

IP Address Definition in Computer Networking

- A numerical label assigned to every device on an IP network
- Identifies a network interface and locates a device for routing
- Name tells what we seek; address tells where it is
- Roadmap: structure, versions, assignment, subnets, commands, safety



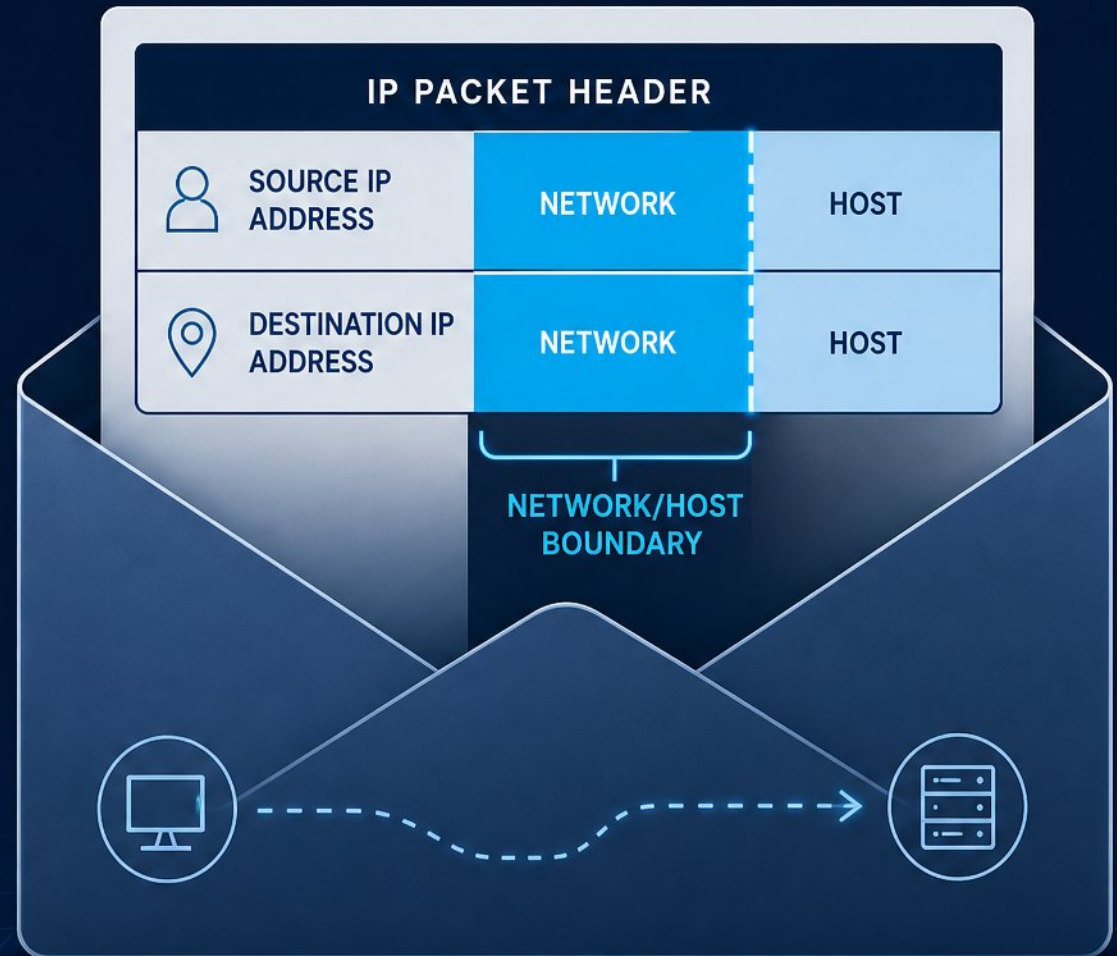
Why Devices Need IP Addresses

- IP addresses uniquely identify devices and enable location on a network
- Data travels in packets carrying source and destination addresses
- DNS translates human-readable names into routable IP addresses
- Routers use IP addresses to forward packets across networks
- Home routers, phones, laptops, printers, and web servers all use IPs

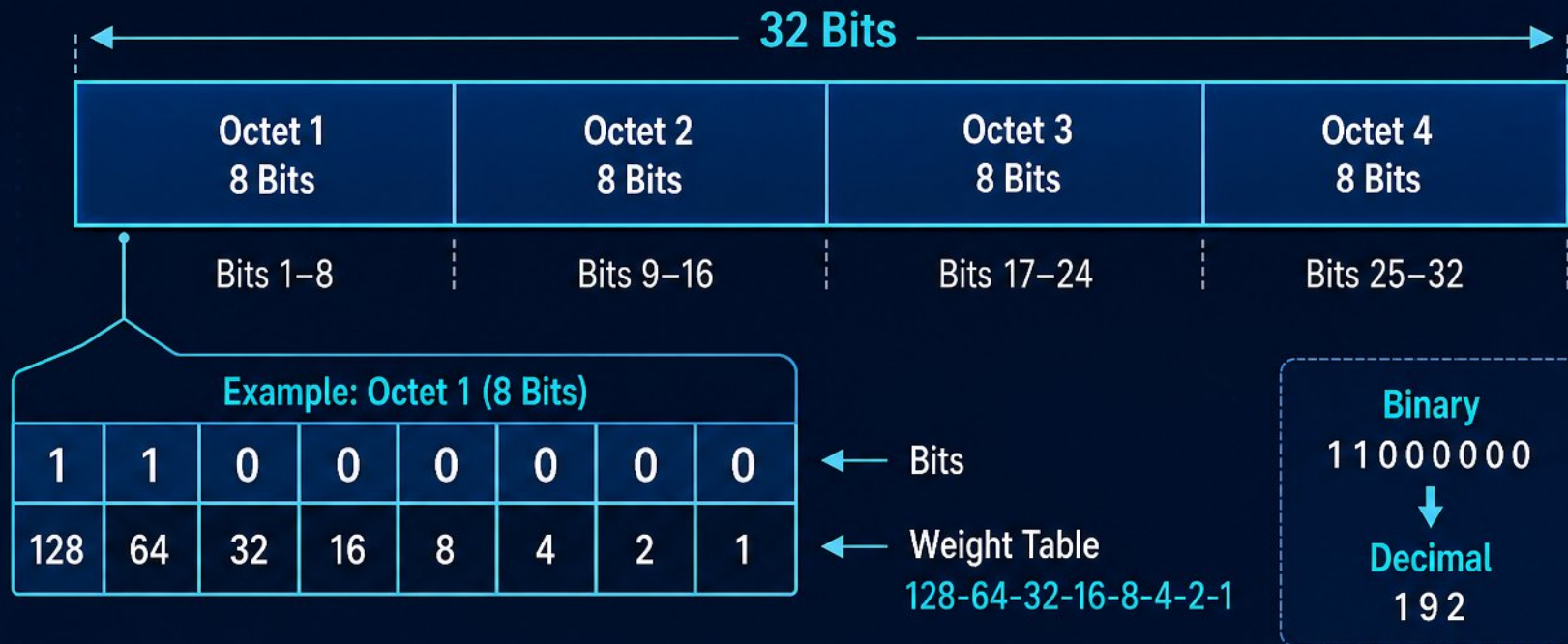


Packets, Protocols, and the **Two-Part Address**

- IP packets carry source and destination addresses in a header.
- An IP address has two parts: network and host.
- The subnet mask marks the network/host boundary.
- Without a mask or prefix, the address is ambiguous.



IPv4 Structure: 32 Bits in Four Octets



- An IPv4 address is a 32-bit number written as four octets



- Each octet is 8 bits, ranging from 0 to 255 in decimal



- Example: 192.168.1.100 in binary is 11000000.10101000.00000001.011100100



- Conversion uses the weight table: 128-64-32-16-8-4-2-1



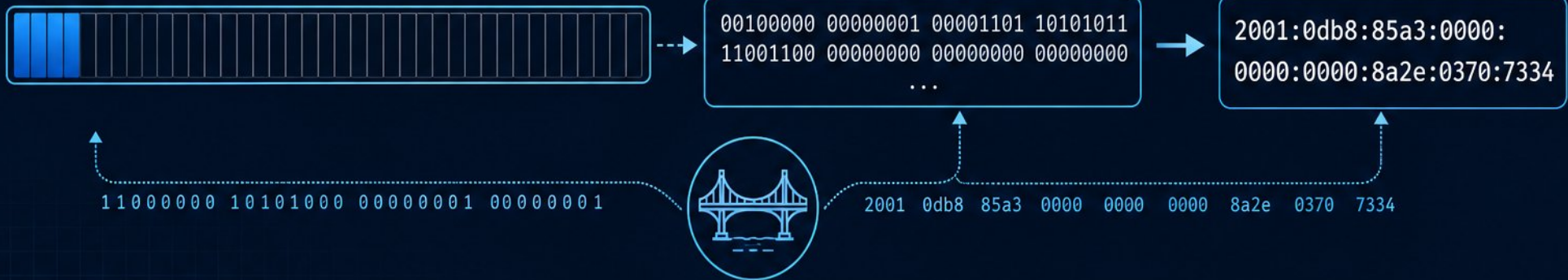
- Invalid addresses contain octets over 255, like 256.0.0.1

IPv6: A Larger Address Space for a Growing Internet

IPv4 (32-bit)



IPv6 (128-bit)



- - IPv4's 4.3 billion addresses ran out; NAT delayed the exhaustion
- - IPv6 uses 128-bit hexadecimal notation: eight groups separated by colons
- - Leading zeros drop; consecutive zero groups compress into one '::'
- - Vast address space reduces NAT need and enables device autoconfiguration

Recognizing IPv4 and IPv6 at a Glance

IPv4

EXAMPLE

192.168.1.1

Octet 1 Octet 2 Octet 3 Octet 4



Four decimal octets
separated by dots

IPv6

EXAMPLE

2001:db8::1

Group 1 Group 2 Group 3 ... Group 8



Eight colon-separated
hexadecimal groups

- IPv4: four decimal octets separated by dots (e.g., 192.168.1.1)
- IPv6: eight colon-separated hexadecimal groups (e.g., 2001:db8::1)
- Loopback: 127.0.0.1 (IPv4) vs ::1 (IPv6)
- Documentation ranges: 192.0.2.0/24 and 2001:db8::/32
- IPv6 has no broadcast; multicast replaces it

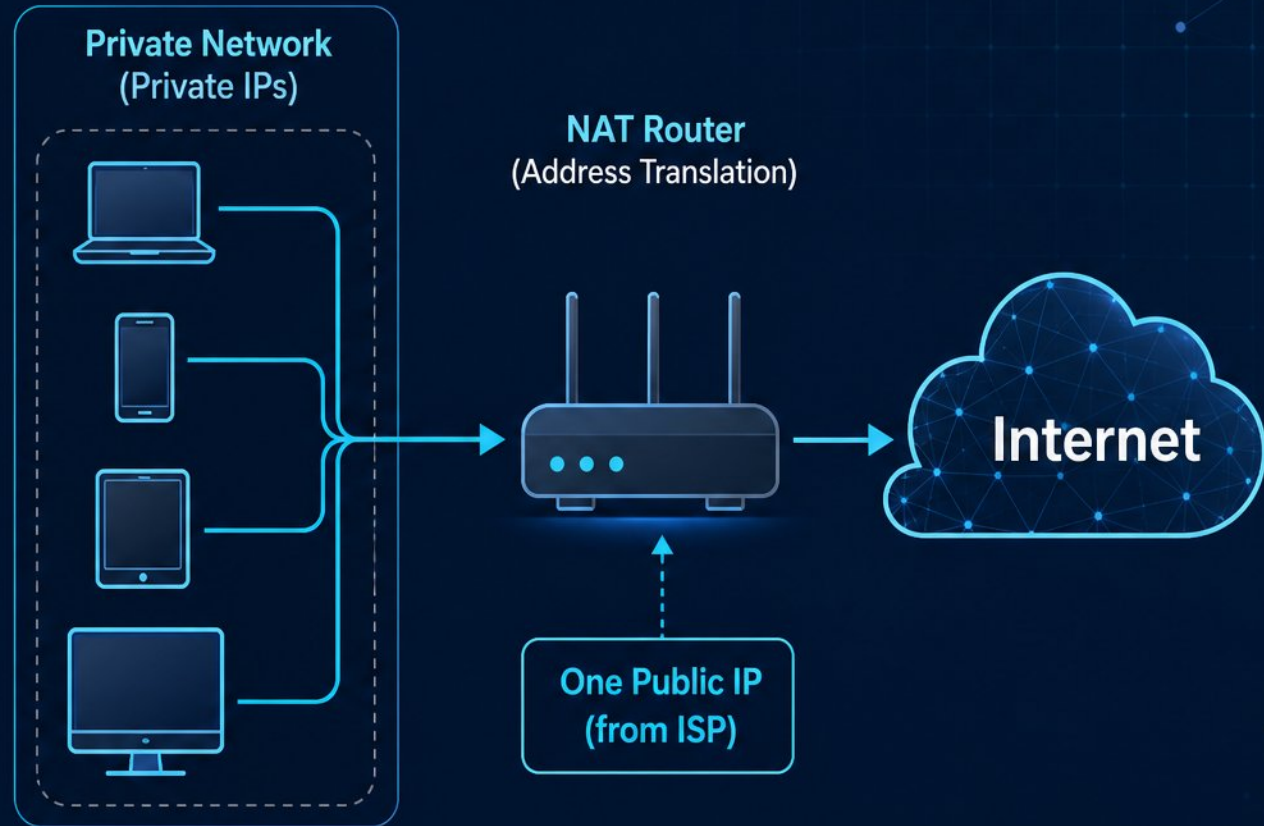
Public and Private IP Addresses

- Public IPs are globally unique and routable on the internet
- Private IPs are reusable locally and not routed on the internet
- RFC 1918 private ranges:
 - 10.0.0.0/8
 - 172.16.0.0/12
 - 192.168.0.0/16
- 10.0.0.0/8 for enterprise and cloud VPCs
- 192.168.0.0/16 for home and small office routers



How NAT Connects Private Networks to the Internet

- NAT lets many private devices share one public IP
- Home laptops and phones use the router's public address
- The router translates private IPs for outbound traffic
- Private IPs alone are not a security boundary
- Carrier-grade NAT extends address sharing across many subscribers



Carrier-grade NAT extends address sharing across many subscribers.



Static vs. Dynamic IP Addresses and DHCP



STATIC IP
(MANUALLY CONFIGURED)

IP ADDRESS

192.168.1.50|

VS.



DYNAMIC IP
(DHCP ASSIGNED)

IP ADDRESS

192.168.1.105

LEASE EXPIRES IN

00:00:00



- Static IP: manually configured; does not change until an administrator changes it
- Dynamic IP: automatically assigned with a lease period, then expires
- DHCP automates assignment, reducing typos and duplicate-address errors
- Static for servers, printers, and infrastructure; dynamic for laptops, phones, and guests

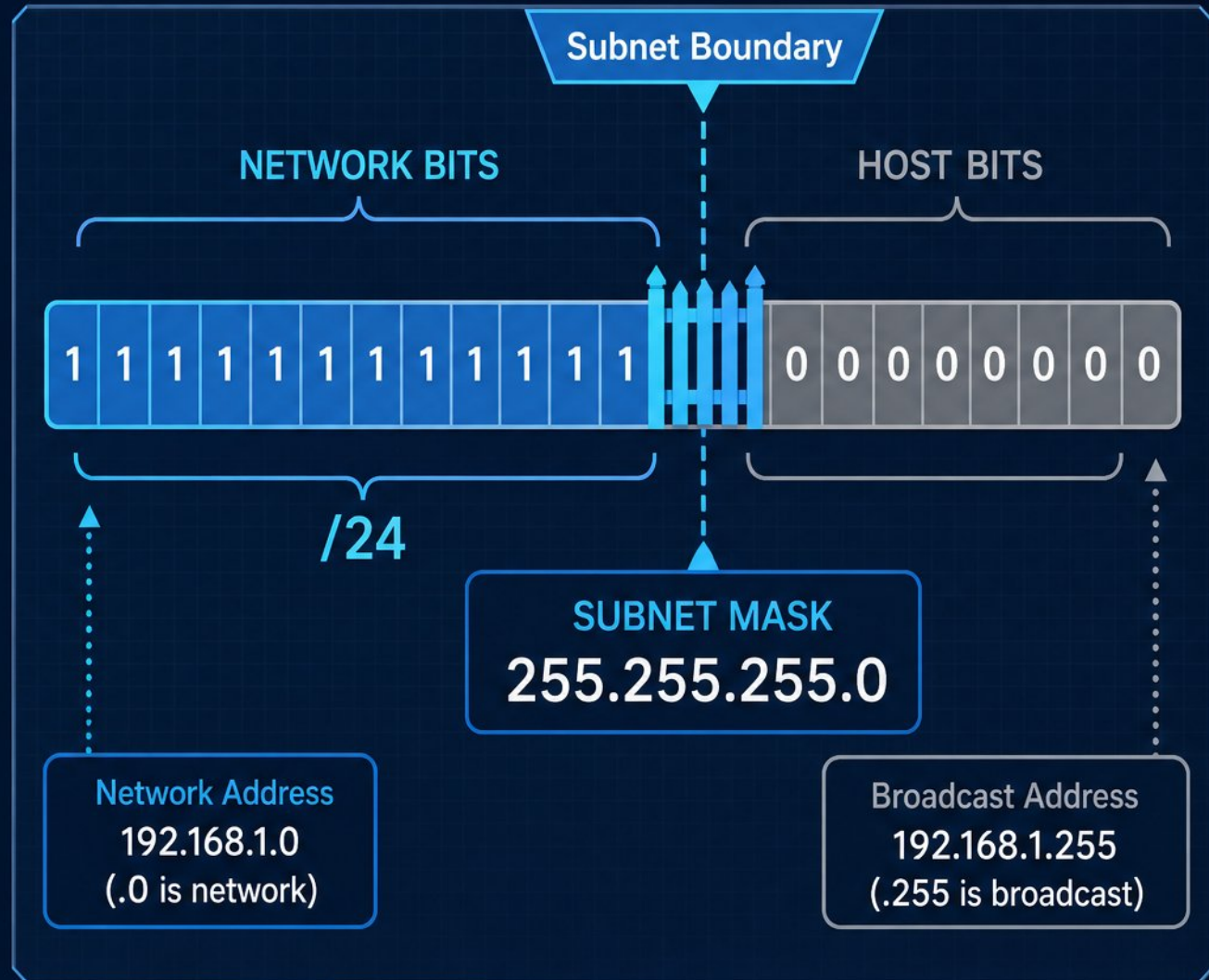
How a Device Gets Its IP Address



- DHCP uses four steps: Discover, Offer, Request, Acknowledge (DORA)
- Discover: client broadcasts to find any available DHCP server
- Offer: server proposes an IP address, subnet mask, gateway, and DNS
- Request and Acknowledge: client accepts; server confirms the lease
- Home router acts as DHCP server for LAN clients and DHCP client to ISP

Subnets and CIDR Notation

- A subnet is a logical subdivision of a network.
- The mask marks network bits as 1s and host bits as 0s.
- Prefix /24 equals subnet mask 255.255.255.0.
- In 192.168.1.0/24, .0 is network and .255 is broadcast.



Viewing IP Configuration with **ipconfig** and **ip addr**

- Use `ipconfig` on Windows; `ip addr` on Linux or macOS
- Check IPv4 address, subnet mask, and default gateway values
- Use `ipconfig /release` then `ipconfig /renew` to refresh a DHCP lease
- The `169.254.x.x` address indicates DHCP failure and no internet access



```
C:\> ipconfig
```

```
Windows IP Configuration
```

```
Ethernet adapter Ethernet:
```

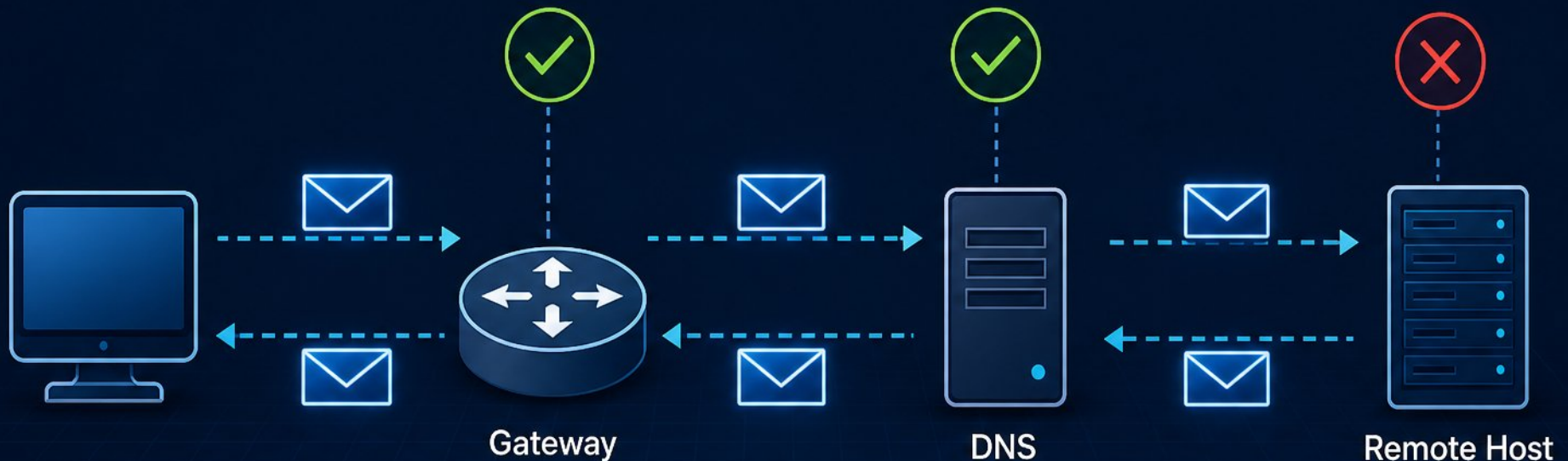
```
Connection-specific DNS Suffix . :  
IPv4 Address. . . . . : 192.168.1.100  
Subnet Mask . . . . . : 255.255.255.0  
Default Gateway . . . . . : 192.168.1.1  
IPv6 Address . . . . . : 2001:db8:acad:1::10  
Link-local IPv6 Address . . . . . : fe80::1c2b:3d4e:5f60:7080
```

```
$ ip addr
```

```
2: eth0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc fq_codel state UP  
link/ether 00:0c:29:1a:2b:3c brd ff:ff:ff:ff:ff:ff  
inet 192.168.1.100/24 brd 192.168.1.255 scope global eth0  
    valid_lft forever preferred_lft forever  
inet6 2001:db8:acad:1::10/64 scope global  
    valid_lft forever preferred_lft forever  
inet6 fe80::1c2b:3d4e:5f60:7080/64 scope link  
    valid_lft forever preferred_lft forever  
inet 169.254.10.20/16 brd 169.254.255.255 scope link  
    valid_lft forever preferred_lft forever
```

Testing Connectivity with Ping

- Ping sends ICMP Echo Requests and waits for Echo Replies
- Ping by IP tests reachability only
- Ping by hostname also tests DNS resolution
- Ping yourself, gateway, then DNS, then remote host



Common Issues, Privacy, and Practical Safety

- IP conflicts cause intermittent connectivity and duplicate address warnings
- An IP address reveals approximate location, not exact identity
- It can identify your ISP but not your name or street address
- IP geolocation is often city-level, not precise enough for tracking
- Use strong passwords, updates, and careful port forwarding
- VPNs offer optional privacy but are not required for basic safety



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