Exercises on

- Network Layer

Exercise 1

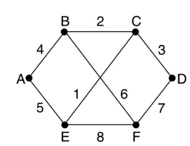
a) Consider the following design problem concerning implementation of virtual-circuit service.
b) If virtual circuits are used internal to the subnet, each data packet must have a 3-byte header and each router must tie up 8 bytes of storage for circuit identification.
c) If datagrams are used internally, 15-byte headers are needed but no router table space is required.
d) Transmission capacity costs 1 cent per 106 bytes, per hop.
e) Very fast router memory can be purchased for 1 cent per byte and is depreciated over two years, assuming a 40-hour business week.
f) The statistically average session runs for 1000 sec, in which time 200 packets are transmitted. The mean packet requires four hops.
g) Which implementation is cheaper, and by how much?

Exercise 1 - Solution

a) Four hops means that five routers are involved.
b) The virtual-circuit implementation requires tying up 5 x 8 = 40 bytes of memory for 1000 sec.
c) The datagram implementation requires transmitting 12 x 4 x 200 = 9600 bytes of header over and above what the virtual-circuit implementation needs.
d) Thus, the question comes down to the relative cost of 40,000 byte-sec of memory versus 9600 byte-hops of circuit capacity.
e) If memory is depreciated over 2 x 52 x 40 x 3600 = 1.5 x 10^7 sec, a byte-sec costs 6.7 x 10^{-8} cents, and 40,000 of them cost just over 2 millicents.
f) If a byte-hop costs 10^{-6} cents, 9600 of them cost 9.6 millicents.
g) Virtual circuits are cheaper for this set of parameters.

Exercise 2

a) Consider the subnet
b) Distance vector routing is used, and the following vectors have just come in to router C:
   - from B: (5, 0, 8, 12, 6, 2);
   - from D: (16, 12, 6, 0, 9, 10);
   - from E: (7, 6, 3, 9, 0, 4).
c) The measured delays to B, D, and E, are 6, 3, and 5, respectively.
d) What is C's new routing table? Give both the outgoing line to use and the expected delay.

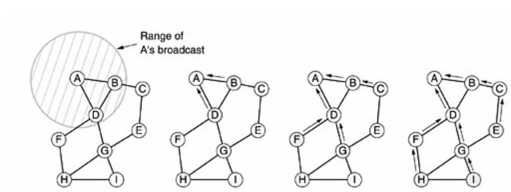


Exercise 2 - Solution

a) Going via *B* gives (11, 6, 14, 18, 12, 8).
b) Going via *D* gives (19, 15, 9, 3, 9, 10).
c) Going via *E* gives (12, 11, 8, 14, 5, 9).
d) Taking the minimum for each destination except *C* gives (11, 6, 0, 3, 5, 8).
e) The outgoing lines are (*B*, *B*, –, *D*, *E*, *B*).

Exercise 3

a) Suppose that node B has just rebooted and has no routing information in its tables.
b) It suddenly needs a route to H.
c) It sends out broadcasts with TTL set to 1, 2, 3, and so on.
d) How many rounds does it take to find a route?



Exercise 3 - Solution

a) Node *H* is three hops from *B*, so it takes three rounds to find the route.

Exercise 4

a) Is fragmentation needed in concatenated virtual-circuit internets or only in datagram systems?

Exercise 4 - Solution

a) It is needed in both.

b) Even in a concatenated virtual-circuit network, some networks along the path might accept 1024-byte packets, and others might only accept 48-byte packets.

c) Fragmentation is still needed.

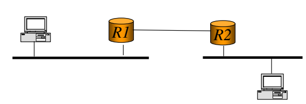
Exercise 5

a) Suppose that host A is connected to a router R1, R1 is connected to another router, R2, and R 2 is connected to host B.

b) Suppose that a TCP message that contains 900 bytes of data and 20 bytes of TCP header is passed to the IP code at host A for delivery to B.

c) Show the Total length, Identification, DF, MF, and Fragment offset fields of the IP header in each packet transmitted over the three links.

d) Assume that:
   - link A-R1 can support a maximum frame size of 1024 bytes including a 14-byte frame header,
   - link R1-R2 can support a maximum frame size of 512 bytes, including an 8-byte frame header
   - link R2-B can support a maximum frame size of 512 bytes including a 12-byte frame header.



Exercise 6 - Solution

a) Link *A-R1*:
   - *Length* = 940; *ID* = x; *DF* = 0; *MF* = 0; *Offset* = 0

b) Link *R1-R2*:
   - (1) *Length* = 500; *ID* = x; *DF* = 0; *MF* = 1; *Offset* = 0
   - (2) *Length* = 460; *ID* = x; *DF* = 0; *MF* = 0; *Offset* = 60

c) Link *R2-B*:
   - (1) *Length* = 500; *ID* = x; *DF* = 0; *MF* = 1; *Offset* = 0
   - (2) *Length* = 460; *ID* = x; *DF* = 0; *MF* = 0; *Offset* = 60

Exercise 6

a) An IP datagram using the Strict source routing option has to be fragmented.

b) Do you think the option is copied into each fragment, or is it sufficient to just put it in the first fragment? Explain your answer.

Exercise 6 - Solution

a) Since the information is needed to route every fragment, the option must appear in every fragment.

Exercise 7

a) Suppose that instead of using 16 bits for the network part of a class B address originally, 20 bits had been used.
b) How many class B networks would there have been?

Exercise 7 - Solution

a) With a 2-bit prefix, there would have been 18 bits left over to indicate the network.
b) Consequently, the number of networks would have been 2^{18} or
c) 262,144. However, all 0s and all 1s are special, so only 262,142 are available.

Exercise 8

a) A network on the Internet has a subnet mask of 255.255.240.0.
b) What is the maximum number of hosts it can handle?

Exercise 8 - Solution

a) The mask is 20 bits long, so the network part is 20 bits.
b) The remaining 12 bits are for the host, so 4096 host addresses exist.

Exercise 9

a) A large number of consecutive IP address are available starting at 198.16.0.0.
b) Suppose that four organizations, A, B, C, and D, request 4000, 2000, 4000, and 8000 addresses, respectively, and in that order.
c) For each of these, give:
   - the first IP address assigned
   - the last IP address assigned
   - the mask in the w.x.y.z/s notation.

Exercise 9 - Solution

a) All the requests are rounded up to a power of two.
b) The starting address, ending address, and mask are as follows:
   - *A:* 198.16.0.0 – 198.16.15.255 written as 198.16.0.0/20
   - *B:* 198.16.16.0 – 198.16.23.255 written as 198.16.16.0/21
   - *C:* 198.16.32.0 – 198.16.47.255 written as 198.16.32.0/20
   - *D:* 198.16.64.0 – 198.16.96.255 written as 198.16.64.0/19

Exercise 10

a) A router has just received the following new IP addresses:
   - 57.6.96.0/21
   - 57.6.104.0/21
   - 57.6.112.0/21
   - 57.6.120.0/21
b) If all of them use the same outgoing line, can they be aggregated?
c) If so, to what?
d) If not, why not?

Exercise 10 - Solution

a) They can be aggregated to 57.6.96/19.

Exercise 11

a) The set of IP addresses from 29.18.0.0 to 29.18.128.255 has been aggregated to 29.18.0.0/17.
b) However, there is a gap of 1024 unassigned addresses from 29.18.60.0 to 29.18.63.255 that are now suddenly assigned to a host using a different outgoing line.
c) Is it now necessary to split up the aggregate address into its constituent blocks, add the new block to the table, and then see if any re-aggregation is possible?
d) If not, what can be done instead?

Exercise 11 - Solution

a) It is sufficient to add one new table entry: 29.18.60.0/22 for the new block.
b) If an incoming packet matches both 29.18.0.0/17 and 29.18.0.0./22, the longest one wins.
   - Ex. 29.18.60.26
c) This rule makes it possible to assign a large block to one outgoing line but make an exception for one or more small blocks within its range.

Exercise 12

a) A router has the following (CIDR) entries in its routing table:
   - 135.46.56.0/22 Interface 0
   - 135.46.60.0/22 Interface 1
   - 192.53.40.0/23 Router 1
   - Default Router 2
b) For each of the following IP addresses, what does the router do if a packet with that address arrives?
   - (a) 135.46.63.10
   - (b) 135.46.57.14
   - (c) 135.46.52.2
   - (d) 192.53.40.7
   - (e) 192.53.56.7

Exercise 12 - Solution

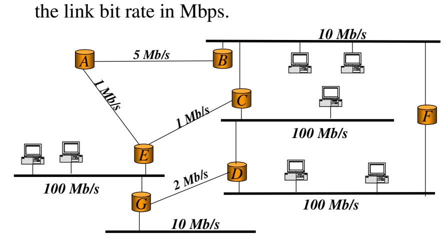
a) The packets are routed as follows:
- (a) Interface 1
- (b) Interface 0
- (c) Router 2
- (d) Router 1
- (e) Router 2

Exercise 13

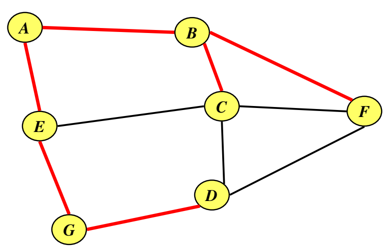
a) Represent the network as a graph

b) Apply Dijkstra algorithm to find the shortest path from router A to all the others, by considering links with unitary weights

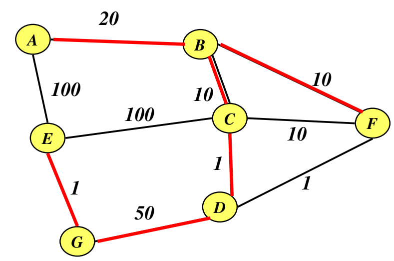
c) Repeat a) while considering a weight equal to 100/*c* where *c* is the link bit rate in Mbps.



Exercise 13 – Solution (i)

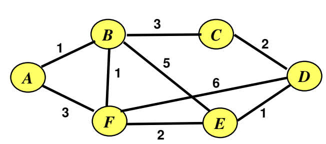


Exercise 13 – Solution (ii)

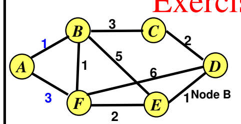


Exercise 14

a) Show how node A build its Distance Vector



Exercise 14 - Solution



Node B

step 1

D	cost	R
A	1	A
B	-	-
C	3	C
E	5	E
F	1	F

step 2

D	cost	R
A	1	A
B	-	-
C	3	C
D	5	C
E	3	F
F	1	F

step 3

D	cost	R
A	1	A
B	-	-
C	3	C
D	4	F
E	3	F
F	1	F

+1

Node A

step 1

D	cost	R
A	-	-
B	1	B
F	3	F

step 2

D	cost	R
A	-	-
B	1	B
C	4	B
D	9	F
E	5	F
F	2	B

step 3

D	cost	R
A	-	-
B	1	B
C	4	B
D	6	F
E	4	B
F	2	B

step 4

D	cost	R
A	-	-
B	1	B
C	4	B
D	5	B
E	4	B
F	2	B

+3

Node F

step 1

D	cost	R
A	3	A
B	1	B
D	6	D
E	2	E
F	-	-

step 2

D	cost	R
A	2	B
B	1	B
C	4	B
D	3	E
E	2	E
F	-	-

step 3

D	cost	R
A	2	B
B	1	B
C	4	B
D	3	E
E	2	E
F	-	-

Exercise 15

a) A small number of consecutive IP address are available starting at 192.214.11.0.

b) Suppose that four organizations, A, B, and C, request 100, 50, and 50 addresses, respectively, and in that order.

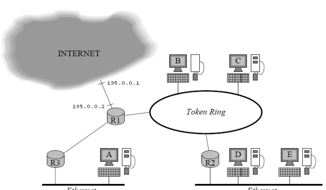
c) For each of these, give:
  - the first IP address assigned
  - the last IP address assigned
  - the mask in the w.x.y.z/s notation.

Exercise 15 - Solution

a) The 3 subnets can be address using the first 2 bits of the last byte. Then each subnet can contains up to 64 hosts.

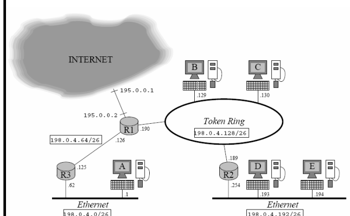
b) Using VLSM we can fix this issue:
  - A: 192.214.11.0/25
  - B: 192.214.11.128/26
  - C: 192.214.11.192/26

Exercise 16



a) Sia data la rete in figura, e supponiamo che sia stato assegnato l'indirizzo di classe C 198.0.4.0.
  - Assegnare a ciascuna delle restanti interfacce un indirizzo coerente con questa assegnazione, supponendo che non ci siano vincoli precisi sul numero di host per sottorete, per cui si consideri l'ipotesi migliore
  - Costruire tutte le tabelle di routing dei router.

Exercise 16 - Solution



R1

198.0.4.0/26	198.0.4.125
198.0.4.64/26	198.0.4.126
198.0.4.128/26	198.0.4.190
198.0.4.192/26	198.0.4.189
195.0.0.1/32	195.0.0.2
Default	195.0.0.1

R2

198.0.4.192/26	198.0.4.254
198.0.4.128/26	198.0.4.189
Default	198.0.4.190

R3

198.0.4.0/26	198.0.4.62
198.0.4.64/26	198.0.4.125
Default	198.0.4.126

Exercise 17

- Con riferimento all'indirizzamento IP di tipo classless, si consideri l'arco di indirizzi IP da 134.132.0.0 a 134.136.255.255.
  - Scrivere sia in notazione [indirizzo, subnet mask] che in notazione slash il blocco CIDR piu piccolo in grado di contenere tale arco.
  - Quante reti di classe B sono contenute da tale blocco CIDR?
  - Suddividere il blocco CIDR in 8 sottoreti (che chiameremo nell'ordine *sub1*, *sub2*,. . . , *sub8*) di uguale dimensione. Scrivere in notazione slash gli indirizzi delle 8 sottoreti.
  - Qual'e l'indirizzo di broadcast della sottorete *sub3*?

Exercise 17 - Solution

a) 134.128.0.0/255.240.0.0 oppure 134.128.0.0/12

b) Una rete di classe B prevede 16 bit di rete, noi ne abbiamo 12 fissi, ne restano 4 da variare, per un totale di 2^4 = 16 sottoreti di classe B

c) Per individuare 8 sottoreti sono necessari ⌈log2 8⌉ = 3 bit. Ciascuna delle sottoreti sara' quindi caratterizzata dai primi 12 + 3 bit:
  - sub1 = 134.128.0.0/15
  - sub2 = 134.130.0.0/15
  - sub3 = 134.132.0.0/15
  - sub4 = 134.134.0.0/15
  - sub5 = 134.136.0.0/15
  - sub6 = 134.138.0.0/15
  - sub7 = 134.140.0.0/15
  - sub8 = 134.142.0.0/15

d) Vanno posti a 1 i bit di host (cio`e i restanti 17) della rete sub3. Attenzione a porre a 1 anche il bit meno significativo del secondo ottetto, che fa parte dell'indirizzo di host:
  - 134.133.255.255