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DESIGNING AN IP ADDRESSING SCHEME

CI5220 Networking and Operating Systems Coursework

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1 - Designing an IP Addressing Scheme

In this coursework, a US enterprise called **"We've Got Worms"** wishes to develop a public **IP addressing scheme** to allow it to connect to the Internet.
An IP address [1] consists of four bytes, of which each octet corresponds to a decimal number. IP addresses are used to uniquely identify a host throughout the Internet and are composed of three fields:

1. The **domain ID**, identifies a domain and is assigned by the Internet authorities
2. The **subnet ID**, identifies a network and is assigned by the enterprise
3. The **host ID**, identifies individual machines in subnets and is assigned by the administrator of that subnet.

In the case of "We've Got Worms", the assigned Network address is **80.169.96.0**.
In the Internet Layer, routers use the IP address in each incoming packet to decide how to forward it. Routers on the Internet backbone use the domain ID, routers within an organisation use the subnet ID.

In carrying out this first phase of the coursework, the following instructions will be followed:

"The key focus in designing an IP addressing scheme (for an enterprise which wishes to connect to the Internet) is computing the supernet mask, and hence the size of the public address space sought.

The key design steps:
1. Design an initial physical network based on workgroups
2. Identify (1) number of subnets, and (2) the largest subnet(s)
3. Compute the subnet and supernet masks
4. Compute address utilisation (Terminate on optimal design)
5. Revisit physical design segmenting largest subnet(s)
6. Goto Step 2." [2]

1. James F. Kurose, Keith W. Ross., 2013. Computer networking : a top-down approach. 6th Edition. John Wiley & Sons., p.338.
2. Mini-Lecture: Designing an IP Addressing Scheme

1.1 - Physical Design

The initial physical design is provided by the specification. For each workgroup, the number of hosts that compose it has been added in Figure 1.

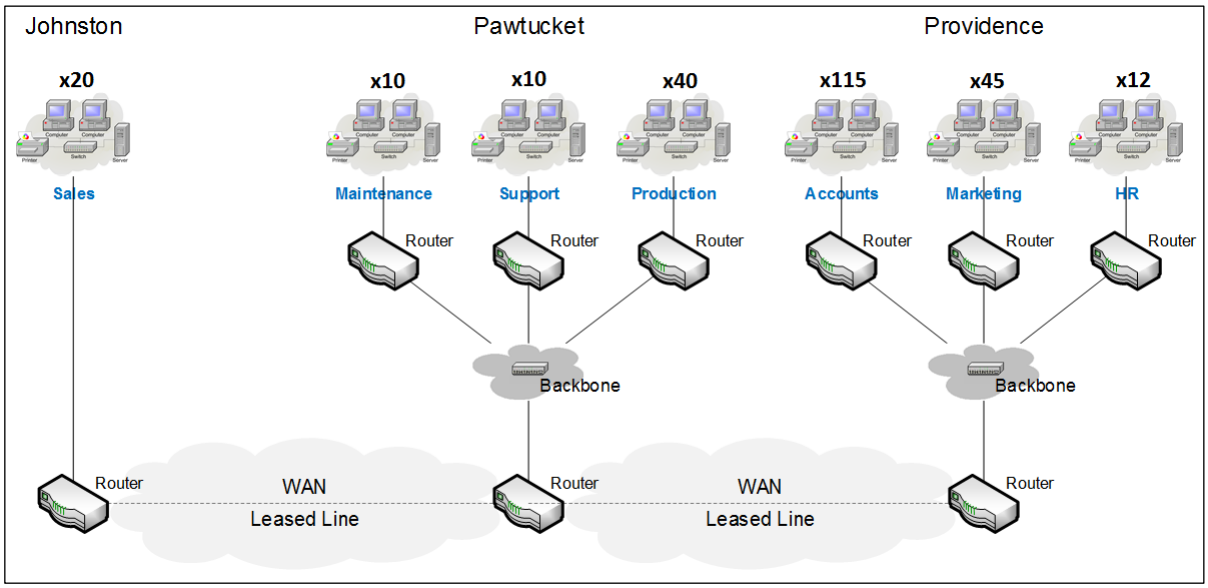

Figure 1

1.2 - Identifying Subnets

1.2.1 - Identifying number of subnets

Number of Switched LANs = 7

Number of Backbones = 2 ⇒ Number of subnets = 7+2+2 = 11

Number of Leased Lines = 2

1.2.2 - Identifying the largest subnet

The largest subnet is **Accounts** in Providence with 115 hosts.

1.3 - Subnet and Supernet Masks

Both for host addresses and for subnet addresses the number of possible different addresses is $\mathbf{2^N - 2}$, with N = number of bits available for the respective ID.

Subnet Mask:

Largest = $115 \leq 126 < 128 = 2^7$ ⇒ Number of host_id bits required is 7 ⇒ Number of 1 bits in Subnet Mask = 32-7 = 25 ⇒ 11111111.11111111.11111111.10000000 ⇒ **255.255.255.128**

Hosts ID 0000000 and 1111111 are reserved (subnet address and broadcast address).

Supernet Mask:

Number of subnets = $11 \leq 14 < 16 = 2^4$ ⇒ Number of subnet_id bits required is 4 ⇒ Number of 1 bits in Supernet Mask = 32-(7+4) = 21 ⇒ **/21**. Subnets ID 0000 and 1111 are reserved (domain address and broadcast address).

1.4 - Address Utilisation

Number of IP addresses = (20)+(10+10+40)+(115+45+12)+(19 routers connections) = 271
Length of Supernet Mask = 21
Size of address space = $2^{(32-21)}$ = 2048 addresses
Utilisation = (271/2048) X 100% **= 13.23%**

1.5 - Improving the Design

To improve the address utilisation it is necessary **to reduce the variation in subnet size**. One of the possible ways to do this is to split the Accounts workgroup into four parts as shown in Figure 2 (noting that this way we will have exactly 14 subnets and we will still be able to use only 4 bits for the subnet ID).

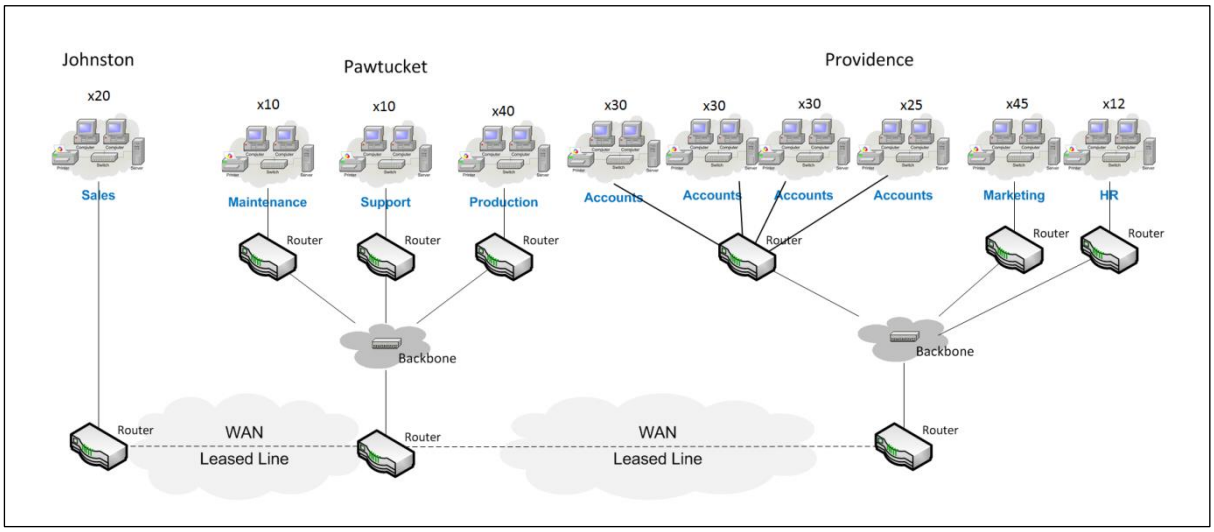

Figure 2

1.2b - Identifying Subnets

1.2.1b - Identifying number of subnets

Number of Switched LANs = 10

Number of Backbones = 2 ⇒ Number of subnets = 10+2+2 = 14

Number of Leased Lines = 2

1.2.2b - Identifying the largest subnet

The largest subnet is **Marketing** in Providence with 45 hosts.

1.3b - Subnet and Supernet Masks

Subnet Mask:
Largest = 45 ≤ 62 < 64 = 2^6 ⇒ Number of host_id bits required is 6 ⇒ Number of 1 bits in Subnet Mask = 32-6 = 26 ⇒ 11111111.11111111.11111111.11000000 ⇒ **255.255.255.192**
Hosts ID 000000 and 111111 are reserved (subnet address and broadcast address).

Supernet Mask:
Number of subnets = 14 ≤ 14 < $16 = 2^4$ ⇒ Number of subnet_id bits required is 4 ⇒ Number of 1 bits in Supernet Mask = 32-(6+4) = 22 ⇒ **/22**
Subnets ID 0000 and 1111 are reserved (domain address and broadcast address).

1.4b - Address Utilisation

Number of IP addresses = (20)+(10+10+40)+(115+45+12)+(22 routers connections) = 274
Length of Supernet Mask = 22
Size of address space = $2^{(32-22)}$ = 1024 addresses
Utilisation = (274/1024) X 100% **= 26.76 %**

2 - Assigning IP Addresses

To make this report more complete, IP addresses will be assigned to both the initial design and, subsequently, to the improved design with a fixed-length subnet mask addressing scheme. Finally, the IP addresses of the improved design will be reassigned using a variable-length subnet mask. In the section concerning the assignment of host addresses, addresses will be assigned explicitly only to router ports and to some hosts to avoid redundancy.

2.1 - Initial Design (FLSM)

In Figure 3 all the subnets and routers of the initial design have been identified and numbered.

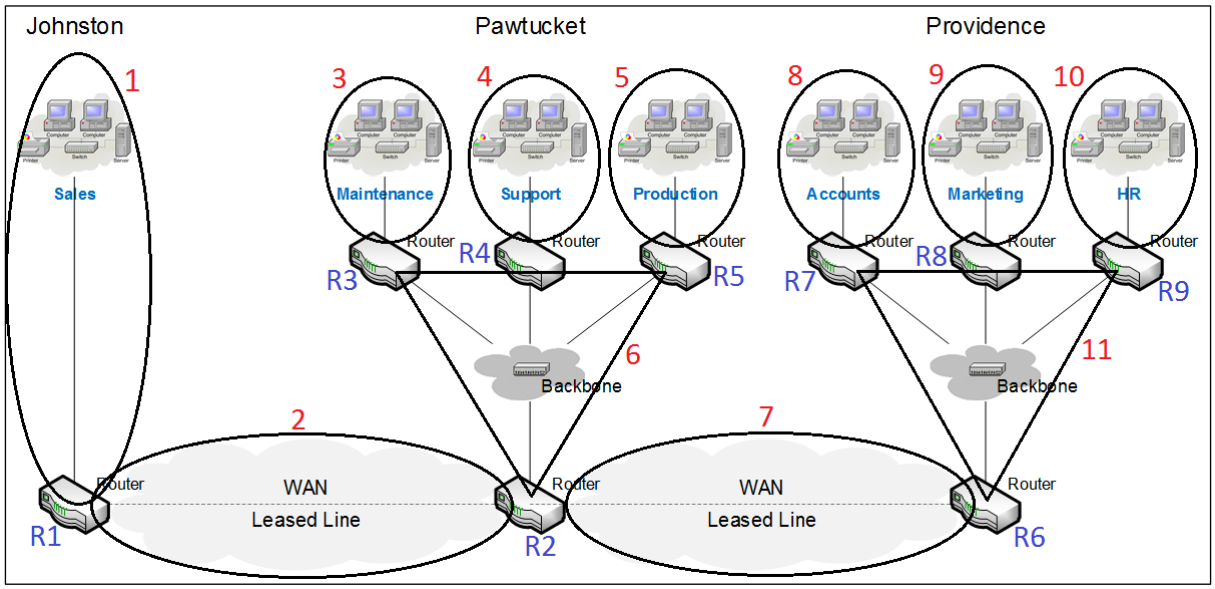

Figure 3

Network address:	01010000	10101001	01100|000	0|0000000	80.169.96.0
Supernet Mask:	11111111	11111111	11111|000	0|0000000	/21
Subnet Mask:	11111111	11111111	11111|111	1|0000000	255.255.255.128

2.1.1 - Subnet Addresses

Subnet 1:	01010000	10101001	01100|000	1|0000000	80.169.96.128
Subnet 2:	01010000	10101001	01100|001	0|0000000	80.169.97.0
Subnet 3:	01010000	10101001	01100|001	1|0000000	80.169.97.128
Subnet 4:	01010000	10101001	01100|010	0|0000000	80.169.98.0
Subnet 5:	01010000	10101001	01100|010	1|0000000	80.169.98.128
Subnet 6:	01010000	10101001	01100|011	0|0000000	80.169.99.0
Subnet 7:	01010000	10101001	01100|011	1|0000000	80.169.99.128
Subnet 8:	01010000	10101001	01100|100	0|0000000	80.169.100.0
Subnet 9:	01010000	10101001	01100|100	1|0000000	80.169.100.128
Subnet 10:	01010000	10101001	01100|101	0|0000000	80.169.101.0
Subnet 11:	01010000	10101001	01100|101	1|0000000	80.169.101.128

Figure 4 shows the subnet addresses:

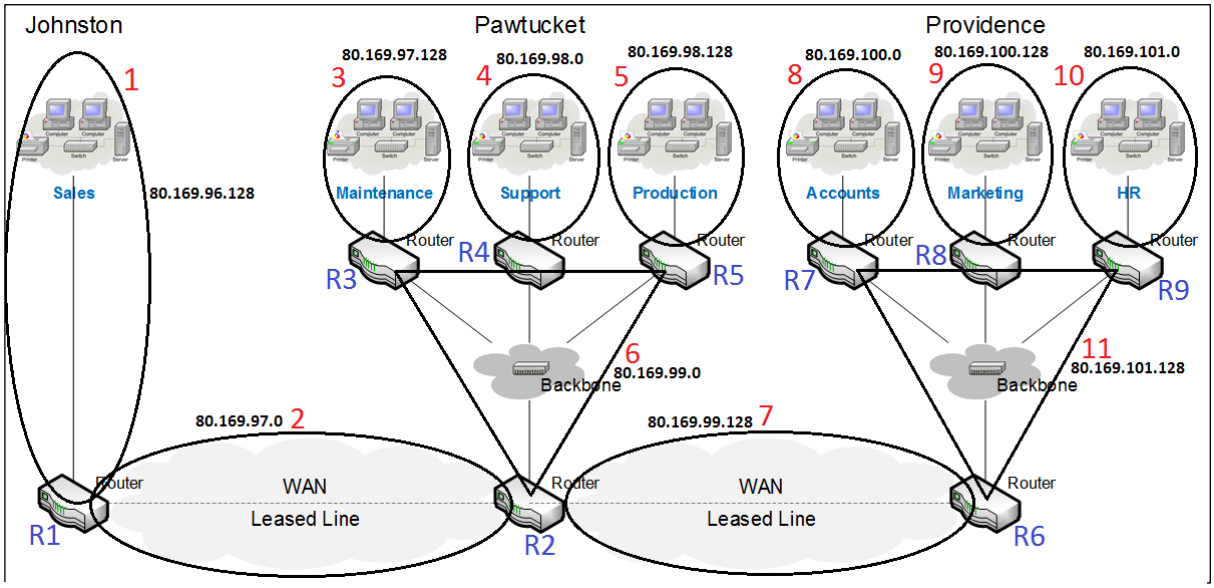

Figure 4

2.1.2 - Host Addresses

Router 1 on Subnet 1: 01010000 10101001 01100|000 1|0000001 ⇒ 80.169.96.129
Hosts on Subnet 1: 80.169.96.130, 80.169.96.131 …

Router 1 on Subnet 2: 01010000 10101001 01100|001 0|0000001 ⇒ 80.169.97.1
Router 2 on Subnet 2: 01010000 10101001 01100|001 0|0000010 ⇒ 80.169.97.2

Router 3 on Subnet 3: 01010000 10101001 01100|001 1|0000001 ⇒ 80.169.97.129
Hosts on Subnet 3: 80.169.97.130, 80.169.97.131 …

Router 4 on Subnet 4: 01010000 10101001 01100|010 0|0000001 ⇒ 80.169.98.1
Hosts on Subnet 4: 80.169.98.2, 80.169.98.3 …

Router 5 on Subnet 5: 01010000 10101001 01100|010 1|0000001 ⇒ 80.169.98.129
Hosts on Subnet 5: 80.169.98.130, 80.169.98.131 …

Router 2 on Subnet 6: 01010000 10101001 01100|011 0|0000001 ⇒ 80.169.99.1
Router 3 on Subnet 6: 01010000 10101001 01100|011 0|0000010 ⇒ 80.169.99.2
Router 4 on Subnet 6: 01010000 10101001 01100|011 0|0000011 ⇒ 80.169.99.3
Router 5 on Subnet 6: 01010000 10101001 01100|011 0|0000100 ⇒ 80.169.99.4

Router 2 on Subnet 7: 01010000 10101001 01100|011 1|0000001 ⇒ 80.169.99.129
Router 6 on Subnet 7: 01010000 10101001 01100|011 1|0000010 ⇒ 80.169.99.130

Router 7 on Subnet 8: 01010000 10101001 01100|100 0|0000001 ⇒ 80.169.100.1
Hosts on Subnet 8: 80.169.100.2, 80.169.100.3 …

Router 8 on Subnet 9: 01010000 10101001 01100|100 1|0000001 ⇒ 80.169.100.129
Hosts on Subnet 9: 80.169.100.130, 80.169.100.131 …

Router 9 on Subnet 10: 01010000 10101001 01100|101 0|0000001 ⇒ 80.169.101.1
Hosts on Subnet 10: 80.169.101.2, 80.169.101.3 …

Router 6 on Subnet 11: 01010000 10101001 01100|101 1|0000001 ⇒ 80.169.101.129
Router 7 on Subnet 11: 01010000 10101001 01100|101 1|0000010 ⇒ 80.169.101.130
Router 8 on Subnet 11: 01010000 10101001 01100|101 1|0000011 ⇒ 80.169.101.131
Router 9 on Subnet 11: 01010000 10101001 01100|101 1|0000100 ⇒ 80.169.101.132

Figure 5 shows the router addresses:

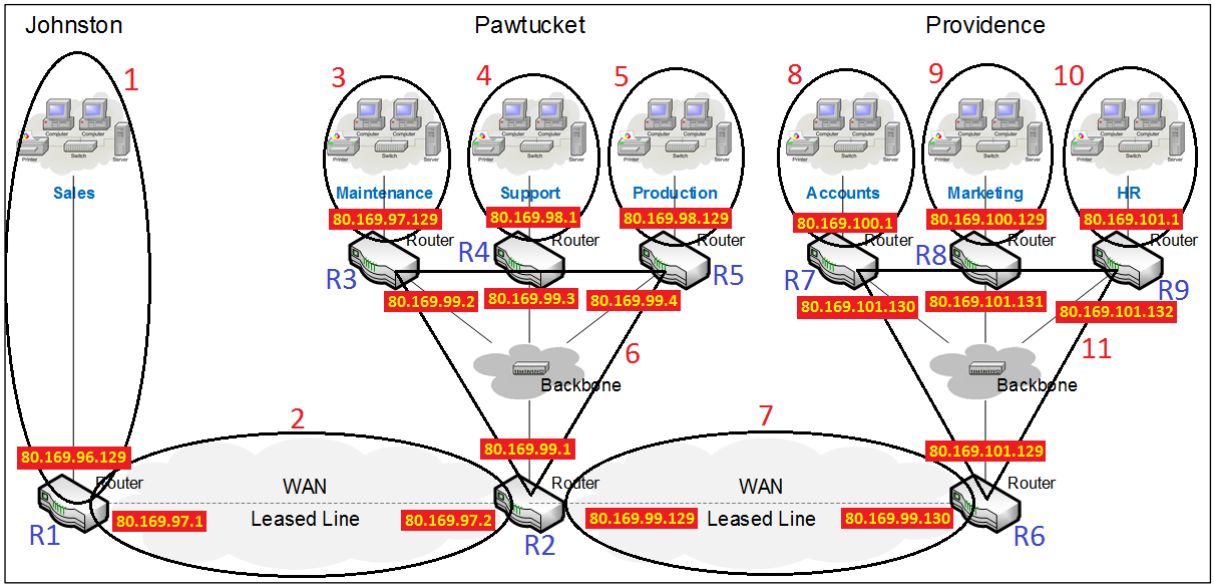

Figure 5

2.2 - Improved Design (FLSM)

In Figure 6 all the subnets and routers of the improved design have been identified and numbered.

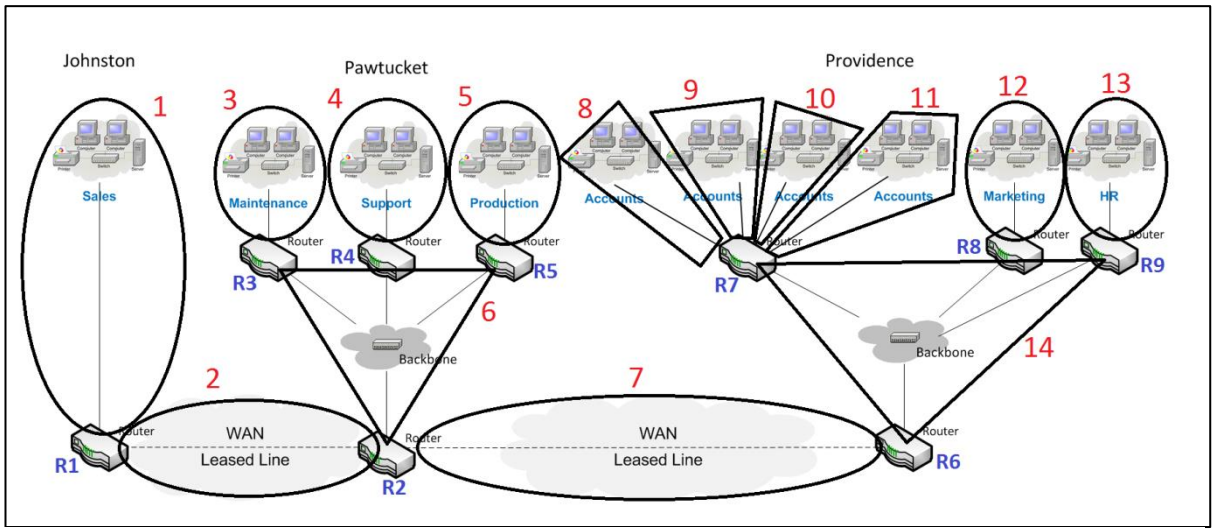

Figure 6

Network address:	01010000	10101001	011000|00	00|000000	80.169.96.0
Supernet Mask:	11111111	11111111	111111|00	00|000000	/22
Subnet Mask:	11111111	11111111	111111|11	11|000000	255.255.255.192

2.2.1 - Subnet Addresses

Subnet 1:	01010000	10101001	011000|00	01|000000	80.169.96.64
Subnet 2:	01010000	10101001	011000|00	10|000000	80.169.96.128
Subnet 3:	01010000	10101001	011000|00	11|000000	80.169.96.192
Subnet 4:	01010000	10101001	011000|01	00|000000	80.169.97.0
Subnet 5:	01010000	10101001	011000|01	01|000000	80.169.97.64
Subnet 6:	01010000	10101001	011000|01	10|000000	80.169.97.128
Subnet 7:	01010000	10101001	011000|01	11|000000	80.169.97.192
Subnet 8:	01010000	10101001	011000|10	00|000000	80.169.98.0
Subnet 9:	01010000	10101001	011000|10	01|000000	80.169.98.64
Subnet 10:	01010000	10101001	011000|10	10|000000	80.169.98.128
Subnet 11:	01010000	10101001	011000|10	11|000000	80.169.98.192
Subnet 12:	01010000	10101001	011000|11	00|000000	80.169.99.0
Subnet 13:	01010000	10101001	011000|11	01|000000	80.169.99.64
Subnet 14:	01010000	10101001	011000|11	10|000000	80.169.99.128

2.2.2 - Host Addresses

Router 1 on Subnet 1: 01010000 10101001 011000|00 01|000001 ⇒ 80.169.96.65

Hosts on Subnet 1: 80.169.96.66, 80.169.96.67 …

Router 1 on Subnet 2: 01010000 10101001 011000|00 10|000001 ⇒ 80.169.96.129
Router 2 on Subnet 2: 01010000 10101001 011000|00 10|000010 ⇒ 80.169.96.130

Router 3 on Subnet 3: 01010000 10101001 011000|00 11|000001 ⇒ 80.169.96.193
Hosts on Subnet 3: 80.169.96.194, 80.169.96.195 …

Router 4 on Subnet 4: 01010000 10101001 011000|01 00|000001 ⇒ 80.169.97.1
Hosts on Subnet 4: 80.169.97.2, 80.169.97.3 …

Router 5 on Subnet 5: 01010000 10101001 011000|01 01|000001 ⇒ 80.169.97.65
Hosts on Subnet 5: 80.169.97.66, 80.169.96.67 …

Router 2 on Subnet 6: 01010000 10101001 011000|01 10|000001 ⇒ 80.169.97.129
Router 3 on Subnet 6: 01010000 10101001 011000|01 10|000010 ⇒ 80.169.97.130
Router 4 on Subnet 6: 01010000 10101001 011000|01 10|000011 ⇒ 80.169.97.131
Router 5 on Subnet 6: 01010000 10101001 011000|01 10|000100 ⇒ 80.169.97.132

Router 2 on Subnet 7: 01010000 10101001 011000|01 11|000001 ⇒ 80.169.97.193
Router 6 on Subnet 7: 01010000 10101001 011000|01 11|000010 ⇒ 80.169.97.194

Router 7 on Subnet 8: 01010000 10101001 011000|10 00|000001 ⇒ 80.169.98.1
Hosts on Subnet 8: 80.169.98.2, 80.169.98.3 …

Router 7 on Subnet 9: 01010000 10101001 011000|10 01|000001 ⇒ 80.169.98.65
Hosts on Subnet 9: 80.169.98.66, 80.169.98.67 …

Router 7 on Subnet 10: 01010000 10101001 011000|10 10|000001 ⇒ 80.169.98.129
Hosts on Subnet 10: 80.169.98.130, 80.169.98.131 …

Router 7 on Subnet 11: 01010000 10101001 011000|10 11|000001 ⇒ 80.169.98.193
Hosts on Subnet 11: 80.169.98.194, 80.169.96.195 …

Router 8 on Subnet 12: 01010000 10101001 011000|11 00|000001 ⇒ 80.169. 99.1
Hosts on Subnet 12: 80.169.99.2, 80.169.99.3 …

Router 9 on Subnet 13: 01010000 10101001 011000|11 01|000001 ⇒ 80.169. 99.65
Hosts on Subnet 13: 80.169.99.66, 80.169.99.67 …

Router 6 on Subnet 14: 01010000 10101001 011000|11 10|000001 ⇒ 80.169.99.129
Router 7 on Subnet 14: 01010000 10101001 011000|11 10|000010 ⇒ 80.169.99.130
Router 8 on Subnet 14: 01010000 10101001 011000|11 10|000011 ⇒ 80.169. 99.131
Router 9 on Subnet 14: 01010000 10101001 011000|11 10|000100 ⇒ 80.169. 99.132

2.3 - Improved Design (VLSM)

In this last section, the information contained in the following website will be used: https://www.computernetworkingnotes.com/ccna-study-guide/vlsm-subnetting-explained-with-examples.html

First, the subnets, the number of hosts and the subnet masks necessary for each one have been listed in Table 1:

N	Subnet Name	Hosts	Subnet Mask
1	Sales	20	255.255.255.224
2	WAN link 1	2	255.255.255.252
3	Maintenance	10	255.255.255.240
4	Support	10	255.255.255.240
5	Production	40	255.255.255.192
6	Backbone 1	4	255.255.255.248
7	WAN link 2	2	255.255.255.252
8	Accounts 1	30	255.255.255.192
9	Accounts 2	30	255.255.255.192
10	Accounts 3	30	255.255.255.192
11	Accounts 4	25	255.255.255.192
12	Marketing	45	255.255.255.192
13	HR	12	255.255.255.240
14	Backbone 2	4	255.255.255.248

Table 1

The aforementioned table has been ordered in descending order in Table 2:

N	Subnet Name	Hosts	Subnet Mask
1	Marketing	45	255.255.255.192
2	Production	40	255.255.255.192
3	Accounts 1	30	255.255.255.224
4	Accounts 2	30	255.255.255.224
5	Accounts 3	30	255.255.255.224
6	Accounts 4	25	255.255.255.224
7	Sales	20	255.255.255.224
8	HR	12	255.255.255.240
9	Maintenance	10	255.255.255.240
10	Support	10	255.255.255.240
11	Backbone 1	4	255.255.255.248
12	Backbone 2	4	255.255.255.248
13	WAN link 1	2	255.255.255.252
14	WAN link 2	2	255.255.255.252

Table 2

2.3.1 - Subnet Addresses

Using the collected data, the subnet addresses were assigned:

Marketing address:	01010000	10101001	01100000	00|000000	80.169.96.0
Production address:	01010000	10101001	01100000	01|000000	80.169.96.64
Accounts 1 address:	01010000	10101001	01100000	100|00000	80.169.96.128
Accounts 2 address:	01010000	10101001	01100000	101|00000	80.169.96.160
Accounts 3 address:	01010000	10101001	01100000	110|00000	80.169.96.192
Accounts 4 address:	01010000	10101001	01100000	111|00000	80.169.96.224
Sales address:	01010000	10101001	01100001	000|00000	80.169.97.0
HR address:	01010000	10101001	01100001	0010|0000	80.169.97.32
Maintenance address:	01010000	10101001	01100001	0011|0000	80.169.97.48
Support address:	01010000	10101001	01100001	0100|0000	80.169.97.64
Backbone 1 address:	01010000	10101001	01100001	01010|000	80.169.97.80
Backbone 2 address:	01010000	10101001	01100001	01011|000	80.169.97.88
WAN link 1 address:	01010000	10101001	01100001	011000|00	80.169.97.96
WAN link 2 address:	01010000	10101001	01100001	011001|00	80.169.97.100

2.3.2 - Host Addresses

Finally, the following tables describe the relevant characteristics of each subnet, including the first and last host addresses as examples:

Segment 1	Marketing
Requirement	45
Subnet mask	255.255.255.192
Network ID	80.169.96.0
First hosts	80.169.96.1
Last hosts	80.169.96.62
Broadcast ID	80.169.96.63

Segment 2	Production
Requirement	40
Subnet mask	255.255.255.192
Network ID	80.169.96.64
First hosts	80.169.96.65
Last hosts	80.169.96.126
Broadcast ID	80.169.96.127

Segment 3	Account 1
Requirement	30
Subnet mask	255.255.255.224
Network ID	80.169.96.128
First hosts	80.169.96.129
Last hosts	80.169.96.158
Broadcast ID	80.169.96.159

Segment 4	Accounts 2
Requirement	30
Subnet mask	255.255.255.224
Network ID	80.169.96.160
First hosts	80.169.96.161
Last hosts	80.169.96.190
Broadcast ID	80.169.96.191

Segment 5	Accounts 3
Requirement	30
Subnet mask	255.255.255.224
Network ID	80.169.96.192
First hosts	80.169.96.193
Last hosts	80.169.96.222
Broadcast ID	80.169.96.223

Segment 6	Accounts 4
Requirement	25
Subnet mask	255.255.255.224
Network ID	80.169.96.224
First hosts	80.169.96.225
Last hosts	80.169.96.254
Broadcast ID	80.169.96.255

Segment 7	Sales
Requirement	20
Subnet mask	255.255.255.224
Network ID	80.169.97.0
First hosts	80.169.97.1
Last hosts	80.169.97.30
Broadcast ID	80.169.97.31

Segment 8	HR
Requirement	12
Subnet mask	255.255.255.240
Network ID	80.169.97.32
First hosts	80.169.97.33
Last hosts	80.169.97.46
Broadcast ID	80.169.97.47

Segment 9	Maintenance
Requirement	10
Subnet mask	255.255.255.240
Network ID	80.169.97.48
First hosts	80.169.97.49
Last hosts	80.169.97.62
Broadcast ID	80.169.97.63

Segment 10	Support
Requirement	10
Subnet mask	255.255.255.240
Network ID	80.169.97.64
First hosts	80.169.97.65
Last hosts	80.169.97.78
Broadcast ID	80.169.97.79

Segment 11	Backbone 1
Requirement	4
Subnet mask	255.255.255.248
Network ID	80.169.97.80
First hosts	80.169.97.81
Last hosts	80.169.97.86
Broadcast ID	80.169.97.87

Segment 12	Backbone 2
Requirement	4
Subnet mask	255.255.255.248
Network ID	80.169.97.88
First hosts	80.169.97.89
Last hosts	80.169.97.94
Broadcast ID	80.169.97.95

Segment 13	WAN link 1
Requirement	2
Subnet mask	255.255.255.252
Network ID	80.169.97.96
First hosts	80.169.97.97
Last hosts	80.169.97.98
Broadcast ID	80.169.97.99

Segment 14	WAN link 2
Requirement	2
Subnet mask	255.255.255.252
Network ID	80.169.97.100
First hosts	80.169.97.101
Last hosts	80.169.97.102
Broadcast ID	80.169.97.103

08/01/2019 author's note: The central server was **not** considered in this report because it was **not** present in the physical design contained in the specification. Adding it now as a subnet would mean having to change all images and IP addresses. Therefore, we could simply assume that the server is one of the hosts contained in the Providence workgroups: doing so the addressing scheme should remain unchanged.