Computer Networks
COL 334/672

IPv4 and IPv6 Packets, and NAT

Slides adapted from KR

Sem 1, 2025-26

Quiz on Moodle (not Moodlenew)
Password: wattlebird

Recap

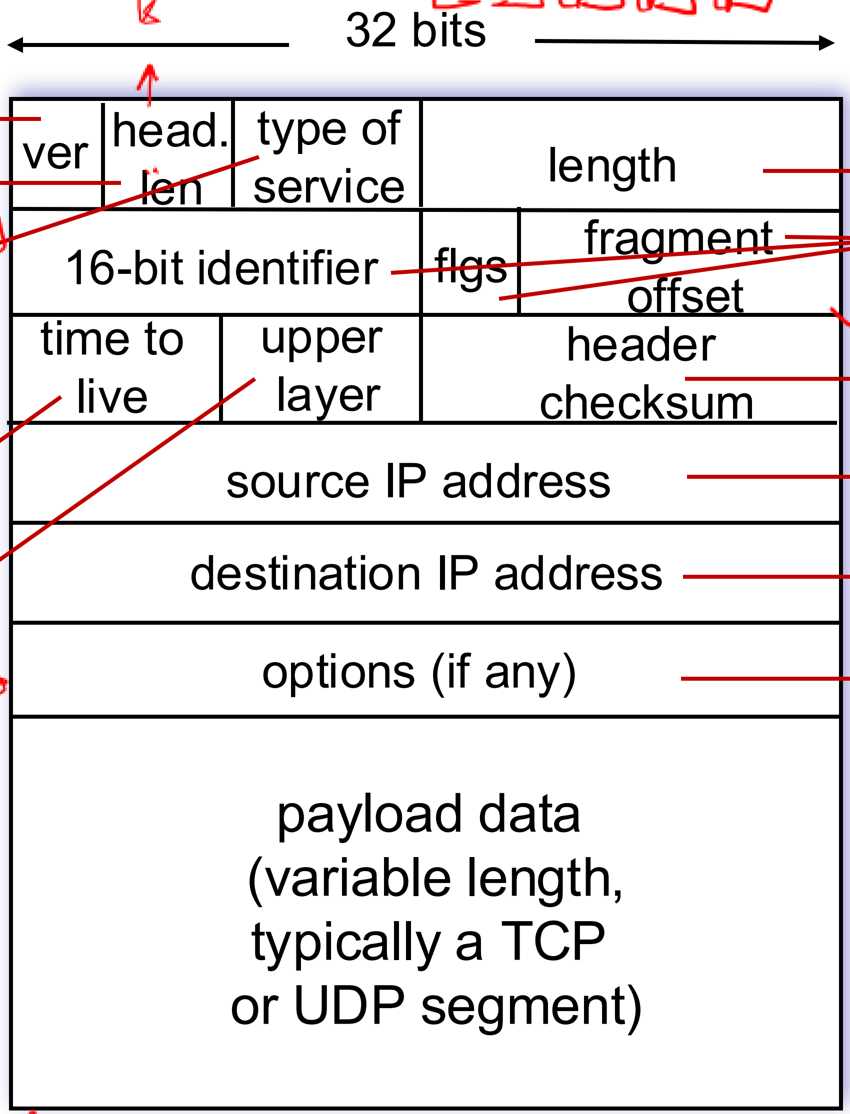
- Control plane functions
  - Inter-domain vs intra-domain routing
- Data plane functions
  - Prefix lookup
  - Switching
  - Buffering
  - Scheduling ..
- Today's lecture: We will meet the IPv4 and IPv6 packets

IPv4 Datagram Format

Subnet

2000 byte

Maximum Transmission Unit is 100 byte



IP protocol version number

header length (bytes)

4

K x 4 bytes

{0...15}

"type" of service:

- diffserv (0:5)
- ECN (6:7)

Explicit Congestion Notification

TTL: remaining max hops (decremented at each router)

upper layer protocol (e.g., TCP or UDP)

6 17

overhead

- 20 bytes of fixed headers
- Upto 40 bytes of options (rarely used)

payload

total datagram length (bytes)

2^{16}

including payload

fragmentation/reassembly

header checksum

32-bit source IP address

Maximum length: 64K bytes

Typically: 1500 bytes or less

e.g., timestamp, record route taken

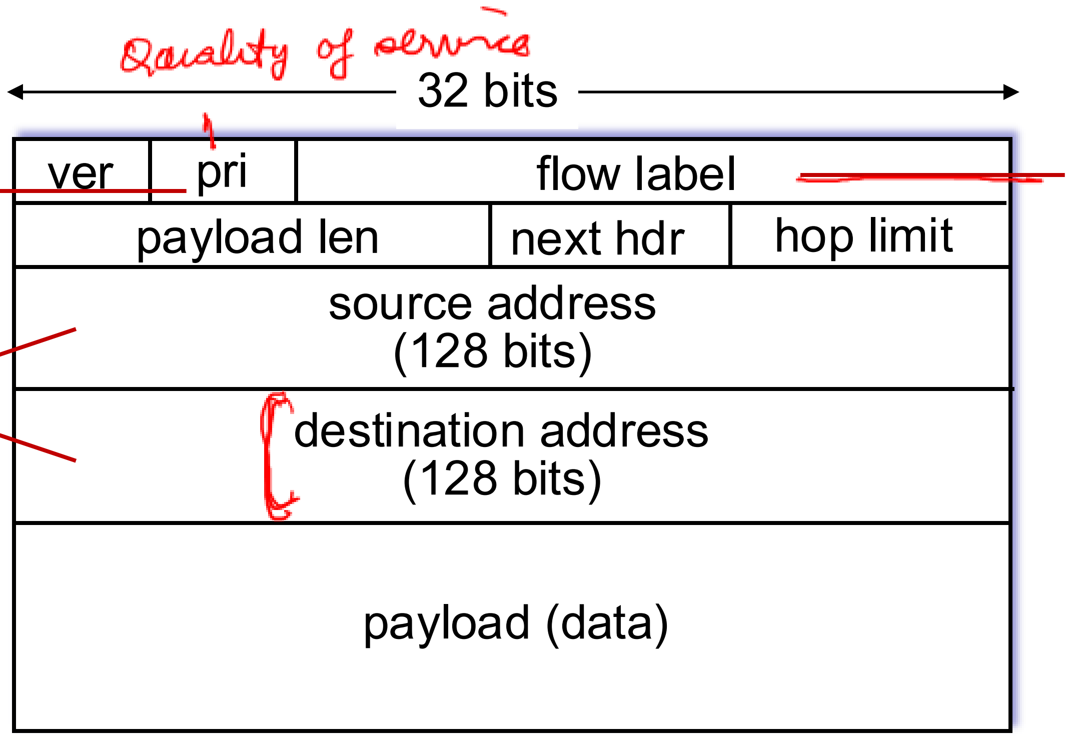
Need For More Addresses

- IPv6 was introduced to overcome IPv4’s limited address space
- Uses 128-bit addresses
- Also uses a simplified header structure

IPv6 datagram format

priority: identify priority among datagrams in flow

128-bit IPv6 addresses



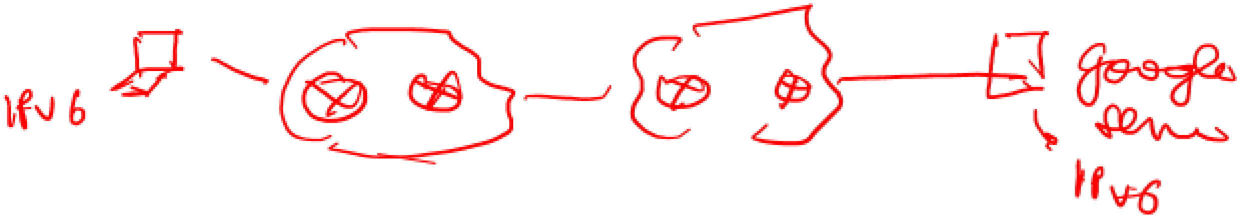
flow label: identify datagrams in same "flow." (concept of "flow" not well defined).

What's missing (compared with IPv4):

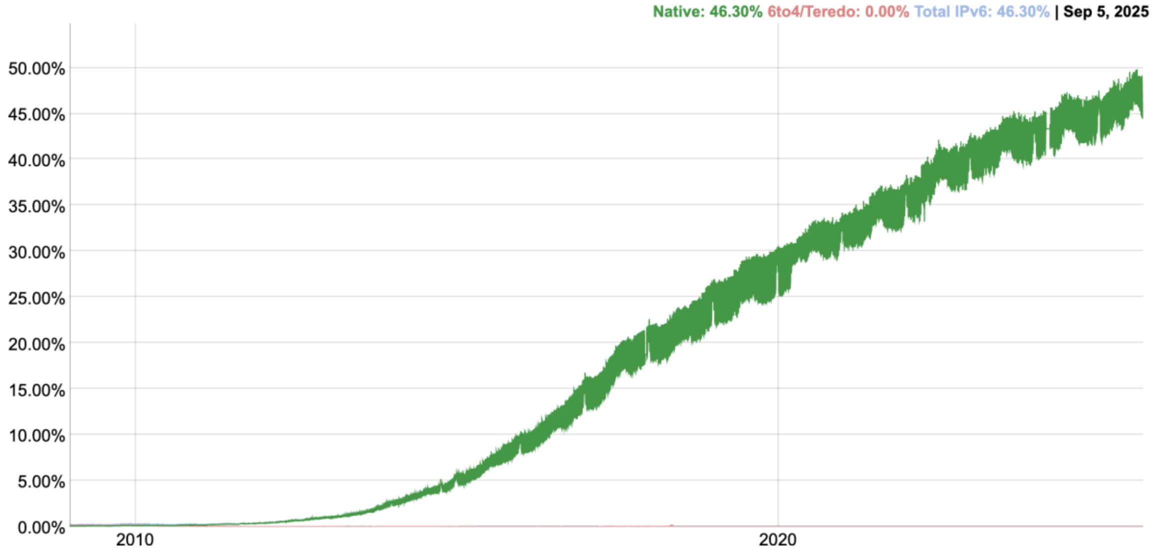
- no checksum (to speed processing at routers)
- no fragmentation/reassembly (let the host figure it out)
- no options (available as upper-layer, next-header protocol at router)

Is IPv6 simply a software upgrade for routers?

IPv6 adoption



- Google[1]: 46% of clients access services via IPv6 (2024)
- India tops the world in IPv6 adoption rates (73% adoption)

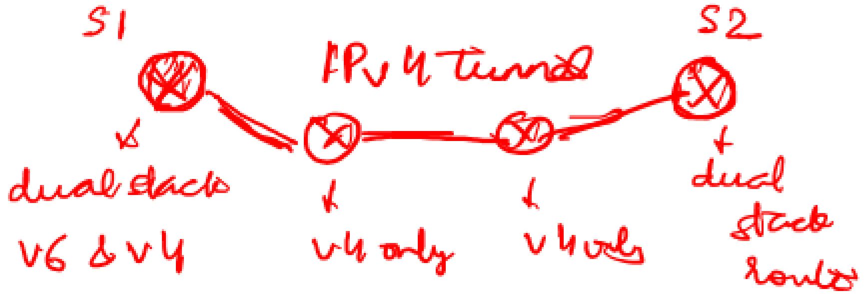


Shouldn't all routers in the network path need to be IPv6 compatible for this to work?

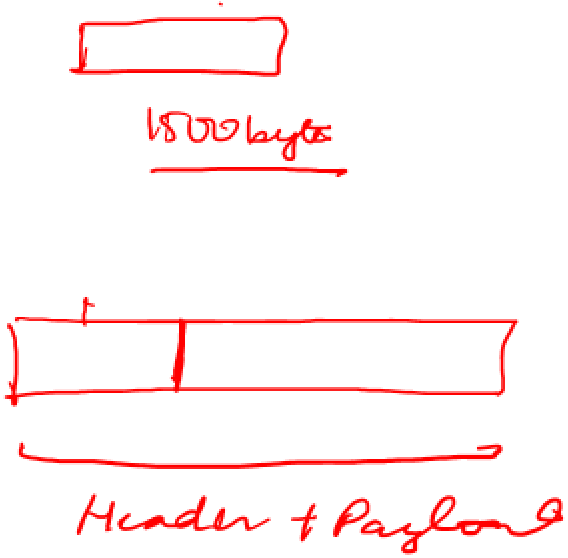
How to make do with limited IPv4 addresses?

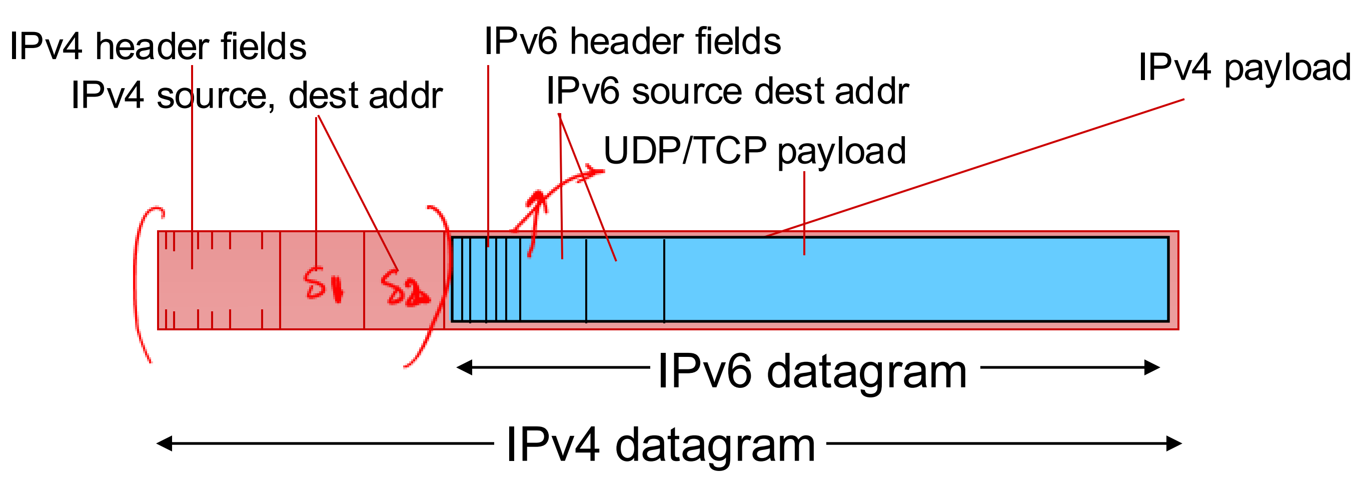
IPv4 tunneling

Transition from IPv4 to IPv6



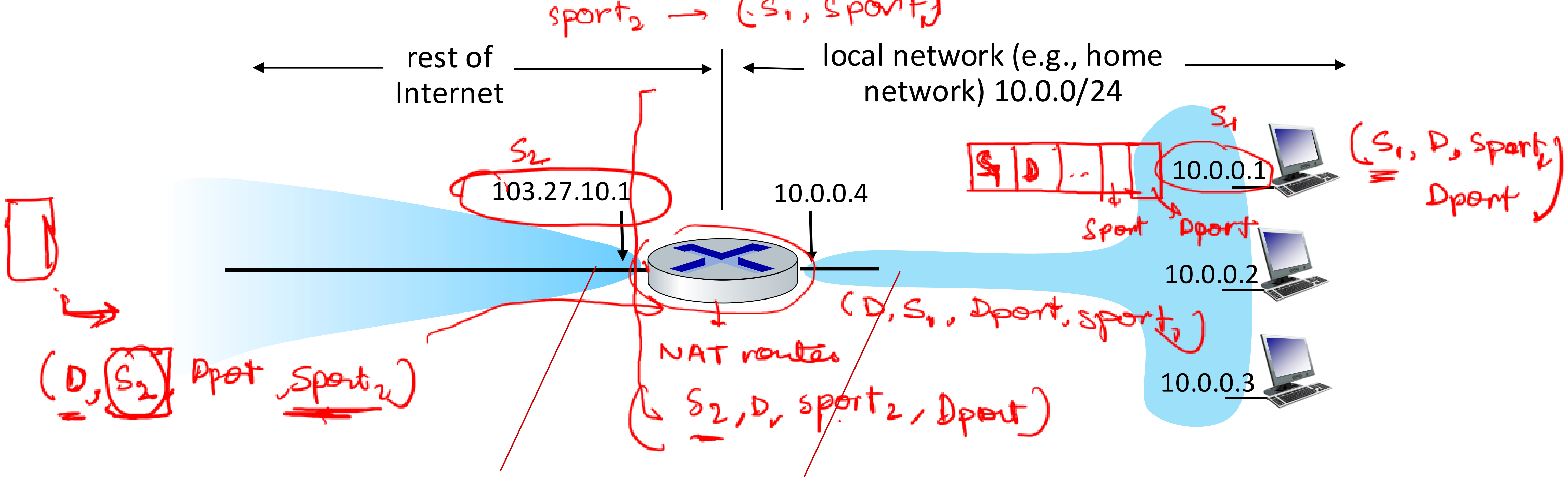
- Operate with mixed IPv4 and IPv6 routers
- tunneling: IPv6 datagram carried as *payload* in IPv4 datagram among IPv4 routers ("packet within a packet")
  - tunneling used extensively in other contexts (4G/5G)





NAT: network address translation

NAT: all devices in local network share just **one** IPv4 address as far as outside world is concerned



all datagrams *leaving* local network have *same* source NAT IP address: 103.27.10.1,

datagrams with source or destination in this network have 10.0.0/24 address for source, destination (as usual)

NAT: network address translation

implementation: NAT router must (transparently):

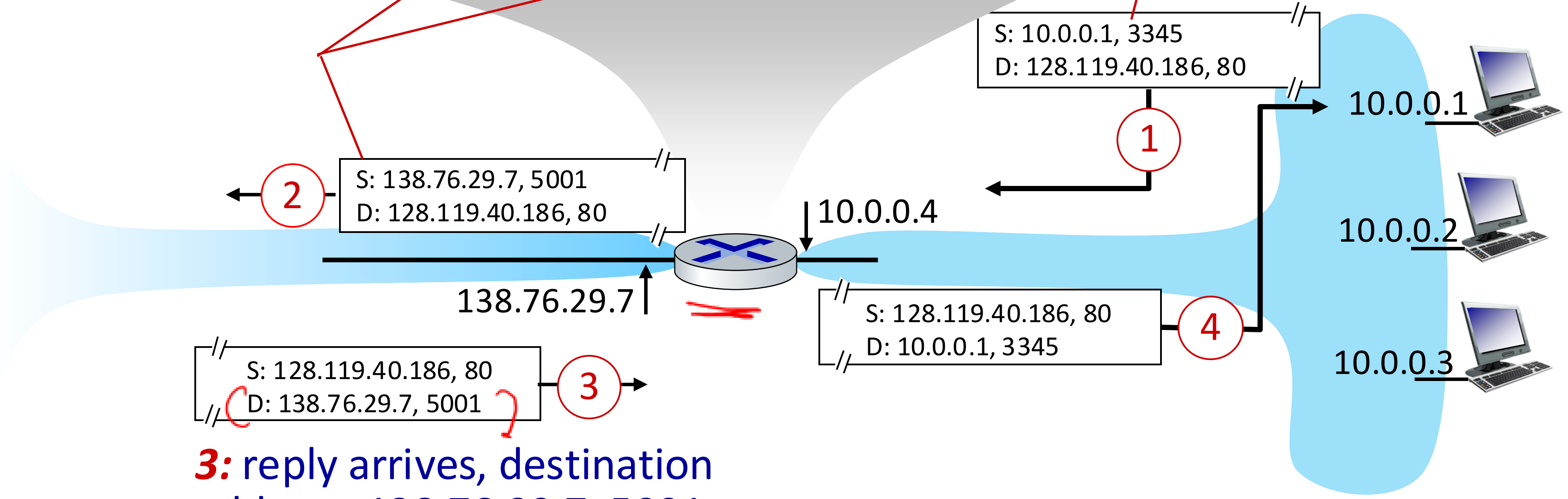
- outgoing datagrams: replace (source IP address, port #) of every outgoing datagram to (NAT IP address, new port #)
  - remote clients/servers will respond using (NAT IP address, new port #) as destination address
- remember (in NAT translation table) every (source IP address, port #) to (NAT IP address, new port #) translation pair
- incoming datagrams: replace (NAT IP address, new port #) in destination fields of every incoming datagram with corresponding (source IP address, port #) stored in NAT table

NAT: network address translation

2: NAT router changes datagram source address from 10.0.0.1, 3345 to 138.76.29.7, 5001, updates table

NAT translation table	
WAN side addr	LAN side addr
138.76.29.7, 5001	10.0.0.1, 3345
138.76.29.7, 5002	10.0.0.2, 3346

1: host 10.0.0.1 sends datagram to 128.119.40.186, 80



3: reply arrives, destination address: 138.76.29.7, 5001

NAT: network address translation

End-to-end principle / Separation of concern

- NAT has been controversial:
  - violates an important design principle of the Internet
  - routers "should" only process up to layer 3 (port # manipulation by network-layer device)
  - Ideally, address "shortage" should be solved by IPv6
  - NAT traversal: what if client wants to connect to server behind NAT?
- but NAT is here to stay:
  - extensively used in home and institutional nets, 4G/5G cellular nets

NAT

Middleboxes

Proxy server / VPN server / Firewall / Cache

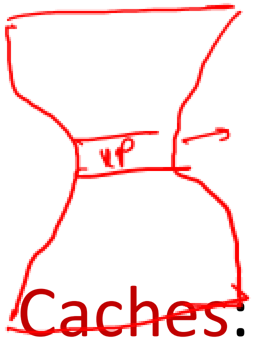
NAT is an example of middlebox

Middlebox (RFC 3234)

"any intermediary box performing functions apart from normal, standard functions of an IP router on the data path between a source host and destination host"

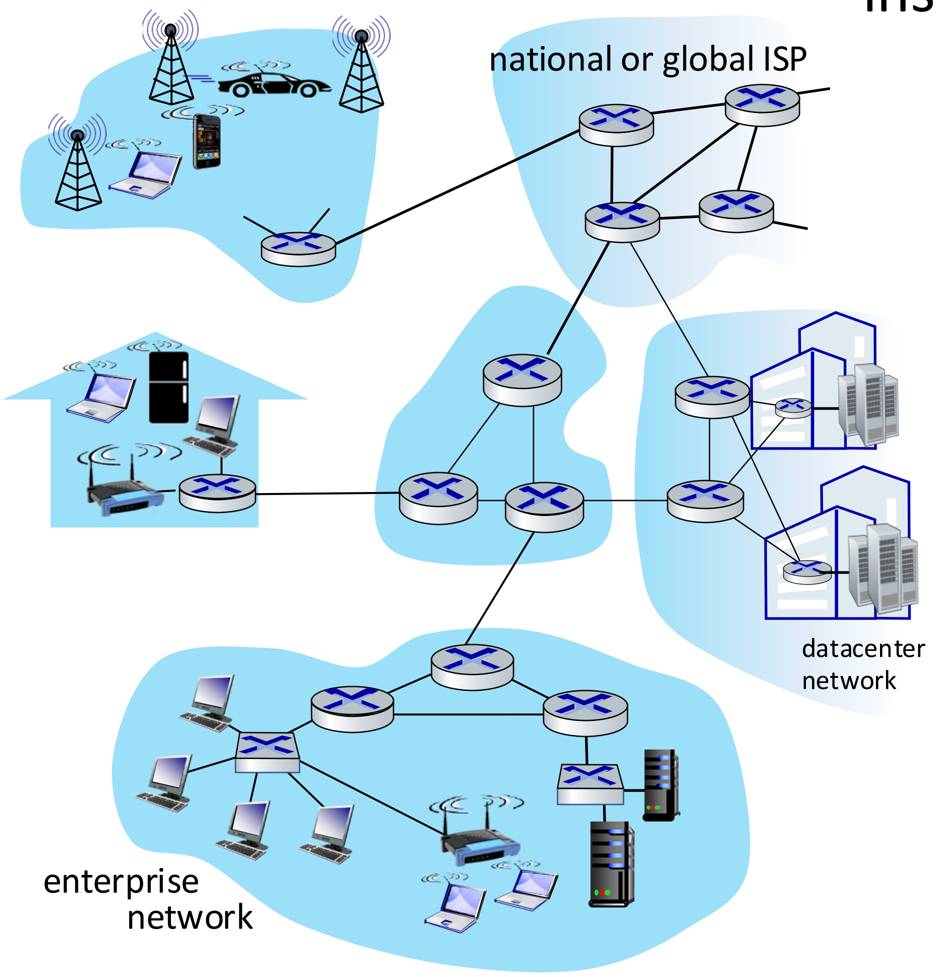
Middleboxes everywhere!

NAT: home, cellular, institutional



Routing & forwarding

Caches: service provider, mobile, CDNs



Firewalls, IDS: corporate, institutional, service providers, ISPs

Load balancers: corporate, service provider, data center, mobile nets

Summary

- IPv4 header structure
- Major limitation with IPv4: limited address space
- IPv6 introduced as a solution with 128 bit addresses
  - But needs everyone in the Internet to upgrade routers
- Till then, makeshift solutions
  - IPv6 to IPv4 tunneling
  - NAT (e.g., of a middlebox)