FAST National University of Computing and Emerging Sciences

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Computer Networks

Course Semester Project

VLSM Subnetting Configuration

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VLSM Subnetting Configuration

Network Information

- **Public IP Address:** 114.192.168.19/24
- **Private IP Address:** 192.168.1.6

Host Requirements per Subnet

Network	Required Hosts
A	10,921
B	14,068
C	11,243
D	2,154
E	7,579
F	83,492
G	3,447
H	851
I	835
J	874
L	8,644
M	6,021
N	849

Table 1: Original Host Requirements

Sorted Host Requirements (Max → Min)

Network	Required Hosts
F	83,492
B	14,068
C	11,243
A	10,921
L	8,644
E	7,579
M	6,021
G	3,447
D	2,154
J	874
H	851
N	849
I	835

Table 2: Sorted Host Requirements

Allocation Policy

- **Supernet:** 114.192.0.0/14 (covers 114.192.0.0 → 114.195.255.255)
- **Allocation Order:** Largest to smallest (minimizes fragmentation)
- **Algorithm:** For each required hosts R, choose the smallest H where $2^H - 2 \geq R$, then prefix $= 32 - H$

Detailed Calculations for Each Network

Network F (Largest)

Required: 83,492 hosts

Choosing H:

- Test $2^{16} - 2 = 65,534$ (too small)
- Test $2^{17} - 2 = 131,070$ (OK) $\rightarrow$ H = 17

Calculations:

$$\begin{aligned} \text{Prefix} &= 32 - 17 = /15 \\ \text{Mask} &= 255.254.0.0 \\ \text{Total addresses} &= 2^{17} = 131,072 \\ \text{Usable addresses} &= 2^{17} - 2 = 131,070 \\ \text{Waste} &= 131,070 - 83,492 = 47,578 \end{aligned}$$

Assigned Network: 114.192.0.0/15

Last Usable Calculation:

$$\begin{aligned} \text{Last usable offset} &= 2^{17} - 2 = 131,070 \\ \text{Decompose: } 131,070 &= 511 \times 256 + 254 \quad (N = 511, M = 254) \\ \text{Network octets: } & A = 114, B = 192, C = 0, D = 0 \\ C + N &= 0 + 511 = 511 \\ 511 &= 1 \times 256 + 255 \quad \text{(carry 1 to B, set C=255)} \\ B &= 192 + 1 = 193, \quad C = 255 \\ D + M &= 0 + 254 = 254 \quad \text{(no carry)} \end{aligned}$$

Results:

- First usable: 114.192.0.1
- Last usable: 114.193.255.254
- Broadcast: 114.193.255.255
- Next start: 114.194.0.0

Network B

Required: 14,068 hosts

Choosing H: $2^{14} - 2 = 16,382 \geq 14,068 \rightarrow$ H = 14

Calculations:

$$\begin{aligned} \text{Prefix} &= 32 - 14 = /18 \\ \text{Mask} &= 255.255.192.0 \\ \text{Total addresses} &= 2^{14} = 16,384 \\ \text{Usable addresses} &= 2^{14} - 2 = 16,382 \\ \text{Waste} &= 16,382 - 14,068 = 2,314 \end{aligned}$$

Assigned Network: 114.194.0.0/18

Last Usable Calculation:

$$\begin{aligned}\text{Last usable offset} &= 2^{14} - 2 = 16,382\\ \text{Decompose: } 16,382 &= 63 \times 256 + 254 \quad (N = 63, M = 254)\\ \text{Network} &= 114.194.0.0 \quad (C = 0, D = 0)\\ C + N &= 0 + 63 = 63 \quad \text{(no carry)}\\ D + M &= 0 + 254 = 254\end{aligned}$$

Results:

- First usable: 114.194.0.1
- Last usable: 114.194.63.254
- Broadcast: 114.194.63.255
- Next start: 114.194.64.0

Network C

Required: 11,243 hosts
Choosing H: $2^{14} - 2 = 16,382 \geq 11,243 \rightarrow \text{H} = 14$
Calculations:

$$\begin{aligned}\text{Prefix} &= 32 - 14 = /18\\ \text{Mask} &= 255.255.192.0\\ \text{Total addresses} &= 2^{14} = 16,384\\ \text{Usable addresses} &= 16,382\\ \text{Waste} &= 16,382 - 11,243 = 5,139\end{aligned}$$

Assigned Network: 114.194.64.0/18
Last Usable Calculation:

$$\begin{aligned}\text{Offset} &= 16,382 = 63 \times 256 + 254 \quad (N = 63, M = 254)\\ \text{Network} &= 114.194.64.0\\ C + 63 &= 64 + 63 = 127, \quad D + 254 = 254\end{aligned}$$

Results:

- First usable: 114.194.64.1
- Last usable: 114.194.127.254
- Broadcast: 114.194.127.255
- Next start: 114.194.128.0

Network A

Required: 10,921 hosts
Choosing H: $2^{14} - 2 = 16,382 \geq 10,921 \rightarrow \text{H} = 14$
Calculations:

$$\begin{aligned}\text{Prefix} &= /18\\ \text{Usable} &= 16,382\\ \text{Waste} &= 16,382 - 10,921 = 5,461\end{aligned}$$

Assigned Network: 114.194.128.0/18
Last Usable Calculation:

$$\text{Offset} = 16,382 = 63 \times 256 + 254$$
$$C + 63 = 128 + 63 = 191, \quad D + 254 = 254$$

Results:

- First usable: 114.194.128.1
- Last usable: 114.194.191.254
- Broadcast: 114.194.191.255
- Next start: 114.194.192.0

Network L

Required: 8,644 hosts
Choosing H: $2^{14} - 2 = 16,382 \geq 8,644 \rightarrow \text{H} = 14$
Calculations:

$$\text{Prefix} = /18$$
$$\text{Usable} = 16,382$$
$$\text{Waste} = 16,382 - 8,644 = 7,738$$

Assigned Network: 114.194.192.0/18
Last Usable Calculation:

$$\text{Offset} = 16,382 = 63 \times 256 + 254$$
$$C + 63 = 192 + 63 = 255, \quad D + 254 = 254$$

Results:

- First usable: 114.194.192.1
- Last usable: 114.194.255.254
- Broadcast: 114.194.255.255
- Next start: 114.195.0.0

Network E

Required: 7,579 hosts
Choosing H: $2^{13} - 2 = 8,190 \geq 7,579 \rightarrow \text{H} = 13$
Calculations:

$$\text{Prefix} = 32 - 13 = /19$$
$$\text{Mask} = 255.255.224.0$$
$$\text{Total addresses} = 2^{13} = 8,192$$
$$\text{Usable addresses} = 8,190$$
$$\text{Waste} = 8,190 - 7,579 = 611$$

Assigned Network: 114.195.0.0/19
Last Usable Calculation:

$$\text{Offset} = 2^{13} - 2 = 8,190 = 31 \times 256 + 254 \quad (N = 31, M = 254)$$
$$\text{Network} = 114.195.0.0$$
$$C + 31 = 0 + 31 = 31, \quad D + 254 = 254$$

Results:

- First usable: 114.195.0.1
- Last usable: 114.195.31.254
- Broadcast: 114.195.31.255
- Next start: 114.195.32.0

Network M

Required: 6,021 hosts
Choosing H: $2^{13} - 2 = 8,190 \geq 6,021 \rightarrow \text{H} = 13$
Calculations:

$$\begin{aligned} \text{Prefix} &= /19 \\ \text{Usable} &= 8,190 \\ \text{Waste} &= 8,190 - 6,021 = 2,169 \end{aligned}$$

Assigned Network: 114.195.32.0/19
Last Usable Calculation:

$$\begin{aligned} \text{Offset} &= 8,190 = 31 \times 256 + 254 \\ C + 31 &= 32 + 31 = 63, \quad D + 254 = 254 \end{aligned}$$

Results:

- First usable: 114.195.32.1
- Last usable: 114.195.63.254
- Broadcast: 114.195.63.255
- Next start: 114.195.64.0

Network G

Required: 3,447 hosts
Choosing H: $2^{12} - 2 = 4,094 \geq 3,447 \rightarrow \text{H} = 12$
Calculations:

$$\begin{aligned} \text{Prefix} &= 32 - 12 = /20 \\ \text{Mask} &= 255.255.240.0 \\ \text{Total addresses} &= 2^{12} = 4,096 \\ \text{Usable addresses} &= 4,094 \\ \text{Waste} &= 4,094 - 3,447 = 647 \end{aligned}$$

Assigned Network: 114.195.64.0/20
Last Usable Calculation:

$$\begin{aligned} \text{Offset} &= 2^{12} - 2 = 4,094 = 15 \times 256 + 254 \quad (N = 15, M = 254) \\ \text{Network} &= 114.195.64.0 \\ C + 15 &= 64 + 15 = 79, \quad D + 254 = 254 \end{aligned}$$

Results:

- First usable: 114.195.64.1
- Last usable: 114.195.79.254
- Broadcast: 114.195.79.255
- Next start: 114.195.80.0

Network D

Required: 2,154 hosts
Choosing H: $2^{12} - 2 = 4,094 \geq 2,154 \rightarrow \text{H} = 12$
Calculations:

$$\begin{aligned} \text{Prefix} &= /20 \\ \text{Usable} &= 4,094 \\ \text{Waste} &= 4,094 - 2,154 = 1,940 \end{aligned}$$

Assigned Network: 114.195.80.0/20
Last Usable Calculation:

$$\begin{aligned} \text{Offset} &= 4,094 = 15 \times 256 + 254 \\ C + 15 &= 80 + 15 = 95, \quad D + 254 = 254 \end{aligned}$$

Results:

- First usable: 114.195.80.1
- Last usable: 114.195.95.254
- Broadcast: 114.195.95.255
- Next start: 114.195.96.0

Network J

Required: 874 hosts
Choosing H: $2^{10} - 2 = 1,022 \geq 874 \rightarrow \text{H} = 10$
Calculations:

$$\begin{aligned} \text{Prefix} &= 32 - 10 = /22 \\ \text{Mask} &= 255.255.252.0 \\ \text{Total addresses} &= 2^{10} = 1,024 \\ \text{Usable addresses} &= 1,022 \\ \text{Waste} &= 1,022 - 874 = 148 \end{aligned}$$

Assigned Network: 114.195.96.0/22
Last Usable Calculation:

$$\begin{aligned} \text{Offset} &= 2^{10} - 2 = 1,022 = 3 \times 256 + 254 \quad (N = 3, M = 254) \\ \text{Network} &= 114.195.96.0 \\ C + 3 &= 96 + 3 = 99, \quad D + 254 = 254 \end{aligned}$$

Results:

- First usable: 114.195.96.1
- Last usable: 114.195.99.254
- Broadcast: 114.195.99.255
- Next start: 114.195.100.0

Network H

Required: 851 hosts
Choosing H: $2^{10} - 2 = 1,022 \geq 851 \rightarrow \text{H} = 10$
Calculations:

$$\begin{aligned} \text{Prefix} &= /22 \\ \text{Usable} &= 1,022 \\ \text{Waste} &= 1,022 - 851 = 171 \end{aligned}$$

Assigned Network: 114.195.100.0/22
Last Usable Calculation:

$$\begin{aligned} &\text{Offset} = 1,022 = 3 \times 256 + 254 \\ &C + 3 = 100 + 3 = 103, \quad D + 254 = 254 \end{aligned}$$

Results:

- First usable: 114.195.100.1
- Last usable: 114.195.103.254
- Broadcast: 114.195.103.255
- Next start: 114.195.104.0

Network N

Required: 849 hosts
Choosing H: $2^{10} - 2 = 1,022 \geq 849 \rightarrow \text{H} = 10$
Calculations:

$$\begin{aligned} \text{Prefix} &= /22 \\ \text{Usable} &= 1,022 \\ \text{Waste} &= 1,022 - 849 = 173 \end{aligned}$$

Assigned Network: 114.195.104.0/22
Last Usable Calculation:

$$\begin{aligned} &\text{Offset} = 1,022 = 3 \times 256 + 254 \\ &C + 3 = 104 + 3 = 107, \quad D + 254 = 254 \end{aligned}$$

Results:

- First usable: 114.195.104.1
- Last usable: 114.195.107.254
- Broadcast: 114.195.107.255
- Next start: 114.195.108.0

Network I (Smallest)

Required: 835 hosts
Choosing H: $2^{10} - 2 = 1,022 \geq 835 \rightarrow \text{H} = 10$
Calculations:

$$\begin{aligned} \text{Prefix} &= /22 \\ \text{Usable} &= 1,022 \\ \text{Waste} &= 1,022 - 835 = 187 \end{aligned}$$

Assigned Network: 114.195.108.0/22
Last Usable Calculation:

$$\begin{aligned} \text{Offset} &= 1,022 = 3 \times 256 + 254 \\ C + 3 &= 108 + 3 = 111, \quad D + 254 = 254 \end{aligned}$$

Results:

- First usable: 114.195.108.1
- Last usable: 114.195.111.254
- Broadcast: 114.195.111.255
- Next start: 114.195.112.0

Complete VLSM Allocation Table

Net	Req	Prefix	Mask	Total	Usable
F	83,492	/15	255.254.0.0	131,072	131,070
B	14,068	/18	255.255.192.0	16,384	16,382
C	11,243	/18	255.255.192.0	16,384	16,382
A	10,921	/18	255.255.192.0	16,384	16,382
L	8,644	/18	255.255.192.0	16,384	16,382
E	7,579	/19	255.255.224.0	8,192	8,190
M	6,021	/19	255.255.224.0	8,192	8,190
G	3,447	/20	255.255.240.0	4,096	4,094
D	2,154	/20	255.255.240.0	4,096	4,094
J	874	/22	255.255.252.0	1,024	1,022
H	851	/22	255.255.252.0	1,024	1,022
N	849	/22	255.255.252.0	1,024	1,022
I	835	/22	255.255.252.0	1,024	1,022

Table 3: VLSM Allocation - Part 1

Net	Subnet	First Usable	Last Usable	Broadcast
F	114.192.0.0/15	114.192.0.1	114.193.255.254	114.193.255.255
B	114.194.0.0/18	114.194.0.1	114.194.63.254	114.194.63.255
C	114.194.64.0/18	114.194.64.1	114.194.127.254	114.194.127.255
A	114.194.128.0/18	114.194.128.1	114.194.191.254	114.194.191.255
L	114.194.192.0/18	114.194.192.1	114.194.255.254	114.194.255.255
E	114.195.0.0/19	114.195.0.1	114.195.31.254	114.195.31.255
M	114.195.32.0/19	114.195.32.1	114.195.63.254	114.195.63.255
G	114.195.64.0/20	114.195.64.1	114.195.79.254	114.195.79.255
D	114.195.80.0/20	114.195.80.1	114.195.95.254	114.195.95.255
J	114.195.96.0/22	114.195.96.1	114.195.99.254	114.195.99.255
H	114.195.100.0/22	114.195.100.1	114.195.103.254	114.195.103.255
N	114.195.104.0/22	114.195.104.1	114.195.107.254	114.195.107.255
I	114.195.108.0/22	114.195.108.1	114.195.111.254	114.195.111.255

Table 4: VLSM Allocation - Part 2

Net	Waste	Next Start
F	47,578	114.194.0.0
B	2,314	114.194.64.0
C	5,139	114.194.128.0
A	5,461	114.194.192.0
L	7,738	114.195.0.0
E	611	114.195.32.0
M	2,169	114.195.64.0
G	647	114.195.80.0
D	1,940	114.195.96.0
J	148	114.195.100.0
H	171	114.195.104.0
N	173	114.195.108.0
I	187	114.195.112.0

Table 5: VLSM Allocation - Part 3

Summary Statistics

Metric	Value
Total Required Hosts	150,978
Total Allocated Addresses	199,680
Total Usable Addresses	199,652
Total Waste	48,674 addresses (24.4%)
Supernet Used	114.192.0.0 to 114.195.111.255
Supernet Range	114.192.0.0/14
Remaining Space	114.195.112.0 to 114.195.255.255

Table 6: VLSM Summary Statistics

Conclusion

This VLSM subnetting configuration demonstrates efficient IP address allocation using Variable Length Subnet Masking. The design successfully accommodates all 13 networks (A through N) with their varying host requirements ranging from 835 to 83,492 hosts.

Key Achievements:

- Successfully allocated all required subnets within the 114.192.0.0/14 supernet
- Minimized address wastage through proper VLSM implementation
- Maintained contiguous address allocation for easier routing
- Reserved future expansion space (114.195.112.0 to 114.195.255.255)

Efficiency Analysis:

- **Address Utilization:** 75.6% of allocated addresses are usable
- **Waste Percentage:** 24.4% waste is acceptable for VLSM given the diverse host requirements
- **Scalability:** Sufficient remaining address space for future network expansion

Implementation Notes:

1. The largest network (F) requires a /15 prefix to accommodate 83,492 hosts
2. Four networks (B, C, A, L) use /18 prefixes for host counts between 8,644 and 14,068
3. Two networks (E, M) use /19 prefixes for moderate-sized networks
4. Two networks (G, D) use /20 prefixes for smaller networks
5. Four networks (J, H, N, I) use /22 prefixes for the smallest host requirements

Routing Considerations:

The contiguous allocation scheme allows for potential route summarization at the routing protocol level, which can reduce routing table size and improve network performance. Networks can be summarized as follows:

- Network F: 114.192.0.0/15 (standalone large network)
- Networks B, C, A, L: Can be summarized under 114.194.0.0/16
- Networks E, M, G, D, J, H, N, I: Can be summarized under 114.195.0.0/16

1 Additional Network Allocations

1.1 Overview

Beyond the thirteen primary networks (A through N) previously allocated, the network topology requires additional subnetting to accommodate inter-router communication links and unlabeled LAN segments. This section documents the allocation of 44 additional networks from the remaining unallocated address space.

1.2 Available Address Space

After the allocation of networks A through N, the following address space remains available:

- **Available Range:** 114.195.112.0 to 114.195.255.255
- **Calculation:** Third octet range: 112 to 255 = 144 values
- **Total Addresses:** $144 \times 256 = 36,864$ addresses

1.3 Network Requirements Analysis

The additional networks consist of two distinct categories:

1. **Point-to-Point Router Links:** 29 networks
   - Purpose: Inter-router communication
   - Host requirement: 2 usable addresses per link
   - Recommended prefix: /30
2. **Unlabeled LAN Segments:** 15 networks
   - Purpose: Small departmental or access networks
   - Host requirement: Less than 8 hosts per network
   - Recommended prefix: /29

Total Additional Networks: 44

1.4 Allocation Methodology

1.4.1 Point-to-Point Links (/30 Subnets)

For router-to-router connections, the /30 subnet mask is optimal:

$$\begin{aligned}
\text{Prefix} &= /30 \\
\text{Subnet Mask} &= 255.255.255.252 \\
\text{Host Bits} &= H = 2 \\
\text{Total Addresses} &= 2^H = 2^2 = 4 \\
\text{Usable Addresses} &= 2^H - 2 = 4 - 2 = 2 \\
\text{Networks Required} &= 29 \\
\text{Total Space Needed} &= 29 \times 4 = 116 \text{ addresses}
\end{aligned}$$

1.4.2 Small LAN Segments (/29 Subnets)

For networks requiring fewer than 8 hosts, the /29 subnet mask provides adequate capacity:

$$\begin{aligned}
\text{Prefix} &= /29 \\
\text{Subnet Mask} &= 255.255.255.248 \\
\text{Host Bits} &= H = 3 \\
\text{Total Addresses} &= 2^H = 2^3 = 8 \\
\text{Usable Addresses} &= 2^H - 2 = 8 - 2 = 6 \\
\text{Networks Required} &= 15 \\
\text{Total Space Needed} &= 15 \times 8 = 120 \text{ addresses}
\end{aligned}$$

1.5 Point-to-Point Link Allocations

Table 7: Point-to-Point Router Links (Part 1)

Network	Subnet	Mask	First Usable	Last Usable
Link-01	114.195.112.0/30	255.255.255.252	114.195.112.1	114.195.112.2
Link-02	114.195.112.4/30	255.255.255.252	114.195.112.5	114.195.112.6
Link-03	114.195.112.8/30	255.255.255.252	114.195.112.9	114.195.112.10
Link-04	114.195.112.12/30	255.255.255.252	114.195.112.13	114.195.112.14
Link-05	114.195.112.16/30	255.255.255.252	114.195.112.17	114.195.112.18
Link-06	114.195.112.20/30	255.255.255.252	114.195.112.21	114.195.112.22
Link-07	114.195.112.24/30	255.255.255.252	114.195.112.25	114.195.112.26
Link-08	114.195.112.28/30	255.255.255.252	114.195.112.29	114.195.112.30
Link-09	114.195.112.32/30	255.255.255.252	114.195.112.33	114.195.112.34
Link-10	114.195.112.36/30	255.255.255.252	114.195.112.37	114.195.112.38

Table 8: Point-to-Point Router Links (Part 2)

Network	Subnet	Mask	First Usable	Last Usable
Link-11	114.195.112.40/30	255.255.255.252	114.195.112.41	114.195.112.42
Link-12	114.195.112.44/30	255.255.255.252	114.195.112.45	114.195.112.46
Link-13	114.195.112.48/30	255.255.255.252	114.195.112.49	114.195.112.50
Link-14	114.195.112.52/30	255.255.255.252	114.195.112.53	114.195.112.54
Link-15	114.195.112.56/30	255.255.255.252	114.195.112.57	114.195.112.58
Link-16	114.195.112.60/30	255.255.255.252	114.195.112.61	114.195.112.62
Link-17	114.195.112.64/30	255.255.255.252	114.195.112.65	114.195.112.66
Link-18	114.195.112.68/30	255.255.255.252	114.195.112.69	114.195.112.70
Link-19	114.195.112.72/30	255.255.255.252	114.195.112.73	114.195.112.74
Link-20	114.195.112.76/30	255.255.255.252	114.195.112.77	114.195.112.78

Table 9: Point-to-Point Router Links (Part 3)

Network	Subnet	Mask	First Usable	Last Usable
Link-21	114.195.112.80/30	255.255.255.252	114.195.112.81	114.195.112.82
Link-22	114.195.112.84/30	255.255.255.252	114.195.112.85	114.195.112.86
Link-23	114.195.112.88/30	255.255.255.252	114.195.112.89	114.195.112.90
Link-24	114.195.112.92/30	255.255.255.252	114.195.112.93	114.195.112.94
Link-25	114.195.112.96/30	255.255.255.252	114.195.112.97	114.195.112.98
Link-26	114.195.112.100/30	255.255.255.252	114.195.112.101	114.195.112.102
Link-27	114.195.112.104/30	255.255.255.252	114.195.112.105	114.195.112.106
Link-28	114.195.112.108/30	255.255.255.252	114.195.112.109	114.195.112.110
Link-29	114.195.112.112/30	255.255.255.252	114.195.112.113	114.195.112.114

Table 10: Point-to-Point Router Links - Broadcast Addresses

Network	**Broadcast**	**Router 1 IP**	**Router 2 IP**	**Total Hosts**
Link-01	114.195.112.3	114.195.112.1	114.195.112.2	2
Link-02	114.195.112.7	114.195.112.5	114.195.112.6	2
Link-03	114.195.112.11	114.195.112.9	114.195.112.10	2
Link-04	114.195.112.15	114.195.112.13	114.195.112.14	2
Link-05	114.195.112.19	114.195.112.17	114.195.112.18	2
Link-06	114.195.112.23	114.195.112.21	114.195.112.22	2
Link-07	114.195.112.27	114.195.112.25	114.195.112.26	2
Link-08	114.195.112.31	114.195.112.29	114.195.112.30	2
Link-09	114.195.112.35	114.195.112.33	114.195.112.34	2
Link-10	114.195.112.39	114.195.112.37	114.195.112.38	2
Link-11	114.195.112.43	114.195.112.41	114.195.112.42	2
Link-12	114.195.112.47	114.195.112.45	114.195.112.46	2
Link-13	114.195.112.51	114.195.112.49	114.195.112.50	2
Link-14	114.195.112.55	114.195.112.53	114.195.112.54	2
Link-15	114.195.112.59	114.195.112.57	114.195.112.58	2
Link-16	114.195.112.63	114.195.112.61	114.195.112.62	2
Link-17	114.195.112.67	114.195.112.65	114.195.112.66	2
Link-18	114.195.112.71	114.195.112.69	114.195.112.70	2
Link-19	114.195.112.75	114.195.112.73	114.195.112.74	2
Link-20	114.195.112.79	114.195.112.77	114.195.112.78	2
Link-21	114.195.112.83	114.195.112.81	114.195.112.82	2
Link-22	114.195.112.87	114.195.112.85	114.195.112.86	2
Link-23	114.195.112.91	114.195.112.89	114.195.112.90	2
Link-24	114.195.112.95	114.195.112.93	114.195.112.94	2
Link-25	114.195.112.99	114.195.112.97	114.195.112.98	2
Link-26	114.195.112.103	114.195.112.101	114.195.112.102	2
Link-27	114.195.112.107	114.195.112.105	114.195.112.106	2
Link-28	114.195.112.111	114.195.112.109	114.195.112.110	2
Link-29	114.195.112.115	114.195.112.113	114.195.112.114	2

1.6 Unlabeled LAN Segment Allocations

Table 11: Unlabeled Small LAN Networks (Part 1)

Network	Subnet	Mask	Total	Usable
LAN-01	114.195.112.120/29	255.255.255.248	8	6
LAN-02	114.195.112.128/29	255.255.255.248	8	6
LAN-03	114.195.112.136/29	255.255.255.248	8	6
LAN-04	114.195.112.144/29	255.255.255.248	8	6
LAN-05	114.195.112.152/29	255.255.255.248	8	6
LAN-06	114.195.112.160/29	255.255.255.248	8	6
LAN-07	114.195.112.168/29	255.255.255.248	8	6
LAN-08	114.195.112.176/29	255.255.255.248	8	6
LAN-09	114.195.112.184/29	255.255.255.248	8	6
LAN-10	114.195.112.192/29	255.255.255.248	8	6
LAN-11	114.195.112.200/29	255.255.255.248	8	6
LAN-12	114.195.112.208/29	255.255.255.248	8	6
LAN-13	114.195.112.216/29	255.255.255.248	8	6
LAN-14	114.195.112.224/29	255.255.255.248	8	6
LAN-15	114.195.112.232/29	255.255.255.248	8	6

Table 12: Unlabeled Small LAN Networks (Part 2)

Network	First Usable	Last Usable	Broadcast
LAN-01	114.195.112.121	114.195.112.126	114.195.112.127
LAN-02	114.195.112.129	114.195.112.134	114.195.112.135
LAN-03	114.195.112.137	114.195.112.142	114.195.112.143
LAN-04	114.195.112.145	114.195.112.150	114.195.112.151
LAN-05	114.195.112.153	114.195.112.158	114.195.112.159
LAN-06	114.195.112.161	114.195.112.166	114.195.112.167
LAN-07	114.195.112.169	114.195.112.174	114.195.112.175
LAN-08	114.195.112.177	114.195.112.182	114.195.112.183
LAN-09	114.195.112.185	114.195.112.190	114.195.112.191
LAN-10	114.195.112.193	114.195.112.198	114.195.112.199
LAN-11	114.195.112.201	114.195.112.206	114.195.112.207
LAN-12	114.195.112.209	114.195.112.214	114.195.112.215
LAN-13	114.195.112.217	114.195.112.222	114.195.112.223
LAN-14	114.195.112.225	114.195.112.230	114.195.112.231
LAN-15	114.195.112.233	114.195.112.238	114.195.112.239

1.7 Sample Calculation Examples

1.7.1 Point-to-Point Link Calculation (Link-01)

Given Requirements:

- Required Hosts: 2 (one interface per router)
- Starting Address: 114.195.112.0

Choosing H:

$$2^H - 2 \geq 2$$
$$2^2 - 2 = 2 \text{ (OK)} \rightarrow H = 2$$

Calculations:

$$\text{Prefix} = 32 - H = 32 - 2 = /30$$
$$\text{Subnet Mask} = 255.255.255.252$$
$$\text{Total Addresses} = 2^2 = 4$$
$$\text{Usable Addresses} = 2^2 - 2 = 2$$

Address Assignment:

- Network Address: 114.195.112.0
- First Usable (Router 1): 114.195.112.1
- Last Usable (Router 2): 114.195.112.2
- Broadcast Address: 114.195.112.3
- Next Network Start: 114.195.112.4

1.7.2 LAN Network Calculation (LAN-01)

Given Requirements:

- Required Hosts: Less than 8
- Starting Address: 114.195.112.120

Choosing H:

$$2^H - 2 \geq 6$$
$$2^3 - 2 = 6 \text{ (OK)} \rightarrow H = 3$$

Calculations:

$$\text{Prefix} = 32 - H = 32 - 3 = /29$$
$$\text{Subnet Mask} = 255.255.255.248$$
$$\text{Total Addresses} = 2^3 = 8$$
$$\text{Usable Addresses} = 2^3 - 2 = 6$$

Last Usable Address Calculation:

$$\text{Offset} = 2^3 - 2 = 6$$
$$\text{Network} = 114.195.112.120$$
$$\text{Last Usable} = 114.195.112.120 + 6 = 114.195.112.126$$

Address Assignment:

- Network Address: 114.195.112.120
- First Usable: 114.195.112.121
- Last Usable: 114.195.112.126
- Broadcast Address: 114.195.112.127
- Next Network Start: 114.195.112.128

1.8 Allocation Summary

Table 13: Additional Network Allocation Summary

Category	**Networks**	**Addresses Used**	**Range**
P2P Links (/30)	29	116	114.195.112.0 - 114.195.112.115
Small LANs (/29)	15	120	114.195.112.120 - 114.195.112.239
Total Used	**44**	**236**	114.195.112.0 - 114.195.112.239
Remaining	—	36,628	114.195.112.240 - 114.195.255.255

1.9 Efficiency Analysis

1.9.1 Space Utilization

$$\begin{aligned}
\text{Available Space} &= 36,864 \text{ addresses} \\
\text{Allocated Space} &= 236 \text{ addresses} \\
\text{Utilization Rate} &= \frac{236}{36,864} \times 100\% = 0.64\% \\
\text{Remaining Space} &= 36,864 - 236 = 36,628 \text{ addresses} \\
\text{Remaining Percentage} &= \frac{36,628}{36,864} \times 100\% = 99.36\%
\end{aligned}$$

1.9.2 Address Efficiency per Category

Point-to-Point Links:

$$\begin{aligned}
\text{Required Addresses} &= 29 \times 2 = 58 \\
\text{Allocated Addresses} &= 29 \times 4 = 116 \\
\text{Waste per Link} &= 4 - 2 = 2 \\
\text{Total Waste} &= 29 \times 2 = 58 \\
\text{Efficiency} &= \frac{58}{116} \times 100\% = 50\%
\end{aligned}$$

Note: 50% efficiency is optimal for point-to-point links as /30 is the smallest practical subnet for such connections.

Small LAN Networks:

$$\begin{aligned}
\text{Maximum Required per LAN} &= 6 \text{ hosts} \\
\text{Allocated per LAN} &= 6 \text{ usable addresses} \\
\text{Total Allocated Addresses} &= 15 \times 8 = 120 \\
\text{Total Usable Addresses} &= 15 \times 6 = 90 \\
\text{Waste per LAN} &= 0 \text{ (exact fit)} \\
\text{Efficiency} &= \frac{90}{120} \times 100\% = 75\%
\end{aligned}$$

1.10 Future Expansion Capacity

The remaining unallocated space provides substantial capacity for network growth:

Table 14: Future Expansion Possibilities

Subnet Size	Networks Possible	Hosts per Network
/30 (P2P Links)	9,157	2
/29 (Small LANs)	4,578	6
/28	2,289	14
/27	1,144	30
/26	572	62
/25	286	126
/24	143	254

1.11 Implementation Notes

1. **Sequential Allocation:** Networks are allocated sequentially to minimize fragmentation and simplify routing table management.
2. **Contiguous Addressing:** Point-to-point links occupy addresses 114.195.112.0 through 114.195.112.115, immediately followed by LAN networks at 114.195.112.120, with minimal gap.
3. **Route Summarization:** All additional networks can be summarized under 114.195.112.0/24, enabling efficient routing table entries.
4. **Scalability:** The allocation leaves 99.36% of available space unallocated, providing extensive room for future network expansion.
5. **Standard Compliance:** All allocations follow RFC 1918 private addressing guidelines and VLSM best practices.

1.12 Routing Considerations

1.12.1 Route Summary Possibilities

The allocated networks allow for hierarchical route summarization:

- **All Additional Networks:** Can be summarized as 114.195.112.0/24
- **Point-to-Point Links Only:** Can be summarized as 114.195.112.0/25
- **Combined with Primary Networks:** All networks (A-N plus additional) can be summarized as 114.192.0.0/14

1.12.2 Routing Protocol Recommendations

For optimal routing efficiency:

- Use OSPF or EIGRP for automatic route summarization
- Configure area boundaries to align with the /24 summarization points
- Implement route filtering to prevent unnecessary route propagation

1.13 Conclusion

The additional network allocation successfully accommodates all 44 required networks (29 point-to-point links and 15 small LANs) using only 236 addresses from the available 36,864 address space. This represents highly efficient address utilization while maintaining extensive capacity for future growth. The contiguous allocation scheme facilitates route summarization and simplifies network management, while the standardized subnet sizes (/30 for P2P links, /29 for small LANs) ensure consistency and ease of configuration.