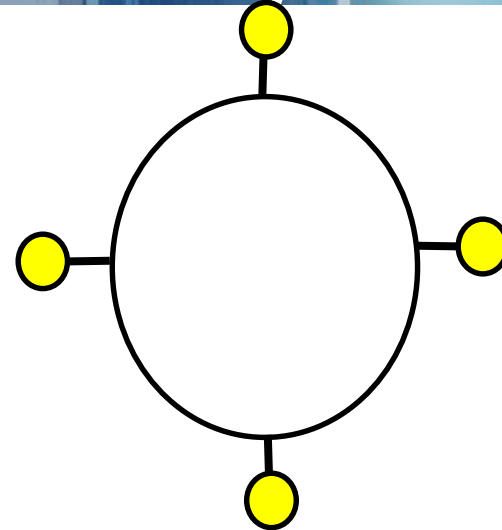
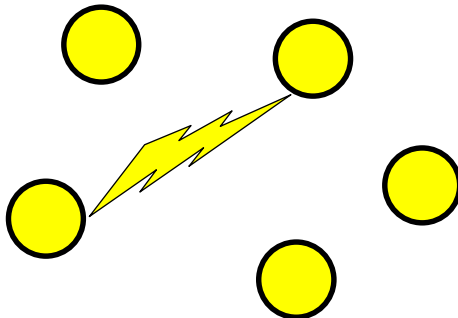
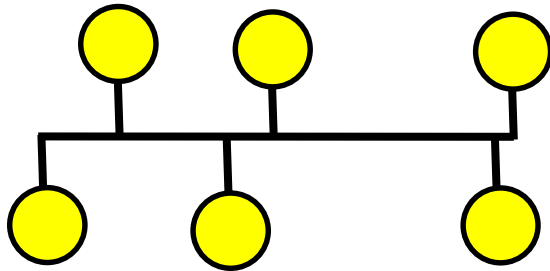


CS2031

Telecommunications II

UDP

Naming at the Link Layer

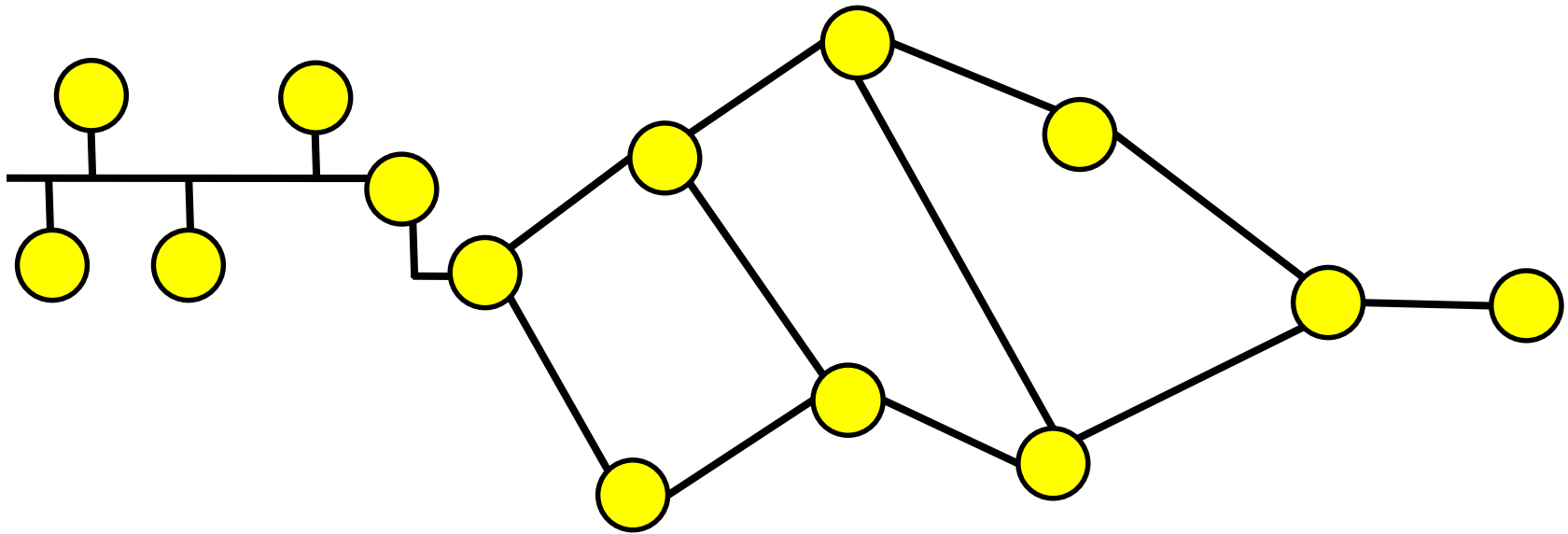


One direct link between
two terminals

● = Terminals or Stations

Data units = Frames

Naming at the Network Layer

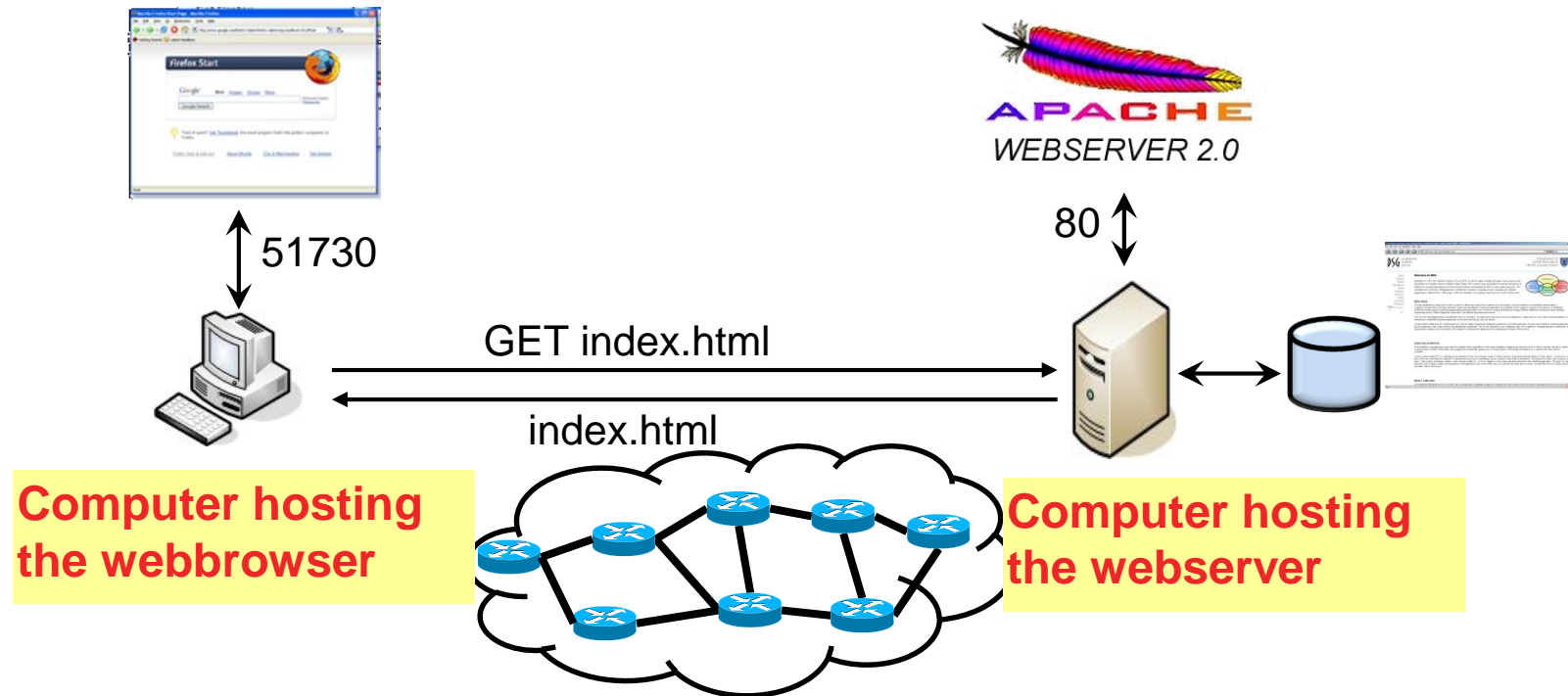


● = Nodes of a graph

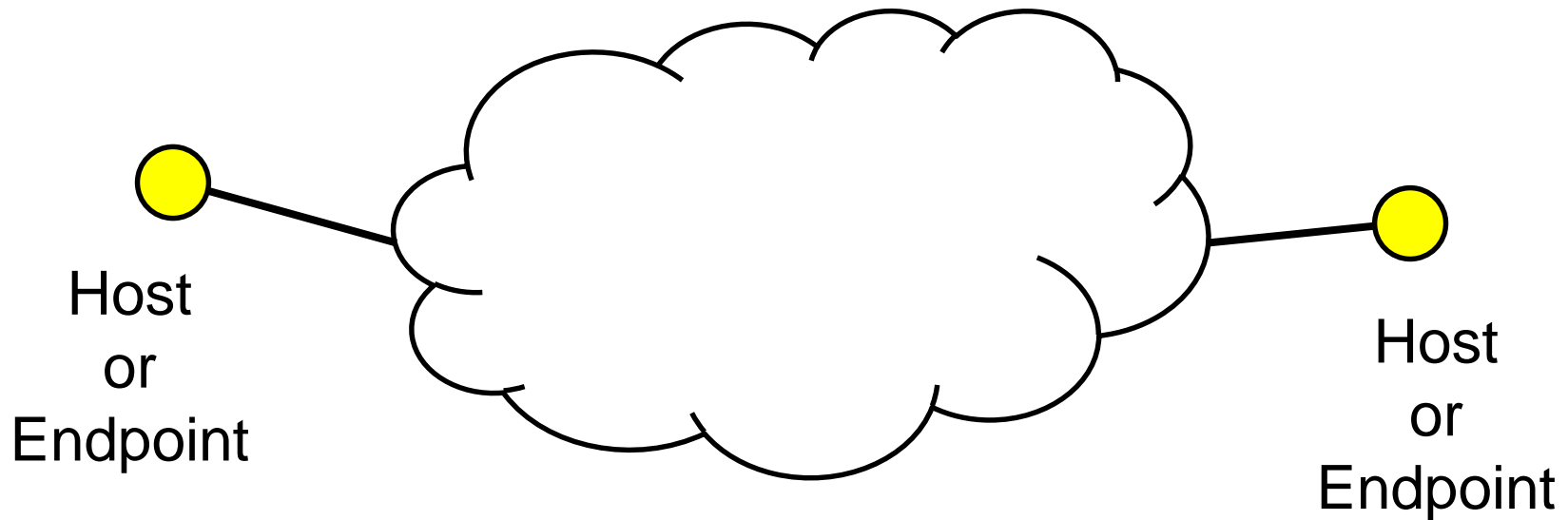
Data units = Packets

Any number of edges
between two nodes

Naming at the Transport Layer



Naming at the Transport Layer

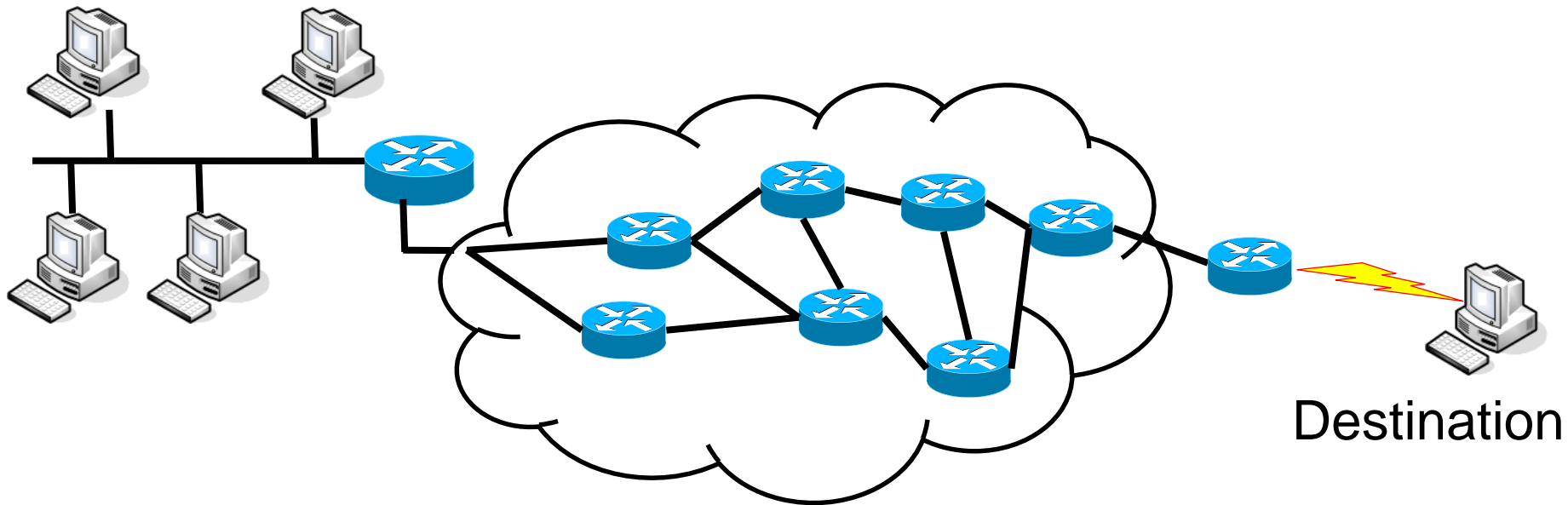


● = Host

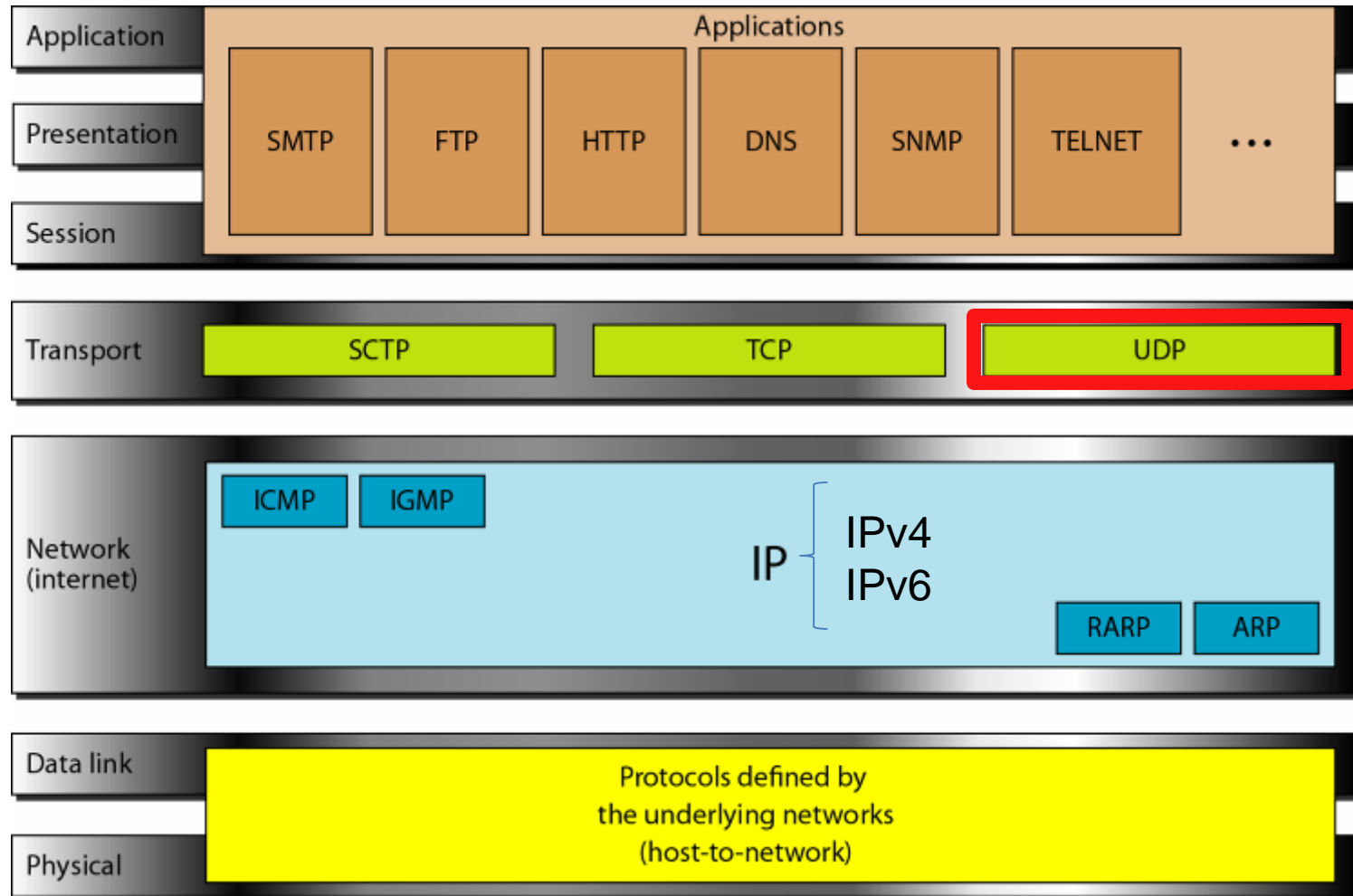
Data units = Segments or Datagrams

Task of the Network Layer

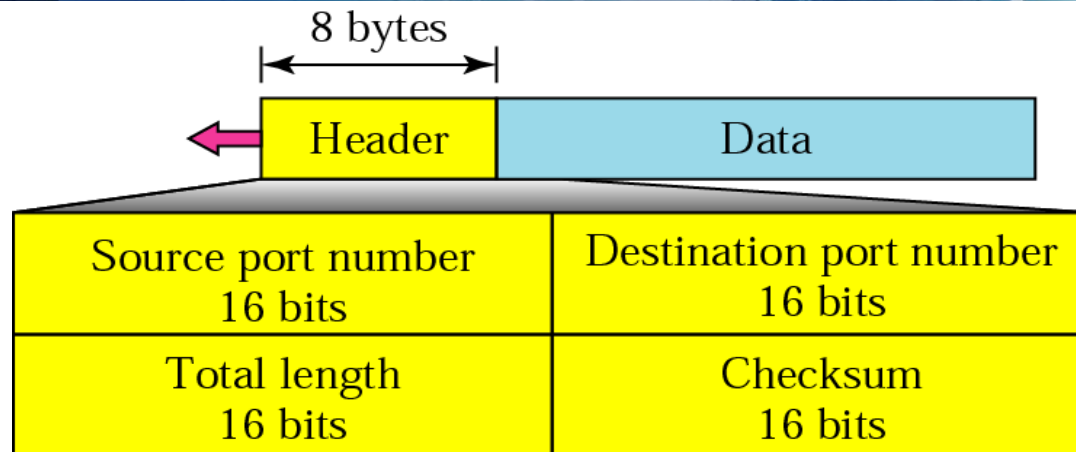
Source



Protocols in the OSI Model

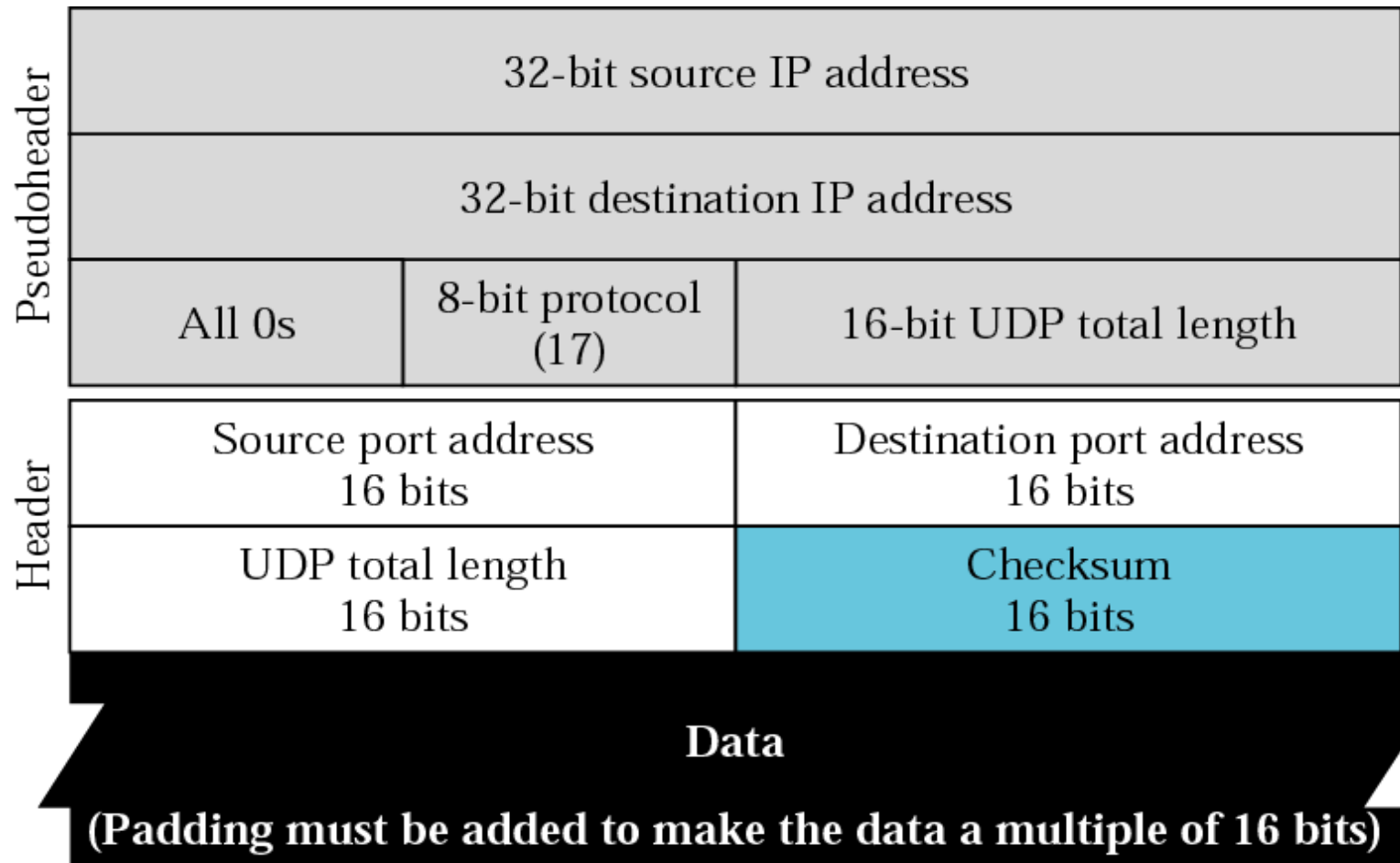


User Datagram Protocol (UDP)

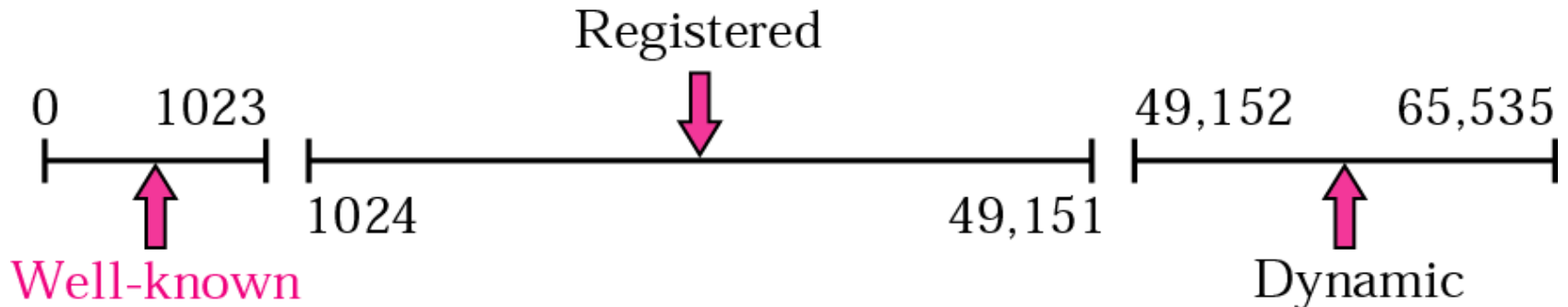


- UDP is a connectionless, unreliable protocol
 - No flow and error control
 - Port numbers are used to multiplex data
- Calculation of checksum & its inclusion in datagram are optional.
- Convenient transport-layer protocol for applications that provide their own flow and error control
 - Also used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

Pseudo-Header for Checksum



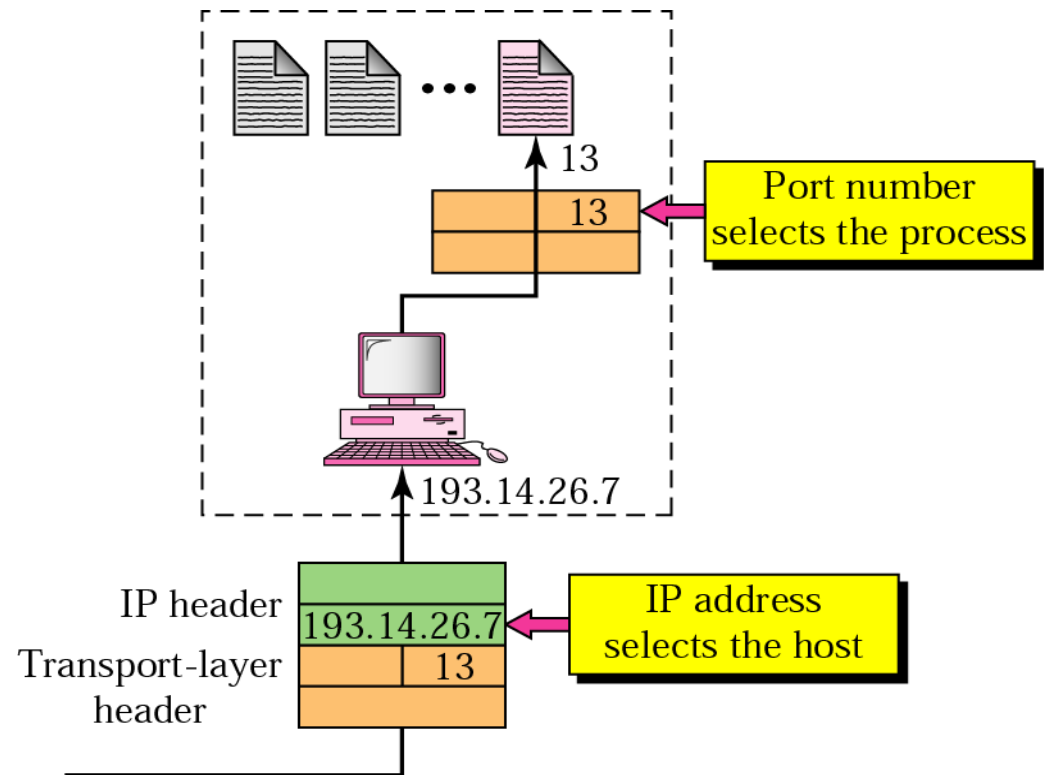
Well-Known Port Numbers



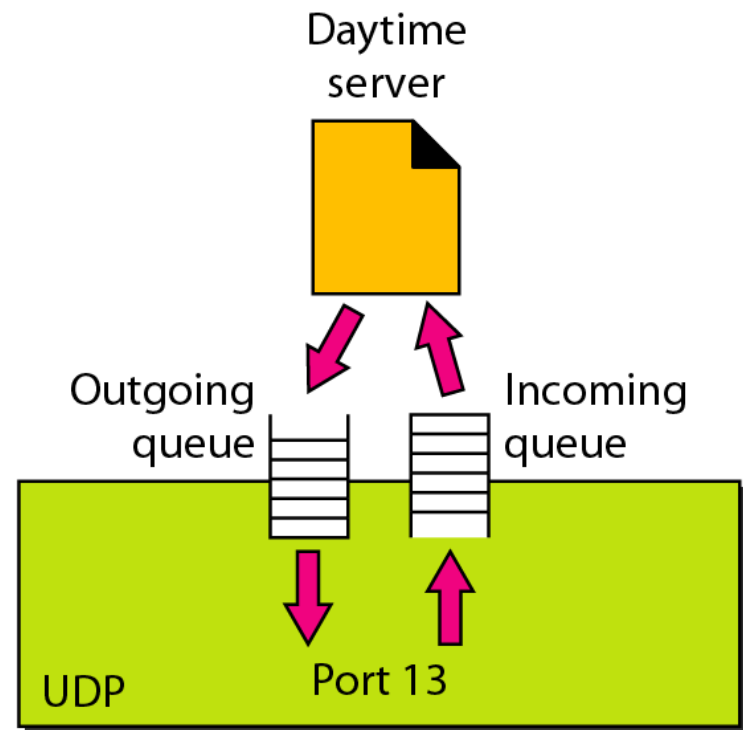
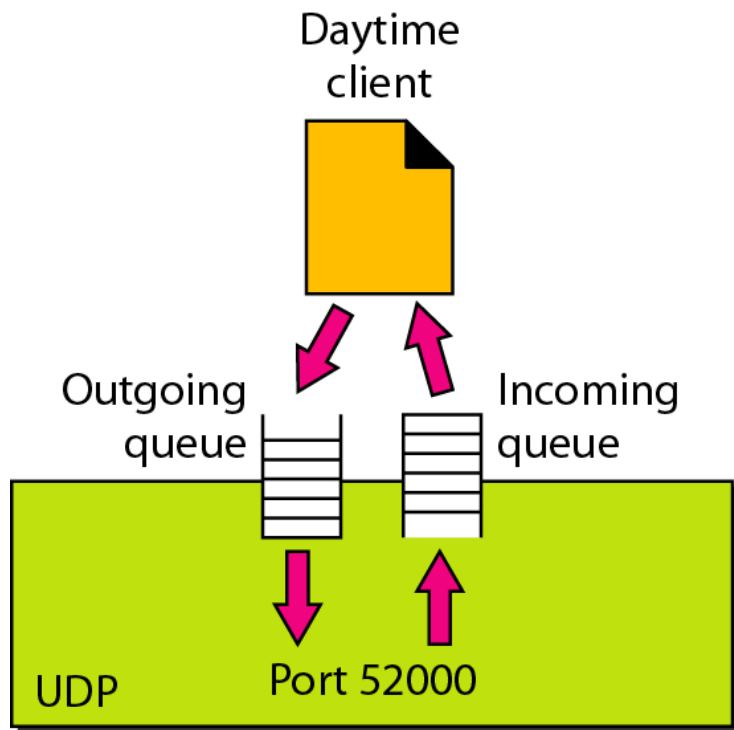
- Assigned by Internet Assigned Numbers Authority (IANA)
- 3 Categories of Ports:
 - Well-known Ports: 0 – 1023 (restricted access)
 - Registered Ports: 1024 – 49151
 - Dynamic/Private Ports: 49152 – 65535

IP Addresses & Port Numbers

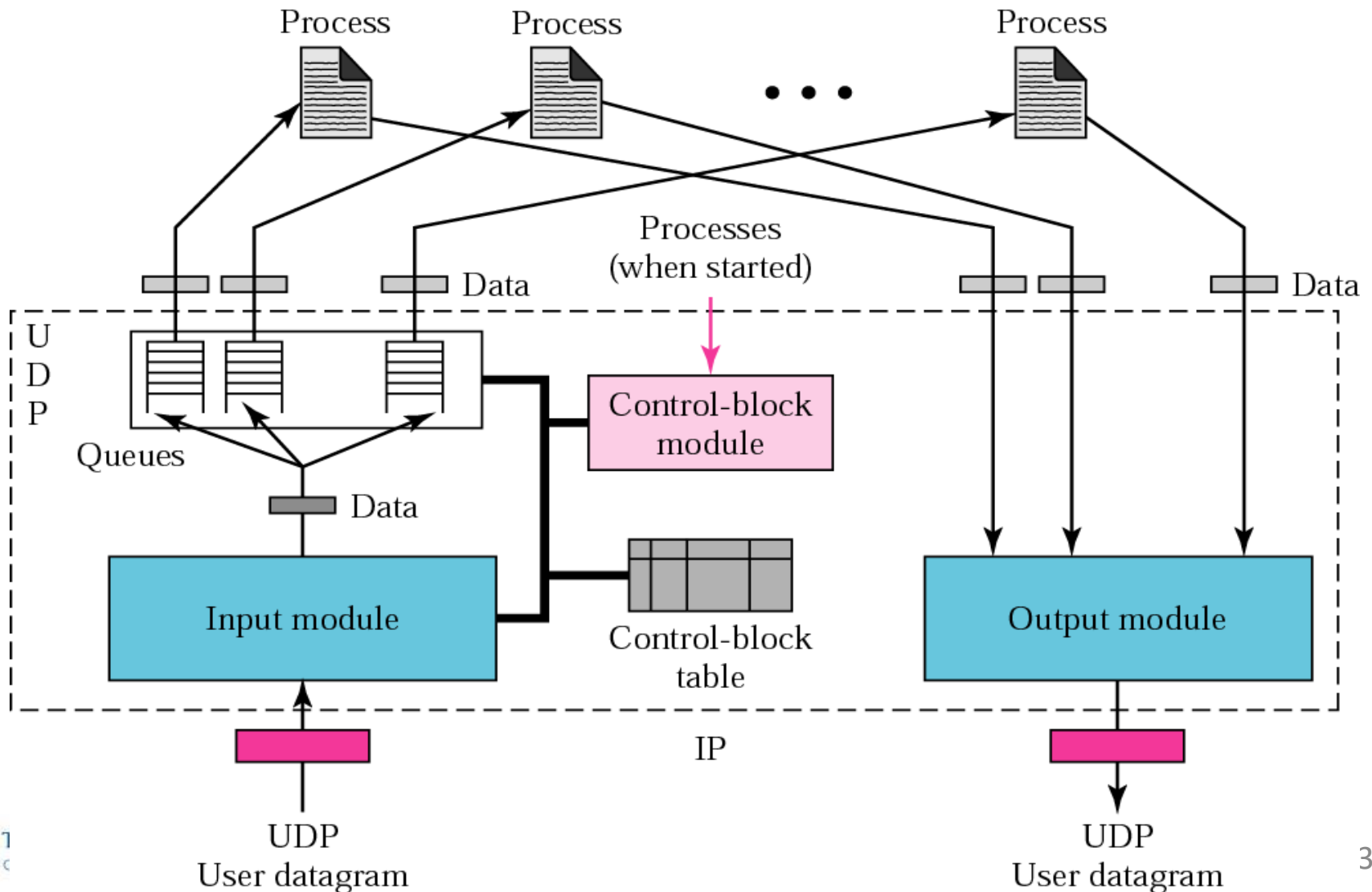
- IP Addresses determine the **host**
- Port Numbers determine the **application**



Queuing in UDP



Processes and UDP Queues



UDP Queue Example I

<i>State</i>	<i>Process ID</i>	<i>Port Number</i>	<i>Queue Number</i>
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

<i>State</i>	<i>Process ID</i>	<i>Port Number</i>	<i>Queue Number</i>
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			

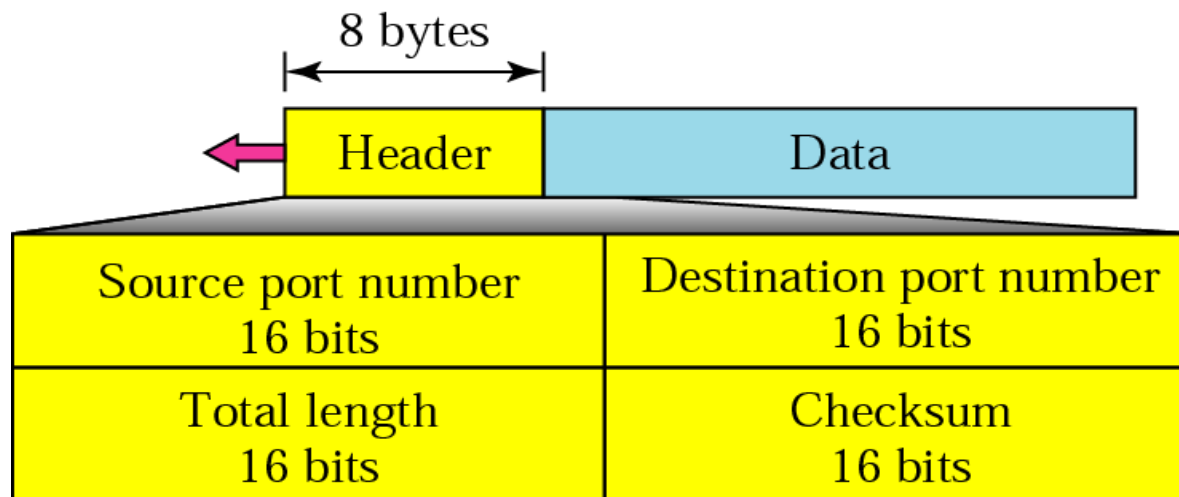
UDP Queue Example II

<i>State</i>	<i>Process ID</i>	<i>Port Number</i>	<i>Queue Number</i>
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:

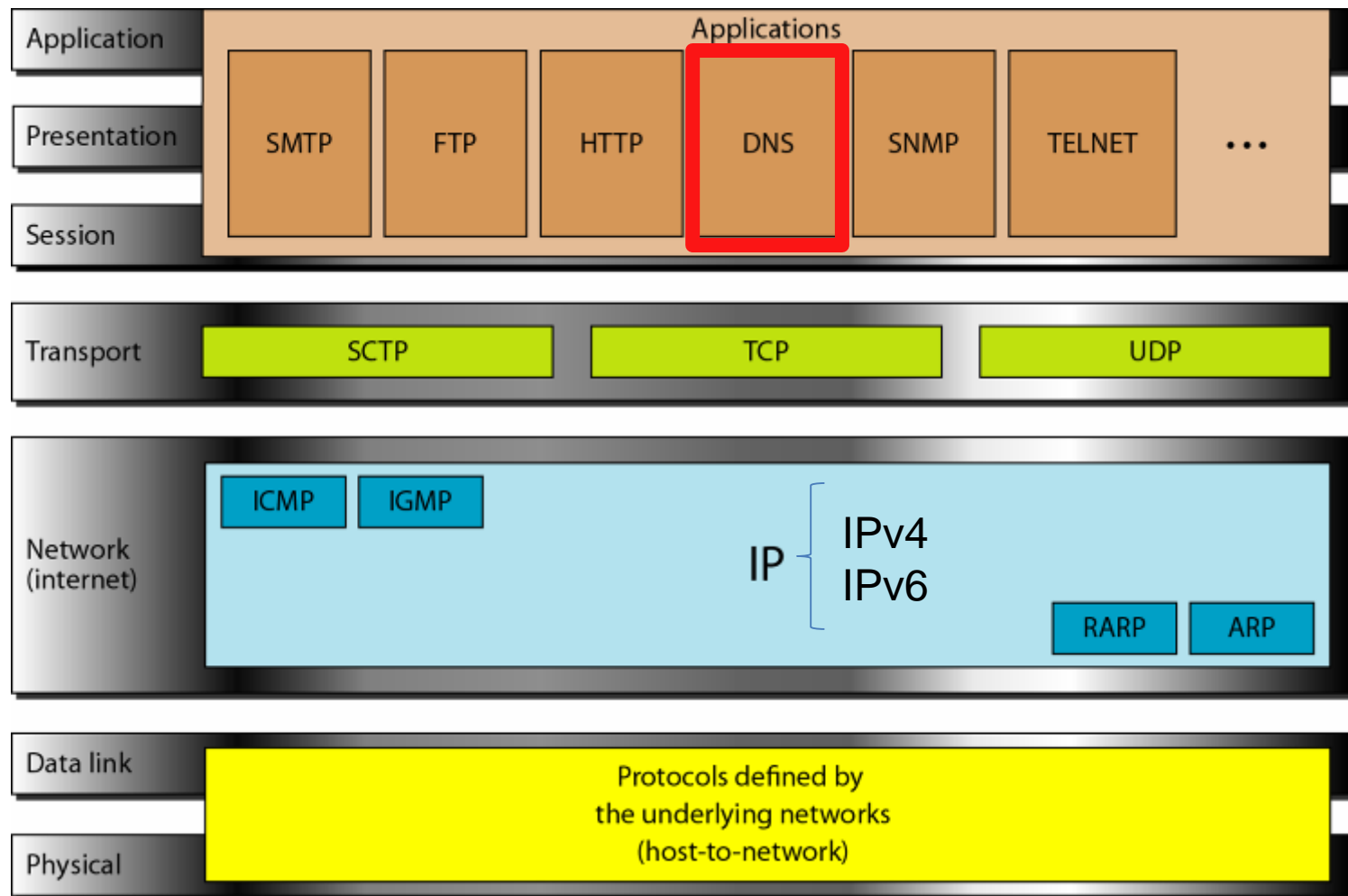


CS2031

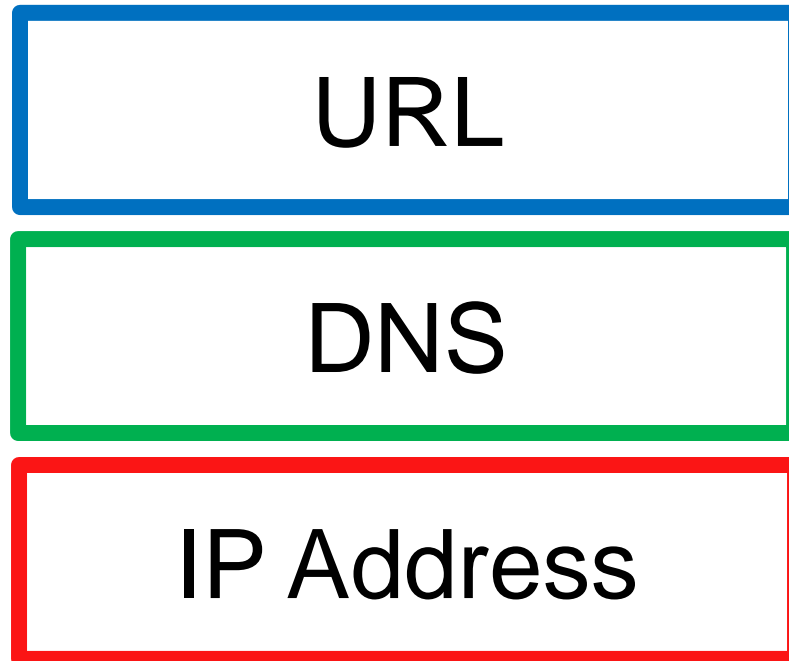
Telecommunications II

DNS

Protocols in the OSI Model



URLs to Names to Addresses



`http://www.wiki.com/index.html`

`www.wiki.com`

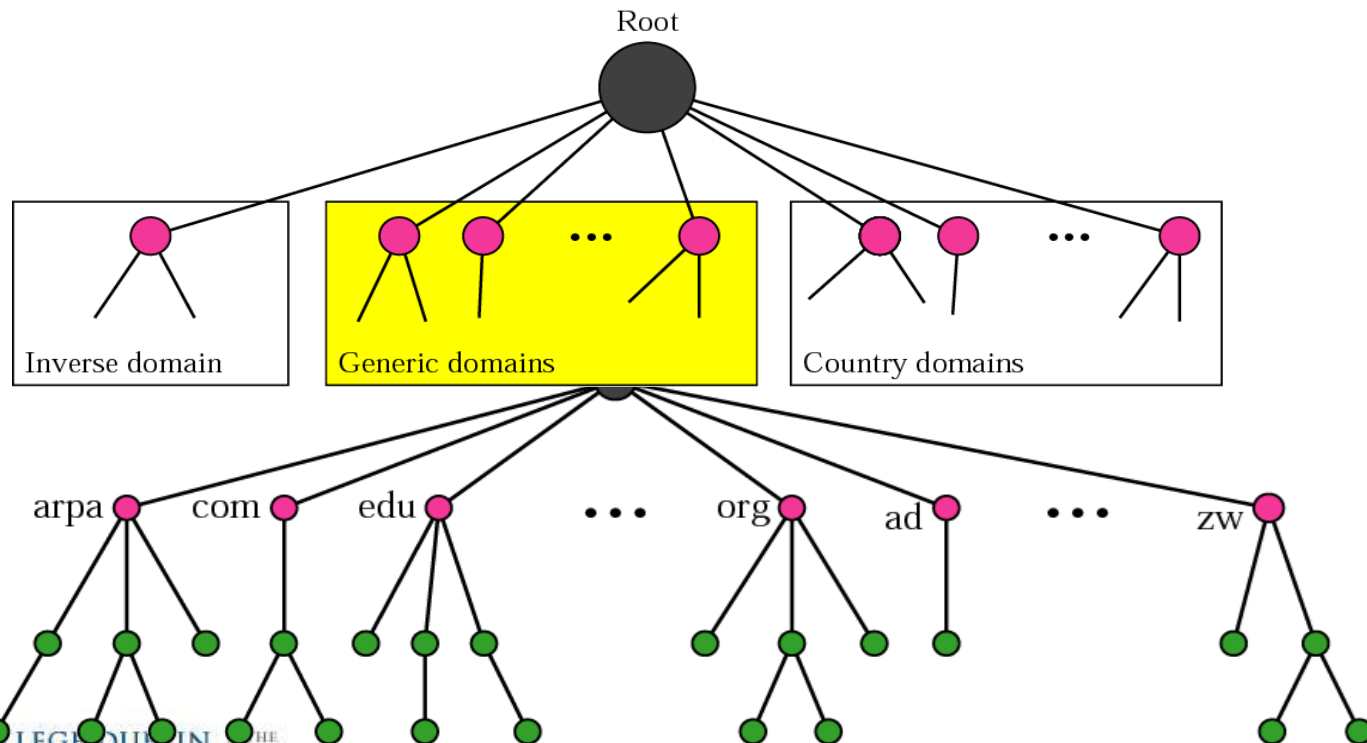
`66.96.149.1`

*URL = Uniform Resource Locator

Domain Name Space

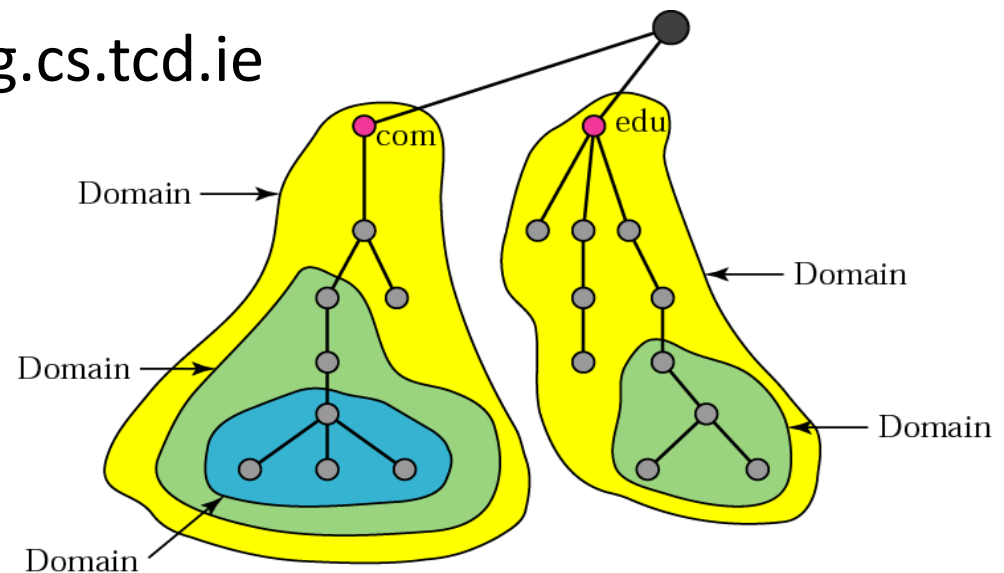
- Association between names and IP addresses

www.dsg.scss.tcd.ie - 134.226.36.14



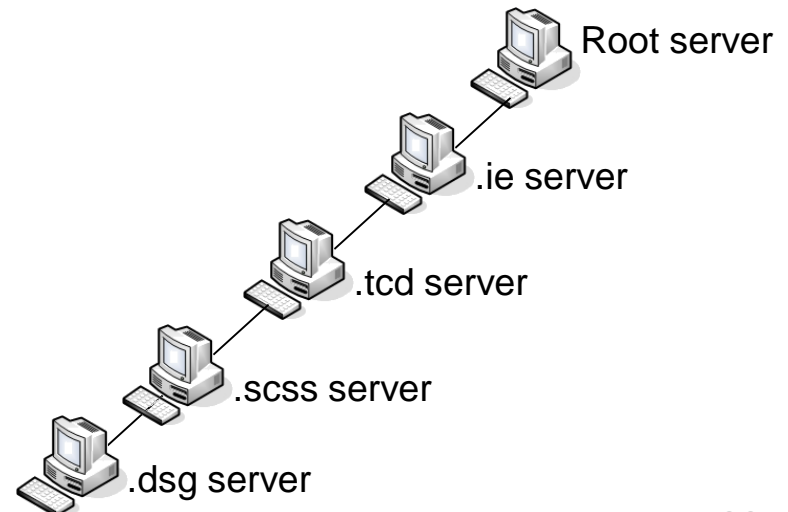
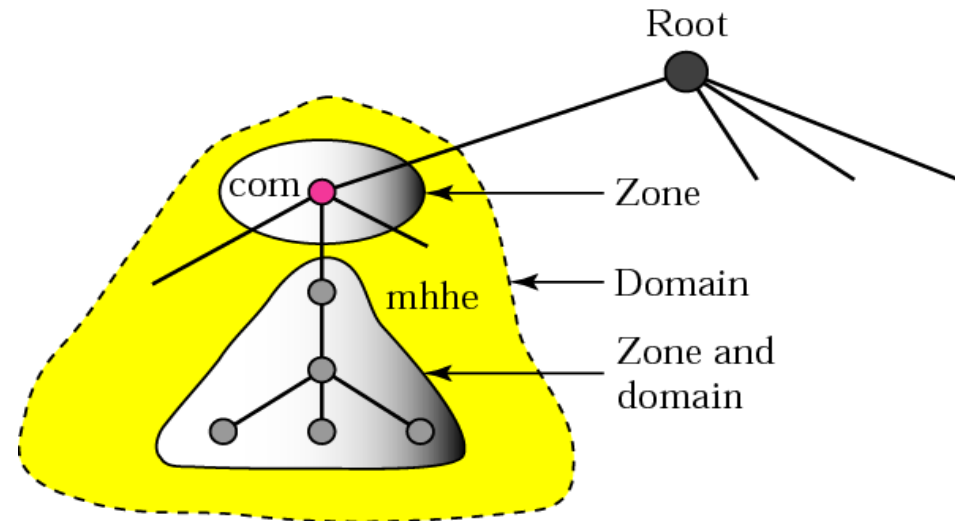
Domain Name Space

- 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



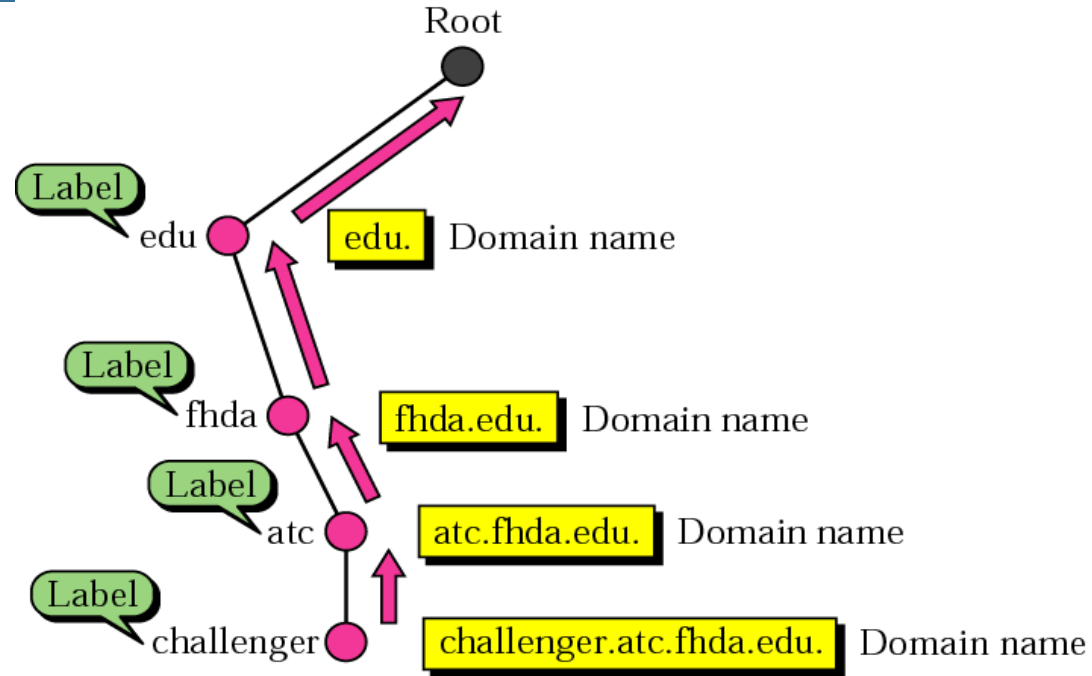
Hierarchy of Name Servers

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



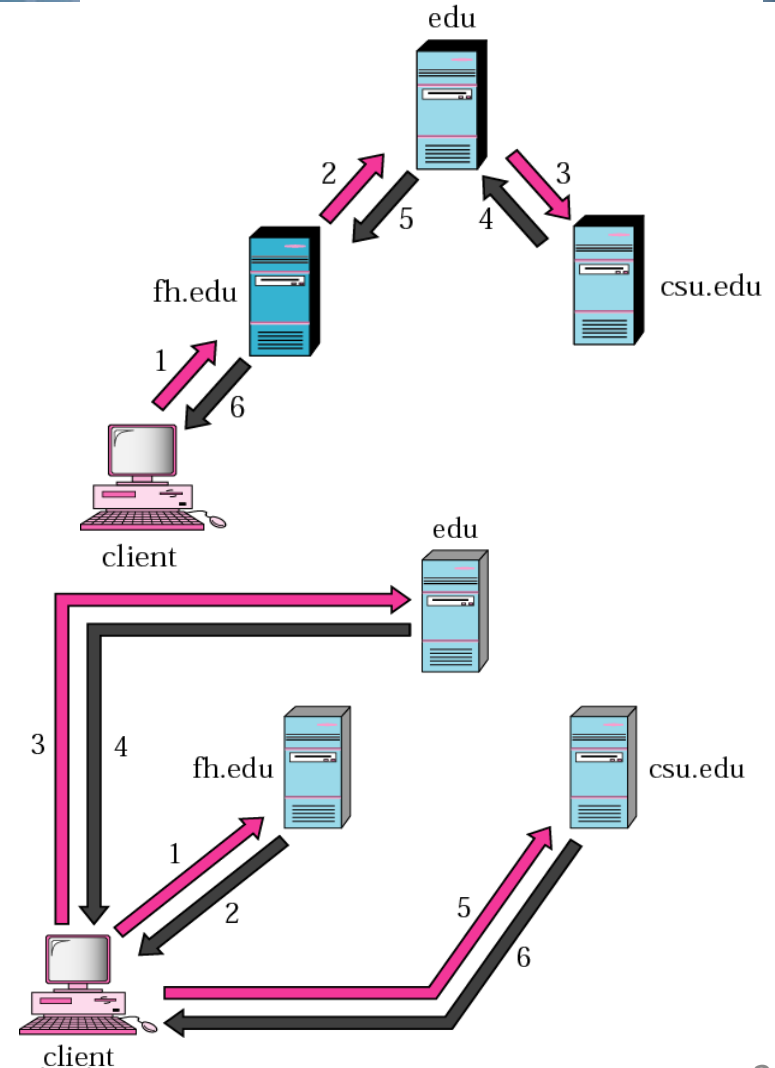
Domain Names and Labels

- A domain name consist of a number of labels

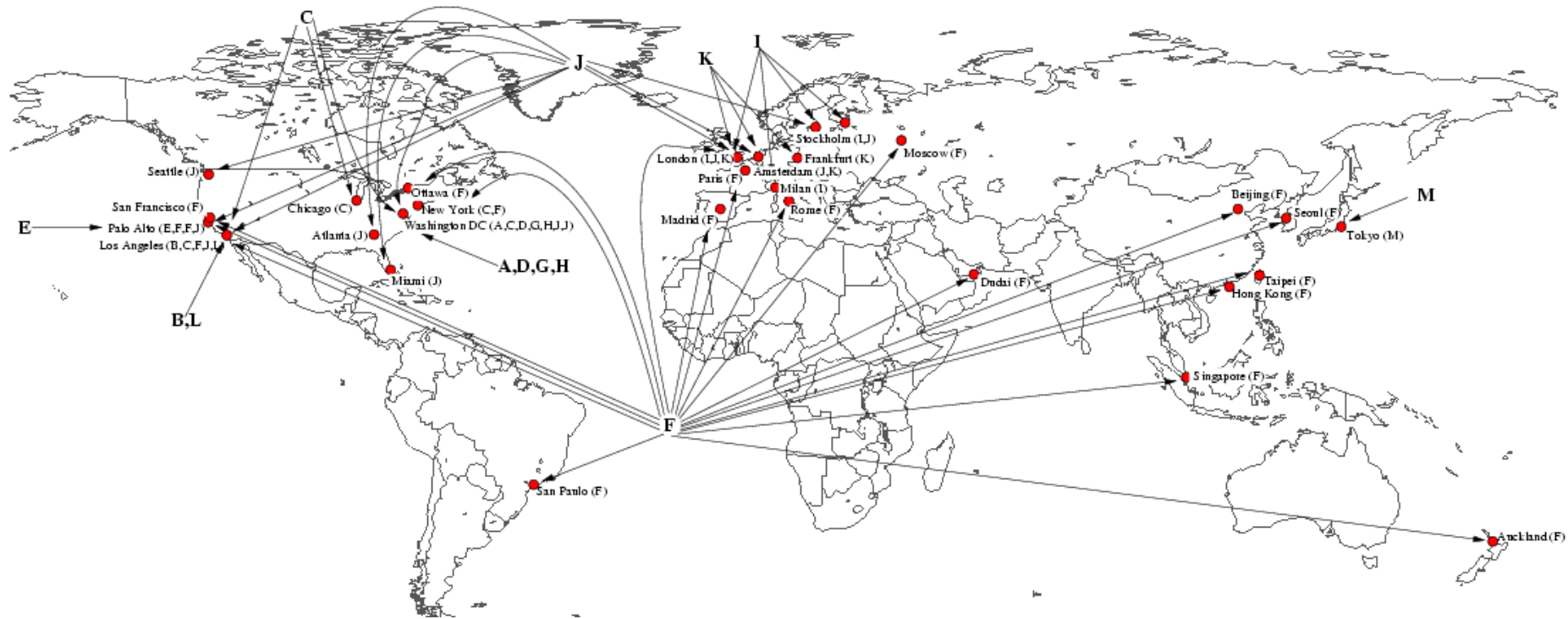


Name Resolution

- Recursive resolution
- Iterative resolution



DNS Root Servers - Anycast



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+mIjN7sPVl27PSK040JkegzC2Pib9+4q6bXYU3L6JPS4oXhsBqhSEA/WP7MvWemL0hSiETvuo3b8CAoMr0oTQnspk
ie.            86400   IN      NSEC     ifm. NS DS RRSIG NSEC
ie.            86400   IN      RRSIG    NSEC 8 1 86400 20151206050000 20151126040000 62530
QXF5lQuk4H1casAa0GTKv2Mueizyb8p06x3RU2BtQBG609nhU9dPHIN8AA6NTQaUTleBBwAaAF3aUh37Q6r2K6+x8gsj46nxs\
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

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(Preferred)
Temporary IPv6 Address. . . . . : 2001:770:10:203:f0c0:4f35:6fd5:90d4(Preferred)
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

```

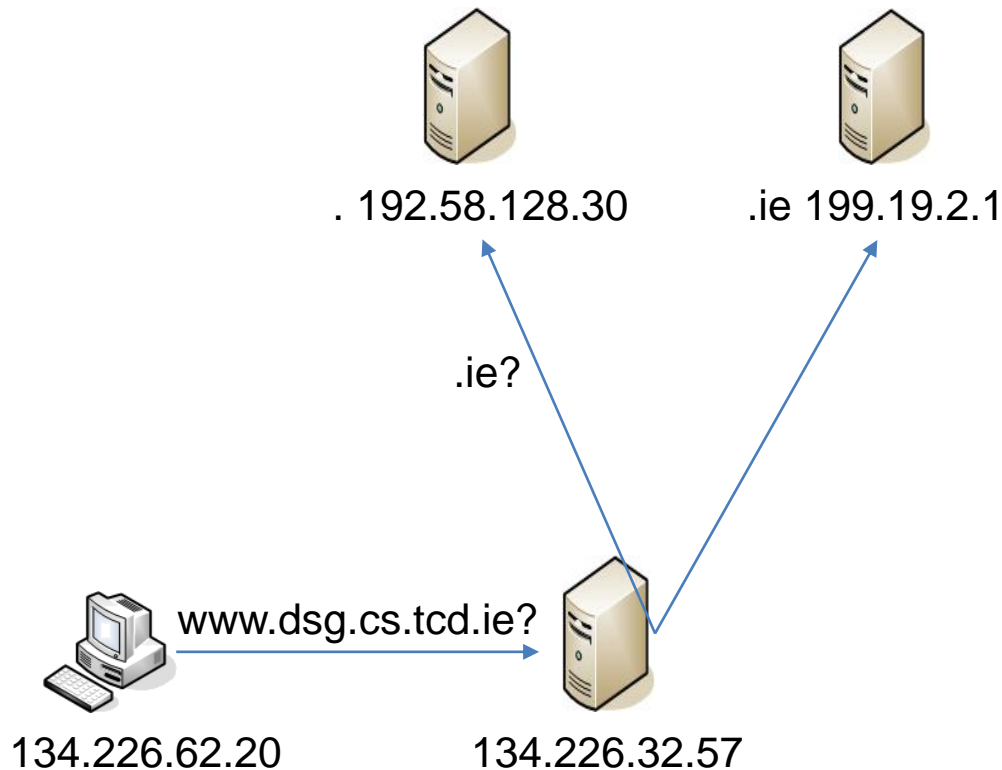
@                IN      SOA      ns1.dsg.cs.tcd.ie. dsgadmin.cs.tcd.ie. (
                                2003100801      ; Serial  yearmonthdayversion
                                7200             ; Refresh 2 hours
                                1800             ; Retry   1/2 hour
                                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.

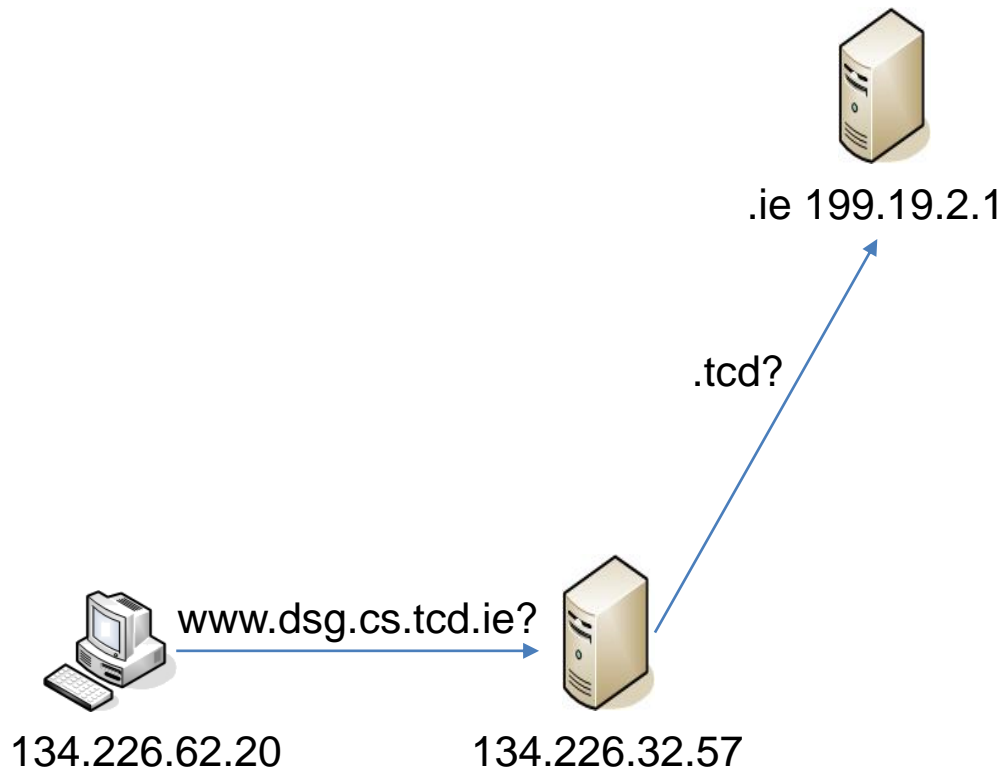
dsg.cs.tcd.ie    IN      A        134.226.36.0
                MX      10      relay.cs.tcd.ie.

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

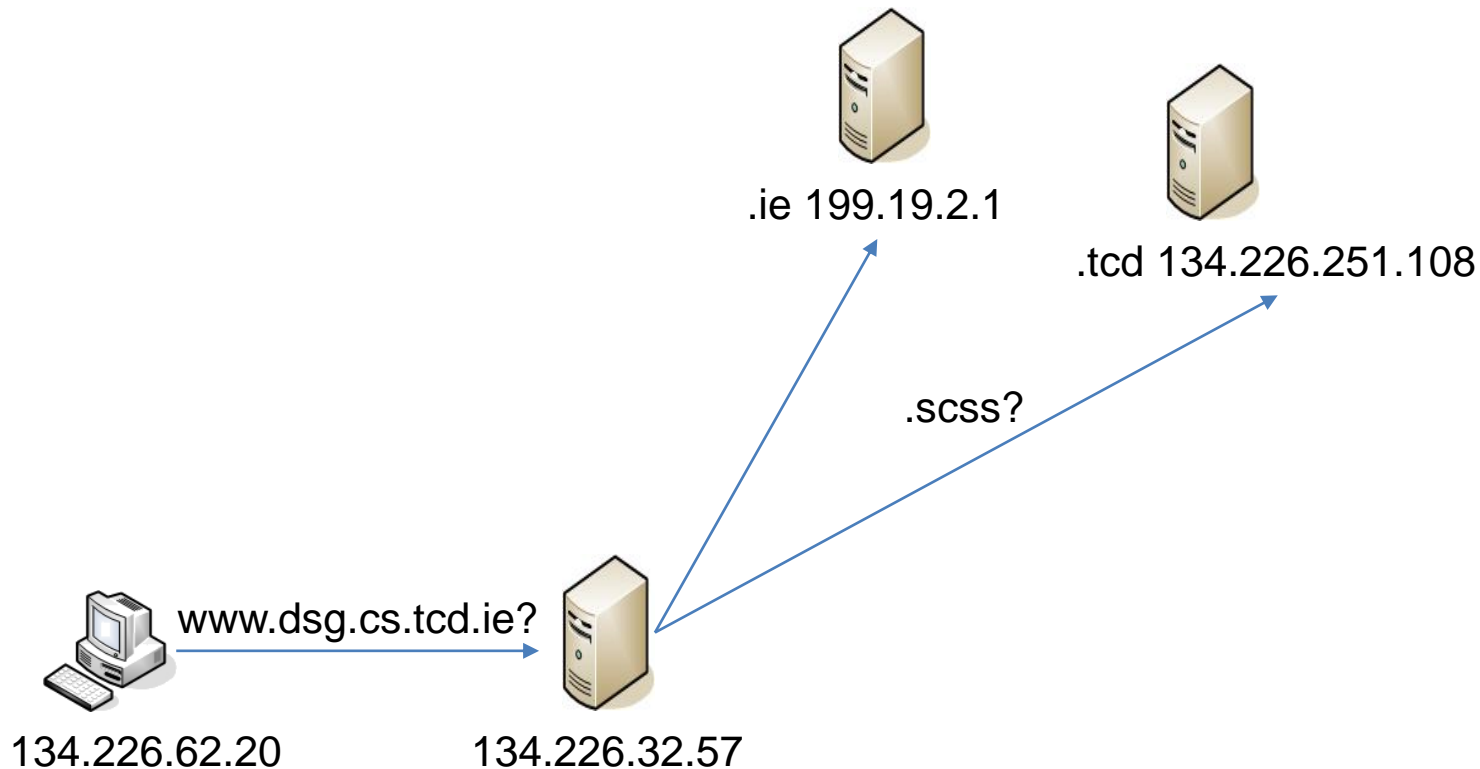
Lookup of www.dsg.scss.tcd.ie.



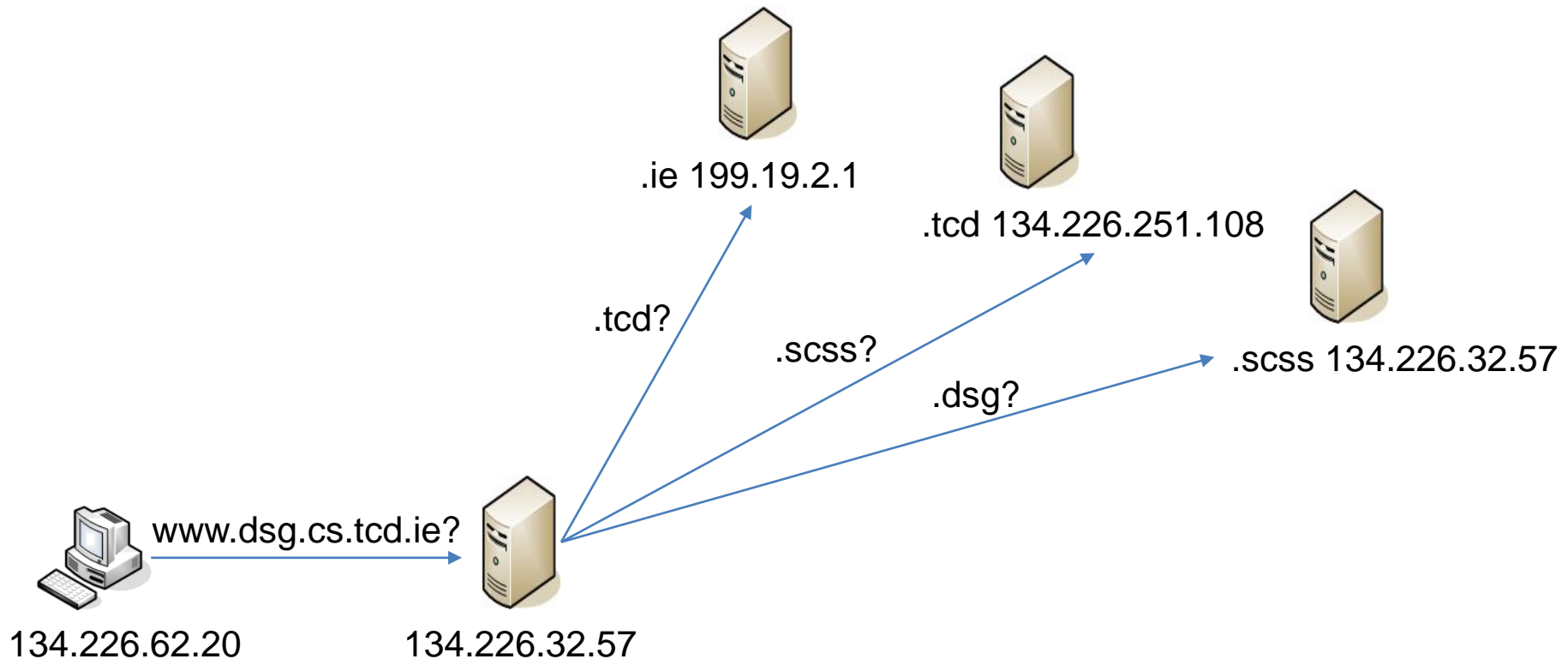
Lookup of `www.dsg.scss.tcd.ie`.



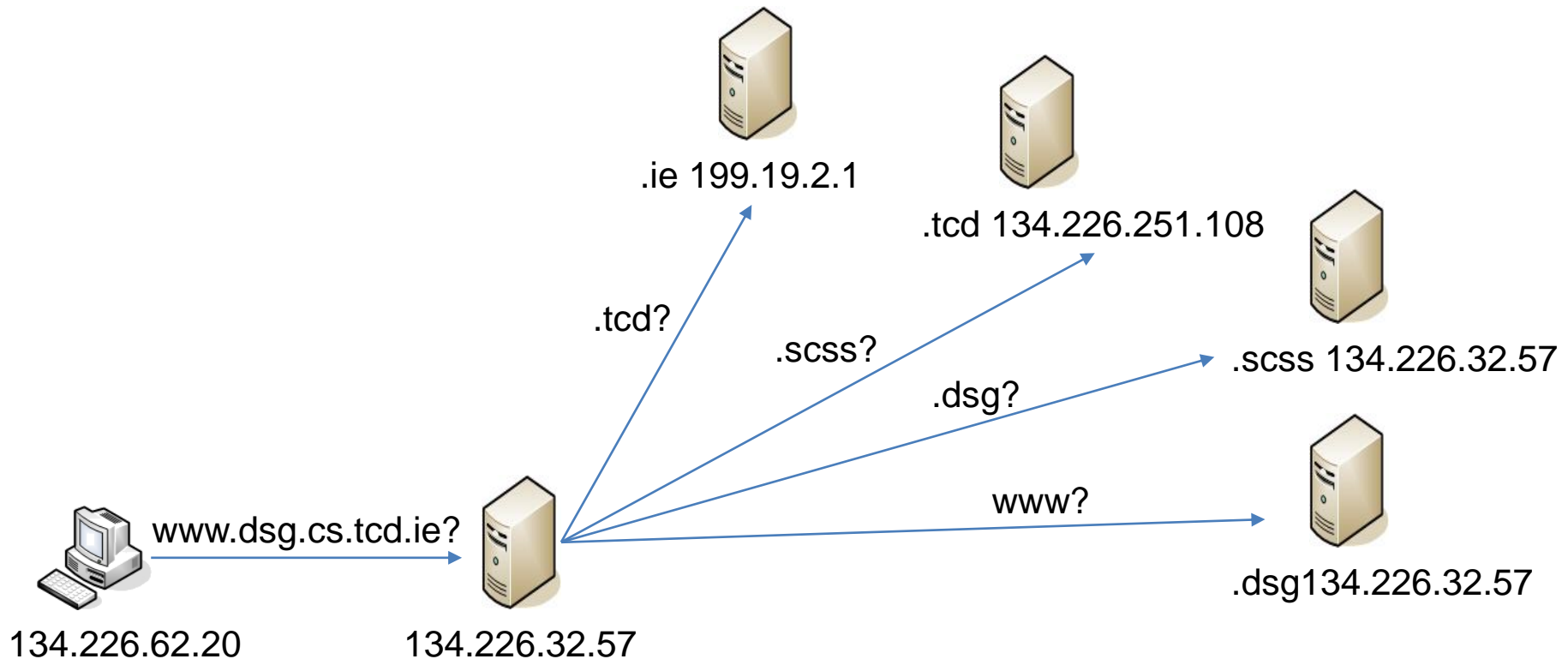
Lookup of `www.dsg.scss.tcd.ie`.



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

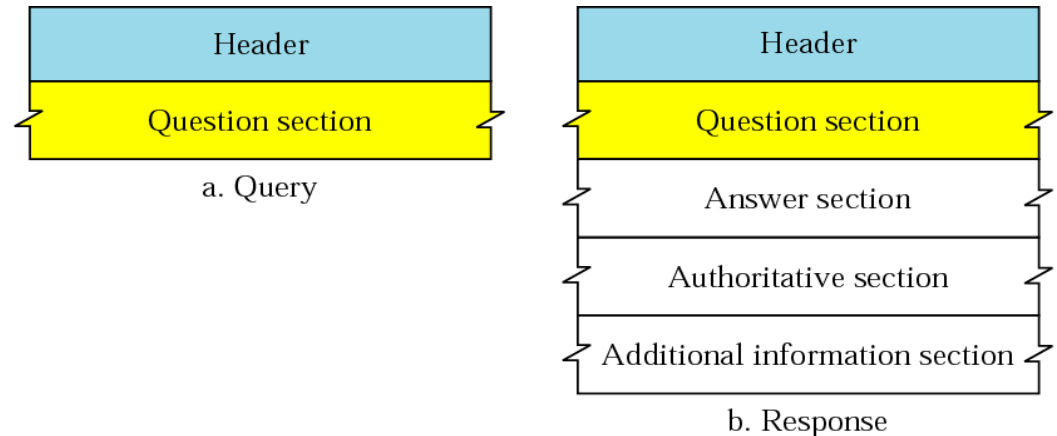


Lookup of `www.dsg.scss.tcd.ie`.



Query and Response Messages

- Two types of replies:
 - Authoritative answers
 - Cached or unauthoritative answers
- 6-byte header



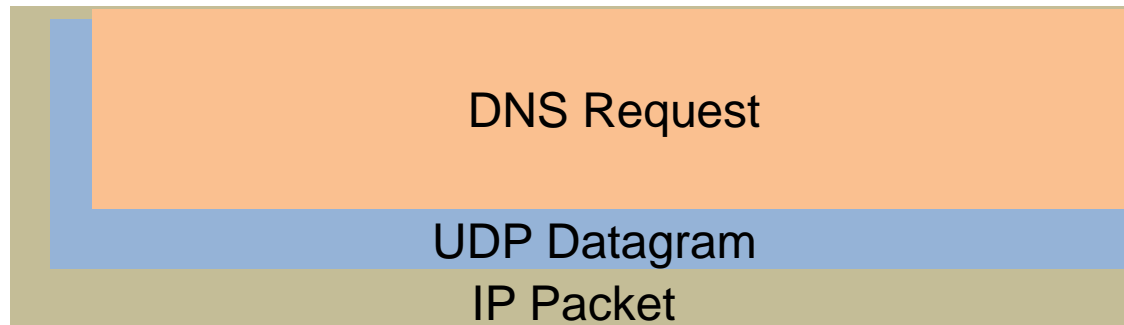
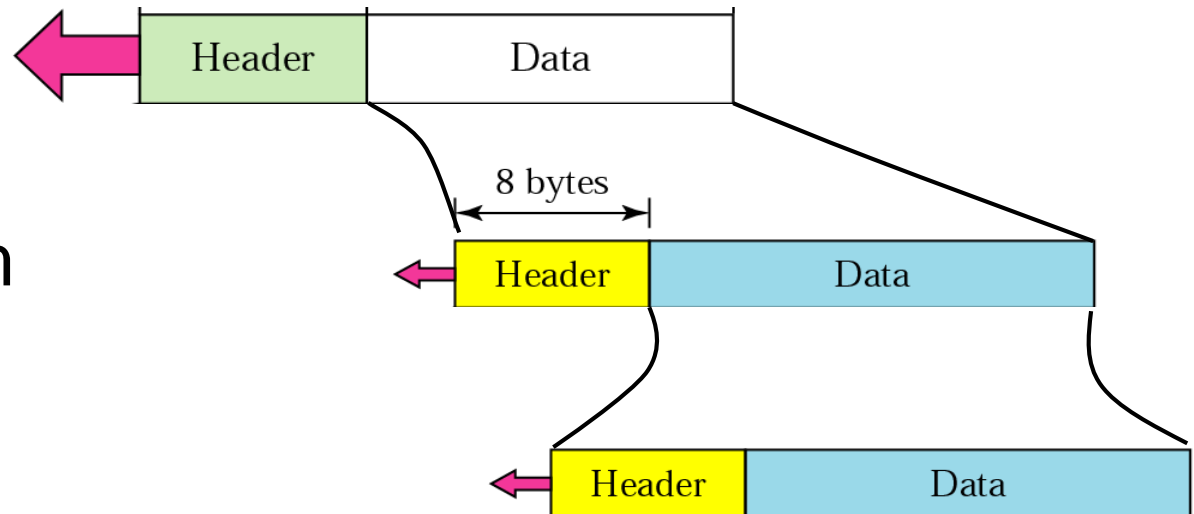
2 bytes		2 bytes	
Identification		Flags	
Number of question records		Number of answer records (All 0s in query message)	
Number of authoritative records (All 0s in query message)		Number of additional records (All 0s in query message)	

DNS Request

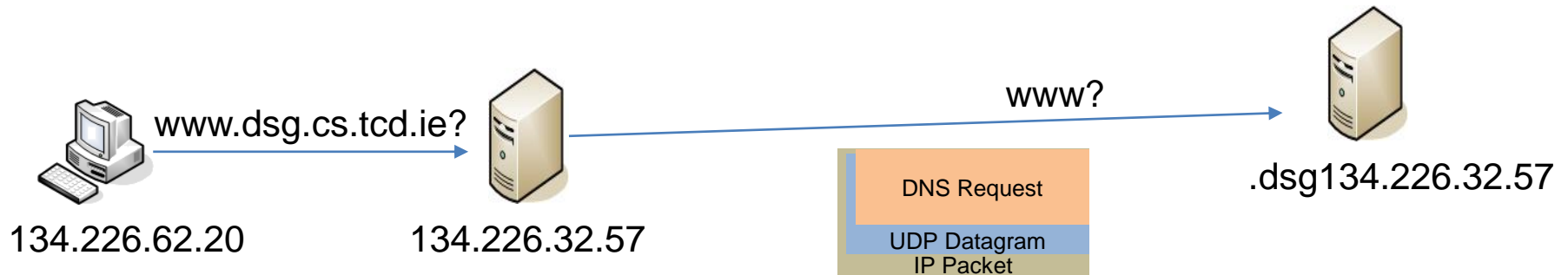
IP Packet

UDP Datagram

DNS Request



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



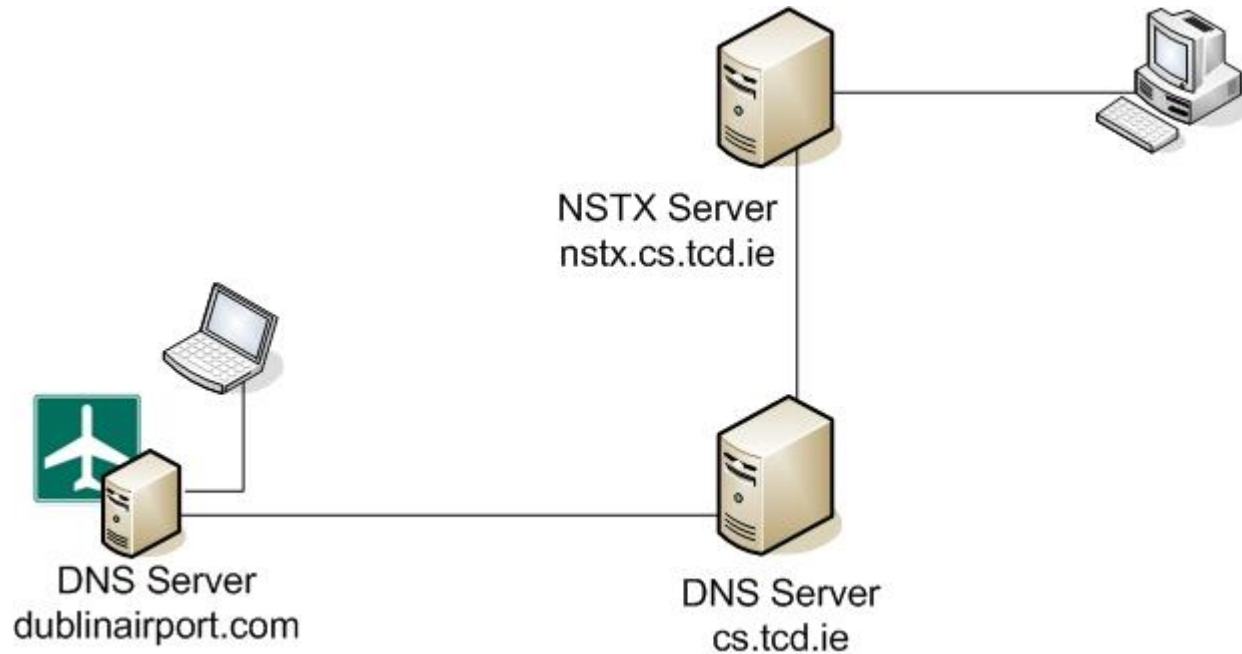
SOA

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

\$ORIGIN .cs.tcd.ie.

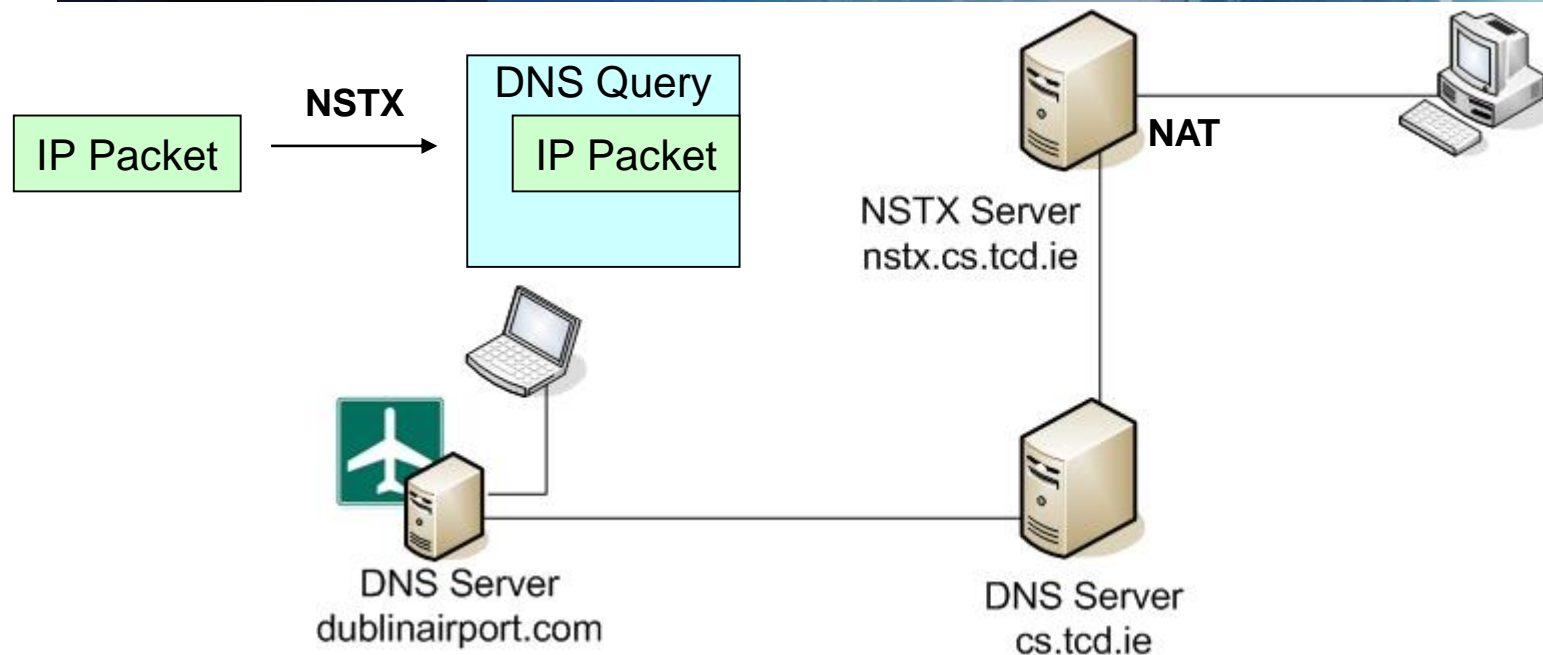
@	IN	NS	nstx.cs.tcd.ie.
nstx	IN	A	134.226.32.44

IP-over-DNS II



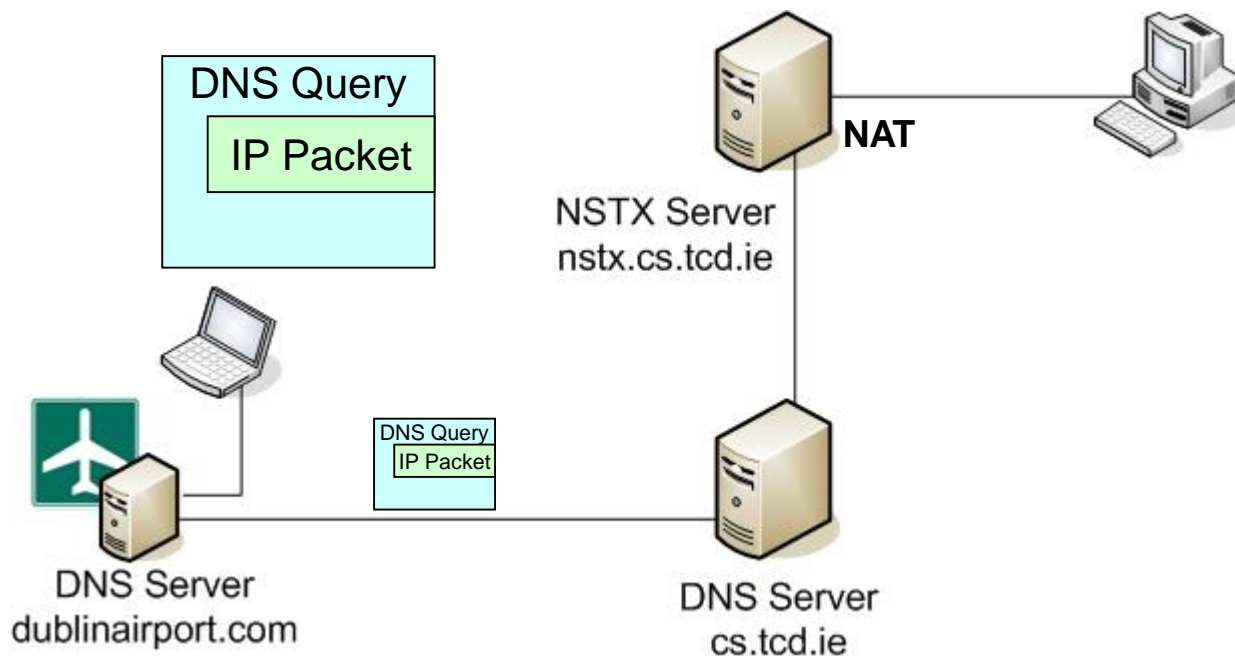
- Laptop with limited access at airport
- Encapsulate IP packet into DNS query
 - Example: NSTX, Iodine

IP-over-DNS II



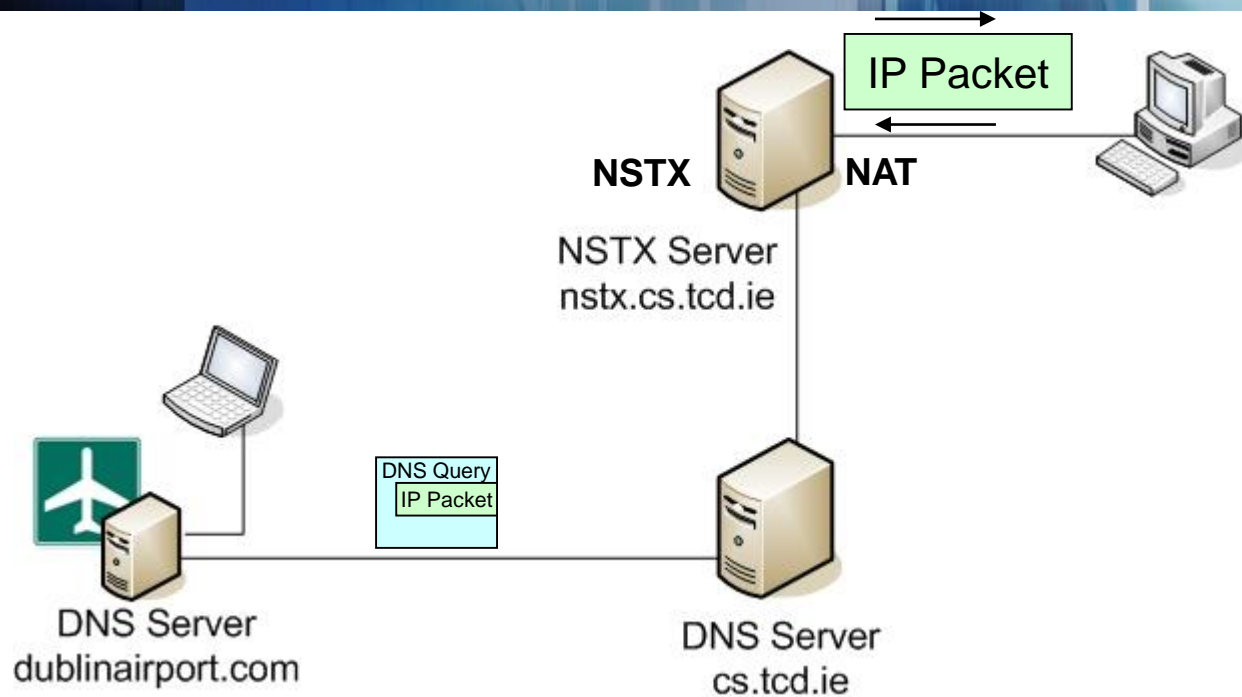
- Laptop with limited access at airport
- Encapsulate IP packet into DNS query
 - Example: NSTX, Iodine

IP-over-DNS III



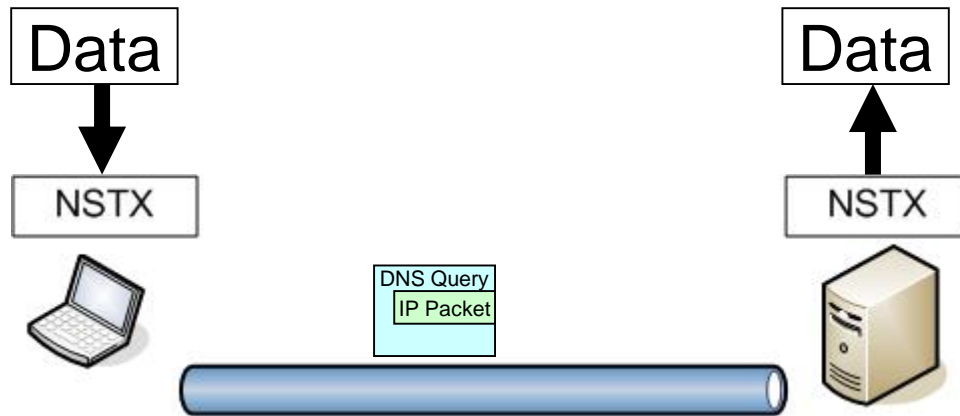
- Laptop with limited access at airport
- Encapsulate IP packet into DNS query
 - Example: NSTX, Iodine

IP-over-DNS IV



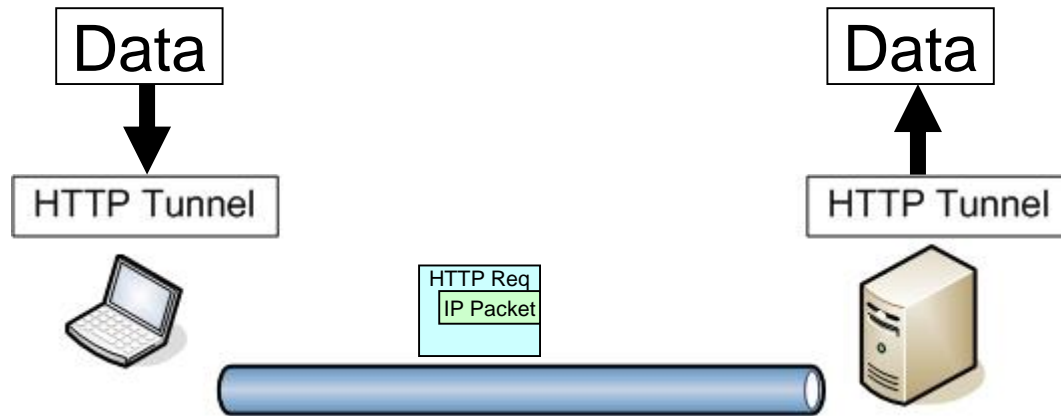
- Laptop with limited access at airport
- Encapsulate IP packet into DNS query
 - Example: NSTX, Iodine

Tunnelling I



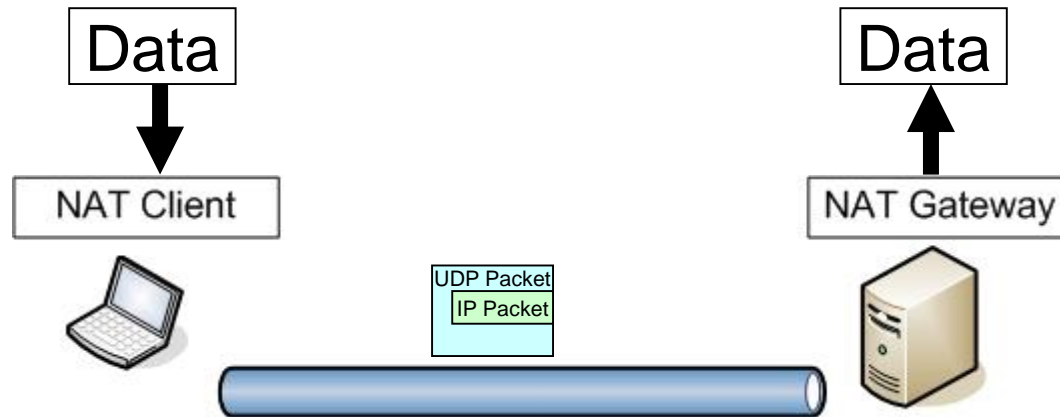
- Machine with access to Internet
- Machine with restricted access
- Both run programs that can pack and unpack data to be tunnelled

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



Fixed Latency



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

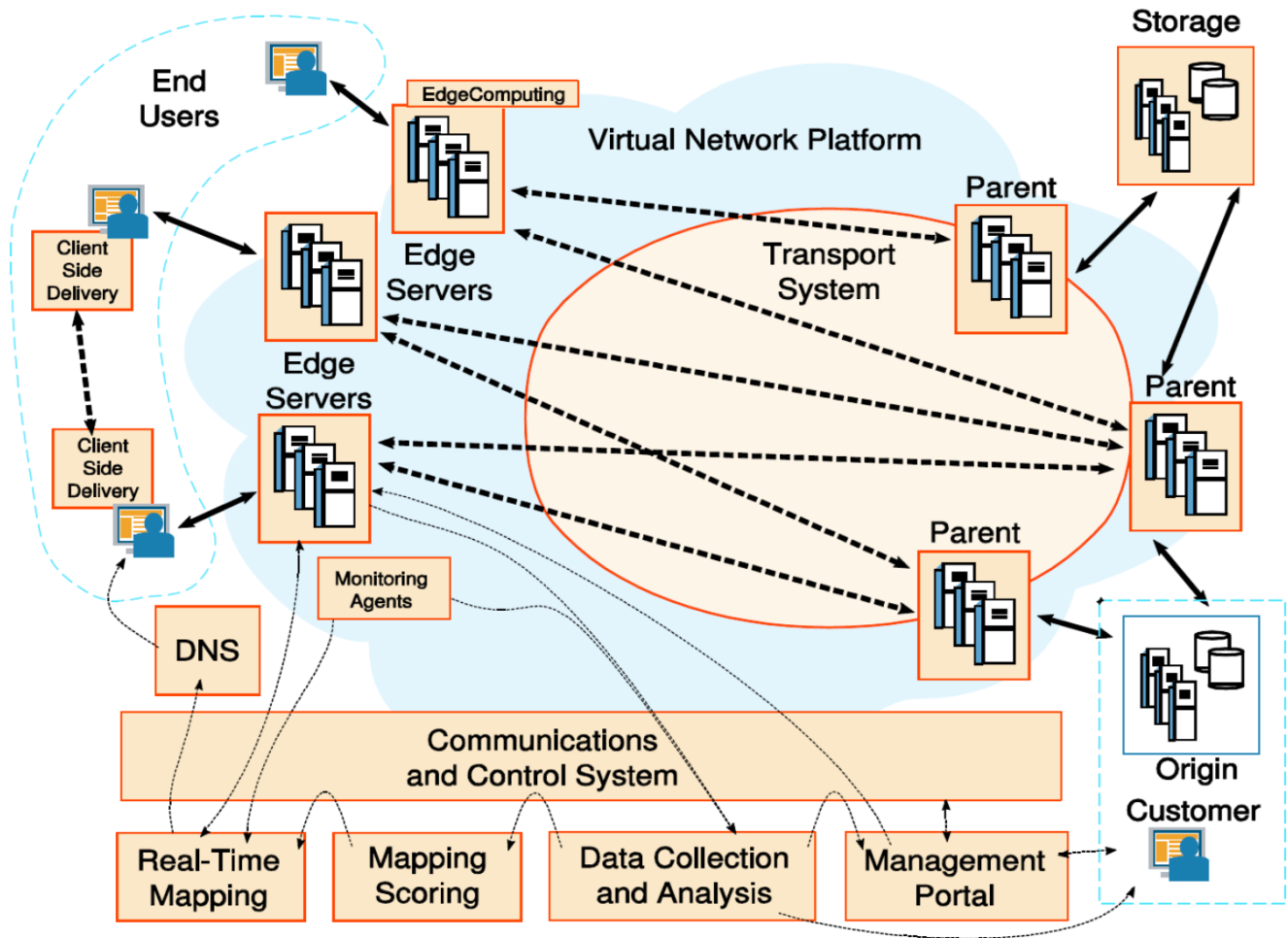
Content-Distribution Networks



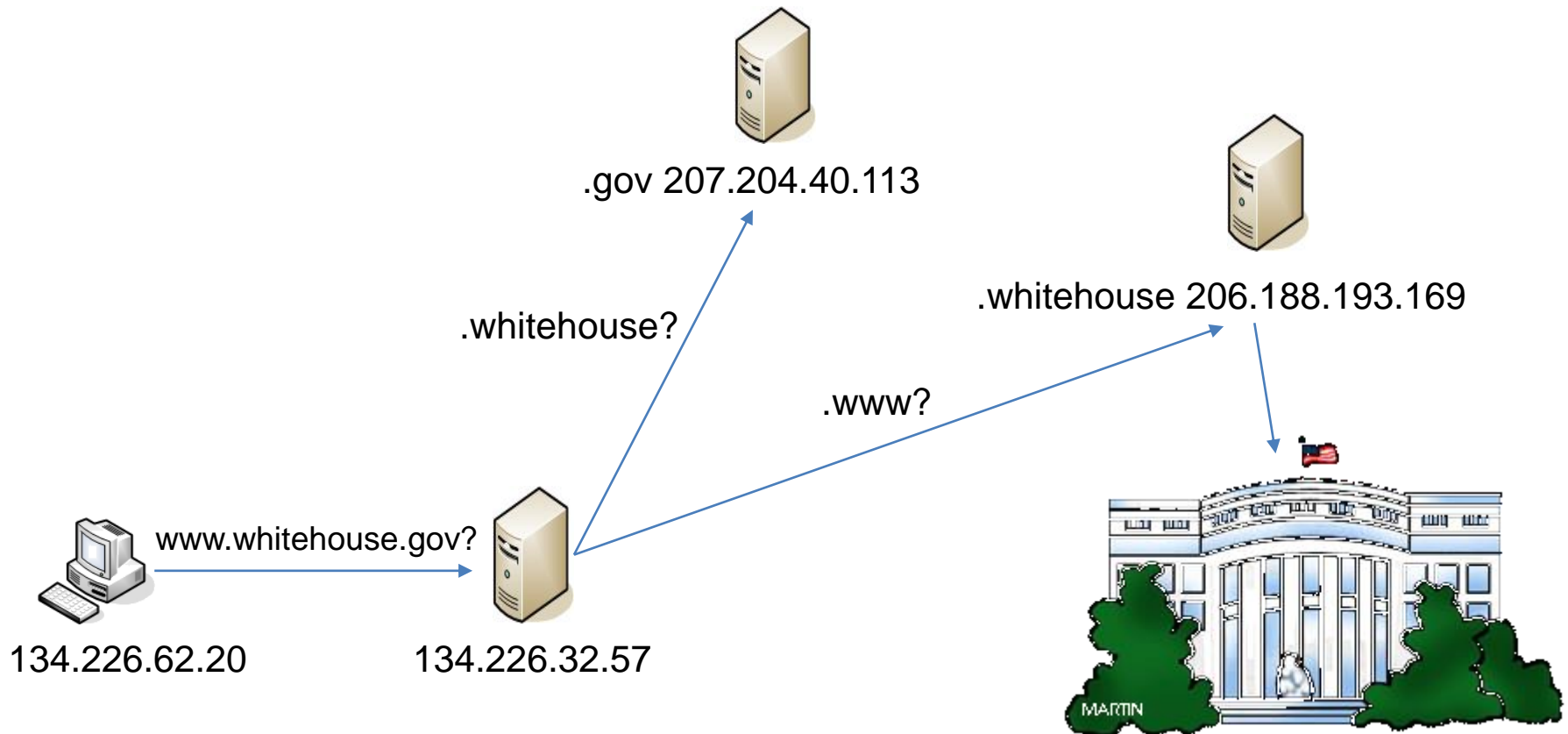
e.g. Akamai, Limelight, Amazon, Netflix, etc

Akamai Scenario

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

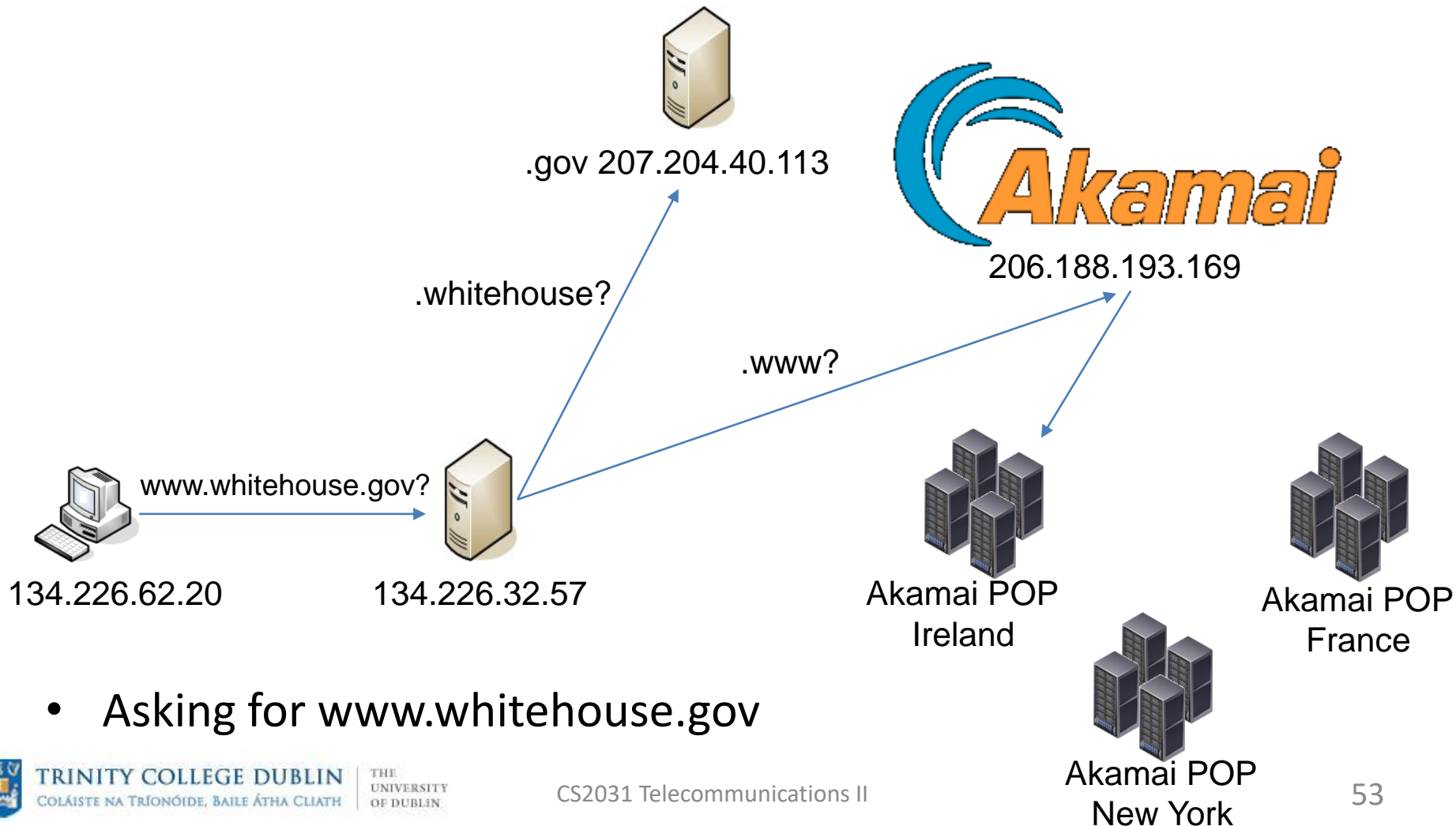


The Usual Case



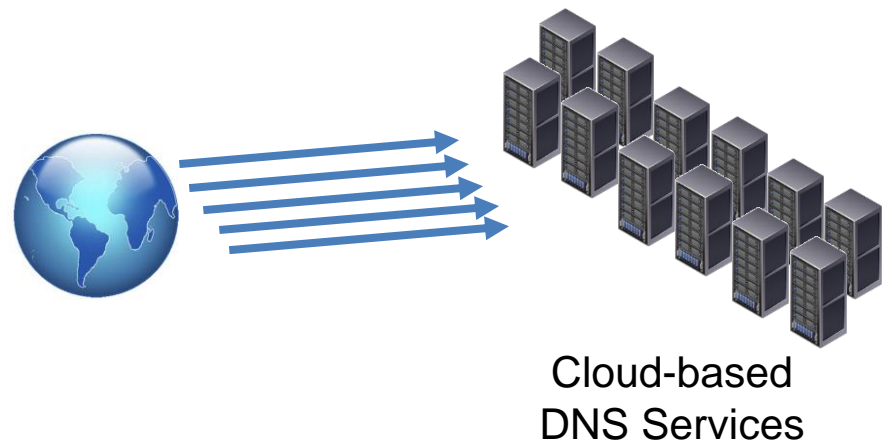
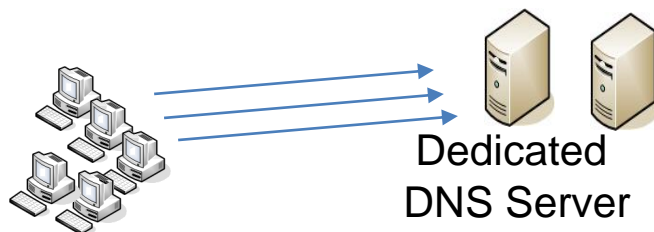
- Asking for `www.whitehouse.gov`

Redirection of DNS

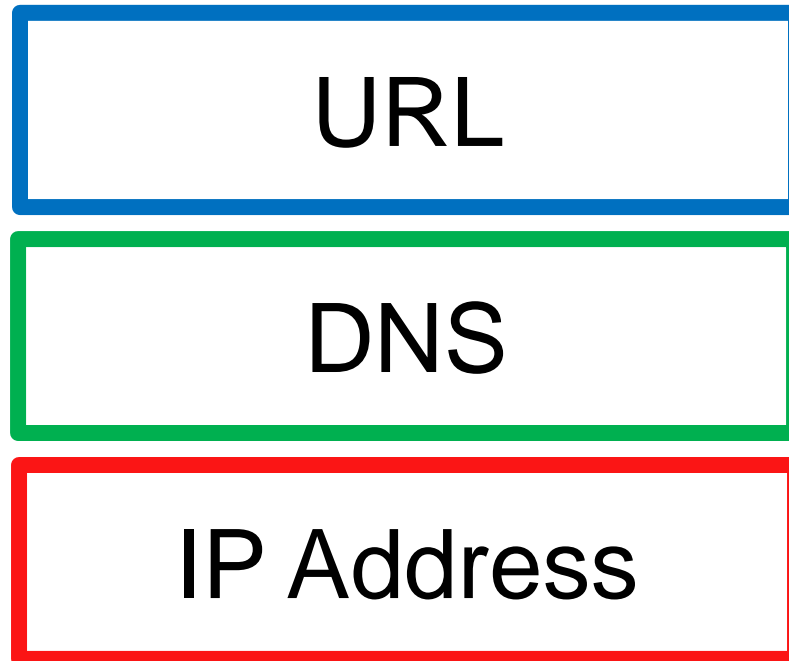


Mirai Bot & The Attack on Dyn

- 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



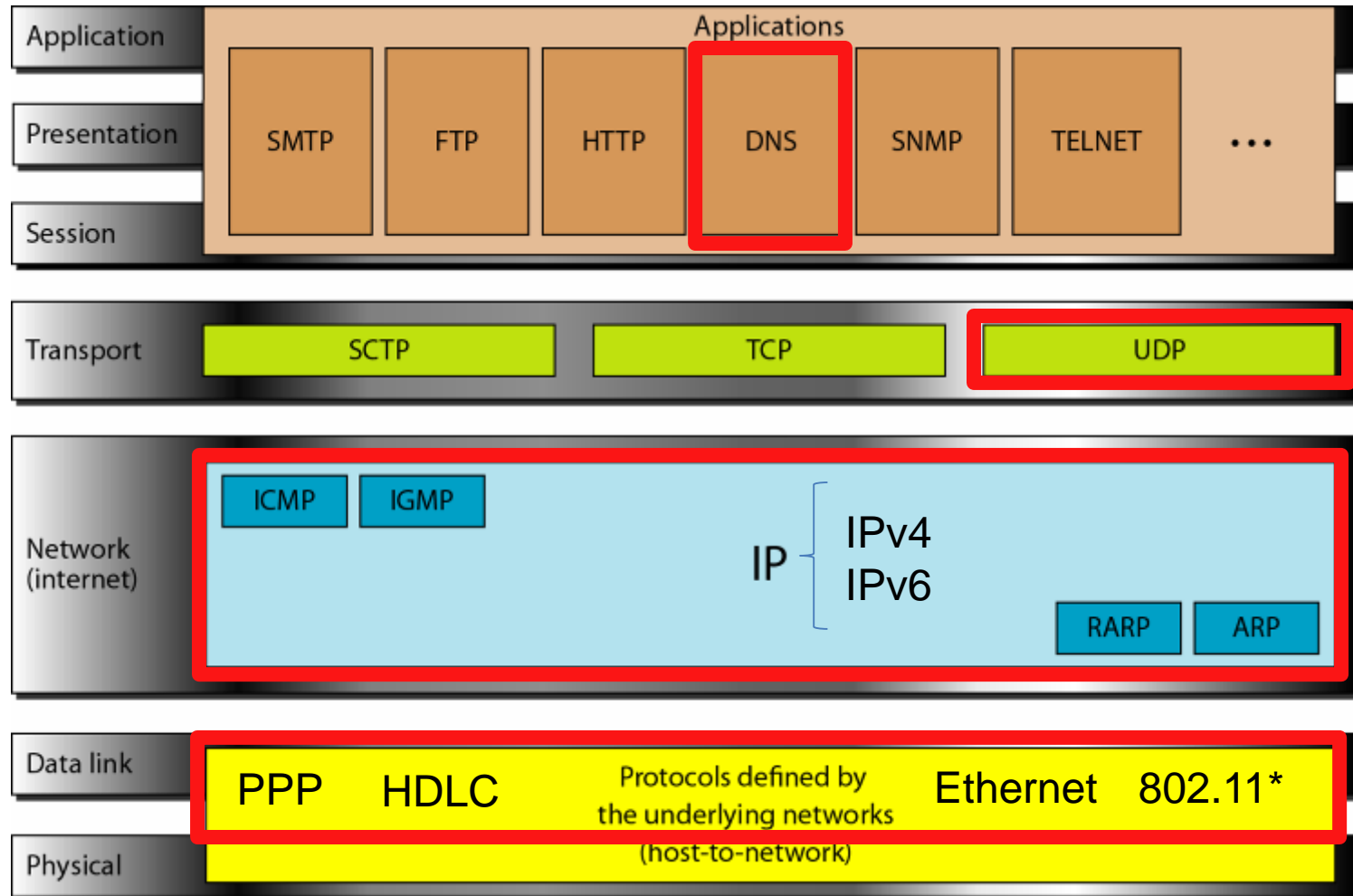
http://www.wiki.com/index.html

www.wiki.com

66.96.149.1

*URL = Uniform Resource Locator

Protocols in the OSI Model



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

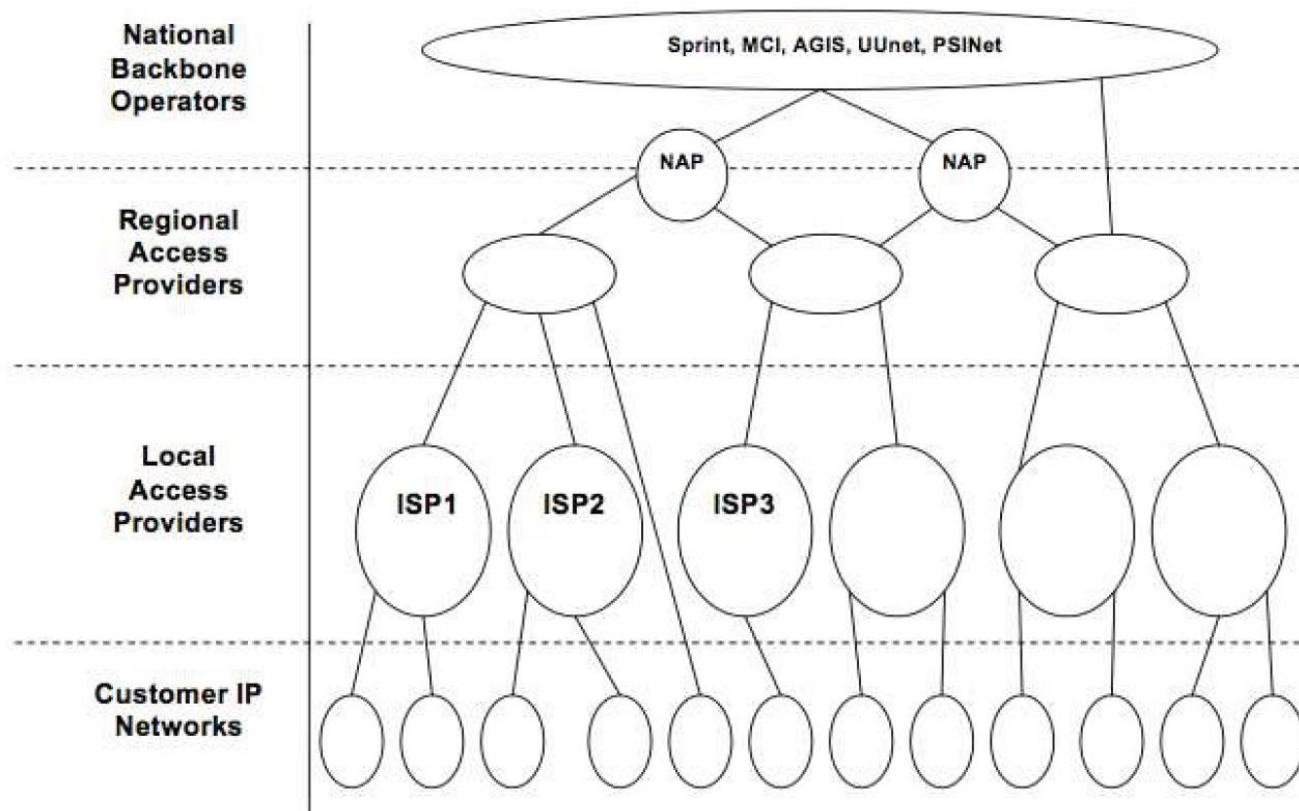
- "I predict the Internet in 1996 will catastrophically collapse."

Robert Metcalfe, 1995

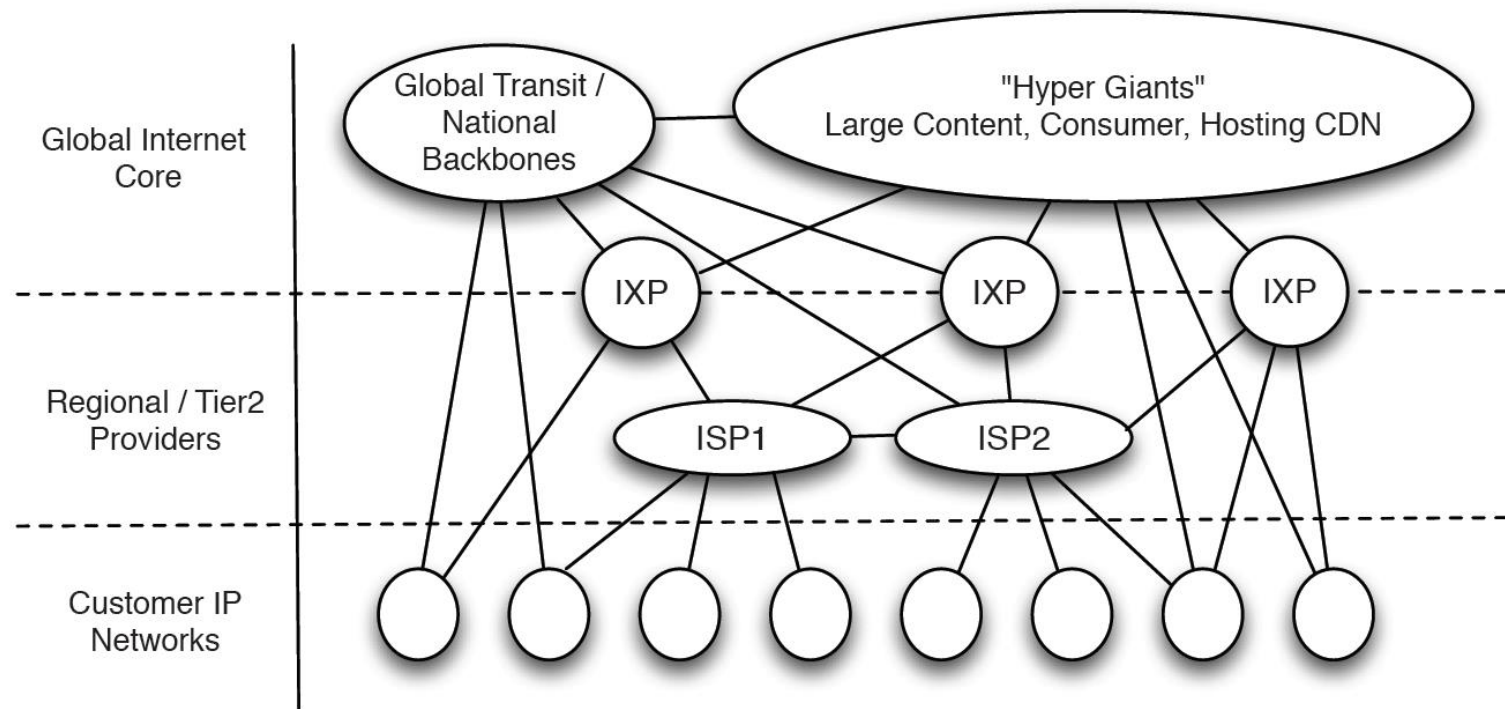
- "IPv6 is dead."

David Cheriton, 1999

Traditional Logical Internet Topology

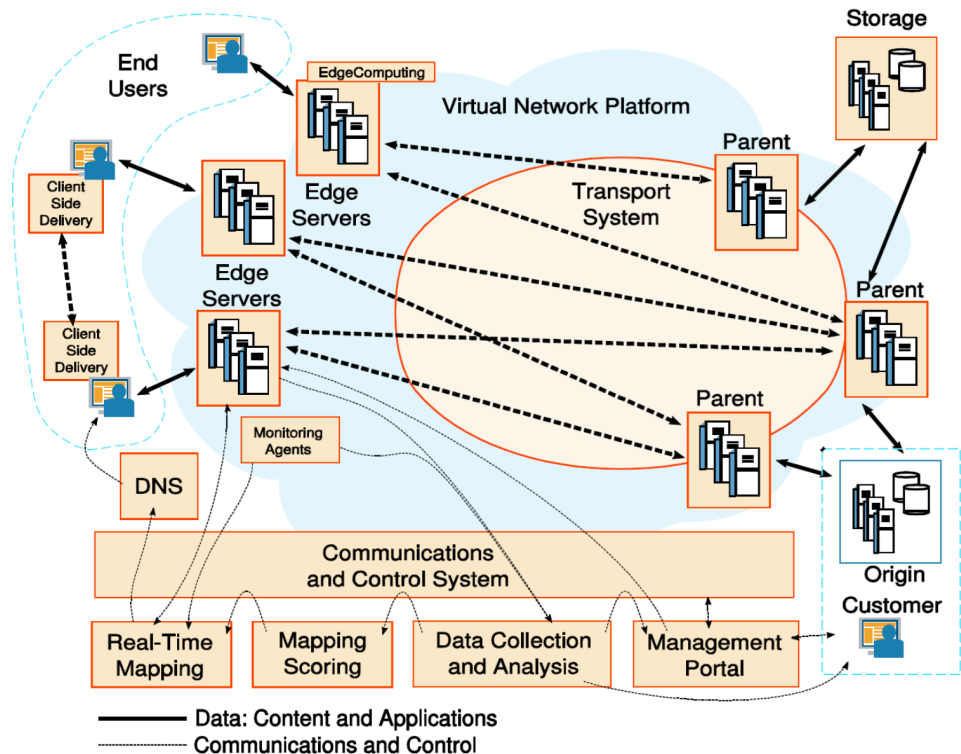
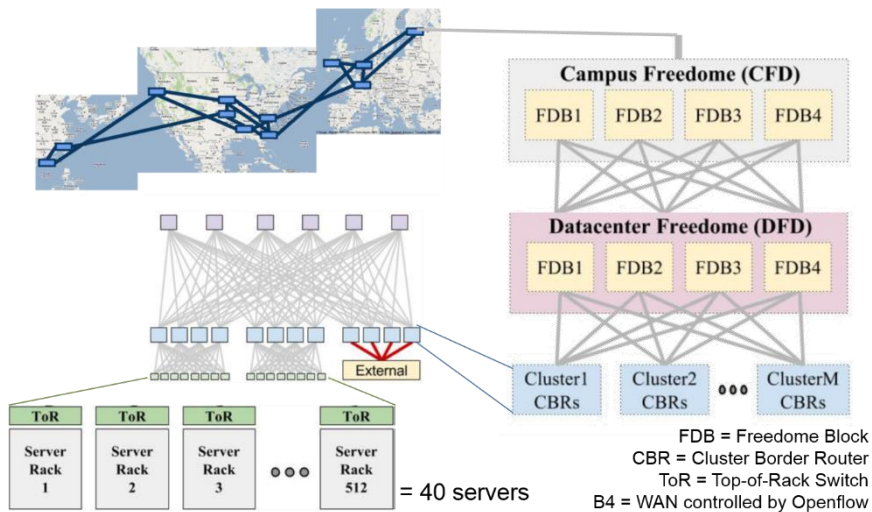


Emerging Logical Internet Topology



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

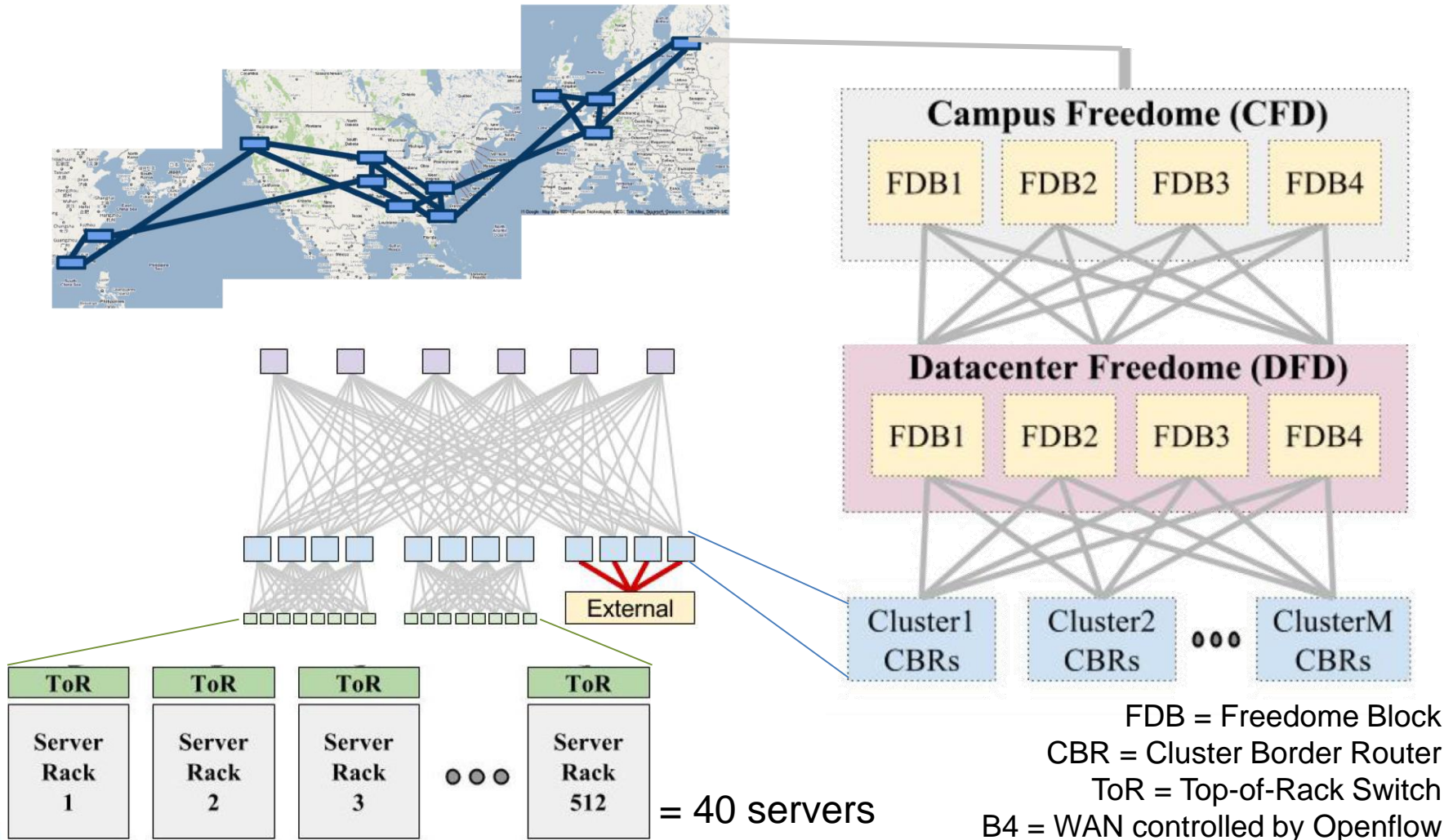
Hyper-Giants



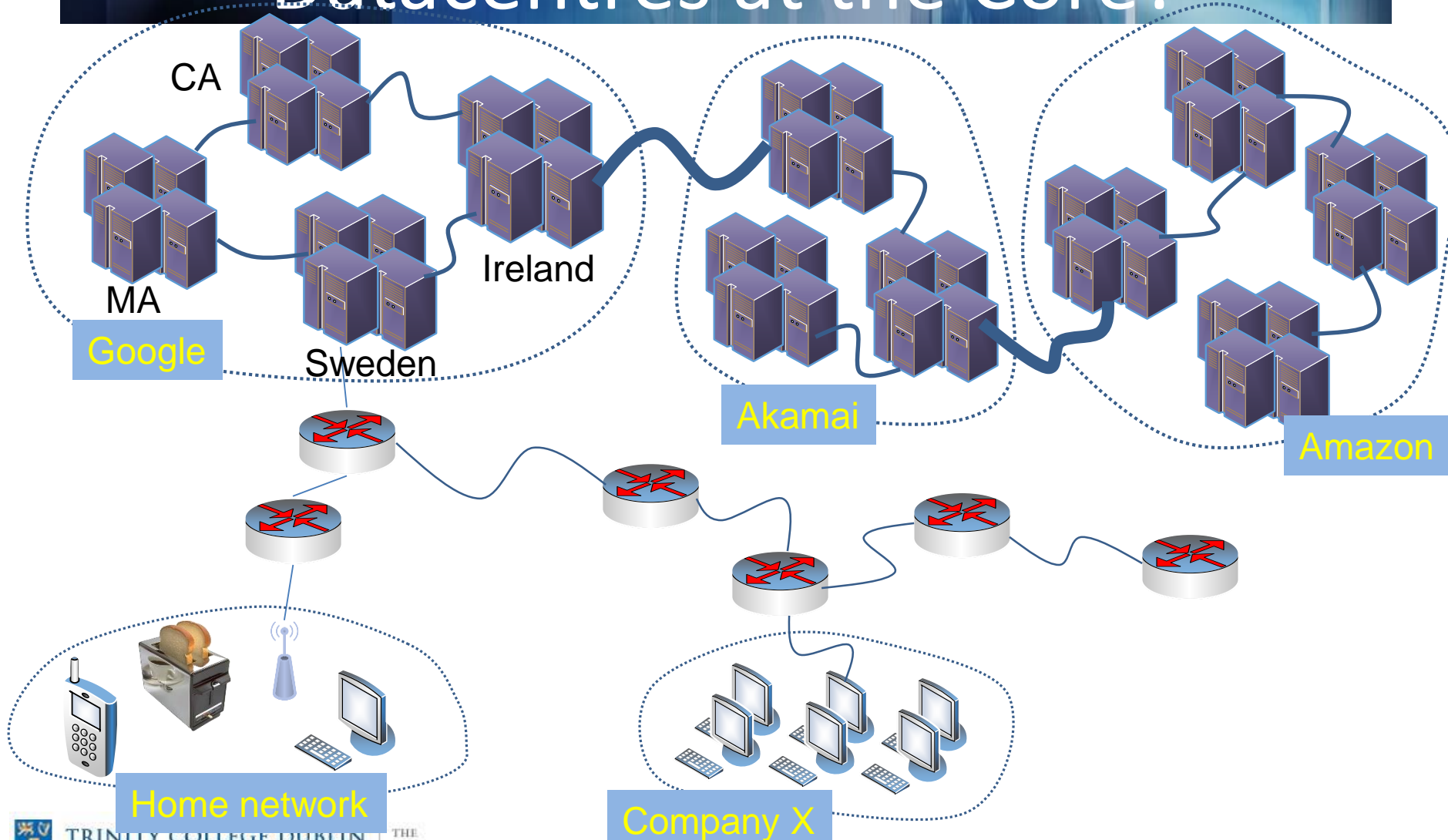
- Google

- Akamai

Google's B4 to Jupiter

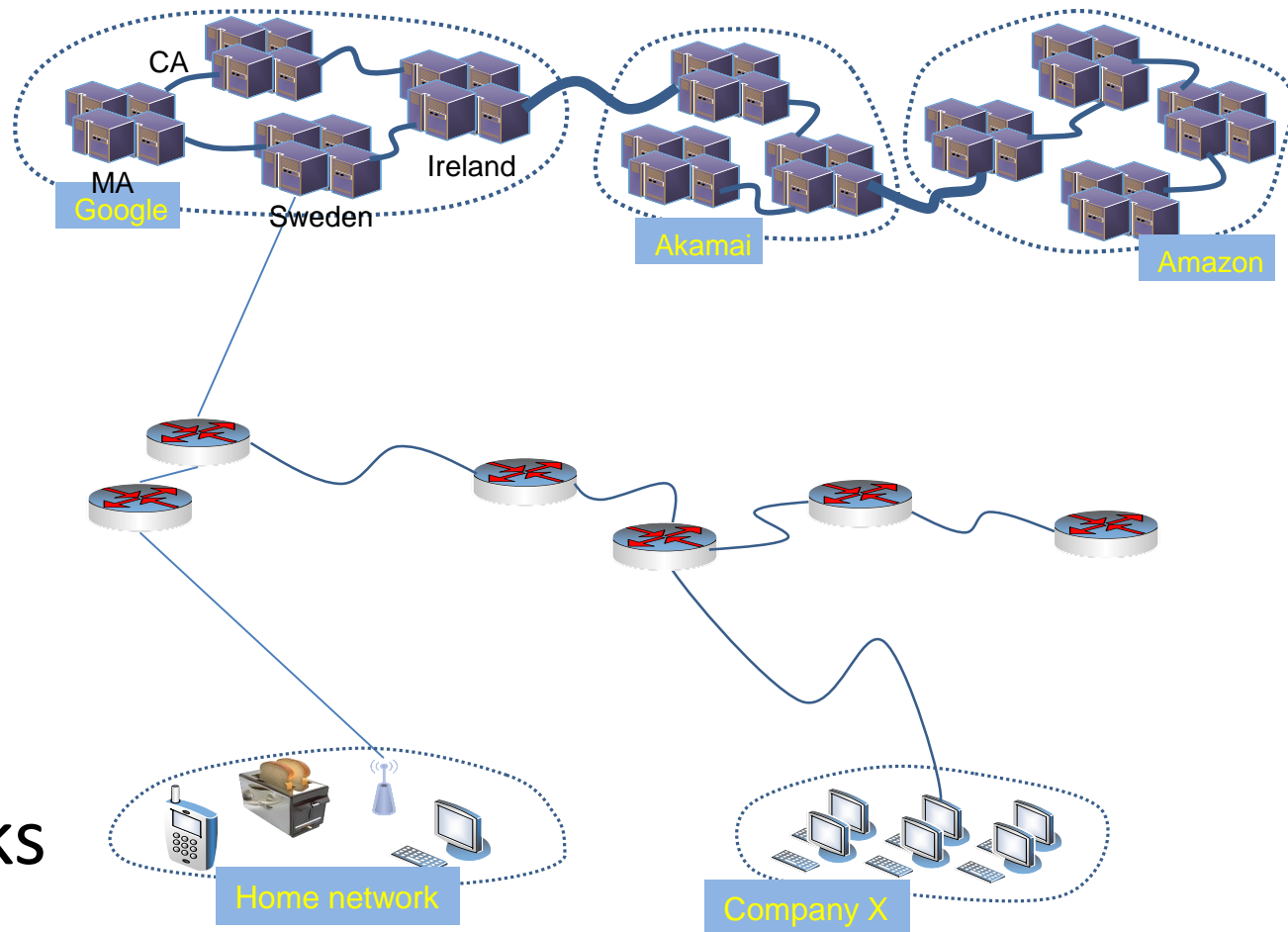


Datacentres at the Core?



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
- ATM/MPLS
- Software-Defined Networking / Openflow
- CLOS / Fat-tree



That's all
folks