System Design Interview Questions on IP Addresses

1. How do IPv4 and IPv6 addresses differ?

Interviewers ask this to assess understanding of IP addressing. When answering, focus on:

- **Address Length**
    - IPv4: 32-bit (e.g., `192.168.1.1`)
    - IPv6: 128-bit (e.g., `2001:0db8:85a3::8a2e:0370:7334`)
- **Address Format**
    - IPv4: Dotted decimal notation (`x.x.x.x`, where x ranges from 0-255)
    - IPv6: Hexadecimal colon-separated notation (`xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx:xxxx`)
- **Scalability**
    - IPv6 offers significantly more addresses and supports auto-configuration.
- **Security**
    - IPv6 includes built-in IPSec encryption, unlike IPv4, which requires additional configurations.

Example Response

IPv4 and IPv6 are the two primary internet protocols. IPv4, with a 32-bit address space, is limited, whereas IPv6, with a 128-bit space, offers a larger pool of addresses and better scalability. IPv6 also improves security with built-in encryption.

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2. Why do we need private IPs in system design?

This question evaluates understanding of network structuring. Key points:

- **Address Conservation**
    - IPv4 addresses are limited; private IPs allow multiple organizations to reuse the same address ranges internally.
- **Security**
    - Private IPs keep internal systems isolated from the public internet, reducing the risk of attacks.
- **Cost Efficiency**
    - Organizations can assign many private IPs while using a single public IP for external communication.

Example Response

Private IPs allow organizations to efficiently manage internal networking without requiring a large number of public IPs. They provide security by isolating internal systems and reducing attack exposure.

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3. How does NAT help in addressing the IPv4 shortage?

Network Address Translation (NAT) is widely used to extend IPv4 usability. Key points:

- **Address Reuse**
    - NAT allows multiple devices to share a single public IP address.
- **Security**
    - NAT hides internal IP addresses, reducing exposure to external threats.
- **Scalability**
    - NAT enables ISPs and enterprises to manage large networks with fewer public IPs.

Example Response

NAT mitigates IPv4 shortages by enabling multiple devices to share a single public IP. It improves security by masking internal IPs and is widely used in enterprise and ISP networks.

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4. Explain how a load balancer distributes traffic using IPs.

Load balancers improve system performance by distributing traffic. Key points:

1. **DNS Load Balancing**
    - Multiple IPs are assigned to a domain, and DNS directs traffic based on availability and location.
2. **Layer 4 Load Balancing** (Transport Layer)
    - Traffic is distributed based on IP addresses and ports.
3. **Layer 7 Load Balancing** (Application Layer)
    - Requests are routed based on HTTP headers, URLs, or session data.

Example Response

A load balancer ensures even distribution of network traffic across multiple servers, improving scalability and reliability. It operates at different layers, including DNS-based distribution and TCP/HTTP routing.

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5. How does DNS resolve IP addresses in a large-scale system?

DNS resolution follows a multi-step process:

1. **Client Queries DNS Resolver**
    - The client requests the IP for a domain (e.g., `example.com`).
2. **Resolver Checks Cache or Queries Root Server**
    - If cached, the IP is returned. Otherwise, the query is forwarded.
3. **TLD Server Responds**
    - The `.com` TLD server points to the authoritative server.
4. **Authoritative DNS Server Provides the IP**
    - The final IP is returned to the client.
5. **Client Connects and Caches the Result**
    - The client stores the IP to avoid repeated lookups.

Example Response

DNS resolution involves multiple steps, including querying root and authoritative servers. Large-scale systems optimize this process using caching and CDNs to reduce latency.

Conclusion

- IPv4 and IPv6 are the primary internet protocols, with IPv6 offering better scalability.
- Private IPs improve security and address conservation in system design.
- NAT enables efficient use of limited IPv4 addresses.
- Load balancers optimize traffic distribution across multiple servers.
- DNS plays a crucial role in resolving domain names to IP addresses, supporting high-scale architectures.

Final Thoughts & Key Takeaways

Best way to answer these questions in an interview:

- **Define the concept** (e.g., what IPv6 is).
- **Explain why it matters** (e.g., solves address exhaustion).
- **Give real-world examples** (e.g., AWS, Google, Netflix).

By mastering these topics, you'll be well-prepared for **technical system design interviews at top tech companies**.