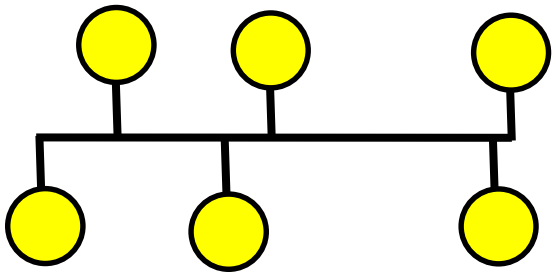
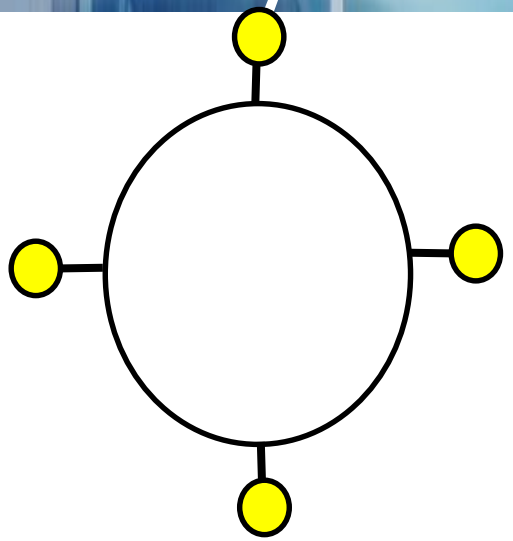
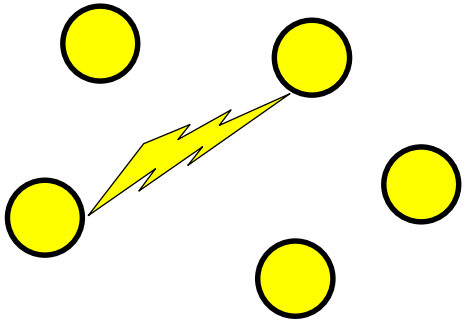
CS2031
Telecommunications II

UDP

Naming at the Link Layer





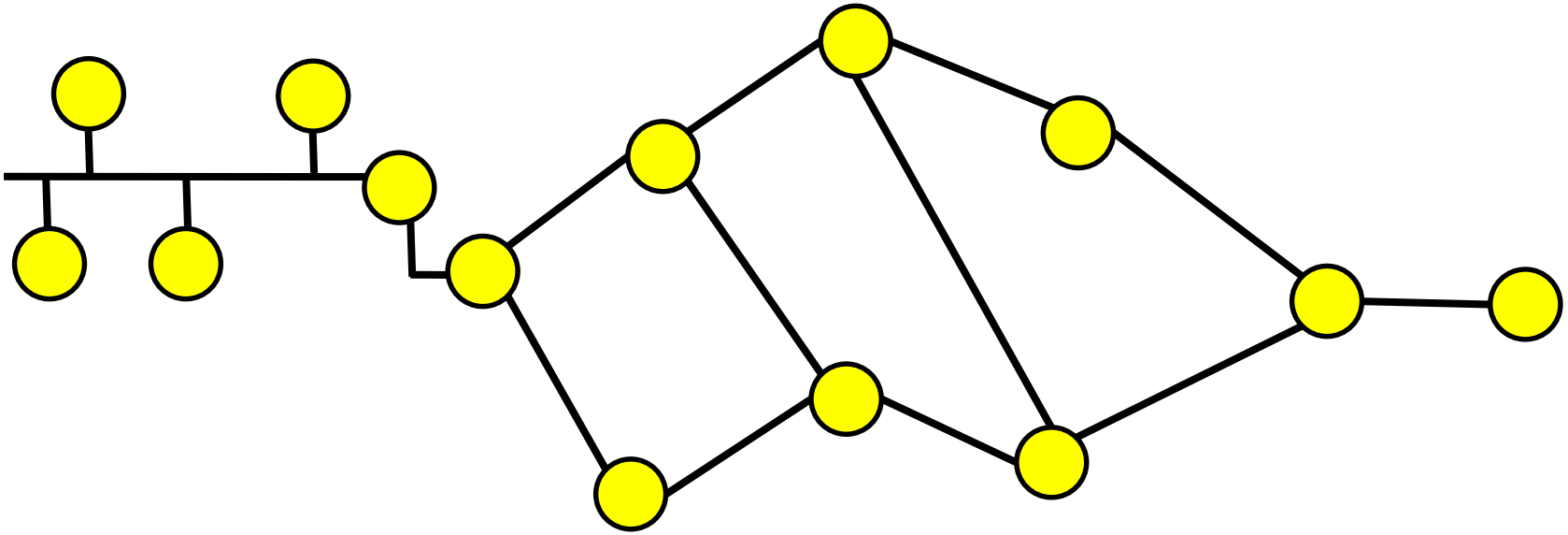


One direct link between two terminals

= Terminals or Stations

Data units = Frames

Naming at the Network Layer

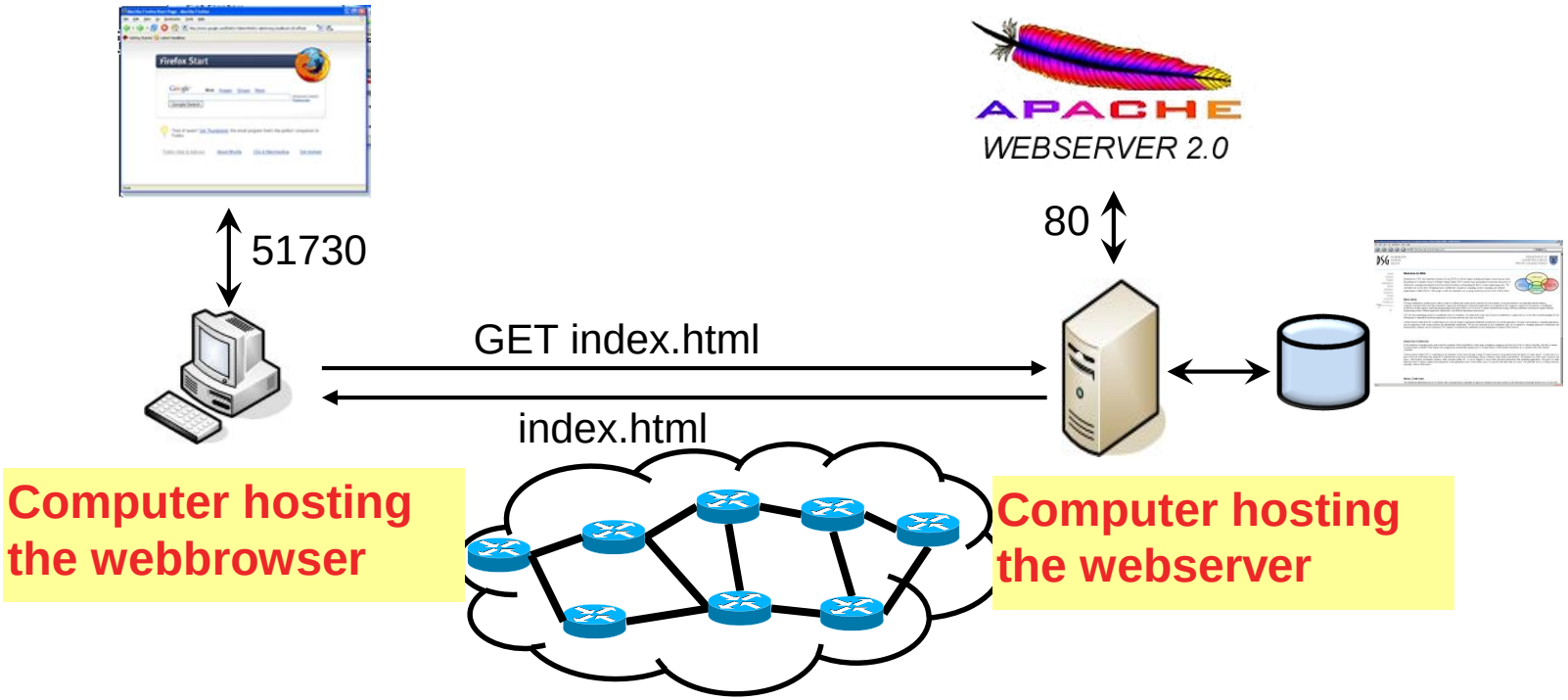


= Nodes of a graph

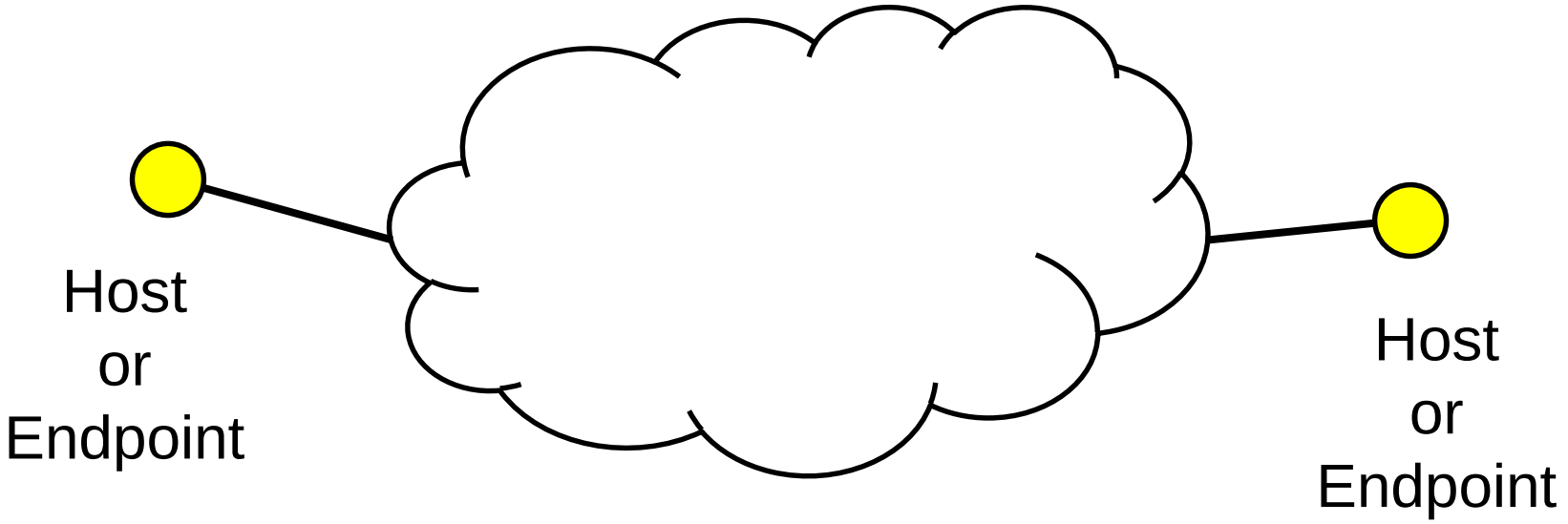
Data units = Packets

Any number of edges between two nodes

Naming at the Transport Layer



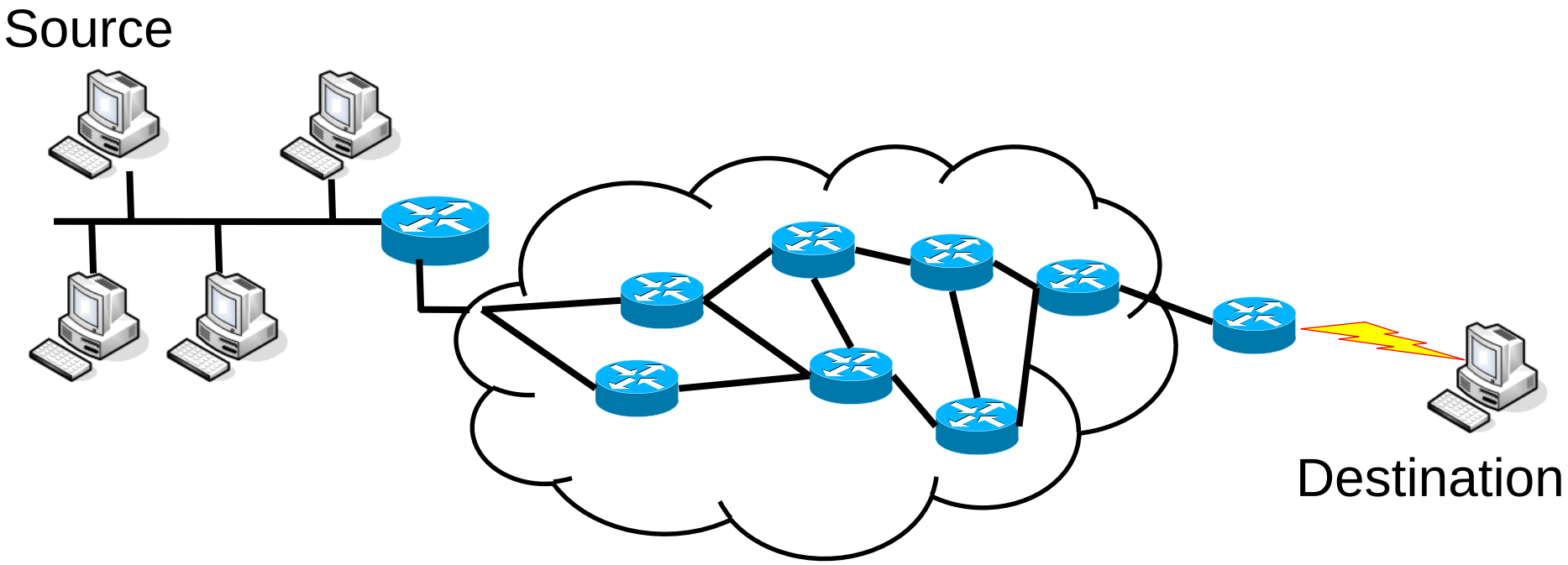
Naming at the Transport Layer



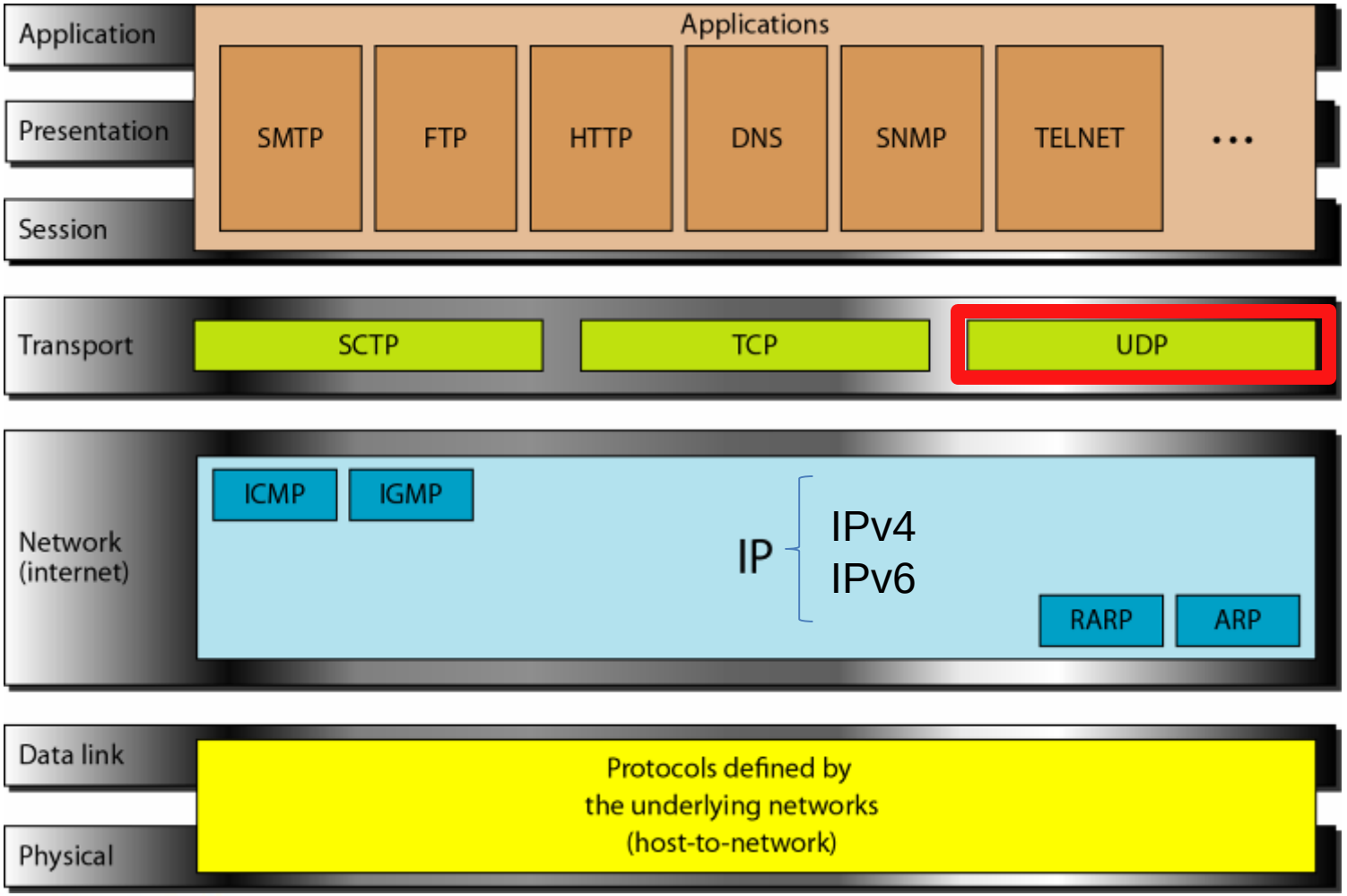
= Host

Data units = Segments or Datagrams

Task of the Network Layer

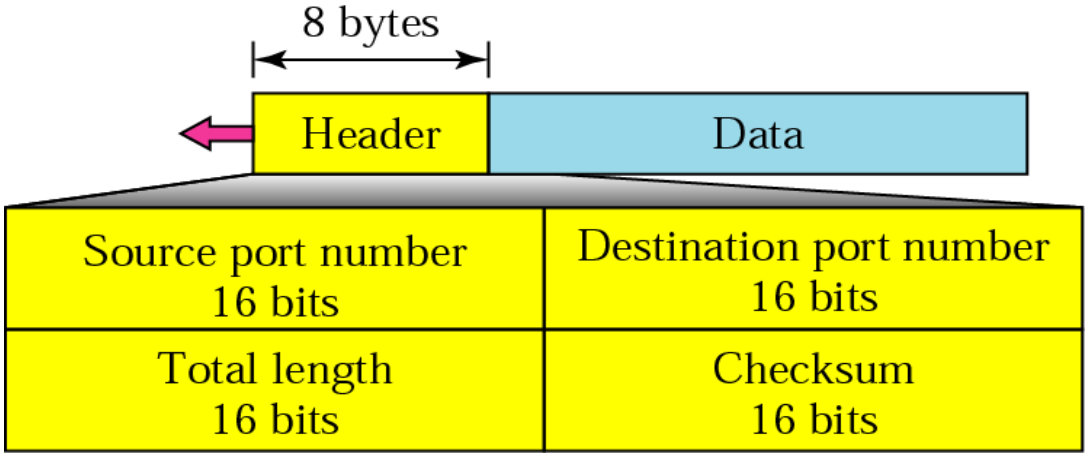


Protocols in the OSI Model



* Figure is courtesy of B. Forouzan

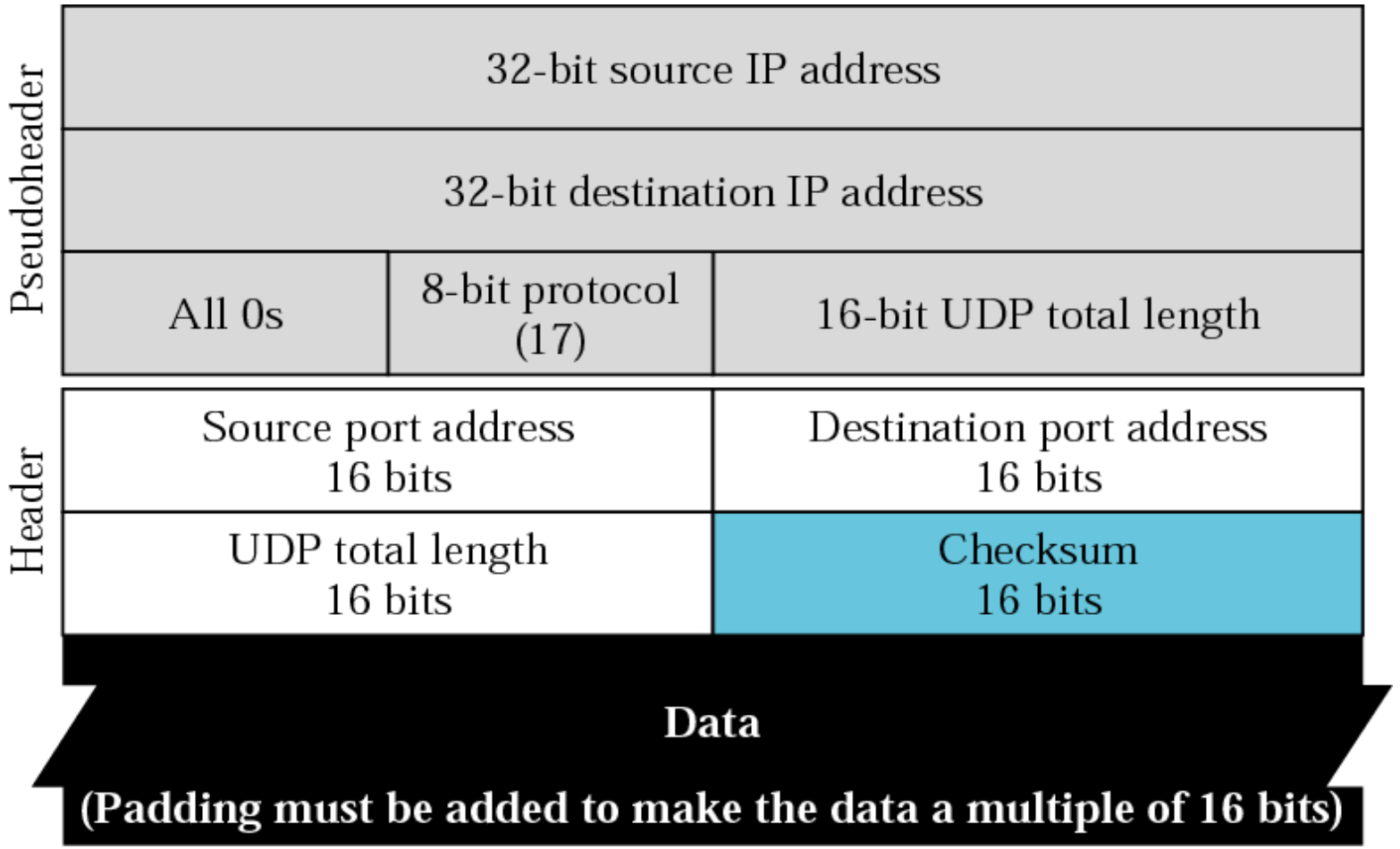
User Datagram Protocol (UDP)



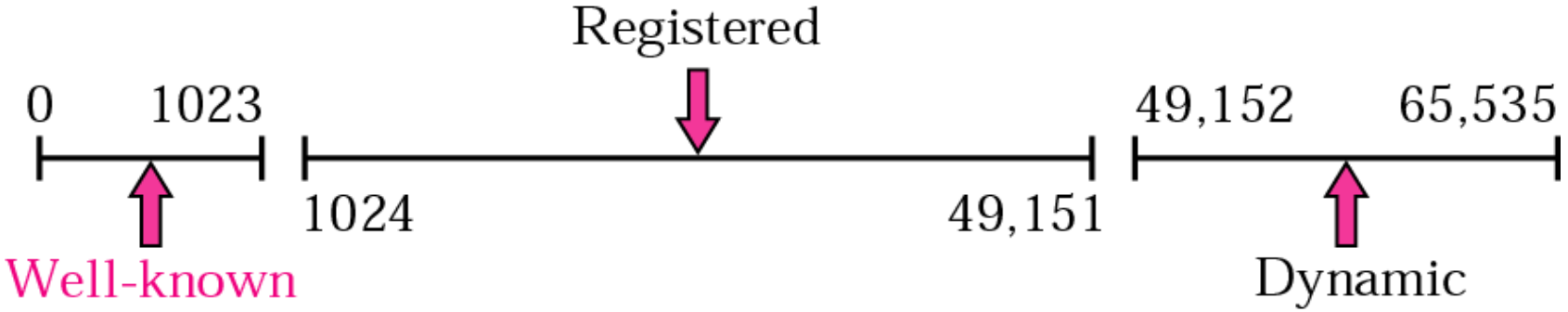
- UDP is a connectionless, unreliable protocol
  - No flow and error control
  - Port numbers are used to multiplex data
- Calculation of checksum & its inclusion in datagram are optional.
- Convenient transport-layer protocol for applications that provide their own flow and error control
  - Also used by multimedia applications.

* Figure is courtesy of B. Forouzan

Pseudo-Header for Checksum



Well-Known Port Numbers

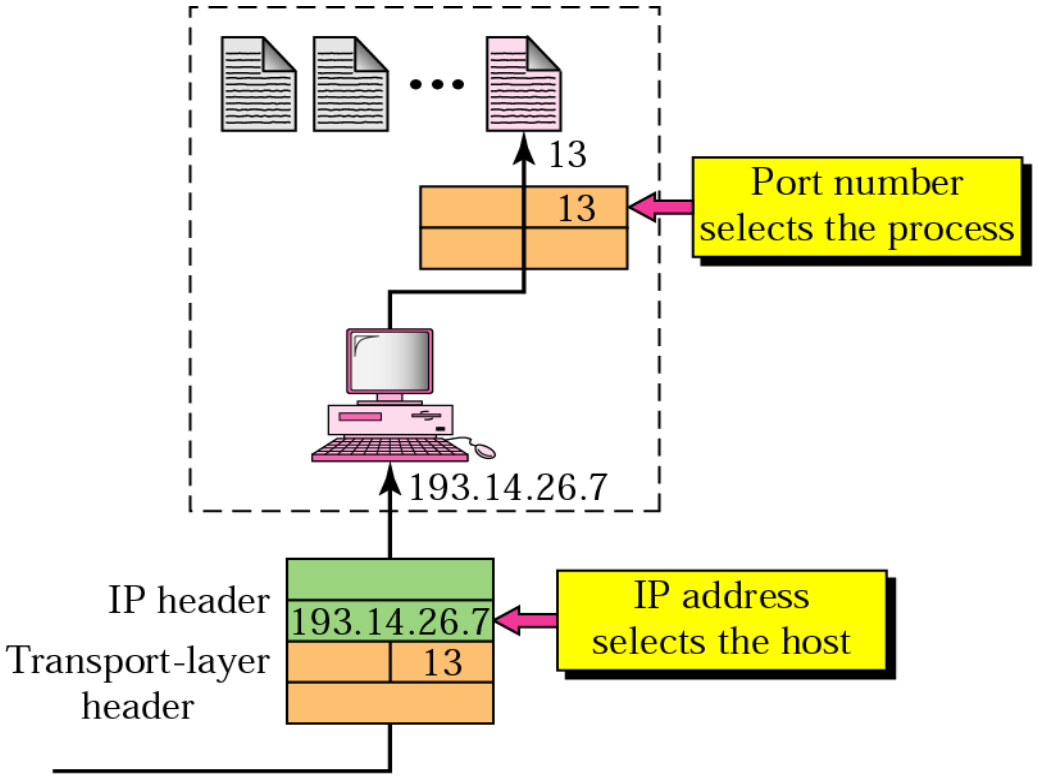


- Assigned by Internet Assigned Numbers Authority (IANA)
- 3 Categories of Ports:
  - Well-known Ports: 0 – 1023 (restricted access)
  - Registered Ports: 1024 – 49151
  - Dynamic/Private Ports: 49152 – 65535

* Figure is courtesy of B. Forouzan

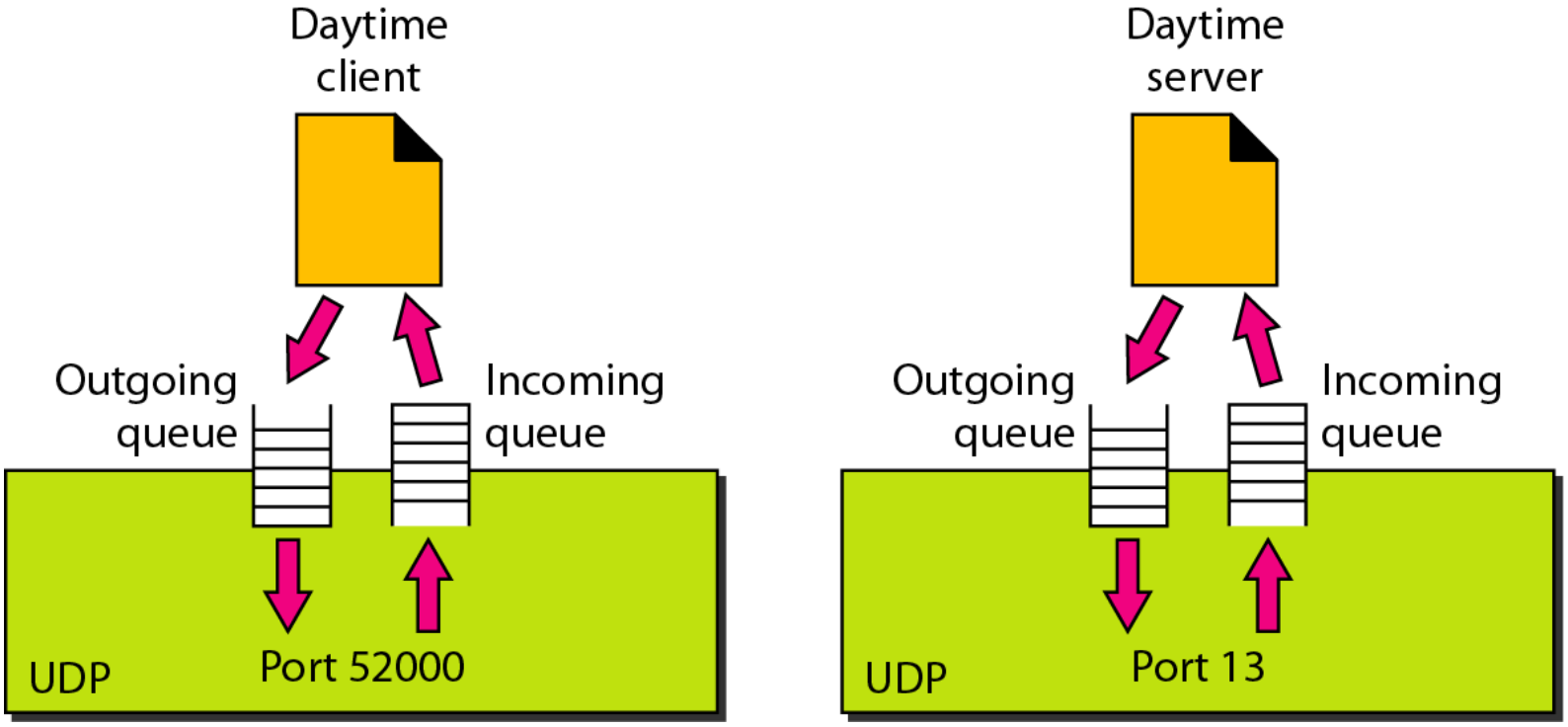
IP Addresses & Port Numbers

- IP Addresses determine the host
- Port Numbers determine the application

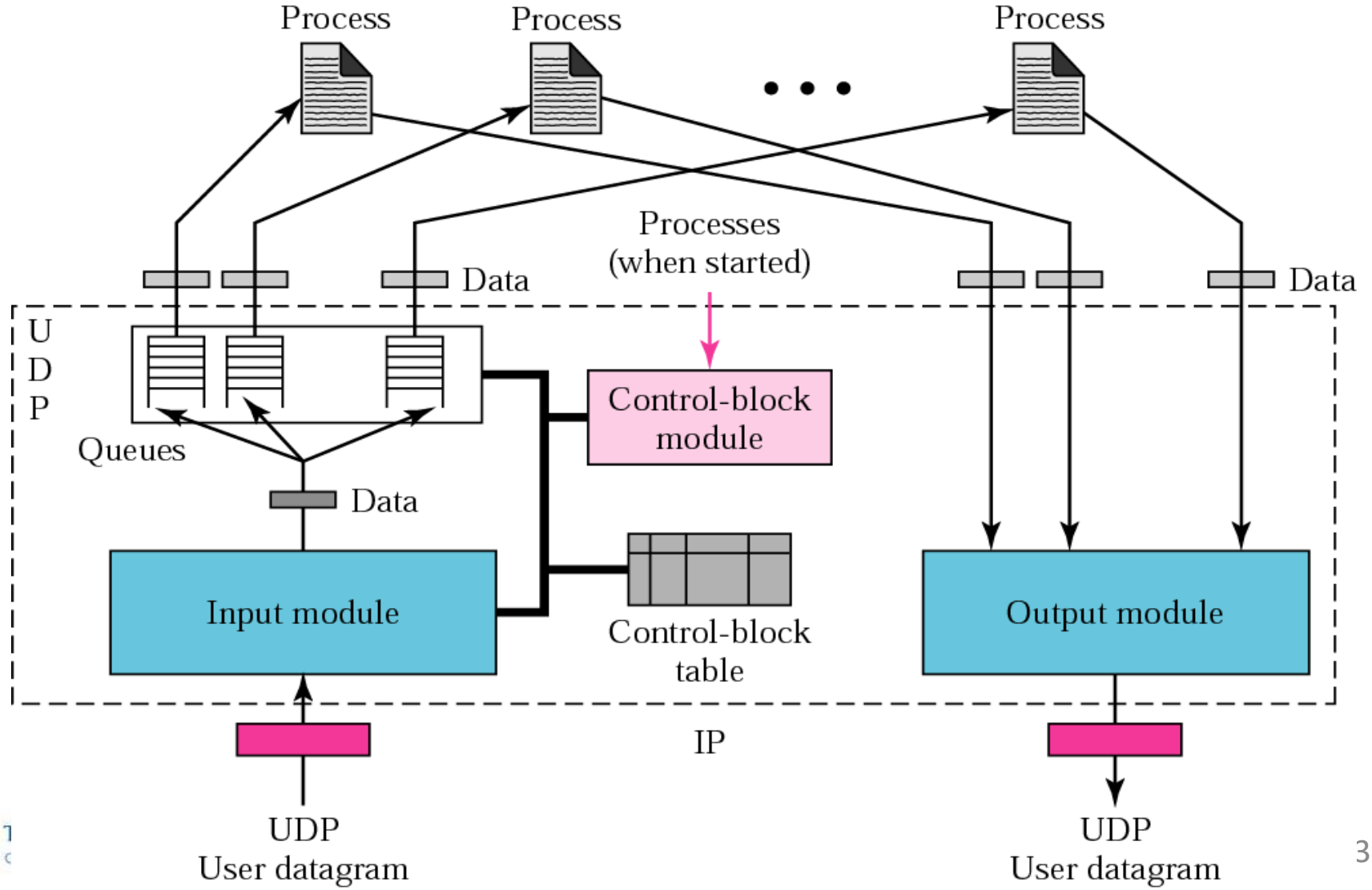


* Figure is courtesy of B. Forouzan

Queuing in UDP



Processes and UDP Queues



UDP Queue Example I

State	Process ID	Port Number	Queue Number
IN-USE	2,345	52,010	34
IN-USE	3,422	52,011	
FREE			
IN-USE	4,652	52,012	38
FREE			

- Socket is opened on port 52014

State	Process ID	Port Number	Queue Number
IN-USE	2,345	52,010	34
IN-USE	3,422	52,011	
IN-USE	**4,978**	**52,014**	
IN-USE	4,652	52,012	38
FREE			

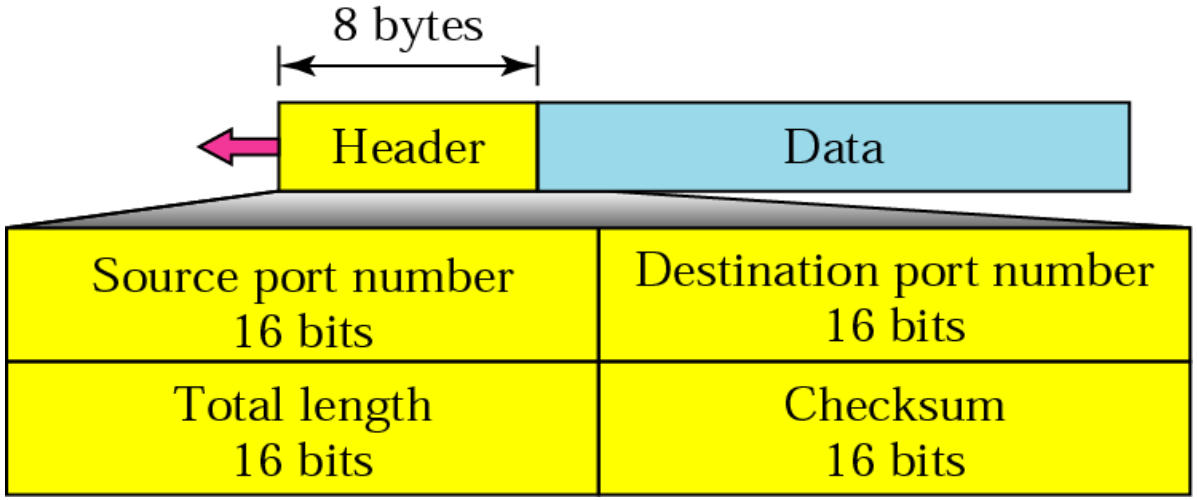
UDP Queue Example II

State	*Process ID*	*Port Number*	*Queue Number*
IN-USE	2,345	52,010	34
IN-USE	3,422	52,011	**43**
IN-USE	4,978	52,014	
IN-USE	4,652	52,012	38
FREE			

- Packet for Port 52011 arrives
  - Queue is created and packet is queued
- Packet for Port 53255 arrives
  - Packet is dropped

User Datagram Protocol (UDP)

- Connectionless
- Unreliable
  - No flow or error control
- Small Header:

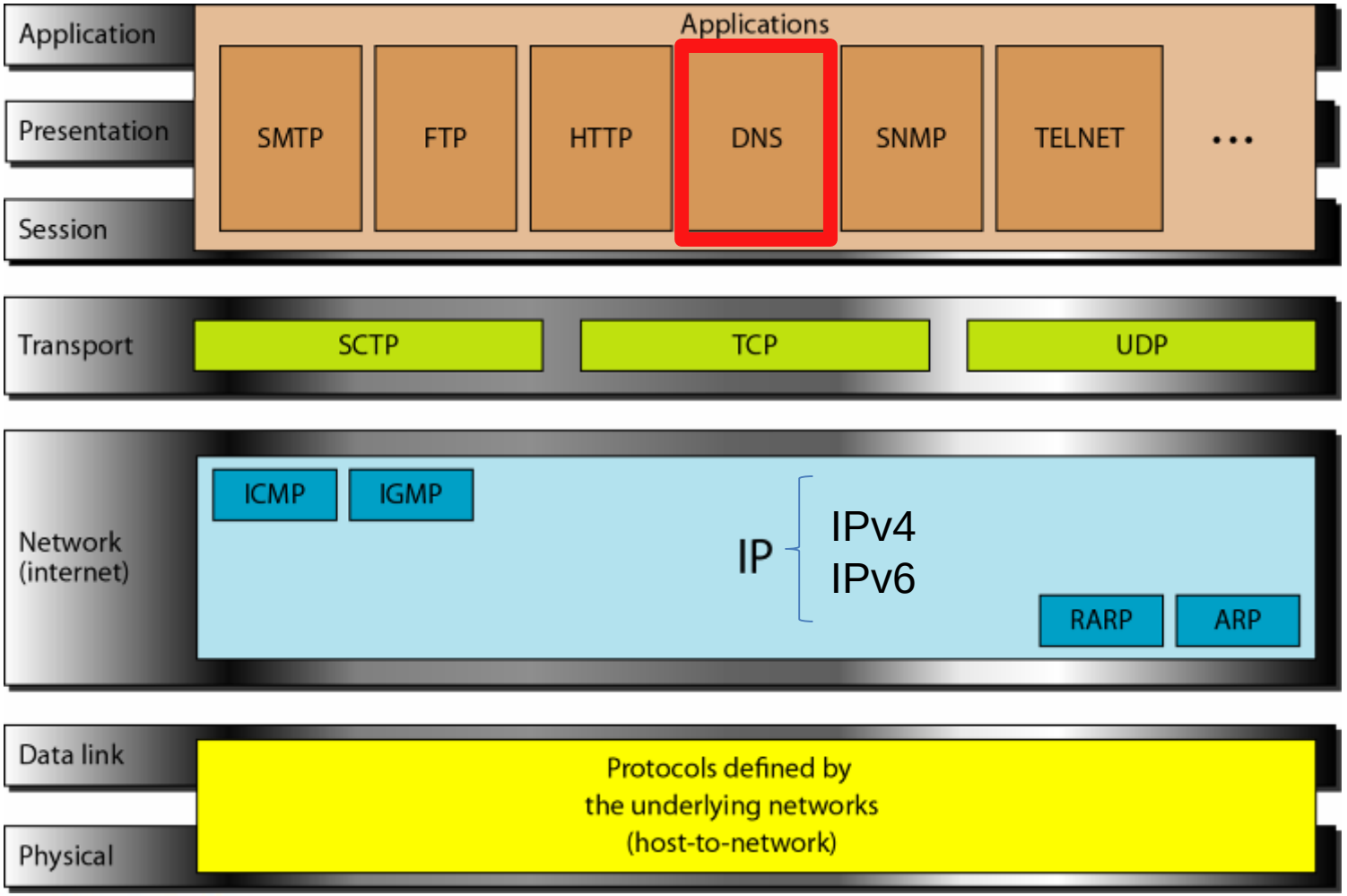


* Figure is courtesy of B. Forouzan

CS2031
Telecommunications II

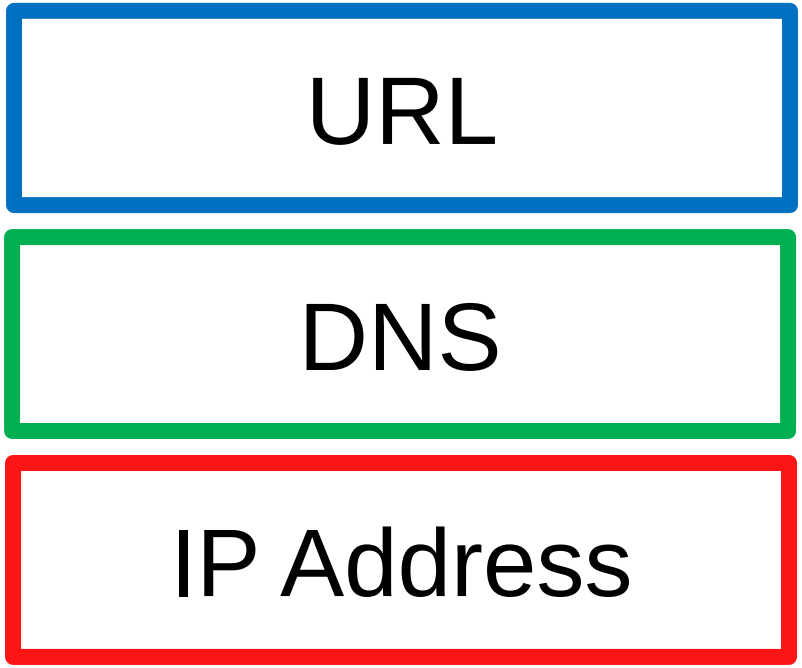
DNS

Protocols in the OSI Model



* Figure is courtesy of B. Forouzan

URLs to Names to Addresses

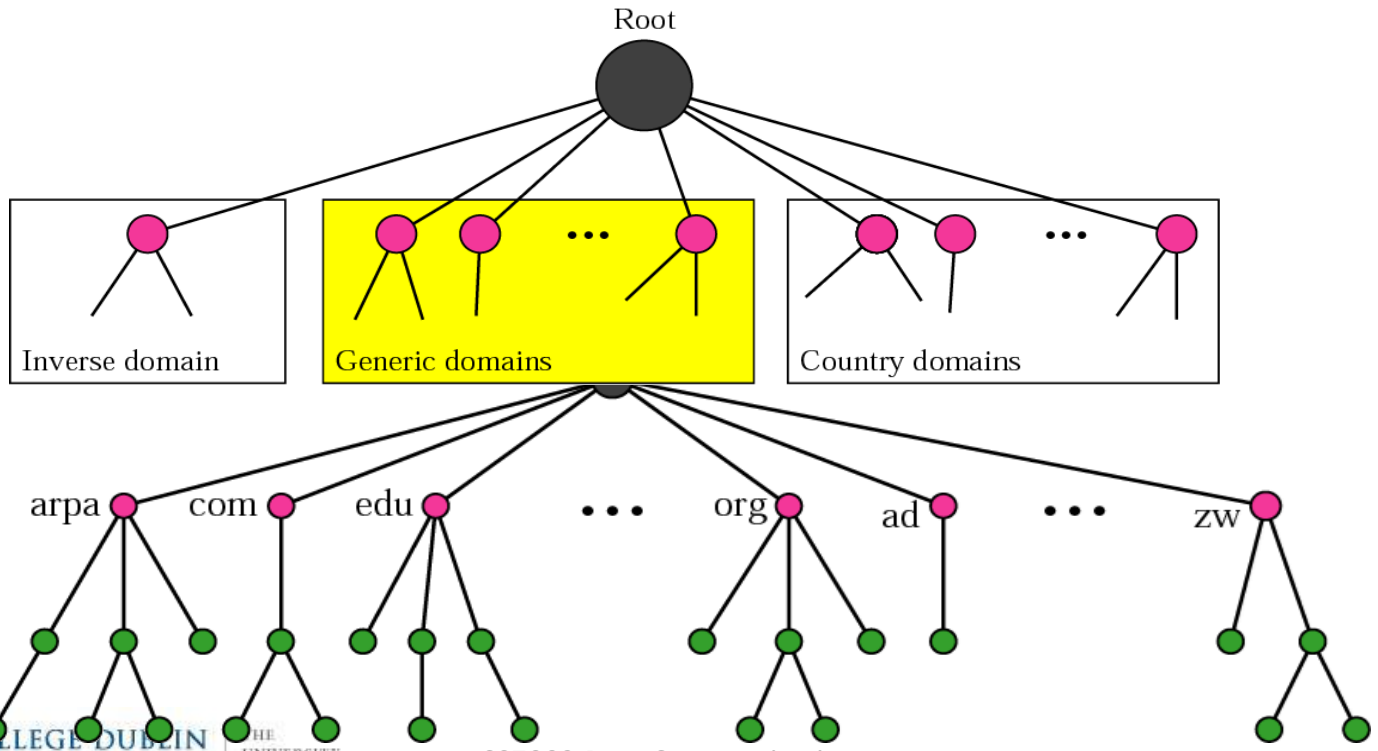


*URL = Uniform Resource Locator

Domain Name Space

- Association between names and IP addresses

  www.dsg.scss.tcd.ie - 134.226.36.14



* Figure is courtesy of B. Forouzan

Domain Name Space

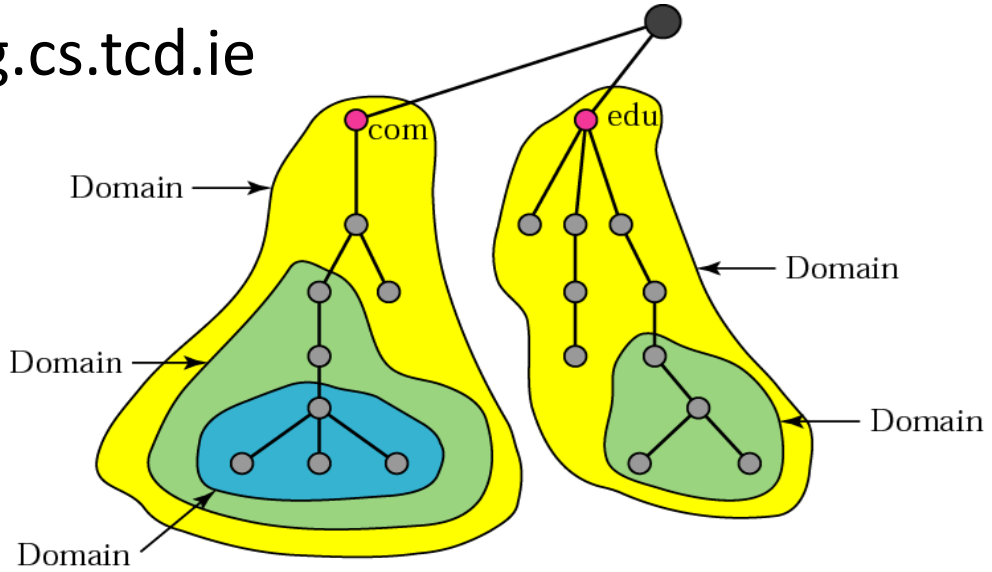
- Association between names and IP addresses

  www.dsg.scss.tcd.ie - 134.226.36.14

- Each domain may contain a number of sub-domains e.g.

  tcd.ie contains cs.tcd.ie, mee.tcd.ie

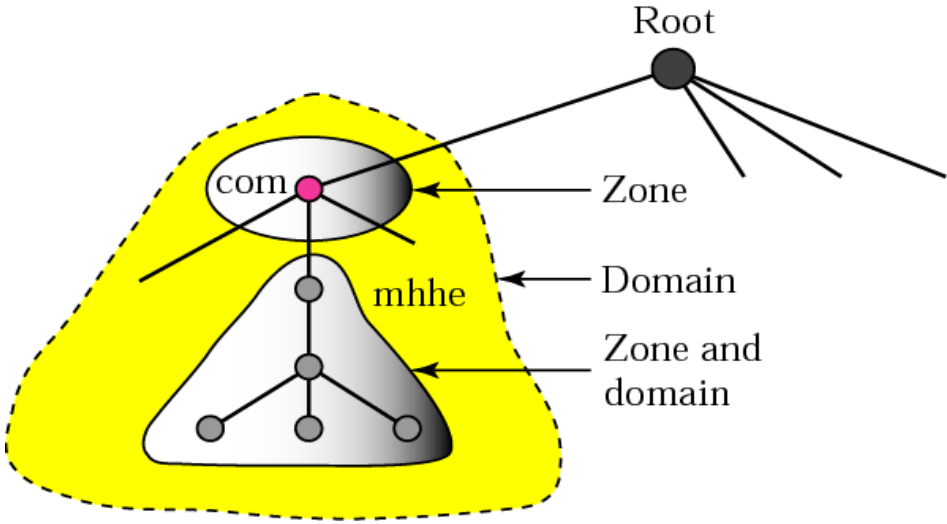
  cs.tcd.ie contains dsg.cs.tcd.ie

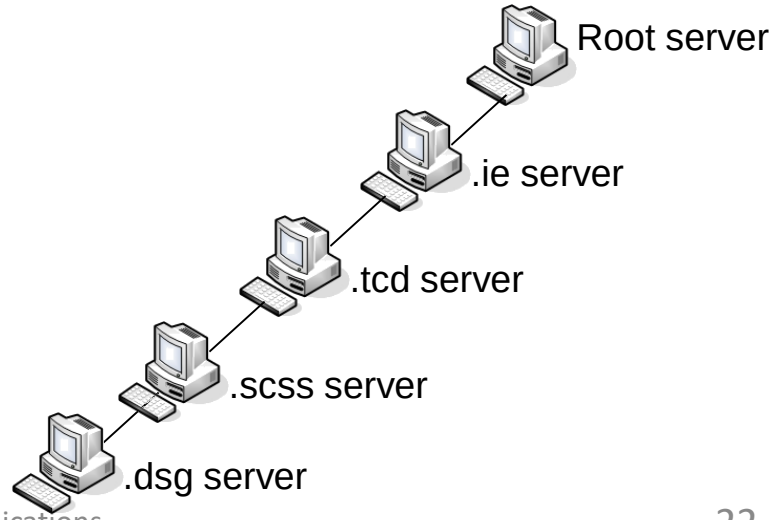


* Figure is courtesy of B. Forouzan

Hierarchy of Name Servers

- Every zone has a DNS server
- DNS server maintain lists of
  - Nodes in the zone
  - References to servers of zones underneath it

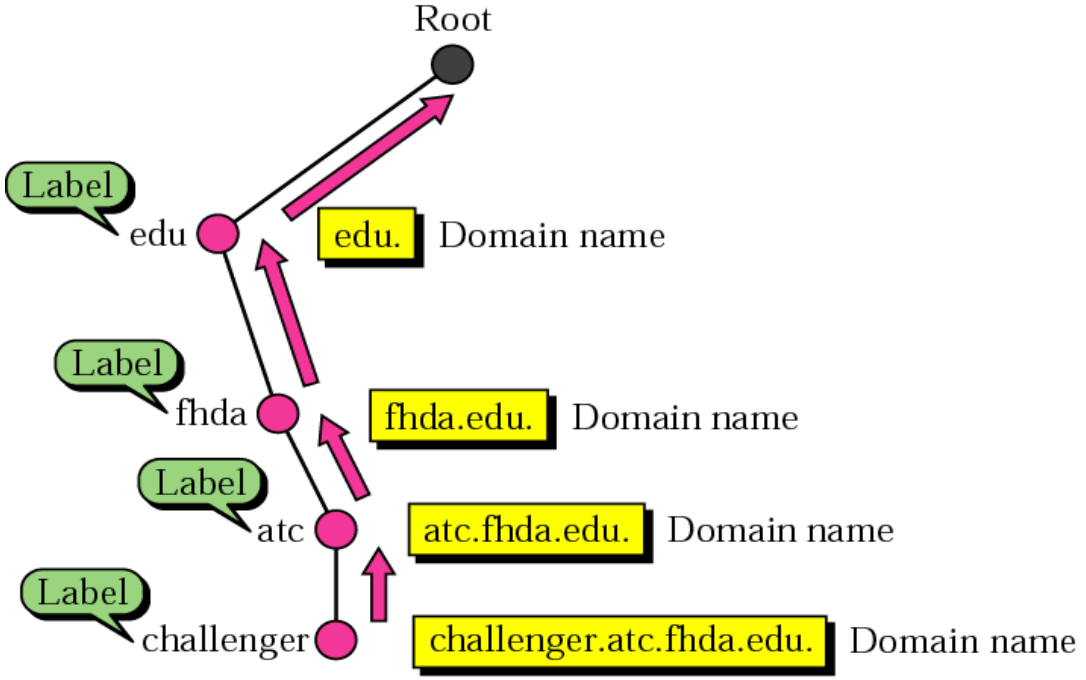




* Figure is courtesy of B. Forouzan

Domain Names and Labels

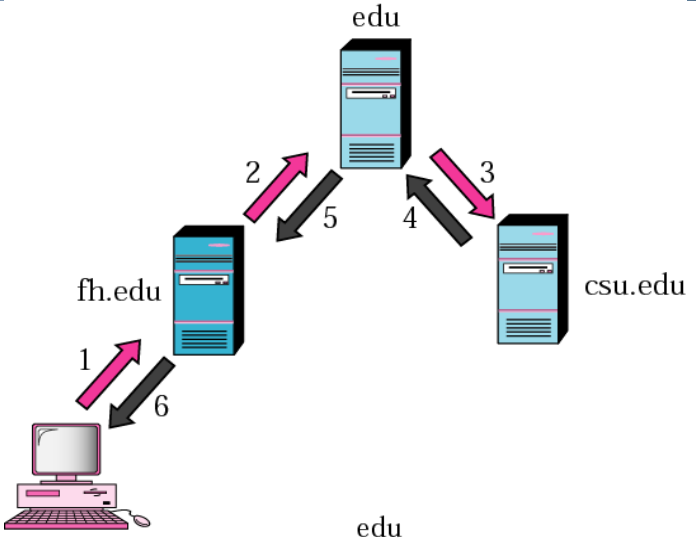
- A domain name consist of a number of labels



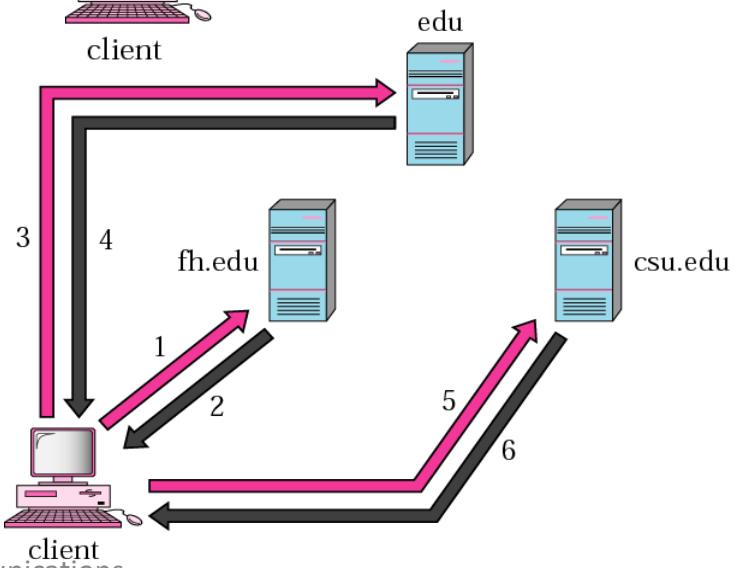
* Figure is courtesy of B. Forouzan

Name Resolution

- Recursive resolution

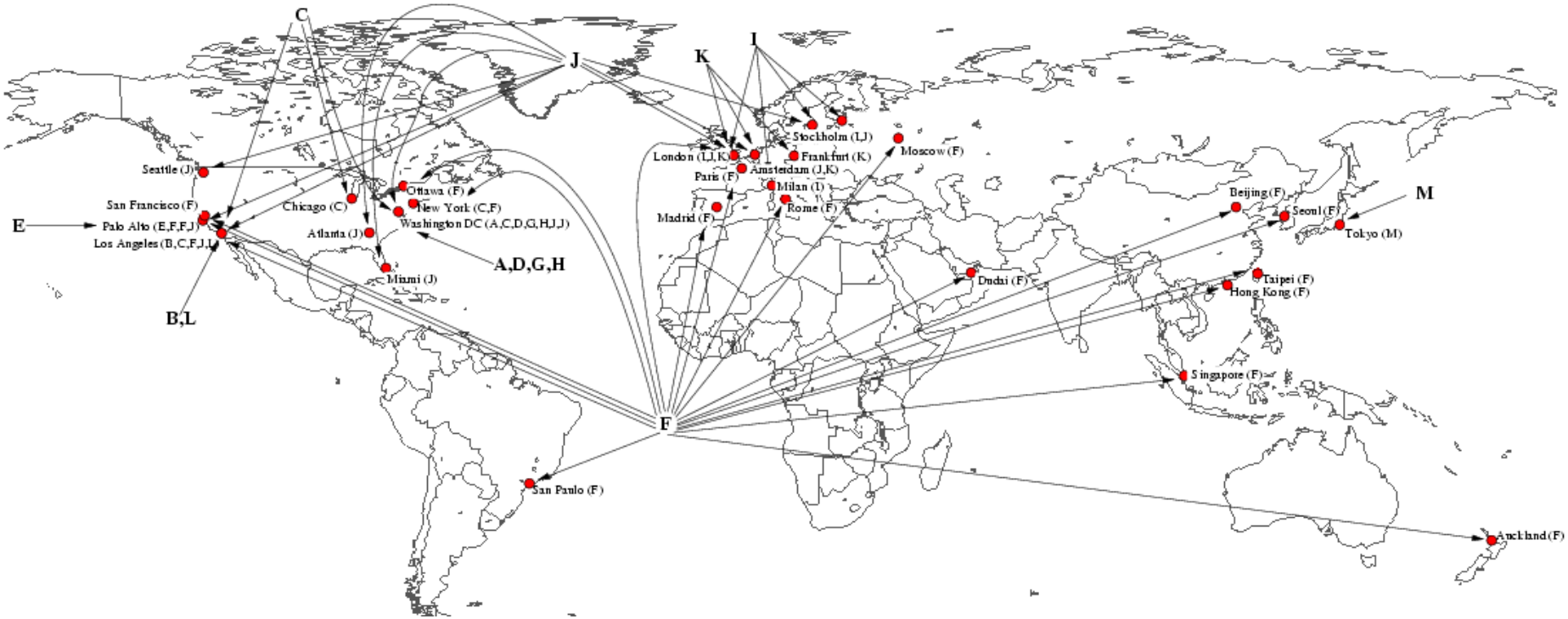


- Iterative resolution



* Figure is courtesy of B. Forouzan

DNS Root Servers - Anycast



* Figure is courtesy of CAIDA

root.zone file

```
e.dns.id.               172800  IN      A       103.19.177.177
e.dns.id.               172800  IN      AAAA    2001:df5:4000:4:0:0:0:4
ie.                     172800  IN      NS      a.ns.ie.
ie.                     172800  IN      NS      b.ns.ie.
ie.                     172800  IN      NS      c.ns.ie.
ie.                     172800  IN      NS      d.ns.ie.
ie.                     172800  IN      NS      e.ns.ie.
ie.                     172800  IN      NS      f.ns.ie.
ie.                     172800  IN      NS      g.ns.ie.
ie.                     172800  IN      NS      h.ns.ie.
IE.                     86400   IN      DS      25105 8 2 3883D06014FA40518A53C70442C3601A271C0F96
IE.                     86400   IN      RRSIG   DS 8 1 86400 20151206050000 20151126040000 62530 .
hHchxthV1+mIjN7sPVl27PSK04OJkegzc2Pib9+4q6bXYU3L6JPS4oXhsBqhSEA/WP7MvWemL0hSiETvuo3b8CAoMr0oTQnspb
ie.                     86400   IN      NSEC    ifm. NS DS RRSIG NSEC
ie.                     86400   IN      RRSIG   NSEC 8 1 86400 20151206050000 20151126040000 62536
QXF5lQuk4H1casAa0GTKv2Mueizyb8p06x3RU2BtQBG6O9nhU9dPHIN8AA6NTQaUTleBBwAaAF3aUh37Q6r2K6+x8gsj46nxsV
a.ns.ie.                172800  IN      A       77.72.72.44
a.ns.ie.                172800  IN      AAAA    2a01:4b0:0:0:0:0:0:3
b.ns.ie.                172800  IN      A       77.72.72.34
b.ns.ie.                172800  IN      AAAA    2a01:4b0:0:0:0:0:0:2
c.ns.ie.                172800  IN      A       194.146.106.98
c.ns.ie.                172800  IN      AAAA    2001:67c:1010:25:0:0:0:53
d.ns.ie.                172800  IN      A       77.72.229.245
d.ns.ie.                172800  IN      AAAA    2a01:3f0:0:309:0:0:0:53
e.ns.ie.                172800  IN      A       199.19.2.1
e.ns.ie.                172800  IN      AAAA    2001:500:93:0:0:0:0:1
f.ns.ie.                172800  IN      A       199.19.3.1
```

.ie Servers

Name Servers

Host Name	IP Address(es)
e.ns.ie	199.19.2.1 2001:500:93:0:0:0:0:1
b.ns.ie	77.72.72.34 2a01:4b0:0:0:0:0:0:2
g.ns.ie	192.111.39.100 2001:7c8:2:a:0:0:0:64
c.ns.ie	194.146.106.98 2001:67c:1010:25:0:0:0:53
d.ns.ie	77.72.229.245 2a01:3f0:0:309:0:0:0:53
f.ns.ie	199.19.3.1 2001:500:95:0:0:0:0:1
a.ns.ie	77.72.72.44 2a01:4b0:0:0:0:0:0:3
h.ns.ie	192.93.0.4 2001:660:3005:1:0:0:1:2

* Information from http://www.iana.org/domains/root/db/ie.html

ipconfig /all

```
Wireless LAN adapter WiFi:

   Connection-specific DNS Suffix  . : scss.tcd.ie
   Description . . . . . . . . . . . : Intel(R) Dual Band Wireless-AC 7260
   Physical Address. . . . . . . . . : 28-B2-BD-A0-C0-A3
   DHCP Enabled. . . . . . . . . . . : Yes
   Autoconfiguration Enabled . . . . : Yes
   IPv6 Address. . . . . . . . . . . : 2001:770:10:203:c018:a372:1daa:424f(Prefe
rred)
   Temporary IPv6 Address. . . . . . : 2001:770:10:203:f0c0:4f35:6fd5:90d4(Prefe
rred)
   Link-local IPv6 Address . . . . . : fe80::c018:a372:1daa:424f%3(Preferred)
   IPv4 Address. . . . . . . . . . . : 134.226.62.20(Preferred)
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Lease Obtained. . . . . . . . . . : 26 November 2015 11:11:18
   Lease Expires . . . . . . . . . . : 26 November 2015 14:26:16
   Default Gateway . . . . . . . . . : fe80::c664:13ff:fe42:7a42%3
                                       134.226.62.254
   DHCP Server . . . . . . . . . . . : 134.226.32.58
   DHCPv6 IAID . . . . . . . . . . . : 52998845
   DHCPv6 Client DUID. . . . . . . . : 00-01-00-01-1B-DD-F3-17-28-B2-BD-A0-C0-A3

   DNS Servers . . . . . . . . . . . : 134.226.32.57
                                       134.226.56.13
```

nslookup

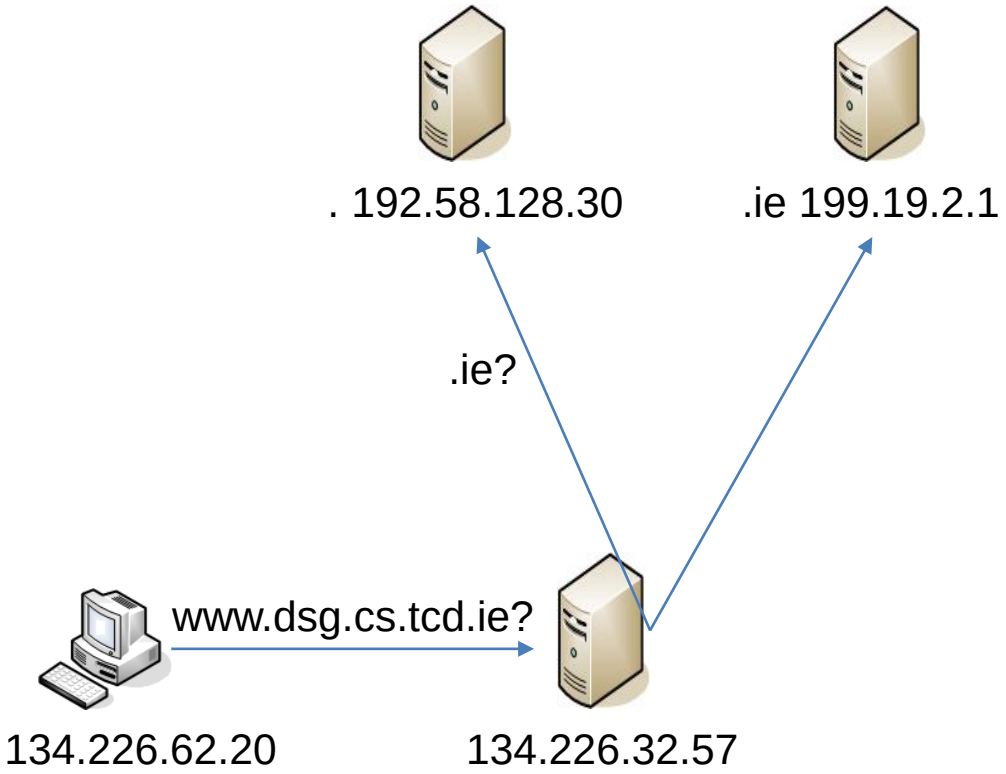
```
C:\Users\sweber>nslookup
Default Server:  challenger.cs.tcd.ie
Address:  134.226.32.57

> set type=NS
> tcd.ie
Server:  challenger.cs.tcd.ie
Address:  134.226.32.57

Non-authoritative answer:
tcd.ie  nameserver = int-ns1.tcd.ie
tcd.ie  nameserver = int-ns2.tcd.ie

int-ns1.tcd.ie  internet address = 134.226.251.108
int-ns2.tcd.ie  internet address = 134.226.251.109
> scss.tcd.ie
Server:  challenger.cs.tcd.ie
Address:  134.226.32.57

scss.tcd.ie      nameserver = ns2.scss.tcd.ie
scss.tcd.ie      nameserver = ns.scss.tcd.ie
ns.scss.tcd.ie   internet address = 134.226.32.58
ns.scss.tcd.ie   AAAA IPv6 address = 2001:770:10:200:e8e0:c8ff:fec5:6b63
ns2.scss.tcd.ie internet address = 134.226.56.13
ns2.scss.tcd.ie AAAA IPv6 address = 2001:770:10:200:a0dd:c1ff:fe89:ed50
```

SOA

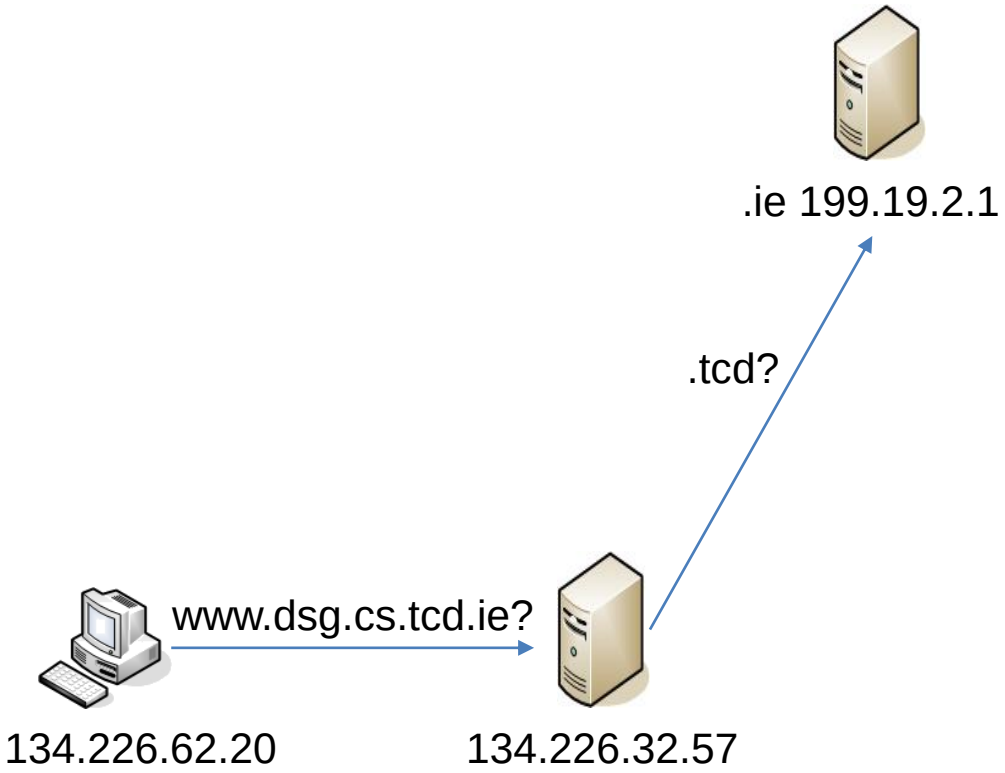
Type	Meaning	Value
SOA	Start of Authority	Parameters for this zone
A	IP address of a host	32-Bit integer
MX	Mail exchange	Priority, domain willing to accept e-mail
NS	Name Server	Name of a server for this domain
CNAME	Canonical name	Domain name

```
@                       IN      SOA     ns1.dsg.cs.tcd.ie. dsgadmin.cs.tcd.ie. (
                                        2003100801      ; Serial   yearmonthdayversion
                                        7200            ; Refresh 2 hours
                                        1800            ; Retry   1/2 hour
                                        86400           ; Expire  1 day
                                        10800 )         ; Minimum 3 hours
                        MX      10      relay.cs.tcd.ie.
                        IN      NS      ns1.dsg.cs.tcd.ie.
                        IN      NS      ns2.dsg.cs.tcd.ie.

dsg.cs.tcd.ie           IN      A       134.226.36.0
                        MX      10      relay.cs.tcd.ie.

computerA   IN          A       134.226.36.1
dilbert                 IN      CNAME   computerA
dogbert                 IN      A       134.226.36.2
                        IN      A       134.226.36.3
```

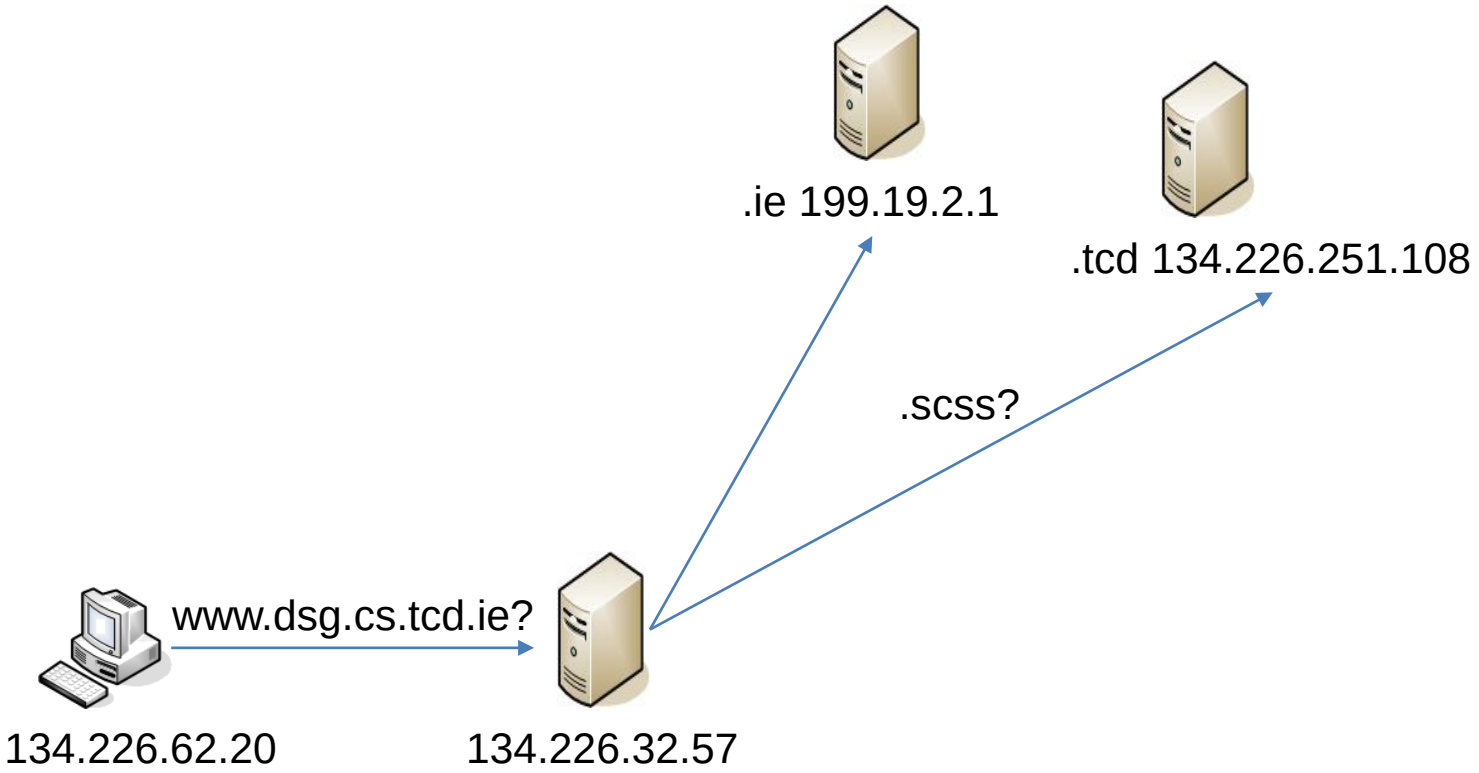
Lookup of www.dsg.scss.tcd.ie.



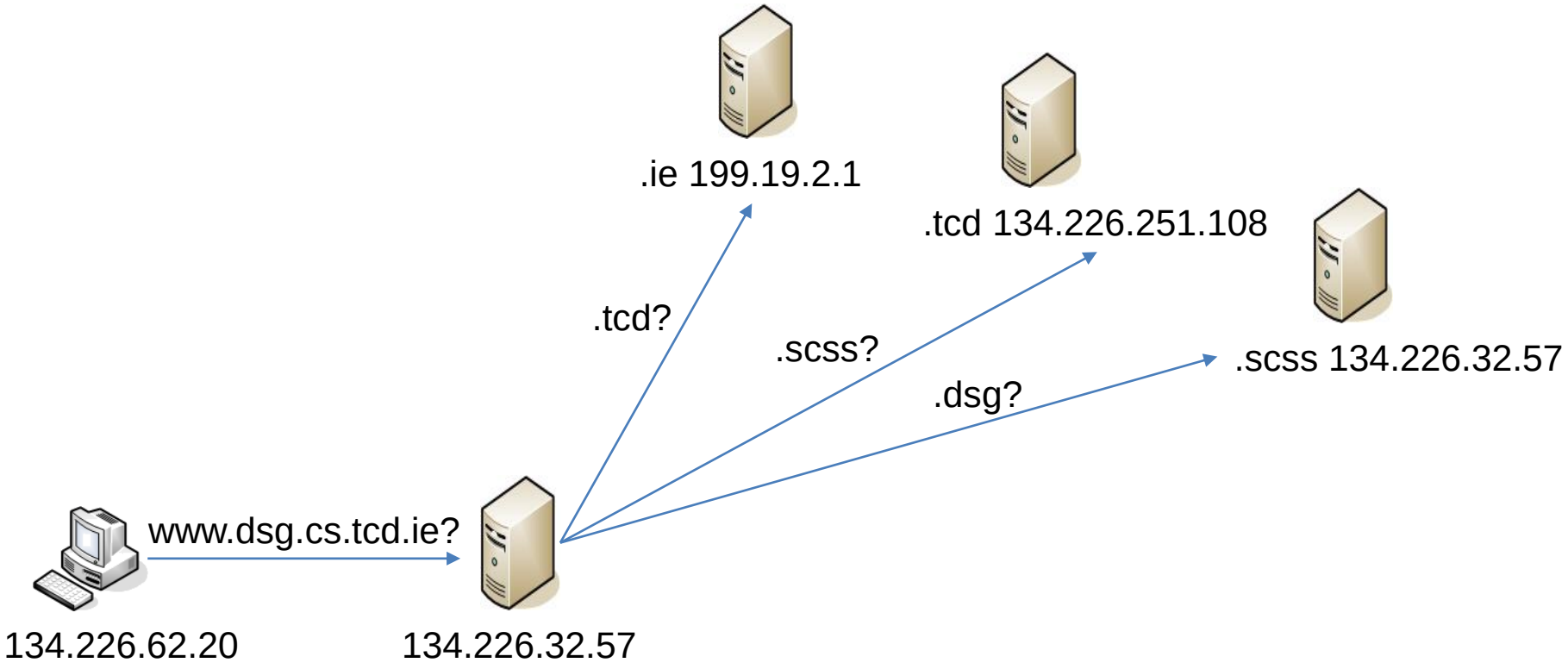
Lookup of www.dsg.scss.tcd.ie.



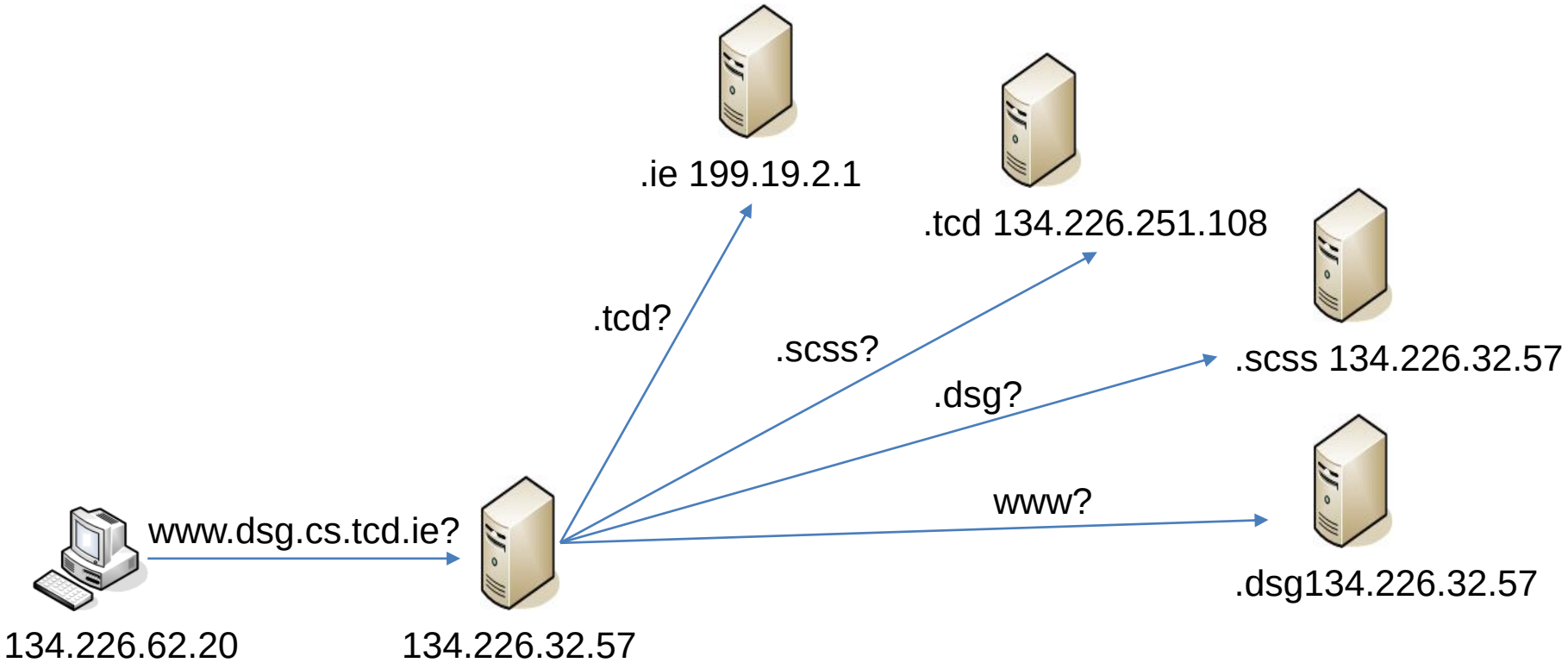
Lookup of www.dsg.scss.tcd.ie.



Lookup of www.dsg.scss.tcd.ie.

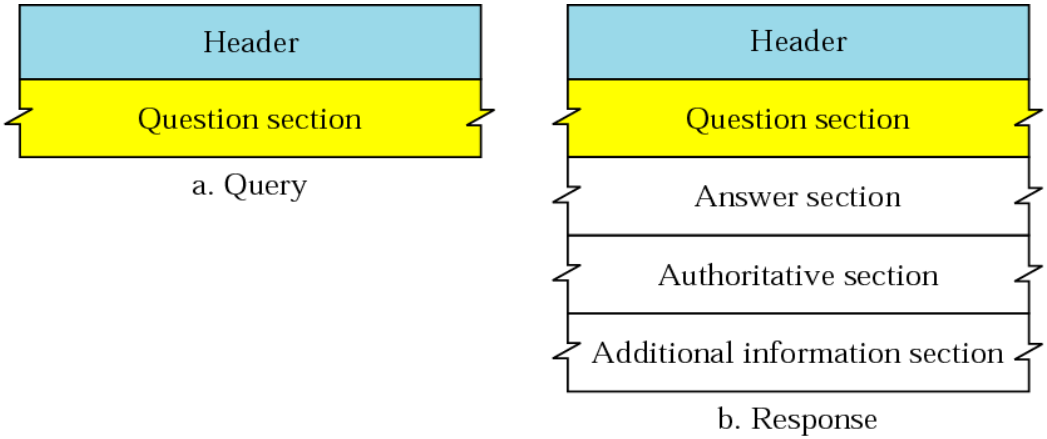


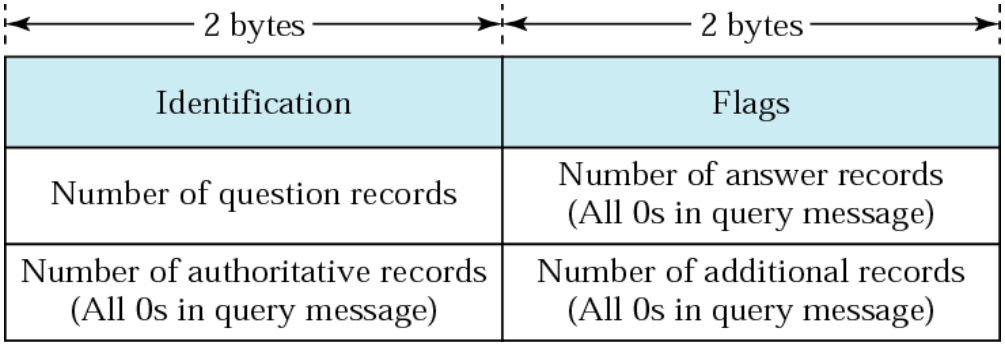
Lookup of www.dsg.scss.tcd.ie.



Query and Response Messages

- Two types of replies:
  - Authoritive answers
  - Cached or unauthoritive answers
- 6-byte header





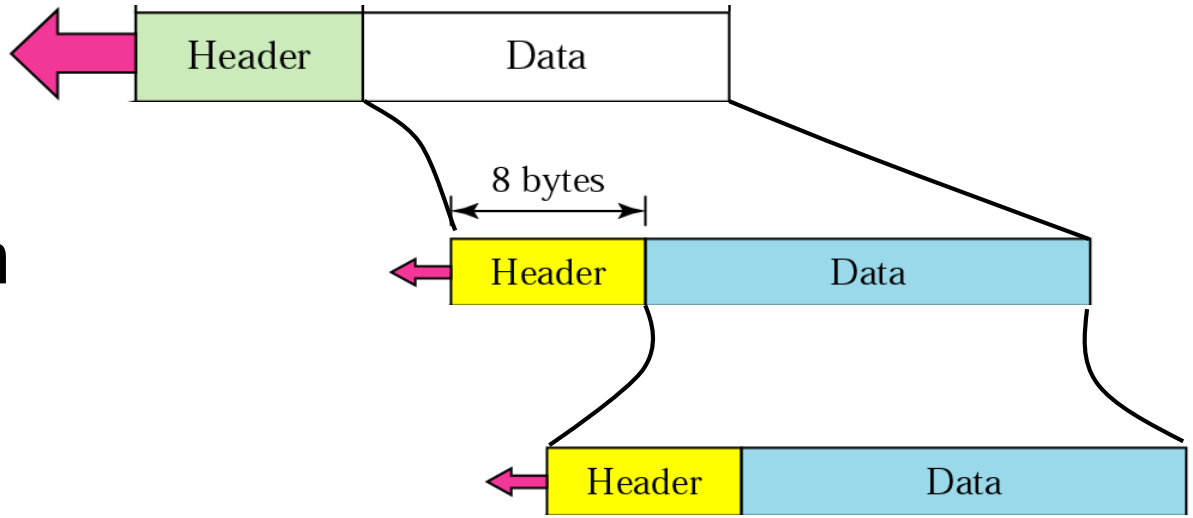
* Figure is courtesy of B. Forouzan

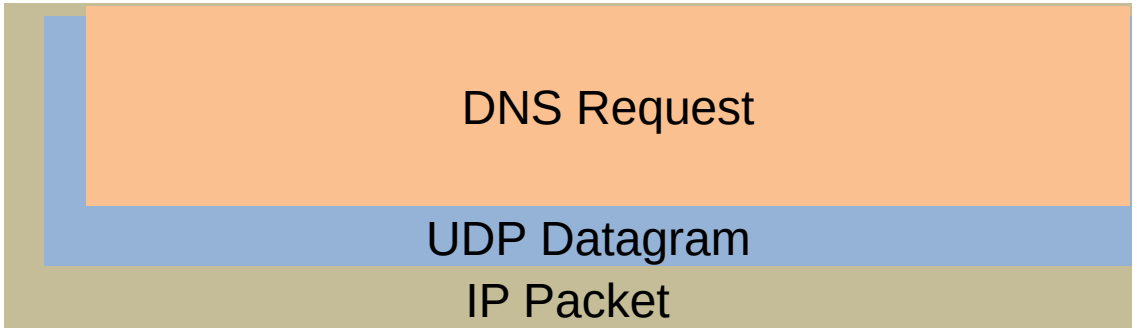
DNS Request

IP Packet

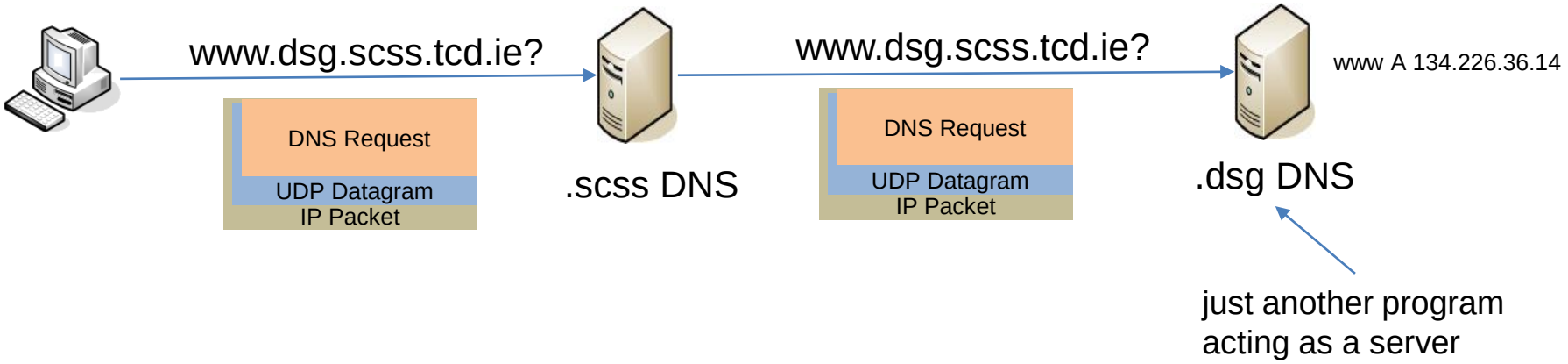
UDP Datagram

DNS Request

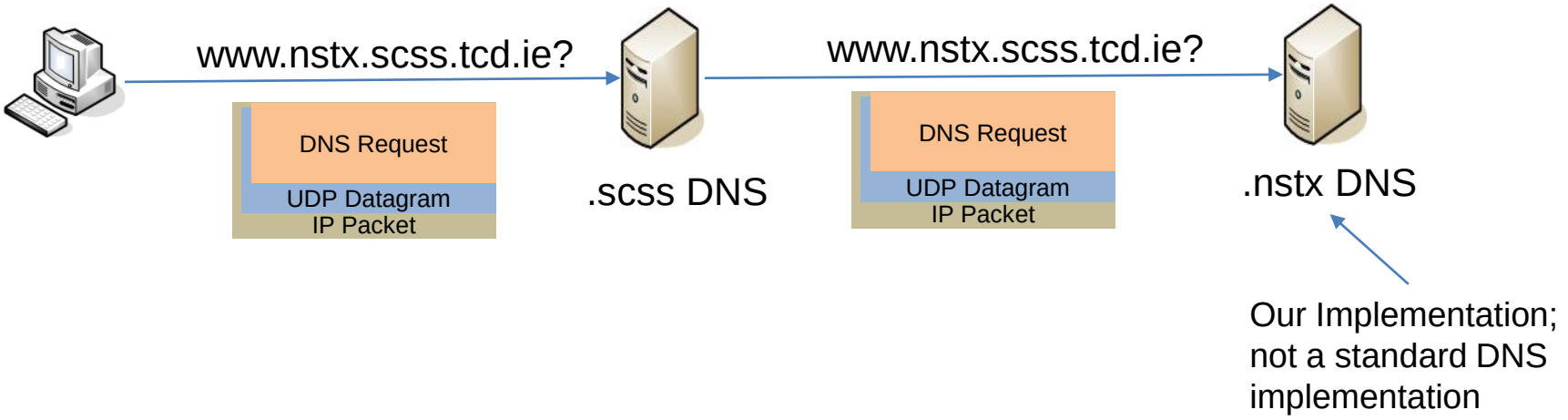




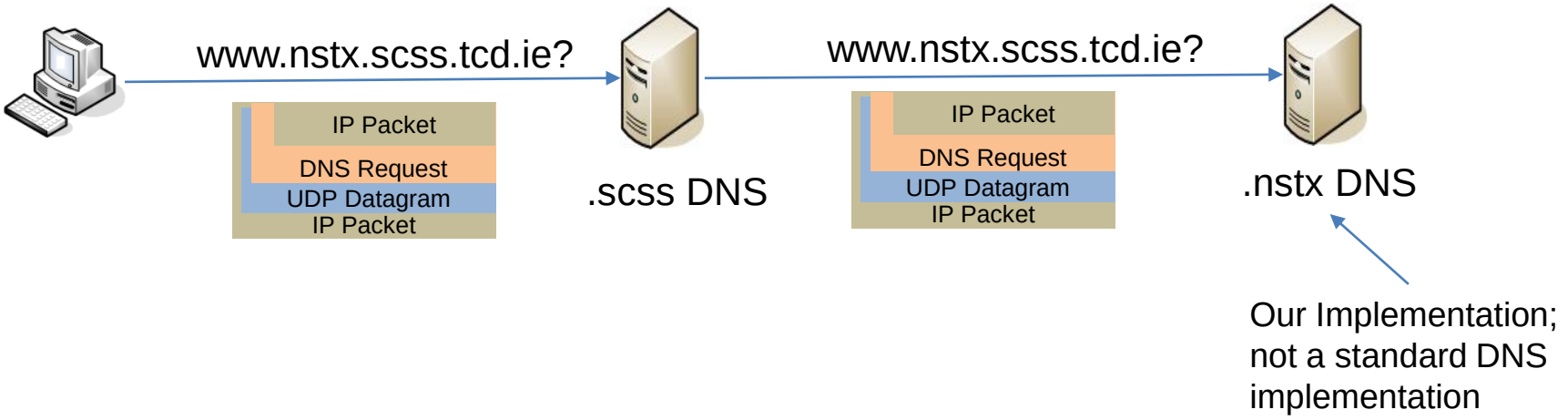
Lookup of www.dsg.scss.tcd.ie.



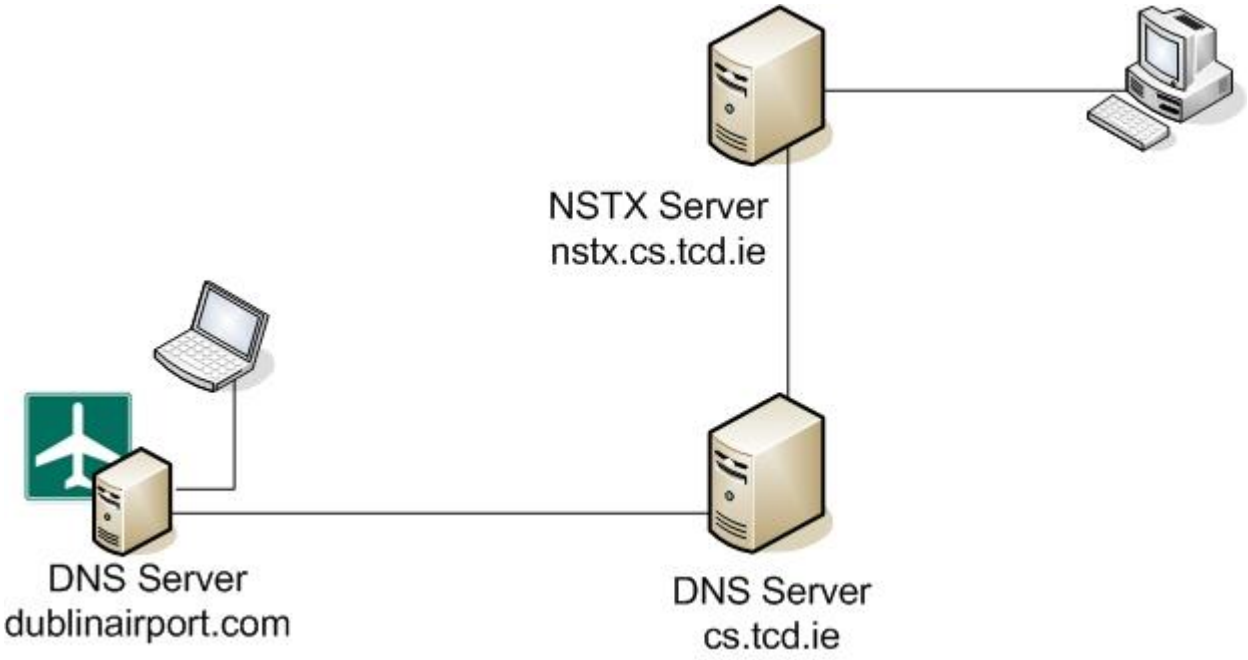
NSTX


www.nstx.scss.tcd.ie?
DNS Request
UDP Datagram
IP Packet
.scss DNS
www.nstx.scss.tcd.ie?
DNS Request
UDP Datagram
IP Packet
.nstx DNS
Our Implementation; not a standard DNS implementation

NSTX

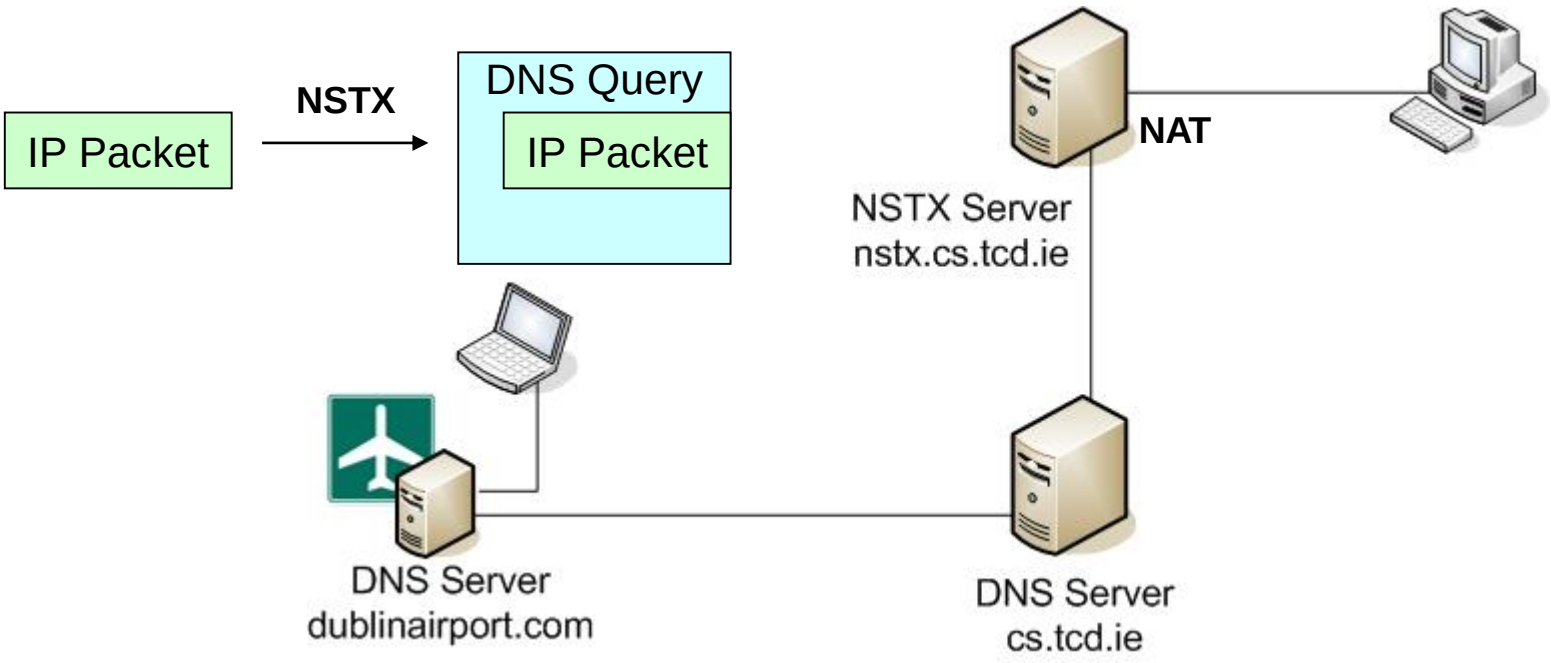

www.nstx.scss.tcd.ie?
IP Packet
DNS Request
UDP Datagram
IP Packet
.scss DNS
www.nstx.scss.tcd.ie?
IP Packet
DNS Request
UDP Datagram
IP Packet
.nstx DNS
Our Implementation; not a standard DNS implementation

IP-over-DNS II



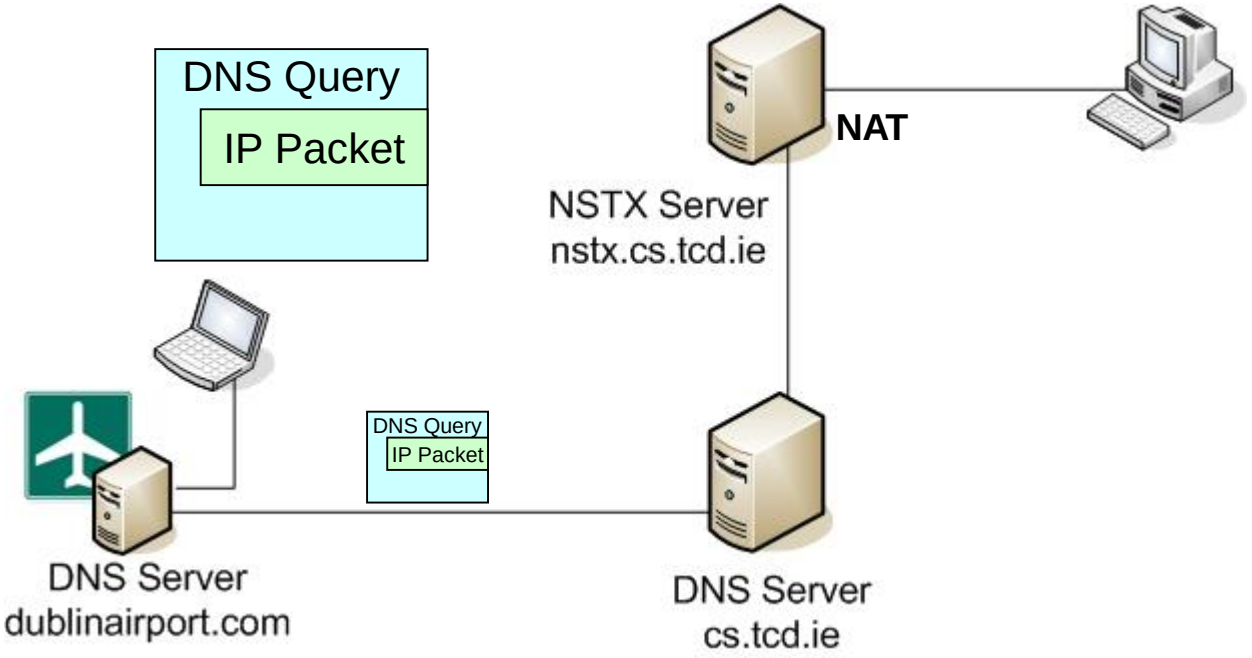
- Laptop with limited access at airport
- Encapsulate IP packet into DNS query
  - Example: NSTX, Iodine

IP-over-DNS II



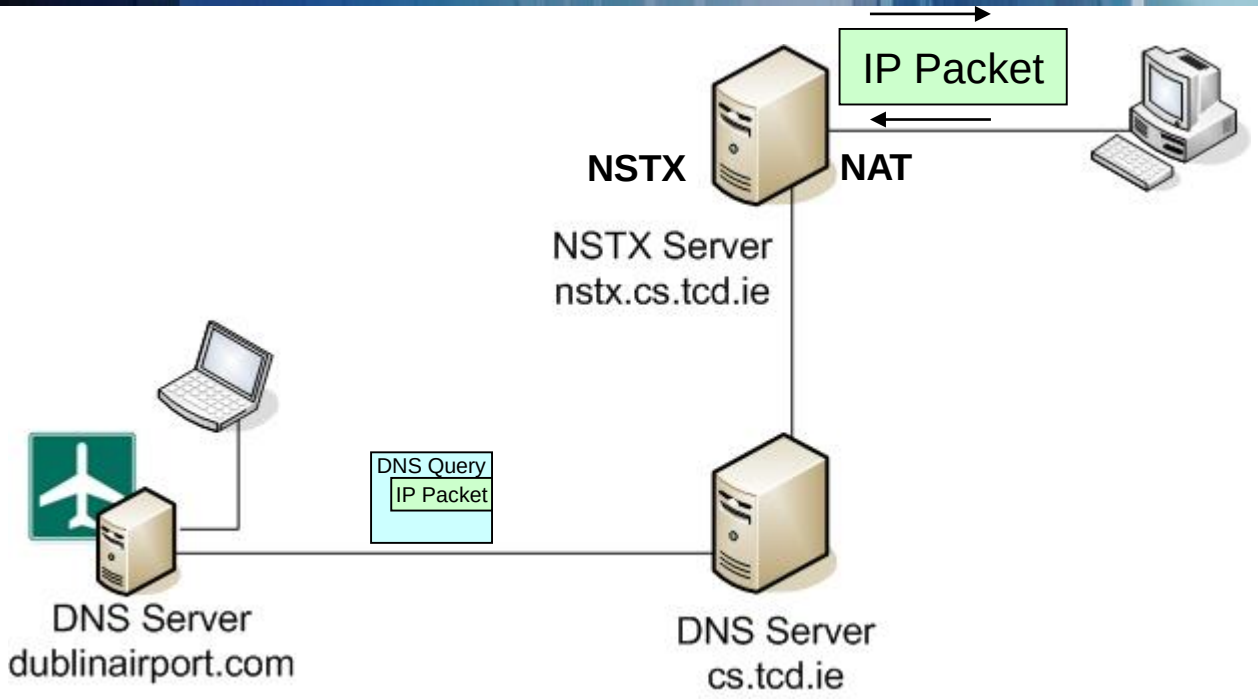
- Laptop with limited access at airport
- Encapsulate IP packet into DNS query
  - Example: NSTX, Iodine

IP-over-DNS III



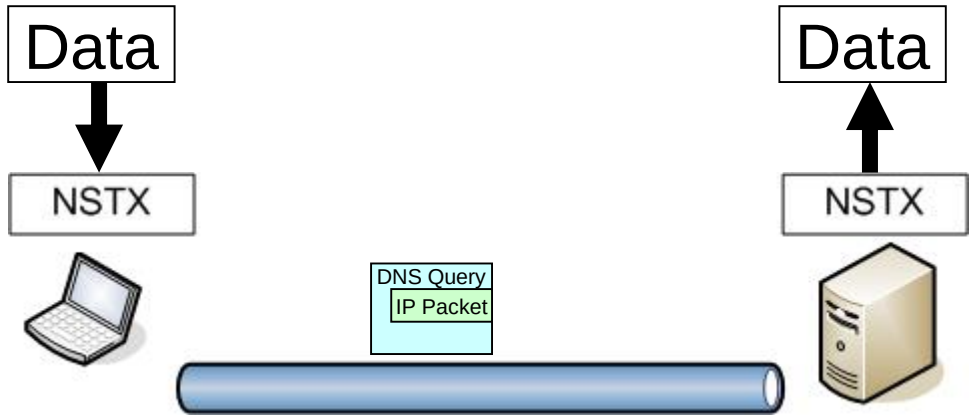
- Laptop with limited access at airport
- Encapsulate IP packet into DNS query
  - Example: NSTX, Iodine

IP-over-DNS IV



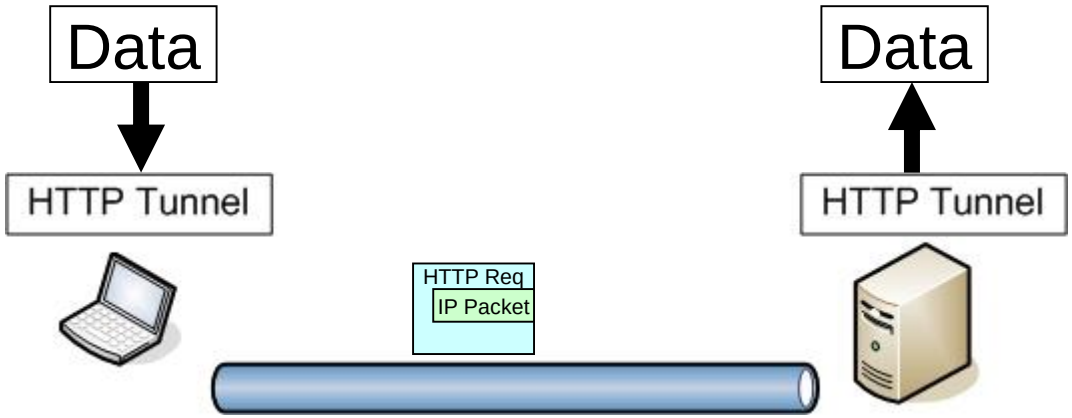
- Laptop with limited access at airport
- Encapsulate IP packet into DNS query
  - Example: NSTX, Iodine

Tunnelling I



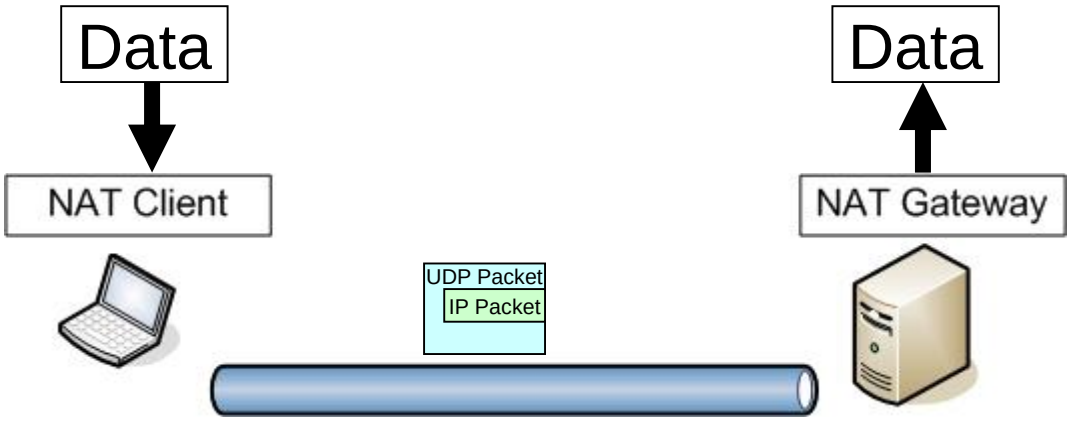
- Machine with access to Internet
- Machine with restricted access
- Both run programs that can pack and unpack data to be tunnelled

Tunnelling II



- Same process: Tunnel runs on both machines to pack and unpack data
- HTTP Request can transverse proxies etc

Tunnelling III



- Same process: Client and gateway should know how to pack and unpack data
- Gateway could be any machine in College with access to machines outside

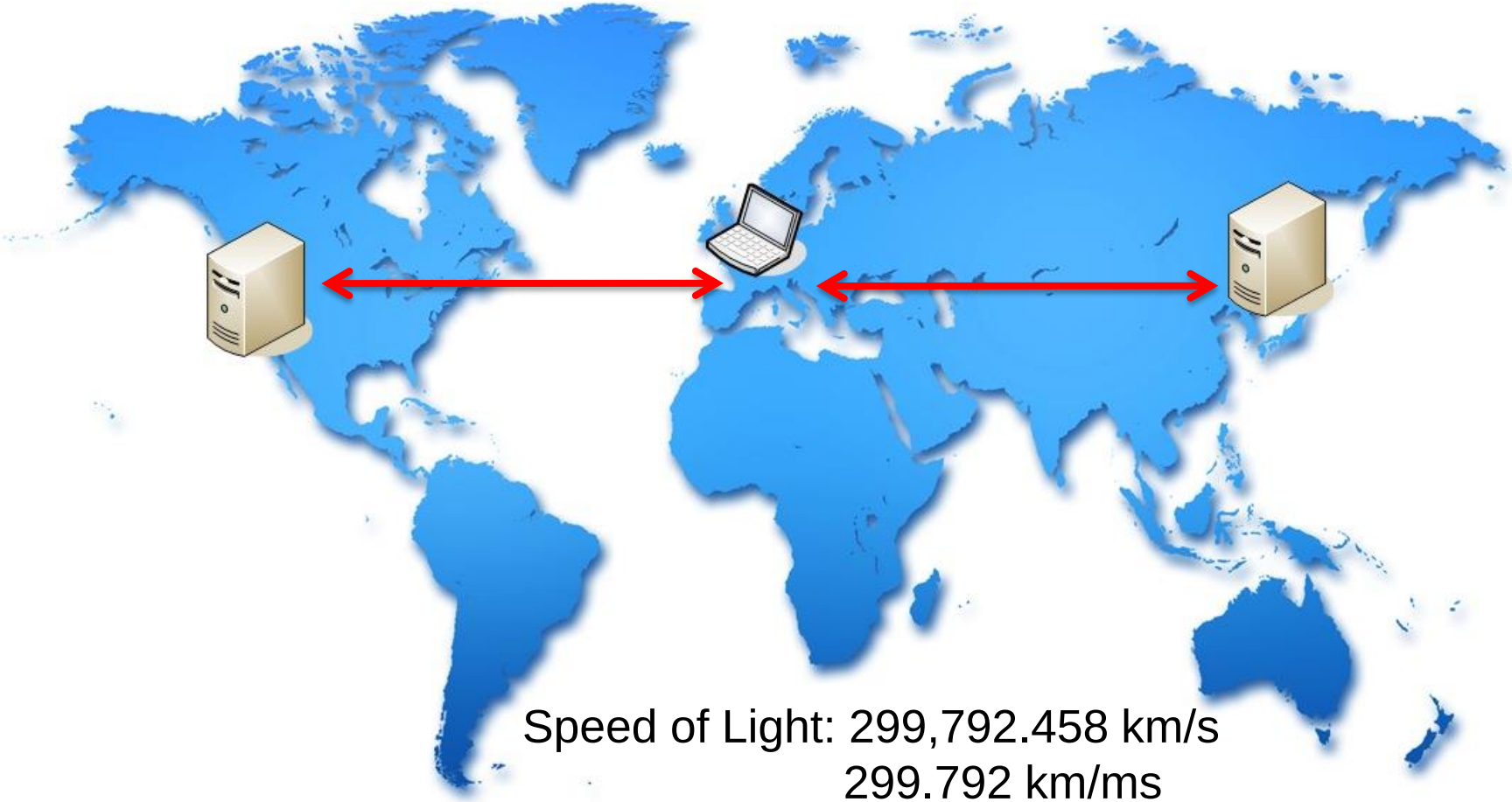
CS2031
Telecommunications II

CDN

CDN - Motivation

* Figure is courtesy of B. Forouzan

Fixed Latency



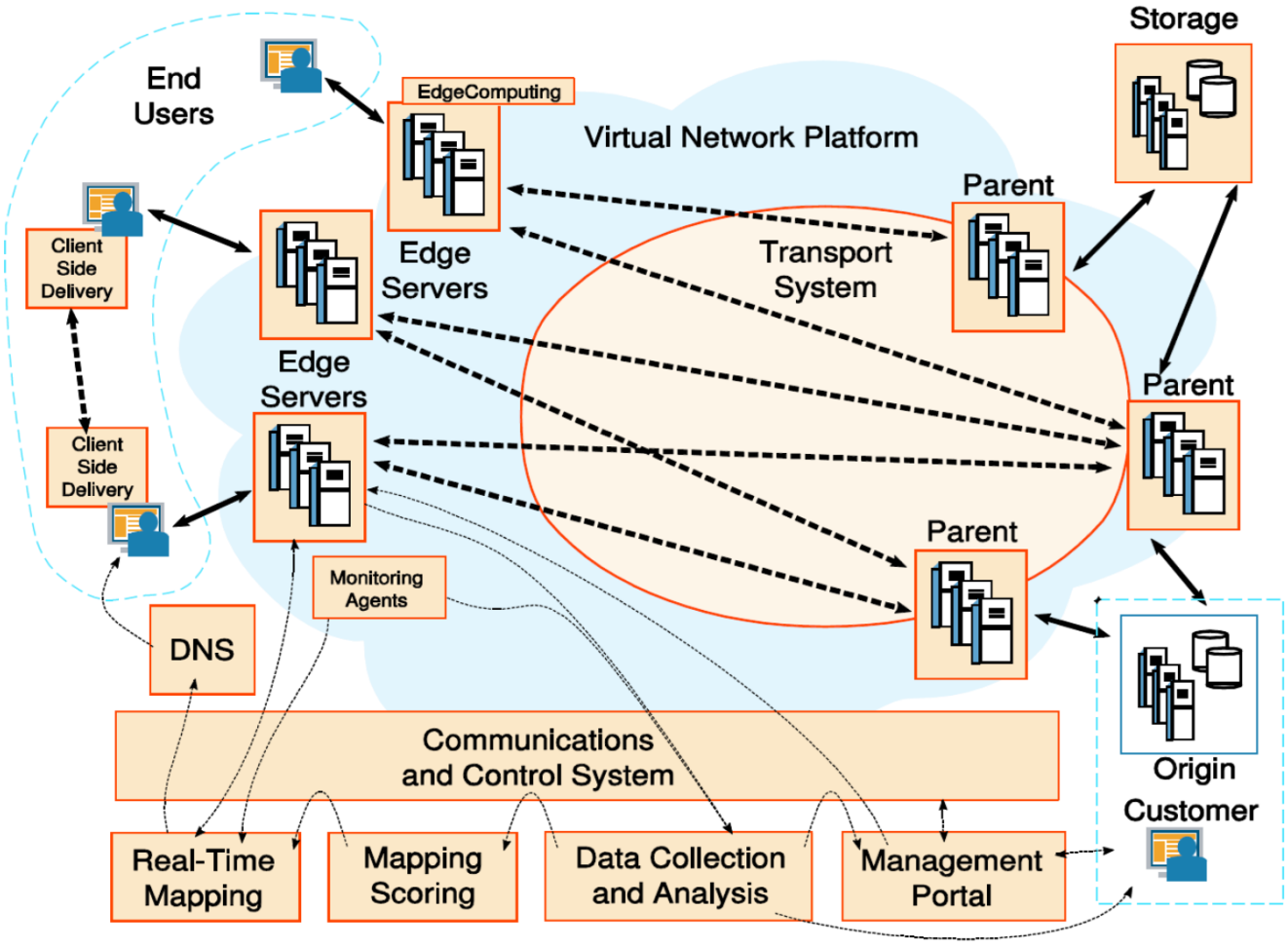
Speed of Light: 299,792.458 km/s
299.792 km/ms
~300 km/ms

Content-Distribution Networks

e.g. Akamai, Limelight, Amazon, Netflix, etc

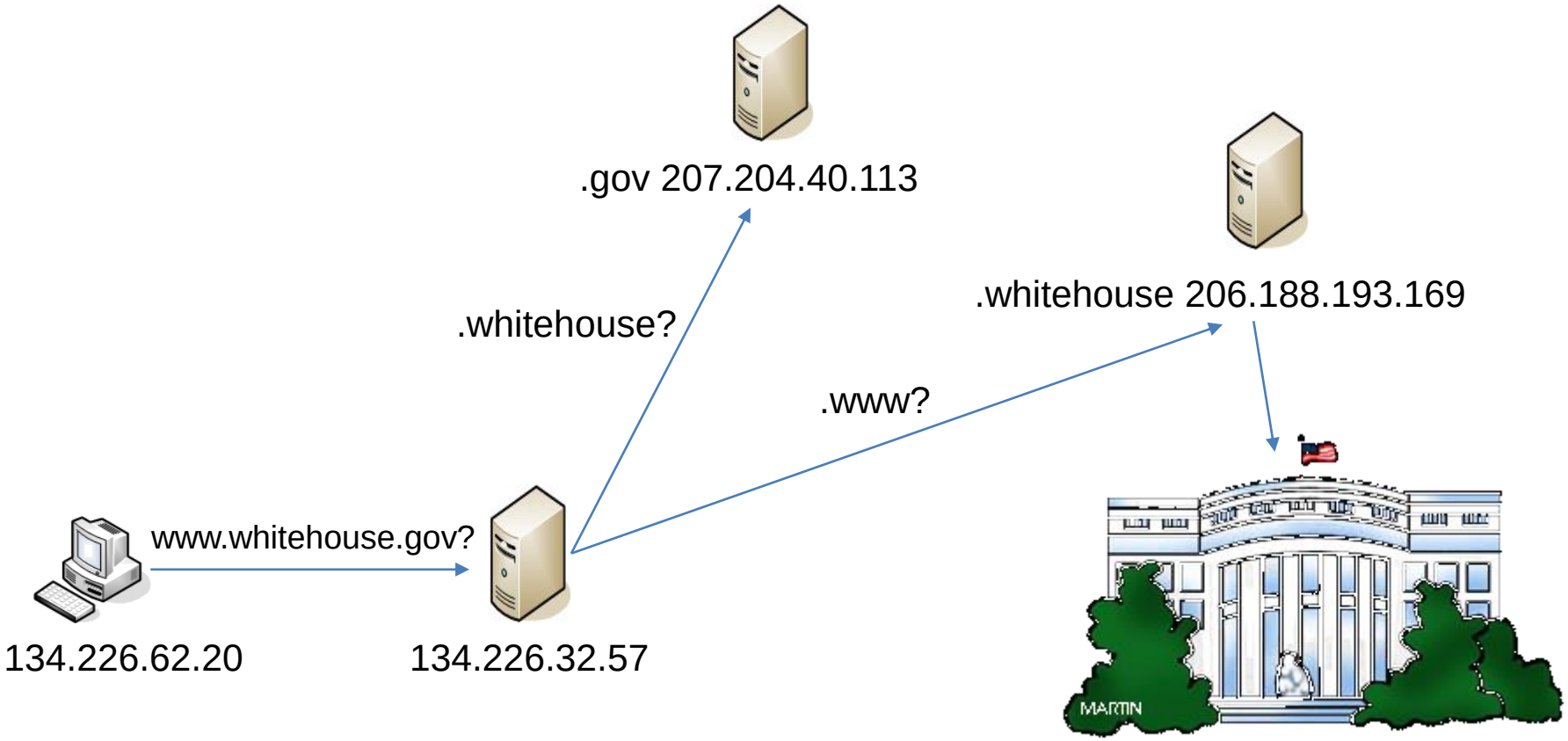
Akamai Scenario

- DNS redirection
- Clusters of servers at points of presence
- Replication



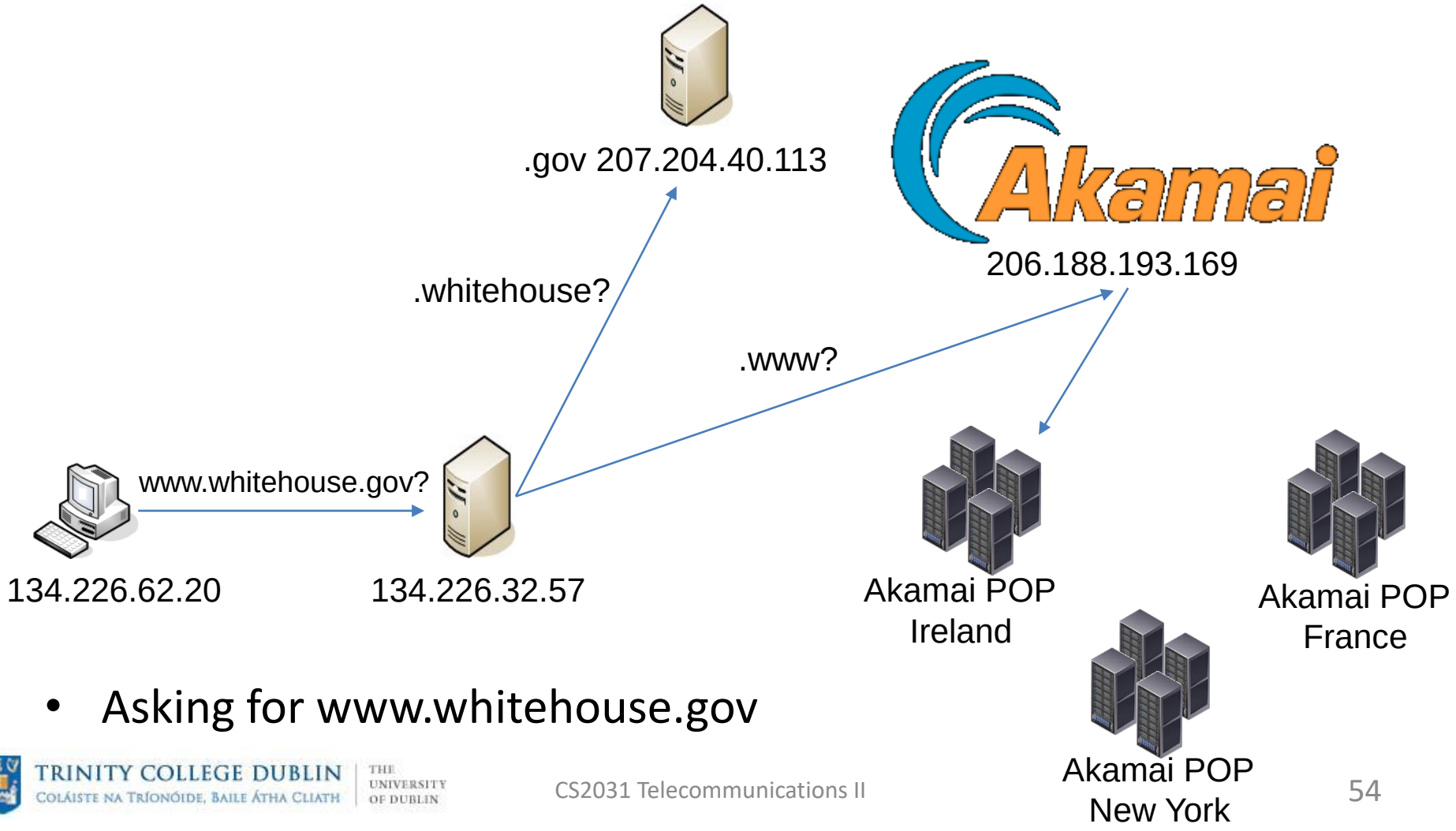
•Figure courtesy of E. Nygren et al

The Usual Case



- Asking for www.whitehouse.gov

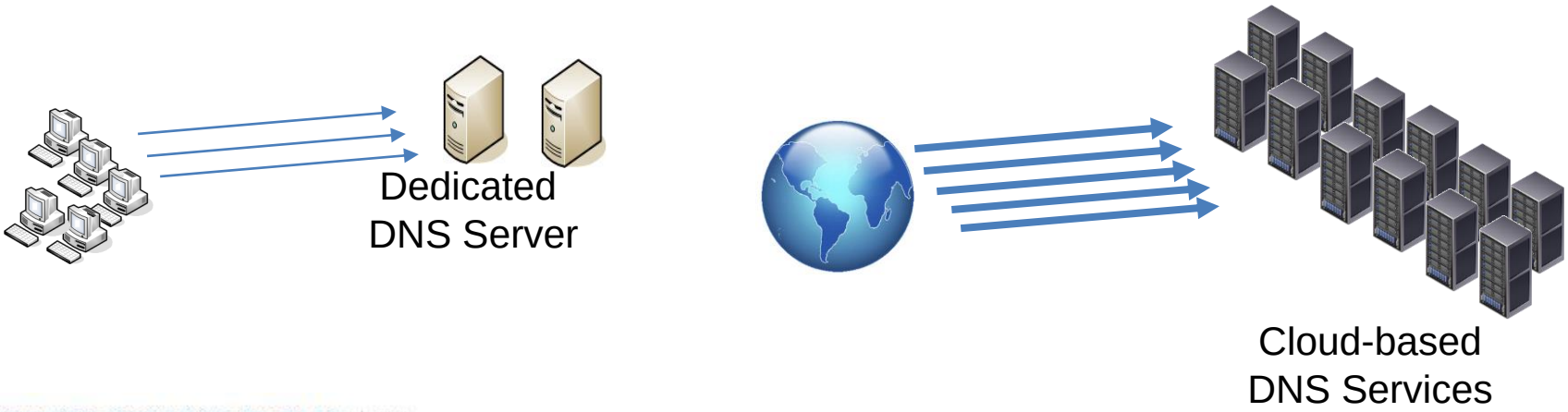
Redirection of DNS



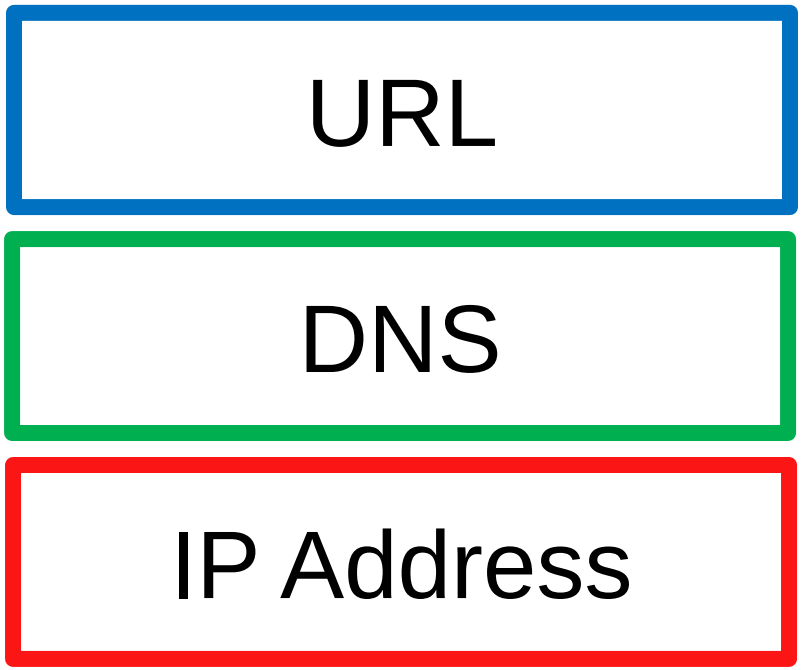
- Asking for www.whitehouse.gov

Mirai Bot & The Attack on Dyn

- Mirai Bot Source published (Sept 30th)
- Attack on Dyn (Oct 21st)
- From one manufacturer:
  "username: root" and "password: xc3511" hardcoded into the device firmware of a number of devices

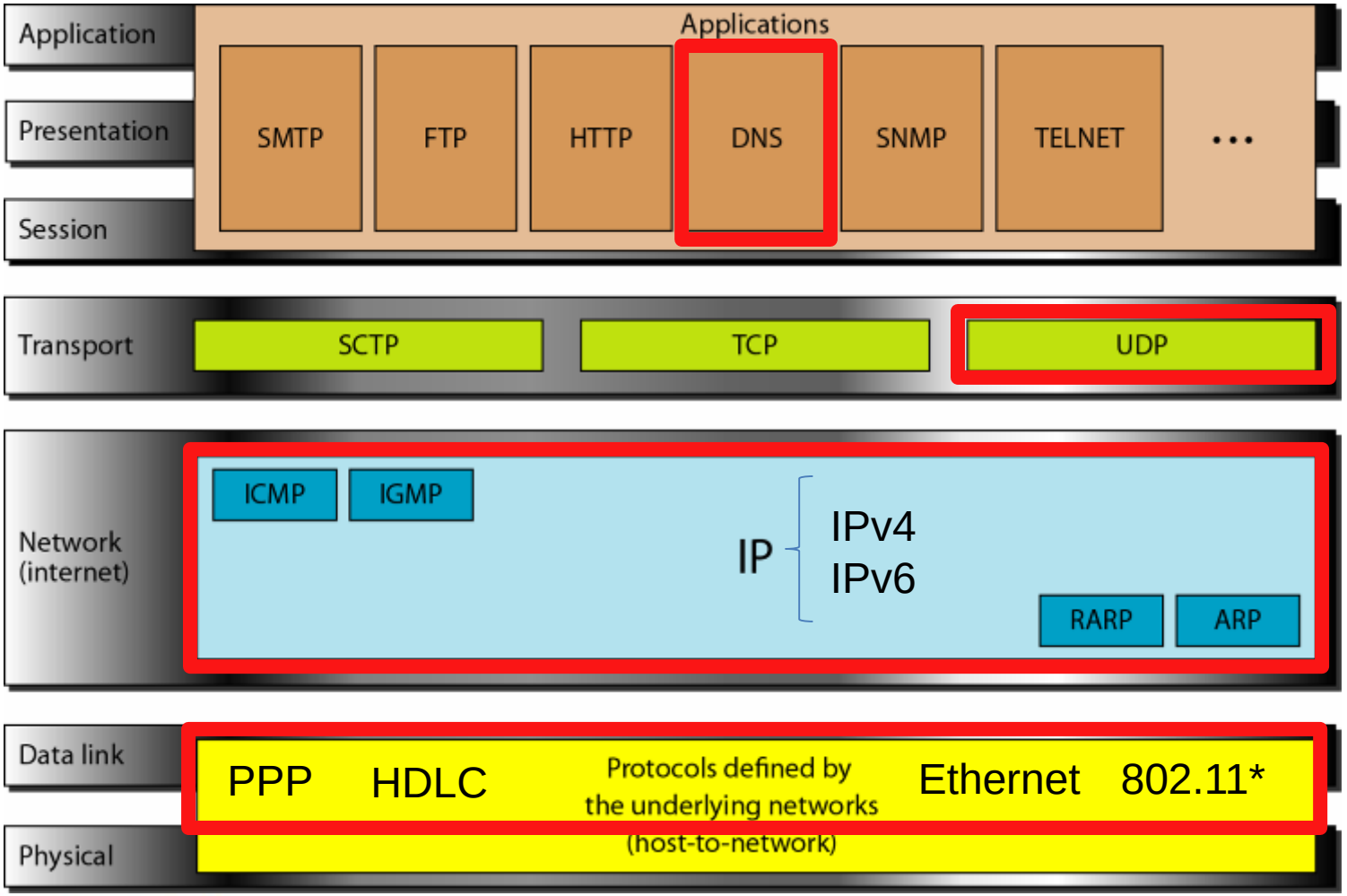


URLs to Names to Addresses



*URL = Uniform Resource Locator

Protocols in the OSI Model



* Figure is courtesy of B. Forouzan

CS Predictions

- "I think there is a world market for maybe five computers."

  Thomas Watson, President of IBM, 1943

- "There is no reason anyone would want a computer in their home."

  Ken Olsen, Founder of Digital Equipment Corporation, 1977

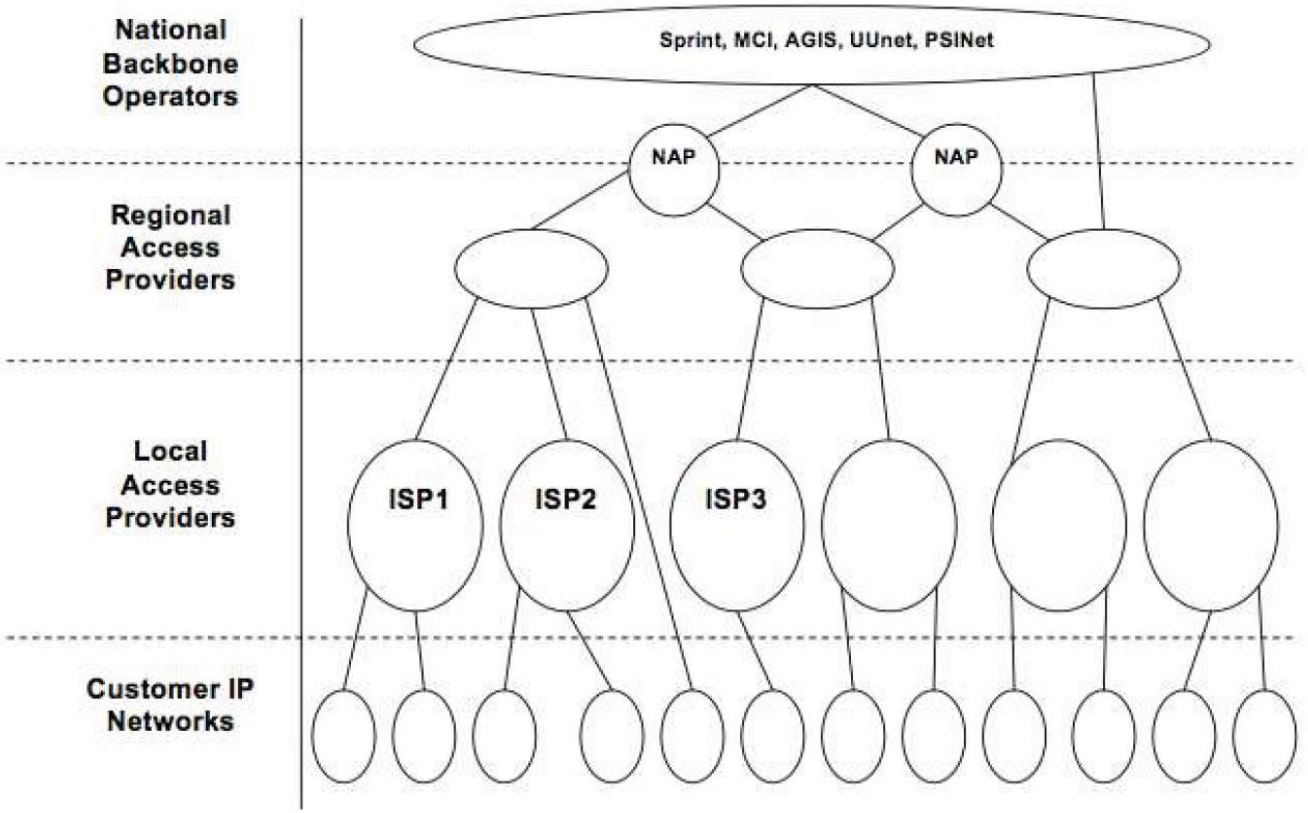
- "I predict the Internet in 1996 will catastrophically collapse."

  Robert Metcalfe, 1995

- "IPv6 is dead."

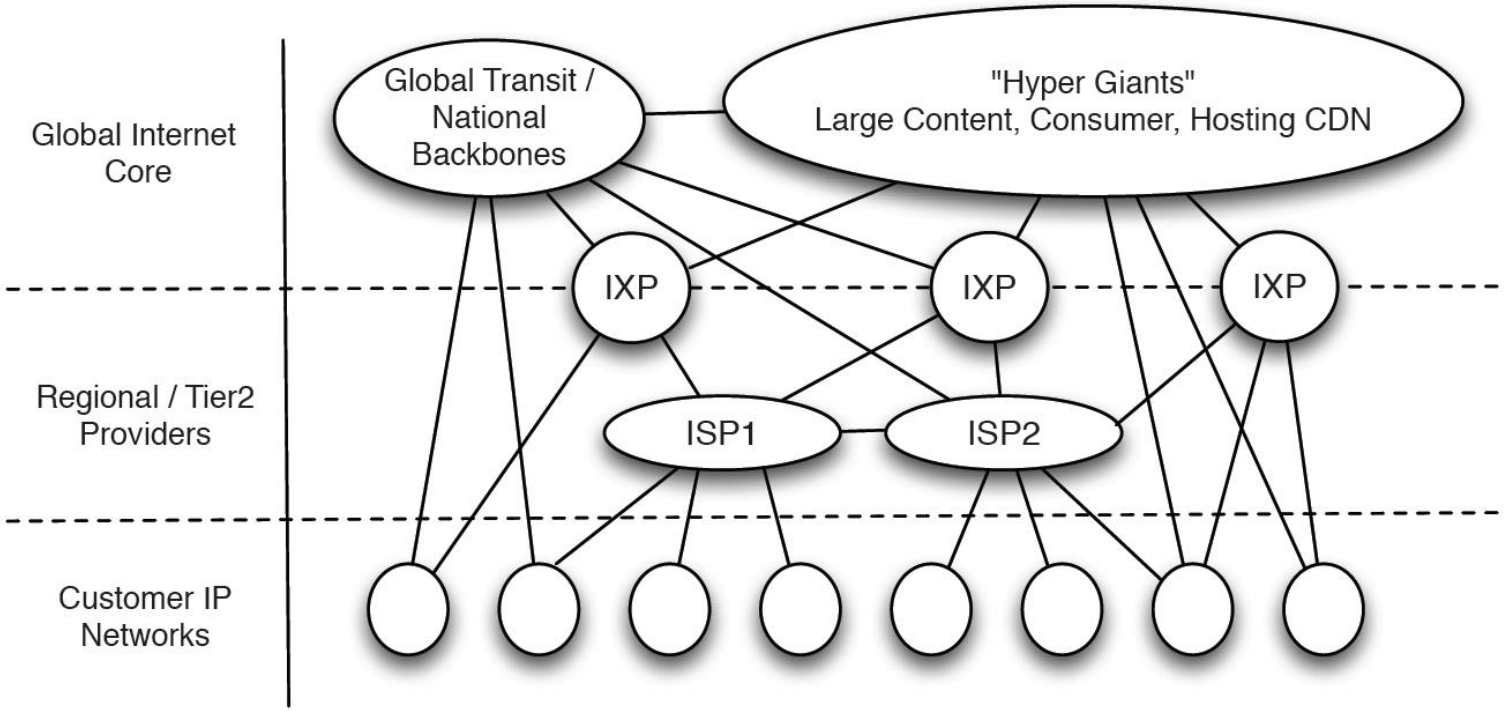
  David Cheriton, 1999

Traditional Logical Internet Topology



* Figure is courtesy of C. Labovitz, et al, SIGCOMM 2010

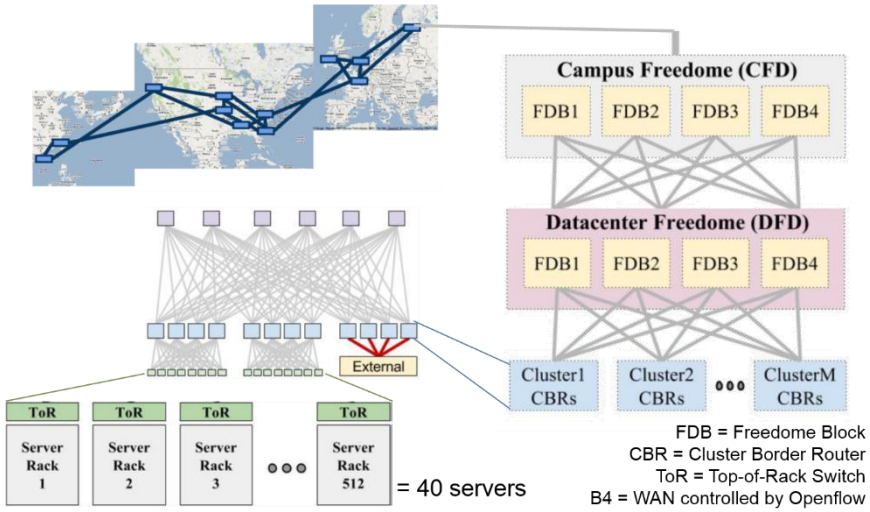
Emerging Logical Internet Topology

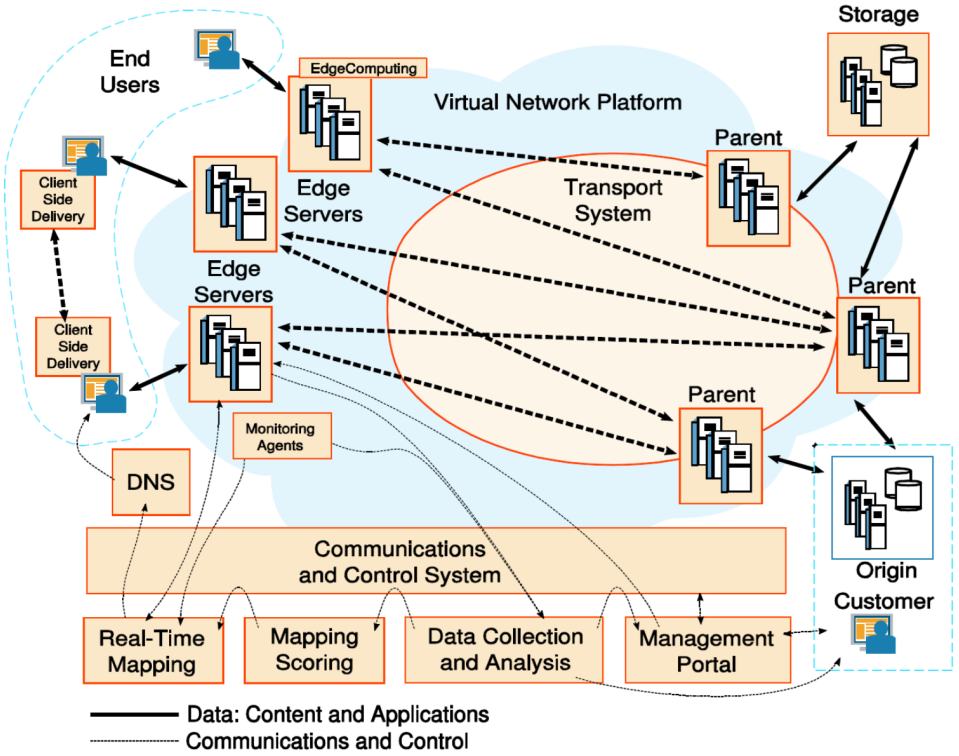


- According to a statement by Craig Labovitz in 2014:
  - 30 Entities created 50% of the traffic in the US at peak time

* Figure is courtesy of C. Labovitz, et al, SIGCOMM 2010

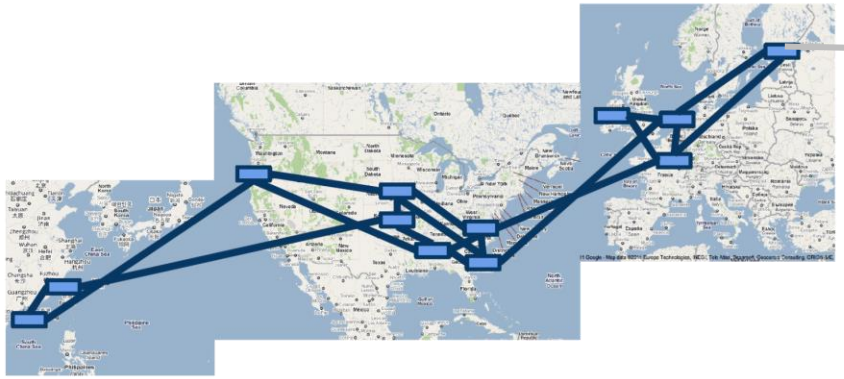
Hyper-Giants

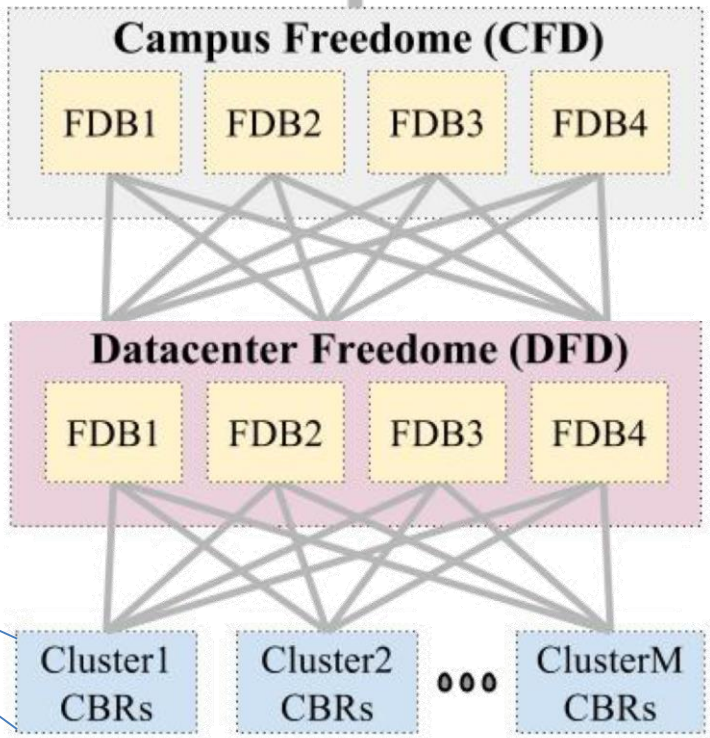


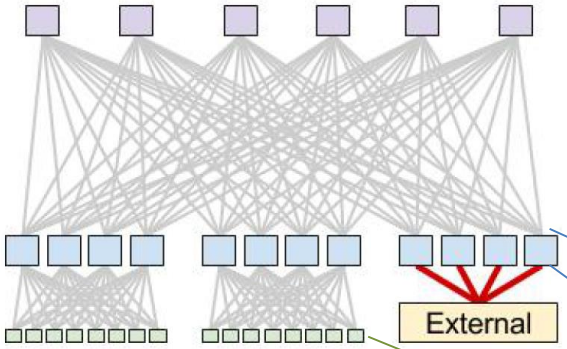


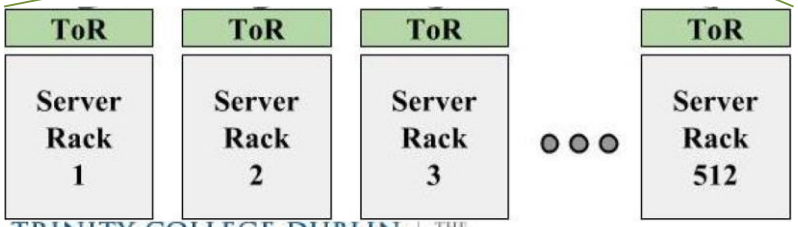
- Google
- Akamai

Google's B4 to Jupiter





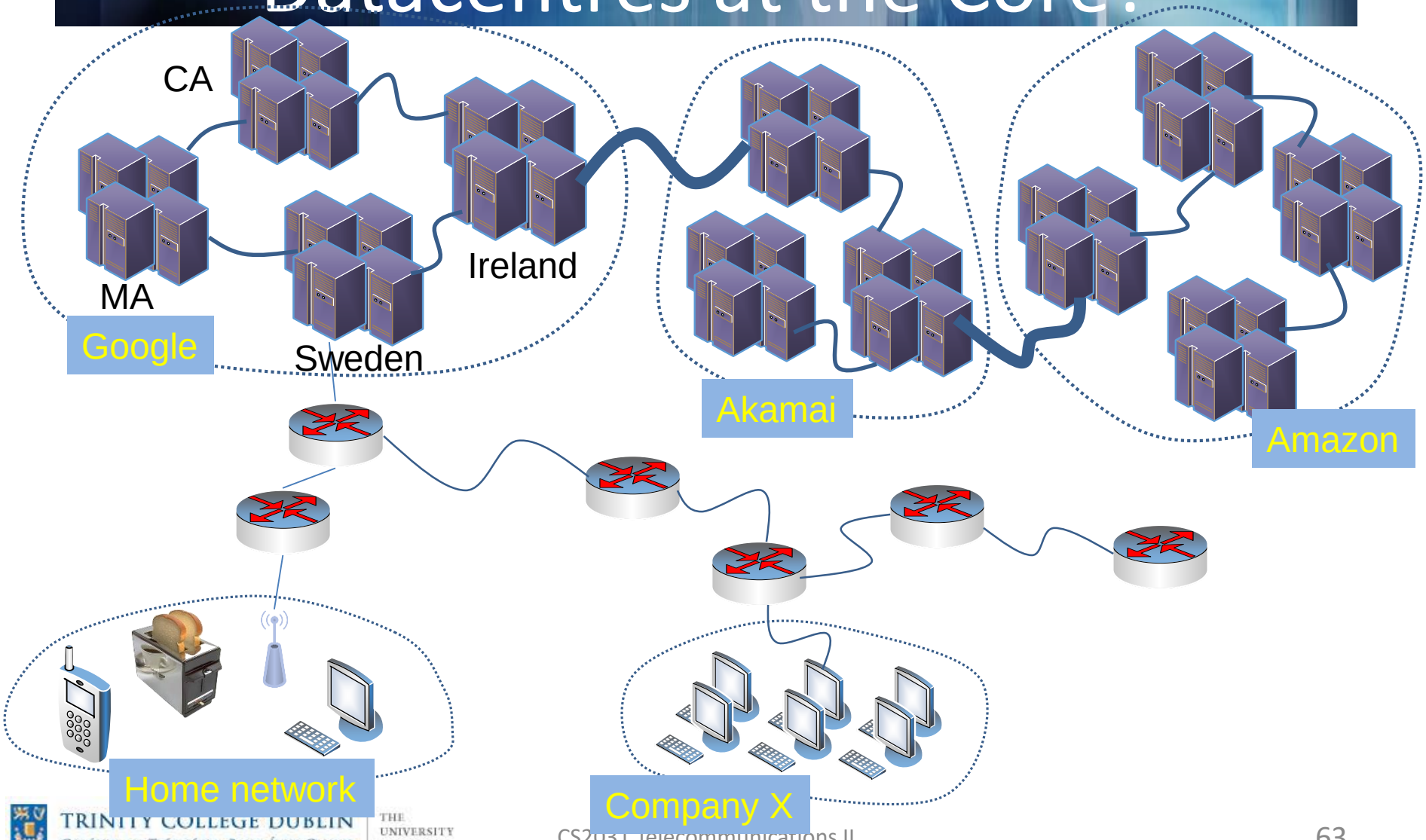




= 40 servers

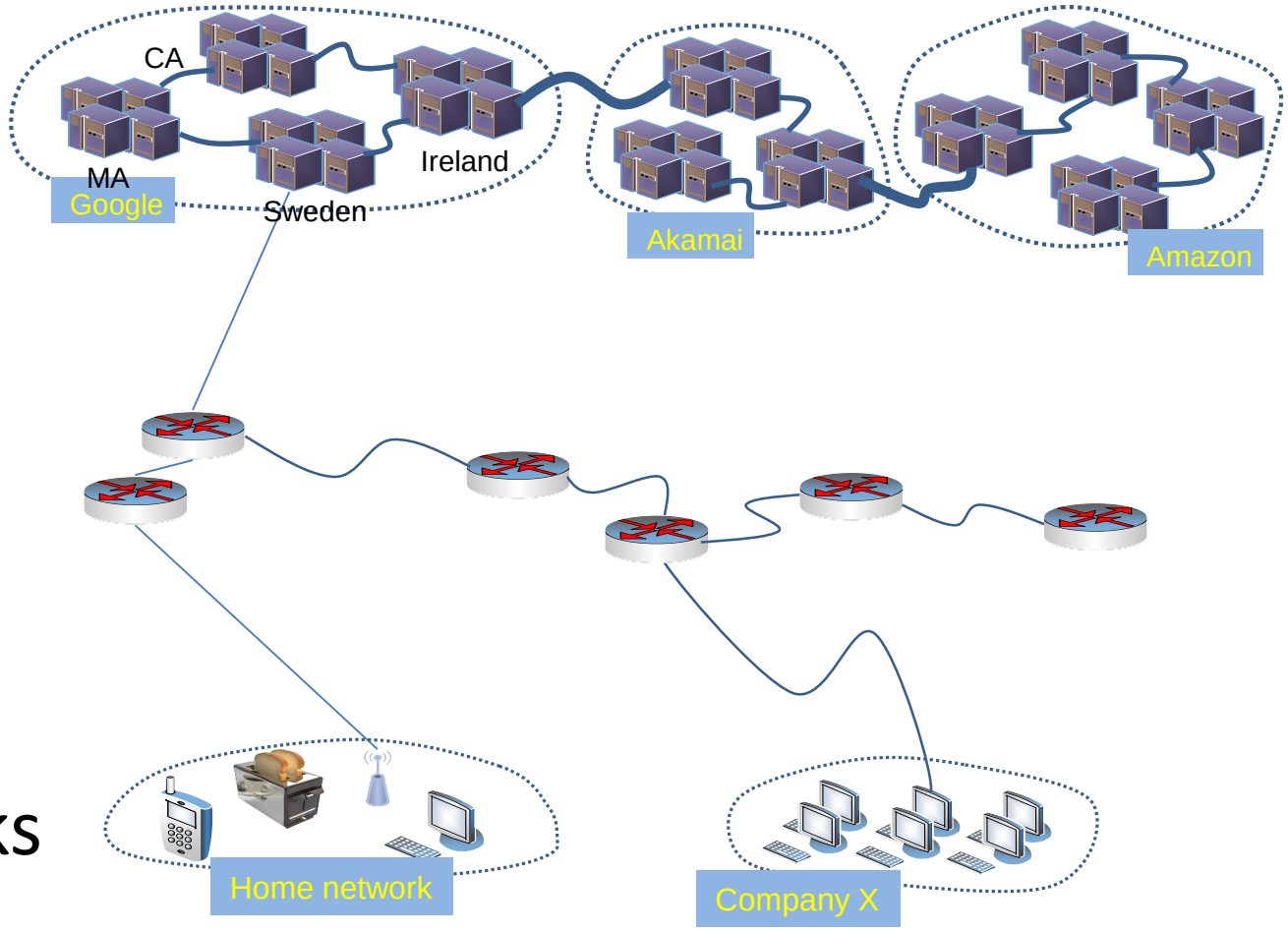
FDB = Freedome Block
CBR = Cluster Border Router
ToR = Top-of-Rack Switch
B4 = WAN controlled by Openflow

Datacentres at the Core?



My view of "future"* networking

- Sets of Datacentres
- Traditional Internet
- Edge networks



*or current?

Overview

- Link Layer
- Network Layer
  - Addressing
  - Address Resolution (ARP)
  - Fragmentation
  - Intra-AS Routing
    - Distance Vector
    - Link State
  - Multicast Routing
  - IPv6
- Transport Layer
  - UDP
  - DNS
- Software-Defined Networking / Openflow
- Google Infrastructure - CLOS / Fat-tree / Peering

That's all folks
Telecomms II