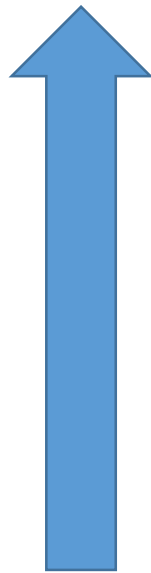
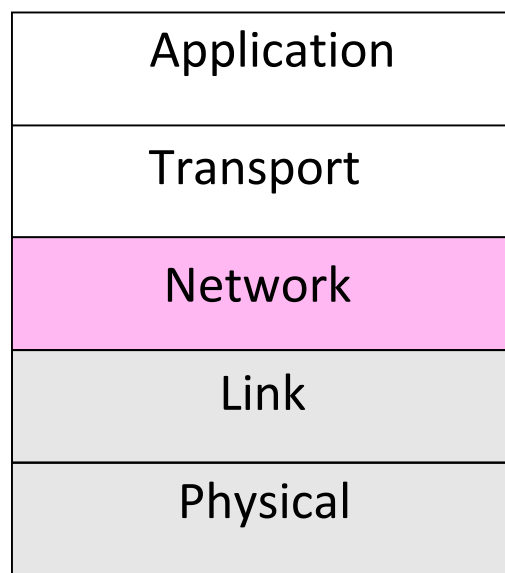


Network Layer

Where we are in the Course

- Moving on up to the Network Layer!



Topics

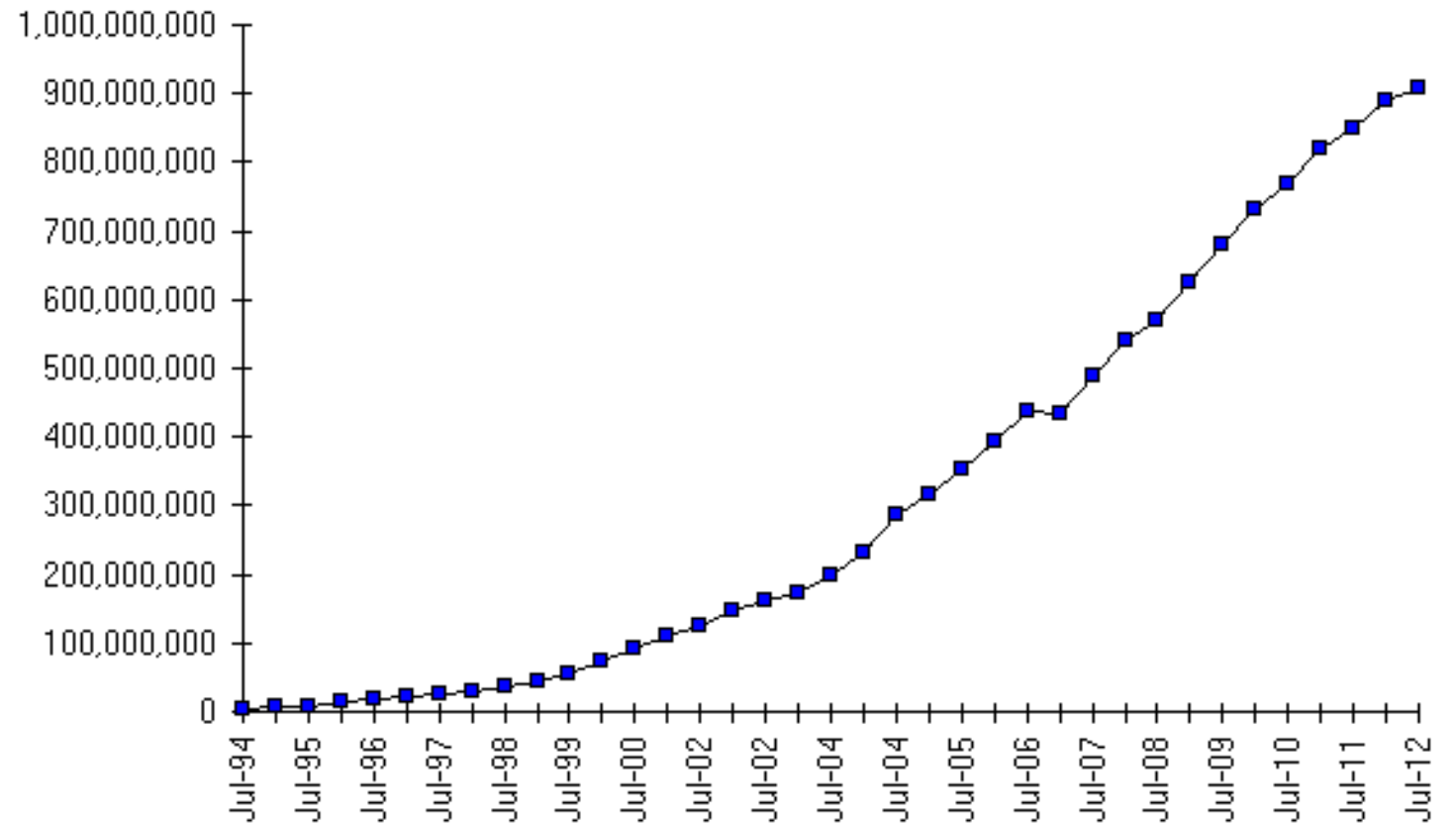
- Network service models
 - Datagrams (packets), virtual circuits
- IP (Internet Protocol)
 - Internetworking
 - Forwarding (Longest Matching Prefix)
 - Helpers: ARP and DHCP
 - Fragmentation and MTU discovery
 - Errors: ICMP (traceroute!)
 - IPv6, scaling IP to the world
 - NAT, and “middleboxes”
- Routing Algorithms

Network Address Translation (NAT)

Problem: Internet Growth

- Many billions of hosts
- And we're using 32-bit addresses!

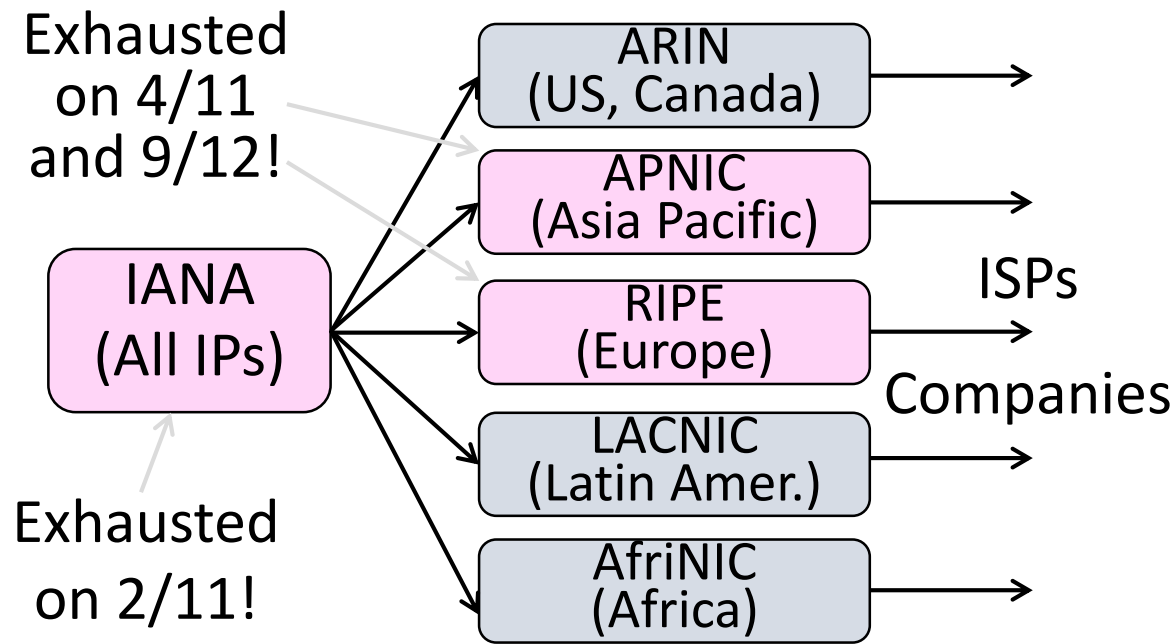
Internet Domain Survey Host Count



Source: Internet Systems Consortium (www.isc.org)

The End of New IPv4 Addresses

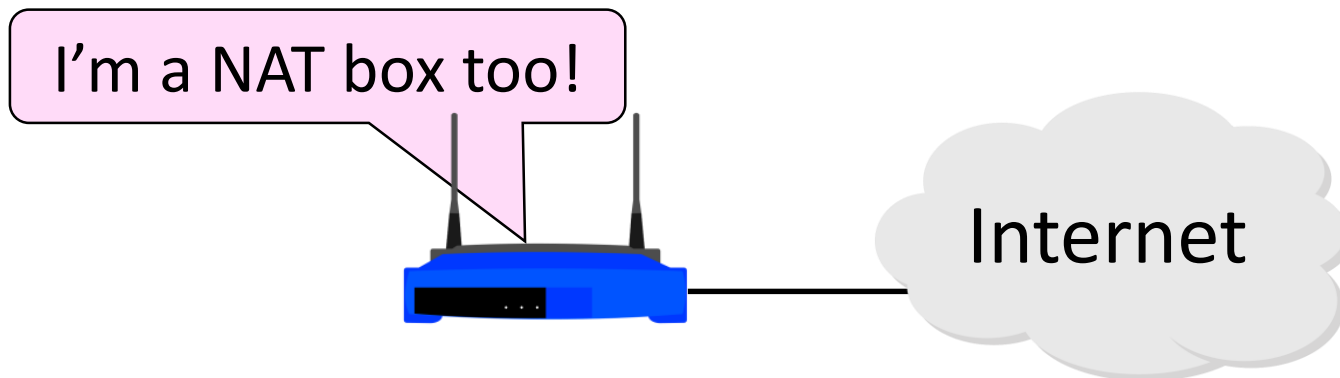
- Now running on leftover blocks held by the regional registries; much tighter allocation policies



End of the world ? 12/21/12?

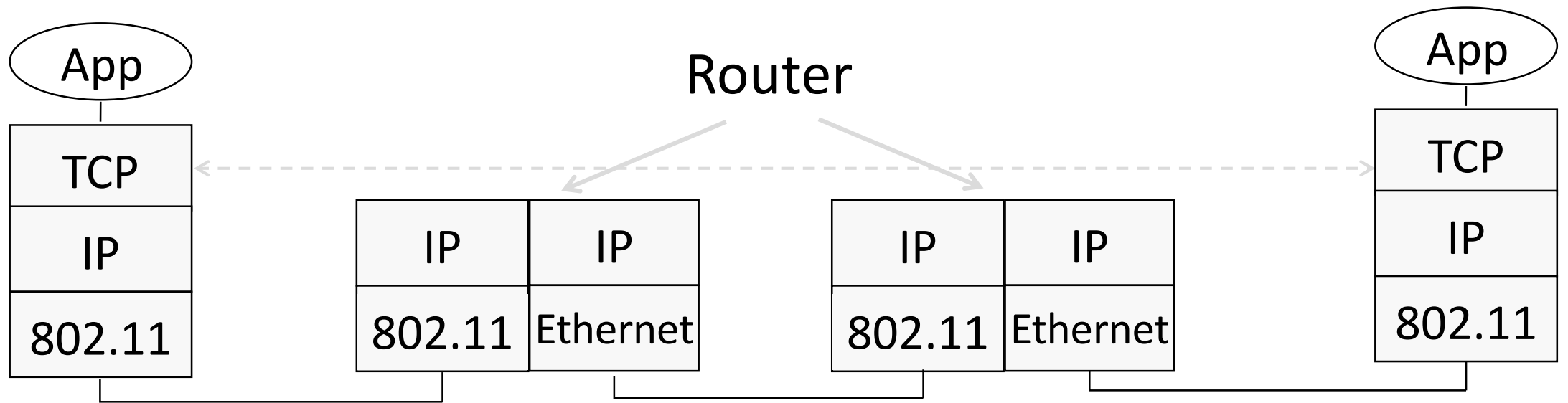
Solution 1: Network Address Translation (NAT)

- Basic idea: Map many “Private” IP addresses to one “Public” IP.
- Allocate IPs for private use (192.168.x, 10.x)



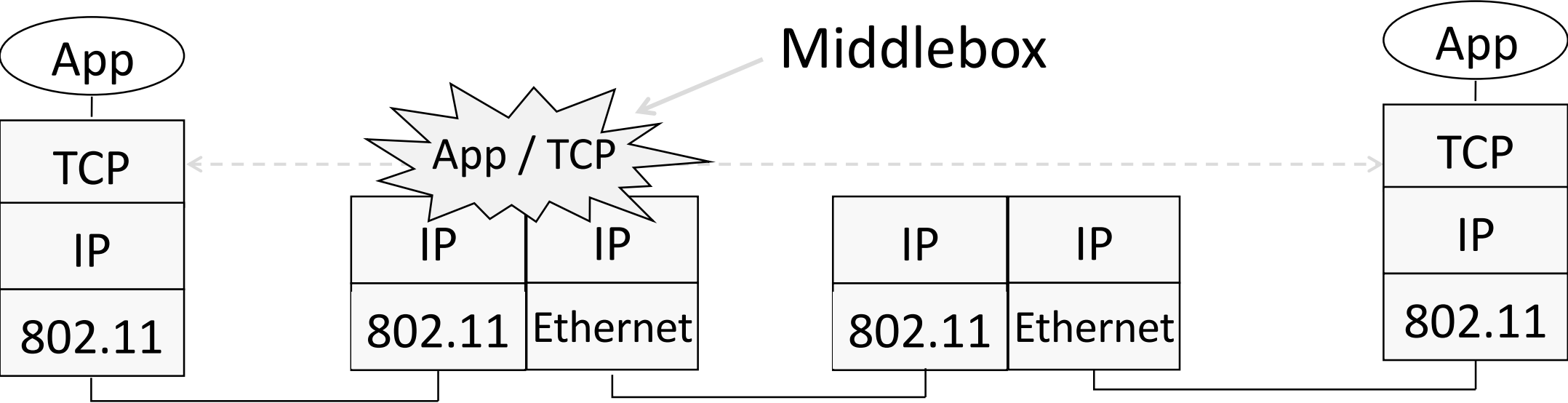
Layering Review

- Remember how layering is meant to work?
 - “Routers don’t look beyond the IP header.” Well ...



Middleboxes

- Sit “inside the network” but perform “more than IP” processing on packets to add new functionality
 - NAT box, Firewall / Intrusion Detection System



Middleboxes (2)

- Advantages

- A possible rapid deployment path when no other option
- Control over many hosts (IT)

- Disadvantages

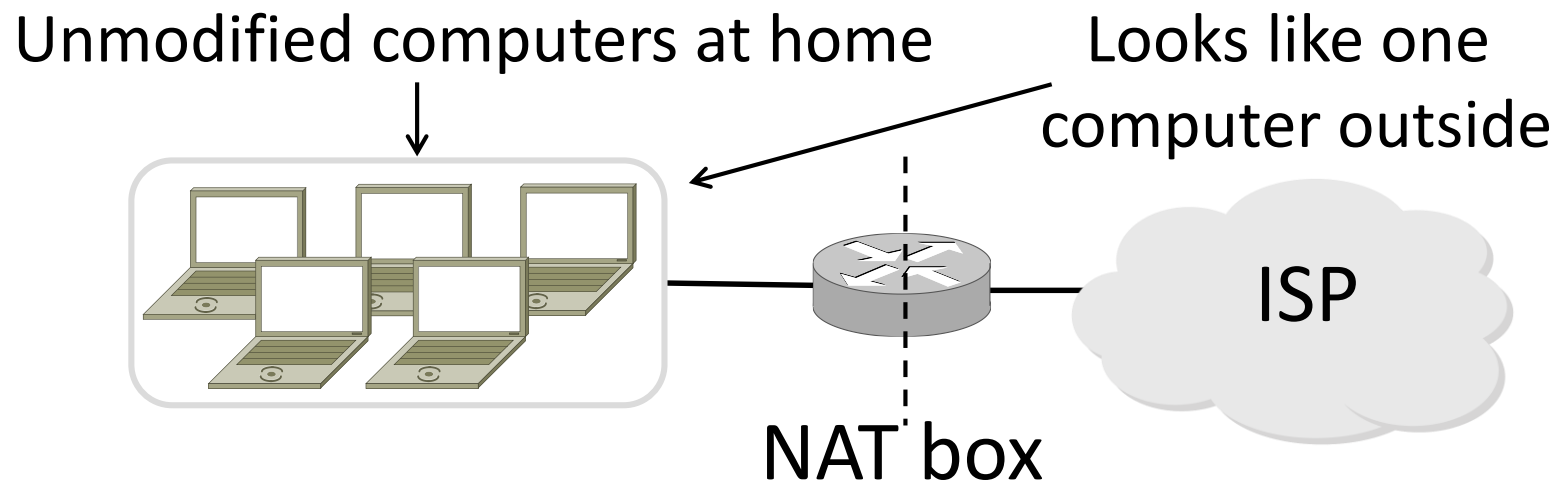
- Breaking layering interferes with connectivity
 - strange side effects
- Poor vantage point for many tasks

NAT (Network Address Translation) Box

- NAT box maps an internal IP to an external IP
 - Many internal hosts connected using few external addresses
 - Middlebox that “translates addresses”
- Motivated by IP address scarcity
 - Controversial at first, now accepted

NAT (2)

- Common scenario:
 - Home computers use “private” IP addresses
 - NAT (in AP/firewall) connects home to ISP using a single external IP address



How NAT Works

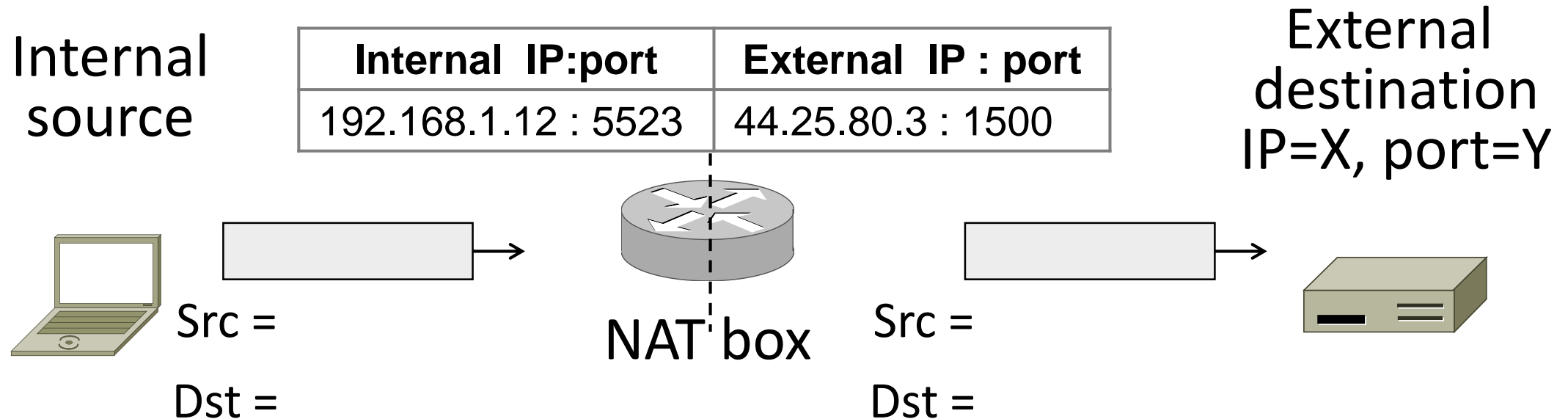
- Keeps an internal/external translation table
 - Typically uses IP address + TCP port
 - This is address and port translation

What host thinks	What ISP thinks
Internal IP:port	External IP : port
192.168.1.12 : 5523	44.25.80.3 : 1500
192.168.1.13 : 1234	44.25.80.3 : 1501
192.168.2.20 : 1234	44.25.80.3 : 1502

- Need ports to make mapping 1-1 since there are fewer external IPs

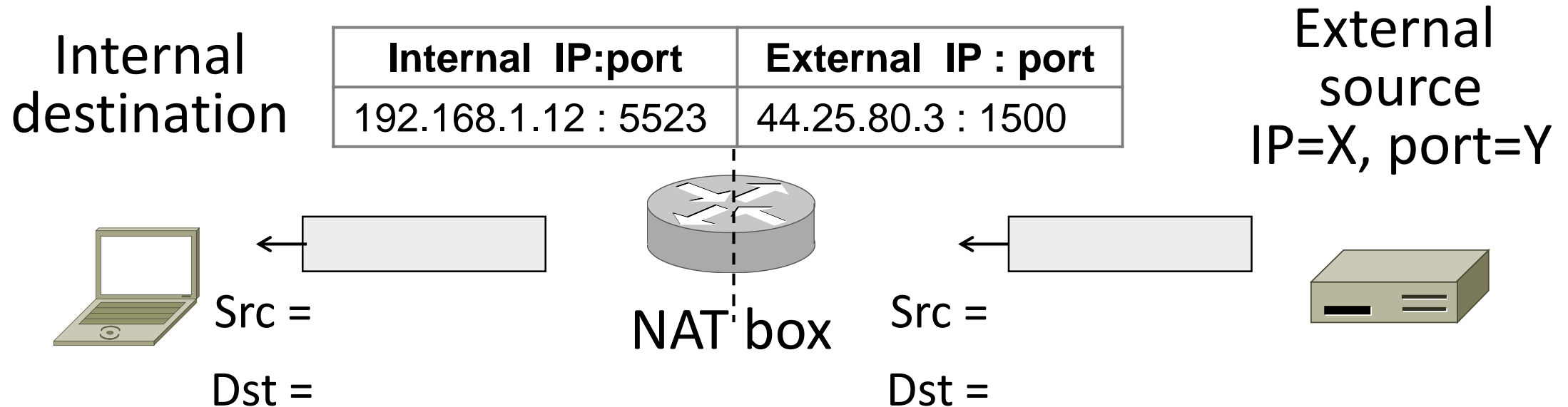
How NAT Works (2)

- Internal → External:
 - Look up and rewrite Source IP/port



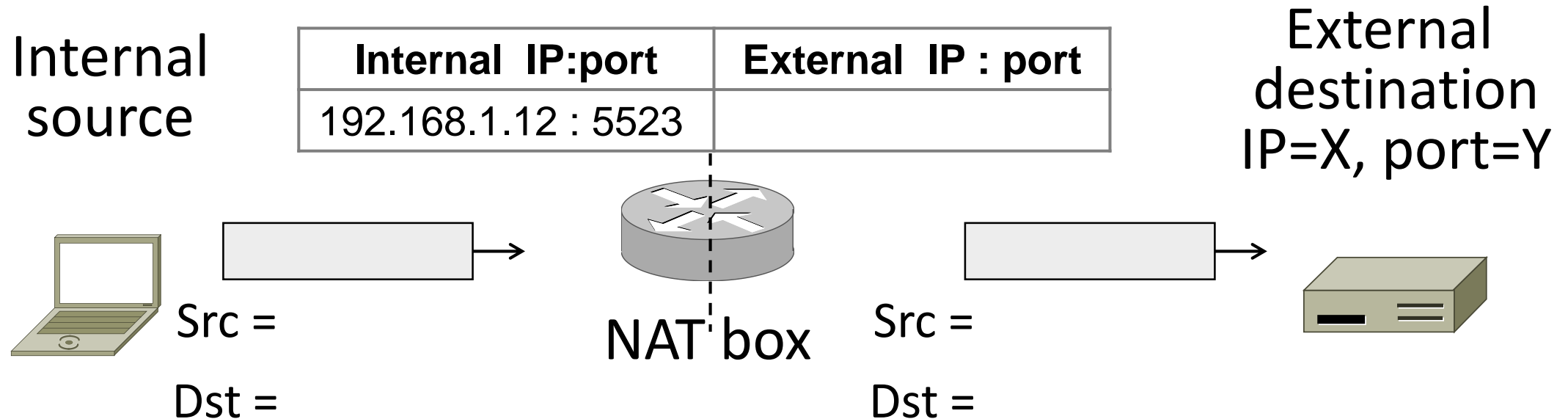
How NAT Works (3)

- External → Internal
 - Look up and rewrite Destination IP/port



How NAT Works (4)

- Need to enter translations in the table for it to work
 - Create external name when host makes a TCP connection



NAT Downsides

- Connectivity has been broken!
 - Can only send incoming packets after an outgoing connection is set up
 - Difficult to run servers or peer-to-peer apps (Skype)
- Doesn't work when there are no connections (UDP)
- Breaks apps that expose their IP addresses (FTP)

NAT Upsides

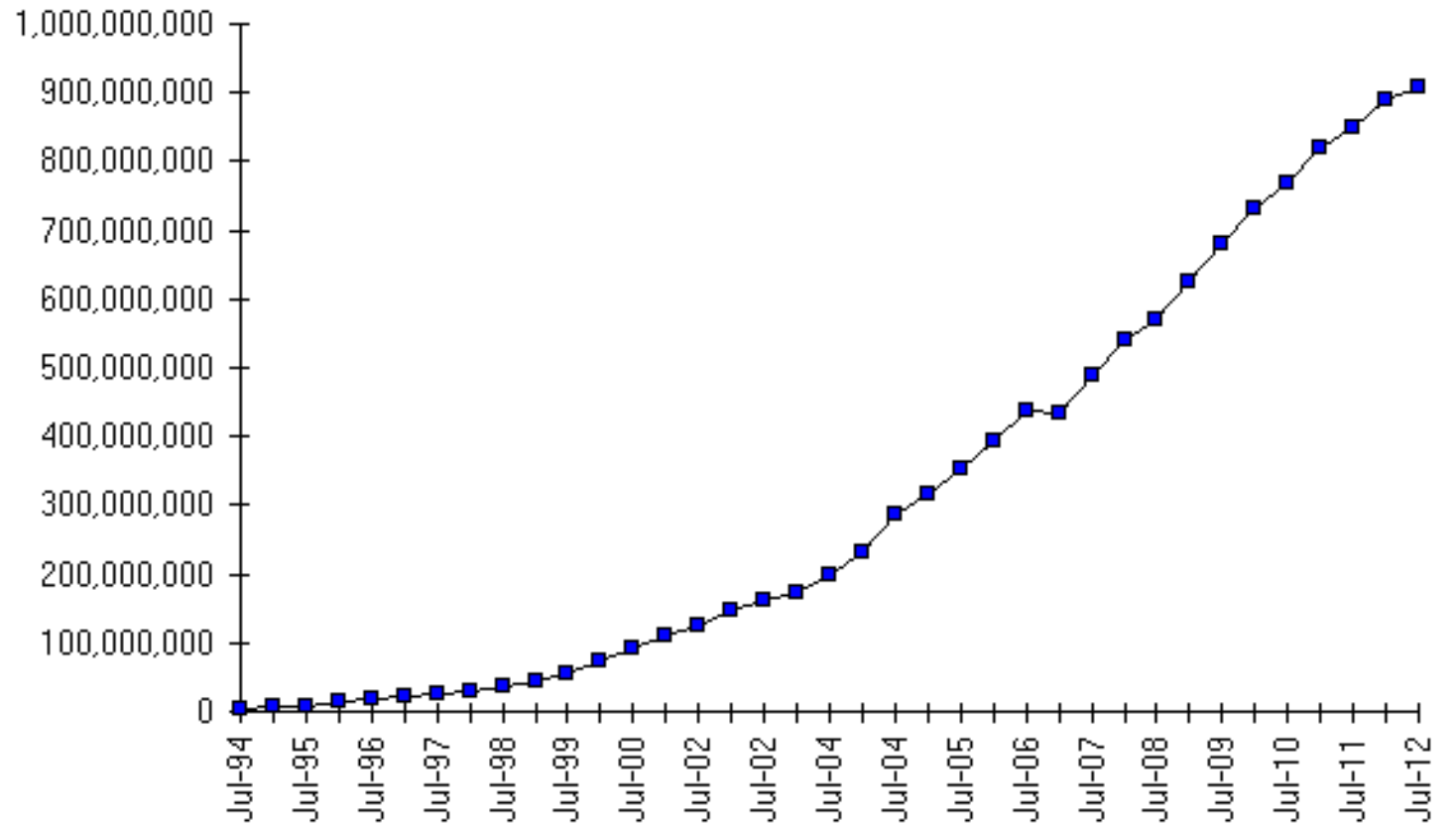
- Relieves much IP address pressure
 - Many home hosts behind NATs
- Easy to deploy
 - Rapidly, and by you alone
- Useful functionality
 - Firewall, helps with privacy
- Kinks will get worked out eventually
 - “NAT Traversal” for incoming traffic

IPv6

Problem: Internet Growth

- Many billions of hosts
- And we're using 32-bit addresses!

Internet Domain Survey Host Count



Source: Internet Systems Consortium (www.isc.org)

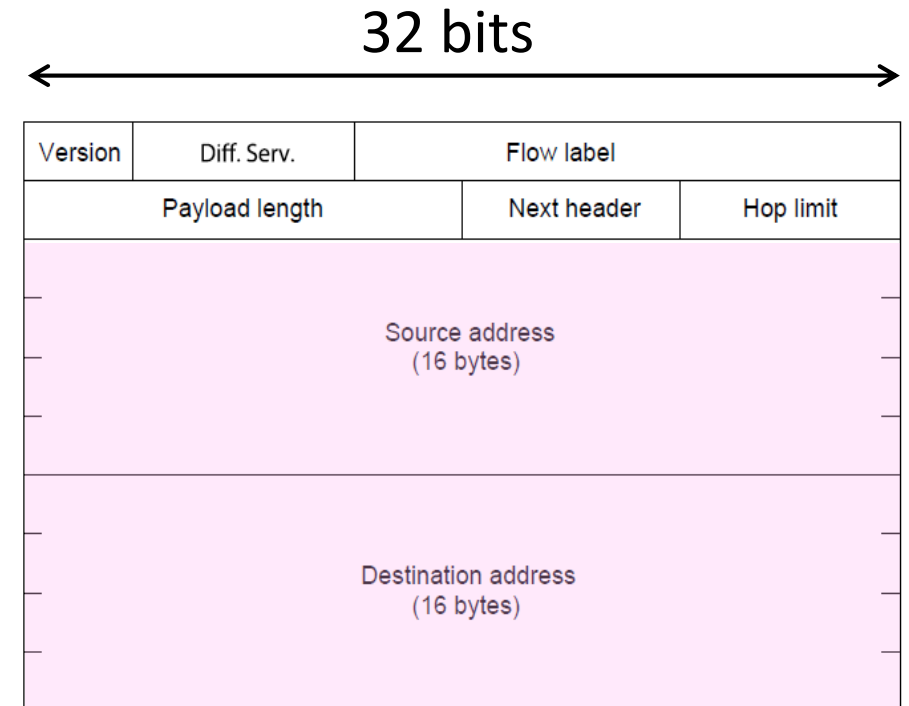
IP Version 6 to the Rescue

- Effort started by the IETF in 1994
 - Much larger addresses (128 bits)
 - Many sundry improvements
- Became an IETF standard in 1998
 - Nothing much happened for a decade
 - Hampered by deployment issues, and a lack of adoption incentives
 - Big push ~2011 as exhaustion looms

IPv6

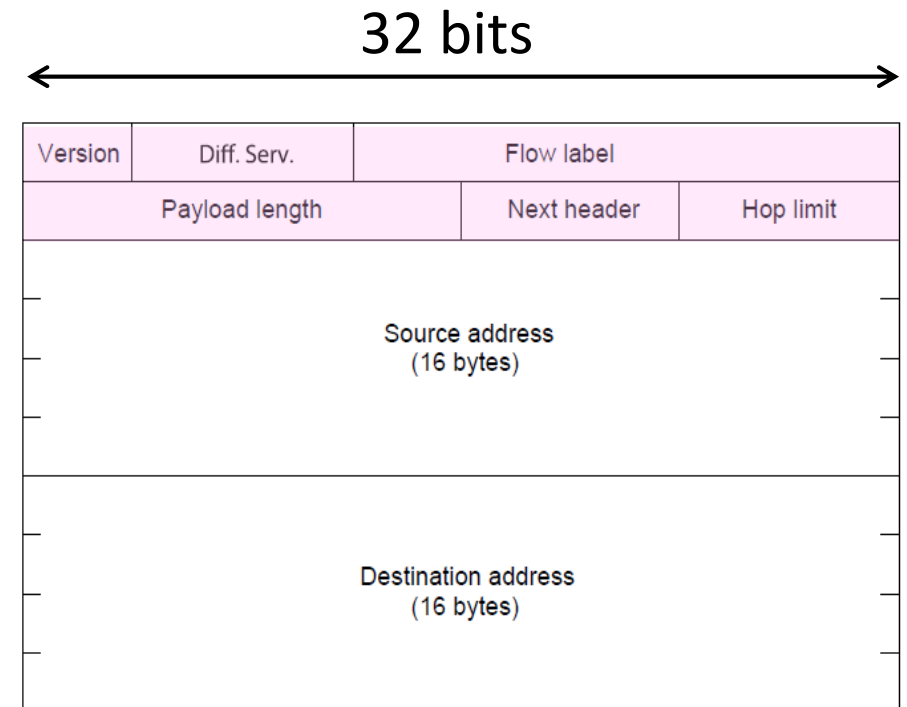
- Features large addresses
 - 128 bits, most of header
- New notation
 - 8 groups of 4 hex digits (16 bits)
 - Omit leading zeros, groups of zeros

Ex: 2001:0db8:0000:0000:0000:ff00:0042:8329
→ 2001:db8::ff00:42:8329



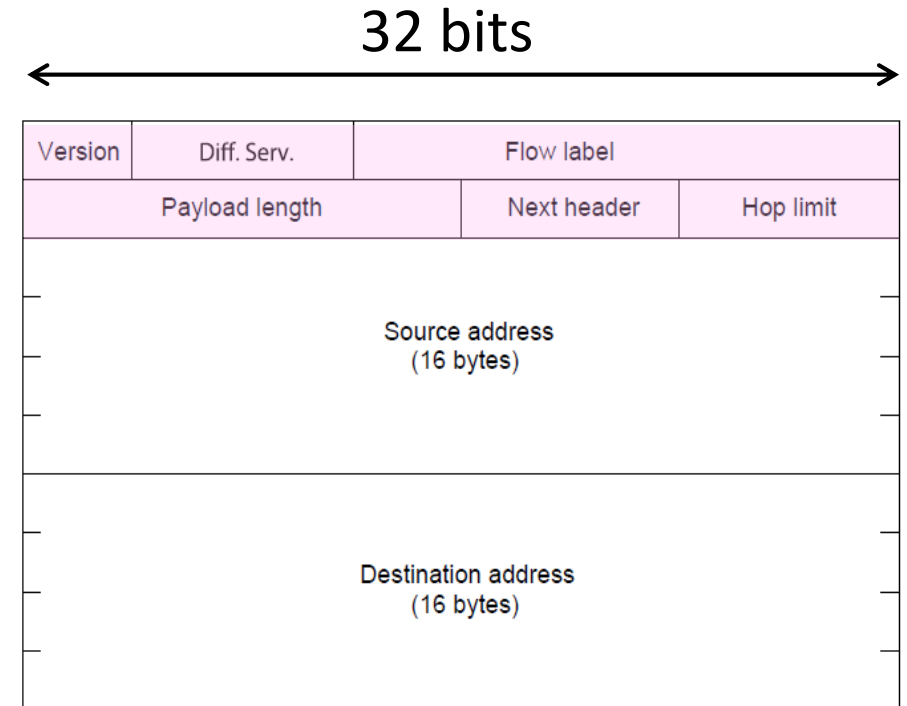
IPv6 (2)

- Lots of other changes
 - Only public addresses
 - No more NAT!
 - Streamlined header processing
 - No checksum (why's that faster?)
 - Flow label to group of packets
 - IPSec by default
 - Better fit with “advanced” features (mobility, multicasting, security)



IPv6 Stateless Autoconfiguration (SLAAC)

- Replaces DHCP (sorta...)
- Uses ICMPv6
- Process:
 - Send broadcast message
 - Get prefix from router
 - Attach MAC to router Prefix

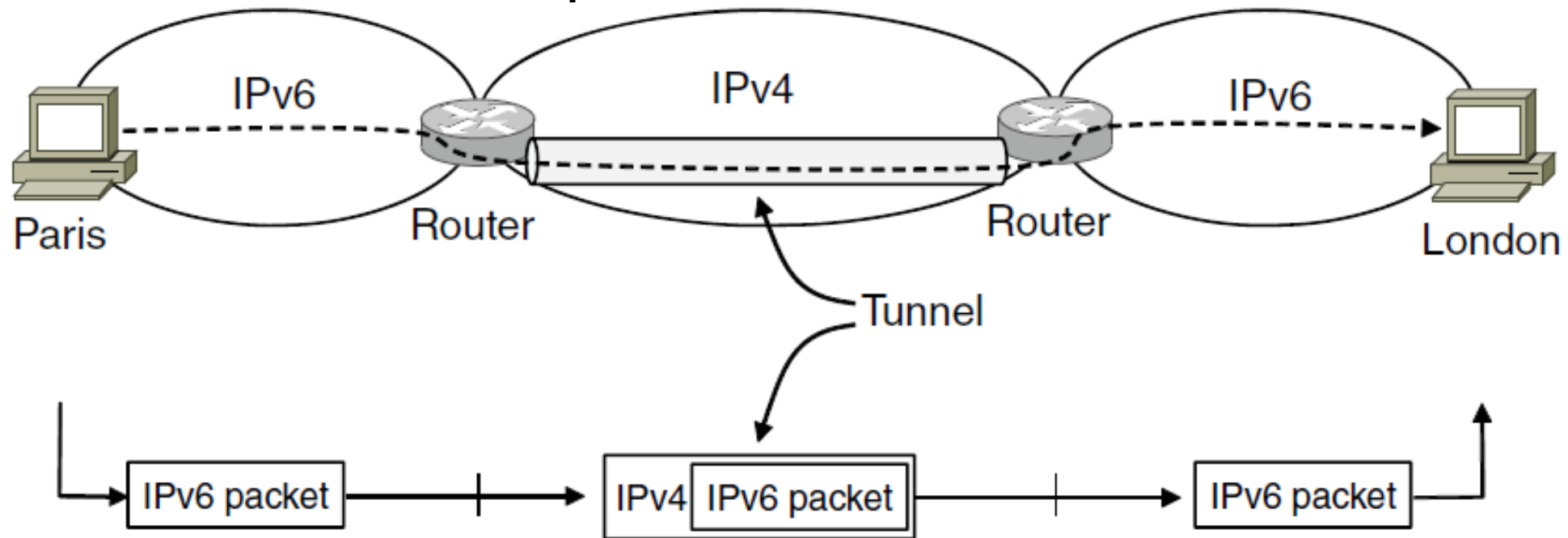


IPv6 Transition

- The Big Problem:
 - How to deploy IPv6?
 - Fundamentally incompatible with IPv4
- Dozens of approaches proposed
 - Dual stack (speak IPv4 and IPv6)
 - Translators (convert packets)
 - Tunnels (carry IPv6 over IPv4)

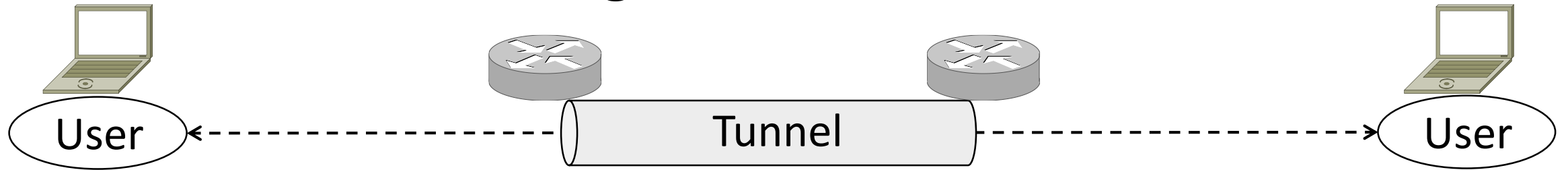
Tunneling

- Native IPv6 islands connected via IPv4
 - Tunnel carries IPv6 packets across IPv4 network



Tunneling (2)

- Tunnel acts as a single link across IPv4 network



Tunneling (3)

- Tunnel acts as a single link across IPv4 network
 - Difficulty is to set up tunnel endpoints and routing

