

LAB WORK 05. IPV4 SUBNETTING (CLASSES, CIDR, VLSM).

1. LAB TARGET.

To study the principles, tools and techniques for dividing the ISP address block allocated to the enterprise into subnets. Get practical skills and learning different technics of dividing networks into the required number of subnets of the desired (different) size.

2. LAB ASSIGNMENT

2.1. CREATE YOUR VARIANT OF THE TASKS.

2.1.1. Generate the node IP-address / subnet prefix for tasks 2.2 and 2.3.

a) Write your surname in the letters of the English alphabet. Must be at least 7 letters, if not enough, then add the required number of letters from the name (if not enough, then repeat name).

For example, for Li Yurijs there will be **LIYURIJS**.

b) Replace the first 7 letters with their ordinal numbers in the alphabet, writing the numbers as two-digit decimal numbers (with leading zero).

For example, **12 09 25 21 18 09 10**.

c) Translate each decimal two-digit number into a binary 5-bit number (with leading zero).
For example, 01100 01001 11001 10101 10010 01001 01010.

Resulting 35 bits sequence: **01100010 01110011 01011001 00100101 010**.

d) The rightmost 3 bits of the sequence are put into the decimal number system, add 19 and get the subnet prefix (from 19 to 26).

For example,

Bits for the prefix: 01100010 01110011 01011001 00100101 010

Resulting prefix: **010=2; 2+19=21 → /21**.

e) The first 32 bits of the received sequence will be your version of the host IP address in the binary representation.

For example,

Bits for the IP-address: 01100010 01110011 01011001 00100101 010

Resulting 32 bits IP-address: **01100010 01110011 01011001 00100101**.

f) Convert the binary IP address to a decimal 4-octet notation.

For example,

01100010.01110011.01011001.00100101

98 . 115 . 89 . 37

We obtain individual variant of the node address and subnet/super-net prefix for tasks 2.2 and 2.3, for example: **98.115.89.37/21**

2.1.2. Generate the variant for task 2.4 (Table 1).

Your variant is the 7th digit from point 2.1.1.b), corresponds to the ordinal number of the letter from A to Z.

For example, for **LIYURIJS**, I get **variant "J"** (line mark letter).

2.2. FIND THE BASIC PARAMETERS OF THE SPECIFIED SUBNET.

For your variant of the IP/prefix from 2.1.1, determine the following subnet parameters:

- Address - address of the node in dotted-binary notation,
- Class - network address class (traditional),
- Netmask - subnet mask (super-net) in dotted decimal notation,
- Wildcard - template for highlighting the addresses of the hosts in the subnet (super-net),
- Hosts - number of nodes in the subnet (super-net),
- Network - IP address of the subnet (super net),
- Gateway - IP address of the gateway,
- Host Min - IP address of the first host on the subnet (super-net),
- Host Max - IP address of the last host on the subnet (super-net),
- Broadcast - IP address of the broadcast messages for this subnet (super-net).

To count the number of hosts in a subnet (super-net), you need to perform 3 operations:

- count the number of bits available for use in host identifiers ($n=32-\text{prefix}$);
- calculate the power of two for this number ($N=2^n$);
- subtract 2 from the resulting number N (net and broadcast addresses).

For example, for nodes IP address in the prefix-notation 98.115.89.37/21, we get answer:

Nr	Parameters	Value of Dot-Dec	Value of Dot-Bin
a	Address:	098.115.089.37	01100010.01110011.01011 001.00100101
b	Class:	A	0
c	Netmask:	255.255.248.000	11111111.11111111.11111 000.00000000
d	Wildcard:	000.000.007.255	00000000.00000000.00000 111.11111111
e	Hosts:	2046	$2^{(32-21)}-2=2^{11}-2=2048-2=2046$
f	Network:	098.115.088.000	01100010.01110011.01011 000.00000000
g	Gateway:	098.115.088.001	01100010.01110011.01011 000.00000001
h	Host Min:	098.115.088.002	01100010.01110011.01011 000.00000010
i	Host Max:	098.115.095.254	01100010.01110011.01011 111.11111110
j	Broadcast:	098.115.095.255	01100010.01110011.01011 111.11111111

2.3. VERIFY THAT THE SUBNET PARAMETERS ARE CORRECT.

Learn how to use it to split IPv4 networks of classes A, B and C into subnets with an equal number of hosts. Verify the correct calculation of the IPv4 subnet parameters for your variant. Select any IPv4 network software calculator.

Make a Screenshot of calculator with your variant data.

Address (Host or Network) Netmask (i.e. 24) Netmask for sub/supernet (optional)

98.115.89.37 / 21 move to:

Address: 98.115.89.37 01100010.01110011.01011 001.00100101
 Netmask: 255.255.248.0 = 21 11111111.11111111.11111 000.00000000
 Wildcard: 0.0.7.255 00000000.00000000.00000 111.11111111
 =>
 Network: 98.115.88.0/21 01100010.01110011.01011 000.00000000 (Class A)
 Broadcast: 98.115.95.255 01100010.01110011.01011 111.11111111
 HostMin: 98.115.88.1 01100010.01110011.01011 000.00000001
 HostMax: 98.115.95.254 01100010.01110011.01011 111.11111110
 Hosts/Net: 2046

Select any IPv6 network software calculator. Learn how to use it to split IPv6 networks into subnets with an equal number of hosts.

2.4. SPLIT THE ENTERPRISE NETWORK INTO SUBNETS.

Split the network into the appropriate number of subnets. Use the enterprise network diagram (Fig. 1) and information about the number of computers in the departments (your variant from 2.1.2 in table 1)

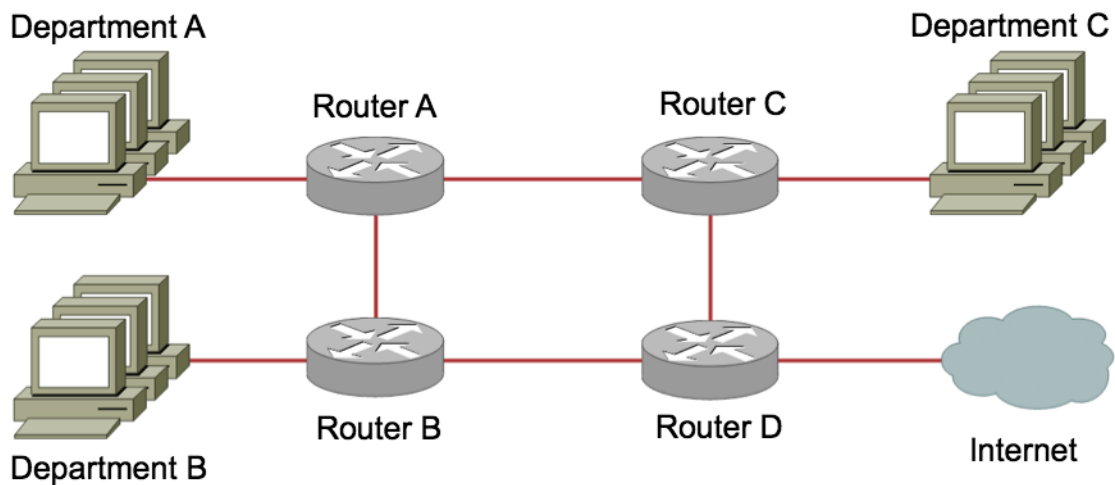


Fig.1. The enterprise network scheme.

Table 1. Variants of tasks

Variant	Origin network (addresses block)	Number of computers in departments		
		A	B	C
A	118.7.50.0 /25	7	9	27
B	39.221.98.0 /25	8	5	18
C	88.27.252.0 /23	30	9	46
D	81.104.216.0 /21	48	120	249
E	7.50.128.0 /19	267	176	678
F	89.151.32.0 /19	311	246	806
G	126.61.74.0 /23	8	61	17
H	36.121.96.0 /19	311	696	226
I	28.54.64.0 /19	957	153	274
J	67.253.1.0 /20	365	116	508
K	77.75.0.0 /18	338	830	1403
L	5.63.168.0 /21	119	61	226
M	85.123.72.0 /21	189	51	72
N	72.241.3.0 /25	12	7	3
O	87.228.68.0 /22	26	45	71
P	46.41.64.0 /18	384	1535	675
Q	57.214.86.0 /23	63	9	21
R	74.30.128.0 /19	346	179	732
S	88.61.128.0 /20	366	77	130
T	10.58.180.0 /22	30	92	43
U	112.56.76.0 /22	23	114	60
V	2.78.160.0 /19	214	443	525
W	30.182.64.0 /18	624	1700	358
X	75.39.128.0 /19	625	219	372
Y	98.115.89.37 /21	48	119	250
Z	35.163.168.0 /21	119	60	224
?	192.168.1.0/24 (see 4.6.3)	100	20	50

2.4.1. Make the optimal network splitting to the subnets.

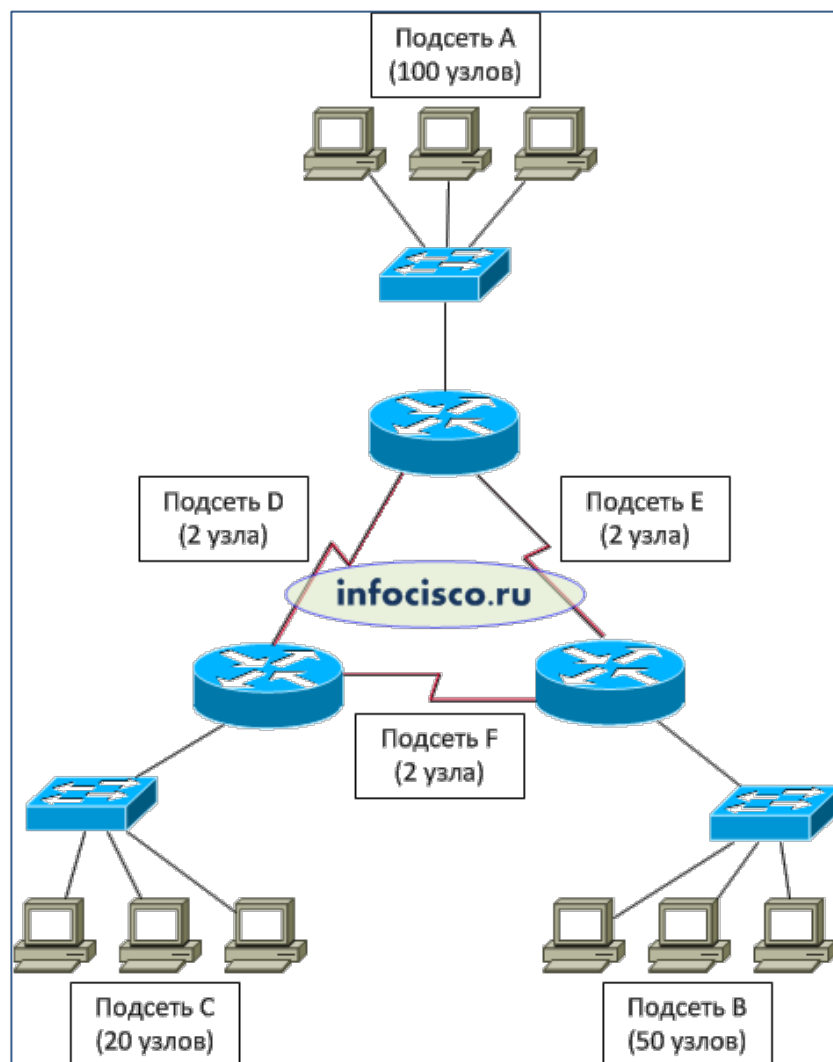
The splitting must be optimal, that is, you should not use a large subnet for the department, if only half of such a subnet is sufficient.

Be sure to consider the 4 subnets between the routers. In total, we get 7 subnets: A, B, C, D, E, F, G. The subnet between the router D and the Internet is not necessary to describe, as its parameters and addresses are determined by the Internet provider.

The Result of Subnetting Example (see description in 4.6.3):

Blocks	Need IP	S	H	IP/prefix	Remain	Possible IP
Subnet A	100+1	1	7	192.168.1.0/25	192.168.1.128/25	$2^7-2=126$
Subnet B	50+1	2	6	192.168.1.128/26	192.168.1.192/26	$2^6-2=62$
Subnet C	20+1	3	5	192.168.1.192/27	192.168.1.224/27	$2^5-2=30$
Subnets DEF		4	4	192.168.1.224/28	192.168.1.240/28	$2^4-2=14$
Subnet D	2	6	2	192.168.1.224/30	-	$2^2-2=2$
Subnet E	2	6	2	192.168.1.228/30	-	$2^2-2=2$
Subnet F	2	6	2	192.168.1.232/30	192.168.1.236/30	$2^2-2=2$
Reserved Block 1		6	2	192.168.1.236/30	-	$2^2-2=2$
Reserved Block 2		4	4	192.168.1.240/28	-	$2^4-2=14$

Summary diagram of the enterprise network with labelled subnets



Use <https://www.draw.io/> for create a summary diagram of the enterprise network.

2.4.2. Describe the following parameters for each of the 7 subnets:

- Subnet Address BIN - subnet address in binary form;
- Subnet Address DEC - subnet address in decimal form;
- Subnet Prefix in decimal form;
- Subnet Mask BIN - subnet mask in binary form;
- Subnet Mask DEC - subnet mask in decimal form;
- Subnet Broadcast address;
- Subnet Gateway address;
- Subnet Host Count Pos - number of possible hosts on the subnet;
- Subnet Host Count Use - number of used IP (occupied by the department);
- Subnet Host Count Free - number of unused IP (department reserve).

For example,

Subnet A

Nr	Parameters	Value
a	Subnet Address BIN:	11000000.10101000.00000001.00000000
b	Subnet Address DEC:	192.168.1.0
c	Subnet Prefix:	25
d	Subnet Mask BIN:	11111111.11111111.11111111.1 0000000
e	Subnet Mask DEC:	255.255.255.128
f	Subnet Broadcast:	192.168.1.127
g	Subnet Gateway:	192.168.1.1
h	Subnet Host Count Pos:	126
i	Subnet Host Count Use:	101
j	Subnet Host Count Free:	25

Other Subnets B, C, D, E, F, G

2.4.3. Describe the enterprise allocated address space:

- Enterprise Reserved addresses count and Address/Prefix of each of the free blocks;
- Used / Free / Reserved - the ratio between the summary number of used, free and reserved addresses;
- Loss Qnt - summary loss of addresses by an enterprise due to subnetting, in quantity (addresses for subnet/free-block numbers and broadcasts, routers (gateways));
- Loss % - summary loss of addresses by an enterprise due to subnetting, in percent.

For example,

Nr	Parameters	Value
a	Enterprise All IP Count:	$2^{(32-\text{Prefix})}=2^{(32-24)}=2^8=256$
b	Enterprise Used IP Count:	$101+51+21+2+2+2=179$
c1	Enterprise Reserved Block 1 (IP/prefix):	2 (192.168.1.236/30)
c2	Enterprise Reserved Block 2 (IP/prefix):	14 (192.168.1.240/28)
d	Department A, B, C Free IP:	$25+11+9=45$
e	Enterprise Used / Free / Reserved:	/ 179 / 45 / 16 = 240
f	Loss IP Count by an enterprise due to subnetting, quantity:	$2+2+2+2+2+2+2=16$
g	Loss IP % by an enterprise due to subnetting, percent:	$16/256*100=6.25\%$

3. LAB REPORT.

The report is provided electronic form with Report Blank.

THE REPORT INCLUDES:

- 3.1. The formation of an individual variant of the assignment from the surname-name to the final address, prefix and letter, see 2.1.
- 3.2. The table of calculation of all subnet parameters in point-decimal notation and binary notation, see 2.2.
- 3.3. A screenshot of the calculation of the parameters of your subnet using the IPv4 calculator, see 2.3.
- 3.4. The final scheme of the enterprise network with signed subnets, see 2.4.1.
- 3.5. Tables with a description of the parameters of each subnet obtained, see 2.4.2.
- 3.6. A table describing the parameters of the unallocated space of addresses (enterprise reserve), see 2.4.3.

GRADE.

Grade on 10 points: correctly formed individual variant IP-address/prefix and correctly made of all assignments (2.1, 2.2, 2.3, 2.4.1, 2.4.2, 2.4.3).

4. LAB GUIDELINES

4.1. TWO-LEVEL IPV4 ADDRESSING (CLASSES ADDRESSING).

IP Address. An IP address, which is 32-bits in length, IPv4 uses hierarchical addressing scheme.

Class - the class of the network is determined by the first 4 bits of the address. IPv4 Addressing system is divided into five classes of IP Addresses – A, B, C, D, E, F. IPv4 hierarchy contains several classes of IP Addresses to be used efficiently in various situations as per the requirement of hosts per network.

Hierarchical Two-level Addressing Scheme (Classes addressing).

A single IP address can contain information about the network and ultimately the host. An IP address, which is 32-bits in length, is divided into two (**Network-Host**) parts:



This scheme enables the IP Address to be hierarchical where a network can have hosts.

Examples of IP Addresses:

17.16.2.15	=	00011101.00010000.00000010.00001111
178.68.128.168	=	10110010.01000100.10000000.10101000
217.20.147.94	=	11011001.00010100.10010011.01011110

The part highlighted by red refers to the network address and the other part refers to the host address.

To find out how many bits pertain to the network address, the network equipment uses a network class (and network mask in sub-netting).

Mask - Subnet mask is also 32 bits long used to describe which portion of the address identifies the network and which portion of the address identifies the node.

In order to see how the mask helps you identify the network and node parts of the address, convert the address and mask to binary numbers.

Examples of network masks:

255.0.0.0	=	11111111.00000000.00000000.00000000
255.255.0.0	=	11111111.11111111.00000000.00000000
255.255.255.0	=	11111111.11111111.11111111.00000000
255.255.240.0	=	11111111.11111111.11110000.00000000

The network mask is applied only locally (where local means - on this particular network segment).

AND operation over IP address and network mask.

If the IP address in binary is AND-ed with its Subnet Mask, the result yields the Network address. For example, say the IP Address is 192.168.1.152 and the Subnet Mask is 255.255.255.0 then:

IP	192.168.1.152	11000000	10101000	00000001	10011000	} ANDed
Mask	255.255.255.0	11111111	11111111	11111111	00000000	
Network	192.168.1.0	11000000	10101000	00000001	00000000	Result

It can be identified now that 192.168.1.0 is the Network number and 192.168.1.152 is the host on that network.

4.1.1. CIDR – Classless Inter-Domain Routing.

CIDR-notation - the modern standard form of specification of the network prefix is CIDR notation, used for both IPv4 and IPv6. It counts the number of bits in the prefix and appends that number to the address after a slash (/) character separator.

The number after / indicates the number of bits pertaining to the network address (subnet, supernet). For example, an administrator have 192.168.1.0/24 network. The suffix /24 (pronounced as "slash 24").

Classes IPv4 addressing uses three fixed sizes of networks A, B and C.

Class A, B, C networks have default masks, also known as natural masks, as shown here:

Class A: 255.0.0.0 /8 = 11111111.00000000.00000000.00000000
 Class B: 255.255.0.0 /16 = 11111111.11111111.00000000.00000000
 Class C: 255.255.255.0 /24 = 11111111.11111111.11111111.00000000

The networks and hosts counts per class can be derived by this formula:

$N = 2^n$ (Networks_count = $2^{\text{network_bits}}$)
 $H = 2^h - 3$ (Hosts_count = $2^{\text{host_bits}} - 3$)

When calculating hosts' IP addresses, 3 IP addresses are decreased because they cannot be assigned to hosts, i.e. the first IP of a network is **network IP** (all hosts bit=0), one IP (second) is used for **gateway** and the last IP is reserved for **broadcast IP** (all hosts bit = 1).

Gateway Address. In addition to the network number and broadcast address, the subnet usually contains a gateway, whose role is usually performed by one of the interfaces of the router. Typically, the gateway receives the first address in the subnet from those addresses that can be assigned to hosts.

4.2. THREE-LEVEL IPV4 ADDRESSING (CLASSLESS ADDRESSING).

Hierarchical Three-level Addressing Scheme (Classless addressing).

A single IP address and mask (or suffix) can contain information about the network and its sub-network and ultimately the host. An IP address, which is 32-bits in length, is divided into three (**Network-SubNetwork-Host**) parts:



This scheme enables the IP Address to be hierarchical where a network can have many sub-networks which in turn can have many hosts.

To find out how many bits pertain to the network address, the network equipment uses a network class and network mask.

In Classless IPv4 addressing (network-subnet-host), the prefix in the network address can differ from /8, /16, /24 and shows the number of high-order bits allocated to the network number and subnet. The remaining bits are allocated to the host number.

/23 = 11111111.11111111.11111110.00000000 = 255.255.254.0

/24 = 11111111.11111111.11111111.00000000 = 255.255.255.0

/25 = 11111111.11111111.11111111.10000000 = 255.255.255.128

The subnetworks and hosts counts can be derived by this formula:

$S = 2^s$, where S – subnetworks count, s – subnetwork bits;

$H = 2^h - 2$, where H – hosts count, h – host bits)

The formula for calculating the required number of bits for addressing S subnets.

$s \geq \text{LOG}_2(S)$, where s - number of bits, S - number of subnets,

4.2.1. VLSM procedure.

VLSM - Variable Length Subnet Masking.

CIDR is based on VLSM, which allows a network to be divided into variously sized subnets, providing the opportunity to size a network more appropriately for local needs. Variable-length subnet masks are mentioned in RFC 950. Accordingly, techniques for grouping addresses for common operations were based on the concept of cluster addressing.

The following procedure shows how VLSM can be used in order to allocate department-wise IP addresses as mentioned in the example.

Step 1. Take the range of IP addresses allocated to your organization. For example, 192.168.1.0/24.

Step 2. Sort the requirements of IPs in descending order (Highest to Lowest).

Sales Department 100

Purchase Department 50

Accounts Department 25

Management Department 5

Step 3. Make a list of Subnets possible.

Subnet Mask	Slash Notation	Hosts/Subnet
255.255.255.0	/24	254
255.255.255.128	/25	126
255.255.255.192	/26	62
255.255.255.224	/27	30
255.255.255.240	/28	14
255.255.255.248	/29	6
255.255.255.252	/30	2

Step 4. Allocate the highest range of IPs to the highest requirement, so let's assign 192.168.1.0/25 (255.255.255.128) to the Sales department. This IP subnet with Network

number 192.168.1.0 has 126 valid Host IP addresses which satisfy the requirement of the Sales department. The subnet mask used for this subnet has 10000000 as the last octet.

Step 5. Allocate the next highest range, so let's assign 192.168.1.128/26 (255.255.255.192) to the Purchase department. This IP subnet with Network number 192.168.1.128 has 62 valid Host IP Addresses which can be easily assigned to all the PCs of the Purchase department. The subnet mask used has 11000000 in the last octet.

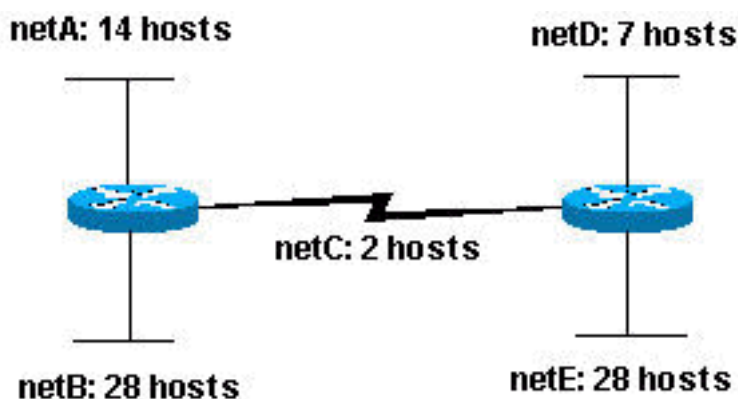
Step 6. Allocate the next highest range, i.e. Accounts. The requirement of 25 IPs can be fulfilled with 192.168.1.192/27 (255.255.255.224) IP subnet, which contains 30 valid host IPs. The network number of Accounts department will be 192.168.1.192. The last octet of subnet mask is 11100000.

Step 7. Allocate the next highest range to Management. The Management department contains only 5 computers. The subnet 192.168.1.224/29 with the Mask 255.255.255.248 has exactly 6 valid host IP addresses. So this can be assigned to Management. The last octet of the subnet mask will contain 11111000.

4.3. SIMPLE SUBNETTING AND VLSM.

4.3.1. Simple subnetting.

Given the Class C network of 204.15.5.0/24, subnet the network in order to create the network in Figure with the host requirements shown.



In classic subnetting network was split into eight equal-size subnets; however, each subnet did not utilize all available host addresses, which results in wasted address space. Each subnetwork could potentially support up to 30 host addresses. Figure 1 (left) illustrates this wasted address space.

4.3.2. VLSM technique.

Variable Length Subnet Masks (VLSM) allows you to use different masks for each subnet, thereby using address space efficiently.

Determine what mask allows the required number of hosts.

- netA: requires a /28 (255.255.255.240) mask to support 14 hosts
- netB: requires a /27 (255.255.255.224) mask to support 28 hosts
- netC: requires a /30 (255.255.255.252) mask to support 2 hosts
- netD: requires a /28 (255.255.255.240) mask to support 7 hosts
- netE: requires a /27 (255.255.255.224) mask to support 28 hosts

The easiest way to assign the subnets is to assign the largest first. For example:

- netB: 204.15.5.0/27 host address range 1 to 30
- netE: 204.15.5.32/27 host address range 33 to 62
- netA: 204.15.5.64/28 host address range 65 to 78
- netD: 204.15.5.80/28 host address range 81 to 94
- netC: 204.15.5.96/30 host address range 97 to 98

This can be graphically represented as shown in Figure 2:

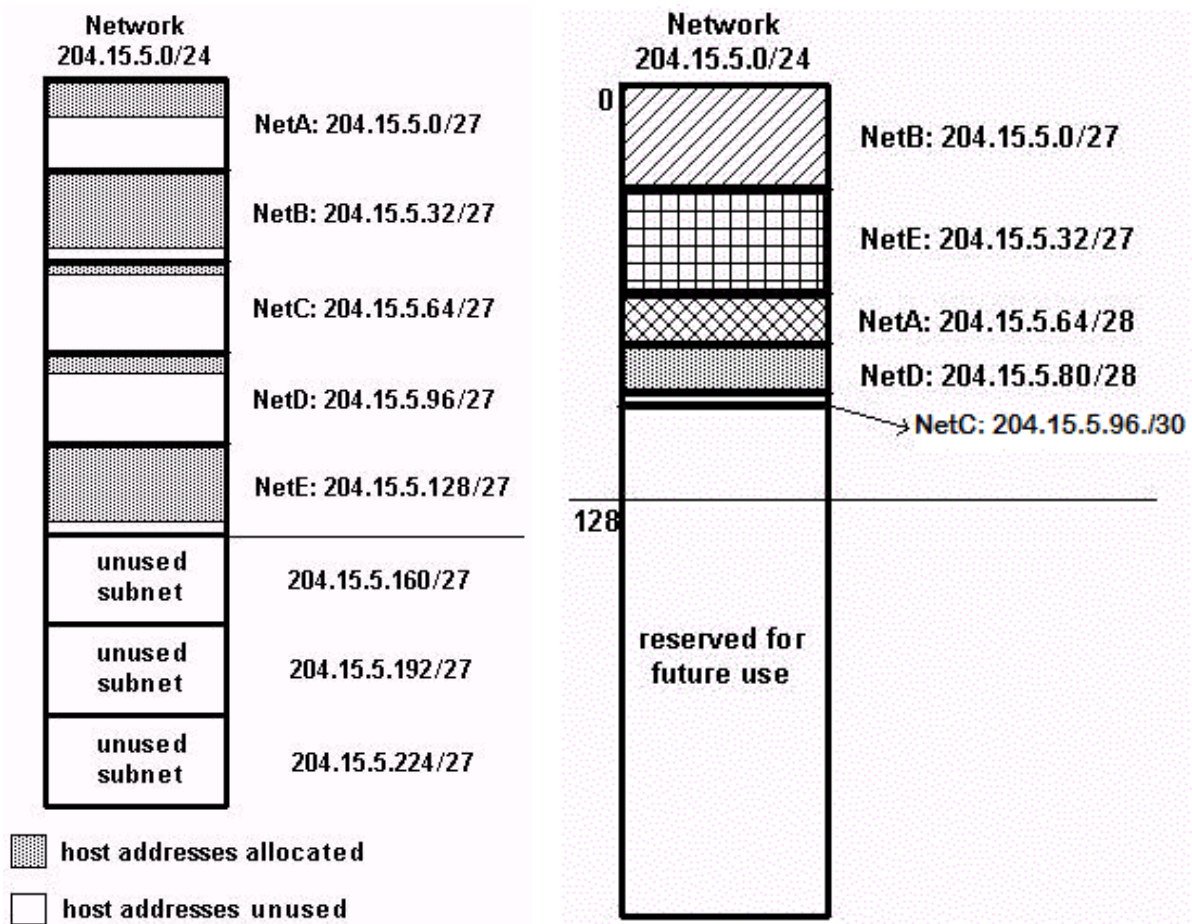


Fig. 2. Illustrates how using VLSM helped save more than half of the address space.

4.4. AUTOMATED SUBNETTING TECHNIQUE USING IP CALCULATORS.

Online and offline versions of the IP Calculator and Subnetwork Calculator allow you to solve problems such as translating numbers from one number system to another, transferring addresses from one form of presentation to another, splitting the network into subnets, and combining networks into a supernet.

On the Internet, there are many implementations of such calculators. Especially useful are IP calculators for subnetting for IPv6.

But, IP calculators do not know how to splitting networks into several different in size subnets (look p.2.3.2.). This task will be solved by running the program multiple times with manual processing of intermediate results, so you need to know the manual subnetting techniques.

To train skills and check the results of manual calculations, it is recommended to learn how to work with several IP/Subnetwork Calculators.

For example.

Address (Host or Network)	Netmask (i.e. 24)	Netmask for sub/supernet (optional)
<input type="text" value="192.168.0.1"/>	/ <input type="text" value="24"/>	move to: <input type="text"/>
<input type="button" value="Calculate"/>		

No host given
No netmask given (using default netmask of your network's class)

Address:	192.168.0.1	11000000.10101000.00000000	.00000001
Netmask:	255.255.255.0 = 24	11111111.11111111.11111111	.00000000
Wildcard:	0.0.0.255	00000000.00000000.00000000	.11111111
=>			
Network:	192.168.0.0/24	11000000.10101000.00000000	.00000000 (Class C)
Broadcast:	192.168.0.255	11000000.10101000.00000000	.11111111
HostMin:	192.168.0.1	11000000.10101000.00000000	.00000001
HostMax:	192.168.0.254	11000000.10101000.00000000	.11111110
Hosts/Net:	254	(Private Internet)	

Fig. 3. Online IP Calculator <http://jodies.de/ipcalc>

VLSM/CIDR Calculator

How many subnets do you need to create?

5

What is the network IP prefix in slash notation (i.e. 192.168.1.0/24)?

192.168.1.0/24

Subnet Names: Number of hosts:

Host1	5
Host2	2
Host3	20
Host4	3
Host5	70

The network 192.168.1.0/24 has 254 hosts.
Your subnets need 100 hosts.

Name	Hosts Needed	Hosts Available	Unused Hosts	Network Address	Slash	Mask	Usable Range	Broadcast	Wildcard
Host5	70	126	56	192.168.1.0	/25	255.255.255.128	192.168.1.1 - 192.168.1.126	192.168.1.127	0.0.0.127
Host3	20	30	10	192.168.1.128	/27	255.255.255.224	192.168.1.129 - 192.168.1.158	192.168.1.159	0.0.0.31
Host1	5	6	1	192.168.1.160	/29	255.255.255.248	192.168.1.161 - 192.168.1.166	192.168.1.167	0.0.0.7
Host4	3	6	3	192.168.1.168	/29	255.255.255.248	192.168.1.169 - 192.168.1.174	192.168.1.175	0.0.0.7
Host2	2	2	0	192.168.1.176	/30	255.255.255.252	192.168.1.177 - 192.168.1.178	192.168.1.179	0.0.0.3

Fig. 4. Online VLSM/CIDR Calculator <http://subnettingpractice.com/vlsm.html>

IPv6 Subnetting Calculator

Input an IPv6 address and the subnet size in slash notation:

IPv6 address:

Compressed Address: 2001:db8::/32

Expanded Address: 2001:0db8:0000:0000:0000:0000:0000:0000/32

Prefix: ffff:ffff:0000:0000:0000:0000:0000:0000

Range: 2001:db8:0:0:0:0:0:0

2001:db8:fff:fff:fff:fff:fff:fff

Number of /64s: 4294967296

Select a number of subnets or a subnet size to divide the above into:

subnets or

To get at least 4 new subnets divide 2001:db8::/32 into 4 new subnets. Each of these subnets is a /34 containing 1073741824 /64s. The new subnets are as follows:

2001:db8::/34

2001:db8:4000::/34

2001:db8:8000::/34

2001:db8:c000::/34

Fig. 5. IPv6 Subnet Calculator http://subnettingpractice.com/ipv6_subnetting.html

4.5. FAST SUBNETTING TECHNIQUE WITH EXCEL RESULTS PRESENTATION.

The subnet is divided into smaller subnets by increasing the subnet prefix. This operation divides the total number of network addresses (subnets) by a number that is a multiple of the power of two.

The source network and its subnets can be represented as a graph, the vertex of which will be the source network, and each child node is obtained as a result of splitting the network into two subnets:

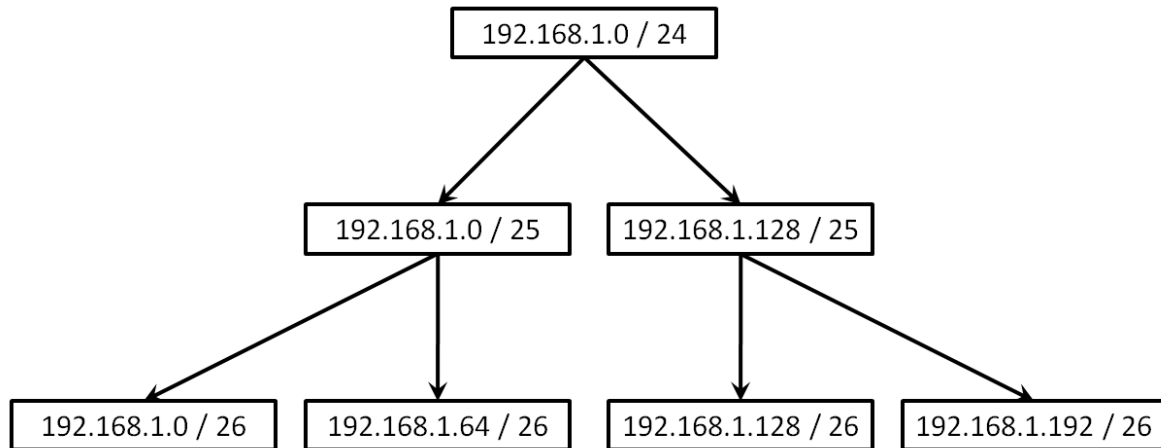


Fig.6. Subnets graph.

Thus, the process of partitioning the source network into the required number of subnets reduces to a **dichotomous division** of the original subnet.

Branching continues until a suitable logical subnet is found for each physical subnet. The dichotomous subnetting method is conveniently represented in spreadsheets, for example, Microsoft Excel.

Each merged cell represents a certain range of addresses, for example, a subnet with the prefix 192.168.1.0/25, describes half of the entire network C, see Fig. 7.

The merged cells to the right are smaller blocks of network addresses, for example, a subnet with the prefix /26 describes 1/4 of the network C.

We continue dividing in half in the following columns, down to the minimum necessary block of addresses, for example, to subnets with the prefix /30, which describe subnets of 1/64 of the network C with 4 addresses in each.

This technique clearly represents the distribution of addresses and allows you to keep records of the distribution of the address block available in the company.

A quick technique is convenient only when you break up networks with a small number of nodes (class C networks), otherwise the technique becomes inefficient.

	1	2	3	4	5	6
1	192.168.1.0 / 25	192.168.1.0 / 26	192.168.1.0 / 27	192.168.1.0 / 28	192.168.1.0 / 29	192.168.1.0 / 30
2						192.168.1.4 / 30
3					192.168.1.8 / 29	192.168.1.8 / 30
4						192.168.1.12 / 30
5				192.168.1.16 / 28	192.168.1.16 / 29	192.168.1.16 / 30
6						192.168.1.20 / 30
7					192.168.1.24 / 29	192.168.1.24 / 30
8						192.168.1.28 / 30
9			192.168.1.32 / 27	192.168.1.32 / 28	192.168.1.32 / 29	192.168.1.32 / 30
10						192.168.1.36 / 30
11					192.168.1.40 / 29	192.168.1.40 / 30
12						192.168.1.44 / 30
13				192.168.1.48 / 28	192.168.1.48 / 29	192.168.1.48 / 30
14						192.168.1.52 / 30
15					192.168.1.56 / 29	192.168.1.56 / 30
16						192.168.1.60 / 30
17		192.168.1.64 / 26	192.168.1.64 / 27	192.168.1.64 / 28	192.168.1.64 / 29	192.168.1.64 / 30
18						192.168.1.68 / 30
19					192.168.1.72 / 29	192.168.1.72 / 30
20						192.168.1.76 / 30
21				192.168.1.80 / 28	192.168.1.80 / 29	192.168.1.80 / 30
22						192.168.1.84 / 30
23					192.168.1.88 / 29	192.168.1.88 / 30
24						192.168.1.92 / 30
25			192.168.1.96 / 27	192.168.1.96 / 28	192.168.1.96 / 29	192.168.1.96 / 30
26						192.168.1.100 / 30
27					192.168.1.104 / 29	192.168.1.104 / 30
28						192.168.1.108 / 30
29				192.168.1.112 / 28	192.168.1.112 / 29	192.168.1.112 / 30
30						192.168.1.116 / 30
31					192.168.1.120 / 29	192.168.1.120 / 30
32						192.168.1.124 / 30

Fig. 7. Subnetting in Microsoft Excel.

Visual Subnetwork Calculator works in a similar Excel method.

Visual Subnet Calculator

Enter the network you wish to subnet:

Network Address Mask bits

Show columns: Subnet address Netmask Range of addresses Useable IPs Hosts Divide Join

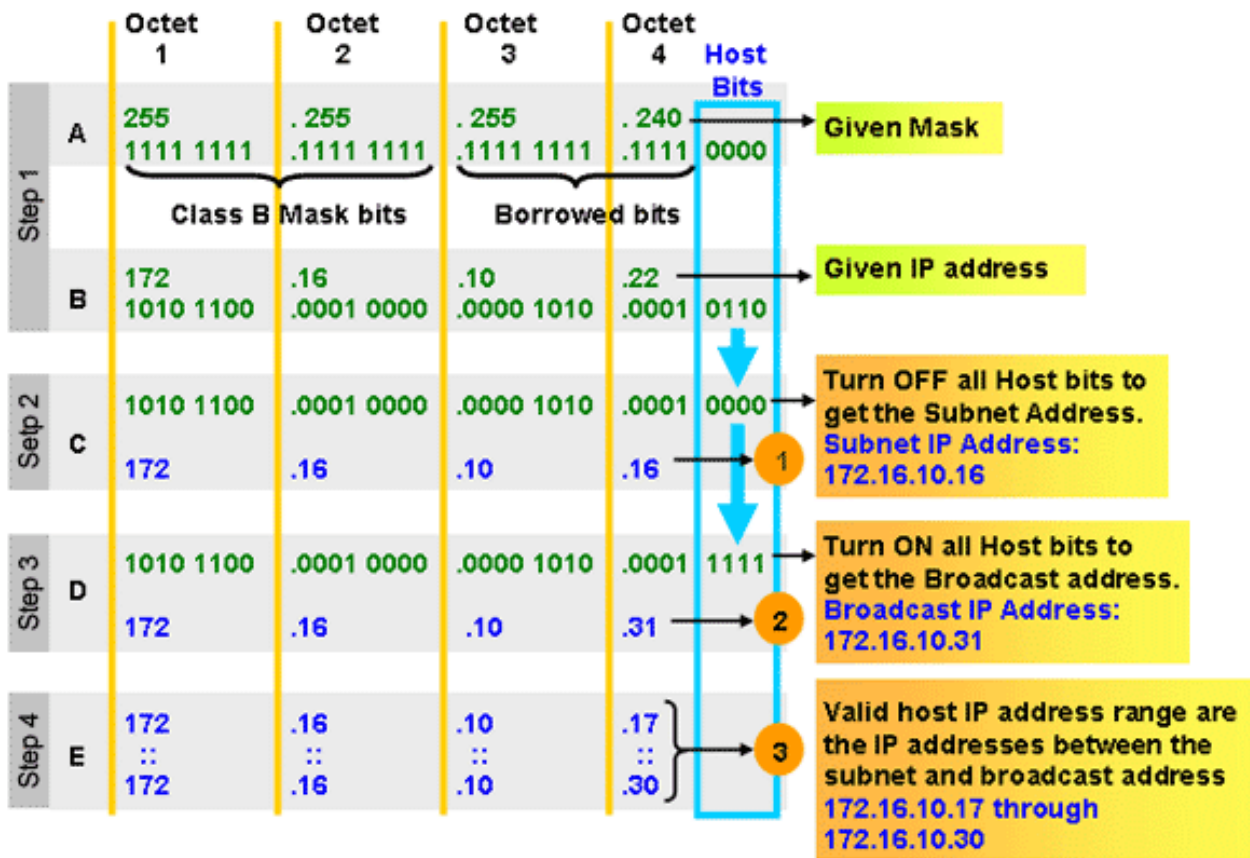
Click below to split and join subnets.
If you wish to save this subnetting for later, bookmark [this hyperlink](#).

Subnet address	Netmask	Range of addresses	Useable IPs	Hosts	Divide	Join
192.168.0.0/18	255.255.192.0	192.168.0.0 - 192.168.63.255	192.168.0.1 - 192.168.63.254	16382	Divide	/18 /17
192.168.64.0/18	255.255.192.0	192.168.64.0 - 192.168.127.255	192.168.64.1 - 192.168.127.254	16382	Divide	/18 /18
192.168.128.0/20	255.255.240.0	192.168.128.0 - 192.168.143.255	192.168.128.1 - 192.168.143.254	4094	Divide	/20 /19 /18
192.168.144.0/20	255.255.240.0	192.168.144.0 - 192.168.159.255	192.168.144.1 - 192.168.159.254	4094	Divide	/20 /19 /18
192.168.160.0/19	255.255.224.0	192.168.160.0 - 192.168.191.255	192.168.160.1 - 192.168.191.254	8190	Divide	/19 /19 /18
192.168.192.0/19	255.255.224.0	192.168.192.0 - 192.168.223.255	192.168.192.1 - 192.168.223.254	8190	Divide	/19 /19 /18
192.168.224.0/19	255.255.224.0	192.168.224.0 - 192.168.255.255	192.168.224.1 - 192.168.255.254	8190	Divide	/19 /19 /18

<https://net.academy.lv/soft/vsc/subnets.html>

4.6. CLASSIC SUBNETTING TECHNIQUE USED IN THE CISCO/CCNA COURSES.

The division of the network is accomplished by assigning bits from the portion of the host address to the portion of the network address. Thus, we increase the possible number of subnets, but we reduce the number of hosts in subnets.



To quickly select the required parameters, you can use the tables from the cheat sheet by IP Subnetting, see the materials for laboratory work.

4.6.1. Example. Network partition into 2 equal-sized subnets.

We have a network address of 192.168.1.0/24, **we need** to divide the network into 4 equal-sized subnets.

For addressing two subnets, only 1 bit is required:

$$n \geq \text{LOG}_2(N) = \text{LOG}_2(2) = 1.$$

Write the address in binary form:

$$192.168.1.0/24 = 11000000.10101000.00000001.00000000$$

We take 1 bit from the host portion to get 2 subnets, this will increase the prefix by one bit: /25.

Now we need to write out 2 identical IP addresses of the network in binary form by changing only the assigned bit (at the first subnet the assigned bit will be 0, and for the second subnet = 1). The captured bit is highlighted in red.

2 subnets:

- 1) 11000000.10101000.00000001.00000000
- 2) 11000000.10101000.00000001.10000000

Now write a decimal next to the binary form, and add a new prefix. Red marked the portion of the subnet, and blue - the portion of the host. We get 2 subnets:

- 1) 11000000.10101000.00000001.00000000 = 192.168.1.0/25
- 2) 11000000.10101000.00000001.10000000 = 192.168.1.128/25

The host portion is now 7 bits. To calculate how many host addresses can be obtained using 7 bits, you need to use the calculation formula for hosts: $H=2^h-2$, where h - number of bits in the host portion.

$$H = 2^7 - 2 = 126 \text{ hosts.}$$

For each subnet, we write out the subnet addresses (in the host portion all 0) and the broadcast addresses in these subnets (in the host portion all 1):

- 11000000.10101000.00000001.00000000 = 192.168.1.0/25 (subnet 1);
- 11000000.10101000.00000001.01111111 = 192.168.1.127/25 (broadcast 1);
- 11000000.10101000.00000001.10000000 = 192.168.1.128/25 (subnet 2);
- 11000000.10101000.00000001.11111111 = 192.168.1.255/25 (broadcast 2).

4.6.2. Example. Network partition into 4 equal-sized subnets.

We have a network address of 192.168.1.0/24, **we need** to divide the network into 4 equal-sized subnets. This task is similar to the previous one.

We calculate by the formula how much we need to take a bit from the host: $\text{LOG}_2(4=2^2)=2$. The prefix changes from /24 to /26.

4 subnets (captured bits are highlighted in red):

- 1) 11000000.10101000.00000001.00000000
- 2) 11000000.10101000.00000001.01000000
- 3) 11000000.10101000.00000001.10000000
- 4) 11000000.10101000.00000001.11000000

The host portion on each subnet is 6 bits. $H = 2^6 - 2 = 62$ hosts. Red - the portion of the subnet, and blue - the portion of the host::

- 1) 11000000.10101000.00000001.00000000 = 192.168.1.0/26
- 2) 11000000.10101000.00000001.01000000 = 192.168.1.64/26
- 3) 11000000.10101000.00000001.10000000 = 192.168.1.128/26
- 4) 11000000.10101000.00000001.11000000 = 192.168.1.192/26

It's all, the network is divided into 4 subnets.

- 11000000.10101000.00000001.00000000 = 192.168.1.0/26 (subnet 1)
- 11000000.10101000.00000001.00111111 = 192.168.1.63/26 (broadcast 1)
- 11000000.10101000.00000001.01000000 = 192.168.1.64/26 (subnet 2)
- 11000000.10101000.00000001.01111111 = 192.168.1.127/26 (broadcast 2)
- 11000000.10101000.00000001.10000000 = 192.168.1.128/26 (subnet 3)
- 11000000.10101000.00000001.10111111 = 192.168.1.191/26 (broadcast 3)
- 11000000.10101000.00000001.11000000 = 192.168.1.192/26 (subnet 4)
- 11000000.10101000.00000001.11111111 = 192.168.1.255/26 (broadcast 4)

In this way, you can divide any network into equal-sized subnets.

4.6.3. Example Splitting the network into several different subnets.

Let the enterprise have three departments with a known number of computers in the departments, the traffic between the departments is required to be logically and physically divided.

When dividing a network into subnets, hosts located in different subnets can not interact at the network level directly. For the interaction of such hosts, the enterprise needs a router that forwards packets between subnets.

Let for greater reliability there are 3 routers.

The enterprise network scheme has three routers, three switches and the specified number of hosts in the segments is shown in Figure 8.

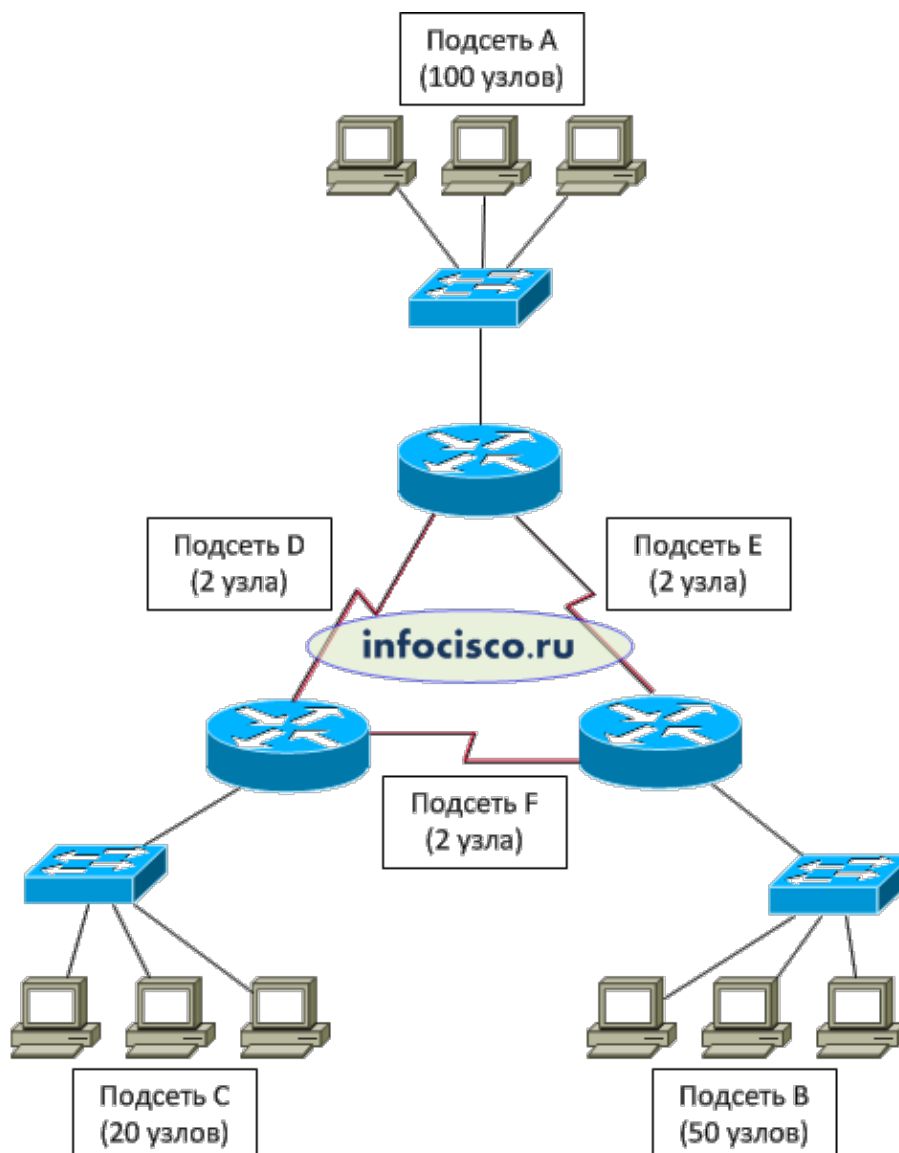


Fig. 8. An example of an enterprise network.

Let the provider allocate one block of IP addresses of class C **192.168.1.0/24** to the entire company network. **Required: splitting this block into 6 different in size subnets.**

4.6.3.1. Required number of hosts in each subnet.

The required number of hosts in each subnet (+1 for the address of the router):

Subnet A – (100+1)=101 hosts

Subnet B – (50+1)=51 hosts

Subnet C – (20+1)=21 hosts

Each pair of routers is connected to each other by a separate subnet, so you need 3 more subnets. Since such subnets contain only two hosts, it is sufficient for them to use the subnet prefix /30:

Subnet D - 2 узла

Subnet E - 2 узла

Subnet F - 2 узла

4.6.3.2. We allocate the largest subnet A.

Let's start with allocate the subnet with the maximum number of nodes.

The IP address block 192.168.1.0/24 In binary form (the network portion of class is highlighted in red):

11000000.10101000.00000001.00000000 .

"/24" - network mask prefix (short mask entry). The complete network mask entry is 255.255.255.0. Binary form the network mask:

11111111.11111111.11111111.00000000

We have 8 bits available for dividing the network into subnets. When selecting the required number of bits in the mask for a given number of nodes in the subnet, you can use the formula $h \geq \text{LOG}_2(H)$ or tables from the cheat sheet by IP Subnetting.

We will use the cheat sheet "BIN to DEC".

For the first subnet A, we need to allocate IP addresses for 101 nodes.

In the table "BIN to DEC" we see that having occupied in the mask one bit of eight, we get 1 bit to the portion of the network (and this is 2 subnets) and 7 bits per address portion (01111111 = 127). 127 is the total number of addresses in the network with the broadcast account, which satisfies the required 101 (and even several addresses remain in reserve).

If you select 2 bits, the number of hosts will be 63, which is less than the required 101 nodes.

We change the mask from "/ 24" to "/ 25", in binary format it will be:

11111111.11111111.11111111.10000000).

Apply a new mask to our block (bit operation AND) and get 2 subnets (the network portion is highlighted in red):

Subnet A - 11000000.10101000.00000001.00000000 (subnet 192.168.1.0/25)

Remain A - 11000000.10101000.00000001.10000000 (block 192.168.1.128/25)

BIN to DEC		
0000	0000	0
0000	0001	1
0000	0011	3
0000	0111	7
0000	1111	15
0001	1111	31
0011	1111	63
0111	1111	127
1111	1111	255

4.6.3.3. We allocate the next largest subnet B.

From 192.168.1.128/25 (remainder A), you need to allocate 51 addresses for the hosts in subnet B. As in the previous time, we see in the table "BIN to DEC" 00111111 = 63, it is more than 51, which means that it meets the requirements.

We occupy one more bit at the address portion, leaving 6 ($2^6-2=62$). The mask becomes one more /26, we apply it to our block and get two new subnets:

Subnet B - 11000000.10101001.00000000.10000000 (subnet 192.168.1.128/26)
Remain B - 11000000.10101001.00000000.11000000 (block 192.168.1.192/26)

4.6.3.4. We allocate the next largest subnet C.

We occupy another 1 bit from the portion of the hosts address (00011111 = 31, which is more than 21, and therefore is suitable), the mask is already /27. We get two subnets:

Subnet C - 11000000.10101001.00000001.11000000 (subnet 192.168.1.192/27)
Remain C - 11000000.10101001.00000001.11100000 (block 192.168.1.224/27)

4.6.3.5. We allocate the smallest subnets D, E, F.

We will allocate hosts numbers for subnets **more economically**, so that the remainder is obtained (the stock of addresses for the future development of the enterprise network).

It remains to allocate 3 subnets to 2 addresses for router communication.

By the table we see that it's enough for a portion of the node address of only two bits (00000011 = 3), $2^2-2=2$ addresses for two hosts.

In turn, for three, equally large subnets, two bits ($2^2=4$, a formula from a cheat sheet) are also sufficient.

In total, in the IP address 32 bits, subtract the required 2 and get 30, so use the mask /30.

Splitting the remain C by 3 subnets and 2 remains blocks:

Remain C - 11000000.10101000.00000001.11100000 (subnet 192.168.1.224/27)
Subnet D - 11000000.10101000.00000001.11100000 (subnet 192.168.1.224/30)
Subnet E - 11000000.10101000.00000001.11100100 (subnet 192.168.1.228/30)
Subnet F - 11000000.10101000.00000001.11101000 (subnet 192.168.1.232/30)
Remain 1 - 11000000.10101000.00000001.11101100 (block 192.168.1.236/30)
Remain 2 - 11000000.10101000.00000001.11110000 (block 192.168.1.240/28)

4.6.3.6. The resulting subnets:

Subnet A - 192.168.1.0/25
Subnet B - 192.168.1.128/26
Subnet C - 192.168.1.192/27
Subnet D - 192.168.1.224/30
Subnet E - 192.168.1.228/30
Subnet F - 192.168.1.232/30
Remain block 1 - 192.168.1.236/30
Remain block 2 - 192.168.1.240/28

4.6.4. Examples of partitioning networks of Class A, B and C into an odd number of subnets.

Each example specifies the network part of the address, mask, prefix, broadcast-address, counted the number of nodes in each subnet.

Splitting the class B network 195.20.0.0/16 into 5 subnets:

IP subnet/prefix	Broadcast DEC	Broadcast BIN	Hosts count
195.20.0.0/18	195.20.63.255	195.20.00111111.11111111	16382
195.20.64.0/18	195.20.127.255	195.20.01111111.11111111	16382
195.20.128.0/18	195.20.191.255	195.20.10111111.11111111	16382
195.20.192.0/18	195.20.255.255	195.20.11111111.11111111	16382
Subnet mask	255.255.192.0 11111111.11111111.11000000.00000000		

Now divide, for example, the first subnet into 2 subnets, i.e. select one more bit in the extended network prefix. Thus. we get 2 subnets with a mask /19.

195.20.0.0/18

IP subnet/prefix	Broadcast DEC	Broadcast BIN	Hosts count
195.20.0.0/19	195.20.31.255	195.20.00011111.11111111	8190
195.20.32.0/19	195.20.63.255	195.20.00111111.11111111	8190
Subnet mask	255.255.224.0 11111111.11111111.11100000.00000000		

Splitting the class C network 211.118.94.0/24 into 3 subnets:

IP subnet/prefix	Broadcast DEC	Broadcast BIN	Hosts count
211.118.94.0/25	211.118.94.127	211.118.94.01111111	126
211.118.94.128/25	211.118.94.255	211.118.94.11111111	126
Subnet mask	255.255.255.128 11111111.11111111.11111111.10000000		

211.118.94.128/25

IP subnet/prefix	Broadcast DEC	Broadcast BIN	Hosts count
211.118.94.128/26	211.118.94.191	211.118.94.10111111	62
211.118.94.192/26	211.118.94.255	211.118.94.11111111	62
Subnet mask	255.255.255.192 11111111.11111111.11111111.11000000		

Splitting the class A network 12.0.0.0/8 into 5 subnets:

IP subnet/prefix	Broadcast DEC	Broadcast BIN	Hosts count
12.0.0.0/10	12.63.255.255	12.00111111.11111111.11111111	4194302
12.64.0.0/10	12.127.255.255	12.01111111.11111111.11111111	4194302
12.128.0.0/10	12.191.255.255	12.10111111.11111111.11111111	4194302
12.192.0.0/10	12.255.255.255	12.11111111.11111111.11111111	4194302
Subnet mask	255.192.0.0 11111111.11000000.00000000.00000000		

102.128.0.0/10

IP subnet/prefix	Broadcast DEC	Broadcast BIN	Hosts count
12.128.0.0/11	12.159.255.255	12.10011111.11111111.11111111	2097150
12.160.0.0/11	12.191.255.255	12.10111111.11111111.11111111	2097150
Subnet mask	255.224.0.0 11111111.11100000.00000000.00000000		