521150A Introduction to Internet

Exercise 2A

Welcome to calculation exercises

In this non-mandatory part of the course, you will learn to

- answer concrete, numerical questions on the subject matter
- model different network scenarios
- use the presented algorithms and methods

Contact info for issues with these exercises

- email: lauri.haverinen@oulu.fi
- room: TS387 (prefer email for contacting)

Before the session

Complete pre-exercises in Moodle

- you will be better prepared for the exercise
- you can earn up to **1 point for final grading** (in Moodle, the points are scaled by 10)

During the session

Follow, participate and solve

- revisiting pre-exercises
- solving example problems together
- describing and going through how to solve the advanced problems

After the session

Solve the rest of the problems presented in this document

- return a scanned version (or good photo) as PDF of your hand-written solutions **with your name on it** to Moodle **before the next exercise**
- you can earn up to **0.5 points for each solved problem**, so a maximum of 1.5 points per exercise (in Moodle, the points are scaled by 10)

Pre-assignments

1. **Network layer uses IP addresses to route packets in networks. Which of the following statements are true?**
   Reititin tietää IP-osoitteen perusteella, mihin suuntaan saapunut paketti reititetään - Router uses the IP address to determine where to route the arrived packet

2. **There are three switches on the route from source to destination. If packets are not fragmented, how many routing tables are required for packet delivery from source to destination?**
   4, source host and all three switches

3. **Subnet mask is 255.255.240.0. What is the maximum number of hosts that can be in this network?**
   Mask = 1111 1111 . 1111 1111 . 1111 **0000 . 0000 0000** -> 12 bits for hosts
   -> 2^12 = 4096, but subtract addresses with only 0's and 1's => 4094 (or 4093 if you subtract one for router as well)

4. **IP address of a host is 172.16.45.13 and the subnet mask is 255.255.224.0. What is the netid?**

Mask	1111 1111 . 1111 1111 . 1110 0000 . 0000 0000
Host address	1010 1100 . 0001 0000 . 0010 1101 . 0000 1101
AND	1010 1100 . 0001 0000 . 0010 0000 . 0000 0000 => 172.16.32.0

5. **If the netid of a network is 192.168.100.0 and the subnet mask is 255.255.255.192, how many subnets does the network have?**
   192.x.y.z -> class C network, so 24 network bits -> mask = 1111 1111 . 1111 1111 . 1111 1111 . **11**00 0000 -> 2^2=4

Pre-assignments

6. **Mikä on 512K-ongelma? What is the 512K problem?**

   Vuonna 2014 internetin BGP-reitittimien reititintaulukot ylittivät useissa laitteissa reititystaulukoiden maksimi reittien määrän (512k), ja internet lakkasi toimimasta. - In 2014, BGP routing tables exceeded the limit of 512k routes, causing internet service issues.

7. **When A transmits a packet to B, the following happens:**
   1. **A does routing table lookup for 111.111.111.110 and uses B's IP address as the destination in the IPv4 datagram**
   2. **A does ARP table lookup for 111.111.111.110 and finds out that E6-E9-00-17-BB-4B is the MAC address for that IP address. A uses that as destination address in the Ethernet-frame and 74-29-9C-E8-FF-55 as the source address.**
   3. **The frame is transmitted to the LAN1 network**
   4. **R finds out that the frame destination MAC address is theirs and receives the message.**
   5. **R reads the payload, parses datagram headers, and does routing table lookup for the destination address, and finds out that the destination is behind the LAN2 link.**
   6. **?**
   7. **The frame is transmitted to the LAN2 network**
   8. **B parses the frame header finds out that the MAC address matches theirs. Therefore, it parses the IP address of the datagram and finds out that the destination IP address matches theirs; therefore, the packet has reached the destination**

   What is performed at step 6?

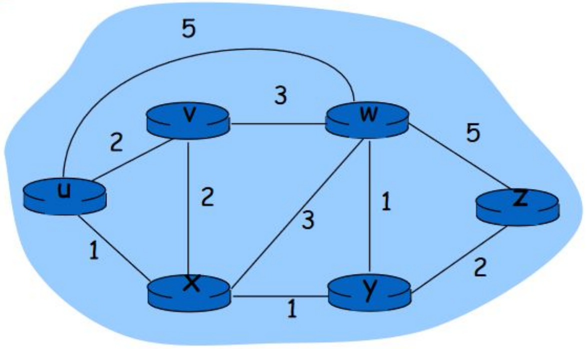
   R lukee ARP-taulukosta osoitteen 222.222.222.222 MAC-osoitteen (49-BD-D2-C7-56-2A), rakentaa Ethernet-kehyksen sillä vastaanottajaosoitteella ja lähettäjäosoitteella 1A-23-F9-CD-06-9B -

   R does ARP lookup for 222.222.222.222, finds out that the MAC address is 49-BD-D2-C7-56-2A, constructs Ethernet frame, and uses that as the destination address and 1A-23-F9-CD-06-9B as the source address

Pre-assignments

Dijkstra's algorithm (2)

Step	N'	D(v),p(v)	D(w),p(w)	D(x),p(x)	D(y),p(y)	D(z),p(z)
0	u	2,u	5,u	1,u	∞	∞
1	ux	2,u	4,x		2,x	∞
2	uxy	2,u	3,y			4,y
3	uxyv		3,y			4,y
4	uxyvw					4,y
5	uxyvwz					



troduction to Internet

8. Which of the following statements is true?

Internet routing is based on the trust that the advertised routes are correct

9. If Dijkstra's algorithm is applied on node w, what is the value of N' after two steps?

wyx

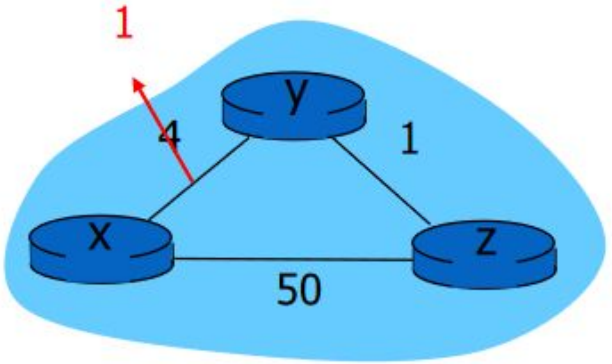
10. The weight of a link is changed as seen from the diagram. When using distance-vector routing, how many time steps it takes until distance-vector tables have stabilized?

Same as in lecture example: 3

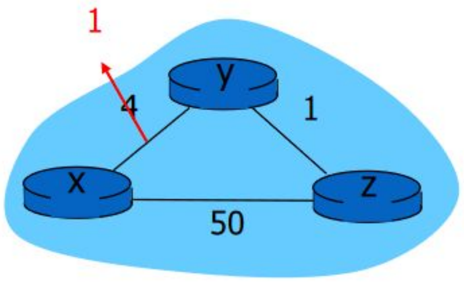
step 1: y detects the link-cost change, updates its distance vector and informs its neighbors

step 2: z receives the update from y, updates its table and computes a new least cost to x and sends its neighbors its DV

step 3: y receives update from z' and updates its distance table, y's least costs do not change and hence y does not send any message to z



Pre-assignment #10



10. The weight of a link is changed as seen from the diagram. When using distance-vector routing, how many time steps it takes until distance-vector tables have stabilized?

T=0 | after step 1 | after step 2 | after step 3

$$Node\ Y: \begin{array}{cccc} & X & Y & Z \\ X & 0 & 4 & 5 \\ Y & 4 & 0 & 1 \\ Z & 5 & 1 & 0 \end{array} -> \begin{array}{cccc} & X & Y & Z \\ X & 0 & 4 & 5 \\ Y & 1 & 0 & 1 \\ Z & 5 & 1 & 0 \end{array} -> \begin{array}{cccc} & X & Y & Z \\ X & 0 & 1 & 5 \\ Y & 1 & 0 & 1 \\ Z & 5 & 1 & 0 \end{array} -> \begin{array}{cccc} & X & Y & Z \\ X & 0 & 1 & 2 \\ Y & 1 & 0 & 1 \\ Z & 2 & 1 & 0 \end{array}$$

$$Node\ X: \begin{array}{cccc} & X & Y & Z \\ X & 0 & 4 & 5 \\ Y & 4 & 0 & 1 \\ Z & 5 & 1 & 0 \end{array} -> \begin{array}{cccc} & X & Y & Z \\ X & 0 & 1 & 5 \\ Y & 4 & 0 & 1 \\ Z & 5 & 1 & 0 \end{array} -> \begin{array}{cccc} & X & Y & Z \\ X & 0 & 1 & 2 \\ Y & 1 & 0 & 1 \\ Z & 5 & 1 & 0 \end{array} -> \begin{array}{cccc} & X & Y & Z \\ X & 0 & 1 & 2 \\ Y & 1 & 0 & 1 \\ Z & 2 & 1 & 0 \end{array}$$

$$Node\ Z: \begin{array}{cccc} & X & Y & Z \\ X & 0 & 4 & 5 \\ Y & 4 & 0 & 1 \\ Z & 5 & 1 & 0 \end{array} -> \begin{array}{cccc} & X & Y & Z \\ X & 0 & 4 & 5 \\ Y & 4 & 0 & 1 \\ Z & 5 & 1 & 0 \end{array} -> \begin{array}{cccc} & X & Y & Z \\ X & 0 & 1 & 5 \\ Y & 1 & 0 & 1 \\ Z & 2 & 1 & 0 \end{array} -> \begin{array}{cccc} & X & Y & Z \\ X & 0 & 1 & 2 \\ Y & 1 & 0 & 1 \\ Z & 2 & 1 & 0 \end{array}$$

Problem #9

Prefix match	Interface	Smallest address	Biggest address	Nr. of addresses
1	0	________	________	
11	1	________	________	
111	2	________	________	
default	3	________	________	

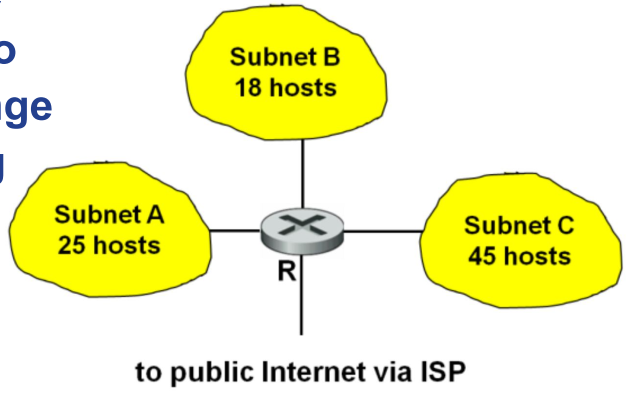
a) **A datagram network uses 8-bit host addresses, and has a router that uses longest prefix matching. Fill in the table the range for destination host addresses and the number of addresses in the range for each prefix. Also, answer which interfaces datagrams with destination addresses** i) 10011001; ii) 11111001; iii) 01100110 **and** iv) 10011001 **are forwarded to.**

b) **Router has the following CIDR entries in its routing table. How does the router forward arriving packets with following destination addresses?**

i) 135.46.63.10
ii) 135.46.57.14
iii) 135.46.52.2
iv) 192.53.40.7
v) 192.53.56.7

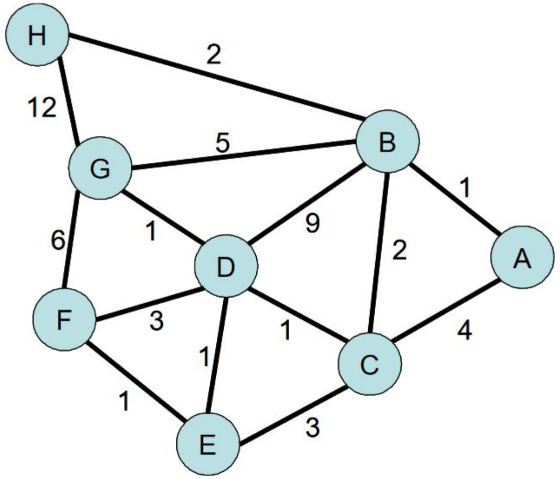
Address/mask	Interface for next hop
135.46.56.0/22	eth0
135.46.60.0/22	eth1
192.53.40.0/23	eth2
default	eth3

c) **Consider the network shown in the picture to the right, which consists of a single router R and three subnets A, B, and C. Assign address ranges to the networks so that each subnet can have their designated number of hosts, and the address range advertised by router R to external network is minimized. Give your answers using both IP address ranges (x.y.z.a-b) and CIDR notation (x.y.z.a/S).**

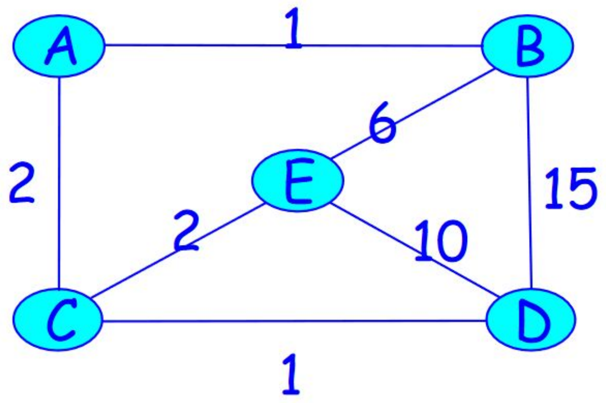


Problem #A

a) **Consider the network on the right (top), where characters indicate network nodes and numbers indicate link costs. Use Dijkstra's algorithm to compute the shortest path from A to all network nodes. You must show how the algorithm works, step by step, in form of a table used in the lecture 8.**



b) **Consider the network right (center) and assume that each node initially knows the costs to each of its neighbors. Using the distance vector algorithm, show the distance table entries at node E.**

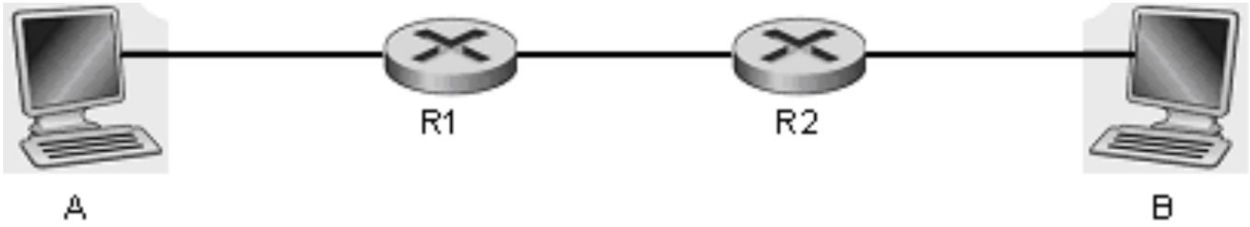


c) **Using a simple network on the right (bottom), show how in distance vector algorithm:**

i) "Good news travel fast"
ii) "Bad news travel slow"
iii) The count-to-infinity problem could arise when a link breaks

Problem #B

Suppose that host A is connected to router R1, R1 is connected to router R2 and R2 is connected to host B. Link A-R1 has maximum frame size of 1024 bytes including 14-byte frame header, link R1-R2 has maximum frame size of 512 bytes including 8-byte frame header and link R2-B has maximum frame size of 512 bytes including 12-byte frame header. Suppose that host A sends host B using IP a TCP segment containing 900 bytes of data and 20 bytes of TCP header. Show the relevant IPv4 header fields for each IP datagram transmitted from A to B. Assume that the original IP datagram id is 123.



Problems 2A

Problem #9:

a) A datagram network uses 8-bit host addresses, and has a router that uses longest prefix matching. Fill in the table the range for destination host addresses and the number of addresses in the range for each prefix. Also, answer which interfaces datagrams with destination addresses
   - i) 10011001
   - ii) 11111001
   - iii) 01100110
   - iv) 10011001

Prefix match	Inter-face	Smallest address	Biggest address	Nr. of addresses
1	0	_________	_________	
11	1	_________	_________	
111	2	_________	_________	
default	3	_________	_________	

are forwarded to.

b) Router has the following CIDR entries in its routing table. How does the router forward arriving packets with following destination addresses?
   - i) 135.46.63.10
   - ii) 135.46.57.14
   - iii) 135.46.52.2
   - iv) 192.53.40.7
   - v) 192.53.56.7

Address/mask	Interface for next hop
135.46.56.0/22	eth0
135.46.60.0/22	eth1
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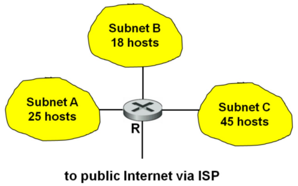
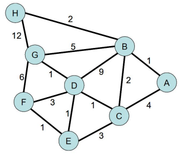
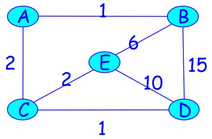
c) Consider the network shown in the picture to the right, which consists of a single router R and three subnets A, B, and C. Assign address ranges to the networks so that each subnet can have their designated number of hosts, and the address range advertised by router R to external network is minimized. Give your answers using both IP address ranges (x.y.z.a-b) and CIDR notation (x.y.z.a/S).



Problem #A:

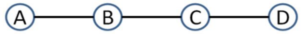
a) Consider the network below (left) where characters indicate network nodes and numbers indicate link costs. Use Dijkstra's algorithm to compute the shortest path from A to all network nodes. You must show how the algorithm works, step by step, in form of a table used in the lecture 8.





b) Consider the network above (right) and assume that each node initially knows the costs to each of its neighbors. Using the distance vector algorithm, show the distance table entries at node E.

c) Using a simple network below, show how in distance vector algorithm:
   - i) "Good news travel fast"
   - ii) "Bad news travel slow"
   - iii) The count-to-infinity problem could arise when a link breaks



Notes for #9

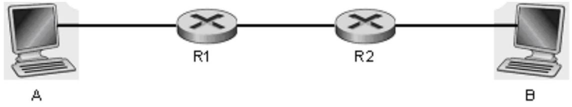
a) longest prefix matching: if multiple matches, choose the longest prefix, there is no overlapping in addresses for different prefixes

b) subnet mask and dest. addr to binary and use their AND to determine the correct subnet

c) round up log2(amount of hosts) to integer to get amount of bits required for addresses

Problem #B:

Suppose that host A is connected to router R1, R1 is connected to router R2 and R2 is connected to host B. Link A-R1 has maximum frame size of 1024 bytes including 14-byte frame header, link R1-R2 has maximum frame size of 512 bytes including 8-byte frame header and link R2-B has maximum frame size of 512 bytes including 12-byte frame header. Suppose that host A sends host B using IP a TCP segment containing 900 bytes of data and 20 bytes of TCP header. Show the relevant IPv4 header fields for each IP datagram transmitted from A to B. Assume that the original IP datagram id is 123.



Notes for #A

a) same process as in pre-assignments and lecture 8 Dijkstra example

b) Start with E, continue from node with the lowest cost and send update to others (order should be E, C, D, A, B and the answer should have total 6-8 steps)

c) lecture 8 example on what happens when link cost changes

Notes for #B

- (at least) ID, length, M-bit (more fragments flag) and offset are relevant headers in this case, descriptions in lecture 7
- All fragments of IP payload data must be in multiples of 8 bytes
- IP datagram header requires 20 bytes

Examples

Problems

a) Consider a network consisting of a single router R and two subnets, A and B, each requiring addresses for 20 hosts. You are allowed to use IP address space 200.100.50.0/24.

   i) Assign a minimal address range to both subnets so that R can advertise both subnets using a single aggregated address.

   ii) How does router forward an arriving packet with address 200.100.50.15? Is it forwarded to subnet A or B?

b) Distance vector routing (from lecture 8)

c) Host A is connected to router R1 and R1 is connected to host B. Link A-R1 has maximum frame size of 1024 bytes including 14-byte frame header, and link R1-B has maximum frame size of 512 bytes including 12-byte frame header. Suppose that host A sends host B using IP a TCP segment containing 600 bytes of data and 20 bytes of TCP header. Show the relevant IPv4 header fields for each IP datagram transmitted from A to B. Assume that the original IP datagram ID is 1.

Solutions

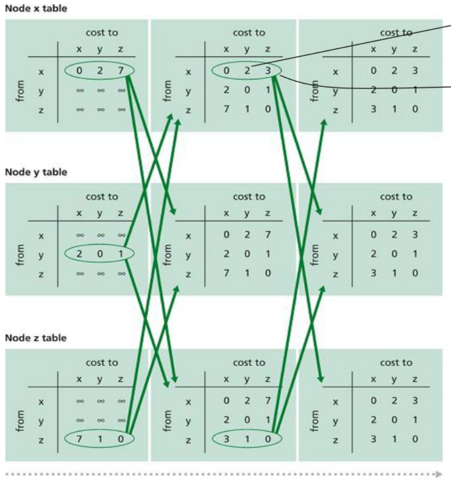
a)

   i) Class C network 200.100.50.0, default subnet mask 255.255.255.0, required subnets 2 with 20 hosts each
   log2(20)≈4.3 -> 5 bits -> 2^5 = 32 addresses required for each (= max. 30 hosts per subnet), 64 total required addresses = 6 bits
   address range for A x.y.z.0000 0000 - 0001 1111 -> 200.100.50.0-31 (CIDR 200.100.50.0/27)
   address range for B x.y.z.0010 0000 - 0011 1111 -> 200.100.50.32-63 (CIDR 200.100.50.32/27)
   advertised network address (CIDR notation) -> 200.100.50.0/26

   ii) Routing table has entries for A: 200.100.50.0/27 and B: 200.100.50.0/27,
   AND operation outputs 200.100.50.0 so packet is forwarded to A

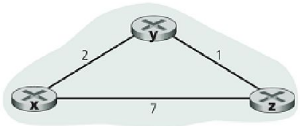
```
 200      100      50       15
 11001000.01100100.00110010.00001111
&11111111.11111111.11111111.11000000
 255      255      255      192
 -----------------------------------
 11001000.01100100.00110010.00000000
 200      100      50       0
```

b)



$D_x(y) = \min\{c(x,y) + D_y(y), c(x,z) + D_z(y)\}$
$= \min\{2+0 , 7+1\} = 2$

$D_x(z) = \min\{c(x,y) + D_y(z), c(x,z) + D_z(z)\}$
$= \min\{2+1 , 7+0\} = 3$



c) ID stays the same, fragmentation is required, TCP header 20 bytes so total length = 620 bytes (also notice 20 byte IP headers!)
A-R1: MTU = 1024B-14B=1010B left for frame data, 620B+20B IP datagram header = 640B<1010B, no need for fragmentation
   headers: ID=1, length=640 bytes, MF=0, Offset=0
R1-B: MTU = 512B-12B=500B left for frame data, after 20B IP header only 480B left, 620B>480B, so fragmentation required
   headers: 1) ID=1, length=500 bytes (480B+20B for IP header), MF=1, offset=0
      2) ID=1, length=160 bytes (620B-480B+20B for IP header), MF=0, offset=60 (480B/8)