

Network Address Translation (NAT)

1 What is NAT?

Network Address Translation (NAT) is a networking technique that allows multiple devices inside a private network to share a single public IP address when communicating with the Internet.

NAT is typically implemented on a **router or firewall** that connects:

- a **private network** (LAN)
- to a **public network** (Internet)

It modifies IP address information in packet headers while traffic is in transit.

2 Why NAT is Needed

2.1 IPv4 Address Exhaustion

IPv4 provides approximately:

$$2^{32} \approx 4.3 \text{ billion IP addresses}$$

Due to the explosive growth of the Internet, this number is insufficient.

2.2 Problems Without NAT

Without NAT:

- Every device would require a **public IP**
- ISPs would quickly run out of addresses
- Network security would be weaker

NAT solves this problem by allowing thousands of devices to use **private IP addresses** internally while sharing a small number of public IPs.

3 Private vs Public IP Addresses

3.1 Private IP Ranges

Private IP addresses are **not routable on the Internet**.

- **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

3.2 Public IP Addresses

Public IPs are:

- Globally unique
- Assigned by ISPs
- Routable on the Internet

4 How NAT Works (Step-by-Step)

Scenario:

- PC inside LAN: 192.168.1.10
- Router public IP: 103.45.12.8
- Destination server: 8.8.8.8

4.1 Outgoing Packet

1. PC sends packet from 192.168.1.10 to 8.8.8.8
2. Router replaces source IP:
 $192.168.1.10 \rightarrow 103.45.12.8$
3. Router stores mapping in NAT table

4.2 Incoming Packet

1. Reply arrives at router for 103.45.12.8
2. Router checks NAT table
3. Packet forwarded to 192.168.1.10

NAT is **transparent** — internal devices are unaware that translation occurs.

5 Types of NAT

5.1 Static NAT

- One-to-one mapping
- Private IP \leftrightarrow Public IP
- Used for servers

192.168.1.100 ↔ 203.0.113.5

5.2 Dynamic NAT

- Maps private IPs to a pool of public IPs
- Temporary mapping
- Less common today

5.3 PAT (Port Address Translation)

Also known as **NAT Overload**.

- Many private IPs share **one public IP**
- Differentiated using **port numbers**
- Most widely used NAT type

Example PAT Mapping:

192.168.1.10 : 3456 → 103.45.12.8 : 50001

192.168.1.11 : 4567 → 103.45.12.8 : 50002

6 NAT Translation Table

A NAT table stores mappings like:

Private IP:Port	Public IP:Port	Protocol
192.168.1.10:3456	103.45.12.8:50001	TCP
192.168.1.11:4567	103.45.12.8:50002	TCP

7 Advantages of NAT

- Conserves IPv4 addresses
- Hides internal network structure
- Adds a basic layer of security
- Reduces ISP cost

8 Disadvantages of NAT

- Breaks end-to-end connectivity
- Complicates peer-to-peer applications
- Requires port forwarding for servers
- Increases router processing overhead

9 NAT vs IPv6

IPv6 provides:
 2^{128} addresses
making NAT technically unnecessary.

However:

- IPv4 is still widely used
- NAT remains essential in modern networks

10 Real-Life Examples

- Home WiFi router
- University campus network
- Office LAN
- Mobile data networks

11 Summary

- NAT translates private IPs to public IPs
- Solves IPv4 address exhaustion
- Uses static, dynamic, or PAT methods
- Commonly implemented in routers

NAT is one of the most important technologies that keeps the IPv4 Internet running today.