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DHCP, DNS, NAT, Congestion Control, Resource Allocation

18 January 2026
Lecture 12

Topics for Today

- Glue Protocols
  - DHCP
  - DNS
  - NAT
- Resource Allocation

- Sources:
  - DHCP: PD 3.2.7
  - DNS: PD 9.3.1
  - NAT: PD 4.3
  - Congestion Control PD 6.1-6.2

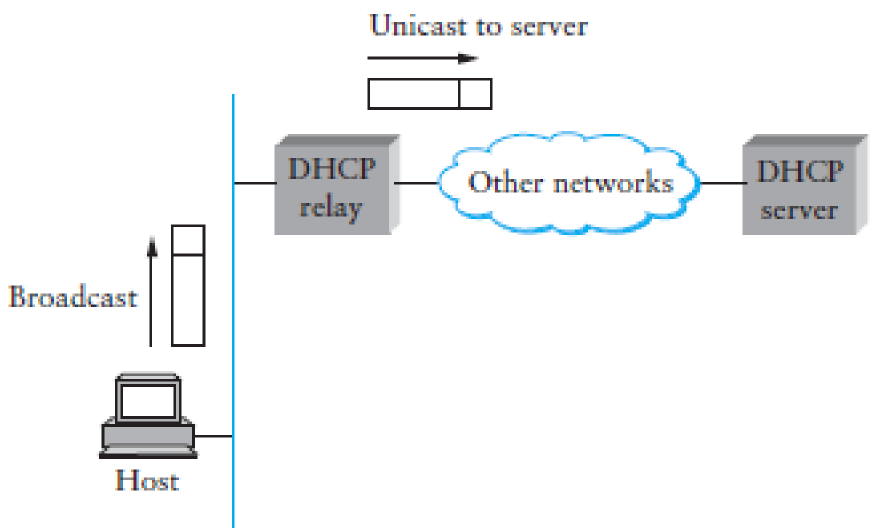
Dynamic Host Configuration Protocol (DHCP)

Goal: Enable computers to get IP addresses dynamically

– For a limited time

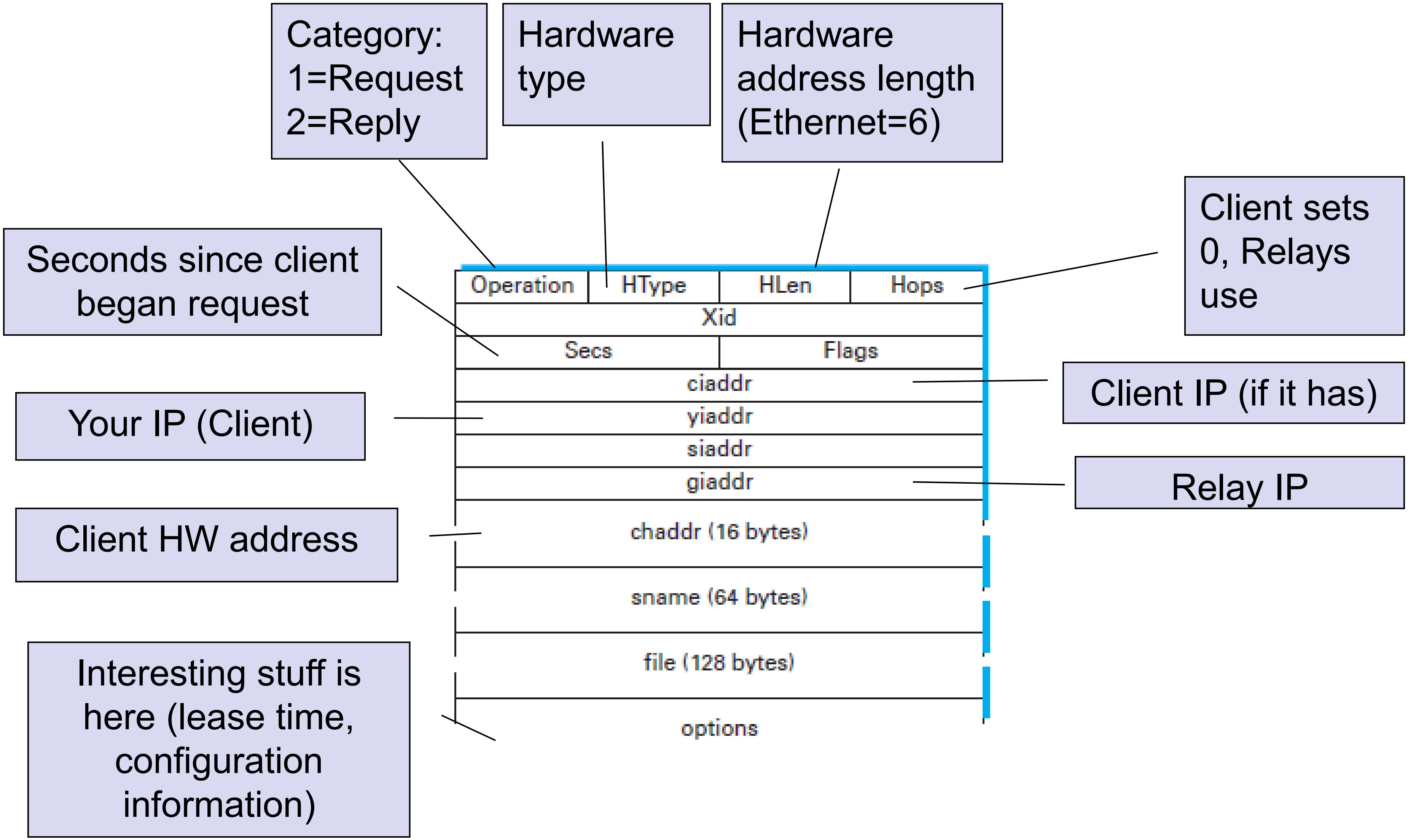
Steps:

1. Client broadcasts DHCP Discover message
2. Servers respond DHCP Offer messages
3. Client sends one DHCP Request (chooses)
4. Chosen DHCP server sends DHCP ACK
5. Work.
6. Client sends DHCP Release
7. Server forgets client



To request an old address, skip 1-2

DHCP Fields



Category: 1=Request 2=Reply
Hardware type
Hardware address length (Ethernet=6)
Client sets 0, Relays use
Seconds since client began request
Your IP (Client)
Client HW address
Interesting stuff is here (lease time, configuration information)
Client IP (if it has)
Relay IP
Operation
HType
HLen
Hops
Xid
Secs
Flags
ciaddr
yiaddr
siaddr
giaddr
chaddr (16 bytes)
sname (64 bytes)
file (128 bytes)
options

DHCP Sample Trace

No.	Time	Source	Destination	Protocol	Length	Info
3	4.357459000	10.0.0.12	10.0.0.138	DHCP	342	DHCP Release - Transaction ID 0xb61cd97f
4	7.490334000	0.0.0.0	255.255.255.255	DHCP	342	DHCP Discover - Transaction ID 0x7983fd04
5	7.506559000	10.0.0.138	10.0.0.12	DHCP	316	DHCP Offer - Transaction ID 0x7983fd04
6	7.506973000	0.0.0.0	255.255.255.255	DHCP	344	DHCP Request - Transaction ID 0x7983fd04
7	7.532959000	10.0.0.138	10.0.0.12	DHCP	316	DHCP ACK - Transaction ID 0x7983fd04

```
⊞ User Datagram Protocol, Src Port: 67 (67), Dst Port: 68 (68)
⊟ Bootstrap Protocol (Offer)
    Message type: Boot Reply (2)
    Hardware type: Ethernet (0x01)
    Hardware address length: 6
    Hops: 0
    Transaction ID: 0x7983fd04
    Seconds elapsed: 0
  ⊞ Bootp flags: 0x0000 (Unicast)
    Client IP address: 0.0.0.0 (0.0.0.0)
    Your (client) IP address: 10.0.0.12 (10.0.0.12)
    Next server IP address: 0.0.0.0 (0.0.0.0)
    Relay agent IP address: 0.0.0.0 (0.0.0.0)
    Client MAC address: Dell_         (44:                 )
    Client hardware address padding: 00000000000000000000
    Server host name not given
    Boot file name not given
    Magic cookie: DHCP
  ⊞ Option: (53) DHCP Message Type (Offer)
  ⊞ Option: (54) DHCP Server Identifier
  ⊟ Option: (51) IP Address Lease Time
      Length: 4
      IP Address Lease Time: (3600s) 1 hour
  ⊟ Option: (1) Subnet Mask
      Length: 4
      Subnet Mask: 255.255.255.0 (255.255.255.0)
  ⊟ Option: (3) Router
      Length: 4
      Router: 10.0.0.138 (10.0.0.138)
  ⊟ Option: (6) Domain Name Server
      Length: 4
      Domain Name Server: 10.0.0.138 (10.0.0.138)
  ⊞ Option: (255) End
```

So Far

- Glue Protocols
  - DHCP
  - DNS
  - NAT
- Resource Allocation

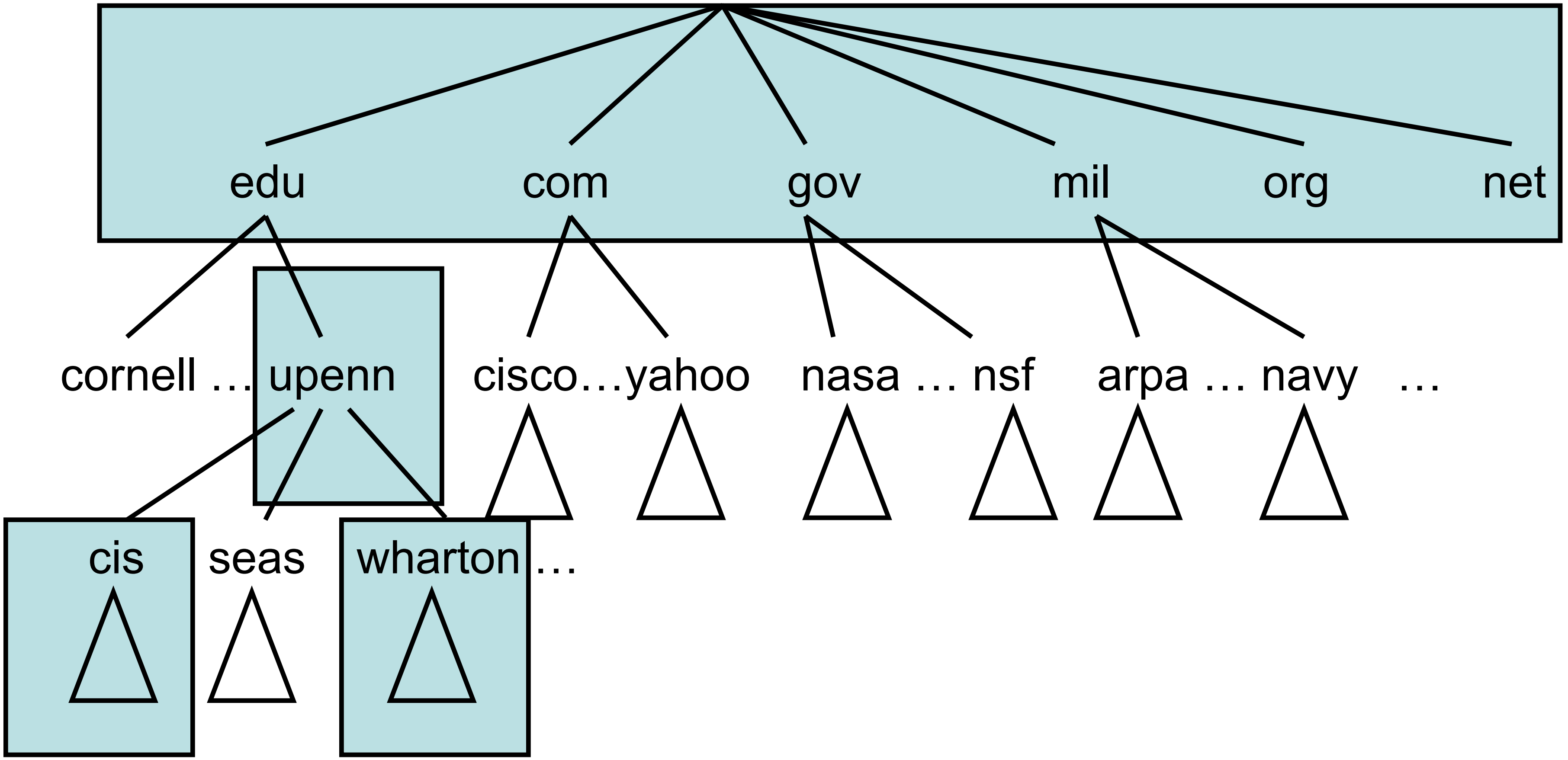
Domain Name System

- System for mapping mnemonic names for computers into IP addresses.

  softwares.kinneret.ac.il ⟶ 172.66.151.156

- Domain Hierarchy
- Name Servers
  - 13 Root servers map top-level domains such as ".com" or ".net"
- Name Resolution
  - Protocol for looking up hierarchical domain names to determine the IP address
  - Protocol runs on UDP port 53

Domain Name Hierarchy



DNS Records

- The most important types of resource records forming the contents of nodes in the DNS name space.

Type of record	Associated entity	Description
SOA	Zone	Holds information on the represented zone
A	Host	Contains an IP address of the host this node represents
MX	Domain	Refers to a mail server to handle mail addressed to this node
SRV	Domain	Refers to a server handling a specific service
NS	Zone	Refers to a name server that implements the represented zone
CNAME	Node	Symbolic link with the primary name of the represented node
PTR	Host	Contains the canonical name of a host
HINFO	Host	Holds information on the host this node represents
TXT	Any kind	Contains any entity-specific information considered useful

Excerpt from the DNS database for the zone *cs.vu.nl*.

Name	Record Type	Record Value
cs.vu.nl.	SOA	primary name server = dns.labs.vu.nl responsible mail addr = hostmaster.labs.vu.nl serial = 2025091500 refresh = 7200 (2 hours) retry = 3600 (1 hour) expire = 2419200 (28 days) default TTL = 7200 (2 hours)
cs.vu.nl	TXT	"v=spf1 redirect=vu.nl"
cs.vu.nl	TXT	"google-site-verification=Hgkj69rep7_FHZsXaTOoO8JxO6e9XUpK1aeNqPKUo7I"
cs.vu.nl	NS	ns1.labs.vu.nl
cs.vu.nl	NS	ns0.labs.vu.nl
cs.vu.nl	NS	ns2.labs.vu.nl
cs.vu.nl	NS	new-ns1.vu.nl
cs.vu.nl	NS	new-ns2.vu.nl

Excerpt from the DNS database for the zone *cs.vu.nl*.

Name	Record Type	Record Value
ns0.labs.vu.nl	A	192.31.231.42
ns1.labs.vu.nl	A	130.37.192.252
ns2.labs.vu.nl	A	130.37.192.254
new-ns1.vu.nl	A	130.37.164.20
new-ns2.vu.nl	A	130.37.164.22
ns0.labs.vu.nl	AAAA	2001:610:110:6e0::2a
ns1.labs.vu.nl	AAAA	2001:610:110:6e0::1:0
ns2.labs.vu.nl	AAAA	2001:610:110:6e0::1:2
cs.vu.nl	MX	0 cs-vu-nl-mail.protection.outlook.com
star.cs.vu.nl	A	192.31.231.42
zephyr.cs.vu.nl	HINFO	"CPU = Sun OS = Unix"
ftp.cs.vu.nl	CNAME	soling.cs.vu.nl

Excerpt from the DNS database for the zone *cs.vu.nl*.

Name	Record Type	Record Value
inkt.cs.vu.nl	A	192.168.4.3
inkt.cs.vu.nl	HINFO	“CPU = OCE OS = Proprietary”
pen.cs.vu.nl	HINFO	“CPU = OCE OS = Proprietary”
pen.cs.vu.nl	A	192.168.4.2

Kinneret DNS Records (1/2)

- An excerpt from the DNS database for zone kinneret.ac.il

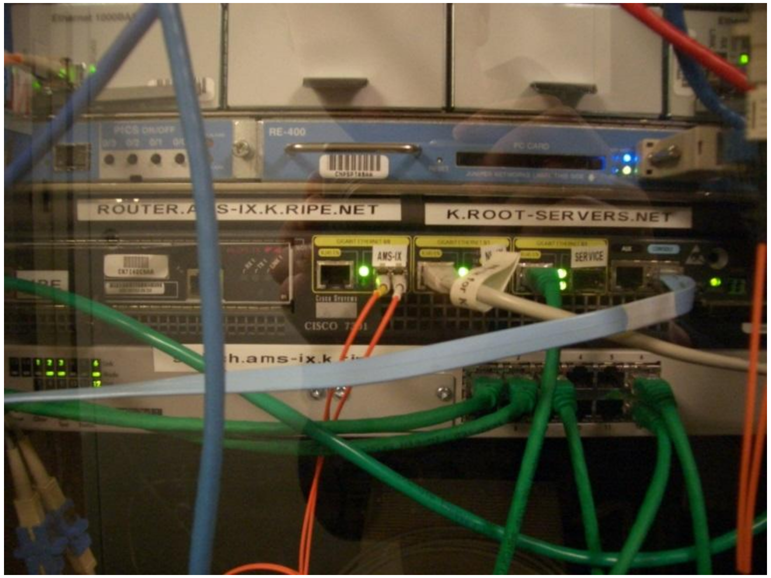
kinneret.ac.il	NS	tiffany.ns.cloudflare.com.
tiffany.ns.cloudflare.com	A	172.64.34.60 108.162.194.60 162.159.38.60
kinneret.ac.il	NS	uriah.ns.cloudflare.com.
uriah.ns.cloudflare.com.	A	108.162.195.194 162.159.44.194 172.64.35.194
kinneret.ac.il	A	172.66.151.156 104.20.35.225
kinneret.ac.il	AAAA	2606:4700:10::6814:23e1 2606:4700:10::ac42:979c

Kinneret DNS Records (2/2)

- An excerpt from the DNS database for zone kinneret.ac.il

kinneret.ac.il	MX	300 kinneret-ac-il.mail.protection.outlook.com.
kinneret.ac.il	SOA	primary name server = tiffany.ns.cloudflare.com responsible mail addr = dns.cloudflare.com serial = 2393182072 refresh = 10000 (2 hours 46 mins 40 secs) retry = 2400 (40 mins) expire = 604800 (7 days) default TTL = 1800 (30 mins)
kinneret-ac-il.mail.protection.outlook.com.	A	52.101.68.39 52.101.68.0 52.101.73.30 52.101.73.1

DNS Roots



Root server K in Amsterdam, Holland (Wikipedia)

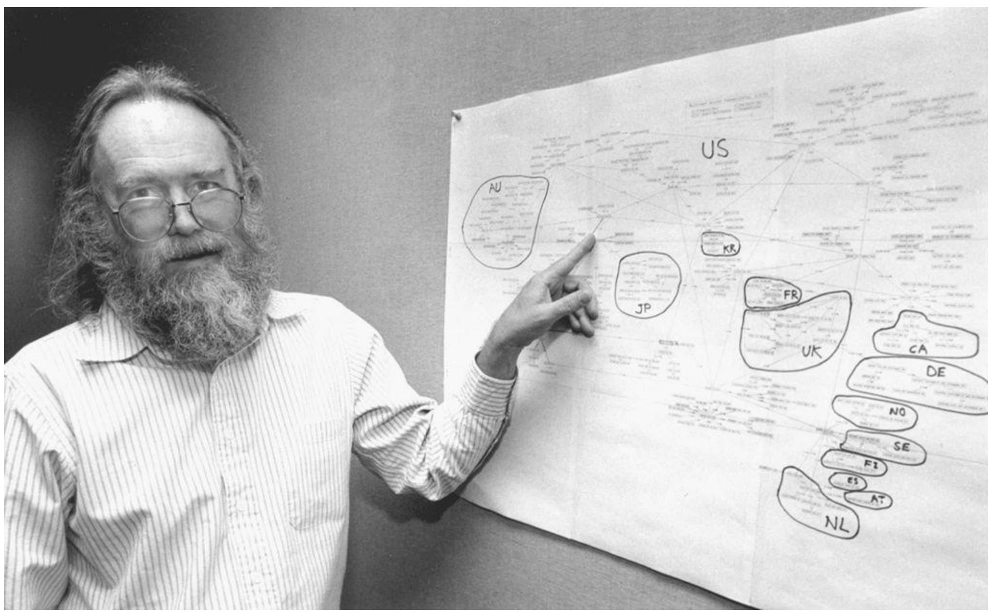
ICANN is responsible for managing roots and top level domains

- 13 DNS root servers heavily replicated around the world
- 12 independent orgs run the roots

Distributed Control (DNS)

Jan 1998: Jon Postel of IANA told 8 of the 12 roots at the time to contact IANA’s root copy instead of the US government’s root copy (Network Solutions, Inc. in Herndon, VA)

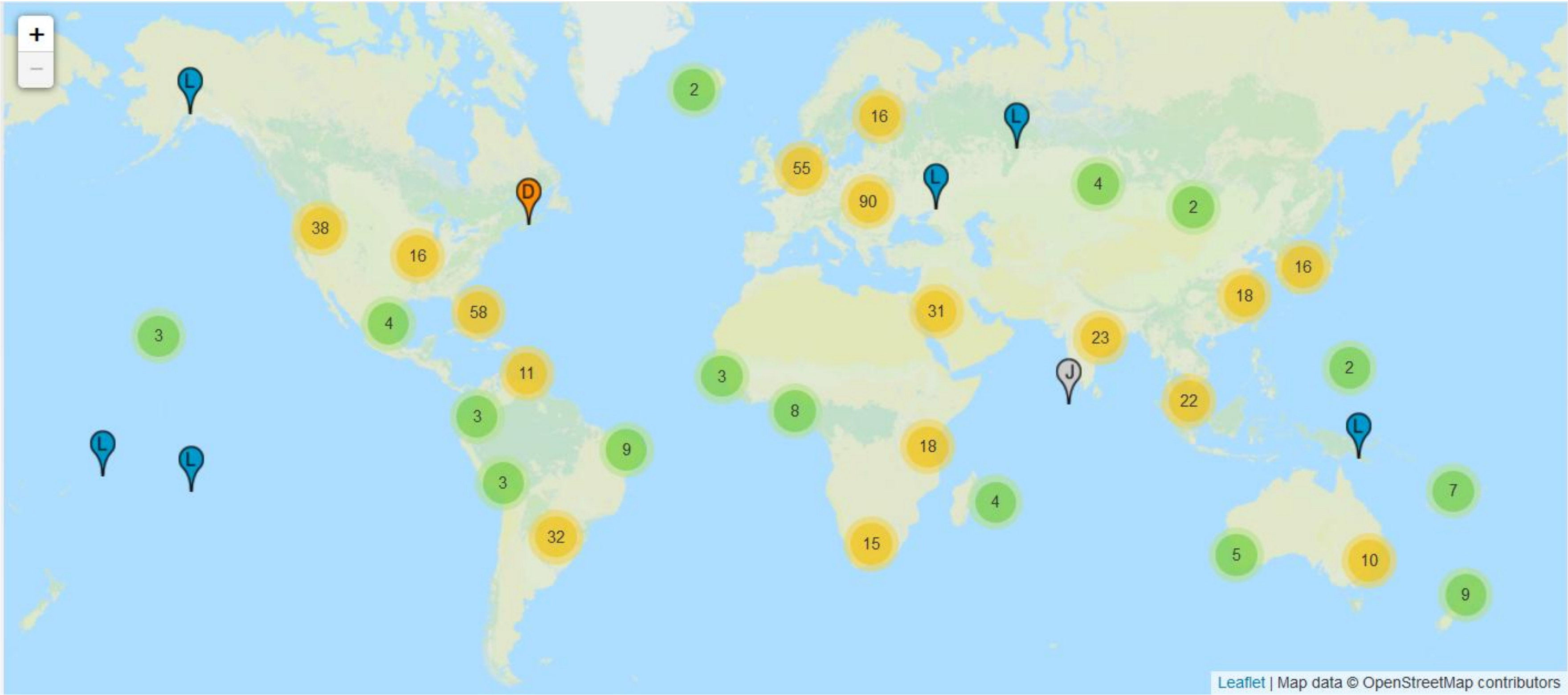
- Postel said it was a test and changed it back when asked (?)
- Sept 1998 – ICANN is formed and takes over IANA’s job



From http://www.postel.org/pr.htm: Photo by Irene Fertik, USC News Service. © 1994, USC. Permission granted for free use and distribution, conditioned upon inclusion of the above attribution and copyright notice.

DNS Roots Worldwide (2015)

DNS Roots Worldwide (2016)

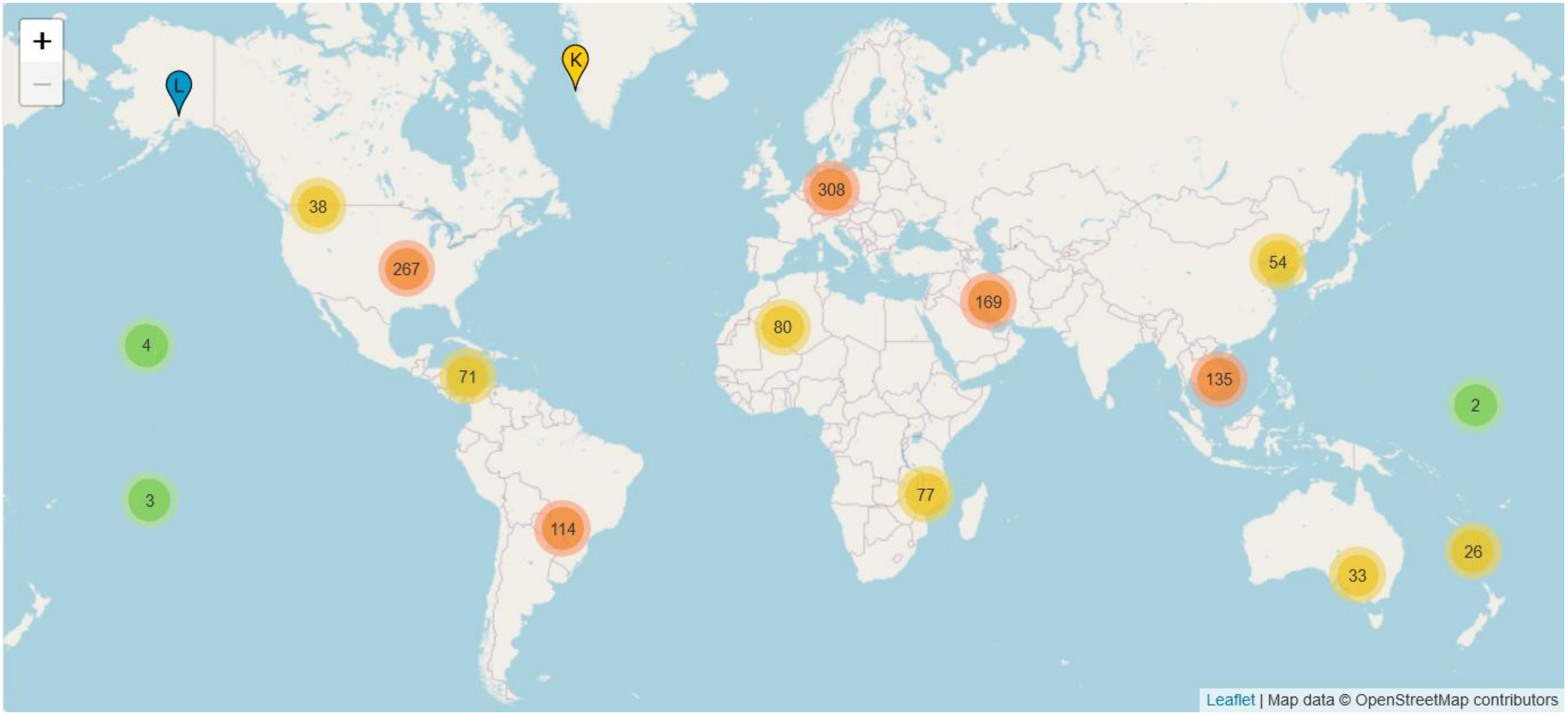


DNS Roots Worldwide (2018)

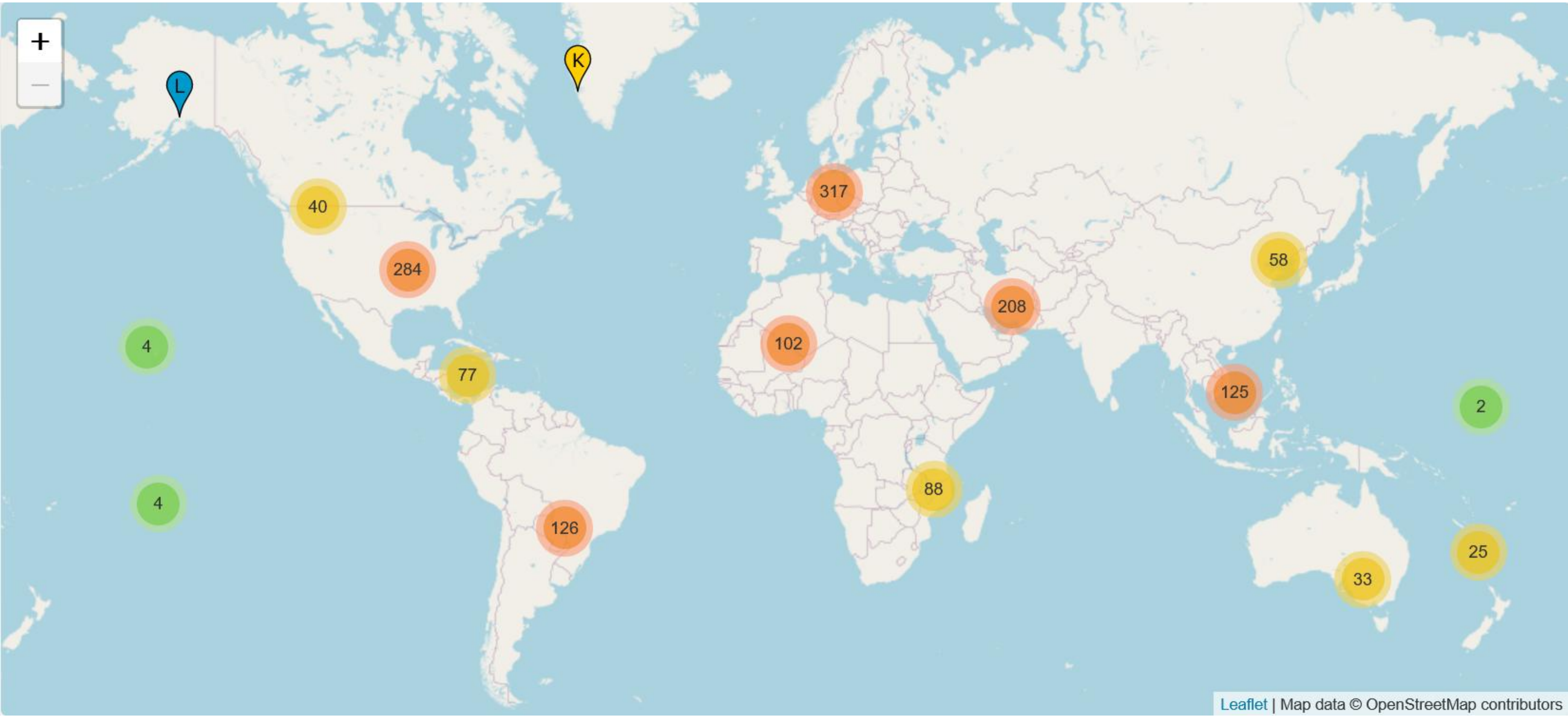
DNS Roots Worldwide (2019)

DNS Roots Worldwide (2021)

DNS Roots Worldwide (2022)



DNS Roots Worldwide (2023)



DNS Roots Worldwide (2024)

DNS Roots Worldwide (2026)

DNS Roots in Israel

- Map includes some in Jordan and Ramallah
- Total of 7 in Haifa and Tel Aviv.

DNS TLDs

1,438 TLDs (Top Level Domains) are maintained by private networking companies and organizations (Jan 2026)

- Private registrars sign up customers

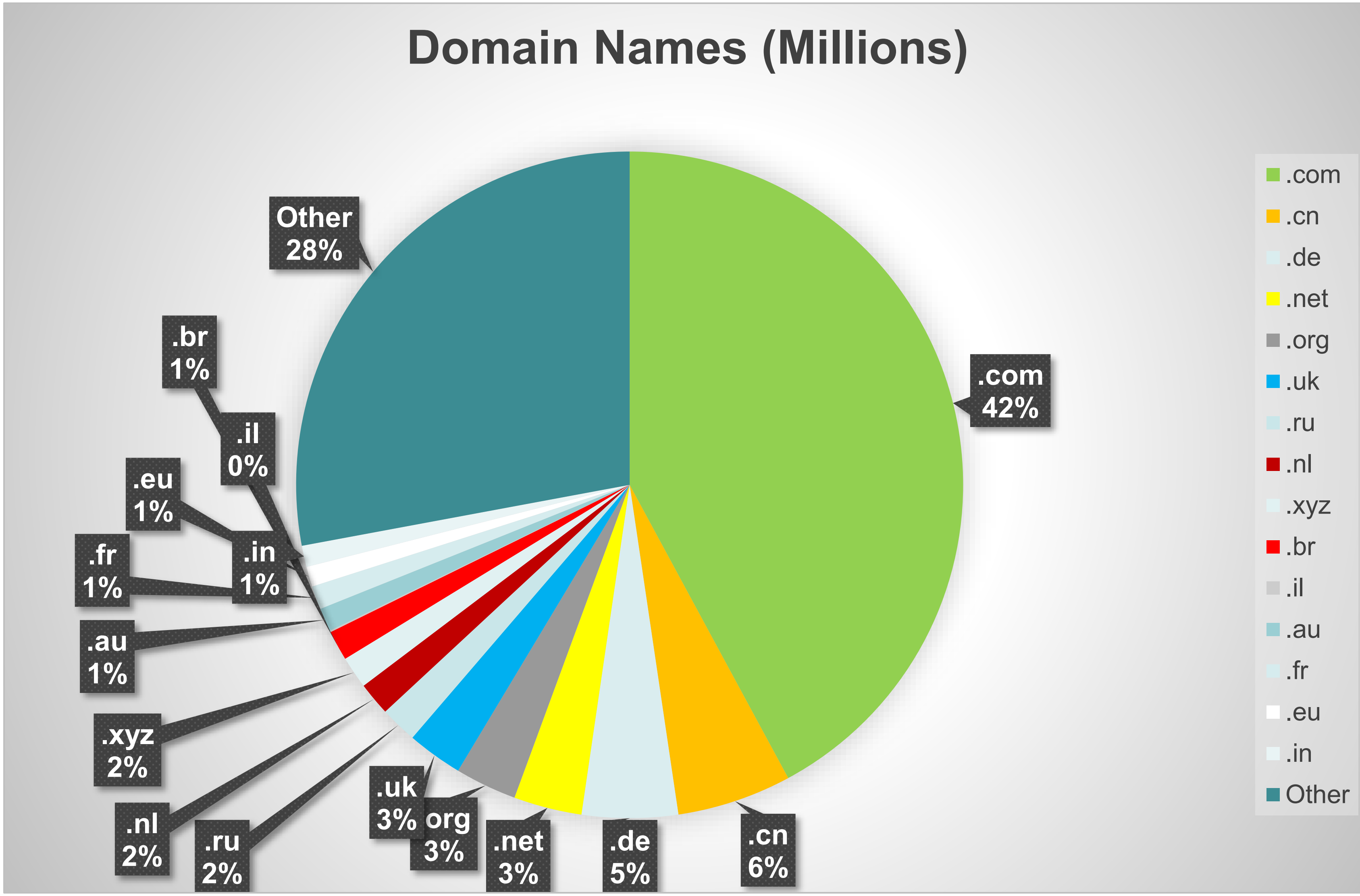
TLDs are

- By business sector (ex. .bike, .clothing, .plumbing)
- By country (ex. .us, .il, .ca, .uk)
- By organization type (ex. .org, .ac.il, .edu, .co.uk)
- By language (ex. XN--1QQW23A (Chinese), XN--3E0B707E (Korean), XN--45BRJ9C (Hindi), XN--4GBRIM (Arabic – Saudi Arabia))
- Generic (ex. .info, .xyz, .center, .cards)

Notable TLDs:

- .com used to be run by US DoD, now by Verisign – 159.4 million domains (2025)
- .edu run by Educause (contracted to Verisign) – 8K domains
- .il is run by ISOC Israel – 289K domains (2026)
  .ישראל is also run by ISOC 8K domains (2026)

Domain Name Distribution



Data source: Domain Name Industry Brief Q3 2025
(https://www.dnib.com/articles/the-domain-name-industry-brief-q3-2025)

So Far

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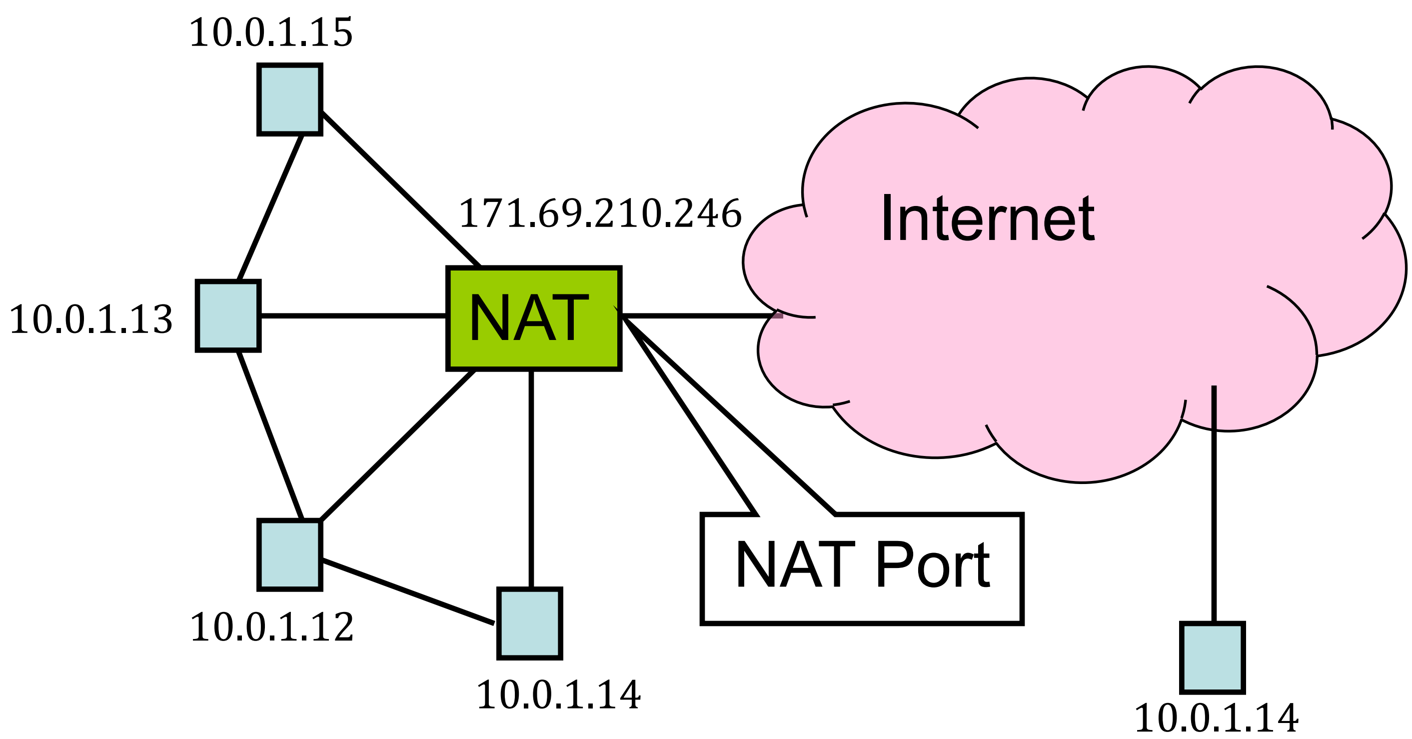
  - DNS
  - NAT
- Resource Allocation

Network Address Translation

- Idea: Break the invariant that IP addresses are globally unique



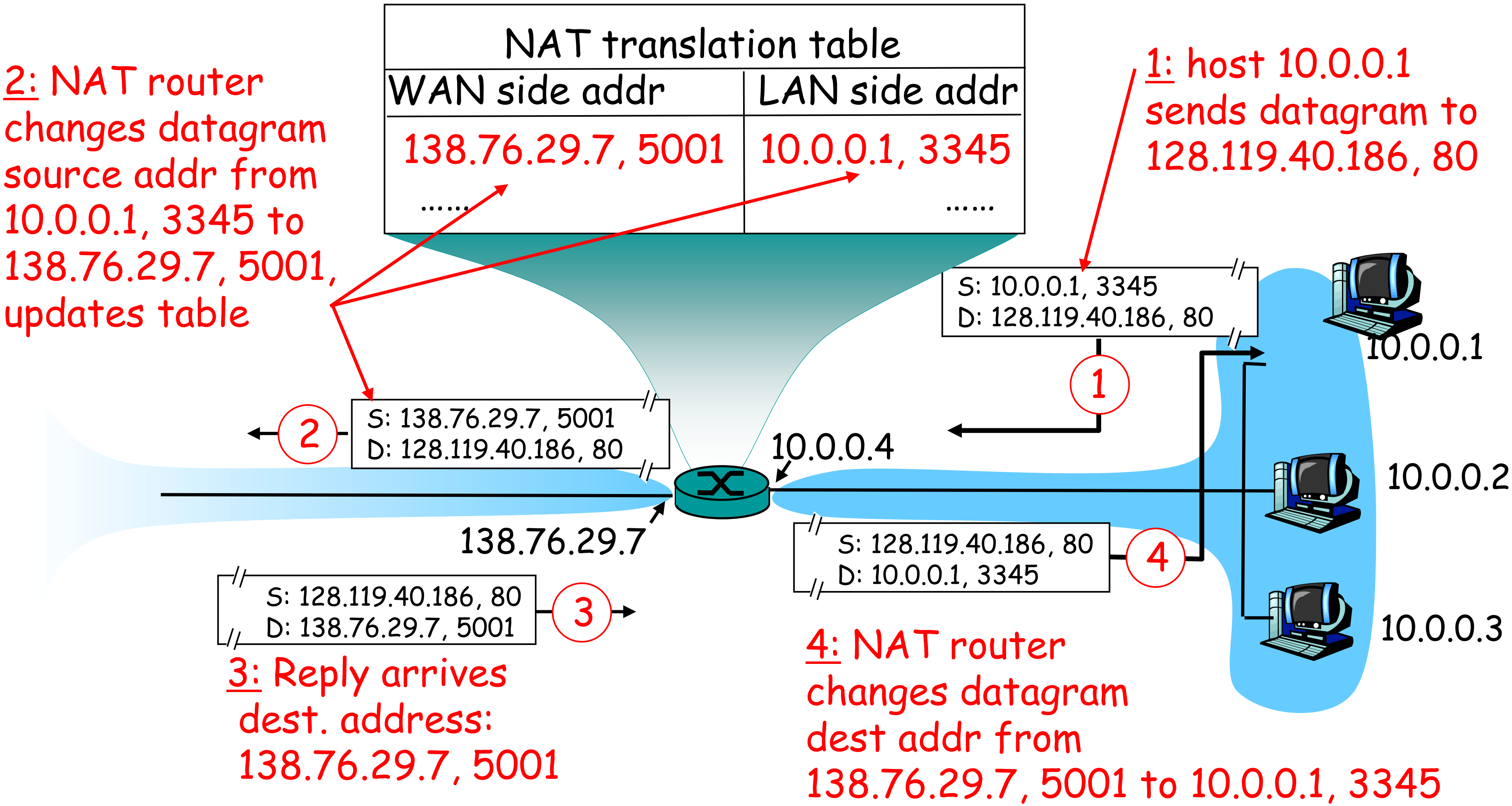
NAT Behavior

- NAT maintains a table of the form:

$$\langle client\ IP \rangle \langle client\ port \rangle \langle NAT\ ID \rangle$$

- Outgoing packets (on non-NAT port):
  - Look for client IP address, client port in the mapping table
  - If found, replace client port with previously allocated NAT ID (same size as PORT #)
  - If not found, allocate a new unique NAT ID and replace source port with NAT ID
  - Replace source address with NAT address

NAT: Network Address Translation



NAT Behavior

- Incoming Packets (on NAT port)
  - Look up destination port number as NAT ID in port mapping table
  - If found, replace destination address and port with client entries from the mapping table
  - If not found, the packet is not for us and should be rejected

- Table entries expire after 2-3 minutes to allow them to be garbage collected

- "Private" IP addresses:
  - $192.168.x.x$
  - $172.16.x.x$-$172.31.x.x$
  - $10.x.x.x$

Benefits of NAT

- Only allows connections to the outside that are established from *inside.*
  - Hosts from outside can only contact internal hosts that appear in the mapping table, and they're only added when they establish the connection
  - Some NATs support firewall-like configurability

- Can simplify network administration
  - Divide network into smaller chunks
  - Consolidate configuration data

- Traffic logging
- Load balancing
- Robust failover

Drawbacks of NAT

Rewriting IP addresses isn't so easy:

- Must also look for IP addresses in other locations and rewrite them (may have to be protocol-aware)
- Potentially changes sequence number information
- Must validate/recalculate checksums

Limited filtering of packets / change packet semantics

- For example, NATs may not work well with encryption schemes that include IP address information

May not work with all protocols

- Clients may have to be aware that NAT translation is going on

Hinders throughput

Slow the adoption of IPv6?

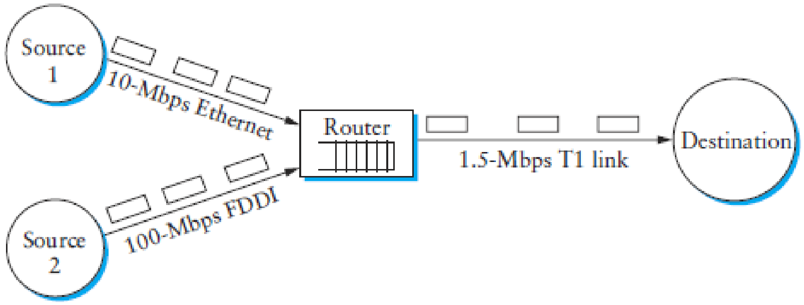
So Far

- Glue Protocols
  - DHCP
  - DNS
  - NAT
- Congestion Control
  - Queuing
  - Fair Queuing
- Congestion Avoidance
  - RED

Resource Allocation

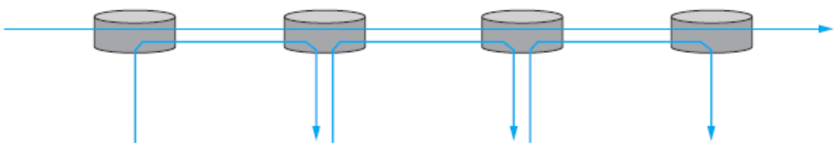
- When we have a real network we must deal with contention and congestion
  - Too many users, not enough resources
- We'll talk about packet switched networks for now

- Congestion can come from:
  - Too many users trying to make small connections
  - A few users making huge connections
  - Fast links that must pass over a slower link

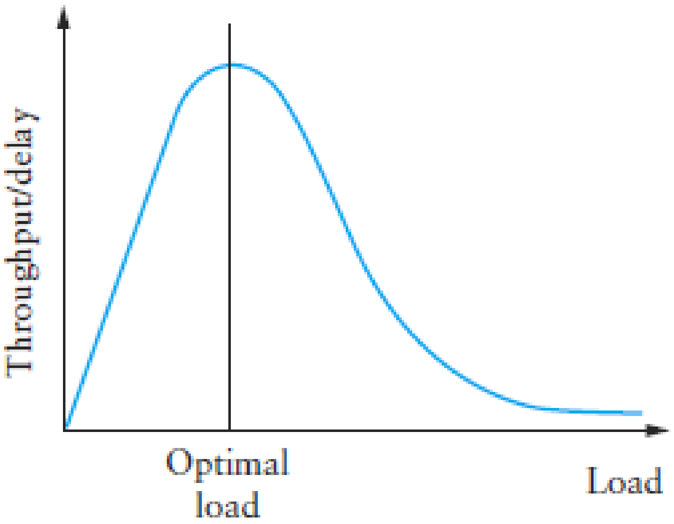


What is the Goal?

Fairness



Utilization



What are we Managing?

Connectionless Flows

- Data sent between sender and receiver
- The routers sees them as moving between addresses (ignore ports)

Routers maintain *soft state* about connections

- Detected automatically
- Lives and dies as the connection does
- Helps the router make better routing decisions

Flows can be *explicit* or *implicit*

- Difference is whether the end points tell the routers before they start
- Datagram versus Virtual Circuits

What is the Network Offering?

Best Effort

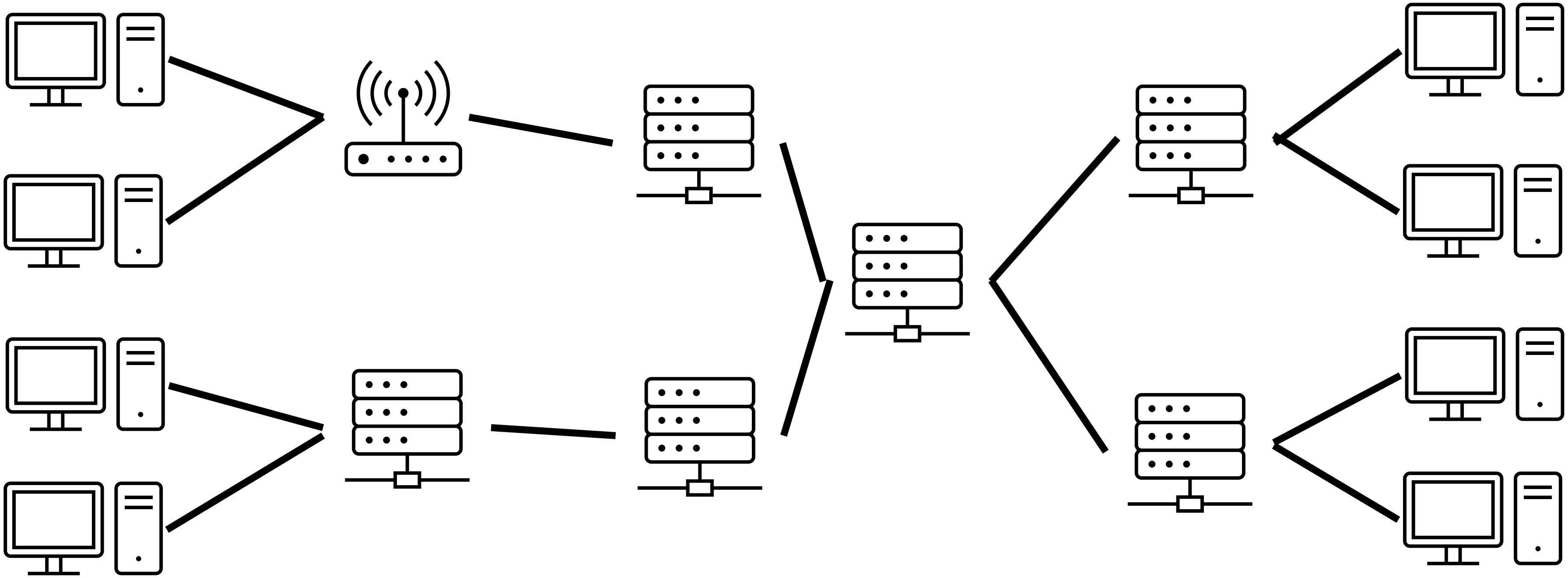
- The basic model
- Try, but no guarantee
- All packets are created (more or less) equal

Quality of Service (QoS)

- More advanced:
- Senders and receivers *request* the routers to guarantee a minimum amount of resources
- Some protocols: RSVP, ATM

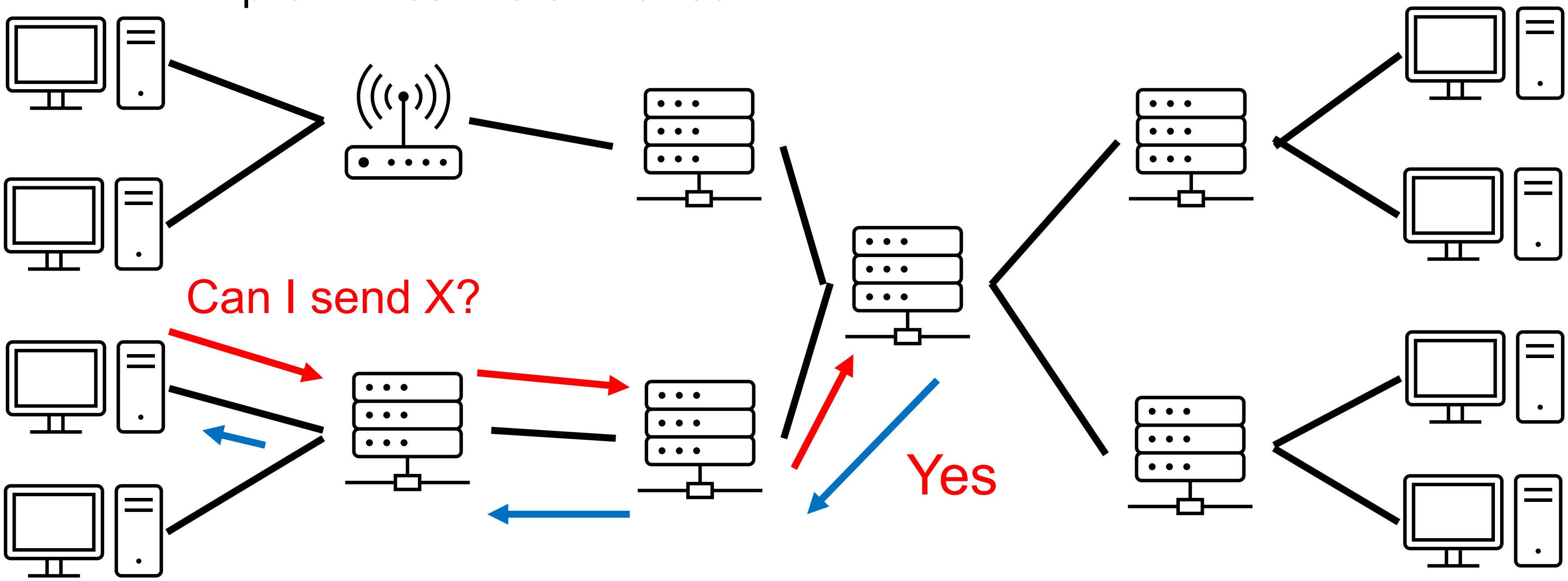
How are we Managing?

- Router Centric vs. Host Centric
  - Who does most decision making?
  - Router Centric – the router tells the hosts how fast they can send
  - Host Centric – the hosts decide how fast to send based on their experiences



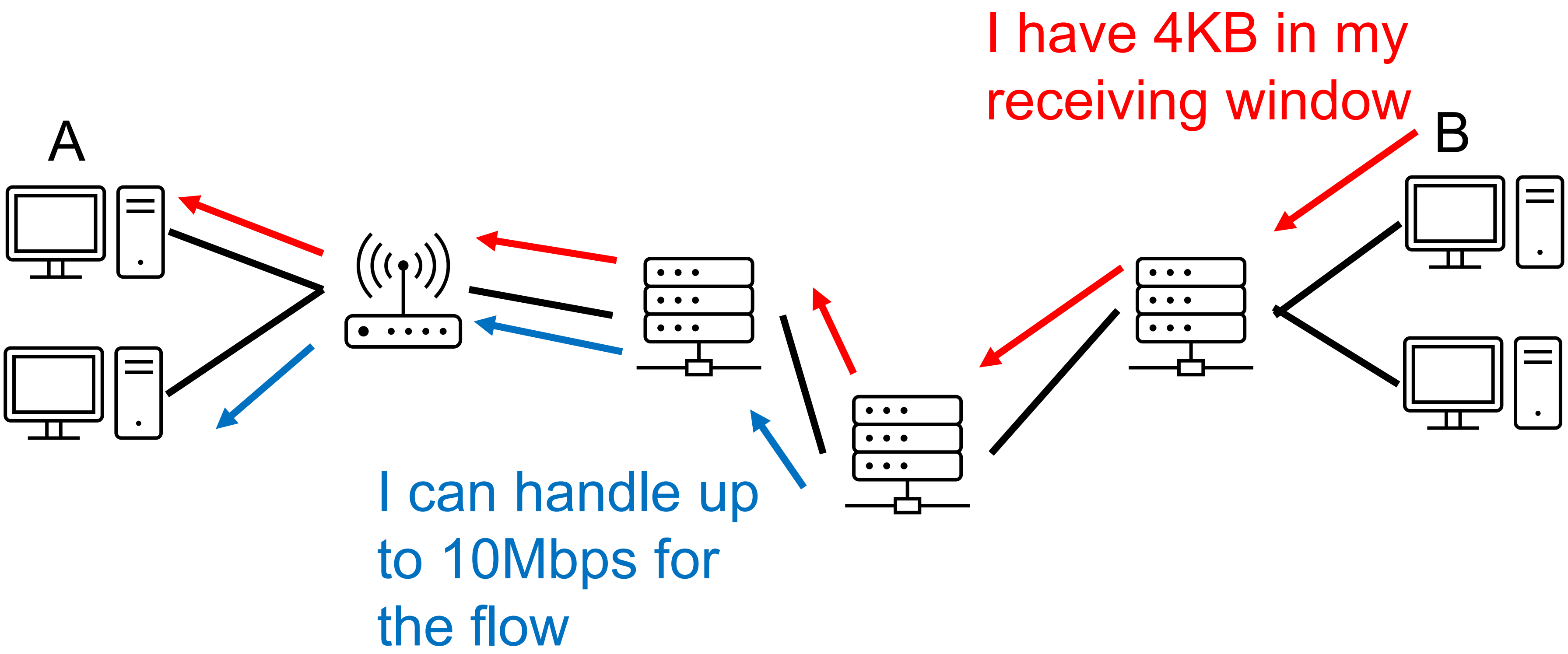
How are we Managing?

- Reservation Based vs. Feedback Based
  - Reservation: send request before
    - Requires Router Centric
  - Feedback: change based on what happens
    - Explicit – Router more involved
    - Implicit – Host more involved



How are we Managing?

- Window Based – Tell the sender the receiving window size
- Rate Based – Give a target sending bps



What is Common?

Best Effort:

- Feedback
  - Since we can’t reserve
- Therefore…
  - Host centric
- Typically Window Based (e.g. TCP)

QoS:

- Reservation
- Therefore…
  - Router centric
- Typically Rate Based (e.g. RSVP)

Conclusion

- Glue Protocols
  - DHCP
  - DNS
  - NAT
- Resource Allocation