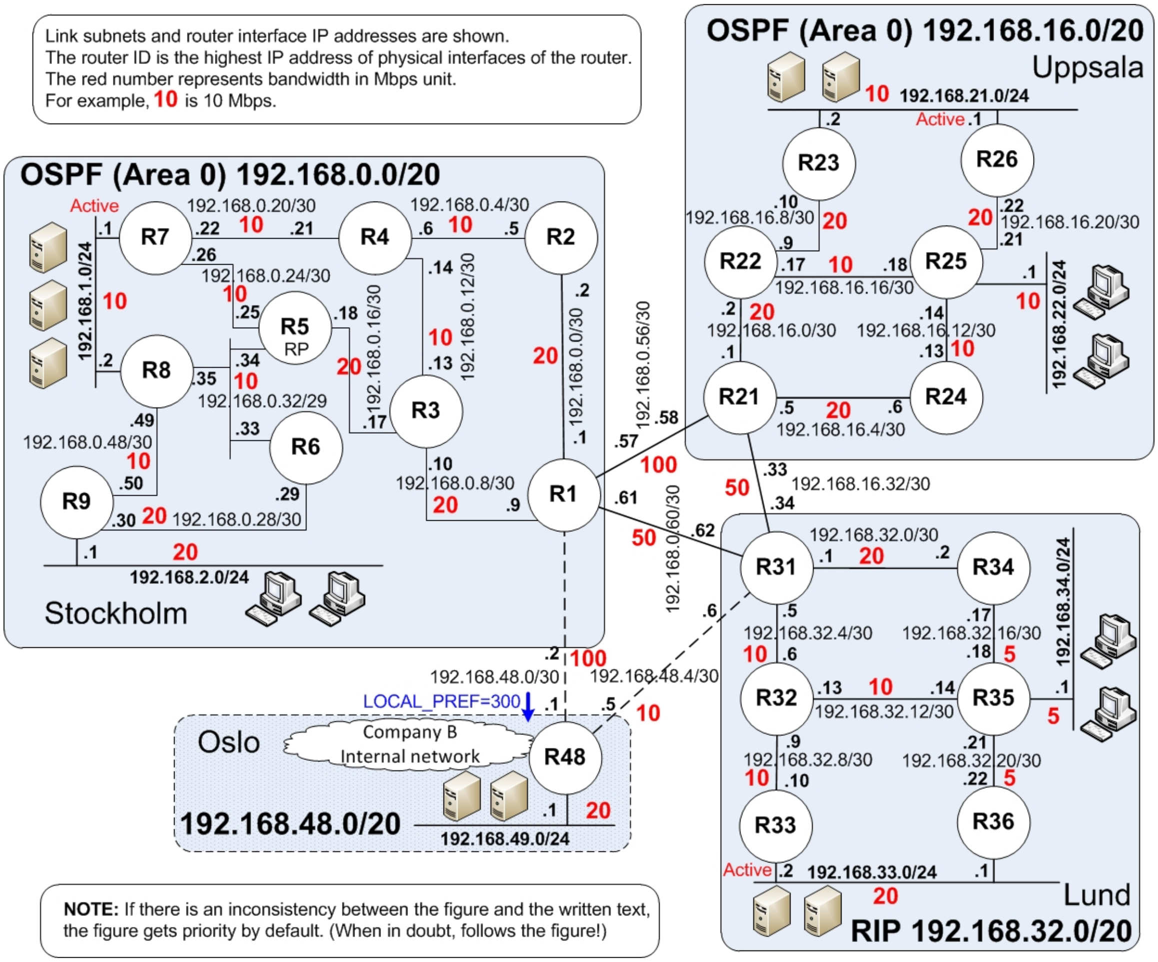
Answer:

Graph that shows swnd = f(transmission round).



Let S(r) denote the sum of the send windows up to and including round *r*. The time it takes to download the file is then equal to the least *r* such that S(r) ≥ 31 kbytes. From the graph follows that S(9) = 1 + 2 + 4 + 6 + 6 + 1 + 2 + 4 + 5 = 31 kbytes, thus *r* = 9 is the least *r* such that S(r) ≥ 31 kbytes.

10) Large-scale network scenario (10p)



The above figure illustrates Company A's network topology. Company A has three branch offices in different cities, each with different networks. The first office is located in Stockholm using the 192.168.0.0/20 subnet. The second office is located in Uppsala using the 192.168.16.0/20 subnet. The last office is located in Lund using the 192.168.32.0/20 subnet. All routers are interconnected with different link bandwidths as shown in the figure. All routers are Cisco routers with default parameters set.

Each office has designed its own internal network and runs its own routing protocol internally. The Stockholm office uses OSPF as its sole routing protocol within its network. All routers (R1-R9) are running in the backbone area (OSPF area 0). Similar to the Stockholm office, the Uppsala office uses OSPF as its sole routing protocol within its network (on routers R21-R26). All routers are running in the backbone area (OSPF area 0). The Lund office uses RIPv2 on all its routers (R31-36). These routing protocols are not running on the links between the offices (no OSPF or RIP on the R1-R21 link, the R21-R31 link, or the R1-R31 link). However, different routing schemes are used for communication between branch offices.

Static route commands are configured as follows:

On R21: ip route 192.168.32.0 255.255.240.0 192.168.16.34
On R31: ip route 0.0.0.0 0.0.0.0 192.168.16.33

Company A runs two iBGP peerings as follows:
between Stockholm's R1 and Uppsala's R21 (over R1-R21 link)
between Stockholm's R1 and Lund's R31 (over R1-R31 link)

All routers run iBGP peering with private AS 65001 and have "no auto-summary" and "no synchronization" commands configured. They also have the following route advertisements:

R1 is configured to generate an aggregate address 192.168.0.0/18 (**IMPORTANT**: R1 uses **/18** here!) and advertises it to all BGP peers with "summary-only". Similarly, R21 advertises an aggregate address 192.168.16.0/20 with "summary-only" while R31 advertises an aggregate address 192.168.32.0/20 with "summary-only".

In addition, the Stockholm office has configured R1 to redistribute BGP routes into OSPF. The Uppsala office has configured R21 to always originate default route in OSPF. The Lund office has configured to redistribute static routes into RIP on R31.

The Stockholm office has one server network (192.168.1.0/24) and one user network (192.168.2.0/24). HSRP (Hot Standby Router Protocol) is used to provide fault-tolerant default gateway for the server network. R7 is active router and R8 is passive router. The virtual IP address is 192.168.1.3, which is used as the default gateway by all servers.

The Uppsala office has one server network (192.168.21.0/24) and one user network (192.168.22.0/24). HSRP is used to provide fault-tolerant default gateway for the server network. R26 is active router and R23 is passive router. The virtual IP address is 192.168.21.3, which is used as the default gateway by all servers.

The Lund office has one server network (192.168.33.0/24) and one user network (192.168.34.0/24). HSRP is used to provide fault-tolerant default gateway for the server network. R33 is active router and R36 is passive router. The virtual IP address is 192.168.33.3, which is used as the default gateway by all servers.

All hosts and servers have the default route configured to the immediate router that they are connected to. In case of the segment with HSRP routers, the default route is set to the virtual IP address.

Assume that default cost models are used for OSPF, RIP, as well as for static routes (a static route has a fixed cost of 1, OSPF cost formula is *cost = <100,000,000 bps>/<bandwidth in bps>*). When a route is redistributed from one protocol to the other, the original cost of the route will be accumulated into the new protocol before the route is forwarded to other routers. For BGP originated routes, the cost will be set to 10. In addition, if a router learns the same route from different routing protocols, it will prefer the route from the routing protocol in the following order: static, eBGP, OSPF, RIP, and iBGP. If a router learns a route with equal cost from the same routing protocol through multiple routers, it will prefer to use the route from the router with the lowest router ID. For example, if R51 (router ID

1.1.1.1) learns an OSPF route 10.0.0.0/24 from R55 (router ID 2.2.2.2) and R60 (router ID 3.3.3.3), it will prefer to use the OSPF route learned from R55 since its router ID 2.2.2.2 is lower than R60 (router ID 3.3.3.3). The router ID is the highest IP address on physical interfaces. The virtual IP address is not considered when deciding the router ID.

Assume that the topology has converged. Answer the following questions:

A. What path does a packet traverse when a host in Stockholm with IP address 192.168.2.11 sends an ICMP echo request to a server in Uppsala with IP address 192.168.21.5? (1p)
B. What path does a packet traverse when a host in Uppsala with IP address 192.168.22.11 sends an ICMP echo request to a server in Lund with IP address 192.168.33.5? (1p)
C. What path does a packet traverse when a host Lund with IP address 192.168.34.11 sends an ICMP echo request to a server in Stockholm with IP address 192.168.1.5? (1p)

IMPORTANT: You must specify the next-hop IP address of every hop the packet traverses. If the ICMP echo request cannot reach the destination then identify what happens to the request.
Example answer
10.0.0.11 -> 10.0.0.1 -> 10.0.1.1 -> 10.0.2.2 -> 10.0.3.3
1.1.1.1 -> 1.1.1.2 -> 2.2.2.2 -> 3.3.3.3 -> R77 drops the packet
4.4.4.4 -> 4.4.4.5 <-> 5.5.5.5 (Loop between R88 and R89!)

Assume that the physical link between Uppsala and Lund (on R21-R31 link) was taken down and the border routers lose all routing information on this link. All routes on this link (including static routes) are removed from the routing tables. Assume that the topology has converged. Answer the following questions:

D. What path does a packet traverse when a server in Uppsala with IP address 192.168.21.5 sends an ICMP echo request to a host in Lund with IP address 192.168.34.5? (1p)
E. What path does a packet traverse when a server in Lund with IP address 192.168.33.5 sends an ICMP echo request to a host in Uppsala with IP address 192.168.22.5? (1p)

IMPORTANT: if the ICMP echo request cannot reach the destination then identify what happens to the request. See example answer above.

Assume that the R21-R31 link is back to normal and the original topology in the figure has converged. A network administrator would like to run a multicast routing protocol in order to distribute a video from a streaming server (IP 192.168.1.9/24) in the Stockholm office to all users in all branch offices. PIM sparse mode is used for this purpose and R5 is selected as a rendezvous point (RP).

To avoid confusion caused by having two routers on the network (HSRP routers), assume that the links between the passive routers and the server networks in each office are removed from the topology (R8-192.168.1.0/24 link, R23-192.168.21.0/24 link, and R36-192.168.33.0/24 link). The routers have HSRP configuration in tact (all virtual IP addresses are still in used) and they have the same router ID as when the passive links were still intact.

Assuming that the SPT-threshold is set to inifinity (the threshold is never exceeded). Answer the following questions:

F. Which path is used for streaming from the streaming server to a host with IP 192.168.22.10 in Uppsala office? (1p)
G. Which path is used for streaming from the streaming server to a host with IP 192.168.34.10 in Lund office? (1p)

Assume the topology is the same as for question F and G above. (All passive routers are still disconnected from the networks). The routers have the same router ID as when the passive links were still intact.

Company A has bought company B in Oslo and decided to connect company B office to Company A's network with two physical links; one from Oslo to Stockholm (R48-R1 link) and another from Oslo to Lund (R48-R31 link). To keep the internal routing policy of Company B intact, the network administrator decided to use BGP as the routing protocol on these links. Company B is assigned a private AS 65002 and runs two eBGP peering sessions with AS 65001; one with R1 in Stockholm and another with R31 in Lund. R48 is configured with "no auto-summary", "no synchronization", and using 192.168.49.1 as its router-id. It is also configured to advertise only an aggregate address 192.168.48.0/20 to all BGP peers with "summary-only" (longer-prefix routes are suppressed and NOT advertised). R48 also redistribute all BGP learned routes into its internal network. In addition, R48 has a BGP policy to set LOCAL_PREF to 300 on all routes learned via R48-R1 link.

Assuming that the existing iBGP configurations on R1, R21, and R31 as described earlier are still in place.
Then, R1 and R31 each adds the following configurations:

- eBGP peering with R48
- "next-hop-self" command for all iBGP peering

Assume that the topology has converged. Answer the following questions:

H. What path does a packet traverse when a host in Lund with IP address 192.168.34.5 sends an ICMP echo request to a server in Oslo with IP address 192.168.49.5? (1p)
I. What path does a packet traverse when a server in Oslo with IP address 192.168.49.5 sends an ICMP echo request to a server in Uppsala with IP address 192.168.21.5? (1p)
J. What path does a packet traverse when a server in Oslo with IP address 192.168.49.5 sends an ICMP echo request to a server in Lund with IP address 192.168.33.5? (1p]

IMPORTANT: if the ICMP echo request cannot reach the destination then identify what happens to the request. See example answer above.

Answer:

A. 192.168.2.11 -> 192.168.2.1 -> 192.168.0.29 -> 192.168.0.34 -> 192.168.0.17 -> 192.168.0.9 -> 192.168.0.58 -> 192.168.16.2 -> 192.168.16.10 -> 192.168.21.5
B. 192.168.22.11 -> 192.168.22.1 -> 192.168.16.13 -> 192.168.16.5 -> 192.168.16.34 -> 192.168.32.6 -> 192.168.32.10 -> 192.168.33.5

C. 192.168.34.11 -> 192.168.34.1 -> 192.168.32.13 -> 192.168.32.5 -> 192.168.0.61 -> 192.168.0.10 -> 192.168.0.18 -> 192.168.0.26 -> 192.168.1.5
D. 192.168.21.5 -> 192.168.21.3 -> 192.168.16.21 -> 192.168.16.13 -> 192.168.16.5 -> 192.168.0.57 -> 192.168.0.62 -> 192.168.32.6 -> 192.168.32.14 -> 192.168.34.5
E. 192.168.33.5 -> 192.168.33.3 -> R33 drops the packet (no route to other branches since static route is not redistributed into RIP)
F. 192.168.1.9 -> 192.168.1.3 -> 192.168.0.25 -> 192.168.0.17 -> 192.168.0.9 -> 192.168.0.58 -> 192.168.16.6 -> 192.168.16.14 -> 192.168.22.10
G. 192.168.1.9 -> 192.168.1.3 -> 192.168.0.25 -> 192.168.0.17 -> 192.168.0.9 -> 192.168.0.62 -> 192.168.32.6 -> 192.168.32.14 -> 192.168.34.10
H. 192.168.34.5 -> 192.168.34.1 -> 192.168.32.13 -> 192.168.32.5 -> 192.168.48.5 -> 192.168.49.5
I. 192.168.49.5 -> 192.168.49.1 -> 192.168.48.2 -> 192.168.0.58 -> 192.168.16.6 -> 192.168.16.14 -> 192.168.16.22 -> 192.168.21.5
J. 192.168.49.5 -> 192.168.49.1 -> 192.168.48.2 -> 192.168.0.62 -> 192.168.32.6 -> 192.168.32.10 ->192.168.33.5

You may remove this page from the exam and use it as your own note page