Information

- This exam is for course codes IK2215, IK2204, and 2G1701
- The duration of the exam is 4 hours (9.00-13.00).
- 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 2 weeks after the exam.
- Results will be published in Daisy no later than November 7, 2012. Graded exams can be found as PDF files in Daisy. Complaints about the grading should be done in writing, and sent to IK2215@ict.kth.se, no later than November 21, 2012.
- 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 OSPF, each node has knowledge about the network topology. (1p)
B. UDP provides a connectionless best-effort service. (1p)
C. BGP uses UDP as the transport service to reduce complexity. (1p)
D. TCP does not provide cumulative acknowledgments. (1p)
E. One of the responsibilities of ICMP is to correct errors related to the operation of IP. (1p)
F. In IP QoS, the term "policing" means to ensure that a traffic flow conforms to the traffic specification. (1p)
G. In IPv6, only the sender of an IP datagram is allowed to do fragmentation. (1p)
H. A multicast router is said to listen promiscuously to all multicast addresses. (1p)
I. Streaming stored video over HTTP/TCP can be preferred over streaming over UDP since firewalls often block UDP. (1p)
J. BitTorrent does not support uploading while downloading.(1p)

Answer:

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

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. Name the five different layers in the TCP/IP protocol stack in correct order, starting with the top-most layer. (1p)
B. The prefixes 199.1.1.0/26, 199.1.1.64/26, 199.1.1.128/26 and 199.1.1.192/26 are aggregated. Specify (in CIDR notation) the resulting aggregated prefix. (1p)
C. What does fast retransmit mean in TCP? (1p)
D. What is the main task of a CDN distribution node? (1p)
E. Give one example (abbreviation is enough) of a multicast routing protocol that uses source-based trees. (1p)

F. Mention two important things that RTP (Real-time Transport Protocol) provides to build a real-time service on top of UDP. (1p)
G. What do we call the mechanism that BitTorrent uses to favor "good" peers? (1p)
H. An OSPF router sends an LSA (Link State Advertisement). What routers are the ultimate receivers of this LSA? (1p)
I. Mention two different strategies that IETF has devised for the transition from IPv4 to IPv6. (1p)
J. What does it mean that RSVP maintains "soft state" in hosts and routers? (1p)

Answer:

A. Application, Transport, Network, Link, Physical
B. 199.1.1.0/24
C. That a packet should be retransmitted after three duplicate ACKs.
D. To replicate content and push it to selected CDN servers.
E. DVMRP, MOSPF, PIM-DM.
F. Sequence numbers and timestamps.
G. Tit-for-tat exchange.
H. All other OSPF routers in the network (or within the area).
I. Dual stacks, tunneling, header translation.
J. That any state will automatically expire unless it is refreshed periodically.

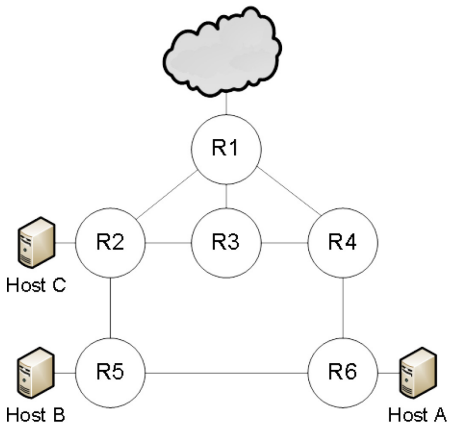
3) Transport layer (2p) (Word limit: 50)

One of the underpinning principles behind TCP congestion control is the so-called "self-clocking" principle. Briefly explain the meaning of this principle.

Answer:

The answer should include the key observation that in equilibrium, the acknowledgements return to the sender at about the rate that packets can be sent over the slowest link in the path.

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. R1 is the rendezvous point of this multicast domain. Identify the path for the 1st and 2nd multicast packets from node A to each receiver when the routers are using PIM sparse-mode and the

threshold to switch to source-based tree is 0. Name the approach used in the multicast routing tree (source-based tree or group-shared tree) for each path.

Example answer:

N packet (x-based tree)

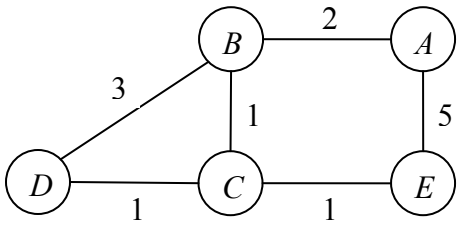
Host A -> Rx -> Ry -> Host B

Answer:

1st packet: (group-shared tree)
Host A -> R6 -> R4 -> R1 -> R2 -> R5 -> Host B
Host A -> R6 -> R4 -> R1 -> R2 -> Host C
2nd packet: (source-based tree)
Host A -> R6 -> R5 -> Host B
Host A -> R6 -> R5 -> R2 -> Host C

5) Link state routing (2p) (Word limit: 100)

Assume a network according to the figure below. Use the shortest path first principle according to Dijkstra's algorithm to compute the best route from A to all other nodes in the network. Your solution should show the steps taken in the execution of the algorithm.



Answer:

M	D_B (Path)	D_C (Path)	D_D (Path)	D_E (Path)
{A}	2 (A-B)	–	–	5 (A-E)
{A, B}	2 (A-B)	3 (A-B-C)	5 (A-B-D)	5 (A-E)
{A, B, C}	2 (A-B)	3 (A-B-C)	4 (A-B-C-D)	4 (A-B-C-E)
{A, B, C, E}	2 (A-B)	3 (A-B-C)	4 (A-B-C-D)	4 (A-B-C-E)
{A, B, C, E, D}	2 (A-B)	3 (A-B-C)	4 (A-B-C-D)	4 (A-B-C-E)

6) Peer-to-peer networking? (2p) (Word limit: 50)

BitTorrent makes use of a technique called "speculative upload". What are the two main purposes for using speculative upload?

Also, mention a disadvantage/risk with speculative upload.

Answer:

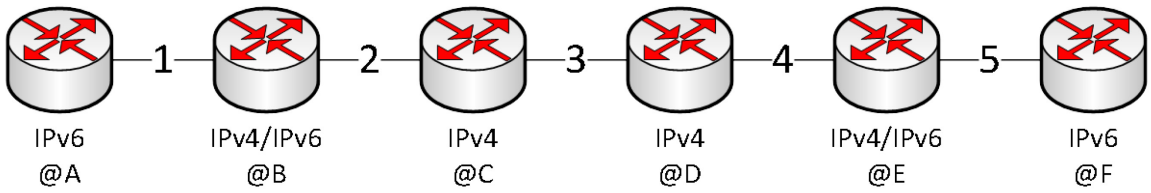
The two main purposes with speculative upload are:
1) To find better peers
2) To give new peers a chance to join

A disadvantage with speculative upload is that it can be exploited by free-riders.

7) IPv6 (2p) (Word limit: 100)

Tunneling is considered one of the approaches to ease the transition from IPv4 to IPv6.

A. Briefly explain the idea behind tunneling.
B. Illustrate the packet encapsulation in each segment of the following figure. Your illustration needs to show addresses (@A,@B, etc), payload and type of packet (IPv6 or IPv4).



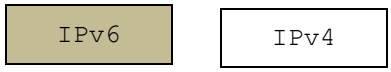
Answer:

Tunneling approach uses an encapsulation technique to put one network packet as a payload for another network packet so that the original packet can be delivered over an incompatible network.

1: IPv6

2, 3 and 4: IPv4

5: IPv6



Exam Part B (20p)

8) Quality of service in IP networks (5p)

Suppose that the following flows, specified with token bucket traffic specifications, have been accepted by an int-serv (Integrated Services) capable router:

Flow #	R (rate in packets/second)	B (bucket depth in no of packets)
1	2	10
2	5	8
3	8	7
4	6	15

All flows are in the same direction and the router forwards 40 packets per second. Note that the example is unrealistic in its use of packets, instead of bytes.

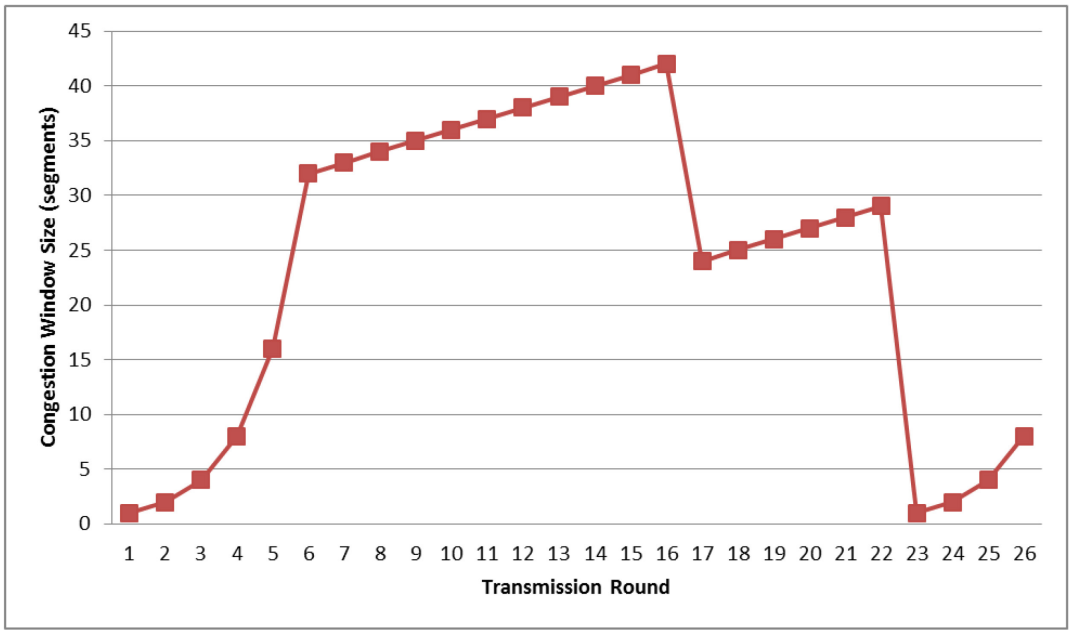
A. What is the maximum delay a packet may face? Show your calculations. (2p)
B. What is the maximum number of packets from the fourth flow (r = 6, B = 15) that the router would send over 4.0 seconds, assuming the router sends packets at its maximum rate uniformly? Show your calculations. (1p)
C. What are the main drawbacks with the integrated service model for IP quality of service? (2p)

Answer:

A. Max delay is given by max queue length, which is the sum of all buckets. B_{tot} = 10+8+7+15 = 40. Max delay = B_{tot}/link capacity = 40/40 = 1 second.
B. Max no of packets over 4 seconds for the third flow = rT + B = 6x4 + 15 = 39 pkts.
C. The end-to-end connection set-up and the resource reservations on a per flow basis make int-serv very unpractical (impossible) to scale. There could literally be millions of flows to keep track of, each requiring its own buffer. The required state per flow in each router along the path is very costly for routers.

9) Transport protocol (5p)

Consider the figure below. The figure shows the evolution of the congestion window of TCP Reno, i.e., TCP with both fast retransmit and recovery.

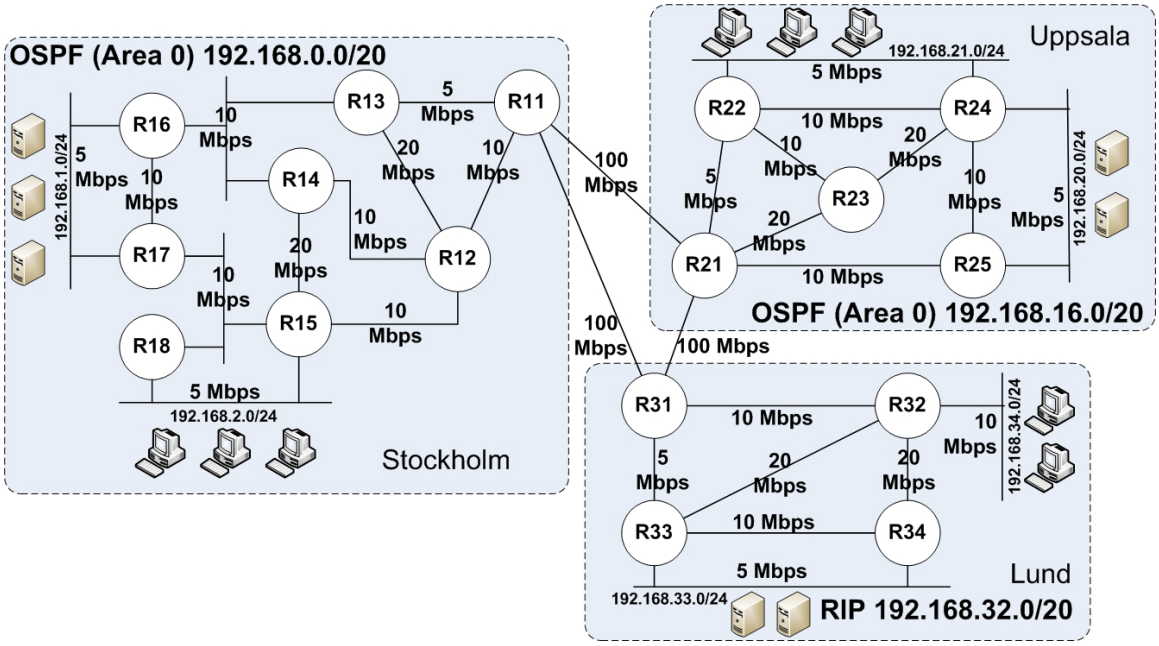


A. Identify the intervals when TCP Reno is in slow start and congestion avoidance, respectively. (1p)
B. During the 16th transmission round, TCP Reno experiences a packet loss. How does it detect the packet loss: through timeout or the reception of three duplicate acknowledgements? (1p)
C. What is the initial size of the slow-start threshold, i.e., the size of the slow-start threshold at the beginning of the first transmission round? (1p)
D. What is the size of the slow-start threshold at the beginning of the 17th transmission round? (2p)

Answer:

A. Slow start: [1,6] and [23,26], congestion avoidance: [6,16] and [17,22].
B. TCP Reno detects the packet loss through the reception of three duplicate acknowledgements.
C. The initial slow-start threshold is 32 segments, since slow-start ends at round 5, i.e., when the congestion window is 2^5 or 32 segments.
D. The slow-start threshold is set to half the value of the congestion window at the time the packet loss is detected, i.e., 42 segments / 2 = 21 segments.

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 (R11-R18) 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-R25). All routers are running in the backbone area (OSPF area 0). On the other hand, the Lund office uses RIPv2 on all its routers (R31-34). These routing protocols are not running on the links between the offices! (no OSPF or RIP on R11-R21 link, R21-R31 link, and R31-R11 link). However, different routing schemes are used for communication between branch offices.

Static routes are configured on the following routers as follows:
On R11, traffic to 192.168.32.0/20 forwards to R31.
On R21, set default route (0.0.0.0/0) to forward to R31.
On R31, there are two static routes
1) all traffic destined to 192.168.16.0/20 forwarded to R21
2) Set default route to forward to R11

In addition, BGP is used between R11 and R21 (over R11-R21 link). Both routers run BGP with private AS 65001 and the following route advertisements:

On R11, advertise aggregate address 192.168.0.0/20 with summary-only as well as advertise network 192.168.32.0/20 (R11 will advertise this prefix as long as it exists in the routing table).
On R21, redistribute ospf routes into BGP.

In addition, the Stockholm office is configured to redistribute BGP routes into OSPF on R11. The Uppsala office has configured R21 to always originate default route in OSPF. The Lund office has configured R31 to redistribute all static routes into RIP.

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-tolerance default gateway for each network. For the server network, R16 is active router and R17 is passive router. For the user network, R18 is active router and R15 is passive router.

The Uppsala office has one server network (192.168.20.0/24) and one user network (192.168.21.0/24). HSRP is used to provide fault-tolerance default gateway for each network. For the server network, R25 is active router and R24 is passive router. For the user network, R22 is active router and R24 is passive router.

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-tolerance default gateway for the server network. R34 is active router and R33 is passive router.

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 inherited to the new protocol and accumulated with the new cost before the route is forwarded to other routers. For BGP routes, the cost will be set to 100 when redistribute to other protocols. 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, 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 number. For example, if R51 learns a route 10.0.0.0/24 from R55 and R60, it will prefer to use the route learned from R55.

A host in Lund with IP address 192.168.34.5 is trying to ping a server in Stockholm with IP address 192.168.1.2. Answer the following questions:

A. What path does an ICMP echo request take? (1p)
B. What path does an ICMP echo reply take? (1p)

Example answer
10.0.0.1 -> RTX -> RTY -> RTZ -> 10.0.0.2

A host in Stockholm with IP address 192.168.2.3 is trying to ping a server in Uppsala with IP address 192.168.20.2. Answer the following questions:

C. What path does an ICMP echo request take? (1p)
D. What path does an ICMP echo reply take? (1p)

Example answer
10.0.0.1 -> RTX -> RTY -> RTZ -> 10.0.0.2

Assume that a link between Uppsala and Lund (R21-R31 link) became faulty. Despite the fact that the link layer is still up and active, it lost IP connectivity. After the topology has converged, a host in Uppsala with IP address 192.168.21.3 is trying to ping a server in Lund with IP address 192.168.33.3. Answer the following questions:

E. What path does an ICMP echo request take? (1p)
F. What path does an ICMP echo reply take? (1p)

Example answer
10.0.0.1 -> RTX -> RTY -> RTZ -> 10.0.0.2

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 broadcast recorded multimedia, stored on a streaming server (IP 192.168.1.9/24) in the Stockholm office, to all users in all branch offices.
Answer the following questions:

G. Assume that you are using PIM sparse mode to distribute your multicast stream, R13 is selected as a rendezvous point (RP). If the SPT-threshold is set very high and never exceeded, identify which path that will be used for streaming from the streaming server to the different hosts in each office according to a-b below.
   To avoid confusion caused by having two routers on the network (HSRP routers), assume that the links between the passive routers and the server and client networks in each office are removed from the topology (R17-192.168.2.0/24 link, R15-192.168.2.0/24 link, R24-192.168.20.0/24 link, R24-192.168.21.0/24 link, and R33-192.168.33.0/24 link). The hosts in each office are as follows:
   a. 192.168.2.10 in Stockholm office (1p)
   b. 192.168.21.10 in Uppsala office (1p)
   c. 192.168.34.10 in Lund office (1p)

Assume that in each office, there is one centralized DHCP server, which is responsible for DHCP within each office's network. (These servers are 192.168.1.2 in Stockholm, 192.168.20.2 in Uppsala and 192.168.33.2 in Lund).

H. All DHCP servers are configured to be authoritative for all branches and they are acting as redundant DHCP servers for one another. However, when the DHCP server in Lund office is taken offline, all hosts in Lund lose IP addresses and do not receive any new addresses from the other two DHCP servers. Explain what could be the reason why the hosts do not get IP addresses from the other redundant DHCP servers? (1p)

Answer:

A. 192.168.34.5 -> R32 -> R31 -> R11 -> R12 -> R13 -> R16 -> 192.168.1.2

B. 192.168.1.2 -> R16 -> R13 -> R12 -> R11 -> R31 -> R32 -> 192.168.34.5
C. 192.168.2.3 -> R18 -> R15 -> R12 -> R11 -> R21 -> R23 -> R24 -> 192.168.20.2
D. 192.168.20.2 -> R25 -> R21 -> R11 -> R12 -> R15 -> 192.168.2.3
E. 192.168.21.3 -> R22 -> R23 -> R21 -> R11 -> R31 -> R33 -> 192.168.33.3
F. 192.168.33.3 -> R34 -> R32 -> R31 -> packet lost in R21-R31 link
G. The paths used for sending the stream are as follow:
    a. 192.168.1.9 -> R16 -> R13 -> R12 -> R15 -> R18 -> 192.168.2.10
    b. 192.168.1.9 -> R16 -> R13 -> R12 -> R11 -> R21 -> R23 -> R22 -> 192.168.21.10
    c. 192.168.1.9 -> R16 -> R13 -> R12 -> R11 -> R31 -> R32 -> 192.168.34.10
H. Since the DHCP server in each branch is not located in the same network as the hosts, there must be a DHCP relay agent that forwards the DHCP messages between the host and the server. However, it is likely that the relay agent in Lund is only configured to forward DHCP messages only to/from 192.168.33.2 but not to/from the other redundant DHCP servers.