Data Centre

Data Centre: Data centers are specialized facilities designed to house computer systems and associated components, such as telecommunications and storage systems. They are essential for various reasons:

1. **Centralized Control:** Data centers help companies manage all their IT resources in one place. This makes it easier to maintain and update systems.
2. **Adaptability:** They can easily grow to accommodate increasing demands. If a website becomes popular, a data center can quickly add more servers to handle the extra traffic.
3. **Reliability and Backup:** Data centers have backup systems to prevent downtime. If one server fails, another can take its place.
4. **Security:** They have strict security measures to protect sensitive data from hackers and other threats.
5. **Energy Efficiency:** Modern data centers use energy-efficient technologies to reduce their environmental impact.

Step-by-Step Load Balancing Process

1. **Client Request**:

An external client sends a request to a publicly accessible IP address associated with an application.

2. **Load Balancer Receives Request**:

The request first reaches the load balancer, which is configured to handle traffic for specific applications.

3. **Load Assessment**:

The load balancer checks the current load on each host (server) that handles the application. This assessment includes metrics like CPU load, memory usage, and active connections.

4. **Routing Decision**:

Using a predefined algorithm (e.g., round-robin, least connections, or IP hash), the load balancer determines the optimal host to handle the incoming request.

5. **Forwarding the Request**:

The load balancer forwards the request to the selected host, translating the public IP address to the host's internal IP address.

6. **Host Processes Request**:

The chosen host processes the request, which may involve additional calls to other hosts or services.

7. **Response Sent to Load Balancer**:

Once processing is complete, the host sends the response back to the load balancer.

8. **Response Relay**:

The load balancer receives the response and translates the internal IP address back to the client's public IP address, then forwards the response to the client.

9. **Security Layer**:

Throughout the process, the load balancer prevents clients from accessing hosts directly, enhancing security by masking the internal network structure.

10. **Ongoing Load Monitoring**:

The load balancer continuously monitors the performance of each host and adjusts traffic distribution in real time based on current load conditions.

Transition from IPV4 to IPv6: Overall, IPv6 addresses the limitations of IPv4, such as address exhaustion and scalability issues, making it a crucial technology for the continued expansion and development of the internet.

The transition from IPv4 to IPv6 is a gradual process to accommodate the ever-increasing demand for IP addresses. Here are some key concepts involved in this transition:

1. Dual Stack:

- Definition: A dual-stack network is a network that supports both IPv4 and IPv6 protocols simultaneously.
- How it works: Devices on a dual-stack network can communicate using either protocol, allowing a smooth transition to IPv6.
- Benefits:
    - Provides flexibility and compatibility during the transition period.
    - Ensures uninterrupted service for both IPv4 and IPv6 users.

2. Tunneling:

- Definition: Tunneling involves encapsulating IPv6 packets within IPv4 packets (or vice versa) to enable communication between IPv6 and IPv4 networks.
- How it works: An IPv6 packet is wrapped in an IPv4 header, allowing it to traverse IPv4 networks.
- Benefits:
    - Enables IPv6 communication over existing IPv4 infrastructure.
    - Facilitates gradual deployment of IPv6.

3. Header Translation (NAT-PT):

- Definition: NAT-PT is a technology that translates IPv4 packets into IPv6 packets and vice versa.
- How it works: NAT-PT devices translate the headers of IPv4 packets to IPv6 headers and vice versa, enabling communication between IPv4 and IPv6 networks.
- Benefits:
    - Allows IPv4 devices to communicate with IPv6 devices.

- Can be used to extend the life of IPv4 infrastructure.

Advantages of IP4 and IP6

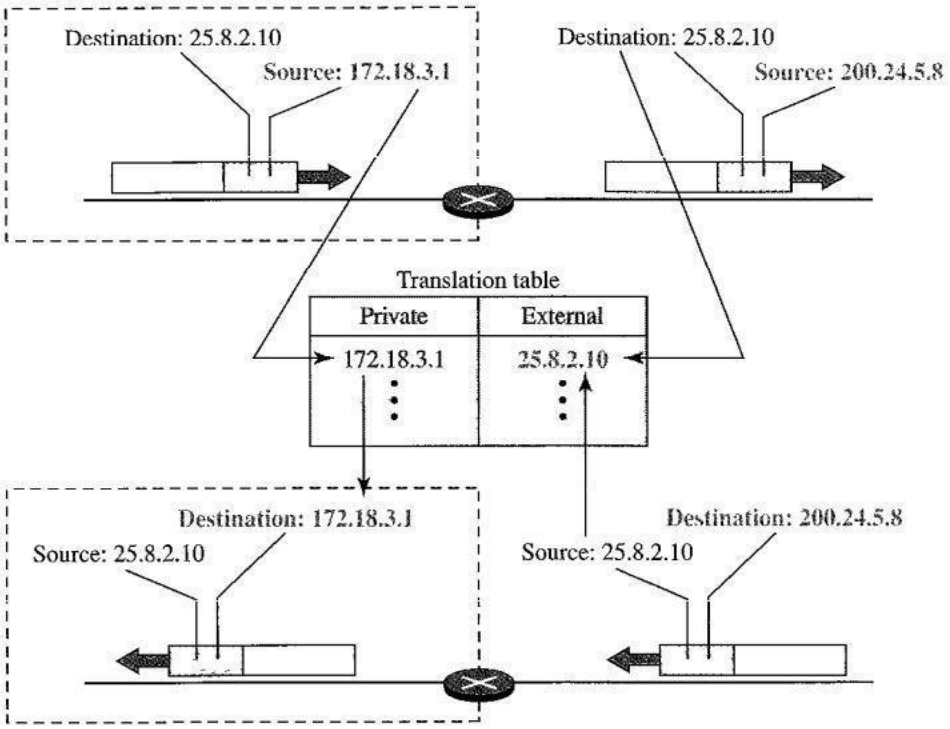
Aspect	IPv4	IPv6
Address Space	Well-established and widely used	Vast address space (128-bit), virtually unlimited
Configuration	Simple and well-understood configuration	Supports auto-configuration (stateless address autoconfiguration)
Security	Security can be added with external protocols (e.g., IPsec)	Built-in security features (mandatory IPsec support)
Network Complexity	More complex due to NAT (Network Address Translation)	Simplified network architecture, no need for NAT
Compatibility	Fully compatible with existing IPv4 infrastructure	Designed to coexist with IPv4, supports dual-stack and tunneling methods

Limitations of IP4 and IP6

Aspect	IPv4	IPv6
Address Space	Limited to 4.3 billion addresses (32-bit)	Vast address space (128-bit), virtually unlimited
Configuration	Requires manual or DHCP configuration	Supports auto-configuration (stateless address autoconfiguration)
Security	Security is optional and relies on external protocols (e.g., IPsec)	Built-in security features (mandatory IPsec support)
Network Complexity	More complex due to NAT (Network Address Translation)	Simplified network architecture, no need for NAT
Compatibility	Widely supported and used, but running out of addresses	Not fully compatible with IPv4, requires dual-stack or tunneling methods

NAT- Network Address Translation

What is NAT: NAT stands for **Network Address Translation**. It's a process used in computer networking that modifies **network address information** in the IP header of packets while they are in transit across a traffic routing device that is to translate Public IP to Private IP and vice versa. This is often used to allow multiple devices within a local network to share a single public IP address.



Where is it used?

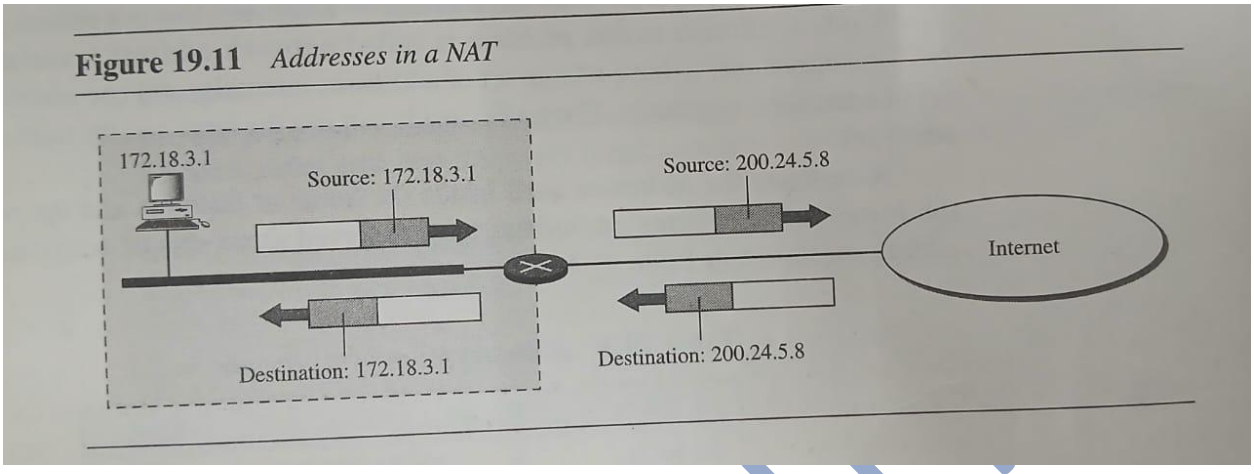
NAT is commonly employed in home or office networks where several devices, like computers, smartphones, or tablets, need to access the internet using a single IP address provided by an internet service provider.

How does it Work??

Translation Process:

- **Outgoing Traffic**: When a device sends a request to the internet, the router captures the private IP address and the port number used by the device. It then replaces this information with its own public IP address and a unique port number, creating a mapping in its NAT table.

- **Incoming Traffic**: When the response returns from the internet, the router uses the mapping in its NAT table to translate the public IP and port back to the original private IP address and port, forwarding the data to the correct device



Transport Layer

Network Congestion

Network Congestion: Network congestion occurs when the amount of data being transmitted exceeds the network's capacity, causing delays and packet loss. It typically arises from high traffic volume, inefficient routing, or insufficient bandwidth.

Key Effects of Network Congestion:

1. **Increased Latency:** Data takes longer to travel from source to destination.
2. **Packet Loss:** Some packets may be discarded, leading to retransmissions.
3. **Reduced Throughput:** The effective data transfer rate decreases, impacting performance.

Causes of Congestion:

- **High User Demand:** Many users trying to access the network simultaneously.
- **Insufficient Bandwidth:** The network cannot handle the amount of traffic.
- **Network Configuration Issues:** Poorly optimized settings can contribute to congestion.

Congestion Control Approaches:

End-to-End Congestion Control Procedure

1. **Connection Establishment**:
    - The sender and receiver establish a connection (e.g., using TCP's three-way handshake).
2. **Initial Transmission**:
    - The sender starts transmitting data using an initial congestion window size, which is often small.
3. **Monitoring Feedback**:
    - The sender monitors acknowledgments (ACKs) from the receiver. These ACKs inform the sender that packets have been successfully received.
    - If the sender does not receive an ACK for a packet within a certain timeframe (timeout), it assumes packet loss has occurred.

4. **Adjusting Transmission Rate**:
    - **Slow Start**: The sender exponentially increases the congestion window size for each ACK received until a threshold (slow start threshold) is reached.
    - **Congestion Avoidance**: Once the threshold is reached, the sender switches to linear growth of the congestion window to avoid further congestion.
    - **Fast Retransmit**: If the sender receives multiple duplicate ACKs (indicating a packet loss), it retransmits the lost packet immediately without waiting for a timeout.
    - **Fast Recovery**: After retransmitting, the sender reduces its congestion window and enters congestion avoidance mode to stabilize the transmission rate.
5. **Feedback Loop**:
    - The process continues, with the sender adjusting its transmission based on the feedback from the network (via ACKs or timeouts) to ensure it doesn't overwhelm the network.

Network-Assisted Congestion Control Procedure

1. **Packet Transmission**:

- Similar to end-to-end, the sender transmits packets to the receiver. However, network elements (routers and switches) monitor the state of the network.

2. **Network Monitoring**:

- Routers track metrics such as queue lengths and packet loss rates. Routers take action when congestion is detected (e.g., queues are filling up).

3. **Explicit Congestion Notification (ECN)**:

- Instead of dropping packets when congestion occurs, routers can mark packets with a congestion notification.

- This notification signals to the sender that the network is experiencing congestion.

4. **Feedback to Sender**:

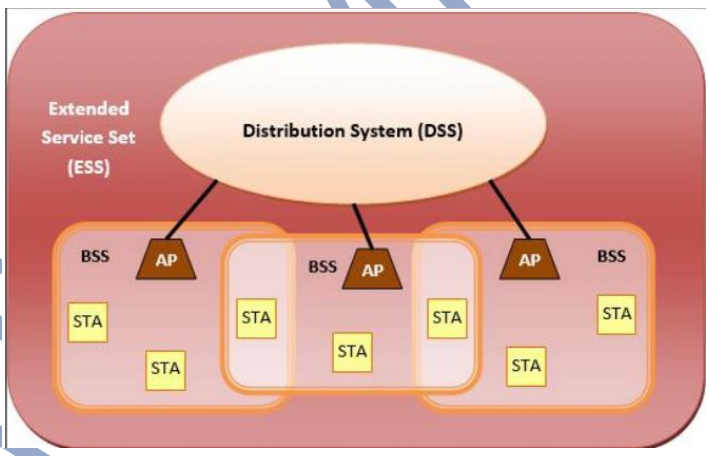
- When the sender receives a marked packet or feedback from the network, it adjusts its sending rate:

  Reduce Rate: The sender may decrease its congestion window or send fewer packets until congestion is alleviated

Wireless Network

IEEE 802.11 Architecture

The components of an IEEE 802.11 architecture are as follows



1. Stations (STA)

- **Wireless Access Point (WAP):** Also known as an access point (AP), it's like a central hub that connects devices to the network. Think of it as the main gateway to the internet.
- **Clients:** These are the devices that connect to the WAP, such as computers, laptops, smartphones, tablets, etc.

2. Basic Service Set (BSS)

- A BSS is a group of stations that communicate directly with each other.
- **Infrastructure BSS:** Devices communicate through a central access point. This is the most common type of wireless network, like your home Wi-Fi.

- **Independent BSS:** Devices communicate directly with each other in a peer-to-peer fashion, without a central access point. This is often used for temporary networks or in situations where an access point isn't available.

3. Extended Service Set (ESS)

- An ESS is a collection of multiple BSS connected together.
- This allows devices in different BSS to communicate with each other, creating a larger network.

4. Distribution System (DS)

- The DS is responsible for connecting the access points in an ESS.
- It ensures that data can be transmitted between devices in different BSS.

Wireless Links: A wireless link is the invisible connection that allows data to travel between devices in a wireless network. It uses electromagnetic waves, which are similar to radio waves, to transmit data without needing physical cables. This is how your smartphone can connect to the internet or your laptop can print a document wirelessly.

- **Mobile to Base Station Connection**: Wireless links connect mobile devices (smartphones) to base stations (cell towers) in **cellular networks** (4G, 5G).
- **Backhaul Links**: Wireless links also serve as backbone connections between base stations and the core network.

    - These connections are often made using microwave or satellite technology
    - They ensure that data from different base stations can be transmitted efficiently to the core network.

Multiple Access Protocols: These protocols manage how multiple devices share the wireless medium:

- **TDMA** (Time Division), **FDMA** (Frequency Division), **CDMA** (Code Division), **OFDMA** (used in 4G/5G), and **CSMA/CA** (used in Wi-Fi) are common protocols.

<u>Communication mode of devices:</u>

In wireless networks, the **infrastructure mode** and **ad hoc mode** are two fundamental modes of communication that define how devices connect and communicate within the network

1. Infrastructure Mode

- **Centralized:** This mode uses a central access point (like a Wi-Fi router) to manage communication.
- **How it works:** Devices connect to the access point, and the access point then routes the data to the intended destination.
- **Common use:** Most home and office Wi-Fi networks use this mode.

2. Ad Hoc Mode

- **Decentralized:** This mode doesn't rely on a central access point.
- **How it works:** Devices directly connect with each other to form a temporary network.
- **Common use:** This mode is useful for creating temporary networks, like connecting devices for file sharing without a Wi-Fi router.

The mode used depends on the specific needs of the network and the devices involved.

Advantages of Wireless Networks:

- It increases the mobility of network devices connected to the system since the devices need not be connected to each other.
- Accessing network devices from any location within the network coverage or Wi-Fi hotspot becomes convenient since laying out cables is not needed.
- Installation and setup of wireless networks are easier.
- New devices can be easily connected to the existing setup since they needn't be wired to the present equipment. Also, the number of equipment that can be added or removed to the system can vary considerably since they are not limited by the cable capacity. This makes wireless networks very scalable.

Wireless networks require very limited or no wires. Thus, it reduces the equipment and setup costs.

Cryptography

➢ Types and difference of Cryptography:

Cryptography can be broadly classified into several types based on the methods used to secure data. The two primary types are **Symmetric-key cryptography** and **Asymmetric-key cryptography**, along with other specialized techniques like **hashing** and **digital signatures**.

1. Symmetric-Key Cryptography (Secret Key Cryptography)

In symmetric-key cryptography, the **same key** is used for both encryption and decryption. This means that both the sender and the recipient must share the secret **key before communication can take plac**e. Symmetric-key cryptography is fast and efficient, making it ideal for encrypting large amounts of data.

- **Examples of Symmetric Algorithms**:
  - **AES (Advanced Encryption Standard)**
  - **DES (Data Encryption Standard)**
  - **RC4: Rivest Cipher 4**
  - **3DES (Triple DES): Triple Data Encryption Standard**

Advantages:

- Faster and more efficient, especially for encrypting large amounts of data.
- Suitable for bulk data encryption.

Disadvantages:

- Key distribution is a challenge, as the key must be securely shared between the parties involved.
- If someone steals the key, they can access the communication and break its security.

2. Asymmetric-Key Cryptography (Public Key Cryptography)

In **asymmetric cryptography**, there are two keys: a **public key** and a **private key**. The public key is used to encrypt the message, and the private key is used to decrypt it. The public key can be freely shared with anyone, while the private key must remain secret. This method allows secure communication between parties who have never shared a key in advance.

- **Examples of Asymmetric Algorithms**:
  - **RSA (Rivest-Shamir-Adleman)**
  - **ECC (Elliptic Curve Cryptography)**
  - **DSA (Digital Signature Algorithm)**

Advantages:

- Solves the problem of key distribution because only the public key is shared.
- Provides mechanisms for **digital signatures**, allowing for authentication and non-repudiation.

Disadvantages:

- Slower than symmetric-key encryption, which makes it less efficient for encrypting large volumes of data.
- Requires more computational resources.

Symmetric Key	**Asymmetric Key**
It only requires a single key for both encryption and decryption.	It requires two keys, a public key and a private key, one to encrypt and the other to decrypt.
The size of the ciphertext is the same or smaller than the original plaintext.	The size of the ciphertext is the same or larger than the original plaintext.
The encryption process is very fast.	The encryption process is slow.
It is used when a large amount of data needs to be transferred.	It is used to transfer small amount of data.
It only provides confidentiality.	It provides confidentiality, authenticity, and non-repudiation.
The length of key used is 128 or 256 bits	The length of key used is 2048 or higher

Symmetric Key	Asymmetric Key
In symmetric key encryption, resource utilization is low compared to asymmetric key encryption.	In asymmetric key encryption, resource utilization is high.
It is efficient as it is used for handling large amount of data.	It is comparatively less efficient as it can handle a small amount of data.
Security is lower as only one key is used for both encryption and decryption purposes.	Security is higher as two keys are used, one for encryption and the other for decryption.
Examples: 3DES, AES, DES and RC4	**Examples:** Diffie-Hellman, ECC, El Gamal, DSA and RSA