Facultat Informàtica de Barcelona (FIB)
Bachelor in Informatics Engineering

Computer Networks Problem Collection Grau-XC

ENGLISH VERSION

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Unit IP Protocol

Problem 1. ***(2014p-c1)***

We have the private address bloc 192.168.8.0/22. The network manager defines a sub-network X1 with the network prefix 192.168.8.0/26

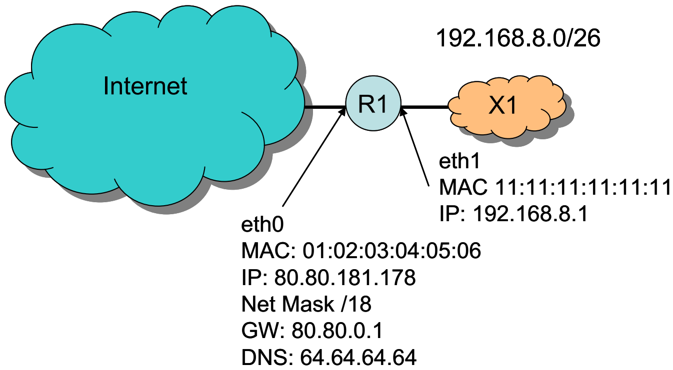
a) How many IP interfaces can be configured? Which is the range of IP addresses that may be assigned?

Once sub-network X1 is defined, make the addressing plan splitting the rest of the address bloc with the minimum number of sub-networks; that is with the biggest network size.

b) Complete the following table with all the sub-networks.

Subnet	Subnet prefix	Mask /n	# avaliable IP addresses	Address for the subnet router
X1	192.168.8.0	/26		192.168.8.1
X2				
X3				

Sub-network X1 is connected to the Internet through router R1, as shown in the figure.



c) Considering the configuration of the interface eth0 shown in the figure, which is the network prefix?

Give the network prefix using the decimal dotted / mask notation to which the address 80.80.181.178/18 belongs.

Which is the "broadcast" address for this sub-network?

d) Complete the routing table for router R1:

Destination network	Mask /bits	Router (IP gw)	interface
192.168.8.0 (X1)	26	192.168.8.1	eth1

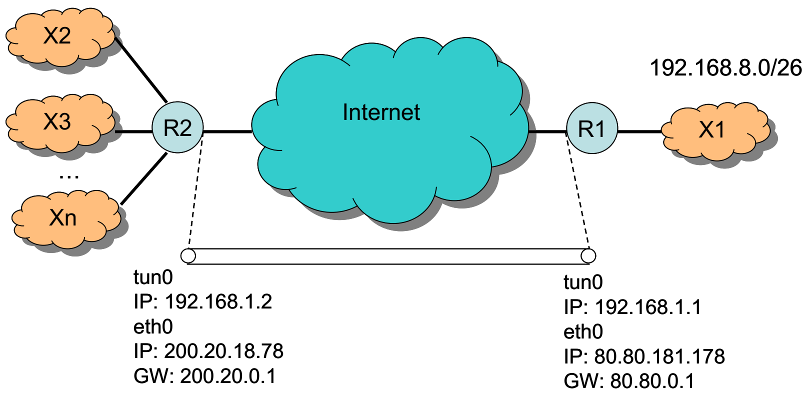
R1 performs NAT (sub-network X1 has private addresses). R1 is the DHCP too and allows automatic configuration of the terminals in X1. Terminal A belongs to sub-network X1 and executes the command "ping www.upc.edu". Terminal A IP address is 192.168.8.8, its MAC address is aa:aa:aa:aa:aa:aa, and its ARP table is empty. Be aware that R1 performs NAT. DNS will answer that the IP address for UPC's web server is 147.83.2.135.

e) Complete the following table with the sequence of frames and IP datagrams transmitted through router R1until the first "echo" response comes back to terminal A.

For the sake of simplicity, use the following notation for the pairs IP address and MAC address: Terminal A: A, a. Router R at interface eth0: R0, r0. Router Rat interface eth1: R1, r1. DNS server: D, d. ISP router (GW): G, g. Web server at UPC: U, u.

Ethernet Header		ARP Message		IP Header		IP packet
MAC source	MAC destination	Type Req/Resp	Requested IP address	IP source	IP destination	Contents

Sub-network X1 is connected with the rest of sub-networks X2 ... Xn through the Internet, as shown in the figure. To do this, a tunnel is configured between routers R1 and R2.



f) Complete the routing tables for routers R1 and R2.

Router R1

Destination	Mask /bits	Router (IP gw)	Interf.
192.168.8.0 (X1)	26	192.168.8.1	eth1

Router R2

Destination	Mask /bits	Router (IP gw)	Interf.

Terminal A (192.168.8.8) executes the command “ping 192.168.9.33”.

g) Show the contents of the IP datagram going through the Internet. Be aware of the NAT and tunnel configurations.

Include the IP headers (IP source address, IP destination address) of the datagram in the Internet going from router R1 to router R2.

External IP header		Internal IP header		
IP source	IP destination	IP source	IP destination	protocol

Solution:

a) Subnetwork 192.168.8.0/22: 1022 (1021) interfaces; range of available addresses 192.168.8.1 – 192.168.11.254

Subnetwork 192.168.8.0/26: 62 (61) interfaces; range of available addresses 192.168.8.1 – 192.168.8.62

b)

Sub-Network	Sub-Network prefix	Mask /n	# available IP addresses	Address for the sub-network router
X1	192.168.8.0	/26	62	192.168.8.1
X2	192.168.8.64	/26	62	192.168.8.65
X3	192.168.8.128	/25	126	192.168.8.129
X4	192.168.9.0	/24	254	192.168.9.1
X5	192.168.10.0	/23	510	192.168.10.1

c) Network: 80.80.128.0/18. Broadcast address: 80.80.191.255

d)

Destination network	Mask /bits	Router (IP gw)	interface
192.168.8.0 (X1)	26	192.168.8.1	eth1
80.80.128.0	18		eth0
0.0.0.0	0	80.80.181.1	eth0

e)

Ethernet Header		ARP Message		IP Header		IP packet
MAC source	MAC destination	Type Req/Resp	Requested IP address	IP source	IP destination	Contents
a	Bcast	Req	R1			
r1	a	Resp				
a	r1			A	D	DNS req “www.upc.edu”
r0	g			R0	D	DNS req “www.upc.edu”
g	r0			D	R0	DNS resp U
r1	a			D	A	DNS resp U
a	r1			A	U	ICMP echo req
r0	g			R0	U	ICMP echo req
g	r0			U	R0	ICMP echo resp
r1	a			U	A	ICMP echo resp

f)

Router R1

Destination	Mask /bits	Router (IP gw)	Interf.
192.168.8.0 (X1)	26	192.168.8.1	eth1
192.168.1.0	30*		tun0
192.168.8.64 (X2)	26	192.168.1.2	tun0
192.168.8.128 (X3)	25	192.168.1.2	tun0
192.168.9.0 (X4)	24	192.168.1.2	tun0
192.168.10.0 (X5)	23	192.168.1.2	tun0
80.80.128.0	18		eth0
0.0.0.0	0	80.80.0.1	eth0

Router R2

Destination	Mask /bits	Router (IP gw)	Interf.
192.168.8.64 (X2)	26		eth1
192.168.8.128 (X3)	25		eth2
192.168.9.0 (X4)	24		eth3
192.168.10.0 (X5)	23		eth4
192.168.1.0	30*		tun0
192.168.8.0 (X1)	26	192.168.1.1	tun0
200.20.0.0	16**		eth0
0.0.0.0	0	200.20.0.1	eth0

* It may be /24 or another value, but the typical value for a point to point link is /30

** We do no know the value of the network mask. We know that the gw (200.20.0.1) and the router (200.20.18.78) are in the same network. The network mask may be 16, 17, 18 or 19.

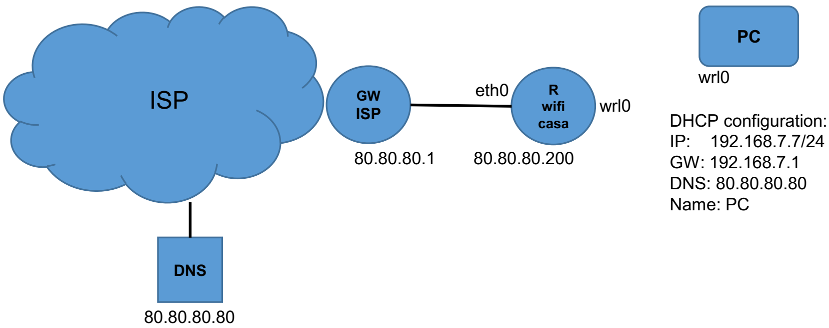
g)

External IP header		Internal IP header		
IP source	IP destination	IP source	IP destination	protocol
80.80.181.178	200.20.18.78	192.168.8.8	192.168.9.33	ICMP

IP Protocol

Problem 2. *(2015p)*

The figure shows a domestic network with and ADSL/cable router (**Router wifi casa**). The domestic network is WLAN using private IP addresses. PC is a wireless device; its interface is **wrl0** and uses DHCP for its configuration. The figure shows its configuration. The **router wifi casa** has two interfaces: the internal one WiFi (**wrl0**) and the external one to the ISP (**eth0**). The assigned IP addresses are shown in the figure.



a) Complete the routing table for *router wifi casa*.

Destination network	Mask	Gateway	Interface

b) The PC uses DHCP for its configuration. Show the sequence of **packets** exchanged between the PC and the DHCP server, which is located in *router wifi* casa.

Source	Destination	Protocol	Transport protocol	DHCP Message
		DHCP	UDP	Discover

c) Complete the routing table of the PC once it is completely configured.

Destination network	Mask	Gateway	Interface

d) After the configuration of the PC, ARP and DNS tables are empty. From the PC, the user accesses "www.abclab.upc.edu". Complete the **sequence of frames** observed at router interfaces **wrl0** & **eth0** until the **first TCP segment arrives from UPC server**.

Assume that the router is on since a long time ago. Take into account that the router performs PNAT.

Use the following notation: PC (192.168.7.7), wpc (PC's MAC address), RI (192.168.7.1), wri (internal interface MAC address), R (80.80.80.200), r (external interface MAC address), GW (80.80.80.1), gw (MAC address of the ISP's router), UPC (IP address of the web server), DNS (80.80.80.80), 53 for DNS server's port, 80 for HTTP server's port, and P1, P2, P3, P4 for NAT's dynamic ports.

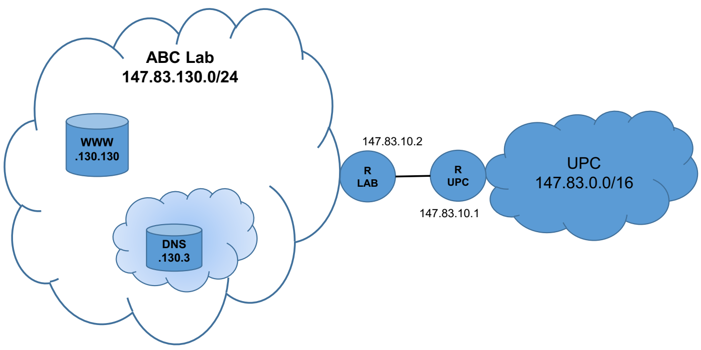
Router Interface	Ethernet			IP					Message Information
	Source	Destination	ARP Message	Source	Port	Destination	Port	Protocol	

The figure shows the network at UPC's ABC Lab (147.83.130.0/24). Router RLAB connects ABC Lab to UPC's network. The IP address of the external interface of RLAB is 147.83.10.2.

e) The IP address assigned to the Lab's web server is 147.83.130.130/27.

What is its corresponding subnetwork (subnetwork address, broadcast address, and address for router RLAB)?

How many /27 subnetworks may be configured in the ABC Lab?



The subnetwork 147.83.130.192/26 is "moved" to the home. To do this, a tunnel is established between routers RLAB and router WifiCasa. The tunnel uses the subnetwork 10.0.0.0/30.

f) Complete the routing table for router RLAB.

Destination network	Mask	Gateway	Interface
147.83.10.0	/23		eth0
147.83.130.0	/25		eth1
147.83.130.128	/26		eth2
147.83.130.192	/26		eth3
0.0.0.0	/0		eth4

g) Assume that ARP and DNS tables contain already the information needed. From the PC a user accesses the server "www.abclab.upc.edu". Complete the **sequence of frames** observed at the router's **wrl0** and **eth0** until **first TCP segment arrives from UPC server**. Use the same notation than in d) plus RLAB (147.83.10.2).

IP Protocol

Router Interface	Ethernet header		IP External header		IP header					Message payload
	Source	Destination	Source	Destination	Source	Port	Destination	Port	Protocol	

Solution:

a)

Destination network	Mask	Gateway	Interface
192.168.7.0	/24		wrl0
80.80.80.0	/24 (/x on 8 <= x <= 24)		eth0
0.0.0.0	/0	80.80.80.1	eth0

b)

Source	Destination	Protocol	Transport protocol	DHCP Message
0.0.0.0	255.255.255.255	DHCP	UDP	Discover
192.168.7.1	255.255.255.255	DHCP	UDP	Offer
0.0.0.0	255.255.255.255	DHCP	UDP	Request
192.168.7.1	192.168.7.7	DHCP	UDP	Ack

c)

Destination network	Mask	Gateway	Interface
192.168.7.0	/24		wrl0
0.0.0.0	/0	192.168.7.1	wrl0

d)

Router Interface	Ethernet			IP					Message Information
	Source	Destination	ARP Message	Source	Port	Destination	Port	Protocol	
wrl0	wpc	ff:ff:ff:ff:ff:ff	ARP REQ RI						
wrl0	wri	wpc	ARP RES wri						
wrl0	wpc	wri		PC	P1	DNS	53	UDP	DNS REQ
eth0	r	gw		R	P2	DNS	53	UDP	DNS REQ
eth0	gw	r		DNS	53	R	P2	UDP	DNS RESP
wrl0	wri	wpc		DNS	53	PC	P1	UDP	DNS RESP
wrl0	wpc	wri		PC	P3	UPC	80	TCP	SYN
eth0	r	gw		R	P4	UPC	80	TCP	SYN
eth0	gw	r		UPC	80	R	P4	TCP	ACK/SYN
wrl0	wri	wpc		UPC	80	PC	P3	TCP	ACK/SYN

e)

147.83.130.130/27 belongs to the subnetwork: 147.83.130.128/27; gw: 147.83.130.129; bcast: 147.83.130.159

Eight subnetworks may be configured. (27-24=3; 2^3=8)

147.83.130.0/27; 130.32/27; 130.64/27; 130.96/27; 130.128/27; 130.160/27; 130.192/27; 130.224/27

f)

Destination network	Mask	Gateway	Interface
147.83.10.0	/23		eth0
147.83.130.0	/25		eth1
147.83.130.128	/26		eth2
~~147.83.130.192~~	~~/26~~		~~eth3~~
10.0.0.0	/30		tun0
147.83.130.192	/26	10.0.0.2	tun0
0.0.0.0	/0	147.83.10.1	eth4

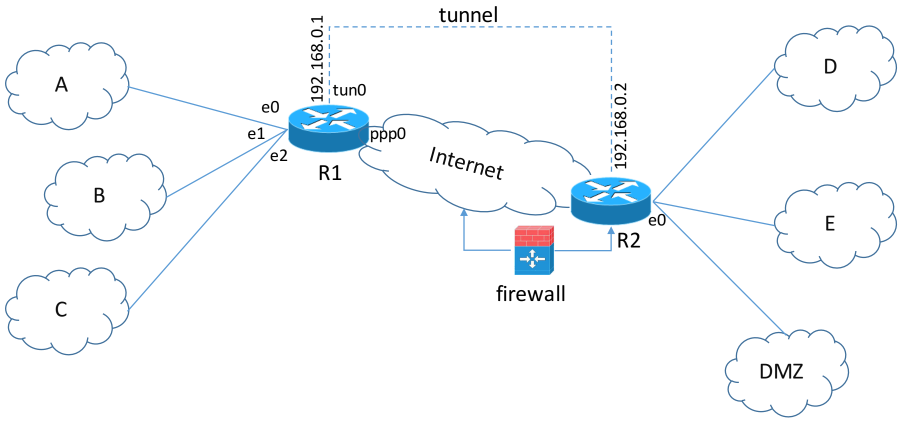
g)

Router Interface	Ethernet header		IP External header		IP header					Message payload
	Source	Destination	Source	Destination	Source	Port	Destination	Port	Protocol	
wrl0	wpc	wri			PC	P1	UPC	80	TCP	SYN
eth0	r	gw	R	RLAB	R	P2	UPC	80	TCP	SYN
eth0	gw	r	RLAB	R	UPC	80	R	P2	TCP	ACK/SYN
wrl0	wri	wpc			UPC	80	PC	P1	TCP	ACK/SYN

R (80.80.80.200); RLAB (147.83.10.2); The tunnel ends at the external interface of R(wifi casa) and it applies PNAT.

Problem 3. ***(2016p)***

A company organized into five departments (A, B, C, D and E) of equal size, decides to set up its infrastructure using a combination of private and public IP addresses. Private addresses are used for the workstations and the public IPs are used for the DMZ. The base range for the private network is 10.0.0.0/8. The public range is 212.13.14.16/28. Departments B and C are part of the same location in the company, while the D and E departments, as well as the DMZ are in part of a different location. The connection between the locations is performed via a tunnel through the public Internet. Two routers manage the company inbound and outbound traffic. The tunnel is configured using two addresses of the range 192.168.0.0/24. The following diagram shows the configuration described above. All inbound and outbound traffic to the Internet (which runs out of the tunnel encapsulation) goes through R2, where the corporate firewall is implemented.



a) Propose an addressing scheme that satisfies the above requirements. The networks of all departments will be the same size and will accommodate 100 machines each. Assign networks to departments in alphabetical order (first network for A, the last for E), and make the ranges of the networks are as tight as possible to the current size of the departments.

Network	Address / mask	Broadcast
A		
B		
C		
D		
E		
Tunnel	192.168.0.0/24	
DMZ	212.13.14.16 / 28	

b) Show the contents of the Routing table of R1. All Machines in the network must be able to reach the Internet through the firewall. Use default routes if possible. The routers of the ISP that provides Internet connectivity to the company are 'R1_ISP' and 'R2_ISP' for R1 and R2 correspondingly.

Address	Mask	Gateway	Interface

c) In the case an intruder gains access to any of the DMZ machines, we want to avoid the possibility that this machine could be used afterwards to launch an attack to other machines (inside the company or external). For this reason, a series of firewall policies are implemented to limit the potential damage in case of such attack. For the case of **inbound traffic to interface e0 of R2** (that is generated in the DMZ), indicate what packages should be allowed so that the machines in the company could connect to the corporate Web server (IP 212.13.14.17, port 80) and SMTP server (IP 212.13.14.18, port 25). At the same time, it must be guaranteed that no connections could be initiated from any machine in the DMZ. The two machines of the DMZ must be freely accessible from the Internet as well. Remember that this ACL is only for the inbound traffic for interface e0 in R2. Assume that any other necessary rules have been established in other interfaces as needed. Remember to include a final rule (accepting or denying all traffic).

Source address	Destination Address	Source port	Destination port	Accept/Deny

d) Redo the previous table, but this time thinking about the **outbound traffic for e0 in R2** (heading toward the DMZ).

Source address	Destination Address	Source port	Destination port	Accept/Deny

Solution:

a)

Network	Address / mask	Broadcast
A	10.0.0.0/25	10.0.0.127
B	10.0.0.128/25	10.0.0.255
C	10.0.1.0/25	10.0.1.127
D	10.0.1.128/25	10.0.1.255
E	10.0.2.0/25	10.0.2.127
Tunnel	192.168.0.0/24	192.168.0.255
DMZ	212.13.14.16 / 28	212.13.14.31

b)

Address	Mask	Gateway	Interface
R2	255.255.255.255	R1_ISP	ppp0
10.0.0.0/25	255.255.255.128	-	e0
10.0.0.128/25	255.255.255.128	-	e1
10.0.1.0/25	255.255.255.128	-	e2
192.168.0.0	255.255.255.0	-	tun0
0.0.0.0	0.0.0.0	192.168.0.2	tun0

c)

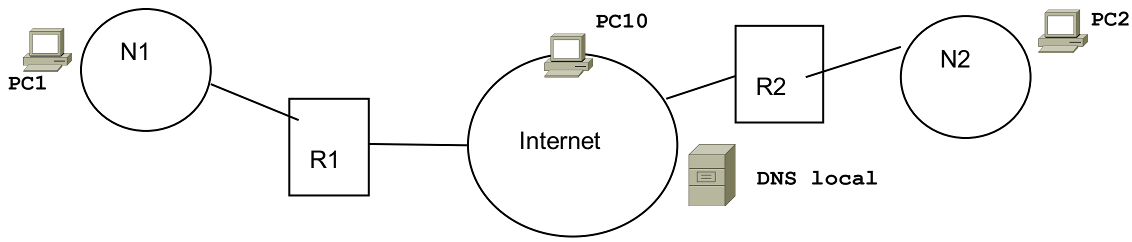
Source address	Dest. Address	Source port	Destination port	Accept/Deny
212.13.14.17	any	80	any	Accept
212.13.14.18	any	25	any	Accept
DENY ALL				

d)

Source address	Dest. Address	Source port	Destination port	Accept/Deny
any	212.13.14.17	any	80	Accept
any	212.13.14.18	any	25	Accept
DENY ALL				

Problem 4.

Assume the following configuration:



The N1 and N2 networks are from the same organization O and they are united by a tunnel. We want to create in both of them subnets using the private address range 10.0.0.0/24. To configure the tunnel the 192.168.0.0/24 address is used. On the other hand, the public interfaces of the Routers R1 and R2 have the addresses 200.0.0.1/24 and 200.0.0.2/24 respectively assigned. The local DNS server of N1 and N2 has the address 200.1.0.2, and PC10, which is outside N1 and N2, has the address 200.100.100.100.

1) We want to design an address space for all the networks of the organization O. Concretely, we want a subnet in N2 that can withstand up to 100 machines, and we want to use the rest of addresses to structure N1 in the biggest possible number of subnets.

1.1) Give the addresses and masks (in "/n" format) of each one of the subnets, both from N1 and N2. (Note: Assign the addresses with lower numbers to the nets with more machines).

1.2) What is the maximum number of subnets that we can have in N1?

1.3) How many addresses will be left without being able to be assigned to a machine?

2) With the available data and doing the justified assumptions that you need, give the routing table of Router R1, with the following format:

`Destination Net | Interface | Gateway | Metric`

3) If PC1 makes a PING towards **PC2** (assuming that we already have all the needed information to send an output ICMP message),

3.1) Draw the structure of the first frame that will leave R1 towards PC2 indicating all the headers and user data fields that contains.

3.2) What will be the values of the following header's fields of the datagram that contains the previous frame?:

- Destination address,
- Source destination,
- Protocol,
- offset.

4) At a given moment, we have all the ARP tables of the machines in N1 empty (we have just started the machines) and the local DNS server without any information. PC1 makes a "ping PC10.xc.com", being "PC10.xc.com" the name of the machine that we have identified as PC10, from which PC1 does not know the address.

4.1) Fill the **following table** with information of the frames that will circulate through N1 until the ping has finished.

Notes:

Each row of the table has to correspond to a frame.

Some columns do not apply to some frames (indicate it with "-").

If physical addresses are needed (columns 3 and 4), give them any indicator; for the IP addresses (columns 5 and 6), use some that could be correct.

In the column "ARP Message" (column 2) you only need to indicate if it is a request ("Req") or response ("Resp").

In the "Transport" column (column 8) indicate which type of transport protocol does it use (UDP or TCP), in case it uses any.

In column 9 indicate 1) if a a routing table has been consulted previous to the sending, 2) which one, 3) which question has been made and 4) which answer has been obtained.

Column 1	2	3	4	5	6	7	8	9
Frame order	**ARP Message Req/Resp**	**Addresses Source**	**Dest**	**IP Addresses Source**	**Dest**	**ICMP Message**	**Transport UDP / TCP**	**routing table checked?**

4.2) To make the previous ping (ping PC10.xc.com), which DNS messages will go through the router R1? **For each message** (in passing order) **indicate**: Type (request/response), which request/response does it carry, who has generated it and who is the receiver of the message. (Help yourself with a table).

Solution:

(1.1)
N2: 100 machines need 7 bits. The 8th of the ones we have (the one with the greatest weight) identifies it. The mask will have 25 bits (24+1).
N1: To have the maximum number of subnets, we have to minimise their size (number of bits of the host). With only 1 bit we would only have subnet and broadcast; with 2 bits we can have subnet, broadcast, router and 1 machine. We would still have 5 bits for the subnet (since the 6th (the 8th of N1) is to distinguish it from N2). So, 2^5=32 subnets. The subnet with more machines is N2, therefore, the addresses will be:

N2: 10.0.0.0/25
N1: 32 subnets from 10.0.0.128/30 to 10.0.0.252/30 (going through .132/30, .136/30, … .244/30 and 248.30).

(1.2) As said before, 32.
(1.3) In N2 we will have 128 – 2 - 1 (router) – 100 (machines) = 25. In N1, none are left (Note: Considering that if we had only 1 subnet instead of 32, we would assign more addresses to machines is also accepted).

2
We assume that R1 has a ppp link to an ISP router "Risp" (Risp would be an address in the net 200.0.0.0/24) and another eth for N1. There also exists a tunnel to connect to N2 through R2.

Destination net	Interface	Gateway	Metric
10.0.0.128/30 (N1.1)	eth.1	-	1
10.0.0.252/30 (N1.32)	eth.32	-	1
10.0.0.0/25 (N2)	tunnel	192.168.0.1	2
192.168.0.0/24	tunnel	-	1
200.0.0.0/24	ppp	-	1
0.0.0.0	ppp	Risp	-

(Note: The loop addresses could be added)

(3.1) MAC header –external IP header – internal IP header – ICMP message – CRC MAC

(3.2)
External datagram:
Destination address = 200.0.0.2 Source address = 200.0.0.1
Protocol = IP Offset = 0

Internal datagram:
Destination address = 10.0.0.2 Source address = 10.0.0.130
Protocol = ICMP Offset = 0

(4.1)

Column 1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Frame order	**ARP Message Req/Resp**	**ARP Addresses Source**	**ARP Addresses Dest**	**IP Addresses Source**	**IP Addresses Dest**	**ICMP Message**	**Transport UDP / TCP**	**routing table checked?**

To be able to make the ping, PC1 needs to consider the local DNS. Its routing table says him to go to R1. It needs its MAC to access (makes ARP). We assume that the IP of PC1 is 10.0.0.130.

1	Req	PC1	Bcast					PC1: Way to local DNS? R1
2	Resp	R1	PC1					
3				10.0.0.130	200.1.0.2		UDP (DNS request)	

All the name resolution process is done outside N1.

4				200.1.0.2	10.0.0.130		UDP (DNS response)	

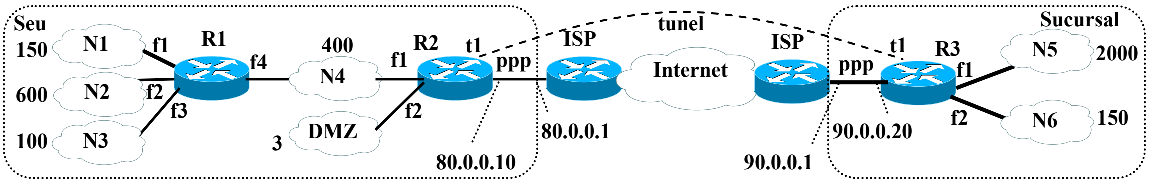
(The private address of PC1 circulates through N1)
Now PC1 has the IP address of PC10, so it can send the ping

5				10.0.0.130	200.100.100.100	Echo req		PC1: Way to PC10? R1
6				200.100.100.100	10.0.0.130	Echo resp		

(4.2)
Only the local DNS request and response fo through the R1 router (frames 3 and 4).
The recursive access (root, .com, xc.com) is done from the local DNS.

Request of PC1 to local DNS: What is the IP of PC10.xc.com?
Response of the local DNS to PC1: 200.100.100.100.

Problem 5.



The network of the figure is formed by a VPN between a HQ and a branch office. They both have only one public address available. The figure shows how many machines we want to connect to each net. In all routers RIPv2 is activated with class summarization. Meaning that when sending RIP updates, it aggregates the subnets that could have been defined in each net with class, when the update is sent in an interface that does not belong to the aggregation. For example, if in the routing table we have the destinations 192.168.0.0/25 and 192.168.0.128/25, only the destination 192.168.0.0/24 will be sent (when the update is sent in an interface that does not belong to the 192.168.0.0/24 range). We have also activated split horizon. We want RIP to configure as many things as possible. We also want the chosen routing to make proper routing tables and that they have, on average and in the router R2, THE MINIMUM NUMBER OF ENTRIES POSSIBLE. We also want only the machines in N1, N5 and DMZ to be able to access the Internet, and always through R2. There is a web, smtp and DNS server in the DMZ (*well-known* ports 80, 25, 53) and they have to be accessible from the Internet.

A) Propose a routing scheme for the internal networks.

B) Say which ones would be the routing tables of the routers when RIP converges. Use the following convention for the tables: N1, N2, … to refer to the previous nets, define other names (specify them below the tables as we show in the example) to refer to other address ranges. For the gateways, for example, R1.f1 to refer to the IP address of the router R1 on the interface f1.

C) RIP messages that each router will send in the interfaces where the other routers are present (use N1, N2--- and the names defined previously).

D) NAT configuration. Help yourself with the following table. In the table SNAT (source NAT) means that the first change is done over the source IP address (the usual NAT), and DNAT (destination NAT) is done over the destination IP address.

Router	Protocol (TCP/UDP)	Source Address (@IP/mask)	Destination address (@IP/mask)	Type of change (SNAT/DNAT)	Change to @IP	Port

Solution:

A)

As summarization is required we should use subnetworks addresses that miaght be summarized to a class. That is why we should use a class B (/16) address. Private addresses in class B are 172.16.0.0 a 172.31.0.0.

Net	address/mask
N1	172.16.0.0/18
N2	172.16.64.0/18
N3	172.16.128.0/18
N4	172.17.0.0/18
N5	172.18.0.0/18
N6	172.18.64.0/18
DMZ	172.17.64.0/18
Tunnel	192.168.0.0/24

IP Addresses			
	R1	f1	172.16.0.1
		f2	172.16.64.1
		f3	172.16.128.1
		f4	172.17.0.1
	R2	f1	172.17.0.2
		f2	172.17.64.1
		t1	192.168.0.1
	R3	f1	172.18.0.1
		f2	172.18.64.1
		t1	192.168.0.2

IP addresses of servers	
Web	172.17.64.2
SMTP	172.17.64.3
DNS	172.17.64.4

B)

R1

Destination	Gateway	Iface	M
N1	*	f1	1
N2	*	f2	1
N3	*	f3	1
N4	*	f4	1
DMZ	R2.f1	f4	2
Tunnel	R2.f1	f4	2
P3	R2.f1	f4	3
0/0	R2.f1	f4	2

R2

Destination	Gateway	Iface	M
ISP1	*	ppp	1
N4	*	f1	1
DMZ	*	f2	1
Tunnel	*	t1	2
P1	R1.f4	f1	2
P3	R3.t1	t1	2
0/0	ISP1	ppp	1

R3

Destination	Gateway	Iface	M
ISP2	*	ppp	1
N5	*	f1	1
N6	*	f2	1
Tunnel	*	t1	1
P2	R2.t1	t1	2
P1	R2.t1	t1	3
0/0	R2.t1	t1	2

ISP1: 80.0.0.1/32
P1: 172.16.0.0/16 (summarizes N1, N2 and N3)
P2: 172.17.0.0/16 (summarizes N4 and DMZ)
P3: 172.18.0.0/16 (summarizes N5 and N6)
0/0: 0.0.0.0/0

ISP2: 90.0.0.1/32

C)

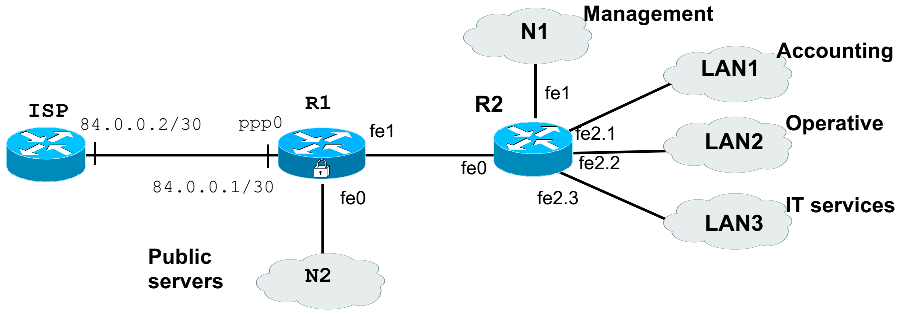
R1 in f4: Destinations: P1 with metrics: 1
R2 in f1: Destinations: DMZ, Tunel, 0/0, P3 with metrics: 1, 1, 1, 2
R2 in t1: Destinations: DMZ, 0/0, P1, P2 with metrics: 1, 1, 2, 1
R3 in t1: Destinations: P3 with metrics: 1

D)

Router	Protocol (TCP/UDP)	Source Address (@IP/mask)	Destination Address (@IP/mask)	Change type (SNAT/DNAT)	Changes to @IP	port
R2	TCP	N1	Any	SNAT	80.0.0.10	Any
R2	TCP	DMZ	Any	SNAT	80.0.0.10	Any
R2	TCP	N5	Any	SNAT	80.0.0.10	Any
R2	TCP	Any	80.0.0.10	DNAT	Web	80
R2	TCP	Any	80.0.0.10	DNAT	Smtp	25
R2	UDP	Any	80.0.0.10	DNAT	DNS	53

Problem 6.

The HQ of a company has the following configuration



We ask:

a) A valid routing for this company knowing that: 1) the router R1 separates the N2 public servers net from the rest of private nets; 2) the ISP provides a public address range from 200.0.0.0/24; 3) the company wants to maintain the 5 public servers (http, DNS, mail, ssh, fax) always visible from the Internet and wants to acquire the minimum number of public addresses; 4) in the private net there are 2 hosts in the Management net, 10 in the Accounting, 10 in operative and 5 in IT services. Motivate your reasoning and choices.

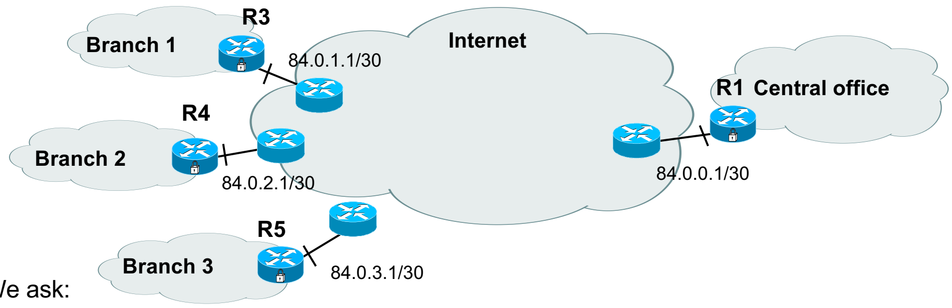
b) Explain what should be done to make the nets from Management, Accounting and Operative have access to the Internet. Motivate your reasoning and choices.

c) Configure the interfaces of the routers R1 and R2 and indicate their routing tables specifying the values of "**destination, mask, gateway, interface and metric**". Assume that RIPv2 has been activated and the tables have converged.

d) Configure the router R1 to act as firewall. In particular: 1) any Internet client should be able to access the public servers but not the private network; 2) the host on the private network can access the public servers and the Internet servers. Indicate clearly the interface where you apply the ACL rules, and if it's in the input or output of the interface. For the ACL rules use the following format:

Destination IP/mask destination_port source IP/mask source_port protocol status accept/deny

Assume now that this HQ belongs to a company that also has three branch offices.



We ask:

e) Propose which tunnels should be configured if we wish the least number of tunnels in the VPN of the company

f) Configure the IP addresses of the tunnels.

Solution

a) 5 public servers + router + broadcast + net = 8 @IP --> 3 bits for hostID, mask 29
200.0.0.0/29

We can also assign private addresses, for example 192.168.0.0/29 and configure a static NAT (or also static PAT being the ports of the server different amongst them) in the router R1. It is essential that they are static for each server to have only one address visible from the Internet (or an address-port tuple in the case of PAT).

We use private addresses for private networks

10.0.0.0/24 for the net R1-R2
10.0.1.0/24 for Management
10.0.2.0/24 for Accounting
10.0.3.0/24 for Operative
10.0.4.0/24 for IT services
We need 8 public addresses for the routing

b) We configure dynamic PAT (or dynamic NAT by ports) in the router R1 using the public address of the interface ppp0.

c)

R1-ppp0: 84.0.0.1/30,	R1-fe0: 200.0.0.1/29,	R1-fe1: 10.0.0.1/24
R2-fe0: 10.0.0.2/24,	R2-fe1: 10.0.1.1/24	
R2-fe2.1: 10.0.2.1/24,	R2-fe2.2: 10.0.3.1/24,	R2-fe2.3: 10.0.4.1/24

	Destination	Mask	Gateway	Intf	Hop
ISP-R1	80.0.0.0	30	-	ppp0	1
N2	200.0.0.0	29	-	fe0	1
R1-R2	10.0.0.0	24	-	fe1	1
N1	10.0.1.0	24	10.0.0.2	fe1	2
LAN1	10.0.2.0	24	10.0.0.2	fe1	2
LAN2	10.0.3.0	24	10.0.0.2	fe1	2
LAN3	10.0.4.0	24	10.0.0.2	fe1	2
	0.0.0.0	0	80.0.0.2	ppp0	-

Table R1

	Destination	Mask	Gateway	Intf	Hop
R1-R2	10.0.0.0	24	-	fe0	1
N1	10.0.1.0	24	-	fe1	1
LAN1	10.0.2.0	24	-	fe2.1	1
LAN2	10.0.3.0	24	-	fe2.2	1
LAN3	10.0.4.0	24	-	fe2.3	1
N2	200.0.0.0	29	10.0.0.1	fe0	2
	0.0.0.0	0	10.0.0.1	fe0	-

We assume R1 announces N2 and the default route

Table R2

d) 1) Interface fe0 out (it can also be grouped with 3 and configured in pp0 in)

destinationIP/mask	Destination_port	sourceIP/mass	Source_port	protocol	status	accept/deny
200.0.0.0/29	http	0.0.0.0/0	>1023	TCP	any	accept
200.0.0.0/29	DNS	0.0.0.0/0	>1023	TCP	any	accept
200.0.0.0/29	mail	0.0.0.0/0	>1023	TCP	any	accept
200.0.0.0/29	fax	0.0.0.0/0	>1023	TCP	any	accept
200.0.0.0/29	ssh	0.0.0.0/0	>1023	TCP	any	accept
0.0.0.0/0	any	0.0.0.0/0	any	any	any	deny

IP addresses for a single host may use /32

SMTP and DNS servers behave as clients of external servers too. This is taught in the last part of the course.

2) Interface fe1 in

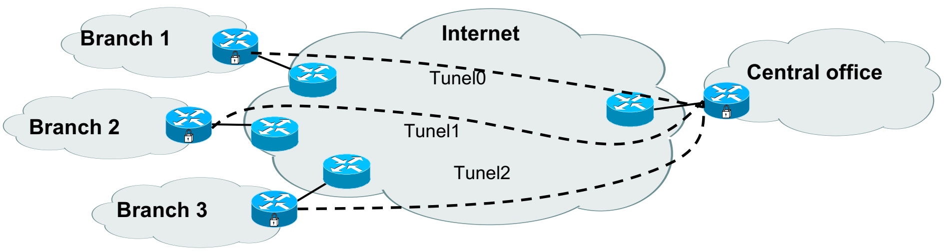
0.0.0.0/0	<1024	10.0.1.0/24	>1023	any	any	accept
0.0.0.0/0	<1024	10.0.2.0/24	>1023	any	any	accept
0.0.0.0/0	<1024	10.0.3.0/24	>1023	any	any	accept
0.0.0.0/0	any	0.0.0.0/0	any	any	any	deny

3) Interface fe1 out

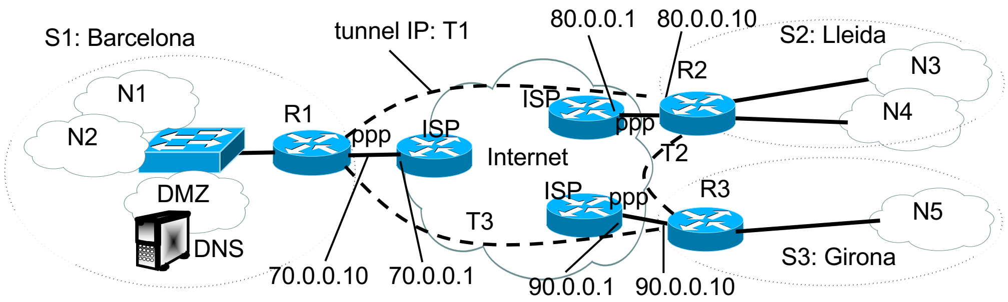
10.0.1.0/24	>1023	0.0.0.0/0	<1024	any	established	accept
10.0.2.0/24	>1023	0.0.0.0/0	<1024	any	established	accept
10.0.3.0/24	>1023	0.0.0.0/0	<1024	any	established	accept
0.0.0.0/0	any	0.0.0.0/0	any	any	any	deny

e) Three tunnels

Tunnel0 between 84.0.0.1 and 84.0.1.1, interface tun0 in R1: 10.100.0.1/24, interface tun0 in R3: 10.100.0.2/24
Tunnel1 between 84.0.0.1 and 84.0.2.1, interface tun1 in R1: 10.100.1.1/24, interface tun0 in R4: 10.100.1.2/24
Tunnel2 between 84.0.0.1 and 84.0.3.1, interface tun2 in R1: 10.100.2.1/24, interface tun0 in R5: 10.100.2.2/24



Problem 7.



IP public addresses:
IP-R1: 70.0.0.10, ISP: 70.0.0.1
IP-R2: 80.0.0.10, ISP: 80.0.0.1
IP-R3: 90.0.0.10, ISP: 90.0.0.1
200.0.0.0/27

Number of stations:
N1: 750
N2: 150
N3: 100
N4: 350
N5: 100
DMZ: 4 servers

This corporate network has a VPN with 3 branches (S1, S2, S3) connected with IP tunnels. In each branch there's a router with the subnets shown in the figure. All the routers have DHCP servers. Assume that the connections with the ISPs are formed by ppp links with the addresses shown in the figure. Additionally, the address range 200.0.0.0/27 has been contracted to the ISP of branch S1. The 200.0.0.0/27 addresses are wanted to be assigned to the DMZ servers (the ones with lowest numeric value), and the rest, as many as possible, to access to the Internet with PAT (also known as NAT-PAT). The figure also shows the name of stations that will exist in each net. We want all the stations to have access to the Internet, and that all the connections made from inside the corporate network go through R1. In the network we want to use RIPv2. We have to keep to a minimum the static routes added manually. Assume that we want the IP addresses of the router R1 to have the hostid=1 in all the possible interfaces, the ones of R2 to have the hostid=2 and the ones of R3 to have the hostid=3. Answer the following questions. Make up the data that is left. Justify your answers.

A. Propose a routing schema indicating: (i) The address for each IP subnet that you define with the format @IP/number of bits of the mask. Also give the mask with point's notation. Say how many stations could be connected as a maximum in each of the subnets N1, … , N5 and DMZ that you have defined. (ii) Clearly indicate the configuration regarding the IP addresses that you assume for the tunnels. (iii) Say which is the address range that will be used to access the Internet with PAT, with the format: @IP initial-@IP final.
B. Say if some static route will have to be added. State the routing tables of R1, R2, R3 when RIP has converged. For each entry give: Destination/bit mask, Gateway, interface and RIP metric.
C. Tell which will be the contents of the RIP message that R2 will receive if Split horizon is used.
D. (i) Explain which types of protocols can output to the Internet with PAT, and the packet fields that may be modified when going through the PAT router to reach the Internet. (ii) What's the limitation that PAT will have over the maximum number of connections that can be initiated simultaneously towards the Internet for each one of these protocols, and calculate what will be the maximum number of connections, clearly explaining the assumptions that you make.
E. Assume that a station is booted in the N1 network. Explain the messages that would be generated until the machine is completely configured. Indicate the source/destination IP addresses that the DHCP messages will have, and the entries that the ARP table will have (if any).
F. Assume that all the ARP tables are empty and that in a station in N4 the command ping www.upc.edu is executed. Say all the devices in the corporate network that will have had the ARP table modified, how many entries and their values when the station receives the "echo reply" message.

Solution:

A. For the network N1~N5 we will take private addresses of type B (172.16.0.0~172.31.0.0) to make space for all the stations. For the DMZ we will need 3 hostid bits: We will be able to connect 8-2-1=5 servers. We choose the 200.0.0.0/29 network. For PAT we have the rest of addresses: 200.0.0.8 ~200.0.0.31 (in total, 24 addresses). For the tunnels we will use class C private networks:

Net	Address/Mask	Mask in points notation	#stations
N1	172.21.0.0/16	255.255.0.0	2^{16}-3=65.533
N2	172.22.0.0/16	255.255.0.0	2^{16}-3=65.533
N3	172.23.0.0/16	255.255.0.0	2^{16}-3=65.533
N4	172.24.0.0/16	255.255.0.0	2^{16}-3=65.533
N5	172.25.0.0/16	255.255.0.0	2^{16}-3=65.533
DMZ	200.0.0.0/29	255.255.255.248	5
T1	192.168.1.0/24	255.255.255.0	
T2	192.168.2.0/24	255.255.255.0	
T3	192.168.3.0/24	255.255.255.0	

B. The only static route that has to be added is the by default route in R1. In the following tables, the values Destination/Mask of the corresponding column are indicated in section A.

Dest/Mask	Gateway	Interf	M
N1		E0.1	1
N2		E0.2	1
N3	192.168.1.2	Tun0	2
N4	192.168.1.2	Tun0	2
N5	192.168.2.3	Tun1	2
DMZ		E0.3	1
T1		Tun0	1
T2	192.168.1.2	Tun0	2
T3		Tun1	1
0.0.0.0/0	70.0.0.1	Ppp0	1
70.0.0.1/32		Ppp0	1

Table 1: R1

Dest/Mask	Gateway	Interf	M
N1	192.168.1.1	Tun0	2
N2	192.168.1.1	Tun0	2
N3		E0.1	1
N4		E0.2	1
N5	192.168.2.3	Tun1	2
DMZ	192.168.1.1	Tun0	2
T1		Tun0	1
T2		Tun1	1
T3	192.168.1.1	Tun1	2
0.0.0.0/0	192.168.1.1	Tun0	2
80.0.0.1/32		Ppp0	1

Table 2: R2

Dest/Mask	Gateway	Interf	M
N1	192.168.3.1	Tun0	2
N2	192.168.3.1	Tun0	2
N3	192.168.2.2	Tun1	2
N4	192.168.2.2	Tun1	2
N5		E0	1
DMZ	192.168.3.1	Tun0	2
T1	192.168.3.1	Tun0	2
T2		Tun0	1
T3		Tun1	1
0.0.0.0/0	192.168.3.1	Tun0	2
90.0.0.1/32		Ppp0	1

Table 3: R3

C.

R1:

Dst/Mask	M
N1	1
N2	1
N5	2
DMZ	1
T3	1
0.0.0.0/0	1

R3:

Dst/Mask	M
N1	2
N2	2
N5	1
DMZ	2
T1	2
T3	1
0.0.0.0/0	2

D.

(i) ICMP, TCP, UDP. The router will modify all the datagrams that leave towards the Internet with PAT: source IP address; and maybe, the identifier for ICMP and the source port for UDP and TCP
(ii) Since we have 24 addresses for PAT:
ICMP: $24 \times 2^{16} = 1.572.864$
TCP: $24 \times (2^{16} - 1024) = 1.548.288$
UDP: $24 \times (2^{16} - 1024) = 1.548.288$
Assumptions: we can use all the ephemeral ports.

E.

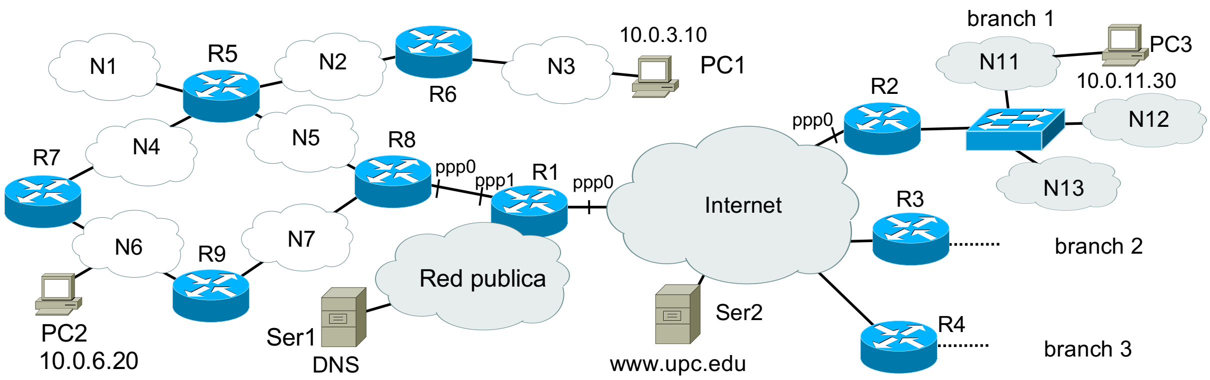
Assumptions: The PC uses the values of the previous session (so the DHCPDISCOVERY/DHCPOFFER is not sent).
The host sends: DHCP-REQUEST: dst = 255.255.255.255, src= 0.0.0.0
The DHCP server sends: DHCP-ACK: dst = 255.255.255.255, src= 172.21.0.1
The ARP tables will be empty (there's no ARP resolution).

F.

There will be 1 entry on the station, R1, R2 and DNS server:
ARP table of the station: @IP = 172.24.0.2 (R2) and @MAC-R2
ARP table of R2: @IP = 172.24.0.10 (station) and @MAC-station
ARP table of R1: @IP = 200.0.0.2 (DNS server) and @MAC-DNS
ARP table of the DNS server: @IP = 200.0.0.1 (R1) and @MAC-R1.

Problem 8.

A company has the network of the figure composed by a central HQ and three branches connected through the Internet.



In the central HQ we have:

- Seven private internal department networks (N1 to N7). These networks have private addresses of type 10.0.X.0/24 where X is the number of the network (for example, N1 has 10.0.1.0/24).
- A network for the public servers (public network).
- A router/firewall that connects the private and public nets to the Internet.

Each branch Y is composed by:

- A router that connects to the central HQ with a VPN through an Internet tunnel.
- 3 LANs (from NY1 to NY3) that compose the private network. The private addresses follow the same schema of the central HQ, for example, the network N31 of branch 3 has the 10.0.31.0/24.

a) From the range 202.0.1.128/25, design a routing schema for the public part knowing that it is composed by 7 networks:
   - Two interconnection nets between routers
   - Three nets with 5 hosts each
   - A net with 28 hosts
   - A net with 50 hosts

b) Knowing that the public IP addresses of the routers R1-R4 are 200.0.1.1, 200.0.2.1, 200.0.3.1 and 200.0.4.1 respectively and that R1 uses dynamic NAT with range 202.0.1.10-202.0.1.19, while R2, R3 and R4 use PAT, deduce:
   - If PC1 makes a ping to PC3, the IP addresses that will have the datagrams in N5, in Internet and in N11.
   - If PC1 makes a ping to Ser2, the IP addresses that will have the datagrams in N5 and in Internet.
   - If PC3 makes a ping to Ser2, the IP addresses that will have the datagrams in N11 and in Internet

c) Assign IP addresses to the internal interfaces (the ones that are connected to the switches) of the routers R2, R3 and R4.

d) Write the sequence of packets that will be sent until the first echo reply is received if we execute in PC2:

   ping www.upc.edu.

   For it, assume:

   - All the ARP caches are empty
   - PC2 doesn't know the IP address of www.upc.edu
   - The name server of PC2 is Ser1
   - Ser1 has the IP address of www.upc.edu cached, which is 209.85.135.99

   Use the following table format to answer the question:

		Ethernet header		IP header		ARP message					ICMP	DNS
		@src	@dst	@src	@dst	Q/R	sender		target		Q/R	Q/R
							MAC	IP	MAC	IP		
1												

To indicate the MAC address of a router use: :X:i where X=number of the net, and i=number of the router. For example, if we want to indicate the MAC of R9 in the net N6 we would do it like this: :6:9. Similarly, to indicate IP addresses, use: .X.i. To indicate broadcast we will use: :FF:FF for Ethernet and .FF.FF for IP.

Solution

a)

	Users	Router interface	Net and broadcast	Total IP	2-Multiple	hostID
Red R-R1	0	2	2	4	$2^2 = 4$	2
Red R-R2	0	2	2	4	$2^2 = 4$	2
Red 1	5	1	2	8	$2^3 = 8$	3
Red 2	5	1	2	8	$2^3 = 8$	3
Red 3	5	1	2	8	$2^3 = 8$	3
Red 4	28	1	2	31	$2^5 = 32$	5
Red 5	50	1	2	53	$2^6 = 64$	6

To assign the IPs you should start with the nets with the lower masks

netID	subID		hostID						@IP net	@IP broadcast	Net
peso	128	64	32	16	8	4	2	1			
202. 0. 1.	1	0	X	X	X	X	X	X	202.0.1.128	202.0.1.191	Net 5
202. 0. 1.	1	1	0	X	X	X	X	X	202.0.1.192	202.0.1.223	Net 4
202. 0. 1.	1	1	1	0	0	X	X	X	202.0.1.224	202.0.1.231	Net 3
202. 0. 1.	1	1	1	0	1	X	X	X	202.0.1.232	202.0.1.239	Net 2
202. 0. 1.	1	1	1	1	0	X	X	X	202.0.1.240	202.0.1.247	Net 1
202. 0. 1.	1	1	1	1	1	0	X	X	202.0.1.248	202.0.1.251	Net R-R1
202. 0. 1.	1	1	1	1	1	1	X	X	202.0.1.252	202.0.1.255	Net R-R2

The masks are

2 bits of hostID => mask 32 – 2 = 30
3 bits of hostID => mask 32 – 3 = 29
5 bits of hostID => mask 32 – 5 = 27
6 bits of hostID => mask 32 – 6 = 26

/24	hostID								Nets
peso	128	64	32	16	8	4	2	1	
255.255.255.	1	1	1	1	1	1	0	0	Net R-R1 and Net R-R2
255.255.255.	1	1	1	1	1	0	0	0	Net 1, Net 2 and Net 3
255.255.255.	1	1	1	0	0	0	0	0	Net 4
255.255.255.	1	1	0	0	0	0	0	0	Net 6

b)

PC1 ping to PC3
N5: @IP source 10.0.3.10, @IP destination 10.0.11.30
Internet: @IP source 201.0.1.1, @IP destination 201.0.1.2 (IPinIP @IP source 10.0.3.10, @IP destination 10.0.11.30)
N11: @IP source 10.0.3.10, @IP destination 10.0.11.30
PC1 ping a Ser2
N5: @IP source 10.0.3.10, @IP destination 209.85.135.99
Internet: @IP source 202.0.1.10, @IP destination 209.85.135.99
PC1 ping a PC3
N11: @IP source 10.0.11.30, @IP destination 209.85.135.99
Internet: @IP source 201.0.2.1, @IP destination 209.85.135.99

c)

R2:	10.0.11.1/24	10.0.12.1/24	10.0.13.1/24
R3:	10.0.21.1/24	10.0.22.1/24	10.0.23.1/24
R4:	10.0.31.1/24	10.0.32.1/24	10.0.33.1/24

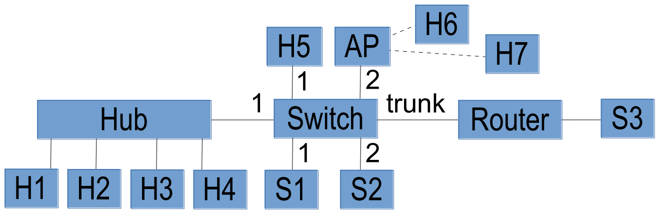
d)

		Eth. header		IP header		ARP message					ICMP	DNS
		@src	@dst	@src	@dst	Q/R	sender		target		Q/R	Q/R
							MAC	IP	MAC	IP		
1	N6	:6:20	:FF:FF			Q	:6:20	10.0.6.20		.6.9		
2	N6	:6:9	:6:20			R	:6:9	.6.9	:6:20	10.0.6.20		
3	N6	:6:20	:6:9	10.0.6.20	.Ser1							Q
4	N7	:7:9	:FF:FF			Q	:7:9	.7.9		.7.8		
5	N7	:7:8	:7:9			R	:7:8	.7.8	:7:9	.7.9		
6	N7	:7:9	:7:8	10.0.6.20	.Ser1							Q
7	ppp			10.0.6.20	.Ser1							Q
8	RP	:R1	:FF:FF			Q	:R1	.R1		.Ser1		
9	RP	:Ser1	:R1			R	:Ser1	.Ser1	:R1	.R1		
10	RP	:R1	:Ser1	10.0.6.20	.Ser1							Q
11	RP	:Ser1	:R1	.Ser1	10.0.6.20							R
12	ppp			.Ser1	10.0.6.20							R
13	N7	:7:8	:7:9	.Ser1	10.0.6.20							R
14	N6	:6:9	:6:20	.Ser1	10.0.6.20							R
15	N6	:6:20	:6:9	10.0.6.20	209.85.135.99						Q	
16	N7	:7:9	:7:8	10.0.6.20	209.85.135.99						Q	
17	ppp			10.0.6.20	209.85.135.99						Q	
18	Internet			202.0.1.10	209.85.135.99						Q	
19	Internet			209.85.135.99	202.0.1.10						R	
20	ppp			209.85.135.99	10.0.6.20						R	
21	N7	:7:8	:7:9	209.85.135.99	10.0.6.20						R	
22	N6	:6:9	:6:20	209.85.135.99	10.0.6.20						R	

Unit Local Area Networks (LAN)

Problem 9. ***(2014t)***

An organisation has a network as shown in the figure.



The switch is configured with 2 VLAN 1 and 2 as shown with the numbers by each port. PCs are connected via wire (H1-H5) and wireless (H6-H7). Server S1 is in VLAN1, and S2 is in VLAN2. Server S3 is available to all PCs through the router. Assume that all connections are at 100 Mbps and that the configuration is optimal.

a) Complete the list of devices that will be accessed when sending a broadcast (for instance, a ping) from:

H1: H6: S3:

b) Complete the list of devices traversed by an Ethernet frame sent from:

H2 to S3: H5 to S2: H7 to S1:

c) If all PCs (H*) transmit Ethernet frames (unicast) at the maximum rate and continuously from the server belonging to its corresponding VLAN (S1 for VLAN 1 and S2 for VLAN 2), compute the maximum transfer speed achieved by:

H3: H5: H6:

d) If all PCs (H*) receive Ethernet frames from their corresponding server in their VLAN, compute the maximum transfer speed they achieve.

Solution:

a)

H1: H1 H2 H3 H4 H5 S1 R

H6: H6 H7 S2 R

S3: R

b)

H2 to S3: H S R

H5 to S2: S R S

H7 to S1: AP S R S

c)

S1 and S2 belong to different VLANs so the limit is 100 Mbps for each port and VLAN.

H3: 100/4/2 Mbps (/4 at the Hub, /2 for sharing ports at Switch for VLAN 1)

H5: 100/2 Mbps (sharing ports at Switch for VLAN 1)

H6: 100/2 Mbps (at the AP, the switch does not limit the rate)

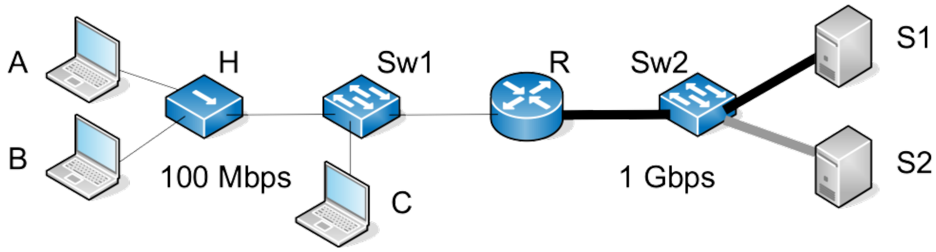
d)

There is no flow control

H1 = H2 = H3 = H4 = H5 = 100/5 = 20 Mbps

H6 = H7 = 100/2 = 50 Mbps

Problem 10.



a) On the network in the figure, computer A only **downloads** an S1 file. What limits the download?

b) Now A, B, C **download** files from S1 at the same time. How do links limit downloads? What does R do?

c) Now A, B, C **send** files to S1 at the same time. How do links limit downloads?

The Sw1 to R link is raised from 100 Mbps to 1 Gbps.

d) How does the result of b) change? What does Sw1 do?

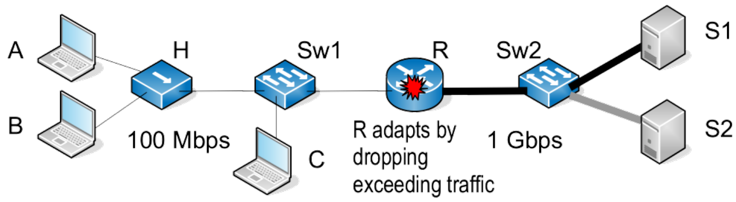
e) How does the result of c) change? What does H do?

Solution:

We do not consider transport (TCP or UDP) only Ethernet.

a) Limitations: the A-H link and the others that run at 100 Mbps, also the CPU and input-output of the hosts.

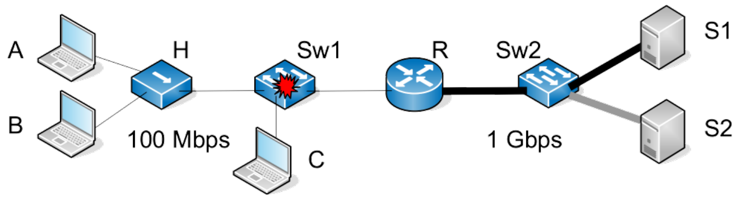
b) The maximum is 3*100, which limits:



H-Sw1: A+B < 100 → A,B < 50

Sw1-R: A+B+C < 100 → A,B,C < (100/3 = 33)

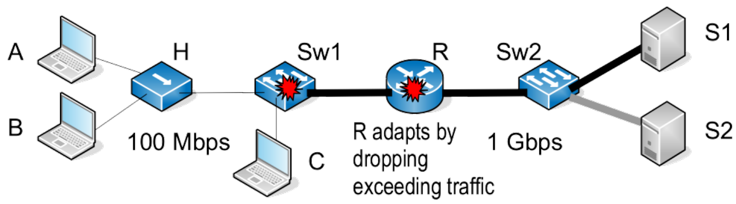
a) The maximum is 3*100, which limits:



H-Sw1: A+B < 100,

Sw1-R: (A+B)+C < 100 → (A+B),C=100/2; A=B=50/2

b) The maximum is 3*100, which limits:

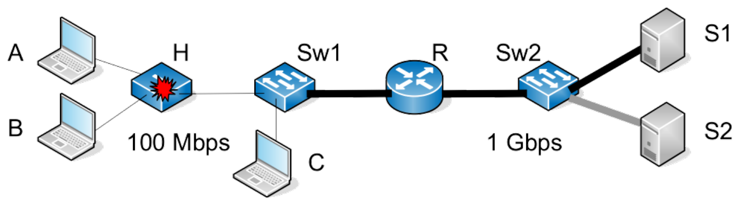


H-Sw1: A+B < 100; A,B < 50

Sw1-R:

- Switch ports: A+B<100, C<100:
  If Sw1-R reaches more than 200 it can send pause frames and the router throws the excess packets.
  200 - 50(A) - 50(B) = 100(C)

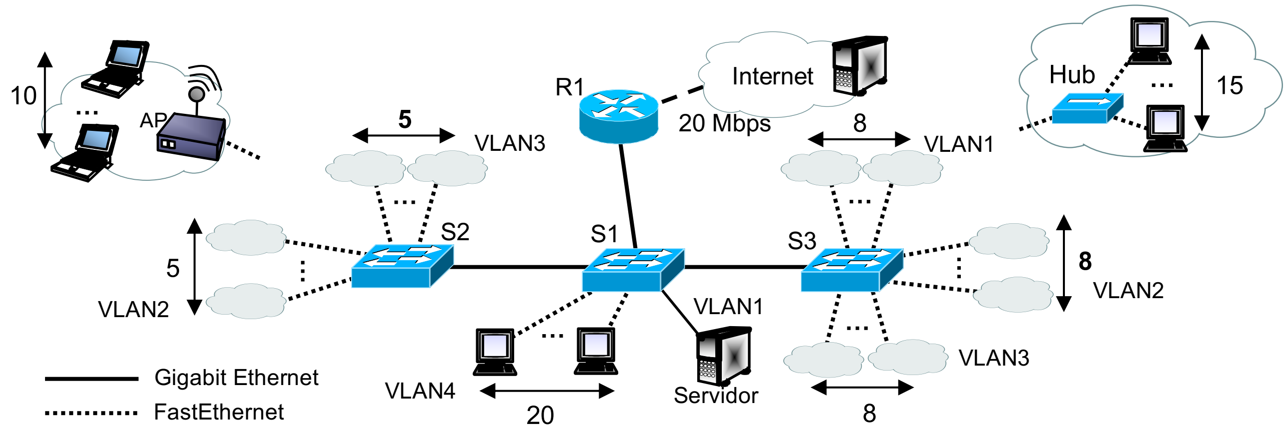
c) The maximum is 3*100, which limits:



H-Sw1: A+B < *100*, A=B=50

C=100

Problem 11.



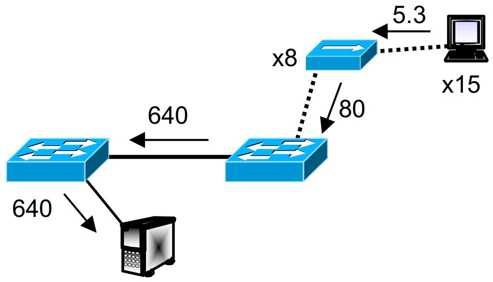
The net of the figure is formed by 460 stations and an internal server. Four VLANs have been configured. All the links are Fast Ethernet except for the links S1-S2, S1-S3, S1-R1 and S1-Server that are Gigabit Ethernet and the link from the router to the internet that is a 20Mbps link. The efficiency of the Switches is 100%, of the Hubs is 80% and of the Access-Points (APs) is 66.7% (two thirds). Each VLAN connected to the switch S3 consists of 8 hubs, each one connected to 15 stations. Each VLAN connected to the switch S2 consists of 5 APs, each one connected to 10 wireless stations. The APs and the wireless stations use 802.11g (54 Mbps). Assume that all the stations use a type of application that uses TCP connections and that they always have information ready to transmit to the server (the answers of the servers are negligible). The stations that are not active do not transmit. Answer these questions for the scenarios that are given: (i) The links where a bottleneck will be created, (ii) Which will be the mechanism(s) that will regulate the effective speed of the stations, (iii) The effective speed that the active stations will achieve. Reason and **motivate** the answers commenting the assumptions made.

A. Only the stations of VLAN1 are active.
B. Only the stations of VLAN2 and VLAN3 are active.
C. Only the stations of VLAN1 and VLAN4 are active.
D. The stations of VLAN1, VLAN2 and VLAN3 access an Internet server.

Solution:

A. The efficiency of the hubs is 80% so, at their maximum capacity, they transmit 80 Mbps to S3. Since there are 8 hubs connected to S3, in the link S1-S3 there's 8x80 = 640 Mbps. Since it is inferior to the capacity of the link (1Gbps), there is no congestion in S3. Since only the stations of VLAN1 are transmitting to the server (which is also in VLAN1), the frames go directly from S1 to the server (without going through the router). Being the link S1-server of 1 Gbps, there is no congestion in S1. So:

(i) The bottlenecks are the hubs
(ii) The CSMA/CD of the stations controls and distributes the 80 Mbps of each hub.
(iii) The 15 stations of each hub share evenly the 80 Mbps, so 80/15 = 5.3 Mbps.



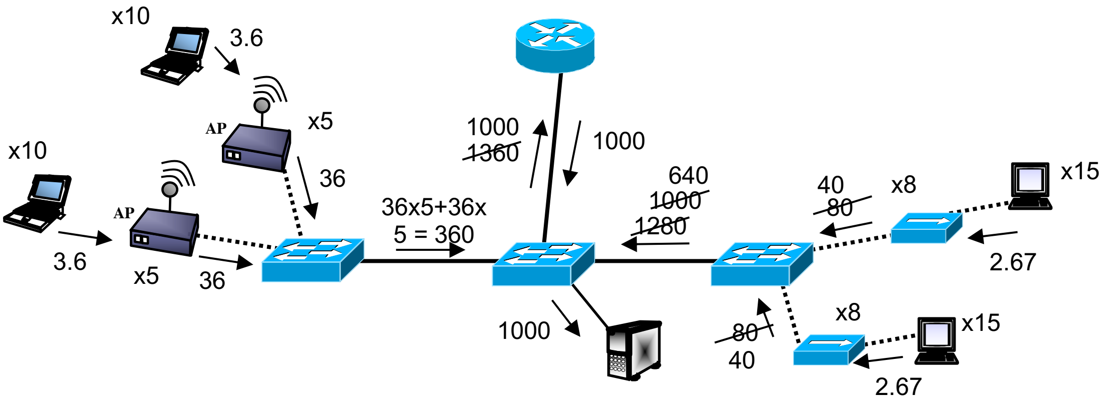
B. We start with the left part of the net. The efficiency of the APs is 66.7% so, at their maximum capacity, they transmit 54x0.67 = 36 Mbps to S2 (which is lower to the capacity of the Fast Ethernet link). Since there are 5 APs in VLAN2 and another 5 in VLAN3, at the output of S2 there's 36x5x5 =360 Mbps. Since it is lower than the capacity of the S2-S1 link (1 Gbps), there is no congestion in S2.

In the right part, there are also stations from VLAN2 and VLAN3. As in the case of point A, each hub transmits 80 Mbps to S3. Since there are 8 hubs in VLAN2 and another 8 in VLAN3, at the output of S3 there are 80x8+80x8 = 1280 Mbps. Since the capacity of the link (1 Gbps) is surpassed, S3 only transmits 1000 Mbps. Differently to the last case, now the stations belong to VLANs different from the server's so, they have to go through the trunk link of the router. Totalling what goes into S1, through the trunk should go 1000+360 = 1360 Mbps. Since this exceeds the capacity of the trunk (1 Gbps), S1 has to do flow control and limit the transmission to 1000 Mbps. From now on there are no more restrictions being the link S1-server of 1 Gbps. So:

(i) The general bottleneck is the trunk S1-R1. In WiFi the bottlenecks are the APs.

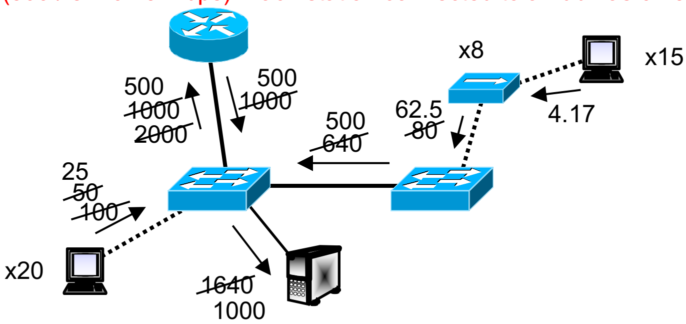
(ii) S1's flow control distributes the 1000 Mbps of the trunk evenly between the two input links (S2-S1 and S3-S1). As in link S2-S1 goes through 360 Mbps, which is less than half of the trunk (500 Mbps), S1 only limits the link S3-S1 to 1000-360 = 640 Mbps. Being a FDX link, flow control is done with pause frames. In the APs speed is regulated by CSMA/CA.

(iii) Going back, S3 distributes this 640 Mbps between the 16 connected hubs (640/16 = 40 Mbps). Since these links are HDX, S3 does flow control with jabber frames. The 15 stations of each hub share the 40 Mbps (40/15 = 2.67 Mbps). On the other hand, S2 does not need to do flow control. The 36 Mbps of each APs are shared amongst the 10 stations (36/10 = 3.6 Mbps) through the CSMA/CA.



C. For the stations of VLAN1 is like the case in section A and for the link S3-S1 we try to transmit 640 Mbps. The 20 stations of VLAN4 have Fast Ethernet links and try to transmit at 100 Mbps. These stations do not belong to the server's net and they need to go through the trunk. Being 20 stations, through the trunk should go through 20x100 = 2000 Mbps which exceeds its capacity. S1 limits then the stations to 50 Mbps each one (1000/20 = 50 Mbps). These 1000 Mbps have to be added to the 640 Mbps that come from VLAN1 and then go towards the server (1000+640 = 1640 Mbps). Since this exceeds the capacity of the link S1-server (1 Gbps), S1 has to limit the inputs. So:

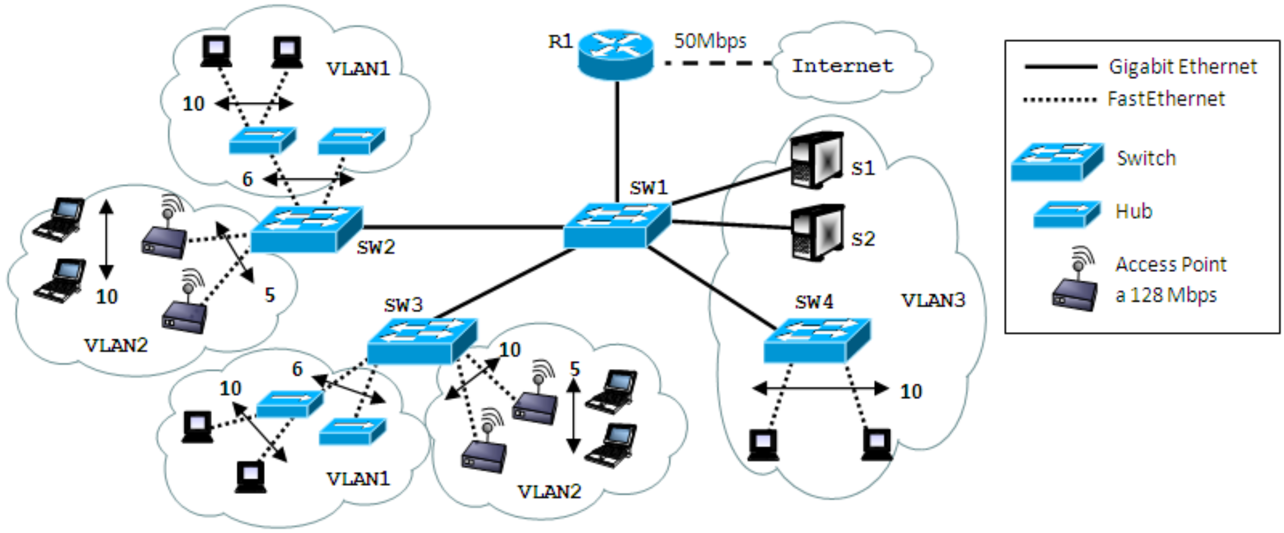
(i) The general bottleneck is the link S1-server
(ii) S1 uses flow control (pause frames) to distribute the 1000 Mbps capacity between the two input links (S3-S1 and R1-S1). Since the router is not able to do flow control, it sends to the server the 500 Mbps that S1 allows and discards the excess traffic (the output queue of the link fills). Therefore, the 500 Mbps of the router are shared amongst the stations of VLAN4 and TCP regulates it.
(iii) Going back, the 20 stations of VLAN4 share evenly the 500 Mbps (500 / 20 = 25 Mbps). The hubs of VLAN1 share the other 500 Mbps (500 / 8 = 62.5 Mbps). Each station connected to a hub has 62.5 / 15 = 4.17 Mbps.



D.
In this case:

(i) The bottleneck is the Internet connection of 20 Mbps
(ii) If all the stations are the same, the losses in the router's buffer regulate the congestion windows (TCP) of the hosts and this capacity is shared evenly.
(iii) Each station has 20 Mbps / (15x8+15x8+15x8+10x5+10x5) = 43.48 kbps.

Problem 12.



The network of the figure is formed by 230 stations and two servers S1 and S2. Three VLANs have been configured where the number of Access Points (APs), hubs and stations per hub or AP is indicated in the figure. The wired links are Gigabit Ethernet or Fast Ethernet depending on whether they are drawn with dotted or solid lines respectively. The APs use a wireless connection at 128 Mbps. The link from the router to the Internet has 50 Mbps. The efficiency of the Switches is 100%, of the Hubs is 80% and of the APs is 50%. Answer for the scenarios that are given assuming that the only stations that transmit information are the active ones, neglecting the effect of the responses. We ask you to determine for each scenario:

(i) The links where the main bottleneck would be created.

(ii) Which would be the mechanism(s) that would regulate the effective speed of the stations?

(iii) The effective speeds that the active stations would achieve.

A. Only the stations from VLAN1 are active and transmit to the server S1.
B. Only the stations from VLAN1 and VLAN2 are active and transmit to the server S1.
C. Only the stations from VLAN3 are active and transmit evenly to the servers S1 and S2.
D. Same case as the previous one but now the servers S1 and S2 also transmit to the stations.
E. The stations of VLAN1 and VLAN2 transmit to an Internet server.

Solution

A.

(i) The bottlenecks are the hubs.
(ii) The CSMA/CD of the stations controls and distributes the 80 Mbps of each hub.
(iii) The 10 stations of each hub distribute evenly the 80 Mbps, so, 80/10 = 8 Mbps.

B.

(i) The main bottleneck is the trunk link between SW1 and R1.
(ii) SW1 does flow control with pause frames and distributes the 1000 Mbps between SW2 and SW3.
(iii) Between SW2 and SW1 there is 500 Mbps that the hubs and APs have to evenly distribute 500/11 = 45.5 Mbps. The stations of each AP would have 45.5/10 = 4.55 Mbps.
Between SW3 and SW1 there is 500 Mbps that the hubs and APs have to evenly distribute 500/16 = 31.25 Mbps. The 10 stations of each hub will have 31.25/10 = 3.125 Mbps. The stations of each AP will have 31.25/5 = 6.25 Mbps.

C.

(i) The bottleneck is the connection host-switch.
(ii) There is no flow control because there is no bottleneck. The TCP of the stations will make each station transmit half of the time to S1 and the other half to S2.
(iii) All the links are FDX and the stations and servers belong to the same VLAN. The 10 stations transmit at 100 Mbps (50 Mbps towards the server); SW4 transmits to SW1 at 1000 Mbps; the servers will receive at 500 Mbps each one.

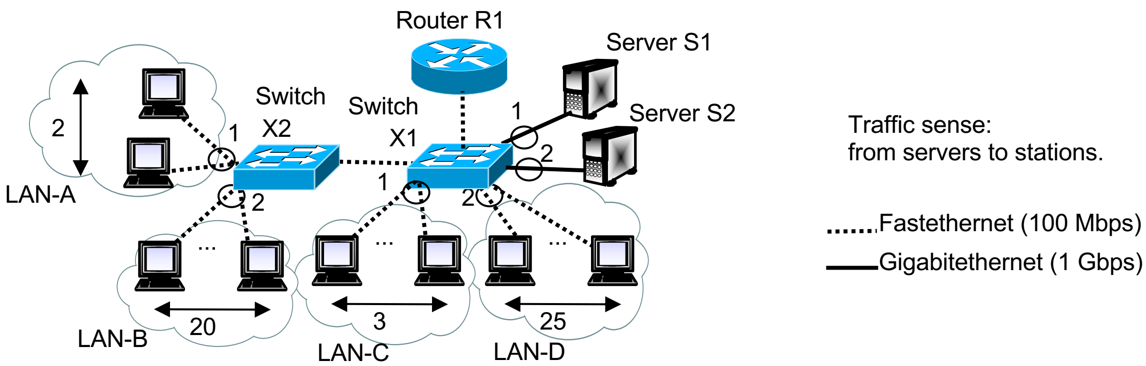
D. As all the links are FDX and the servers and stations belong to the same VLAN, both ways of the transmission can be treated separately. For the station-server way we have the same we determined in the point 3.C. For the server-station way:

(i) The bottleneck is SW1.
(ii) SW1 does flow control towards the servers sending pause frames to distribute the 1000 Mbps of the link SW1-SW4 amongst S1 and S2.
(iii) Each server transmits at 500 Mbps. At the output of SW1 there will be 1000 Mbps that are then distributed amongst the 10 station that will work at 1000/10 = 100 Mbps.

E.

(i) The bottleneck is the Internet connection at 50 Mbps
(ii) If all the stations are the same, the losses in the buffer of router R1 regulate the congestion window of the hosts (i.e. TCP acts) and the 50 Mbps are shared evenly amongst the stations.
(iii) Each station will work at 50 Mbps / (6x10+5x10+6x10+10x5) = 227.3 kbps.

Problem 13.



The network of the figure is formed by 50 stations and 2 servers. Two VLANs have been configured. The numbers in the commuter's ports indicate the VLAN they belong to. All the ports are full duplex. All the links are Fast Ethernet, except for the links with the servers, which are Gigabit Ethernet. The efficiency is 100%. Assume that all stations use a type of application that opens a TCP connection and downloads information from the server. Assume that the flow control of the commuters is activated and works in an optimal way (you can assume that for a same port is capable of controlling different flows in differentiated ways).

Answer for the scenarios that are given next:

(i) The links where the bottlenecks will be.
(ii) The effective speed that a station of each LAN will achieve. Use the notation s_{ef}^A,...s_{ef}^D, to refer to the effective speed of a station of LAN-A,…, LAN-D.

A. All the stations access simultaneously to the server that resides in their VLAN.
B. Repeat section A assuming that the link X1-X2 is Gigabit Ethernet. Say which will be the traffic that will go through the link X1-X2.
C. Repeat section A assuming that the flow control of the commuters is deactivated.
D. Repeat section A assuming that the stations access the server that is not in their VLAN (meaning that the stations connected to VLAN1 access server S2 and vice versa).

Solution:

A.

(i) Clearly, the link X1-X2 will be a bottleneck. The link X1-S2 will also be a bottleneck. The link with server S1 will not be a bottleneck because there are only 5 stations in VLAN1. Since they are connected to an FE port, they cannot congest the GE link with the server. For the stations of VLAN1 connected to X1, the links with the commuter will be the bottleneck.

(ii) We assume that the CF will distribute evenly the capacity of the link X1-X2 amongst the links that send traffic (S1 and S2). We assume that TCP will evenly distribute the capacity that remains available in the link X1-S2 amongst the connections with the stations of LAN-D. So:

Sef^A = (100 Mbps/2)/2 = 25 Mbps
Sef^B = (100 Mbps/2)/20 = 2.5 Mbps
Sef^C = 100 Mbps
Sef^D = (1Gbps - 50Mbps)/25 = 38 Mbps

B.

(i) For the stations of VLAN1 the bottleneck is the connection with the commuter, and for the stations of VLAN2 the link X1-X2.

(ii) TCP will distribute evenly the link X1 –X2 amongst the connections. So:

Sef^A = Sef^C = 100 Mbps
Sef^B = Sef^D = 1Gbps/45 = 22.2 Mbps

The traffic in link X1-X2 will be: = $Sef^{X1\text{-}X2}$ = 2 x Sef^A + 20 x Sef^B = 644 Mbps (we check that it's not a bottleneck).

C

(i) The bottlenecks are the same as in section A.

(ii) Now TCP will distribute the capacity of the link X1-X2 amongst the connection that go through it:

Sef^A = Sef^B = (100 Mbps) / 22 = 4.5 Mbps
Sef^C = 100 Mbps
Sef^D = (1Gbps-20xSef^B)/25 = 36.4 Mbps

D

(i) The bottleneck will be the link X1-R1.

(ii) The commuter X1 will activate the flow control and distribute the capacity of the link X1-R1 amongst the servers: 50 Mbps each. TCP will evenly share the traffic of each server towards the commuter amongst all the connections that use it:

Sef^A = Sef^C = (50 Mbps) / 5 = 10 Mbps
Sef^B = Sef^D = (50 Mbps) / 45 = 1.1 Mbps

Problem 14. *(2014p)*

Figure 1 shows the network configuration for a small company. The Internet connection is a cable connection at 20 Mbps. Ehternet switch 1 (sw1) has Fast Ethernet ports only (100 Mbps) and one 1 Gbps link to sw2. Ethernet switch 2 (sw2) has Gigabit ports only.

Each WiFi Access Point (AP) supports 300 Mbps wireless connection and its efficiency is 70%. Each one of the 5 AP connects 10 laptops. Each one of the 5 switches (C1, .. C5) connects 10 terminals with Fast Ethernet (100 Mbps). Servers A and B are connected at Fast Ethernet to sw1.

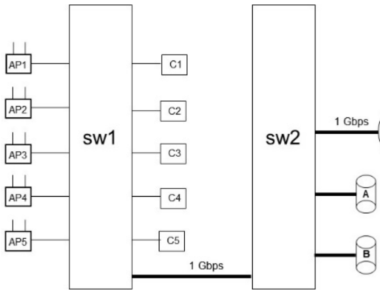


Figure 1

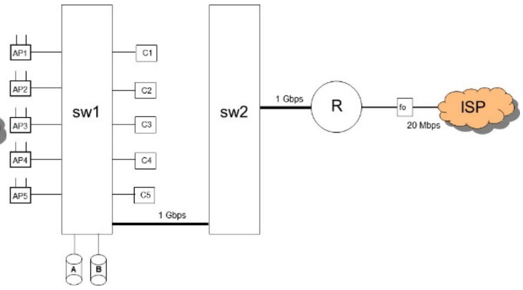


Figure 2

Consider that all laptops and terminals are downloading information continuously from both servers at the same time.

a) What is the download speed for each laptop and terminal from each server?

With the aim of improving the efficiency servers A and B are moved to sw2 and are connected at 1 Gbps as shown in Figure 2.

b) Now, what is the download speed for each terminal and laptop from each server? Explain how the flow control applies.

In order to isolate the departments two sub-networks are configured using two VLAN.

VLAN1 includes AP1, AP2, C1, C2, C3 and server A. VLAN2 includes AP3, AP4, AP5, C4, C5 and server B.

Consider that all laptops and terminals are downloading information continuously from both servers at the same time.

c) Identify the bottlenecks and how the flow control applies. What is the download speed for each terminal and laptop from each server?

d) If all terminals and laptops are downloading data from the Internet and, at the same time, they are downloading from servers A and B, what is the download speed they can achieve? Specify the download speed from A, from B and from the Internet.

Solution:

a)

APs allow an effective bitrate of 300 Mbps * 70% = 210 Mbps.

When downloading from the servers the speed is limited by the 100 Mbps link at sw1.

Each server splits its capacity by 10, sending 10 Mbps to each port for AP and C. Each port receives 20 Mbps.

As all links support 100 Mbps there is no flow control.

Each terminal receives 1 Mbps from each one of the servers A and B, that is 2 Mbps in total.

b) The link between sw1 and sw2 assigns 500 Mbps to each server.

This 500 Mbps are split among the 10 ports. Each port receives 50 Mbps from A and 50 Mbps from B.

Each terminal and each laptop receives 5 Mbps form A plus 5 Mbps from B.

c) The trunk link between sw1 and sw2 splits its capacity among A, B and R; that is, 333.33 Mbps for each.

Terminals in the same VLAN share the 333.33 Mbps among 5 ports and 10 terminals per port. That is 333.33/50=6.66 Mbps.

The port connected to the router splits the 333.33 Mbps between both LANs.

Terminals in VLAN1 receive 6.66 Mbps from A and 3.33 Mbps from B. In total, 10 Mbps.

Terminals in VLAN2 receive 3.33 Mbps from A and 6.66 Mbps from B. In total, 10 Mbps.

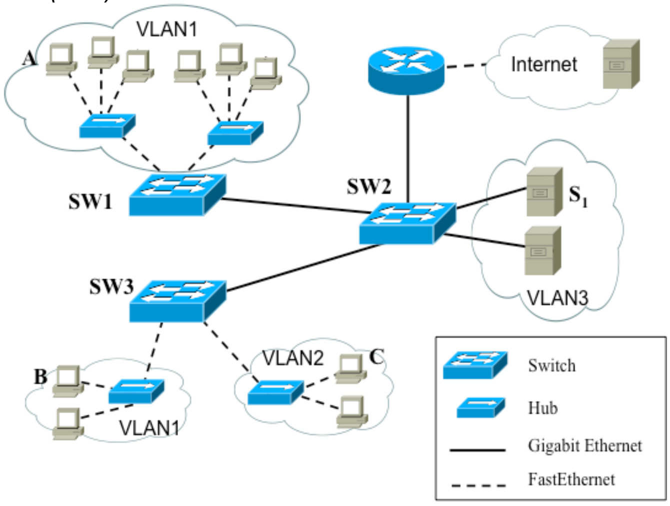
There are 100 terminals competing for the 333.33 Mbps from the router to sw1. Each terminal gets 3.33 Mbps.

The 3.33 Mbps include 20Mbps/100 from outside (Internet) and the rest (3.13Mbps) from the other VLAN.

Terminals in VLAN1 receive 6.66 Mbps from A plus 3.13 Mbps from B and 0.2 Mbps from the Internet.

Terminals in VLAN2 receive 3.13 Mbps from A, 6.66 Mbps from B and 0.2 Mbps from the Internet.

Problem 15. ***(2014t-c3)***



The figure shows a network with 10 workstations connected to Fast Ethernet hubs. Switches are connected using 1Gbps links (SW1-SW2, SW2-SW3, SW2-Router). Two servers are connected at 1Gbps. The connection to the Internet is at 100Mbps. The efficiency of the hubs is 80% and that of the switches is 100%. Workstations and Servers are grouped in VLANs as shown is the figure.

Scenario 1. All workstations in VLAN1 transmit continuously at the maximum speed to server S1.

Calculate the transmission speed achievable from the workstations in network A (S_tA-S1), from network B (S_tB-S1) and the total traffic arriving at server S1 (S_tAB-S1). Identify the bottlenecks and explain how flow control applies.

Scenario 2. To the traffic in scenario 1 add the traffic from S1 towards all the workstations in VLAN1 and VLAN2. Assume that server S1 sends traffic continuously and at the maximum speed.

Calculate the transmission speed from workstations in A to S1 (S_tA-S1), the speed from S1 to A (S_tS1-A). Calculate the same for workstations B (S_tB-S1, S_tS1-B) and C (S_tC-S1, S_tS1-C). Calculate the total traffic sent from S1 (S_tS1-ABC) and received by S1 (S_tABC-S). Identify the bottlenecks and explain how flow control applies.

Scenario 3. All workstations in VLAN1 and VLAN2 transmit continuously towards S1 and, at the same time, both servers are downloading information from the Internet at the maximum speed achievable.

Calculate S_tA-S1, S_tB-S1, S_tC-S1, S_tABC-S1 and the downloading speed from the Internet for S1 (S_tI-S1) and S2 (S_tI-S2). Identify the bottlenecks and explain how flow control applies.

Scenario 4. All workstations in VLAN1 and VLAN2 transmit continuously towards an external server located in the Internet.

Calculate the transmission speed for each workstation S_tA-I, S_tB-I, S_tC-I, and the aggregated traffic towards the Internet S_tABC-I. Identify the bottlenecks and explain how flow control applies.

Scenario 5. Consider now the ideal case where we may add as many workstations as needed to saturate the backbone links when all the workstations transmit continuously towards the servers in VLAN3.

a) Calculate the maximum traffic towards S1 through the links SW2-R, SW1-SW2 and SW3-SW2.

b) Calculate the maximum traffic towards S2 through the links SW2-R, SW1-SW2 and SW3-SW2.

If the workstations in VLAN1 are only the SIX shown in the figure:

c) Calculate the traffic towards S1 through links SW1-SW2 and SW3-SW2.

d) Calculate the traffic towards S2 through links SW1-SW2 and SW3-SW2.

e) Calculate the maximum number of workstations that may fit in VLAN2 in groups of two per hub filling all the available bandwidth.

Solution

Scenario 1

Hub efficiency is 80%: links hub-switch operate at 80Mbps.

S_tA-S1 = 80/3 = 26'66Mbps

S_tB-S1 = 80/2 = 40Mbps

S_tAB-S1 = 80+80+80 = 240Mbps. Flow control at hubs.

Scenario 2

Traffic flows in both directions. Hubs behave as a shared bus and its capacity splits evenly among all its ports.

Hubs A (4 ports): 80/4 = 20 Mbps per port (both directions)

S_tA-S1 = 20 Mbps. S_tS1-A = 20/3 = 6'66 Mbps. Traffic from S1 splits in 3 ports.

Hub B (3 ports): 80/3 = 26'66 Mbps per port. S_tB-S1 = 26'66 Mbps. S_tS1-B = 26'66/2 = 13'33 Mbps.

Hub C: traffic comes from S1 (workstations do not transmit). S_tC-S1 = 0. S_tS1-C = 80/2 = 40 Mbps.

S_tABC-S1 = 60+60 from A + 53'33 from B = 173'33 Mbps.

S_tS1-ABC = 20+20 towards A + 26'66 towards B + 80 towards C = 146'66 Mbps.

Flow control applies at hubs and switches (pause frames).

Scenario 3

S_tA-S1 = 26'66 Mbps; S_tB-S1 = 40 Mbps; S_tC-S1 = 40 Mbps.

S_tABC-S1 = 80+80 from A + 80 from B + 80 from C = 320 Mbps.

From the Internet, only 100Mbps are allowed that are split between S1 and S2: S_tI-S1 = S_tI-S2 = 50 Mbps.

Link SW2-R does not experience congestion. Flow control applies at the hubs.

The router splits the access capacity to the Internet (100Mbps) between the two TCP connections to S1 and S2.

Scenario 4

The bottleneck is at the link to the Internet. The router distributes the 100Mbps evenly among all TCP connections. There are 10 workstations, so 100/10=10 Mbps per workstation.

S_tA-I =S_tB-I = S_tC-I = 10 Mbps. S_tABC-I = 100 Mbps.

The amount of traffic is so small that the flow control is not activated.

Scenario 5

a) The capacity of link SW2-R is shared between the two ports: SW2-R assigns 500 Mbps to S1.

Switch SW2 distributes this capacity between SW1 and SW3: SW1-SW2 for S1 = SW3-SW2 for S1 = 250Mbps.

b) The same applies. SW2-R for S2 = 500Mbps. SW1-SW2 for S2 = SW3-SW2 for S2 = 250Mbps.

c) With the six workstations in VLAN1 the occupancy of the link SW1-SW2 towards S1 is 40+40=80Mbps.

VLAN1 fills 40Mbps of link SW3-SW2 with traffic towards S1; there are 210Mbps available.

VLAN 2 may fill 170 + 210 = 380Mbps towards S1.

d) The same applies. Traffic towards S2 fills 80Mbps of SW1-SW2 link and 40Mbps of SW3-SW2 link. VLAN2 may fill the remaining 380Mbps with traffic towards S2.

e) VLAN2 may fill 380+380= 760Mbps with traffic towards S1 and S2.

Each hub with 2 workstations contributes with 80Mbps. This means that 760/80=9.5 hubs may be connected.

Then, 9 hubs with 2 workstations each makes 18 workstations in total in VLAN2 generating 720Mbps.

Unit TCP Protocol

Problem 16.

Given the following partial TCP capture between two application entities, identified by the numbers of Port 3287 (we will call it A) and 2043 (we will call it B):

```
Time        Source       Destination        Flags           Num. sequence … (Size)
0.000000 200.1.10.5.3287 > 147.83.39.20.2043: S 401040:401040(0) win 5792 <mss 1448>
0.100374 147.83.39.20.2043 > 200.1.10.5.3287: S 906442:906442(0) ack 401041 win 11584 <mss 1448>
0.100483 200.1.10.5.3287 > 147.83.39.20.2043: . ack 1 win 5792
. . .
1  2.100850 200.1.10.5.3287 > 147.83.39.20.2043: . 11025:12473(1448)
2  2.201934 147.83.39.20.2043 > 200.1.10.5.3287: . ack 11025
3  2.202032 200.1.10.5.3287 > 147.83.39.20.2043: . 12473:13921(1448)
4  2.202074 200.1.10.5.3287 > 147.83.39.20.2043: . 13921:15369(1448)
5  2.303513 147.83.39.20.2043 > 200.1.10.5.3287: . ack 11025
6  2.692975 200.1.10.5.3287 > 147.83.39.20.2043: . 11025: 12473(1448)
7  2.794419 147.83.39.20.2043 > 200.1.10.5.3287: . ack 13921
8  2.794503 200.1.10.5.3287 > 147.83.39.20.2043: . 13921:15369(1448)
9  2.795749 200.1.10.5.3287 > 147.83.39.20.2043: P 15369:16145(776)
10 2.896720 147.83.39.20.2043 > 200.1.10.5.3287: . ack 13921
11 3.252974 200.1.10.5.3287 > 147.83.39.20.2043: . 13921:15369(1448)
12 3.354419 147.83.39.20.2043 > 200.1.10.5.3287: . ack 16145
13 3.354519 200.1.10.5.3287 > 147.83.39.20.2043: . 16145:17593(1448)
14 3.354561 200.1.10.5.3287 > 147.83.39.20.2043: . 17593:19041(1448)
15 3.454561 147.83.39.20.2043 > 200.1.10.5.3287: . ack 17593
16 3.454835 200.1.10.5.3287 > 147.83.39.20.2043: FP 19041:20241(1200)
17 4.044446 147.83.39.20.2043 > 200.1.10.5.3287: . ack 19041
18 4.044555 200.1.10.5.3287 > 147.83.39.20.2043: FP 19041:20241(1200)
19 4.145837 147.83.39.20.2043 > 200.1.10.5.3287: F 1:1(0) ack 20242
20 4.145940 200.1.10.5.3287 > 147.83.39.20.2043: . ack 2
```

We have three initial non-numbered sendings and, after some time, the sequence of numbered sendings from 1 to 20, with which the connection ends.

a) Does this sequence correspond to any known application? Application A sends information to B, but does B send something to A? How many bytes does A send exactly?

b) In which of the two machines (A or B) has the capture been done? Identify 3 mechanisms to find it out, and which one(s) could have been used here.

c) Having in mind the available information, what is the approximate value of RTT? Which is the real effective speed? Which maximum effective speed could we reach if A would send B a really big file? What needs to happen to reach this speed?

d) Draw the evolution in time of the congestion window during all the sequence (from 1 to 20), indicating the stages of the SS/CA algorithm. Is there any anomaly in the evolution of the window?

e) If after the 13th sending still 30408 bytes were left to send and there were not more loses, draw the new evolution of the real window until the disconnection time.

Solution:

a) Does this sequence correspond to any known application? No, none of the ports is below 1024.

Application A sends information to B, but Does B send something to A? No, the last ACK that A sends is number 2, which means that B has only sent the SYN and the FYN, but no data.
How many bytes does A send exactly? 20240.

b) In which of the two machines (A or B) has the capture been done? In A. Justification in c).
Identify 3 mechanisms to find it out,
1) Times: According to the times between two consecutive segments we can know where we are. Smaller times imply that we are in the side that sends the second. If the time is bigger (in the order of a RTT, not a CPU time), it would be the opposite.
2) Losses/Repetitions: If repetitions can be seen is that losses have happened and we are in the side of who repeats.
3) Private addresses: If we see a private address means that we are in that machine.
And which one(s) could have been used here.

The 2 first ones. The time are clearly seen in the connection establishment, since between the SYN and the SYN/ACK there's a RTT, while between the SYN/ACK and the ACK there's a much smaller time (CPU time). If the capture were made in B, the smaller time would be between the two first segments. The mechanism loses/repetitions can also be applied, since you can see data segments sent more than once, this means that we are in the side of who is sending them. The third mechanism does not apply, since no private address appears.

c) Having in mind the available information, **a)** What is the approximate value of RTT?

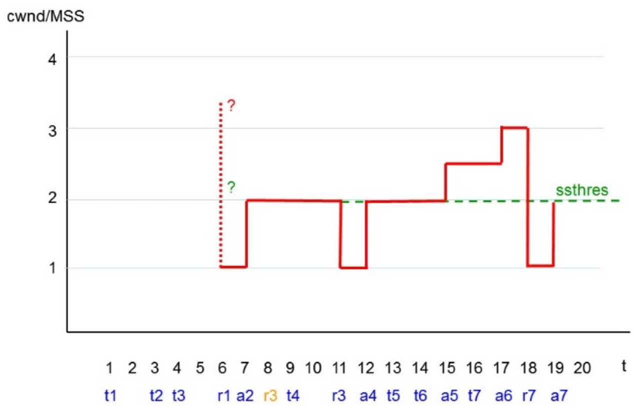
100 milliseconds. It can be seen in several places, for example between the first and second segments of the connection or between the segments 11 and 12 or 13 and 15.
Which is the real effective speed?
It sends 20240 bytes (as seen in segment 18) in an approximate time of t = 4.15 (instant of reception of the last data ACK) – 0.1 (instant when the sending of data starts; moments after the connection ACK) = 4.05 seconds. So, the real Sef is Sef=20240 * 8 / 4.05 = 40,000 bps, approximately.
Which maximum effective speed could we reach if A would send B a really big file?
The window in permanent regime (announced window) in a RTT will be sent; meaning, Smax = 11584*8 / 0.1 = 926720 bps
What needs to happen to reach this speed?
There must be no losses.

d) Draw the evolution in time of the congestion window during all the sequence (from 1 to 20), indicating the stages of the SS/CA algorithm.

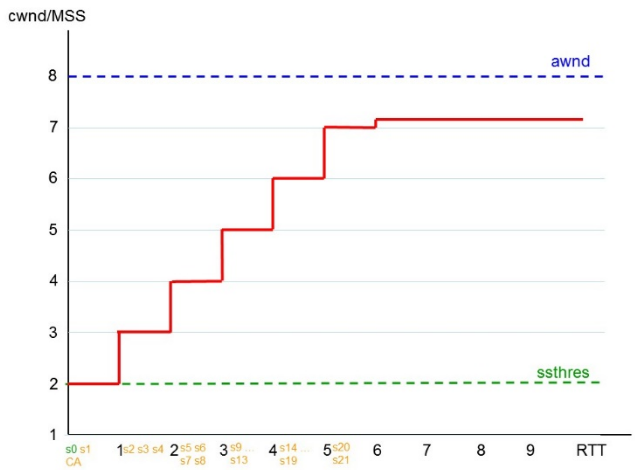
The first correct information that we have about the real window starts in the exchange num. 6, when the first retransmission occurs and the Sc goes down to 1 MSS. When the ACK is received in 7, Sc increases to 2. The window does not increase again, since there is no new ACKs, until there is another retransmission in 11, where the window decreases again to 1. It increases again to 2 when the ACK in 12 arrives. In this case, we know that we have reached a threshold (since we have fallen from a Sc = 2 and the minimum threshold is 2 MSS), so we enter in the Congestion Avoidance phase. The new ACK in 15 makes the Sc increment to 2.5, and the ACL in 17 to 3, but the new retransmission in 18 makes it fall again to 1. It keeps at 2 for the final ACK in 19.
Is there any anomaly in the evolution of the window? No.

e) If after the 13th sending still 30408 bytes were left to send and there were not more loses, draw the new evolution of the real window until the disconnection time.

30408 bytes correspond to 30408/1448 = 21 MSS. Before the 13th sending we had cwnd = 2 and we just entered the CA phase. The awnd is 11584 / 1448 = 8 MSS. After the 13th there will be a new sending and when receiving the 2 ACKs we have cwnd = 3 (we are in CA). From here on, for each RTT the cwnd will increase 1 by 1 when the ACKs of the previous window are received, meaning, 3,4,5,6 (in this moment we would have sent, after the 13th sending, 1+3+4+5+6 = 19 MSS and we will have still 2 to reach the 21, which will become a final cwnd of 7+1/7 (we would not reach the awnd).

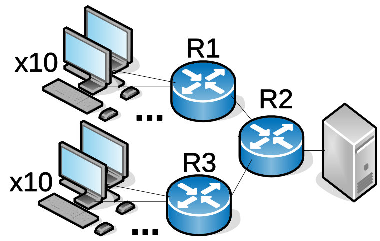


d)



e)

Problem 17.



In the network of the figure there are 20 PCs (10 connected to R1 and 10 connected to R3) that send data to the server, each using a TCP connection and to the maximum throughput allowed by the network. Suppose the following: (1) all links are 10 Mbps; (2) the routers have a memory of 2 MB (2 10^6 bytes) which can store all datagrams pending to be transmitted (and are discarded the datagrams that arrive when the memory is exhausted); (3) all TCP sockets in the PCs and server have a reception buffer of 60 kB; (4) for the sake of simplification, assume all TCP and IP headers of 0 bytes and MSS equal to 1500 B; (5) propagation delays in the cables are 0; (6) the acks transmitted by the server are never lost and arrive immediately to the PCs; TCP always sends ack upon receiving data, only SS/CA is used and it is as efficient as possible (i.e. ack are sent immediately, the process time is 0, etc.); (7) connections are in steady state, i.e. it is long time since they were established. Justify briefly your answers: results without justification will not be accepted.

A Say which will be the throughput, v_{ef}, that will achieve each TCP connection.

B Say which will be the advertised window, awnd. Will it be necessary to use the window scale option?

C Say which will be, approximately, the buffer occupancy of the Routers R1, R2 i R3. Say how many bytes there will be approximately in each buffer. Will there be losses?

D Compute what will approximately be the RTT of each TCP connection.

E Suppose now (and in the remaining items) that it is desired to have an average RTT not larger than approximately 600 ms. To achieve this constrain, the buffer of the routers is reduced. What buffer size of routers R1, R2 and R3 should be configured? Assume that the buffer size is changed only in the routers where it is necessary.

F Say whether losses will occur with the buffers configured in the previous item. What will be now the throughput, v_{ef}, achieved by each TCP connection?

G Compute what will be now, on the average, the window that will use each TCP connection (W). Suppose that, on the average, in every RTT each TCP connection sends a number of bytes equal to the average window, W.

H Draft a possible evolution of the congestion window (cwnd) used by TCP that fits the conditions stated in the previous items. Assume that the evolution of the cwnd is periodic, and draw one period. Indicate in the draft when it is in slow start (SS) and congestion avoidance (CA). Compute what will be the slow start threshold (ssth) and the maximum value that the cwnd will reach in each period ($cwnd_{max}$). Compute ssth and $cwnd_{max}$ such that the throughput and average window are those computed in the previous items. Assume in this calculus that the time in SS is much lower than in CA.

I Compute approximately what will the duration of one period (T) in the previous draft.

Solution:

A. The bottleneck will be the link R2-server. It will be shared between the PCs, thus:

Vef=10Mbps/20=0,5Mbps

B. It will be the buffer size: 60KB.

WS it is not needed, since it is lower than 2^{16}

C. In R1 and R3 depart 5Mbps, on the average. Since their capacity is 10Mbps (the double), the buffers will be empty.

R2 is the bottleneck, since it can receive up to 20Mbps, but it can only transmit 10Mbps. Therefore, its buffer will fill up by what the TCP allow. Approximately: 20 * 60kB = 1,2 MB.

D. The waiting time in R2 queue: 1,2MB/10Mbps = 1,2*8/10 = 0,96 s

E. R1 and R3 does not affect. We can leave the 2MB.

In R2:
We want the the waiting time in the queue it is not higher than 600ms. Thus:
B/10Mbps=600ms, d'on B=10*600/8=750 kB

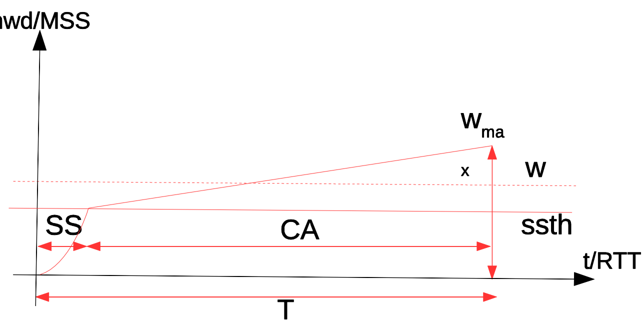
F. Now there will be losses, because the windows of the 20 connections (1,2MB) are higher than the queue of the router. The throughput (0,5 Mbps), does not change, because the 10Mbps are still shared between all TCP connections.

G. The R" buffer de R2 is shared on the average among the connections, thus: W=750kB/20=37,5kB

It can also be reasoned like this: The throughput will be the average window over the RTT, thus:
W=vef*RTT=0,5*600/8=37,5kB

H. We have:

ssth=Wmax/2
On the other hand, from the figure:
W=(ssth+Wmax)/2
Substituting ssth=Wmax/2: W=Wmax/2+Wmax/4 = Wmax * 3/4
Since W= 37,5 kB we have that Wmax=4/3 * W =4/3 * 37,5 = 50 kB and ssth=50/2=25kB



I. During CA the window increases 25kB/1,5kB=16,7 segments (since each segment are 1500 B).

Since during CA the window increases approximately 1 segment each RTT, there will be 16,7 RTTs approximately. That is: T=16,7 * RTT = 16,7 * 0,6 s = 10 s

Problem 18.

We have a system that connects two terminals connected to an Ethernet 100BaseT hub. The client sends data to the server continuously (i.e. sends a really big file). Assume that some of the terminals don't support window-scale; that their processing capacity (CPU, hard disk, etc) is infinite; that the TCP buffers have 64 kB; that the error probability is null (Pe=0):

a) Which is the effective speed that the transmission will achieve? (Assume the size of the ACKs is negligible).

b) Which TCP factor (congestion/advertised window) will govern the transmission?

c) Say what are the buffers involved in the TCP transmission, and say which will be their occupancy.

d) Assume the server has a disk with finite speed of 50 Mbps. Which will be the effective speed at which the transmission will work?

e) Which factor (congestion/advertised window) governs now this speed?

f) Say which one will be the occupancy of the buffers.

g) In this architecture and conditions (sections d and e), is it possible that the effective speed is governed by the congestion window?

h) We substitute the hub for a router (and we do the necessary corrections in the terminals regarding addresses, etc.), meaning that, we have only two terminals connected to a router via two different ports, now of type 100Base T FDX. Assuming that we maintain the disk of (d) 50 Mbps, say what would be the effective speed of the transmission.

i) Say what are the buffers that now affect the TCP transmission, and say which one will be their occupancy.

j) Assume that the latency between client and server (router and LANs included) is 10 ms. No packets are lost. Which is the MSS?

j) Make the sequence diagram of the connection phase of the client to the server. Assume that we connect to the service CHARGEN (TCP port 19) of the server (the CHARGEN answers immediately to the connection with infinite data). Indicate how much time passes from the moment the client does the connection until the first data byte is received.

k) Assume that the client cuts the connection to the CHARGEN service when it gets 1 MB. When that cut happens? (in ms)

Solution:

a) If we assume that the efficiency of the frame and other PDUs, and the efficiency of the MAC are 100%, the speed will be limited by the transmission speed: so, 100 Mbps

b) (A) The only limiting factor is the network, so none of the two windows will limit the effective speed, since none of them will come into action.
(B) Any of them comes into action but the advertised one reaches 64 kB, while the congestion one tends to infinity with time (and the absence of losses). So, the advertised one.

c) Transmission and reception ones on the client and on the server (the hub does not have memory buffers).
All of them will be empty except for the transmission one in the client, which will be full in permanent regime, since its data generation speed is infinite, and otherwise, the network empties the buffer at 100 Mbps

d) Now the limiting factor is the server's disk, so, the effective speed will adjust to 50 Mbps

e) The server cannot assume what the client offers (transiently at 100 Mbps), so it will close the advertised window adjusting it to its processing capacity: 50 Mbps

f) Now the server's reception buffer will be also full since the disk will not clear it fast enough.
The client's transmission buffer and the server's reception buffer will be full. The other two will only have ACKs, virtually empty.

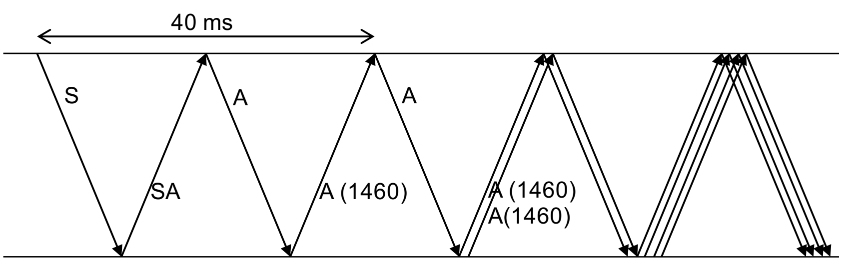
g) It will not be governed by the congestion window while there are no losses. And there aren't.

h) The fact that using FDX does not affect the final result since the file transfer is in one way.
The limiting factor is still the server's disk, so the effective speed is still 50 Mbps

i) Besides, from the client and server's reception and transmission buffers we have the output buffers of the two router ports.
Since the server allows the client only an average of 50 Mbps, the router is not submitted to an unsustainable load since the output port will admit everything it receives from the input one. Therefore, its buffers are basically empty (both of them).
Regarding the client and server, the status of the buffers will be the same that in (f): the client's transmission buffer and the server's reception buffer will be full. The other two (client's reception and server's transmission) will be only occupied with ACKs, and so, virtually empty.

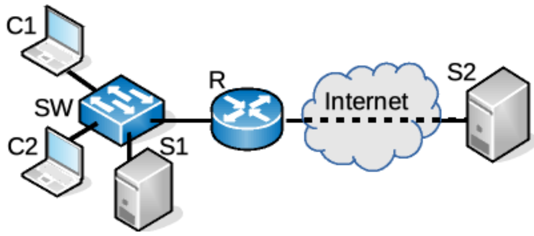
j) $MSS = MTU_{Ethernet} - H_{TCP} - H_{IP} = 1500\ B - 20\ B - 20\ B = 1460\ B$

k)



l) (A) 64 kB are sent at each RTT. Each RTT = 2 · 10 ms = 20 ms. Since to send 1 MB we need:
T_T = 1 MB / 64 kB · RTT = 15,3 RTT then T_T = 15,3 RTT = 15,3 · 20 ms = 0,3 s (*)
(B) The previous calculation doesn't take into account that the total time will slightly increase because initially the slow start will affect the performance of the transfer. The slow start is maintained until the cwnd reaches 64 kB or 64 kB / 1460 B/MSS = 44 MSS
The frame sequence will be: [1, 2, 4, 8, 16, 32], 44, 44... so the first 6 RTT will have sent slightly more than what is sent in permanent regime with only one RTT. This gives a total of (14+6) RTT = 0,4 s (*)
(*) if we also take into account the connection, we have to add 30 ms to the establishment phase.

Problem 19.



Assume a non-congested Internet. All connections are 1 Gb/s full-duplex.
The switch does flow control. Router queues are 10 KB in size.
Minimum latency (RTT): C-S1 or C-R = 1ms, C-S2 = 50ms.
Decimal units: 1 Gbps = 1000 Mbps, 1 kB = 1000 bytes.
Announced window (awnd) for C1, C2 = 100 KB and MSS = 1460.
Assume that there is always data to send and transfers are made at the maximum speed allowed by the network.

a) Determine the optimal reception window when a single client C (C1 or C2) receives data from one of the servers.
C-S1: Wopt (Bytes) = C-S2: Wopt (Bytes) =

b) Determine maximum and minimum reception speed from a single client C when receiving TCP data only from S1 or only from S2.
C-S1: Vmax (Mb/s) = Vmin (Mb/s) = C-S2: Vmax (Mb/s) = Vmin (Mb/s) =

c) Determine the effective speed (average for transfer) if C1 and C2 receive data from S1 simultaneously with TCP. Which link limits the average speed?
In what state are (SS, CA) TCP connections at the end of the transfer? C1-S1: C2-S1:
C1-S1: Vef (Mb/s) = C2-S1: Vef (Mb/s) =

d) If the Sw-R connection is now down to 100 Mb/s, determine the effective speed if C1 and C2 receive S2 data simultaneously with TCP. Which link limits the average speed?
In what state are (SS, CA) TCP connections at the end of the transfer? C1-S2: C2-S2:
What delay does the router queue introduce? C1-S2: Vef (Mb/s) = C2-S2: Vef (Mb/s) =

e) Indicate the ideal value of the router queue to maximize the above speeds.
Queue (KB) = What effect would it have? Which Vef could be achieved in the previous case for each transfer?

Solution:

a) C-S1: Wopt = 1 Gb/s * 1 ms / 8 = 125 KB; C-S2: 1 Gb/s * 50 ms / 8 = 6,25 MB

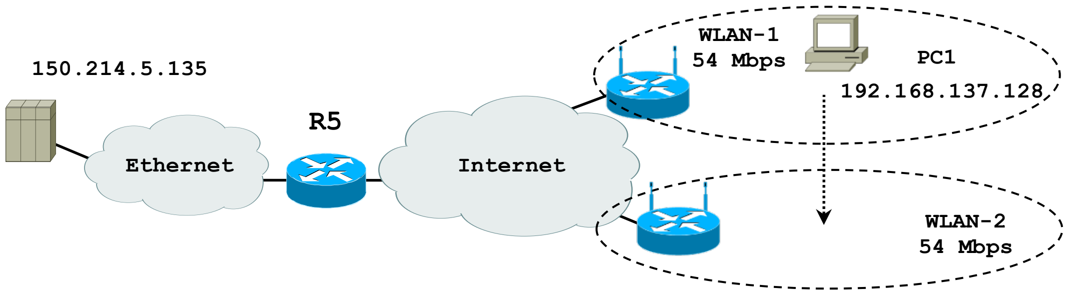
b) C-S1: Vmax = awnd / RTT = 10^5*8 / 0.001 = 800 Mb/s, Vmin = 1 MSS / RTT = 1460*8 / 0.001 = 11,68 Mb/s
C-S2: Vmax = 10^5*8 / 0.050 = 16 Mb/s, Vmin = 1460*8 / 0.050 = 0,234 Mb/s

c) Bottleneck S1-Sw < 1 Gb/s. Status near the end: C1-S1: SS, C2-S1: SS
C1-S1: Vef = max(awnd / RTT, 1000 / 2) = max(10^5*8 / 0.001, 500) = 500 Mb/s, Idem for C2-S1.

d) Bottleneck Sw-R < 100 Mb/s. Status near the end: C1-S2: CA, C2-S2: CA
Delay in the queue of the router: 10^4B * 8 / 10^8 = 0.8 ms, negligible compared to 50 ms.
C1-S2: Vef (Mb/s) = (3/4*10KB*8/2)/50 ms = 30Kb/50ms = 0.6Mb/s. Losses when traffic adds to >10 Kb. Idem C2-S2.

e) Queue: 200 KB, no losses, Vef = (3/4 * 100 KB * 8) / 50 ms = 12 Mb/s (3/4 * 16).

Problem 20.



PC1 is connected to the Internet through a WLAN net with 54 Mbps. A video server is connected in an Ethernet net with 10 Mbps. The transmission speed on the Internet is faster than the ones in both local nets. All the devices have an efficiency of 100% and the buffers of the router and access points are infinite. PC1 establishes a TCP connection (the window scale option is deactivated) with the server and the propagation time from point to point is determined to be 50 ms. We ask the following:

A. From the following capture and knowing that there are not losses, determine: 1) the MSS of the connection server-PC1, 2) the size of the transmission window once the transient has ended, 3) the effective speed and 4) how much times does it take to approximately complete the video download.

```
...
150.214.5.135.80 > 192.168.137.128.39599: P 726852531:726853991(1460) ack 1637 win 5240
192.168.137.128.39599 > 150.214.5.135.80: . ack 726853991 win 64240
150.214.5.135.80 > 192.168.137.128.39599: . 726853991:726855451(1460) ack 1637 win 5240
192.168.137.128.39599 > 150.214.5.135.80: . ack 726855451 win 64240
150.214.5.135.80 > 192.168.137.128.39599: . 726855451:726856911(1460) ack 1637 win 5240
192.168.137.128.39599 > 150.214.5.135.80: . ack 726856911 win 64240
150.214.5.135.80 > 192.168.137.128.39599: F 726856911:726857231(320) ack 1637 win 5240
192.168.137.128.39599 > 150.214.5.135.80: F 1637: 1637(0) ack 726857231 win 64240
150.214.5.135.80 > 192.168.137.128.39599: . ack 1638 win 5240
```

B. Identify if the dump was captured in the server or in PC1.

C. From the conditions in section A, if in the Ethernet net there would be 4 servers transmitting at the same time towards other clients, determine the effective speed of the connection server-PC1 and the approximate length of the download.

D. From the conditions in section A, if the window scale was activated with a multiplicative factor for the advertised window of 4, determine the effective speed and the approximate length of the download.

E. Assume now that PC1 is moved from WLAN-1 to WLAN-2. During this transition, some segments are lost. Knowing that PC1 does the network change when it was in the middle of the download and at its maximum speed, draw a graphic that shows the evolution of the transmission window (axis y: transmission window, axis x: time) from the transmission of the first segment in the first net until 1.5 seconds. Show clearly in the graph the slow-start and congestion avoidance phases and the value of the ssthresh threshold. Assume that the RTO timer is 200 ms.

F. Make a graph like in the previous section but now assuming that, in WLAN-2, a segment is lost each time the congestion window reaches 23360 bytes.

Solution:

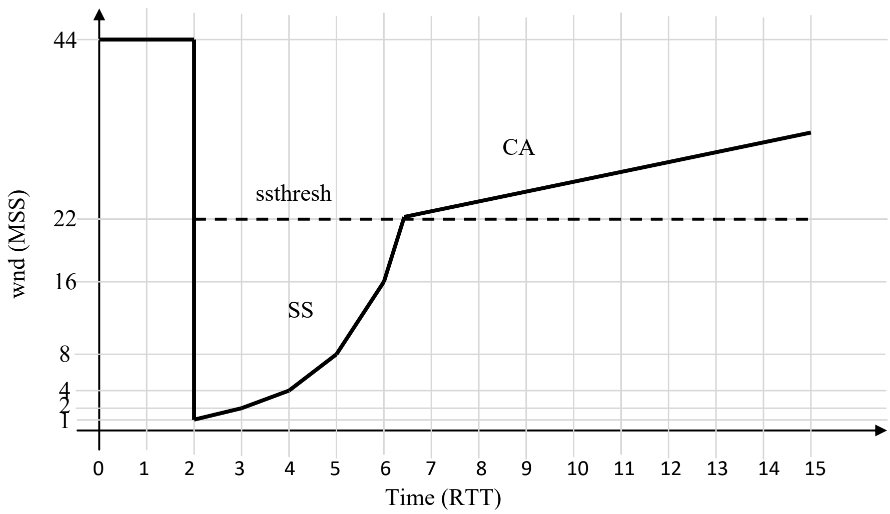
A. MSS of 1460 bytes
wnd of 64240 bytes, 44 MSS (65536/1460 rounding down)
Sef = min(vt, wnd/RTT) = min(10Mbps, 64240 * 8 / (2 * 50 ms)) = 5.14 Mbps
Duration = 726857231 bytes * 8 / 5.14Mbps = 1131 s

B. In PC1 because the private IP of PC1 appears there. If it were in the public server, PC1 would have a public IP.

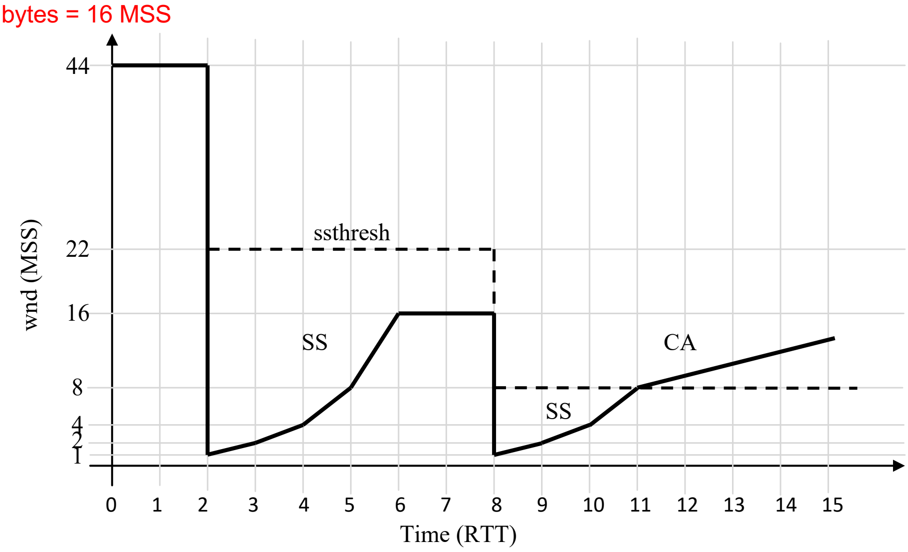
C. In total, in the Ethernet network there are 5 servers transmitting; considering that we have 100% efficiency, this makes that each server can transmit during a 20% of the time. This decreases the effective speed to
Sef = min(vt, wnd/RTT) = min(10 Mbps * 20%, 64240 * 8 / (2 * 50 ms)) = min(2 Mbps, 5.14 Mbps) = 2 Mbps
Duration = 726857231 bytes * 8 / 2Mbps = 2907 s

D. Sef = min(vt, wnd * 4/RTT) = min(10Mbps, 64240 * 8 * 4/ (2 * 50 ms)) = min(10 Mbps, 20.5 Mbps) = 10 Mbps
Duration = 726857231 bytes * 8 / 10 Mbps = 581 s

E.



F. 23360 bytes / 1460 bytes = 16 MSS



Unit Network Applications

Problem 21.

We want to send an email from the domain *xc.com* as a user from the domain *yahoo.com.* Imagine that all the DNS servers of the world (including local and authoritative) are working in recursive mode (recall that the normal mode is iterative). In this scenario, answer the following questions:

a) How many DNS servers will be involved, at least, in the resolution of the destination mail server if the caches of all the DNS are empty?
b) Of which type will be each server (local/authoritative)?
c) Which **resource record** (RR) will give us the information that we seek and which server will contain it?
d) Which server will send us the final message with the answer?

Solution:

a) 4 servers would be involved. There would be two resolutions:

1) The mail client to a **local NS xc.com** to resolve the IP of the SMTP xc.com server.

2) SMTP xc.com to a local NS xc.com (we assume it's the same) to resolve the IP of the mail server of the yahoo.com domain. In this resolution, the local NS xc.com would send the recursive resolution message to an **authoritative root NS**, which would send it to an **authoritative NS of the domain .com** to finally send it to an **authoritative NS of the domain yahoo.com.**

b) Answered in a)

c) MX (Mail eXchange)

d) The answer with the MX record sent by the **authoritative NS yahoo.com** will go through all the servers indicated in a), until the local NS xc.com sends it to SMTP xc.com.

Problem 22.

Which uses do you think are the most adequate to send HTTP data using the method GET and which using the method POST. Give an example of each case, and remark the existing difference between the two methods regarding the data transport mode. How which method to use is decided? Meaning, what makes people use one or the other? Does the user choose it?

Solution:

The GET method is more adequate to the sending of small data volumes to the server (some variables of an HTML form for example) since the data is sent as a part of the URL. The POST method is more adequate to send bigger data volumes, especially if they are binary data codified as ASCII using Base64. In the POST method, the data is sent inside the "Body" field of the HTTP request, and not in the URL as done in GET.

The method is decided from the HTML document that contains the data form, which can indicate if GET or POST is used. The browser will use the method indicated in the form. The user, in principle, does not choose this option.

Problem 23.

We want to send from a host (h1.upc.edu) an email message to x@y.org that includes a short greeting text in Catalan or Spanish and a document in PDF format. Assume that our mail server is smtp.upc.edu.

Consider the hosts: (a) h1.upc.edu, (b) smtp.upc.edu, (c) dns.upc.edu, (d) dns.y.org. Assume that all DNS caches are empty.

a) List the sequence of DNS and SMTP requests and responses sent and received by h1.upc.edu required to deliver the message to smtp.upc.edu.

Destination	Protocol	Description request	Description response
dns.upc.edu	DNS	Recursive request, record A of **b**	…

b) Indicate which DNS requests and responses can send and receive smtp.upc.edu to decide to deliver the message to the mailbox of the final recipient.

c) Indicate the structure (MIME headers) that forms the body of the message.

```
MIME-Version: 1.0
Content-Type: multipart/      boundary=

--BB
Content-Type: text/plain; charset=
Content-Transfer-Encoding:

--BB
Content-Type: application/
Content-Transfer-Encoding:

JVBERi0xLjUKJbXtrvsKMyAwIG9iago8PCAvTGVuZ3RoIDQgMCBSCiAgIC9GaWx0ZXIgL0Zs...
dHhyZWYKNzI4OTUKJSVFT0YK
--BB--
```

d) How does the recipient know which character set to be used to present the text of the message?

e) Which protocols can the owner of the mailbox x@y.org use to read the message?

Solution:

a)

Destination	Protocol	Description request	Description response
dns.upc.edu	DNS	Recursive request, record A of **b**	Register A of smtp.upc.edu
smtp.upc.edu	SMTP	HELO name	220 OK reply (2XX)
smtp.upc.edu	SMTP	mail from: sender@upc.edu	250 OK reply
smtp.upc.edu	SMTP	rcpt to: x@y.org	250 OK reply
smtp.upc.edu	SMTP	data	354 OK reply (3XX)
smtp.upc.edu	SMTP	<content of the message> \n.	250 OK reply
smtp.upc.edu	SMTP	quit	221 OK reply

b) It sends a request for the MX of the domain y.org. It receives the MX register of y.org (name of the smtp server) and the corresponding A register (IP address): **dig -t mx y.org**

y.org. 14400 IN MX 10 custmx.cscdns.net.

Also NS y A records for y.org

c) Content-Type: multipart/mixed; boundary="BB"

Content-Type: text/plain; charset=utf-8
Content-Transfer-Encoding: quoted-printable
Hola, aqu=C3=AD est=C3=A1 el doc.
Content-Type: application/pdf
Content-Transfer-Encoding: base64

d) Based on the charset attribute of the text/plain content type.

e) IMAP, POP or HTTP.

Problem 24.

We want to send an email including an object that contains 3 bytes with values 31 30 80 (base16).
Remember that SMTP is a text-based protocol. The object is encoded in base64 as the following 4 characters: MTCA

a) Why does the base64 encoding of a 3-byte message result in 4 chars?

b) Complete the encoding of the MIME message if it is transferred as image/png:
Content-Type: Content-Transfer-Encoding: Body:

c) The encoding of these three bytes in the ISO8859-15 character set corresponds to the 3 letters: 10€ (one, zero, euro). Complete the encoding of the MIME message if it is transferred as plain text:
Content-Type: Content-Transfer-Encoding: Body:

Solution:

a) Every 6 bits base64 generates a character that occupies one byte.

b) Content-Type: image/png Content-Transfer-Encoding: base64 Body: MTCA
The binary object is sent converted to text in base64 format.

c) Content-Type: text/plain; charset=ISO-8859-15 Content-Transfer-Encoding: quoted-printable Body: 10=80
The textual object (no format, plain) is sent converted to text in quoted-printable format with the charset codes selected.

Problem 25.

In the browser of a PC accesses the page http://a.org/ Suppose that the PC has empty caches DNS and HTTP/1.1, and a fast Internet connection. The DNS servers are connected with the web servers in each domain. Assume a simple browser with "HTTP pipelining" enabled by default.

Indicate the total number of RTTs (consecutive) expected to present the entire page in each case whether the content of the page is (note: the tag <img> indicates an embedded image, other tags indicate links):

a) <html><img src="http://b.org/i.jpg"></html>
b) <html><img src="http://a.org/i.jpg"></html>

c) <html>a b</html>
d) <html><img src="http://a.org/i.jpg"> <img src="http://a.org/j.jpg"></html>
e) (no pipelining) <html><img src="http://a.org/i.jpg"> <img src="http://a.org/j.jpg"></html>
f) <?xml version="1.0" encoding="UTF-8"?><image><src>http://b.org/i.jpg</src></image>
Indicate for each case the number of RTTs corresponding to DNS (UDP), TCP, HTTP.

Solution:

a) <html><img src=”http://b.org/i.jpg”></html>
DNS a.org, TCP a.org, HTTP GET /, DNS b.org, TCP b.org, HTTP GET i.jpg
DNS 2, TCP 2, HTTP 2; total 6 RTT

b) <html><img src=”http://a.org/i.jpg”></html>
DNS a.org, TCP a.org, HTTP GET /, HTTP GET i.jpg
DNS 1, TCP 1, HTTP 2; total 4 RTT

c) <html>a b</html>
DNS a.org, TCP a.org, HTTP GET /
DNS 1, TCP 1, HTTP 1; total 3 RTT

d) <html><img src=”http://a.org/i.jpg”> <img src=”http://a.org/j.jpg”></html>
DNS a.org, TCP a.org, HTTP GET /, HTTP GET i.jpg (pipelined with j.jpg and does not add a RTT)
DNS 1, TCP 1, HTTP 2; total 4

e) (sin pipelining) <html><img src=”http://a.org/i.jpg”> <img src=”http://a.org/j.jpg”></html>
DNS a.org, TCP a.org, HTTP GET /, HTTP GET i.jpg, HTTP GET j.jpg
DNS 1, TCP 1, HTTP 3; total 5 RTT
If the client opens more than one TCP connection in parallel:
DNS a.org, TCP a.org, HTTP GET /, HTTP GET i.jpg and TCP a.org, HTTP GET j.jpg
DNS 1, TCP 1 (+1 in parallel with HTTP GET i.jpg), HTTP 3; total 5 RTT

f) <?xml version=”1.0” encoding="UTF-8"?><image><src>http://b.org/i.jpg</src></image>
DNS a.org, TCP a.org, HTTP GET / = 3 (it is an XML file, not HTML)
DNS 1, TCP 1, HTTP 1; total 3 RTT

Problem 26.

A client accesses the web page www.serveiweb.org/index.htm. This page contains a header image embedded, three images hosted on an external server, an ad hosted on another server and a large image hosted in an image server. Consider the following:

DNS: RTT = 10ms; Assume using UDP for DNS queries

Server serveiweb.org: RTT = 30ms; contains the index.htm page (fits into one segment of data) and the header image (the first data segment)

Image server: RTT = 50ms; contains three small images (one segment/image) and a large image (4 segments)

Ad Server: RTT = 200ms; the ad fits in one segment of data

Consider using persistent HTTP without "pipelining". The web client opens just a TCP connection to each server, and the order in which the objects are downloaded is: 1) index.htm, 2) header image, 3) three small images, 4) the ad, and 5) the large picture. Please detail the sequence of transactions (1 to 5) and the time for each. Do not consider TCP disconnections. Draw a time diagram for each transaction. Calculate the total download time of the page.

Solution:

Step 1: Download html page. Check serveiweb.org DNS (UDP): RTT = 10; TCP connection to www.serveiweb.org TCP connection: RTT = 30, HTTP GET index.htm: RTT = 30

Step 2: Download HTTP GET header image: RTT = 30

Step 3: small images. Check DNS of image server: RTT=10.TCP Connection: RTT=50, HTTP GET Image1: RTT = 50, HTTP GET Image2: RTT = 50, HTTP GET Image3: RTT = 50

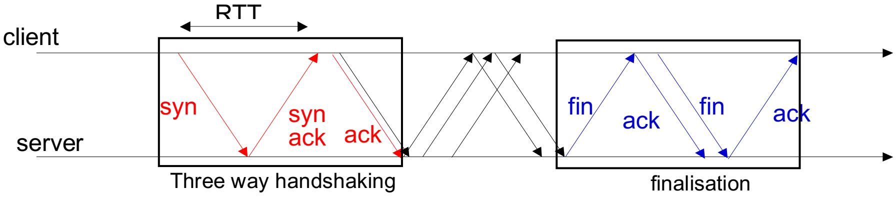
Step 4: ad. Check DNS ad server ad: 10 TCP connection to server: 200, Download Ad: 200

Step 5: large image. We assume the connection to the image server is still established and the window is >= 4. Download large image: RTT = 50
Download Total Time: 70 + 30 + 210 + 410 + 50 = 770 ms

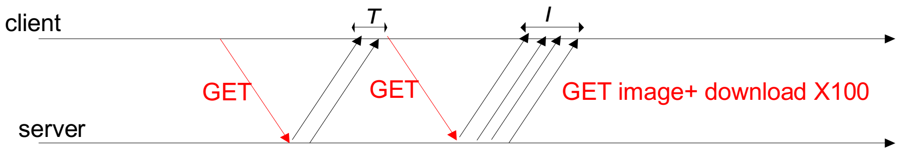
If steps 3 and 4 are in parallel (as they are TCP connections with different servers), then the time of step 3 (210m) is absorbed by step 4 (410m). The large image (step 5) is done the end because it works without "pipelining" and we can say it’s downloaded after the ad. The total download time would be: 70 + 30 + 410 + 50 = 560 ms.

Problem 27.

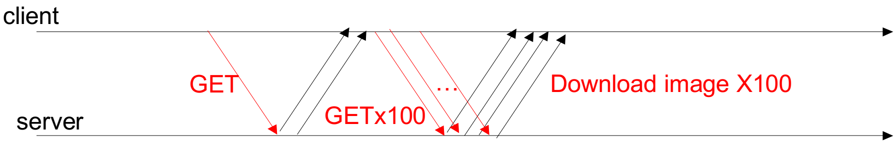
Imagine that a browser downloads an HTML document that contains 100 embedded images. Quantify in RTTs the difference that would be observed when using HTTP without persistence, HTTP with persistence and HTTP with persistence and pipelining. Assume that the browser never opens more than one parallel TCP connection with the server.



The length of the TWH is 1 RTT and the finalisation is approx. 1.5 RTT (see previous figure). A new TCP connection must wait for the termination of the previous one.
Being the transmission time of the HTML document *T* and the time of an image *I*. Without persistence, there will be 101 TCP connections, with persistence only 1. Without pipelining, the transmission will be of the type:



While with pipelining: (the acks are not drawn)



So, the transmission time will be (approximately):
Without persistence: *T* + 100 x*I* + 101 x 2.5 RTT + 101 x RTT, where the 101 x 2.5 RTT are the TWH and finalisation of the TCP connections and the 101 x RTT the 101 GETs. Similarly:
With persistence: *T* + 100 x *I* + 2.5 RTT + 101 x RTT.
With persistence and pipelining: *T* + 100 x *I* + 2.5 RTT + 2 x RTT.

Problem 28. ***(2021t)***

On all XC laboratory PCs, we use a browser configured with an HTTP proxy host with IP 147.83.32.1 to access the web. The teacher visits the website http://w.uoc.edu/ and proposes to the students to visit it that too on their PCs. Assumptions:

- DNS: Customers and the proxy server already have the necessary records in the cache.
- HTTP: The client only opens one HTTP connection per server and uses HTTP 1.1 (persistent).
- HTTP Cache: Proxy cache and web client cache, initially empty.
- Web access order: first access of the teacher and after the students on each PC.
- Latency: for each direction on the HTTP proxy server: 1 ms, web server: 10 ms. RTT: double.
- The visited web page has HTML content with an image embedded: <im src="http://w.uoc.edu/logo.png">
- Response download time (among any host pair) HTTP (HTML or PNG): 3 ms.

The teacher's first visit:

Origin	Proxy	Web server w	RTT (ms)	Justification
PC	GET http://w.uoc.edu/ → ← 200 Ok + HTML	GET / → ← 200 Ok + HTML	2+1 +20+10 +10+3+1+3	Establiment TCP PC→proxy (2) +HTTP GET→proxy (1) +Establiment TCP Proxy→w (20) + HTTP GET→w (10) +Resposta HTTP HTML w → (10+3) proxy → PC (1+3)
PC	GET http://w.uoc.edu /logo.png → ← 200 Ok + PNG	GET /logo.png → ← 200 Ok + PNG	1+10 +10+3+1+3	HTTP GET PNG aprofitant connexió TCP (persistent) PC → (1) proxy → (10) w + Resposta amb PNG w → (10+3) proxy → PC (1+3)
TOTAL			78	

a) What effect does the visit for each of the PC of each student to the same website via the proxy. Conditions:
Server w: HTML and PNG without changes. Non-expired DNS and HTTP caches. TCP proxy-w connection is maintained:

Origin	Proxy	Web server w	RTT (ms)	Justification (steps and RTT values for each step) ...
TOTAL				

b) Un altre PC estudiant visita la mateixa web via el proxy. Condicions:
Servidor w: HTML i PNG han canviat. Cachés DNS i HTTP no expirades. Es manté la connexió TCP proxy-w:

Origin	Proxy	Web server w	RTT (ms)	Justification (explain changes with respect to a) ...
TOTAL				

Solució:

a)

Origin	Proxy	Web server w	RTT (ms)	Justification (steps and RTT values for each step) ...
PC	GET http://w.uoc.edu/→ ← 200 Ok + HTML	GET / If-None-Match:"tag"→ ← 304 Not modified	2+1 +10 +10+0+1+3	Establishment TCP PC→proxy (2) +HTTP GET→proxy (1) + HTTP GET conditional → w (10) + Response HTTP "304 Not modified" w → (10+0) proxy → PC (1+3)
PC	GET http://w.uoc.edu/ logo.png → ← 200 Ok + PNG	GET /logo.png If-None-Match:"tag"→ ← 304 Not modified	1+10 +10+0 +1+3	HTTP GET PNG reusing previous TCP +GET (1+10), response with PNG "Not modified" w→proxy (10+0), only transfer between proxy → PC (1+3)
TOTAL			52	

b)

Origin	Proxy	Web server w	RTT (ms)	Justification (explain changes with respect to a) ...
PC	GET http://w.uoc.edu/→ ← 200 Ok + HTML	GET / If-None-Match:"tag"→ ← 200 Ok + HTML	2+1 +10 +10+3+1+3	Same as a) + changed HTML: server w → (+3) proxy → PC
PC	GET http://w.uoc.edu/ logo.png → ← 200 Ok + PNG	GET /logo.png If-None-Match:"tag"→ ← 200 Ok + PNG	1+10 +10+3 +1+3	Same as a) except transfer changed IMG server w → (+3) proxy → PC
TOTAL			58	