# Week 10 Revision notes

# Week 10 - IPv6: Features, Benefits, and Transition Techniques

## 1. Introduction to IP Addressing and IPv4 Limitations

- **Core Functions of the Internet**:
  - **Addressing**: Assigns unique IP addresses to identify devices on a network.
  - **Naming**: Associates domain names with IP addresses for user-friendly navigation.
  - **Routing**: Directs packets across networks from source to destination.
- **IP Ownership**:
  - The Internet doesn't have a single owner; rather, it's managed by organizations like **IANA** (Internet Assigned Numbers Authority) and **Regional Internet Registries (RIRs)**.
- **IPv4 Address Exhaustion**:
  - IPv4 uses a 32-bit address format, which can represent around 4.3 billion addresses.
  - Due to increased internet use, IPv4 addresses have nearly been depleted, prompting the shift to IPv6.

## 2. Addressing Allocation: IANA and RIRs

- **IANA's Role**:
  - IANA oversees IP address allocation and delegates responsibilities to 5 regional registries (RIRs):
    - **AfriNIC**: Africa
    - **ARIN**: US, Canada, and parts of the Caribbean
    - **APNIC**: Asia-Pacific region
    - **LACNIC**: Latin America and Caribbean regions
    - **RIPE NCC**: Europe, Middle East, and Central Asia

## 3. Strategies for Addressing IPv4 Exhaustion

- **Reclamation of Unused IPs**:
  - Reassigning previously allocated but unused IP blocks.
- **Network Address Translation (NAT)**:

    - NAT allows multiple devices on a local network to share a single public IP address, conserving IP addresses.
    - **Private IP Ranges**: Defined ranges for local use only:
        - Class A: `10.0.0.0 – 10.255.255.255`
        - Class B: `172.16.0.0 – 172.31.255.255`
        - Class C: `192.168.0.0 – 192.168.255.255`
- **IPv6 Adoption**:
    - IPv6 was developed as a long-term solution to address exhaustion, with a vastly larger address space.

## 4. IPv6: Key Features and Enhancements

- **Address Length**:
    - IPv6 uses 128-bit addresses, supporting **340 undecillion (3.4 x 10^38)** unique addresses.
- **Auto-Configuration**:
    - IPv6 devices can configure their IP addresses without a DHCP server, using the **EUI-64** format derived from the MAC address.
- **Quality of Service (QoS)**:
    - IPv6 headers include fields for **Traffic Class** and **Flow Label** to prioritize real-time data (e.g., video streaming, VoIP).
- **Built-in Security**:
    - IPv6 incorporates **IPSec** (Internet Protocol Security) by default, allowing encryption and data integrity checks, unlike IPv4 where it's optional.

## 5. IPv4 vs. IPv6: Key Differences

| Attribute | IPv4 | IPv6 |
|---|---|---|
| **Address Length** | 32 bits | 128 bits |
| **Address Notation** | Dotted decimal (e.g., `192.168.0.1`) | Hexadecimal, colon-separated (e.g., `2001:0db8::1`) |
| **Total Address Space** | 4.3 billion addresses | 340 undecillion addresses |
| **Header Size** | Variable (20-60 bytes) | Fixed (40 bytes) |
| **Fragmentation** | Routers and senders | Only senders |
| **Security** | Optional (IPSec) | Mandatory (IPSec included) |
| **Checksum** | Required | Not used |

## 6. Compact IPv6 Notation

- **IPv6 Address Simplification**:
  - **Zero Compression**: Use `::` to replace consecutive zeros (only once per address).
  - **Leading Zeros**: Can be omitted within each 16-bit block.
  - **Example**:
    - Full: `1090:0000:0000:0000:0009:0900:210D:325F`
    - Compact: `1090::9:900:210D:325F`

## 7. IPv6 Network Prefix

- **Prefix Notation**:
  - IPv6 uses **prefix lengths** (similar to subnet masks in IPv4) to identify the network portion.
  - **Example**: `2001:0DB8:2021::/48` where `/48` indicates the first 48 bits represent the network portion.

## 8. Transition Techniques from IPv4 to IPv6

- **Dual-Stack**:
  - Devices are configured with both IPv4 and IPv6 addresses, allowing communication over both protocols.
  - **Pros**: Smooth transition as it supports both protocols.
  - **Cons**: Still relies on IPv4, doesn't address its depletion.
- **Tunneling**:
  - Encapsulates IPv6 packets within IPv4 to traverse IPv4 networks, or vice versa.
  - **Use Case**: Connects isolated IPv6 networks over existing IPv4 infrastructure.
- **Translation**:
  - Converts IPv4 addresses to IPv6 (and vice versa), typically using NAT64 at the network layer.
  - **Limitation**: Undermines IPv6's benefits like address hierarchy and streamlined headers.

## 9. Advantages of IPv6 Over IPv4

- **Expanded Address Space**:
  - Eliminates the need for NAT, supporting true end-to-end communication.
- **Simplified Header Structure**:

    - IPv6 headers are streamlined with fewer fields, reducing processing overhead.
- **Enhanced Routing Efficiency**:
    - IPv6's large address blocks improve aggregation and reduce the size of global routing tables.
- **Improved Multicasting**:
    - IPv6 replaces broadcast with multicast, reducing unnecessary traffic and enhancing network performance.

## 10. Security in IPv6

- **Built-in IPSec**:
    - IPv6 includes IPSec, ensuring encrypted and authenticated communications.
- **New Security Challenges**:
    - IPv6 introduces potential vulnerabilities such as **neighbor discovery attacks** and **extension header manipulation**.
    - Despite misconceptions, **NAT is not required for IPv6 security** as other firewalls and security measures remain necessary.

## 11. IPv6 Adoption Challenges

- **Deployment Costs**:
    - Upgrading infrastructure to support IPv6 can be costly, especially for legacy systems.
- **Need for Training**:
    - Network administrators and IT staff need new skills to manage and troubleshoot IPv6.
- **NAT Usage**:
    - NAT is still used in some IPv6 environments, despite its limitations, for additional address management or legacy support.
- **Incentives for Adoption**:
    - Businesses may hesitate to switch due to limited immediate benefits, relying on NAT and IPv4 for the time being.

## Summary

- IPv6 is essential to address the limitations of IPv4, providing a nearly unlimited address space, improved security, and support for modern internet applications.
- Transition strategies like Dual-Stack, Tunneling, and Translation aid the gradual shift from IPv4 to IPv6.

- IPv6 brings enhanced efficiency and functionality, but adoption barriers such as cost and training requirements remain.