CSE 461: Computer networks

Spring 2021

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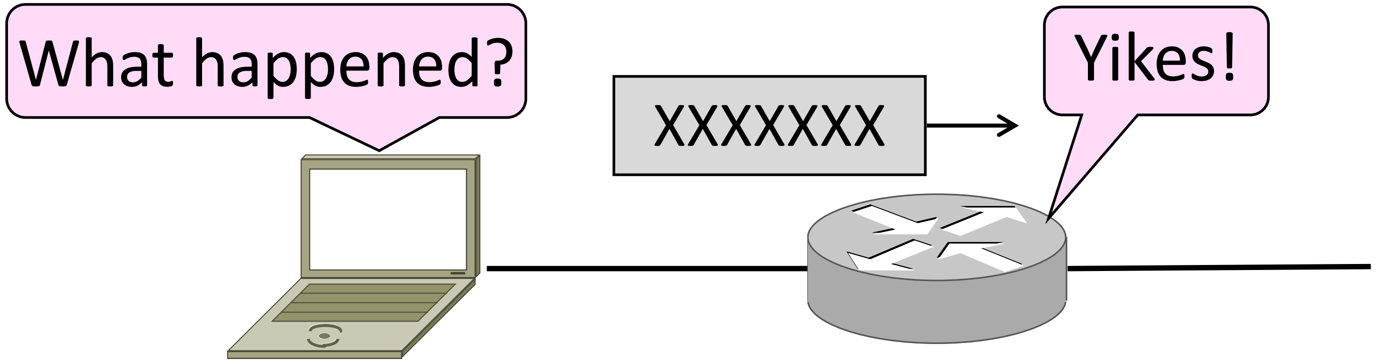
Internet Control Message Protocol (ICMP)

Topic

- Problem: What happens when something goes wrong during forwarding?
  - Need to be able to find the problem



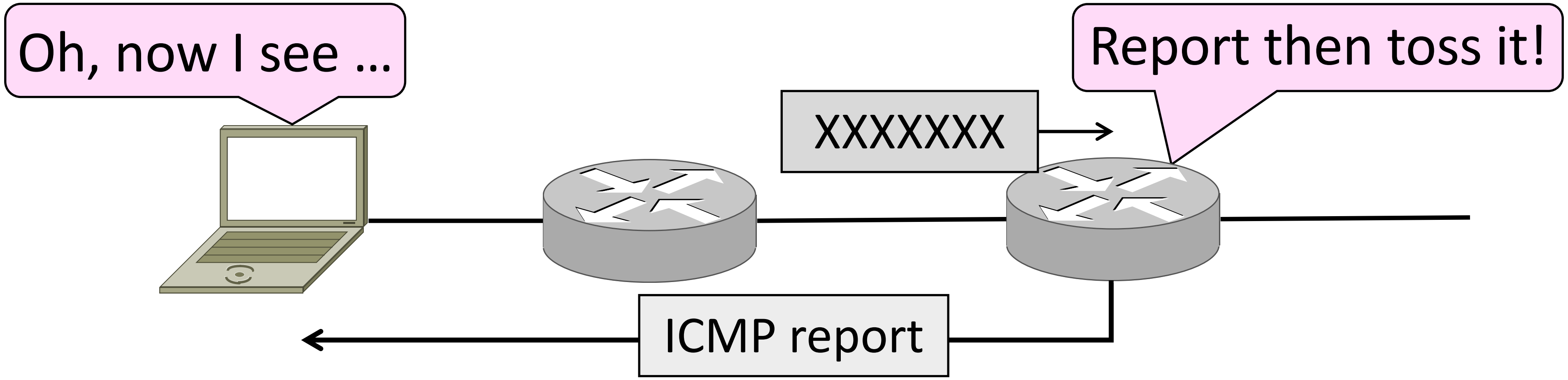
Internet Control Message Protocol

- ICMP is a companion protocol to IP
  - They are implemented together
  - Sits on top of IP (IP Protocol=1)

- Provides error report and testing
  - Error is at router while forwarding
  - Also testing that hosts can use

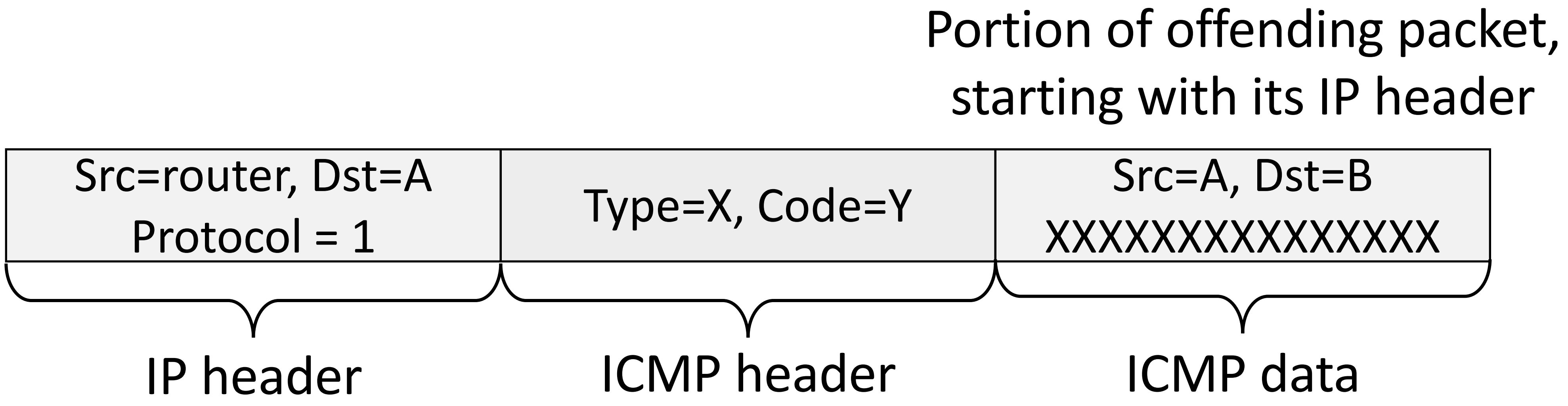
ICMP Errors

- When router encounters an error while forwarding:
  - It sends an ICMP error report back to the IP source
  - It discards the problematic packet; host needs to rectify



ICMP Message Format (2)

- Each ICMP message has a Type, Code, and Checksum
- Often carry the start of the offending packet as payload
- Each message is carried in an IP packet



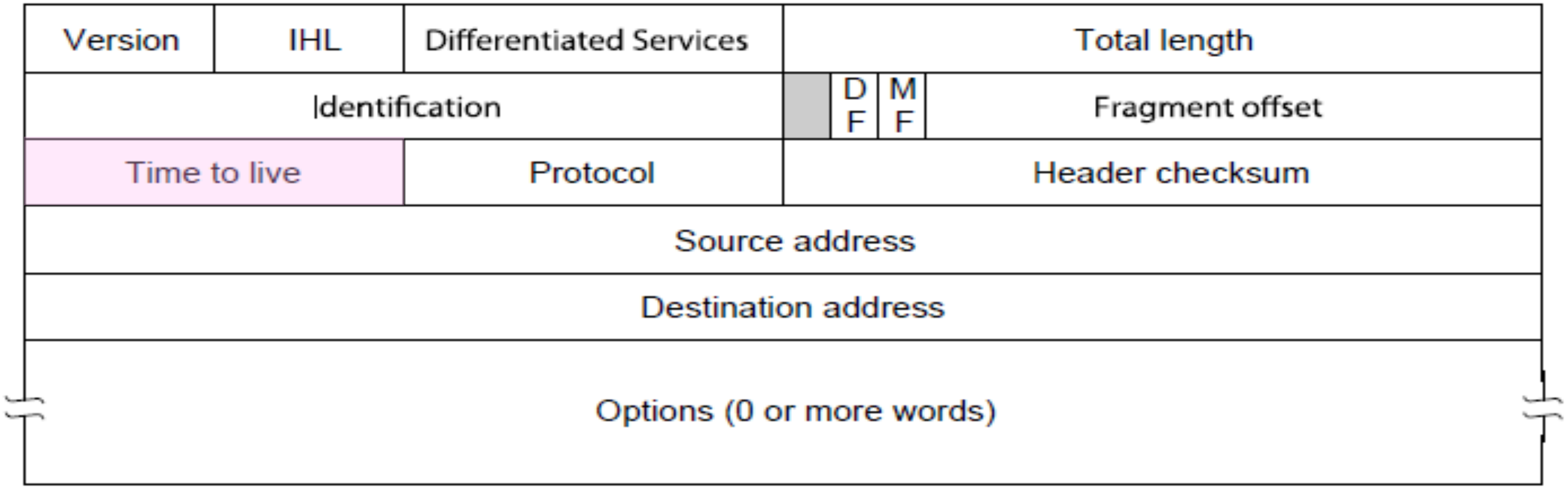
Example ICMP Messages

Name	Type / Code	Usage
Dest. Unreachable (Net or Host)	3 / 0 or 1	Lack of connectivity
Dest. Unreachable (Fragment)	3 / 4	Path MTU Discovery
Time Exceeded (Transit)	11 / 0	Traceroute
Echo Request or Reply	8 or 0 / 0	Ping

Testing, not a forwarding error: Host sends Echo Request, and destination responds with an Echo Reply

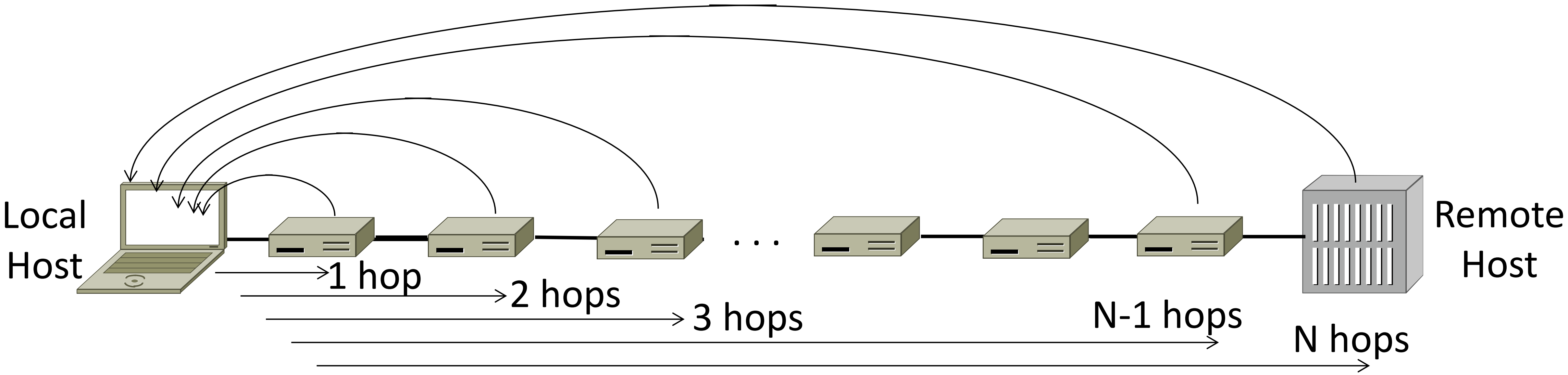
Traceroute

- IP header contains TTL (Time to live) field
  - Decremented every router hop, with ICMP error at zero
  - Protects against forwarding loops



Traceroute (2)

- Traceroute repurposes TTL and ICMP functionality
  - Sends probe packets increasing TTL starting from 1
  - ICMP errors identify routers on the path



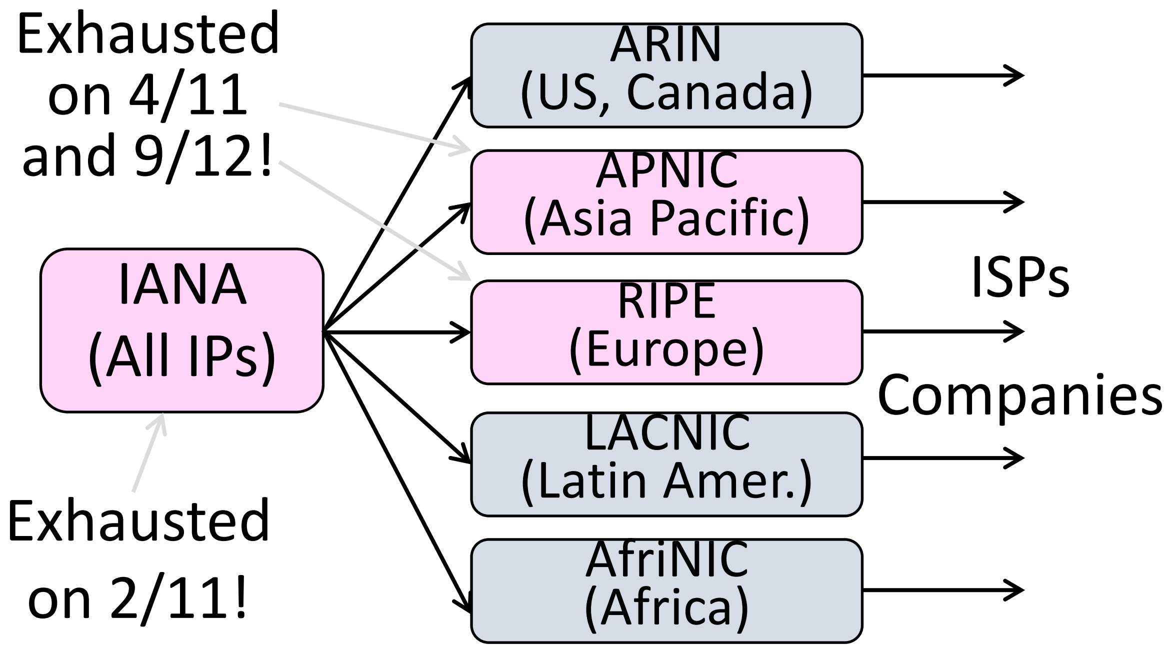
Network Address Translation (NAT)

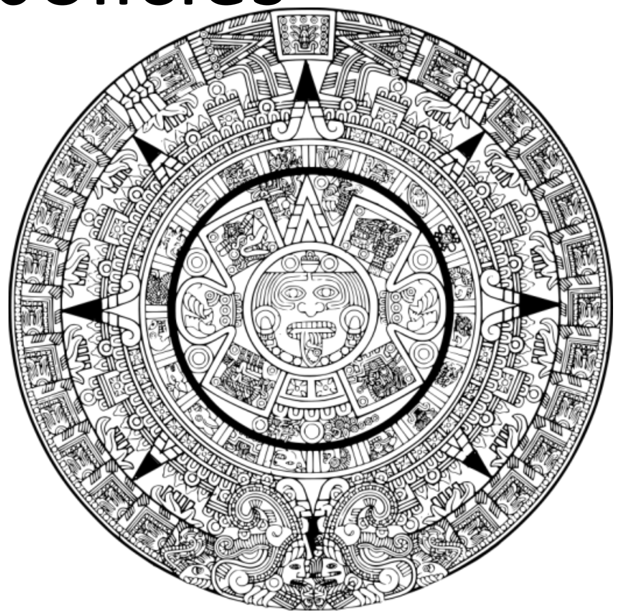
Problem: Internet Growth

- Today, Internet connects
  - 4B people
  - ~50B devices
- And we’re using 32-bit addresses!
  - ~2B unique addresses

The End of New IPv4 Addresses

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





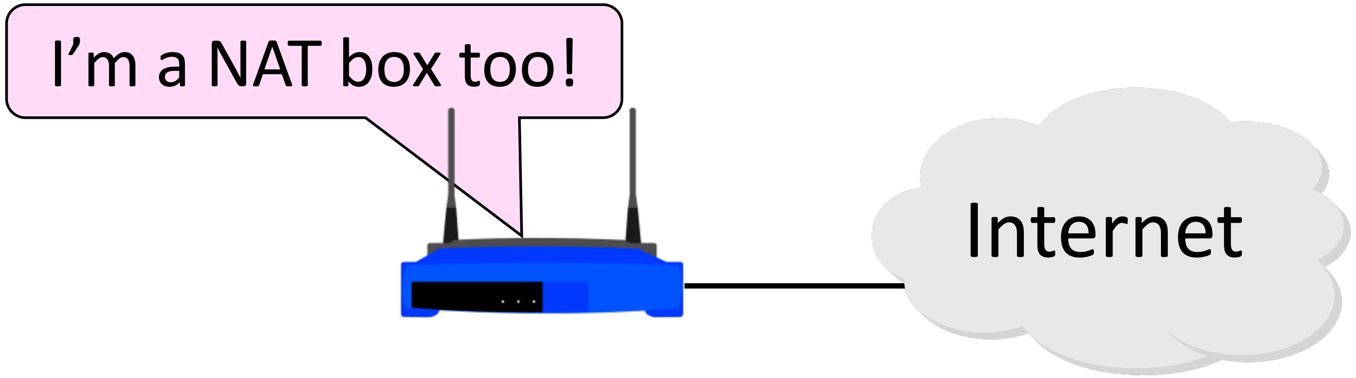
End of the world ? 12/21/12?

A market for IPv4 addresses

https://auctions.ipv4.global/prior-sales

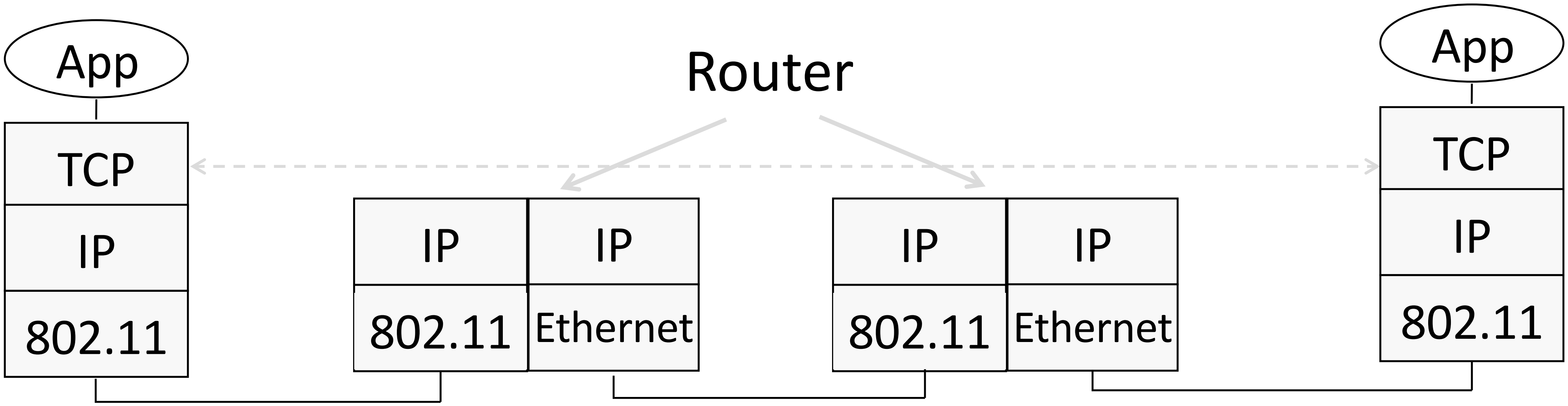
Solution 1: Network Address Translation (NAT)

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



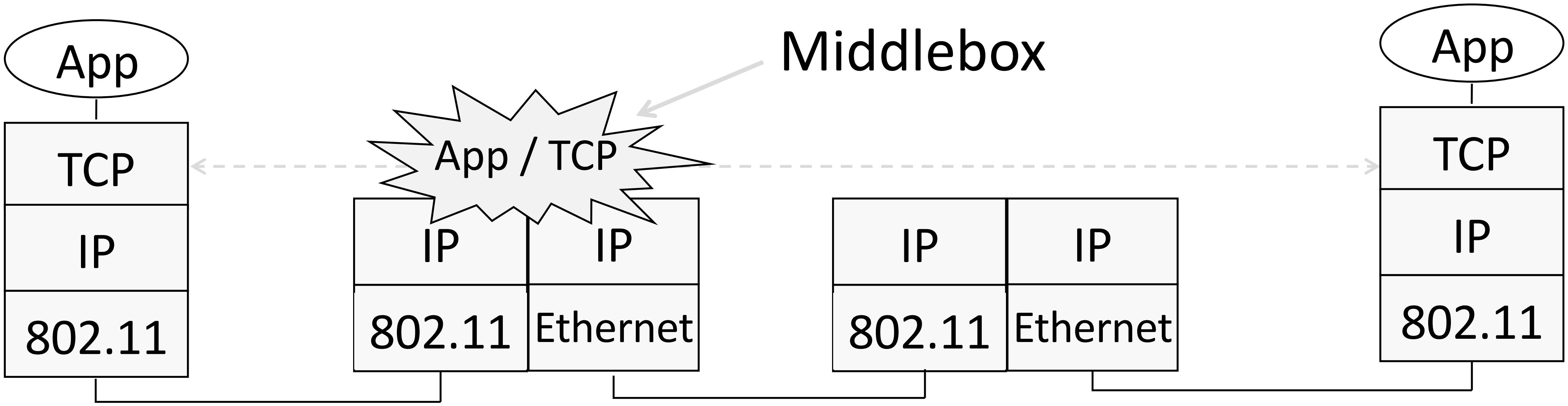
Layering Review

- 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)

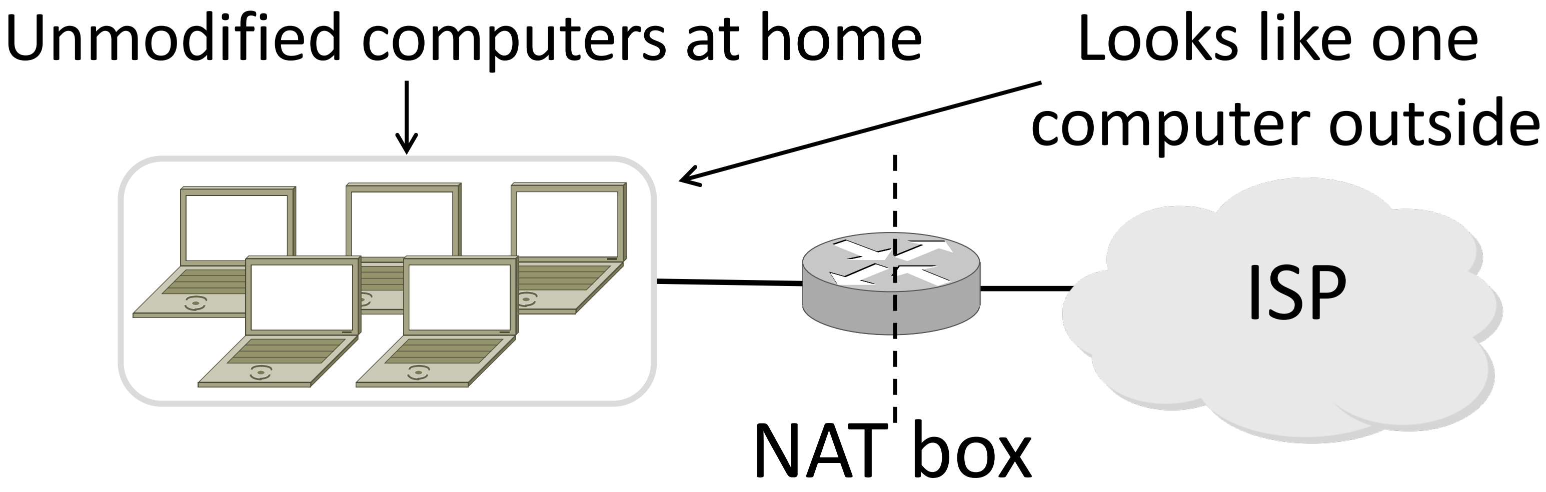
- Advantages
  - A possible rapid deployment path when no other option
  - Control over many hosts (IT)
- Disadvantages
  - Breaking layering interferes with connectivity
    - strange side effects
  - Poor vantage point for many tasks

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

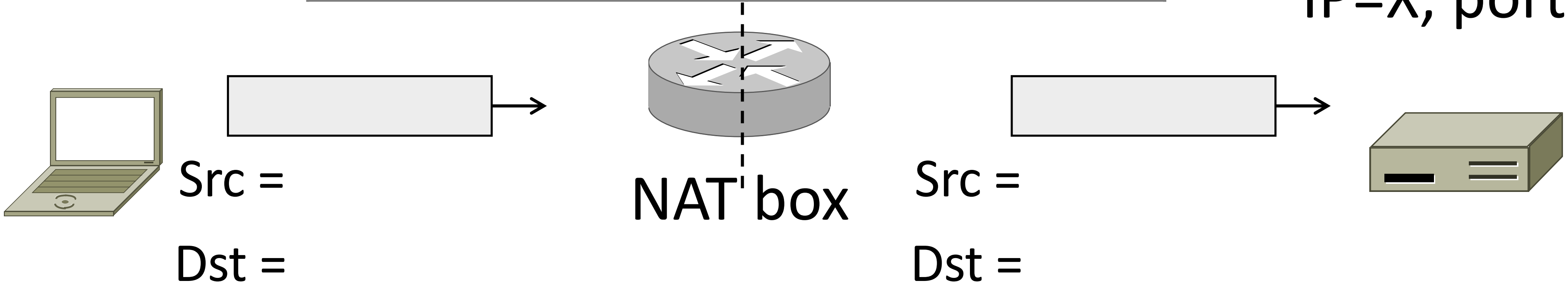
How NAT Works (2)

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

Internal source

Internal IP:port	External IP : port
192.168.1.12 : 5523	44.25.80.3 : 1500

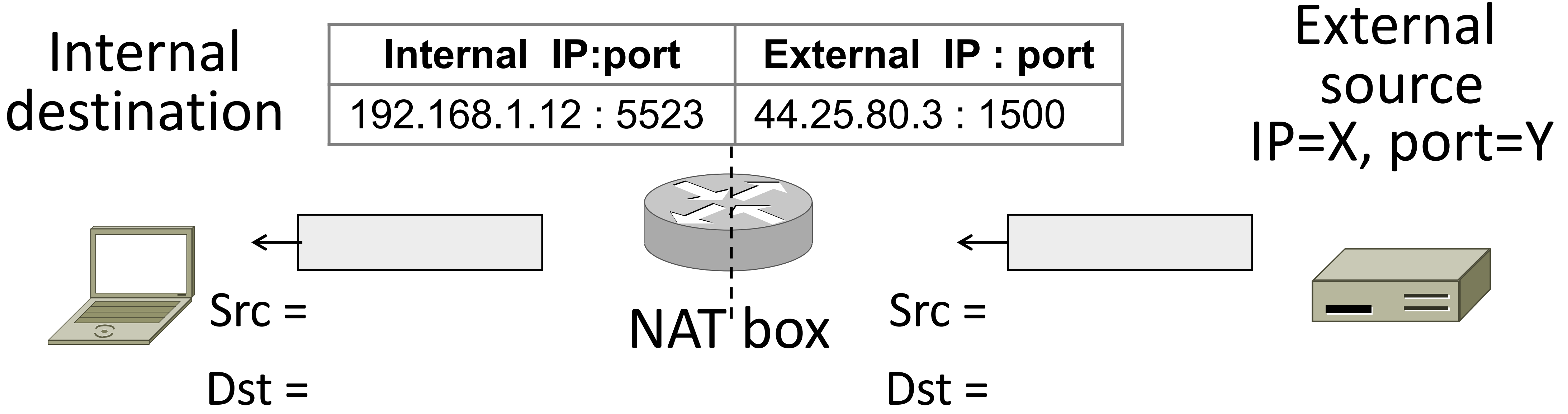
External destination IP=X, port=Y



How NAT Works (3)

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

Internal IP:port	External IP : port
192.168.1.12 : 5523	44.25.80.3 : 1500



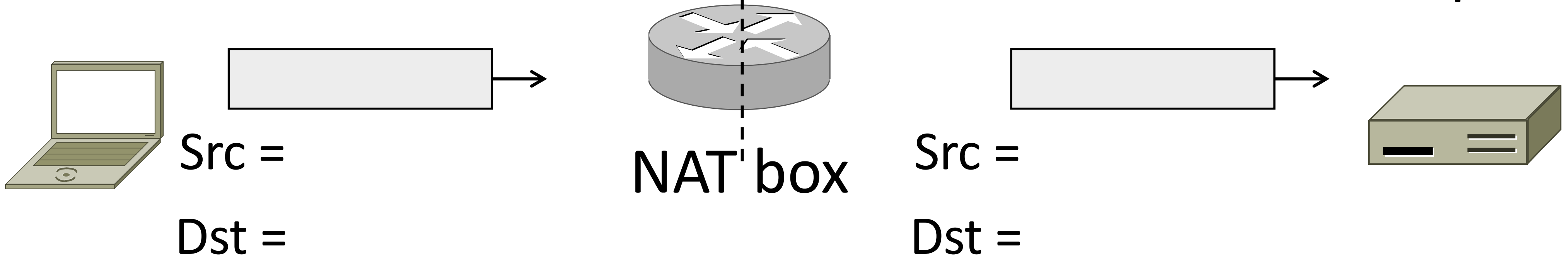
How NAT Works (4)

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

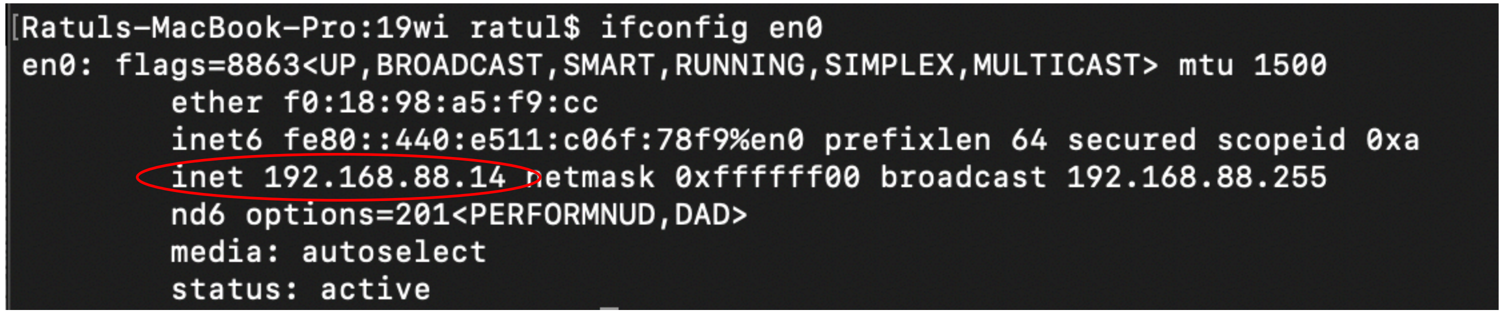
Internal source

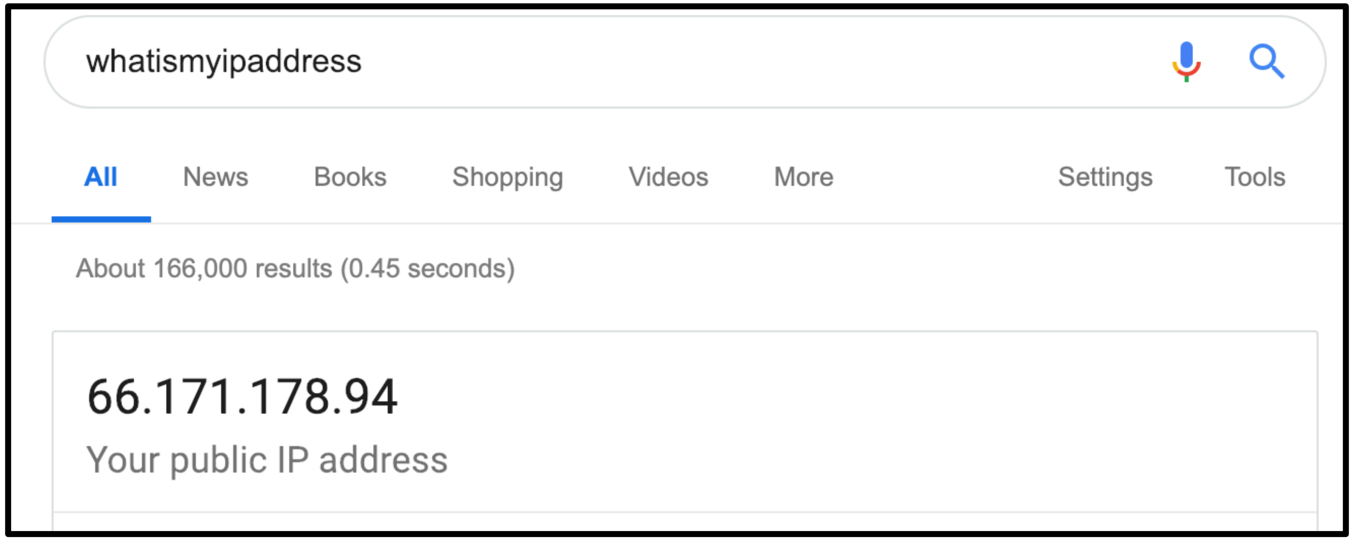
Internal IP:port	External IP : port
192.168.1.12 : 5523	

External destination IP=X, port=Y



NAT in action





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 if return traffic by passes the NAT
- 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

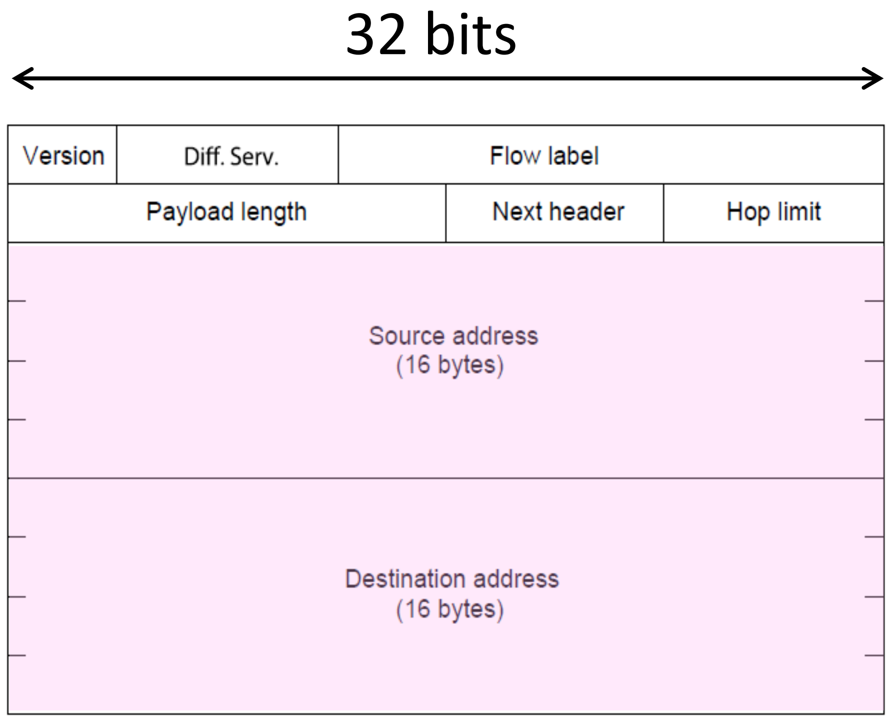
IPv6

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

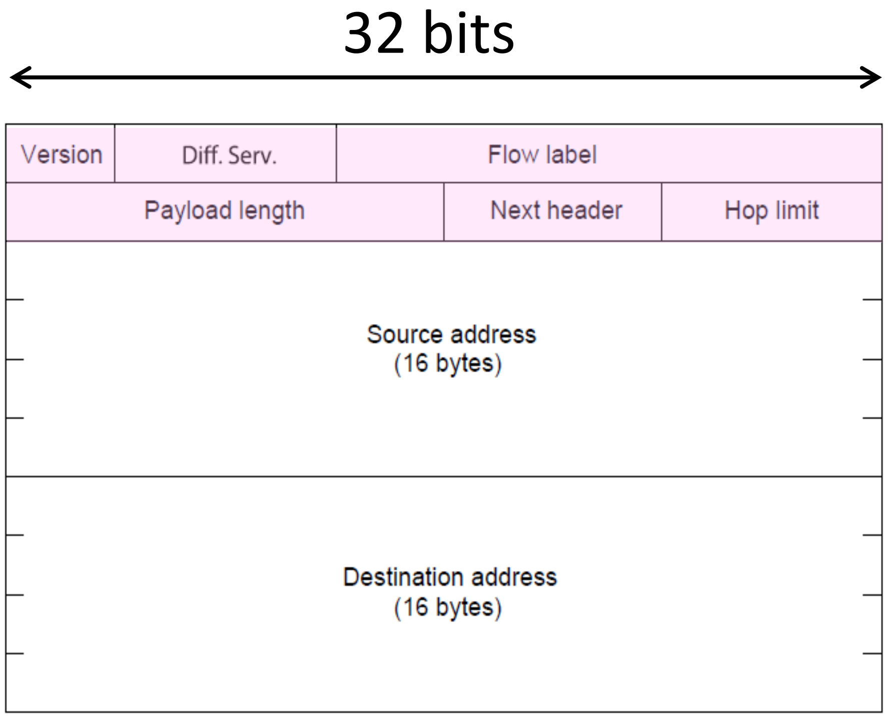


Ex: 2001:0db8:0000:0000:0000:ff00:0042:8329

→ 2001:db8::ff00:42:8329

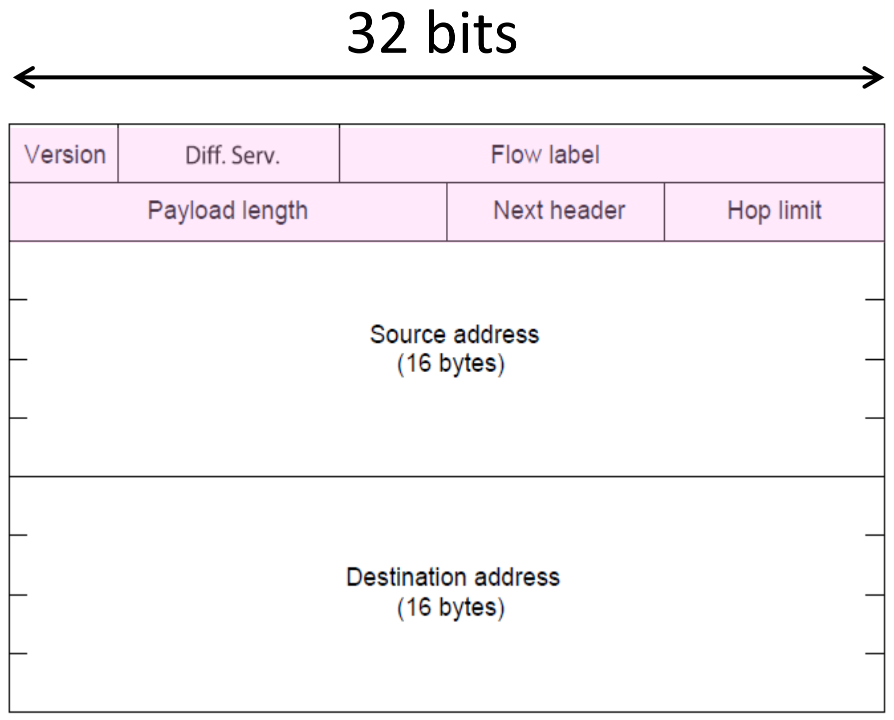
IPv6 (2)

- 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

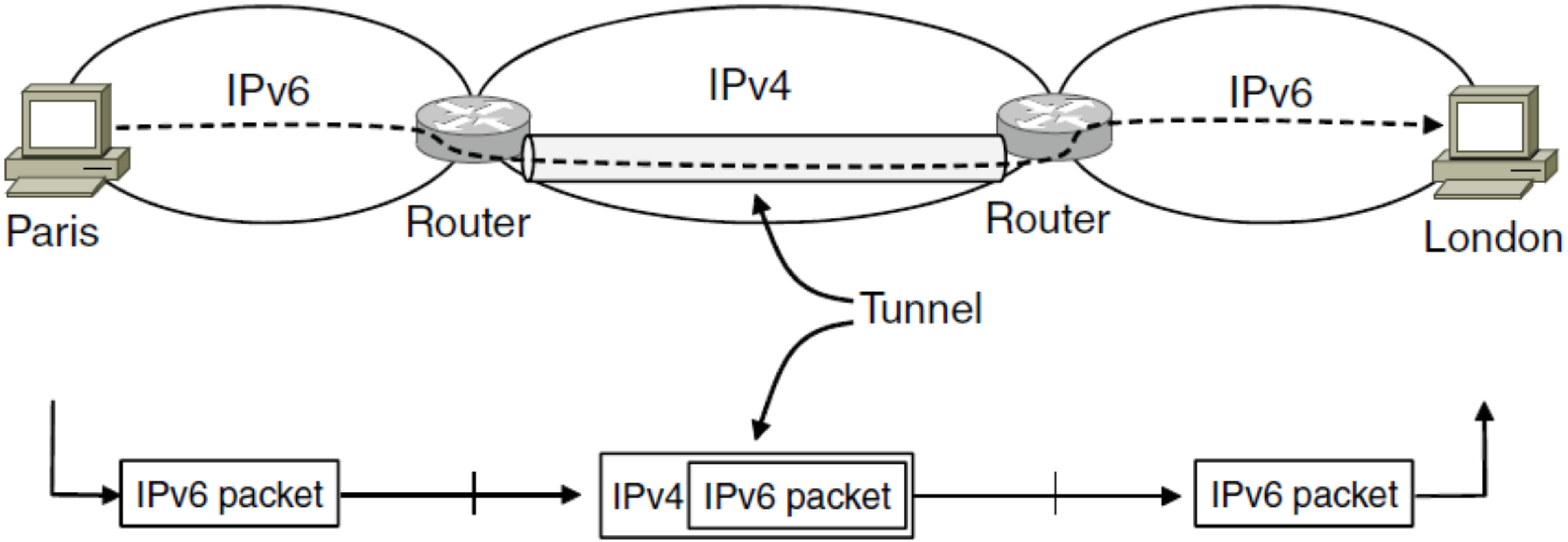


IPv6 Transition

- 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)

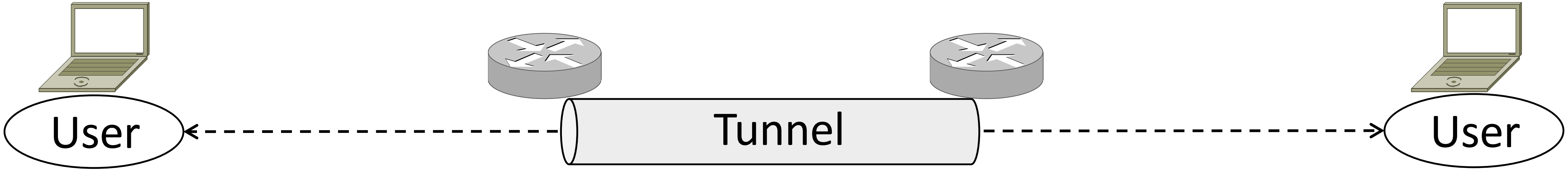
Tunneling

- 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