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Assignment Title 2: (i) Prepare R&D Document on IP Addressing and Subnetting including IPv4 & IPv6

#INTRODUCTION

IP addressing and subnetting are foundational concepts in computer networking. They allow devices to identify each other and efficiently route data across networks. Internet Protocol versions 4 (IPv4) and 6 (IPv6) are widely used for this purpose. While IPv4 has been the standard for decades, the exponential growth of the internet has led to the development and adoption of IPv6. This document explores the structure, types, and usage of IPv4 and IPv6 addresses, along with the concept and importance of subnetting.

#OBJECTIVE

- To understand the structure and purpose of IPv4 and IPv6 addressing.
- To learn about different types of IP addresses and their classifications.
- To explore subnetting and its role in network optimization.
- To compare IPv4 and IPv6 in terms of architecture and implementation.

#SCOPE

This research is limited to:

- The theoretical and practical understanding of IPv4 and IPv6.
- Address classification, subnetting, and CIDR.
- Tools and techniques for subnet calculation.
- Benefits and challenges of IPv6 adoption.

#METHODOLOGY

- Literature review of academic books and RFC documents.
- Use of IP subnet calculators and practical tools (like Cisco Packet Tracer).
- Comparative analysis between IPv4 and IPv6 features.
- Visualization using diagrams and examples.

Theory and Conceptual Understanding

IP Addressing

An IP (Internet Protocol) Address is a numerical label assigned to each device connected to a network using the Internet Protocol for communication.

IPv4 Addressing

Format:

- IPv4 is a 32-bit address.
- Written in dotted-decimal format: e.g., 192.168.1.1
- Divided into four octets (8 bits each).

Classes:

Class	Starting Bits	Address Range	Usage
A	0	1.0.0.0 – 126.255.255.255	Large networks
B	10	128.0.0.0 – 191.255.255.255	Medium networks
C	110	192.0.0.0 – 223.255.255.255	Small networks
D	1110	224.0.0.0 – 239.255.255.255	Multicasting
E	1111	240.0.0.0 – 255.255.255.255	Reserved

Types:

- Public IP: Globally routable (e.g., from ISP).
- Private IP: Used within LAN (e.g., 192.168.x.x, 10.x.x.x, 172.16.x.x – 172.31.x.x).
- Static IP: Manually assigned.
- Dynamic IP: Assigned via DHCP.

IPv6 Addressing

Format:

- IPv6 is a 128-bit address.
- Written in hexadecimal colon-separated format.
    - Example: 2001:0db8:85a3:0000:0000:8a2e:0370:7334
- Can be **abbreviated** using :: to replace consecutive zero fields.

Advantages:

- Vast address space (≈ 340 undecillion addresses).
- Improved routing and network autoconfiguration.
- Built-in security (IPsec).
- No need for NAT (Network Address Translation).

Subnetting

Subnetting is the process of dividing a larger network into smaller, manageable sub-networks (subnets). It improves network efficiency and enhances security.

IPv4 Subnetting Example:

- IP: 192.168.1.0
- Subnet mask: 255.255.255.0 → /24
- Total hosts per subnet: 2^(32 - 24) - 2 = 254

CIDR Notation:

- CIDR (Classless Inter-Domain Routing) notation is a method of representing IP addresses and their associated subnet masks using a slash (/) followed by the number of network bits (e.g., 192.168.1.0/24).
- Classless Inter-Domain Routing (CIDR) uses slash notation to define subnet masks.
- Example: /24 → 255.255.255.0.

Subnet Mask Conversion:

CIDR	Subnet Mask	# Hosts
/24	255.255.255.0	254
/25	255.255.255.128	126
/26	255.255.255.192	62

IPv6 Subnetting:

- Similar concept, but due to the large address space, typically assigned in /64 blocks.
- Example: 2001:db8:abcd::/64

#Analysis and Comparison

IPv4 vs IPv6

Feature	IPv4	IPv6
Address Length	32 bits	128 bits
Address Format	Decimal (e.g., 192.0.2.1)	Hexadecimal (e.g., 2001:db8::1)
Address Space	~4.3 billion	≈ 340 undecillion
Header Size	20 bytes	40 bytes
NAT Requirement	Required	Not required
Security	Optional (IPsec)	Mandatory support (IPsec)
Configuration	Manual/DHCP	Auto-configuration supported
Broadcast	Yes	No (uses multicast instead)

#APPLICATIONS

- IPv4: Still widely used in LANs, older systems, and most public internet infrastructure.
- IPv6: Used in modern networks, mobile devices, and global internet services for future scalability.
- Subnetting: Enterprise-level network segmentation, VLAN configurations, cloud architecture, firewall rules.

#LIMITATIONS

- IPv4: Limited address space, dependence on NAT, security concerns.
- IPv6: Complex to implement, slow global adoption, compatibility with older hardware.
- Subnetting: Can be error-prone if calculated manually; requires understanding of binary.

#FUTURE SCOPE

- Full global transition from IPv4 to IPv6.
- Improved tools and automation for subnetting in large-scale networks.
- Use of AI/ML in dynamic address allocation and routing optimization.

#CONCLUSION

IP addressing and subnetting are essential for the functioning and optimization of computer networks. IPv4 continues to serve reliably despite its limitations, while IPv6 presents a future-ready solution with a vast address space and better functionality. Understanding both, along with efficient subnetting, is vital for network engineers, administrators, and cybersecurity professionals.