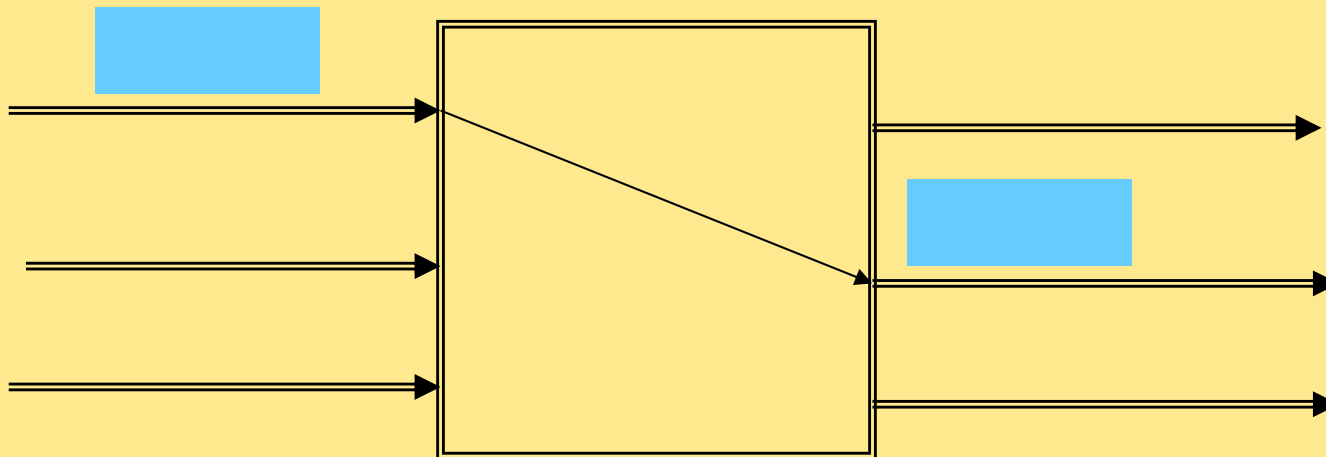# ETSF15: Lecture 6
- Transport protocols
- DHCP, DNS, ICMP
- Encapsulation
- Real Internets

Jens A Andersson

The objective of a switch?

- Connects networks with *same L2 protocol*
- Selects next network for incoming frames depending on destination address.

Routing

- Routing = selection of best path to destination
  - ◆ Router generic name for a best path selector on layer 3
  - ◆ Some layer 2 protocols include some form of routing
- Adapt best path to dynamics in the network
- Based on Graph theory
  - ◆ E.g. Dijkstra Shortest Path First
- Switching/Forwarding = select output interface and next hop based on best path

Flooding

- Incoming frames are copied out on all other ports.
- To break loops: All frames must have a hop counter.
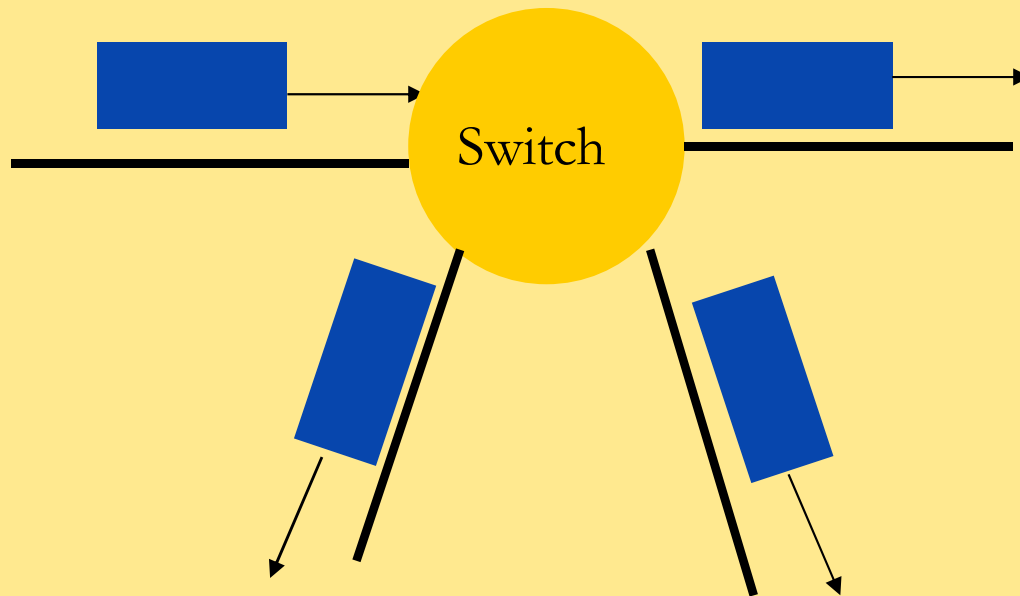
Link cost metrics

⌘ Capacity/Bit rate

⌘ Load

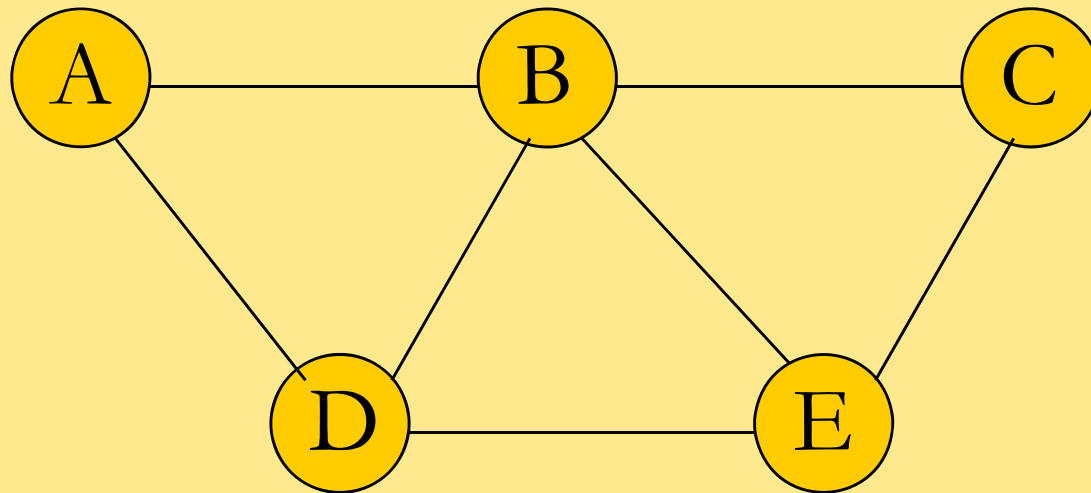⌘ Type of network

   ⌘ Fixed

   ⌘ Mobile
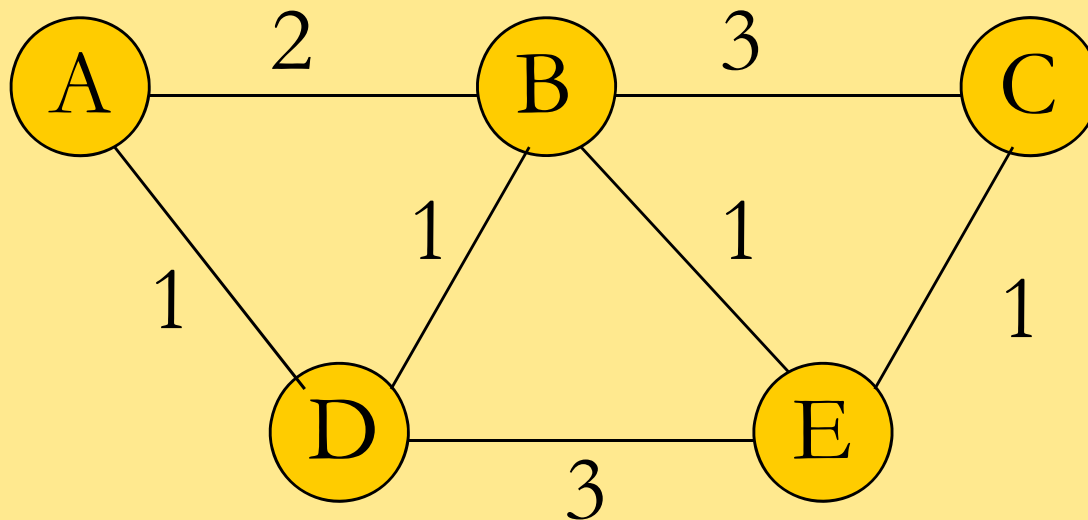
   ⌘ Wifi

⌘ Latency

⌘ Etc …

Least-hop path

- Least-hop path assumes link/edge cost is equal for all links/edges
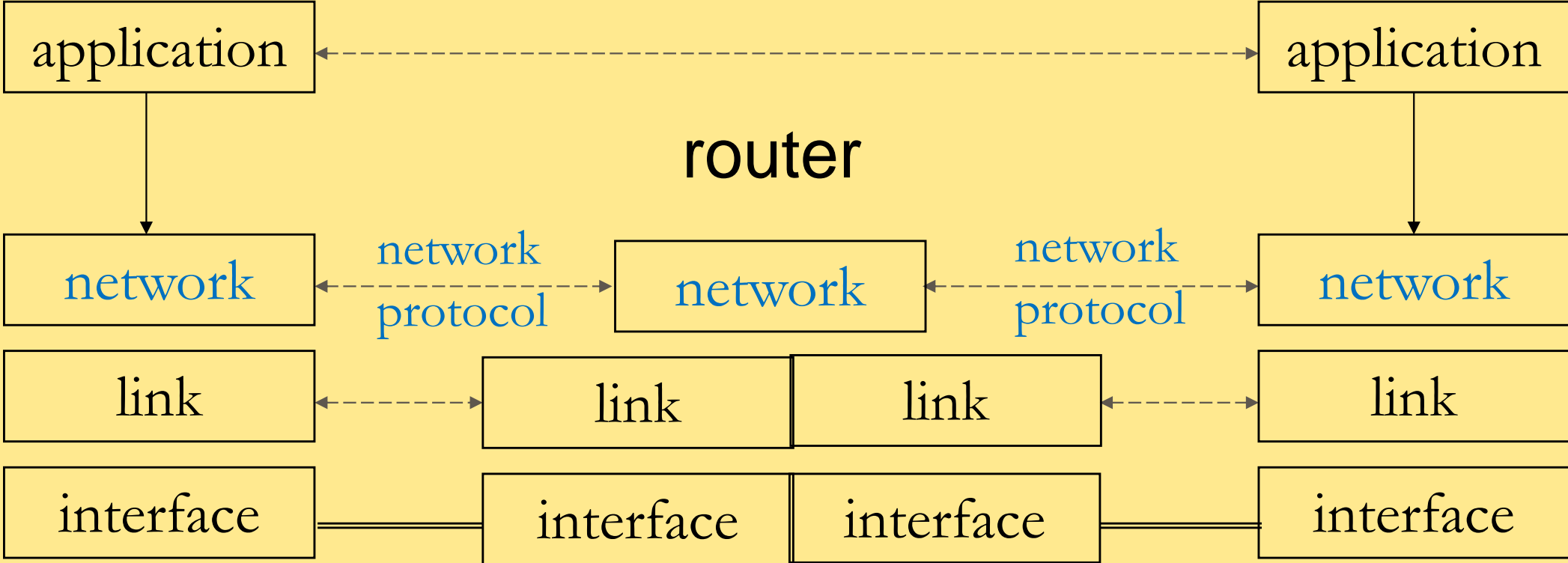- Path with least hop is preferred

Least-cost path

- Adapt to different link/edge cost
- Path with least cumulative cost is preferred

Network Protocol

Sender

Receiver

| application | - | application |

router

| network | - - - network protocol - - - | network | - - - network protocol - - - | network |

| link | - - - | link | link | - - - | link |

| interface | = = = | interface | interface | = = = | interface |

One Network Protocol: IP

- IP = Internet Protocol
- IP used on what is called Internet.
- IP defines IP addresses.
- Data transfered in IP packets/datagrams.
- Connection Free datatransfer.
- No error detection or control.
- This is called "best-effort".

Connection Oriented data transfer

New connection

Connection approved

Data transfer

End connection

Connection ended
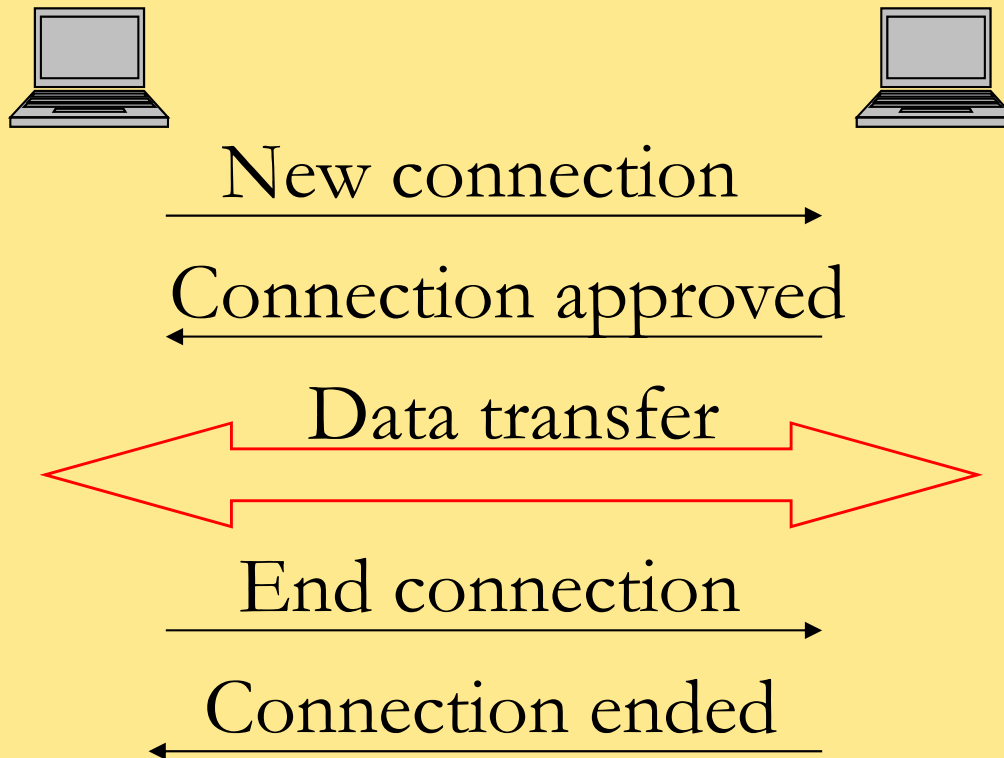
Connection Free data transfer
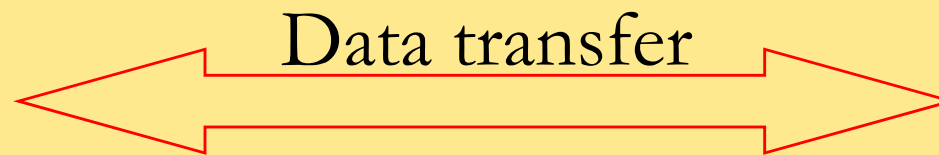
Data transfer

Internet Protocol

- Two versions in parallel: version 4 (IPv4) och version 6 (IPv6).
  - Incompatible
  - Translation needed
- IPv4 developed during 1970s.
  - All IPv4 addresses are allocated!
- IPv6 supports
  - More addresses
  - Realtime media transfer (built in)
  - Encryption and autentication (built in)

IPv4 address structure (2)

- Two parts:
  - Network identity (net id)
  - Host identity (host id)

One EIT IP address = 130.235.202.173

????

EIT network id = 130.235.200

IPv6 address structure

- IPv6 addresses are 128 bits long
  - ◆ 3.4 10^{38} individual addresses

$010A : 1234 : E4F5 : 1003 : 4567 : BC98 : 0000 : 2341_{16}$
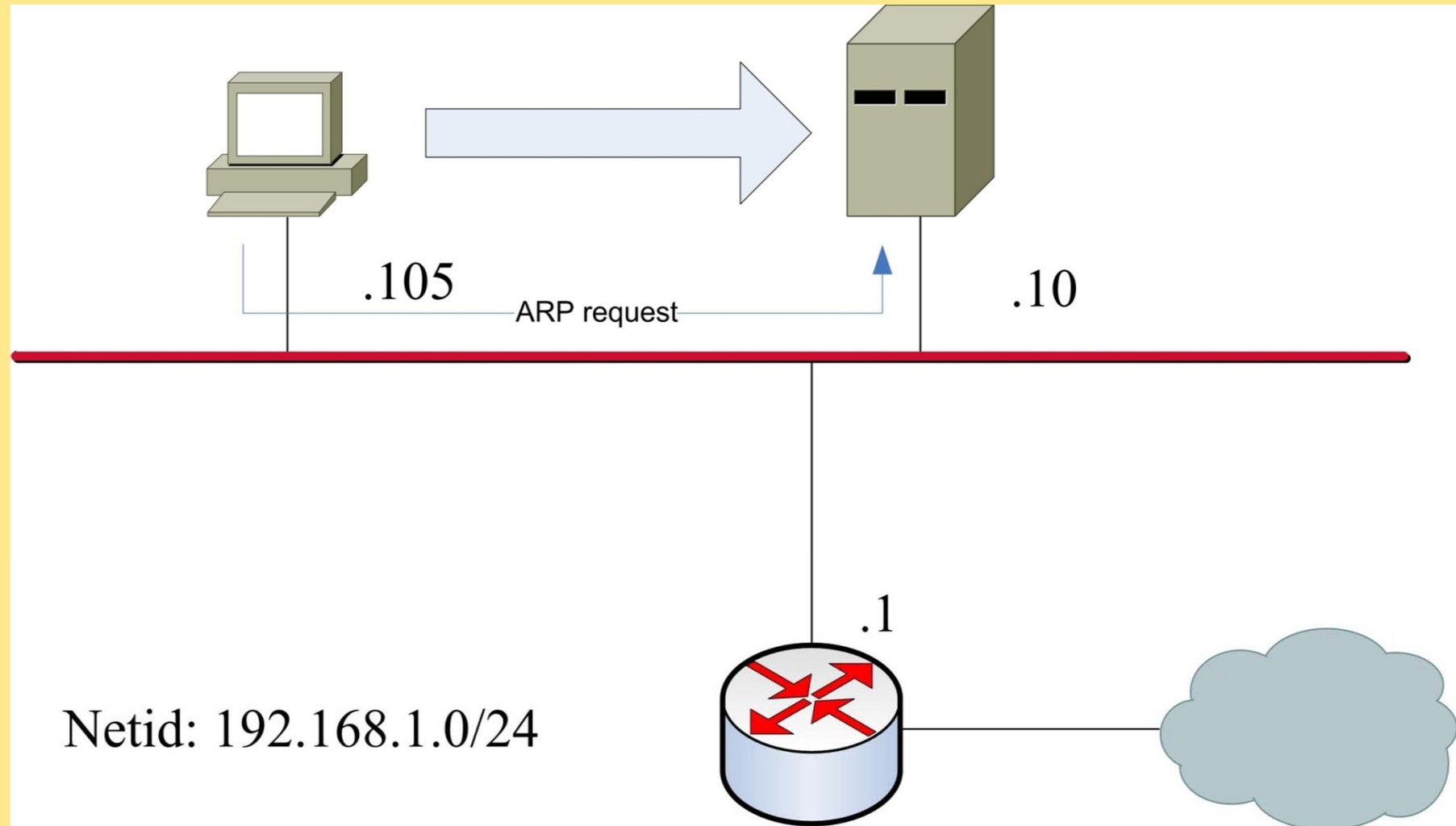
Check Sum (Hash Sum)

- Split the bit vector into equal sized segments
- Calculate sum over all the segments
- Remove carry bits and add to the sum

- Before transmission
  - ♦ Calculate the sum's one complement
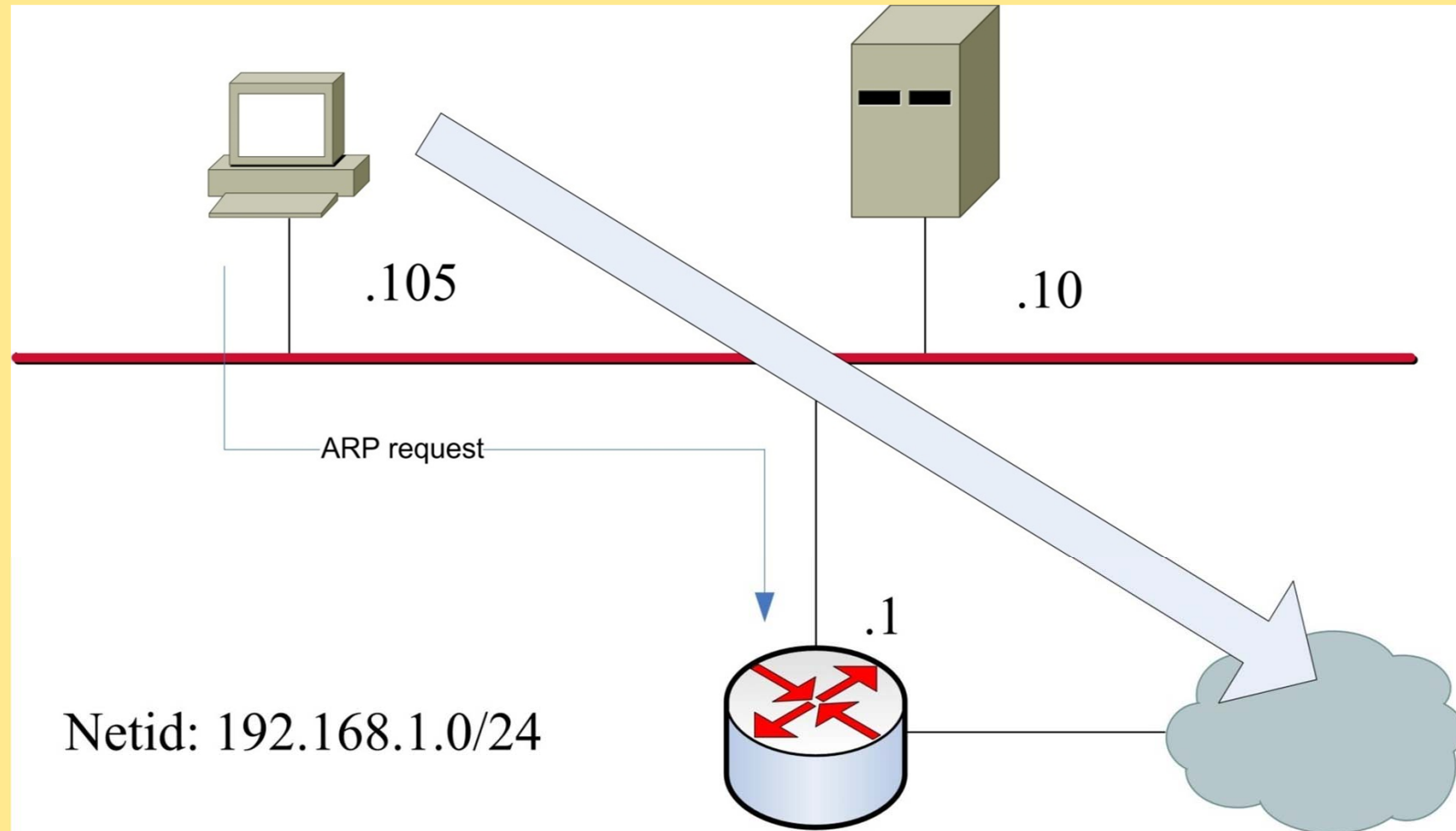- Send segments and the one complemented sum

From IP address to MAC-adress

- Hosts have to know MAC addresses to be able to communicate on one LAN
- Find out the MAC/IP address mapping
  - IPv6 uses sub protocol of Neighbor Discovery Protocol (NDP)
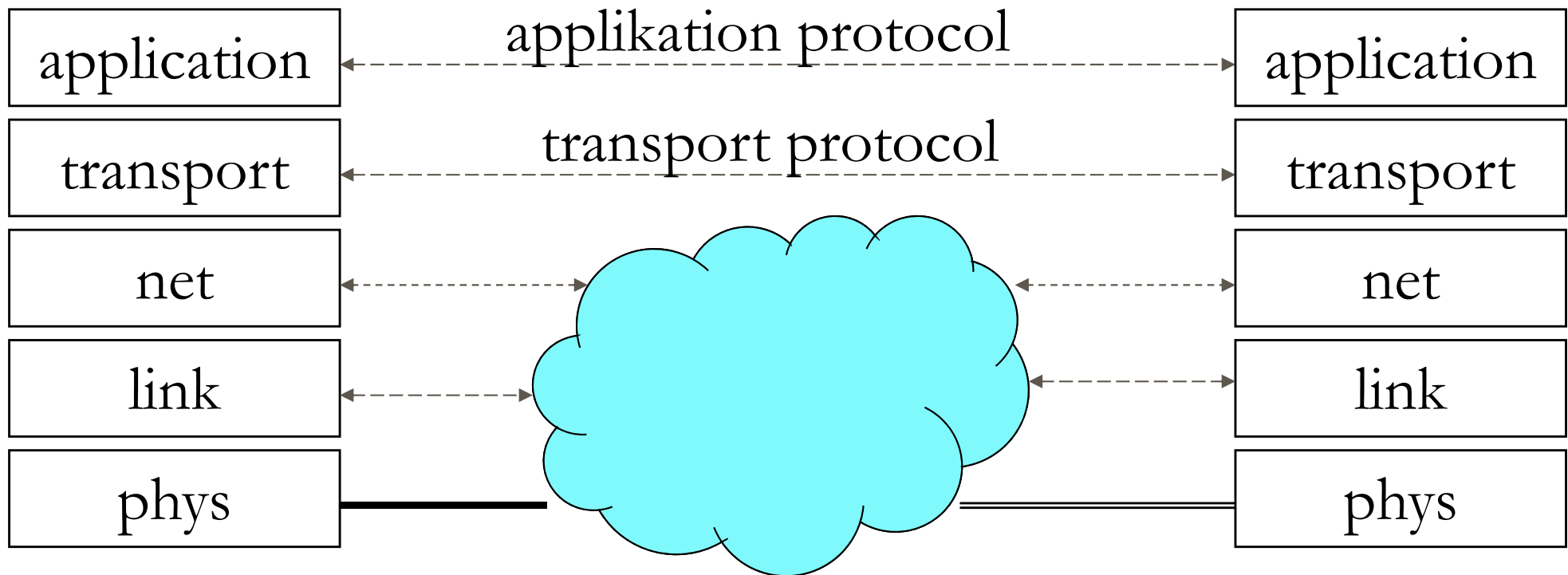 - IPv4 uses Address Resolution Protocol (ARP)

ARP (1)

.105

ARP request

.10

.1

Netid: 192.168.1.0/24

ARP (2)

.105

.10

ARP request

.1

Netid: 192.168.1.0/24

From IPv6 address to MAC address

- NDP ion stead of ARP
- NDP is part of ICMPv6
  - Internet Control Message Protocol
  - Supporting protocol for IPv6
- Neighbor-Solicitation Message corresponds to ARP request
- Neighbor-Advertisement Message corresponds to ARP reply

Transport protocols

application	← — applikation protocol — →	application
transport	← — transport protocol — →	transport
net		net
link		link
phys		phys

- TCP: Förbindelseorieterat
- UDP: Förbindelsefritt

Transport protocols

- End to end = Application to application
- Indepenedent of underlaying network structures

UDP

- UDP = User Datagram Protocol.
- Connection free.
- "best effort"
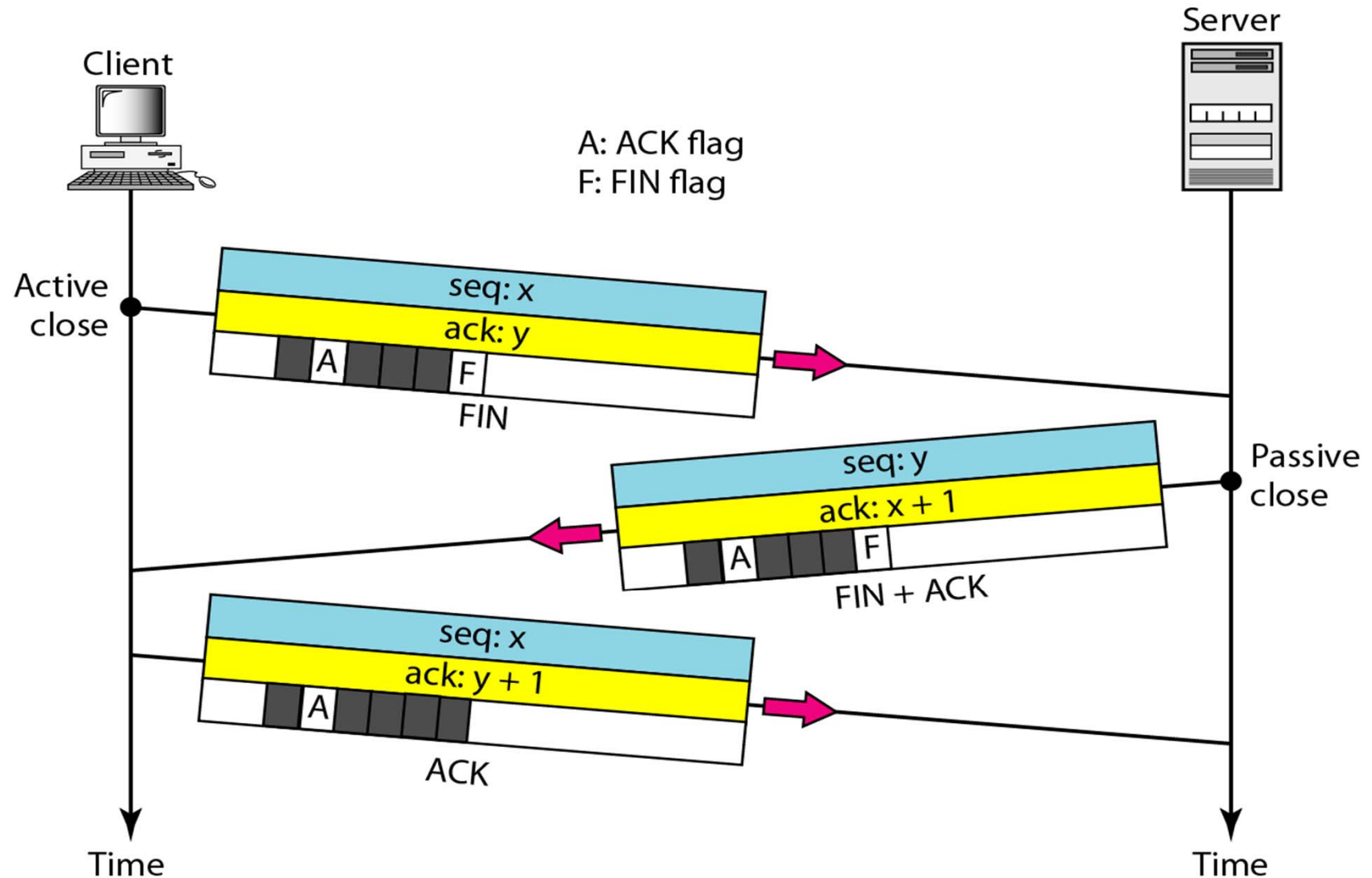- Adds only multiplexing on top of IP.

TCP

- TCP = Transport Control Protocol.
- Connection oriented.
- Reliable transfer.
  - ARQ = Go-Back-N
  - Flow control
    - Receiver control sender's window size
  - Congestion control
    - Requests for retransmission (= packet loss) indicates congestion
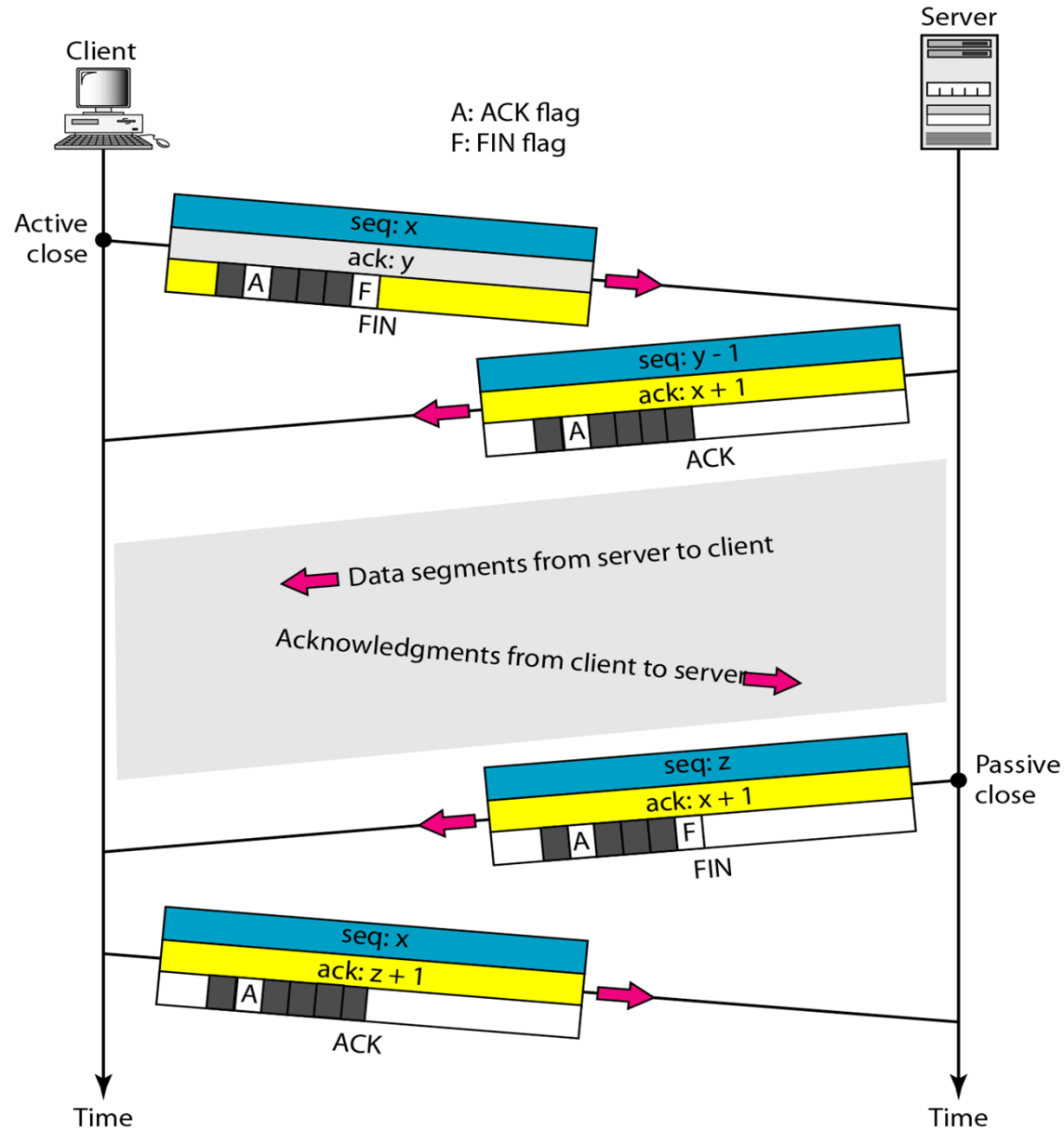   - Controls sender's window size

TCP Three Way Handshake
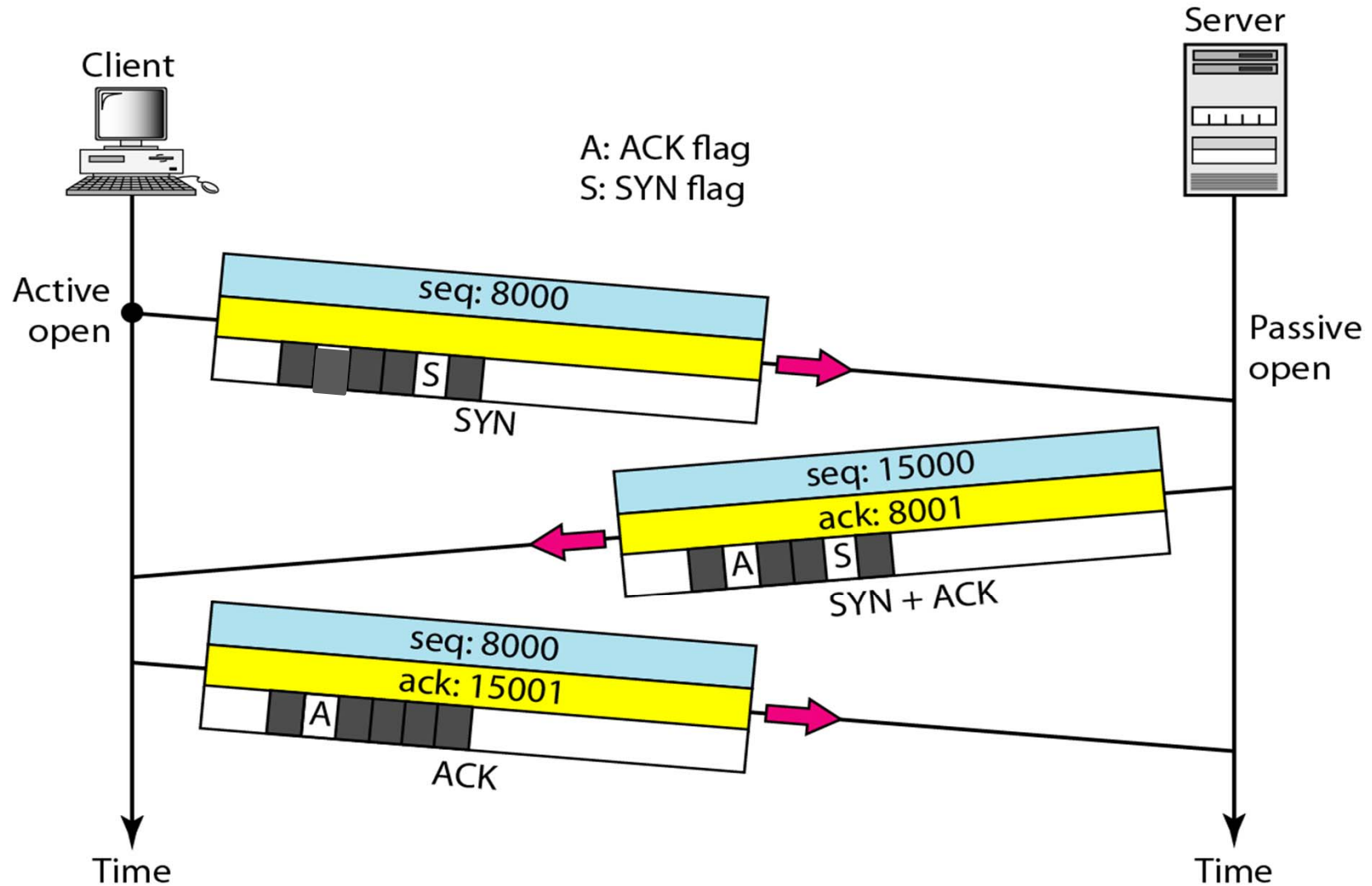
TCP Connection termination

TCP Half-close

Addressis on transport layer

- Ports addresses application.
  - Source and destination
- Well defined destination ports:
  - 80 : http (web)
  - 25 : smtp (mail)
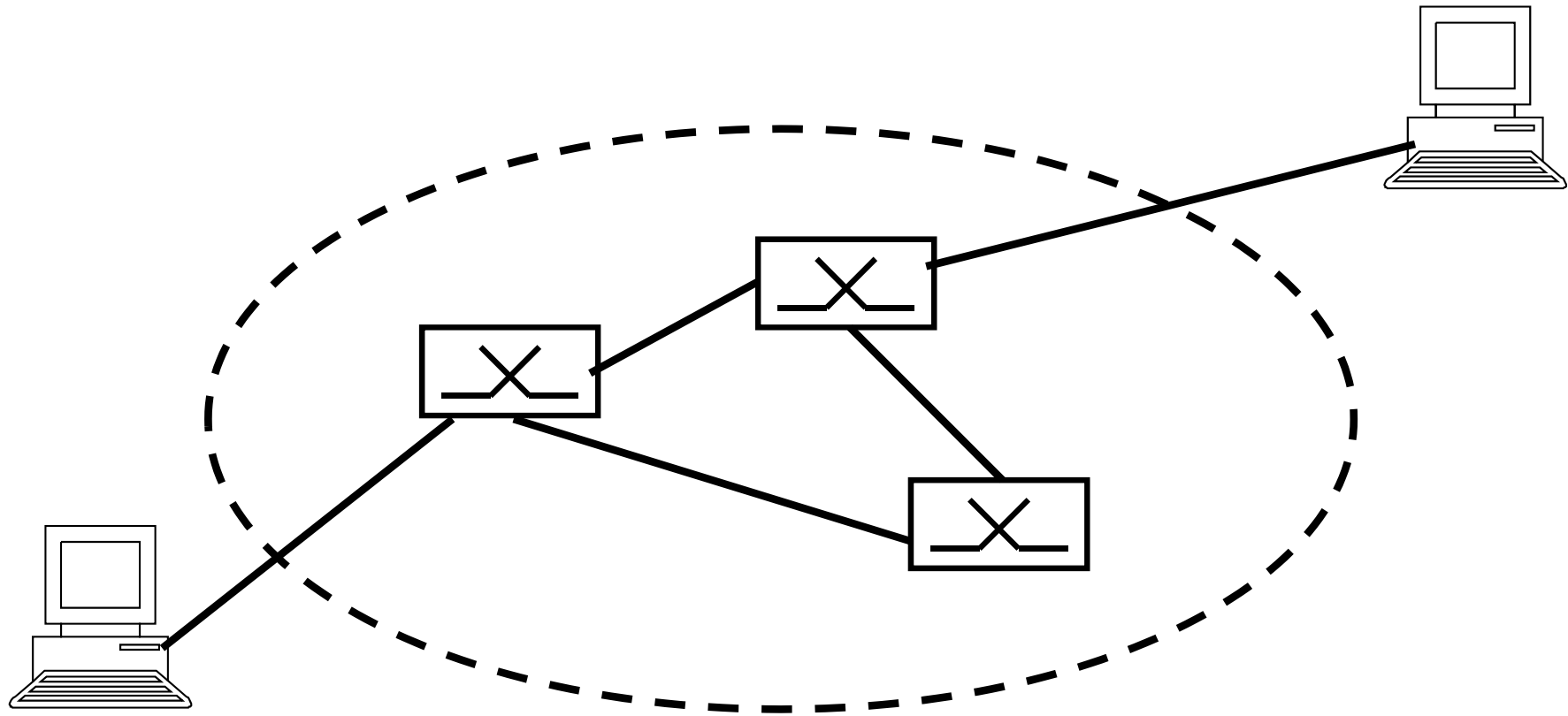 - 22 : ssh
- Source randomly selected

Two layered reference models

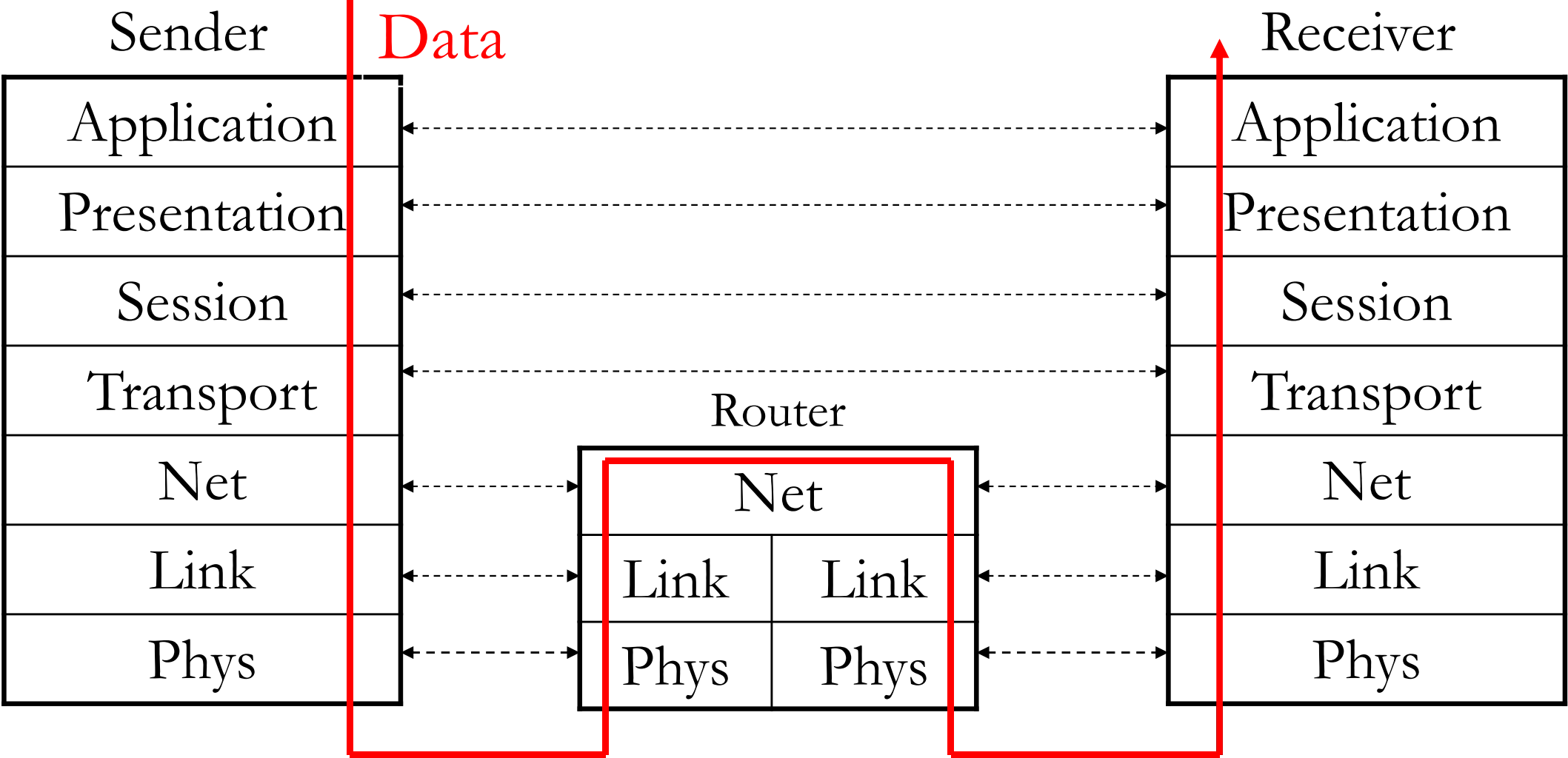| OSI model	TCP/IP model
Application	Application
Presentation	
Session	
Transport	Transport
Net	Net
Link	IP carrying nets
Physical	

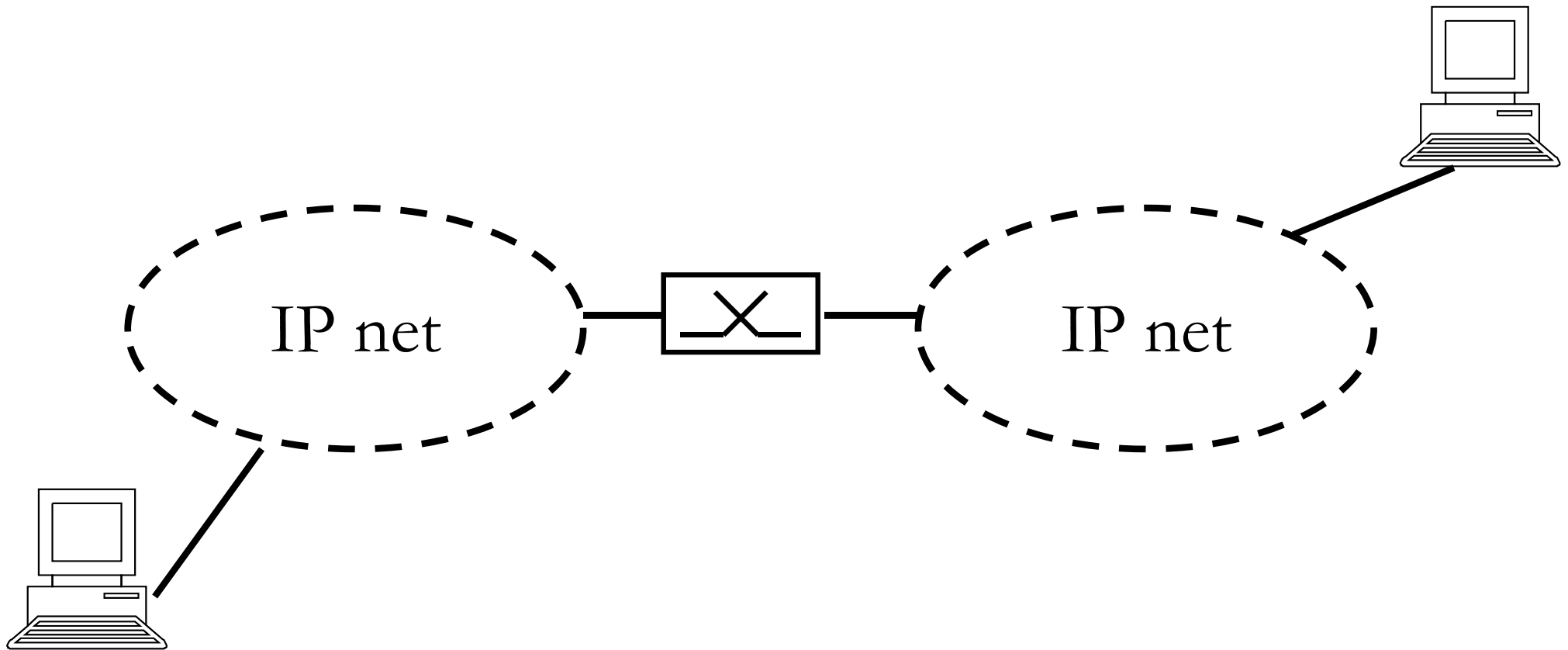# OSI model Protocol Stack (1)
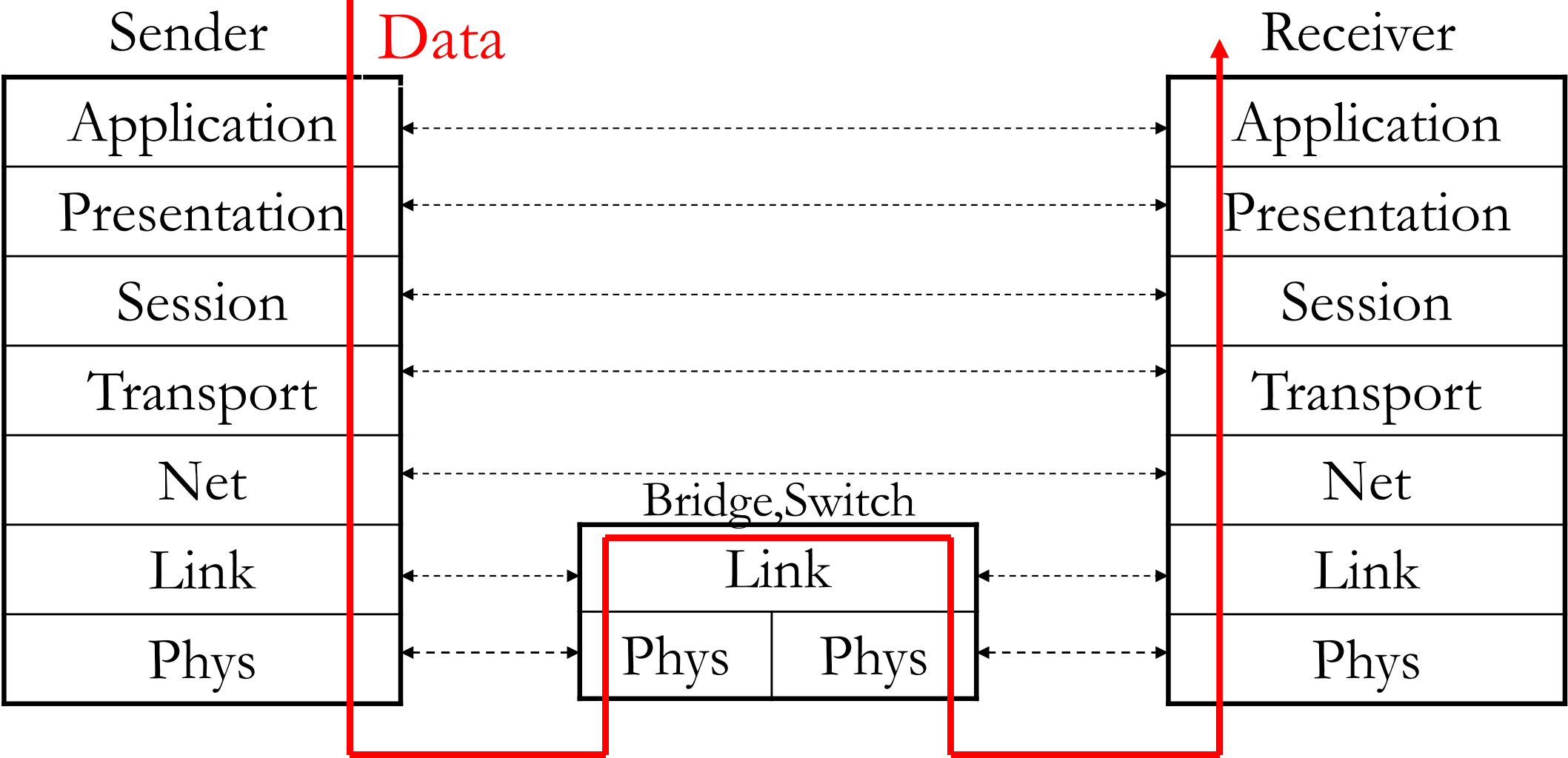
Switches used in a LAN

OSI model Protocol Stack (2)

Routers used between networks with same net protocol

IP net

IP net

OSI model Protocol Stack (3)

Sender		Gateway		Receiver
Application		Application		Application
Presentation		P.	P.	Presentation
Session		S.	S.	Session
Transport		T.	T.	Transport
Net		Net	Net	Net
Link		Link	Link	Link
Phys		Phys	Phys	Phys

Data
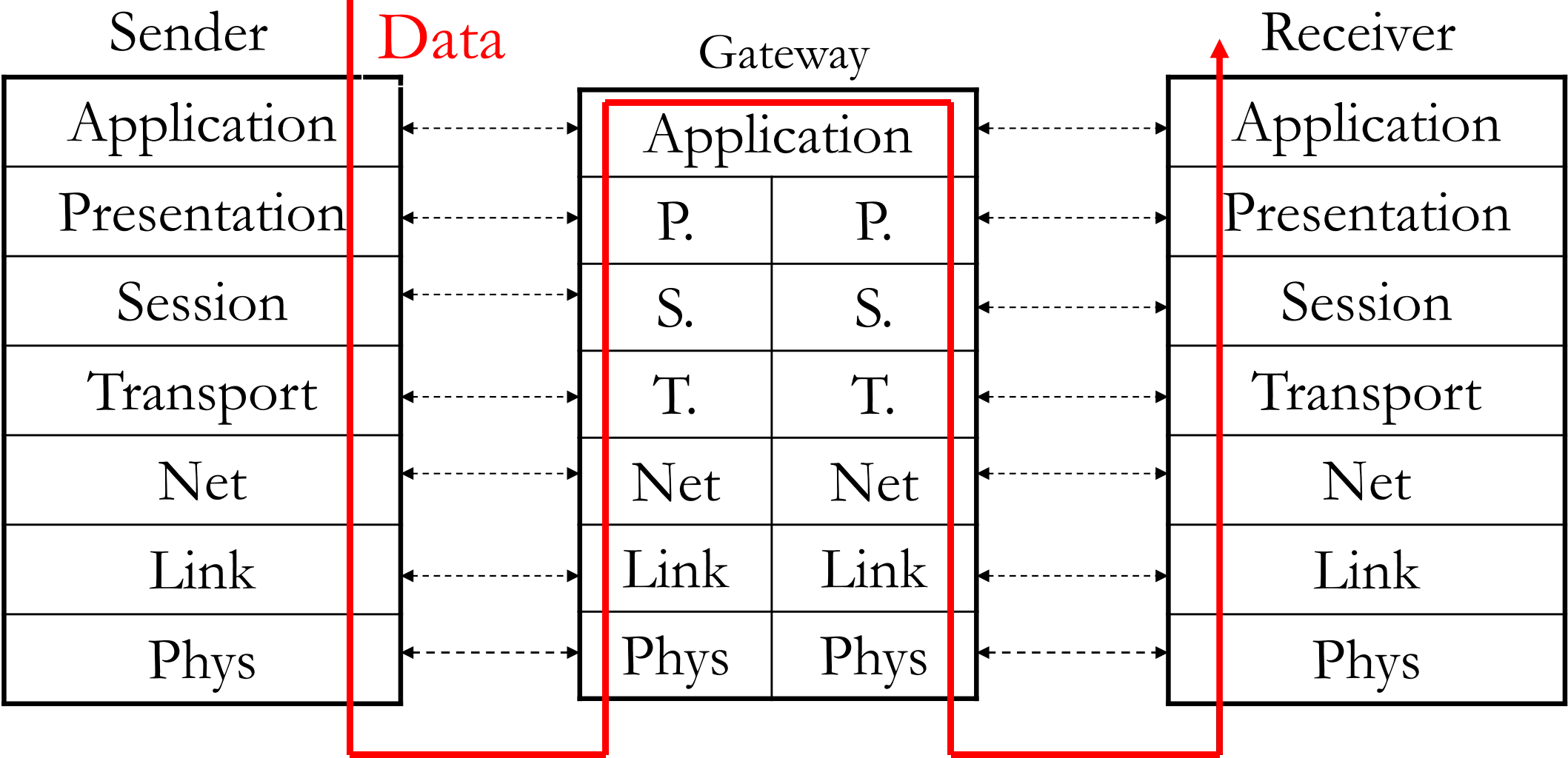
Gateways used between nets with different application protocols
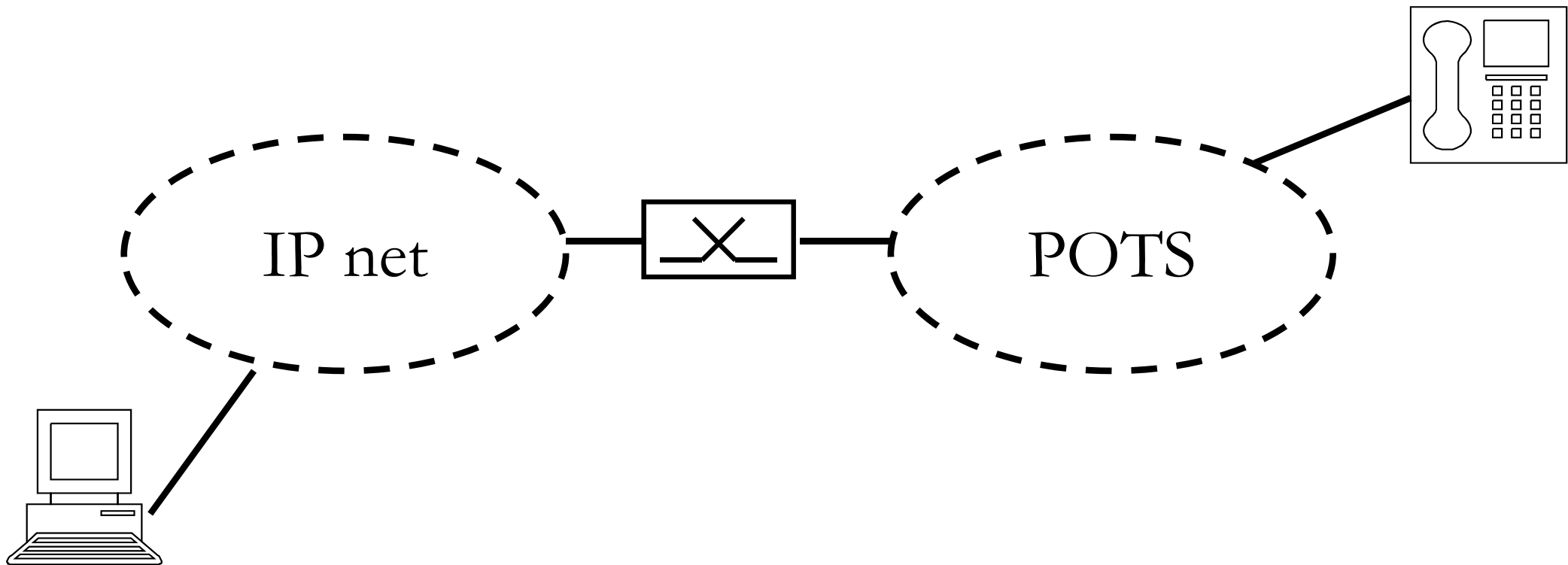
Internet's protocol stack

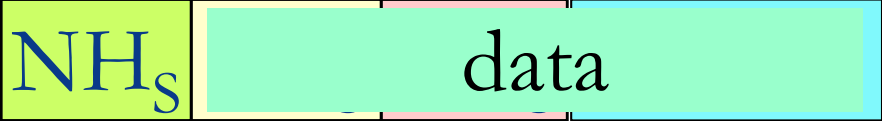|		
Application	HTTP, FTP, SMTP etc.	DNS
Transport	TCP | UDP	
Net	IP	ICMP | ARP
Link	Ethernet, PPP, ATM etc.	
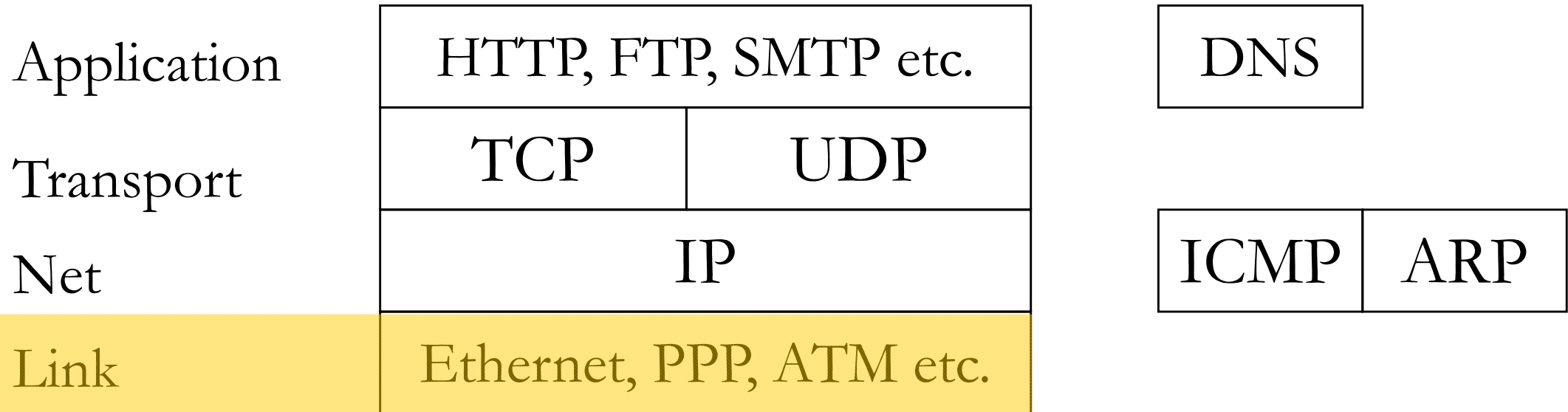
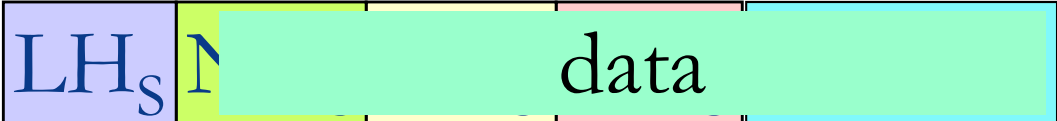# Encapsulation Sender Side

application
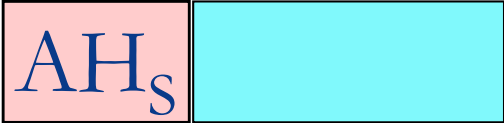
transport

net

link

phys

11010101100011100011....

Switch

Ethernet switchar do not change headers.

To outgoing link

| LH$_S$ | NH$_S$ | TH$_S$ | AH$_S$ | |

Outgoing link header
=
Incoming link header

| LH$_S$ | NH$_S$ | TH$_S$ | AH$_S$ | |

11010101100...

phys
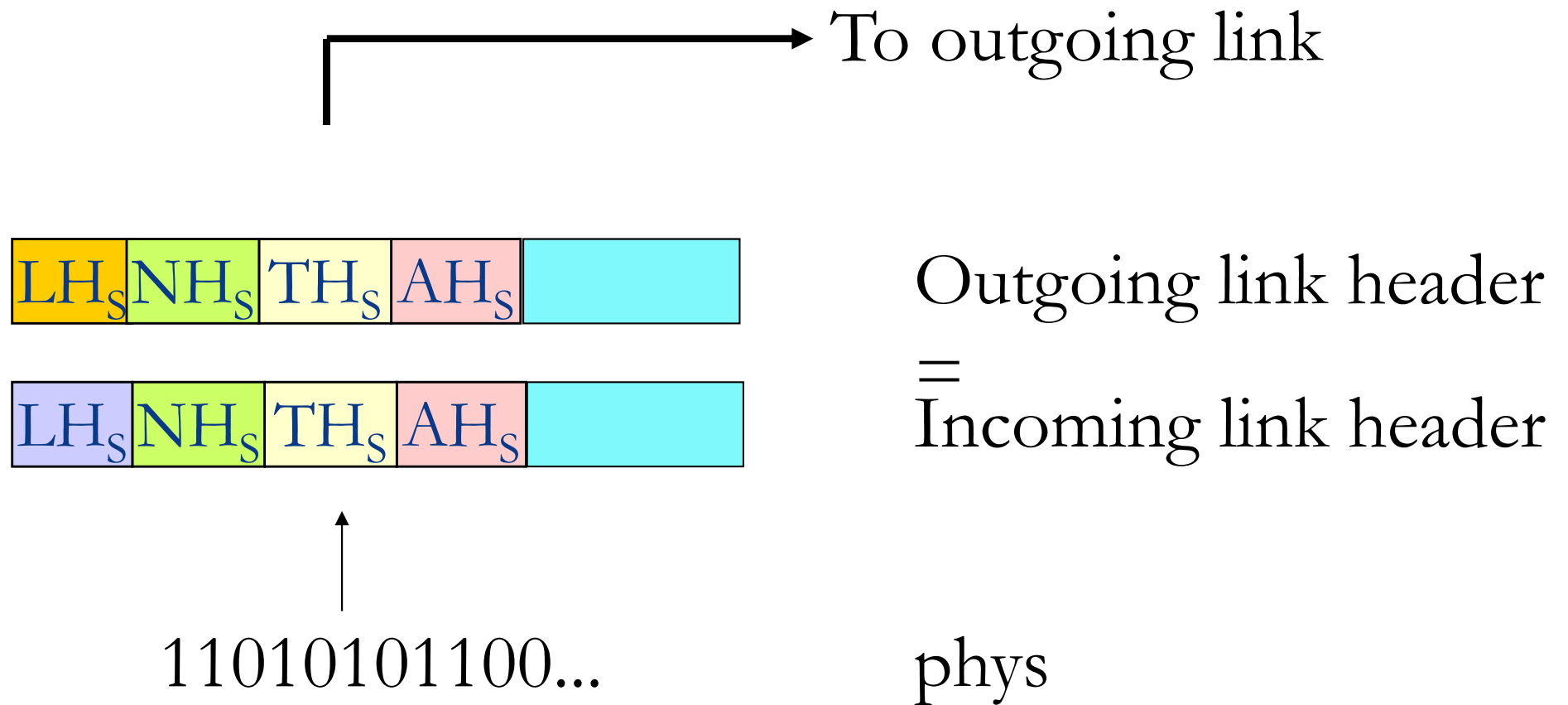
Router

Router creates new link header

Net header *basically(?)* unchanged.

to next network

| LH_U | $NH_{S'}$ | TH_S | AH_S | |

new headers

| LH_X | NH_S | TH_S | AH_S | |

old headers

11010101100...

phys
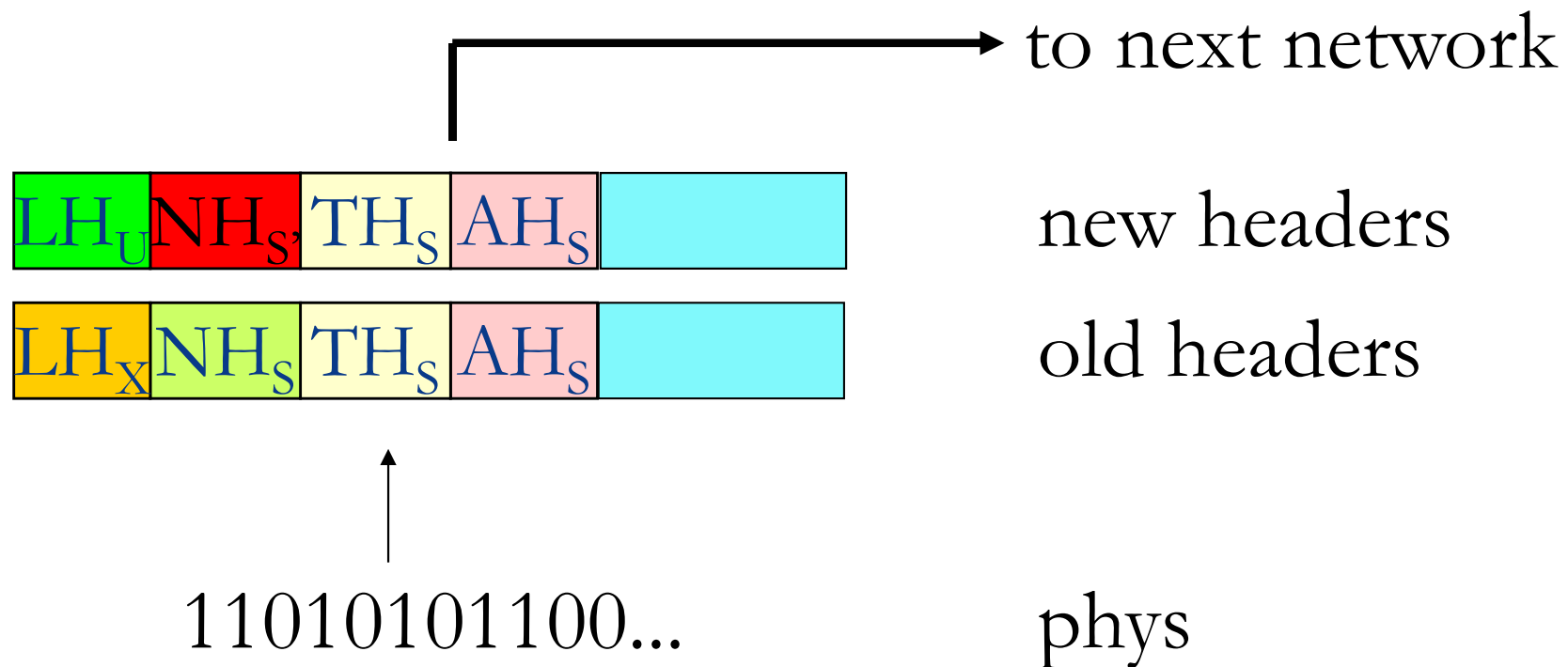
Receiver side decapsulation

application AH_S █

transport TH_S AH_S █

net NH_Z TH_S AH_S █

link LH_U NH_Z TH_S AH_S █

phys   11010011011000011....
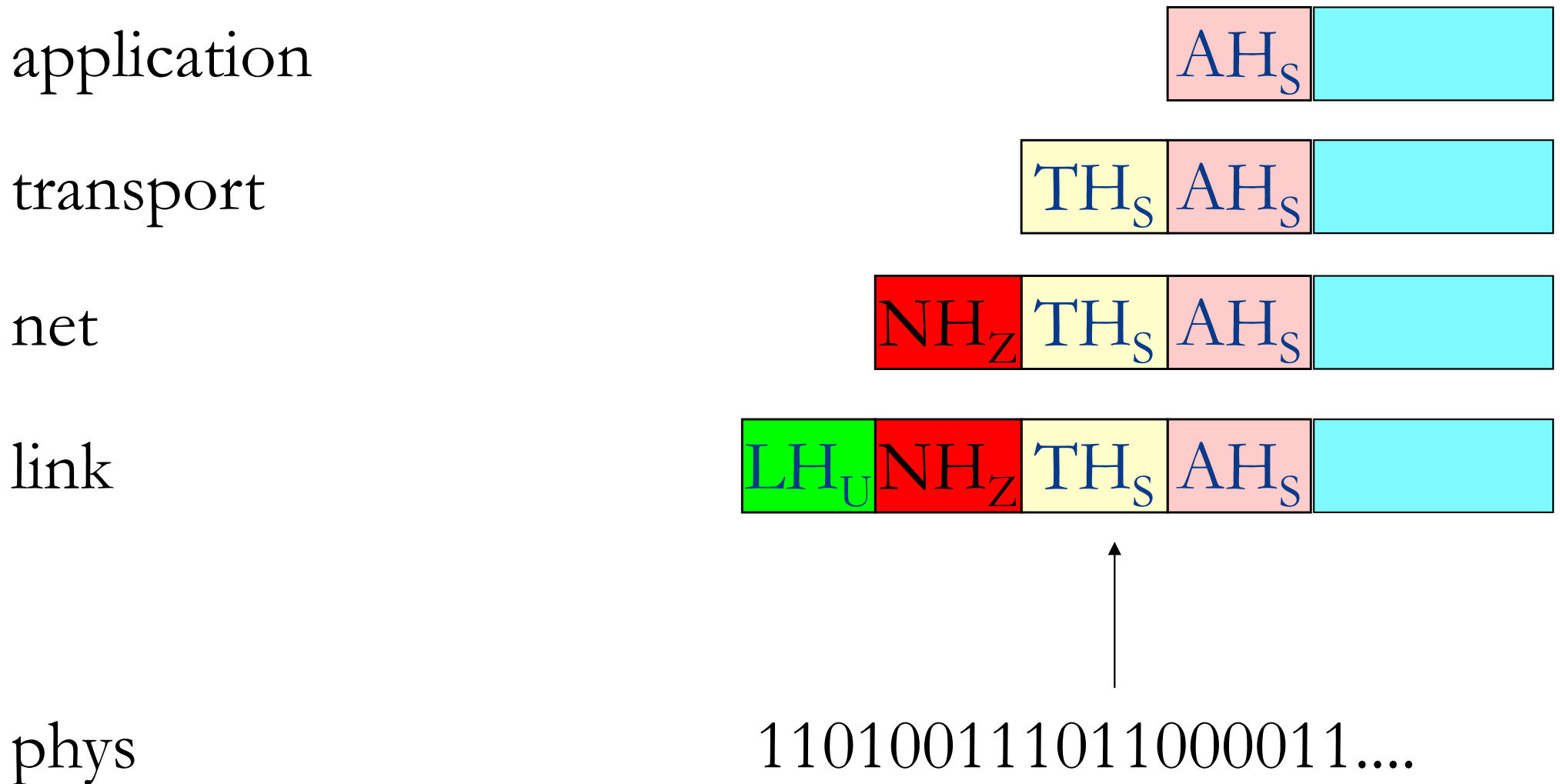
ICMP

- IP supporting protocol
- Messages
  - ◆ Error msgs
    - Host unreachable
    - Net unreachable
    - TTL expired
  - ◆ Request
    - Echo request

MTU
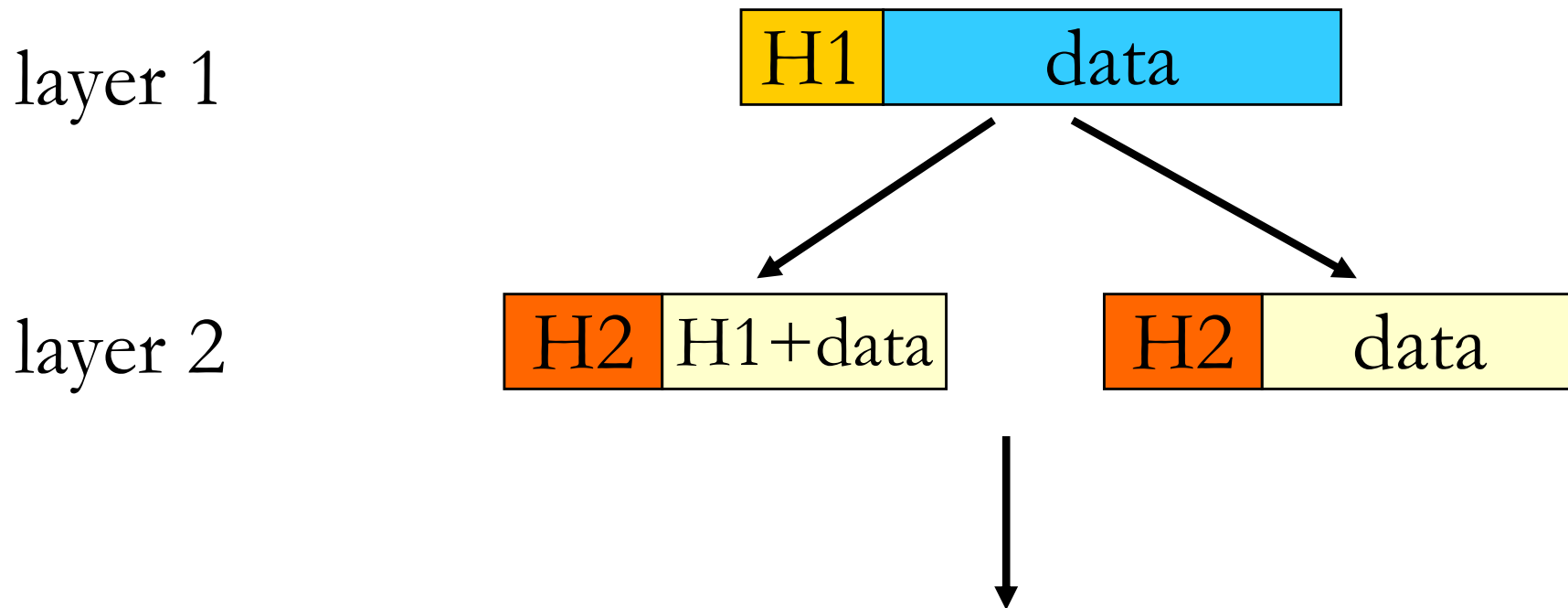
- Maximum Transmission Unit
- Maximum payload size
- Exemple:
  - Ethernet MTU = 1500
  - PPP link over modem = 256/512
  - Gigabit Ethernet Jambo Frames = 9600
  - IPv4 = 65536 inkl header
  - IPv6 = 65536 exkl header

Fragmentation

- When upper layer frame is bigger than underlaying payload to small

layer 1

H1	data

layer 2

H2	H1+data		H2	data

Defragmentation

- Performed by receiver

layer 1 | H1 | data |

layer 2 | H2 | H1+data | | H2 | data |
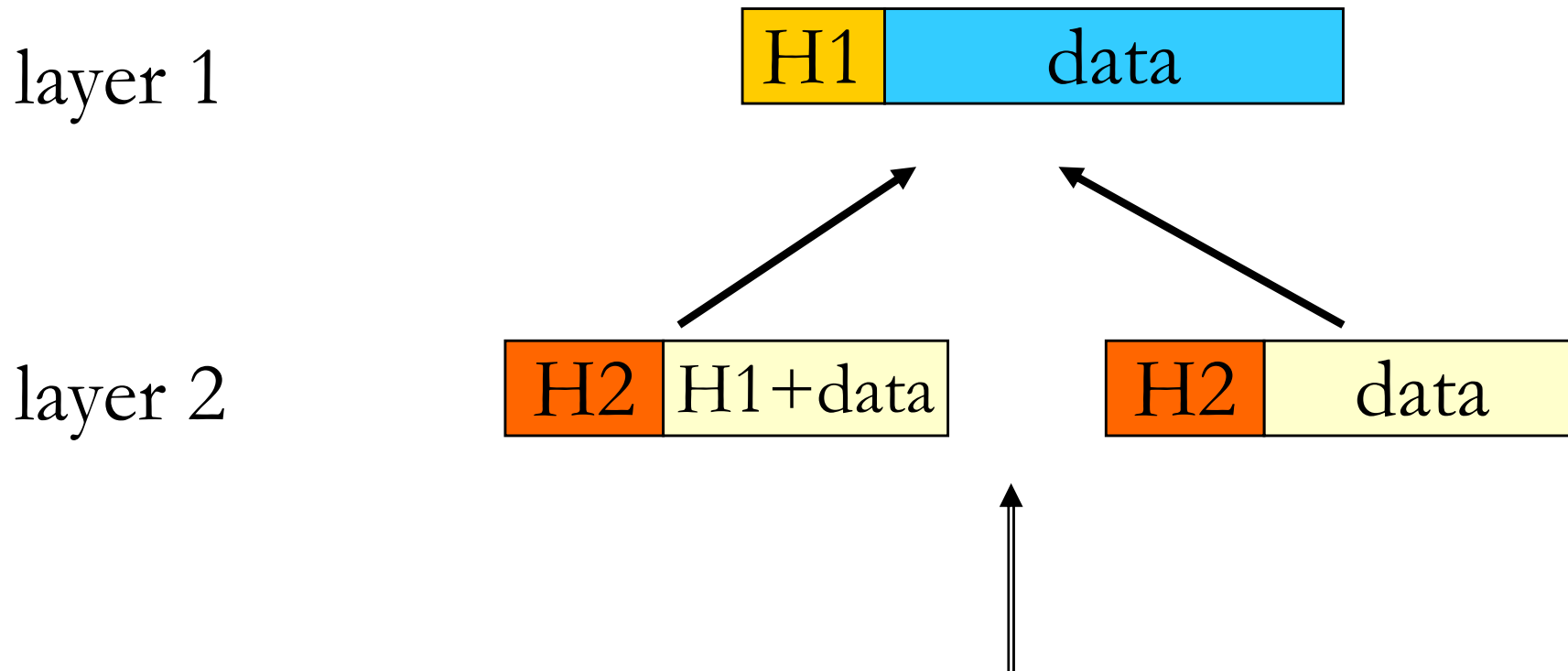
IP fragmentation

- IPv6: only performed by original source.
- IPv4: performed by routers if needed

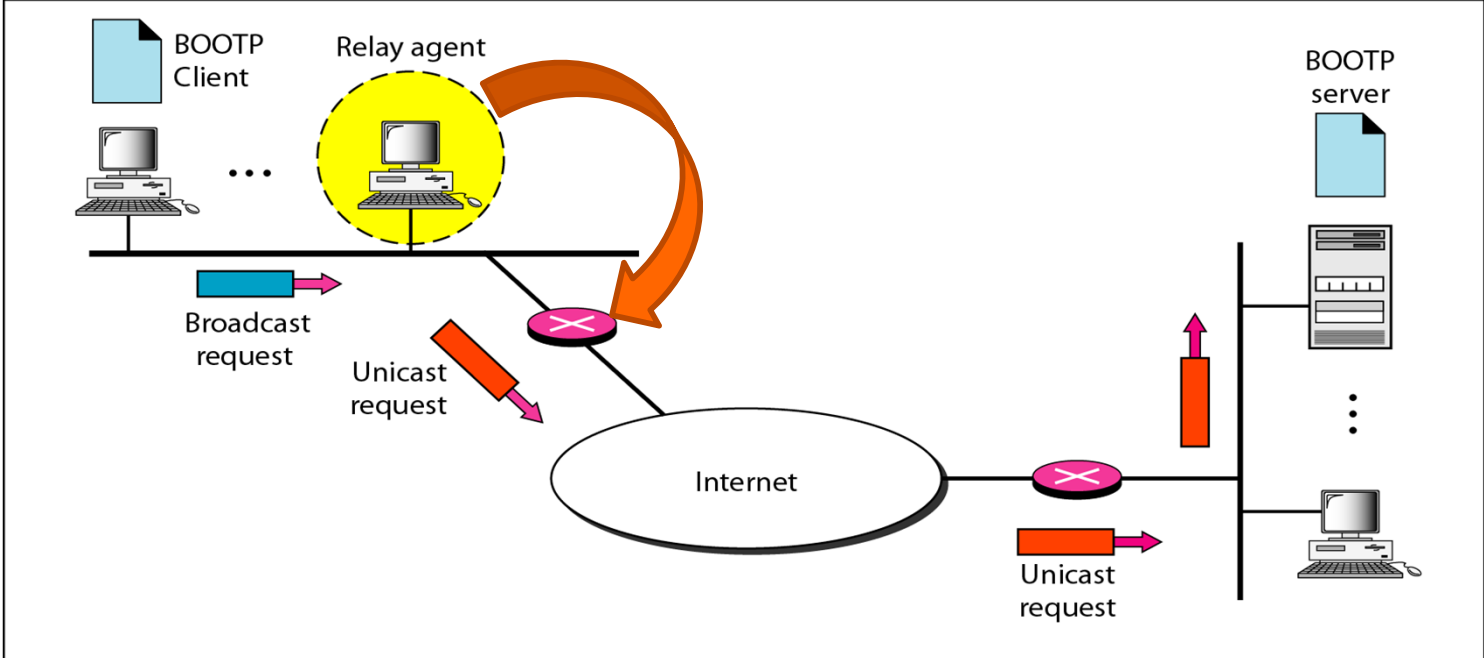- Defragmentation always performed by final reciever.

What to configure

- IP address
- Net mask (specifies network id)
- Default Gateway (at least one)
- DNS server (at least one)
  - ◆ Server's ip address

- Other stuff
  - ◆ TFTP server
  - ◆ Configuration file
  - ◆ Executable image download

Obtaining an IP address (bootp)

- Bootstrap
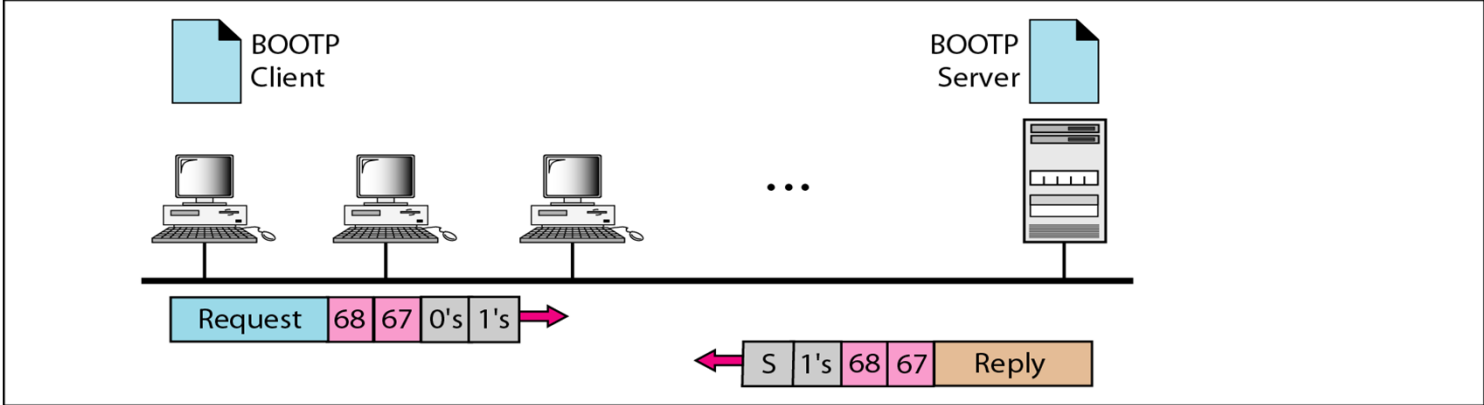
a. Client and server on the same network

b. Client and server on different networks
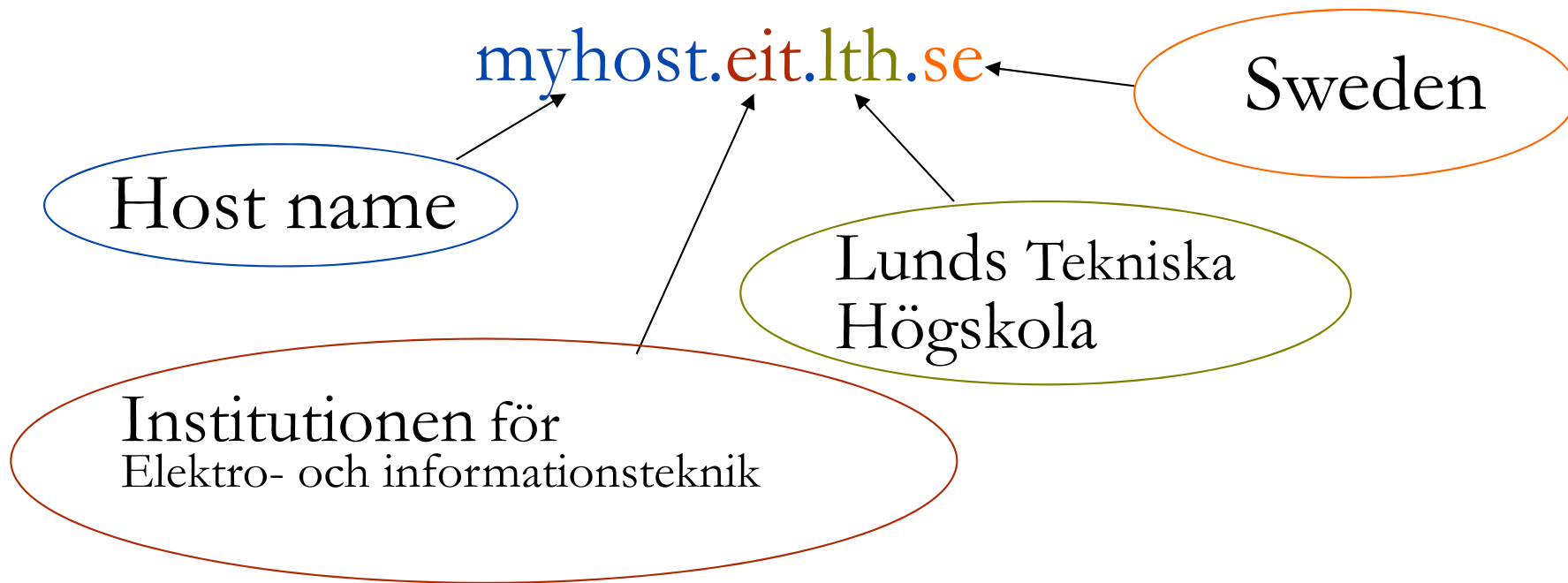
Dynamic Host Configuration Protocol (DHCP)

- BOOTP
  - ◆ Not dynamic!

- DHCP
  - ◆ IP address
    - • Allocation from pool or static
  - ◆ Network mask
  - ◆ Default gateway
  - ◆ DNS server(s)

Domain Name System (DNS)

- Hierarchical name system consisting of a number of levels.

- Internet is divided into a number of domains, and each domain has its own name.

- On top goegraphical or generic root domains.

- Each domain contains subdomains.

- Relies on Domain Name Servers and resolvers (clients)

DNS exemple

myhost.eit.lth.se

Host name

Sweden

Lunds Tekniska Högskola

Institutionen för
Elektro- och informationsteknik

From name to IP address (1)

magi.magicnet.se

berga.trollnet.se
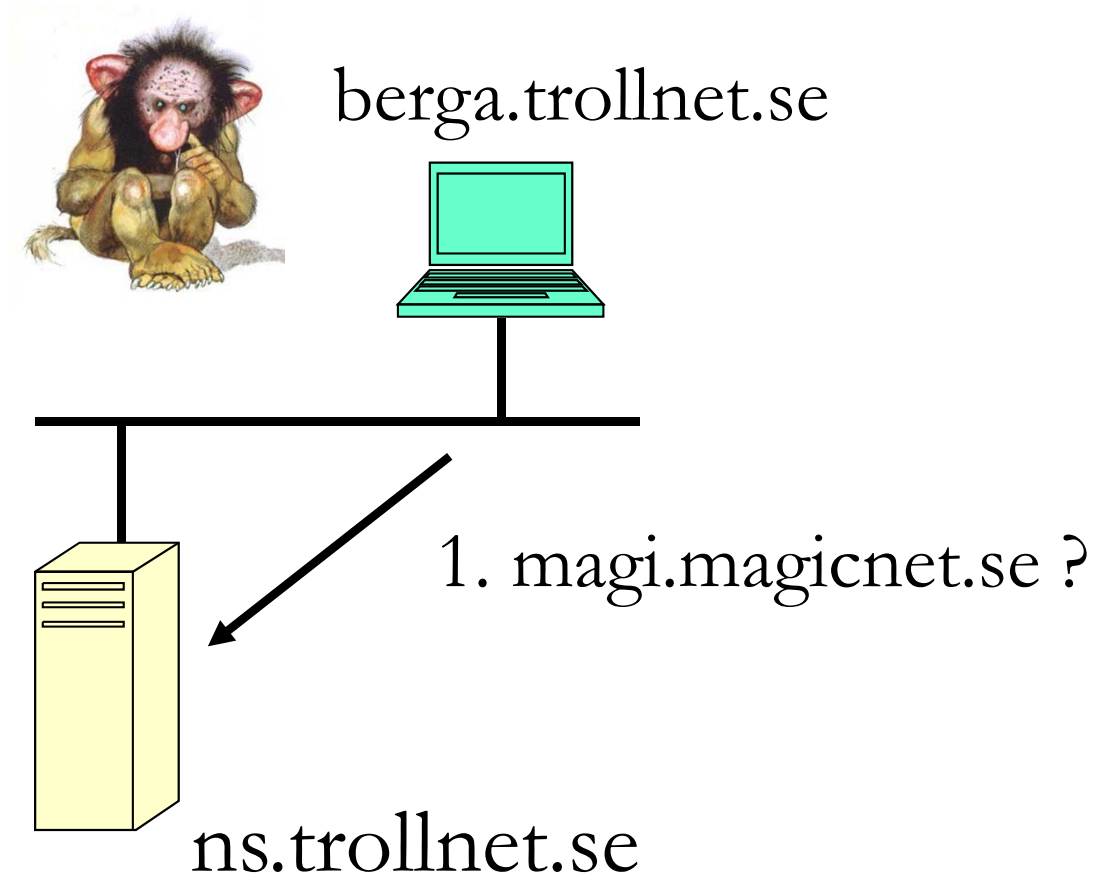
1. magi.magicnet.se ?

ns.trollnet.se

From name to IP address (2)

magi.magicnet.se

berga.trollnet.se

2. magicnet.se ?

3. Ask ns.magicnet.se

ns.trollnet.se

x.ns.se

x=[a..j]

From name to IP address (3)

magi.magicnet.se

berga.trollnet.se

6. IP =
194.52.54.47

4. magi.magicnet.se ?

5. IP = 194.52.54.47

ns.magicnet.se

ns.trollnet.se
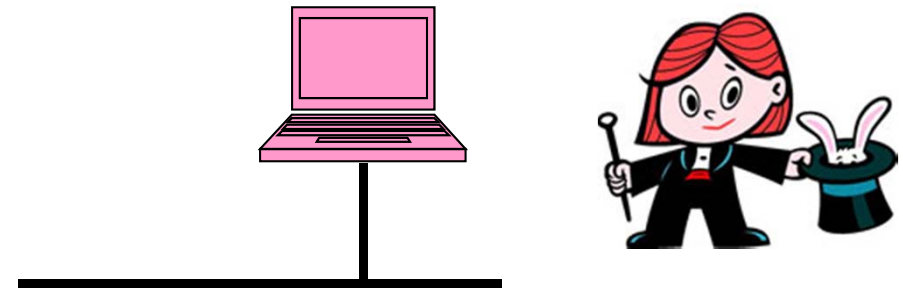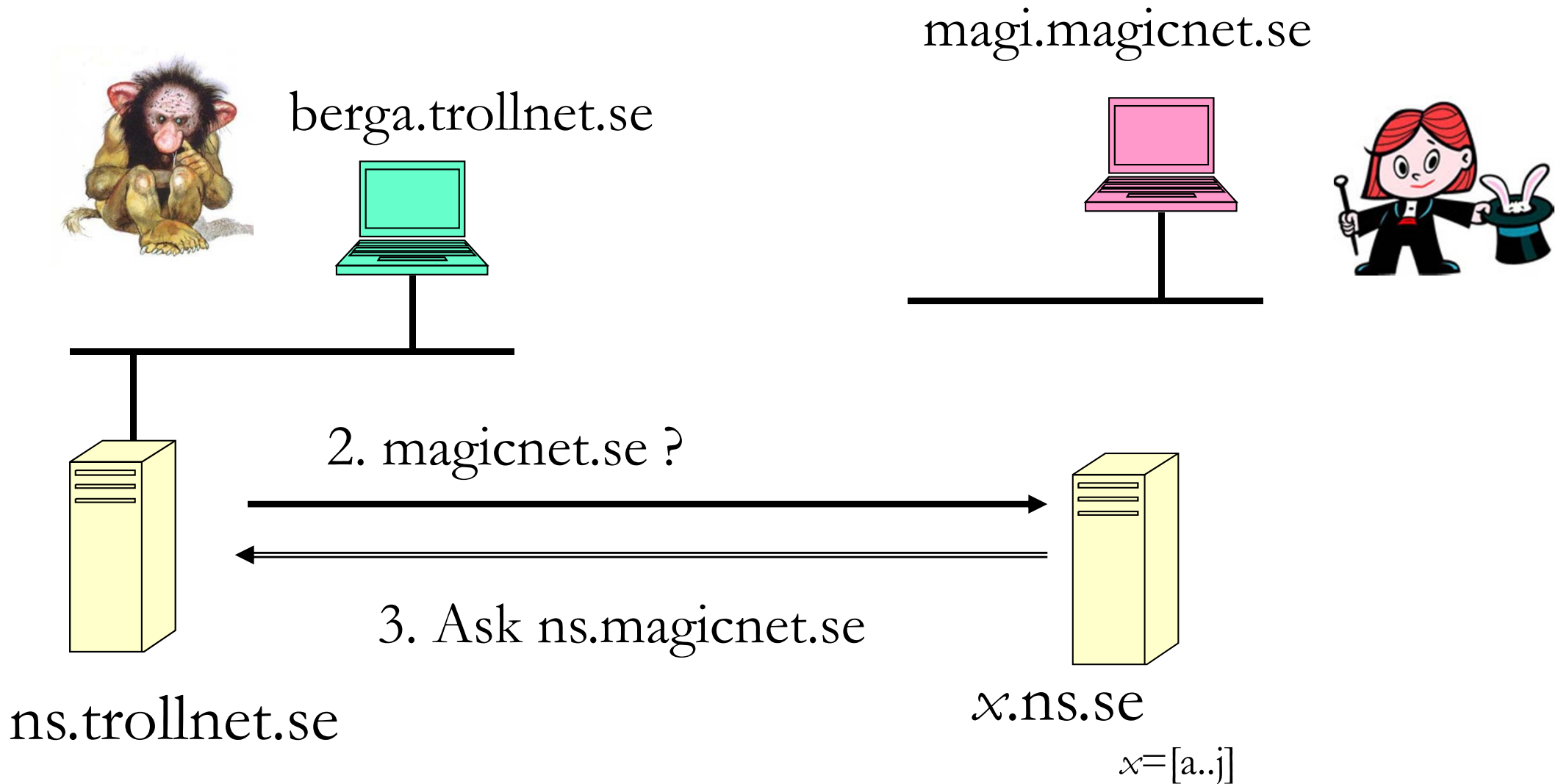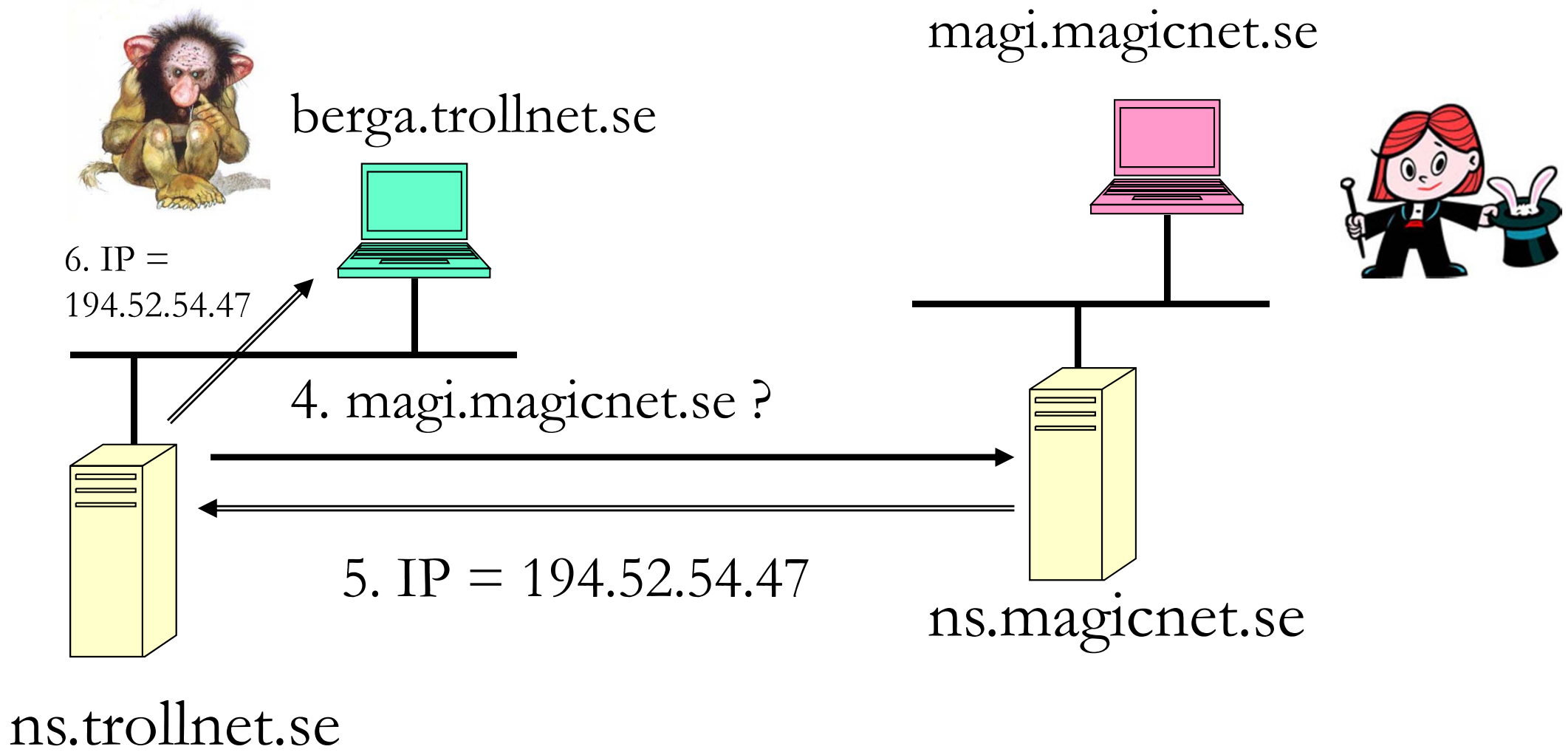
Internet?

- Consists of linked independent networks all running TCP/IP.

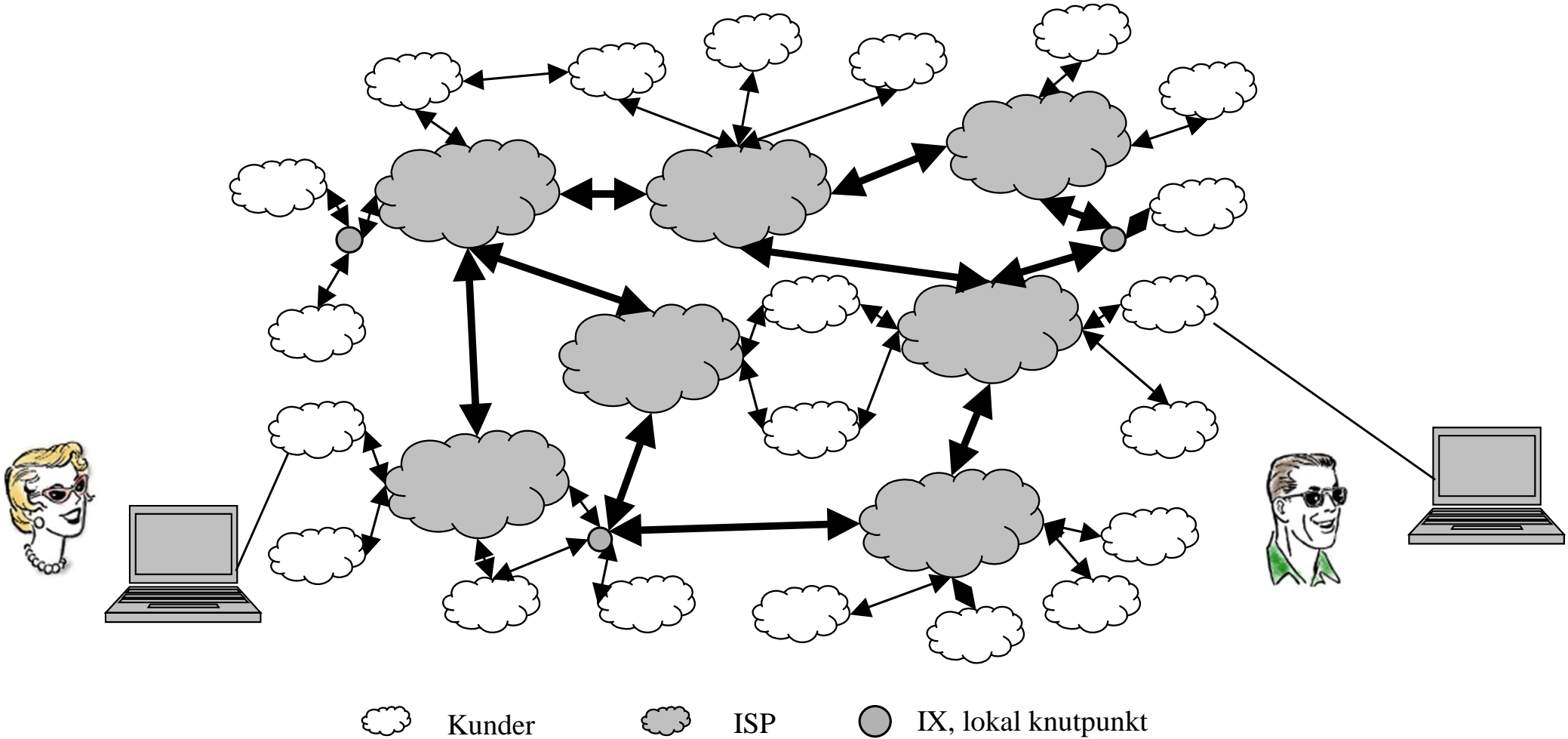- ”Controlled” by Internet Society (ISOC).
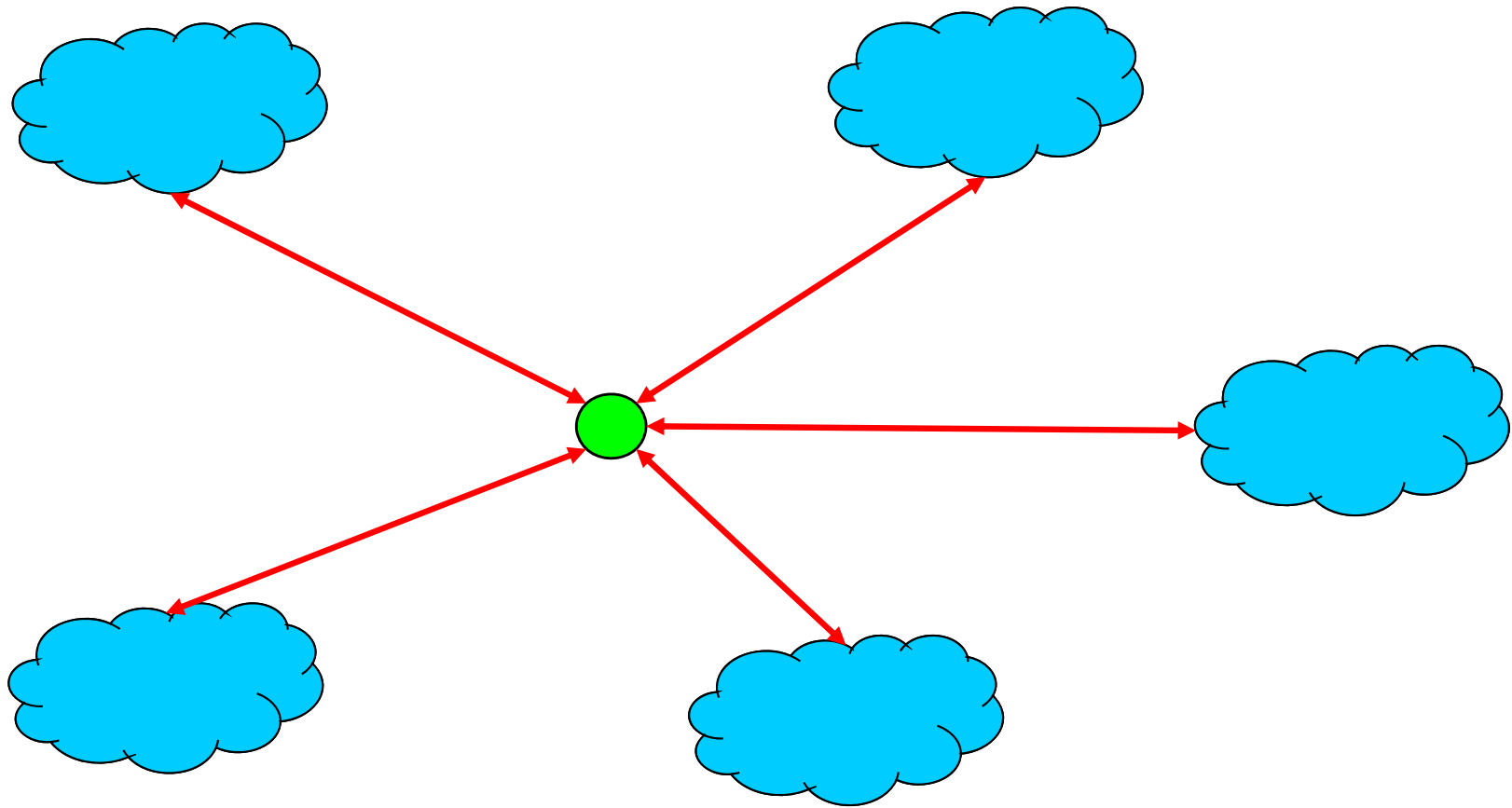
Internet's structure

Kunder   ISP   IX, lokal knutpunkt

Traffic exchange, pair
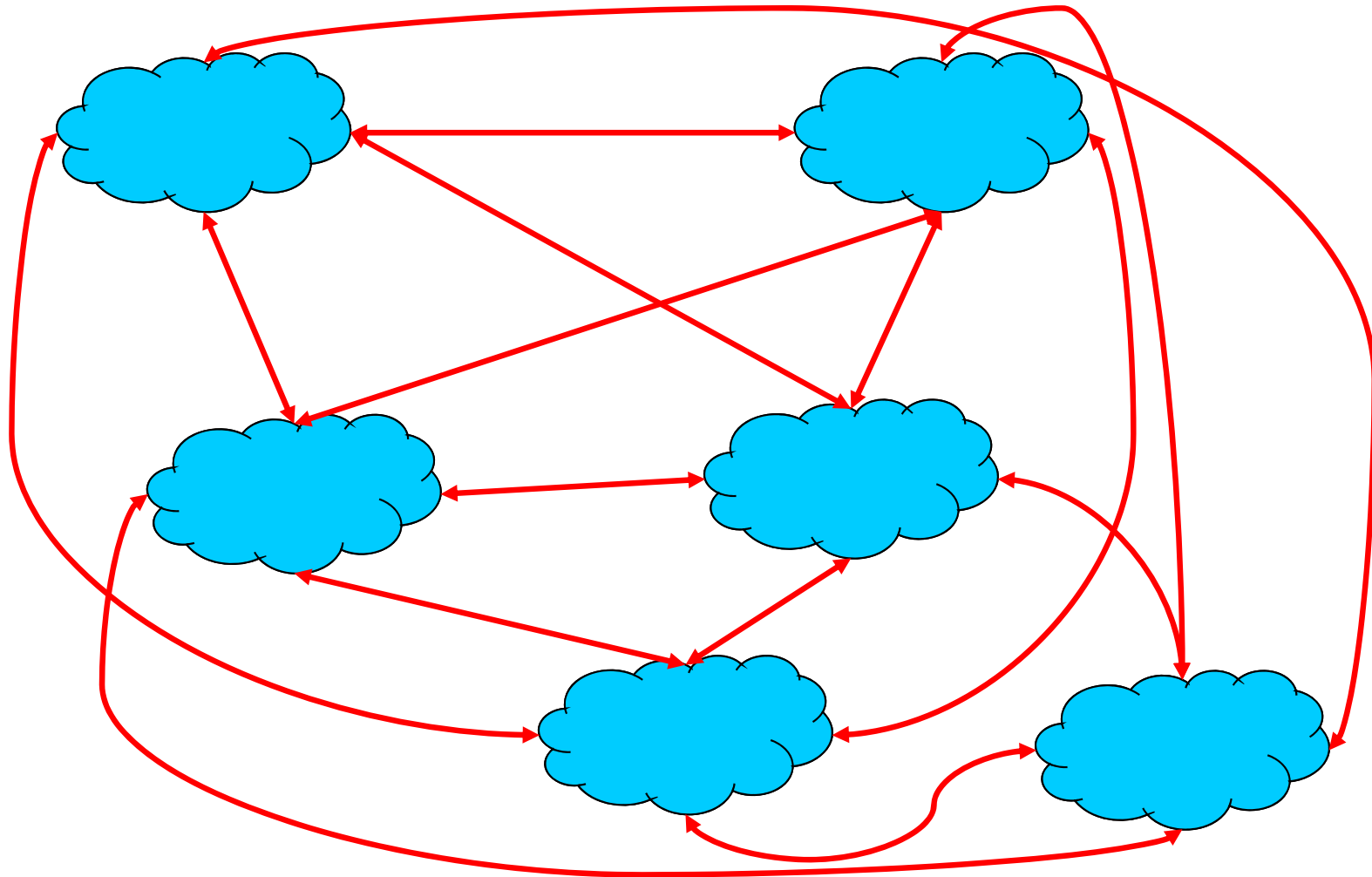
Traffic exchange, internet exchange

The home net

ISP

FW + NAT
(server, WLAN)
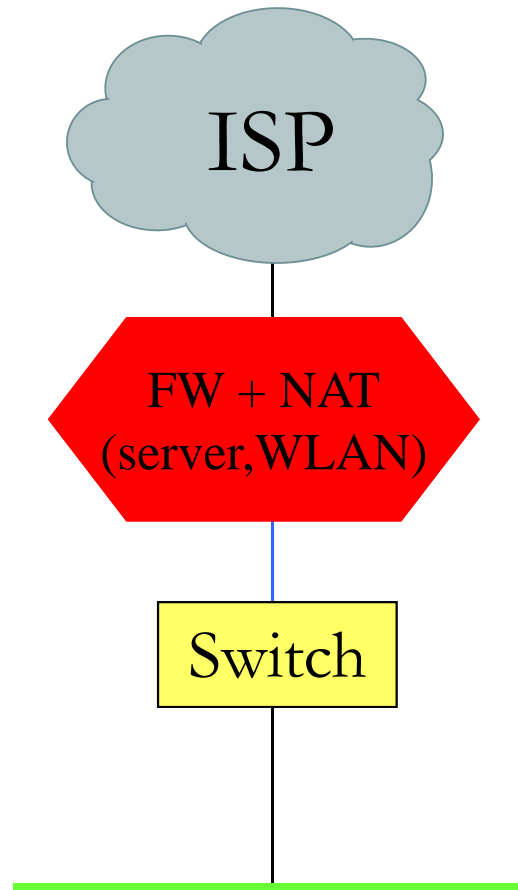
Switch

- CPE
- Firewall
- Router

Minor enterprice

ISP

"Router on a stick"

FW + NAT

Hosting (DMZ)

Servers

Switch with VLAN

Clients

WLAN

58
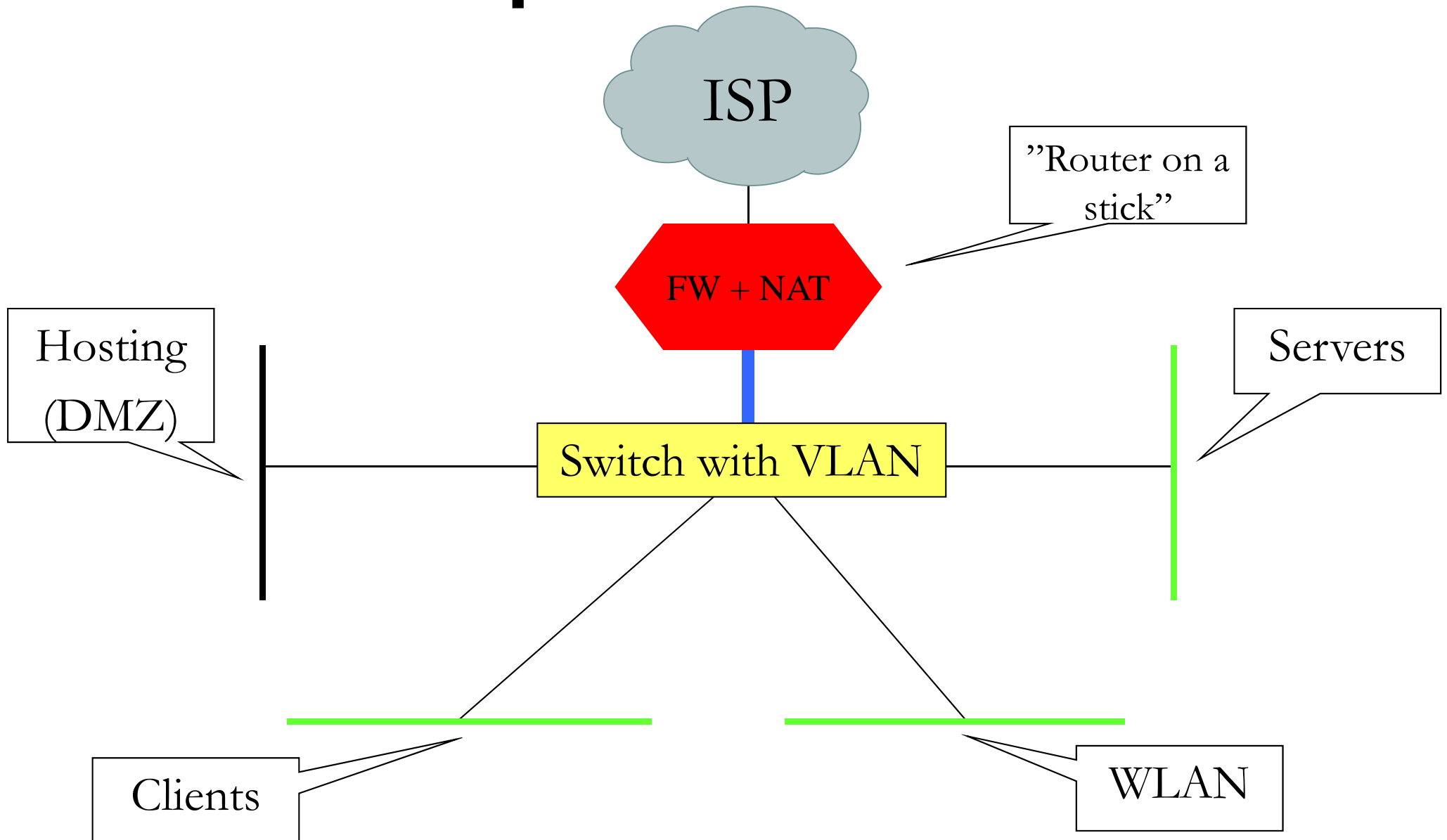
GigaLUNET design Campus Lund

Local IX

Core

Remote campuses connects directly to core with routed connections.

Distribution

Datacenterswitches

Decentralized distributionswitches

Access

Black Diamond 10K

Black Diamond 10K

Black Diamond 10K

Summit 400

Summit 450

L3 10 Gbps

L2/L3 10 Gbps

L2 10 Gbps

L2 1 Gbps

10 Gbps stacking or L2 10 Gbps

L2 1Gbps or 10 Gbps where needed

Purple marking located at site A

Skyblue marking located at site B

Buliding

Local acessnetwork

All L2-loops are protected by EAPS

59

OptoSUNET

OptoSUNET

NORDUnet

NORDUnet NOX
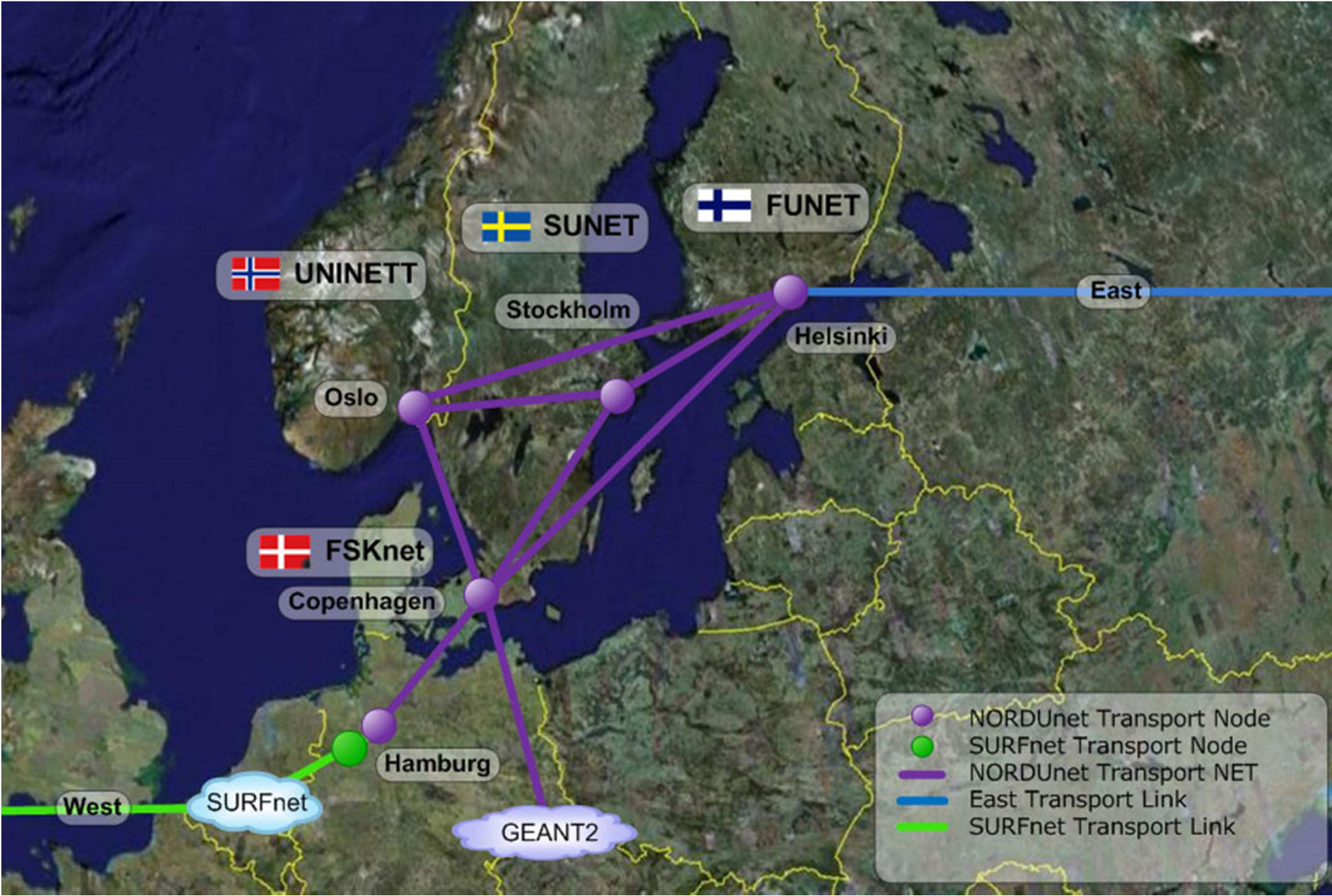
GLIF
(Global Lambda Integrated Facility)

Historia: Internet

1961-69 Forskning packet switching

1969 ARPANET sätts i drift

1971 Email uppfinns

1974 Cerf & Kahn publicera spec för TCP/IP

1978 TCP/IP delas upp i TCP och IP. UDP tillkommer.

1983 **Hela ARPANET byter till IP/TCP/UDP 1/1 09.00.**

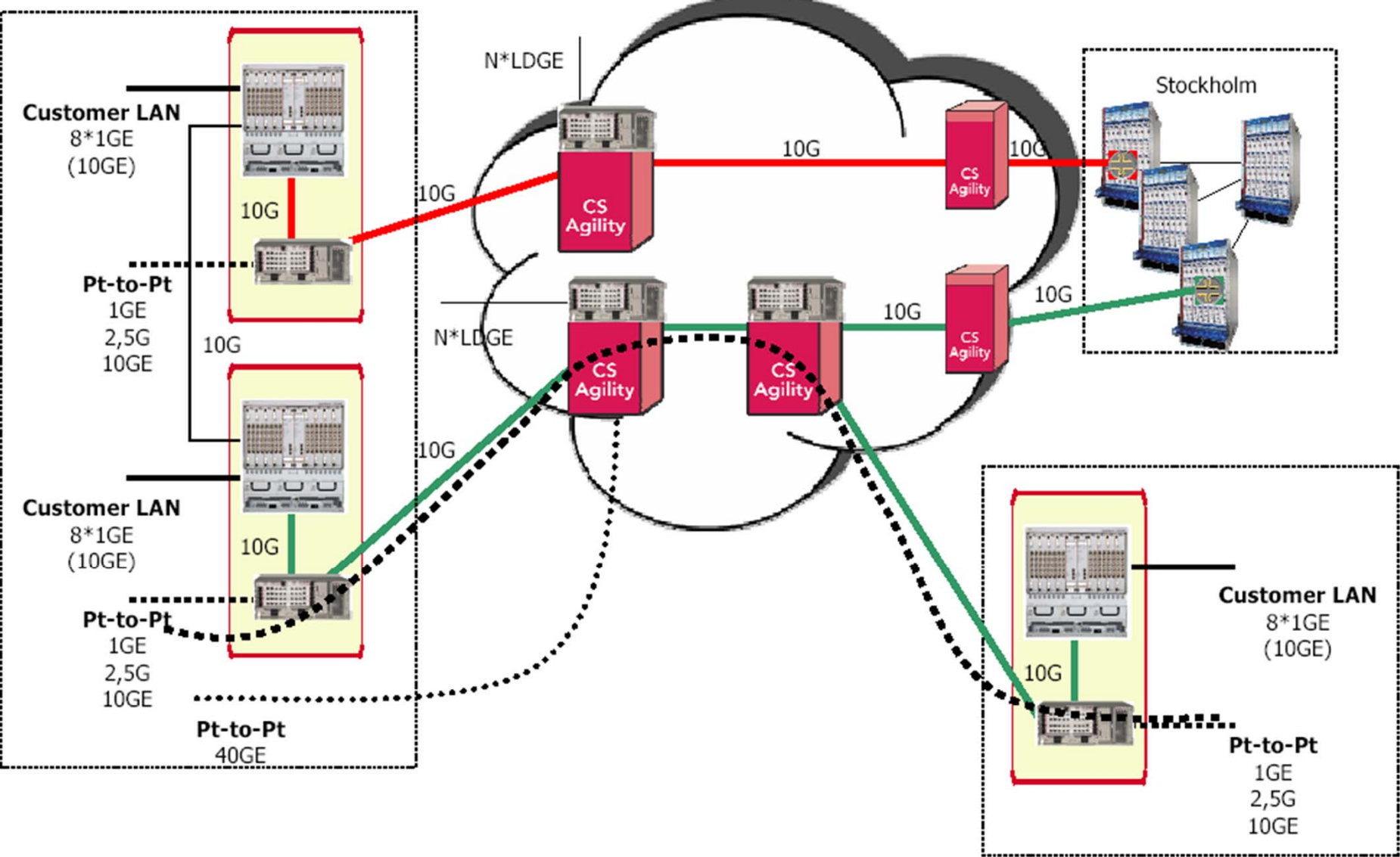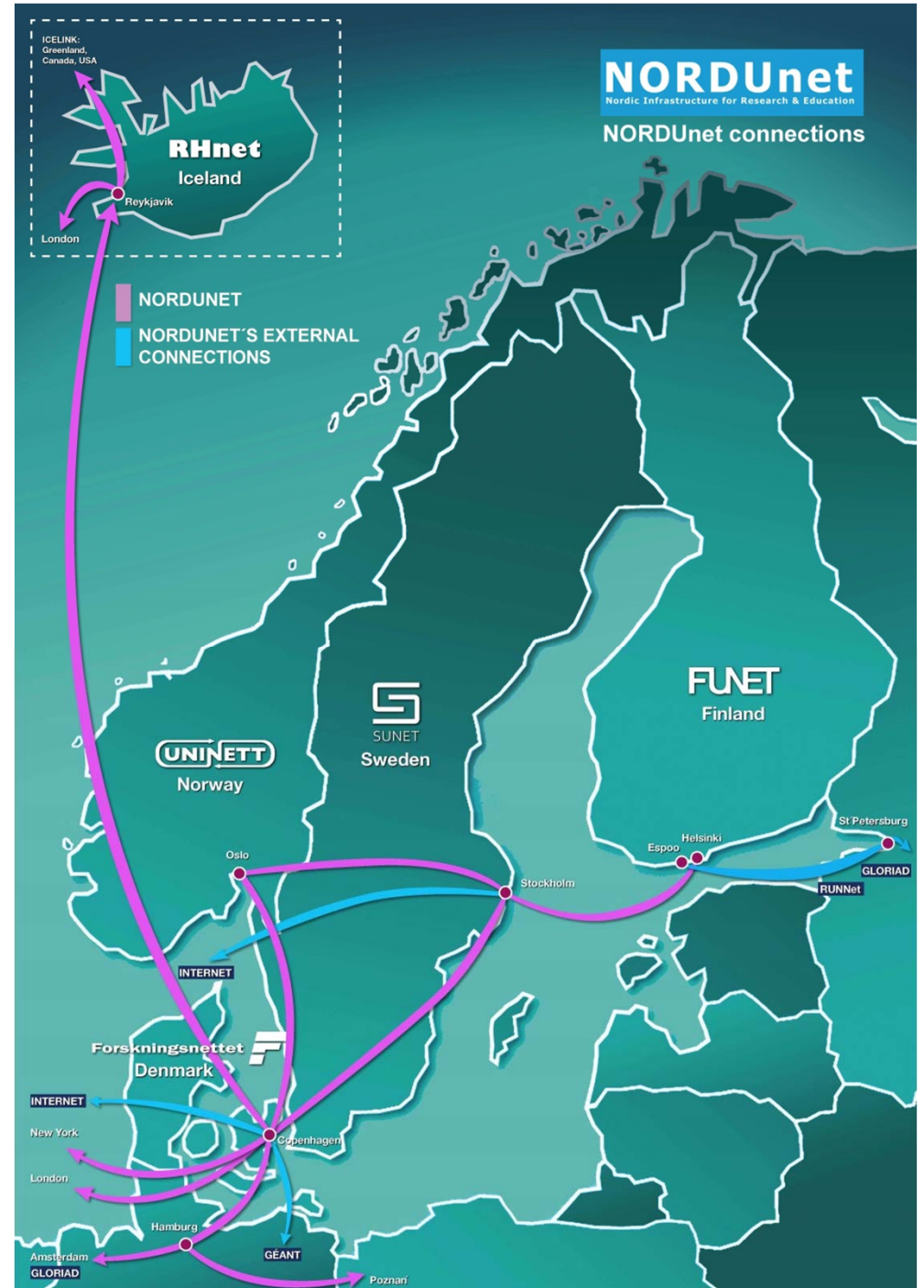**1984** ARPANET delas. MILNET tillkommer. Sammankopplas med router. DNS tas i drift.

1986 **NFSNET blir ryggradsnät i USA.**

1987 Första INTEROP.

1990 ARPANET upphör.

1991 Berners-Lee skapar WWW.

1993 **Webläsaren Mosaic erövrar världen**

1995 NFSNET återgår till rent forskningsnät. Tillräckligt med kommersiella ryggradsnät.

1996 Internet2 grundas.

Historia: LUNET och SUNET

1956 SMIL tas i drift

1970 SMIL ersätts med Univac

1981-82 Sverigetäckande nät för terminaler byggs, kallas SUNET.

1982 Terminalväxelnät börjar byggas i Lund, LUNET.

1982-83 Lokala termvxnät ansluts till SUNET. Nu nät för termvxnät.

1984 LDC och Ehuset bygger varsitt Ethernet.

1985 Optofiber förbinder de två ethernet:en. lth.se och lu.se registreras.

1986 SUNET byggs om till DECnet.

1988 Ryggradsnät (ethernet + optofiber) börjar byggas i Lund. **SUNET kör IP. Lund ansluts till Internet.**

1991-92 SUNET uppgraderas.

1992-94 Lunds termvxnät läggs ner.

1994 SUNET uppgraderas.

1997 Uppgradering av LUNET påbörjas.

1998 SUNET-155 tas i drift.

2002 Giga-SUNET tas i drift

2006 GigaLUNET och OptoSUNET tas i drift

ARPAnet was developed in 1968

- Robert Taylor at ARPA (later DARPA) had three terminals for connecting with different sites:

- "For each of these three terminals, I had three different sets of user commands. So if I was talking online with someone at S.D.C. and I wanted to talk to someone I knew at Berkeley or M.I.T. about this, I had to get up from the S.D.C. terminal, go over and log into the other terminal and get in touch with them. I said, oh, man, it's obvious what to do: If you have these three terminals, there ought to be one terminal that goes anywhere you want to go where you have interactive computing. That idea is the ARPAnet."
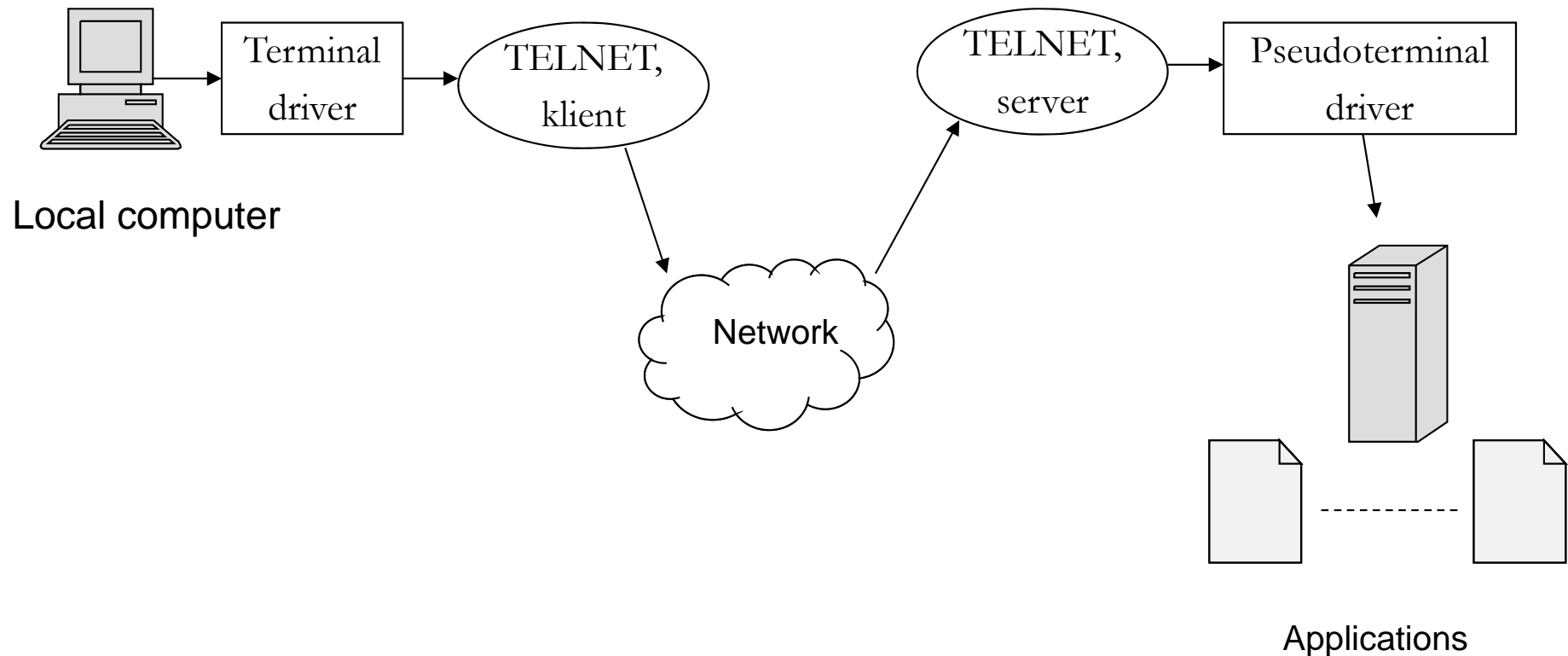
ARPAnet

- Four Interactive Message Processors (IMP) at four universities connected with leased lines of 50 kbps.

- The IMPs could store and forward messages.

- The picture shows Leonard Kleinrock with the first IMP at UCLA.

ARPAnet evolution

December 1969

June 1970

March 1972

July 1977

Telnet

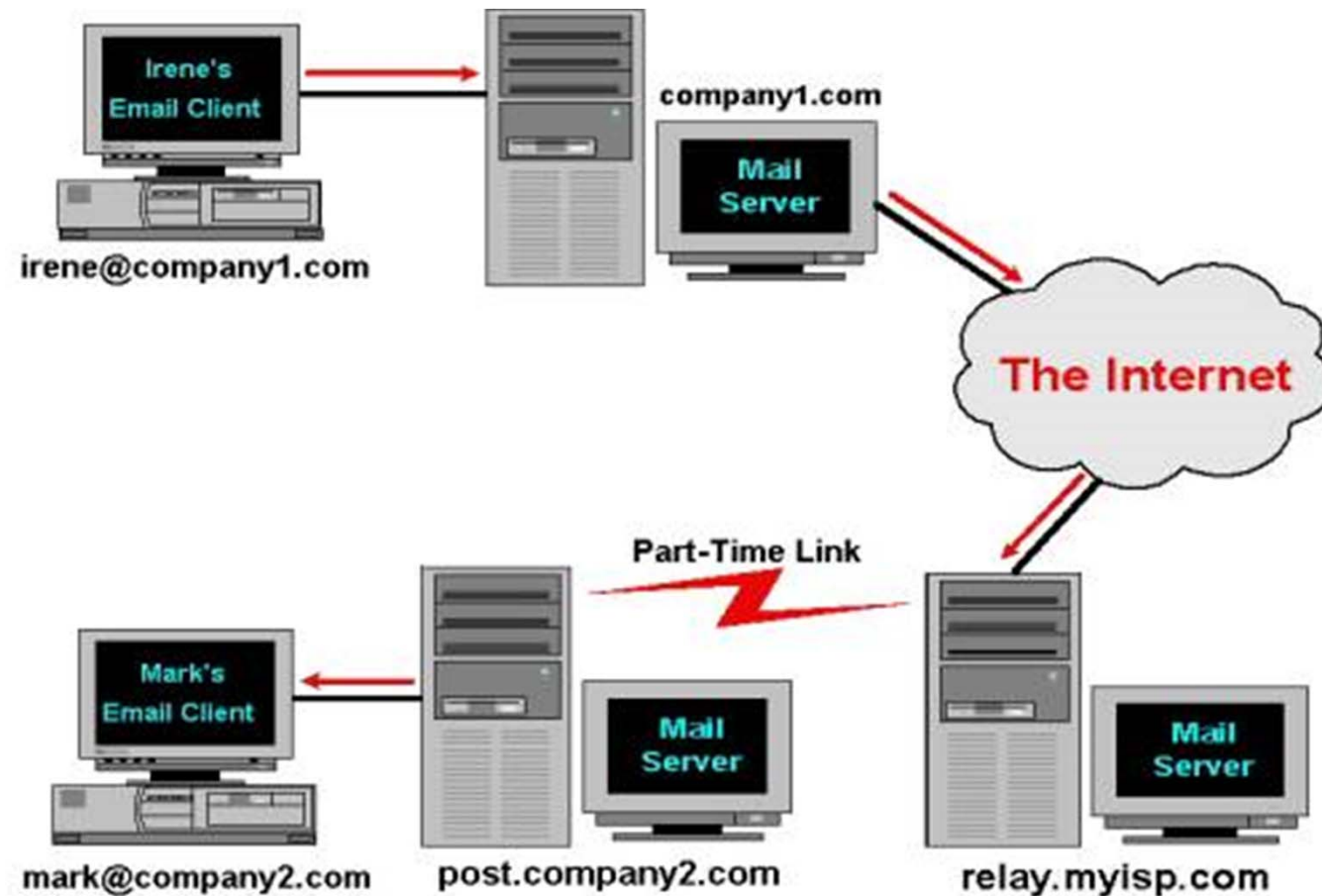- Telnet was invented in 1969, and provided access to a remote terminal.

Email

- Ray Tomlinson sent the first email in 1971 between two computers in the same room.
- To separate a specific user on a host computer, he used the "@" sign, which was unused on the keyboard.
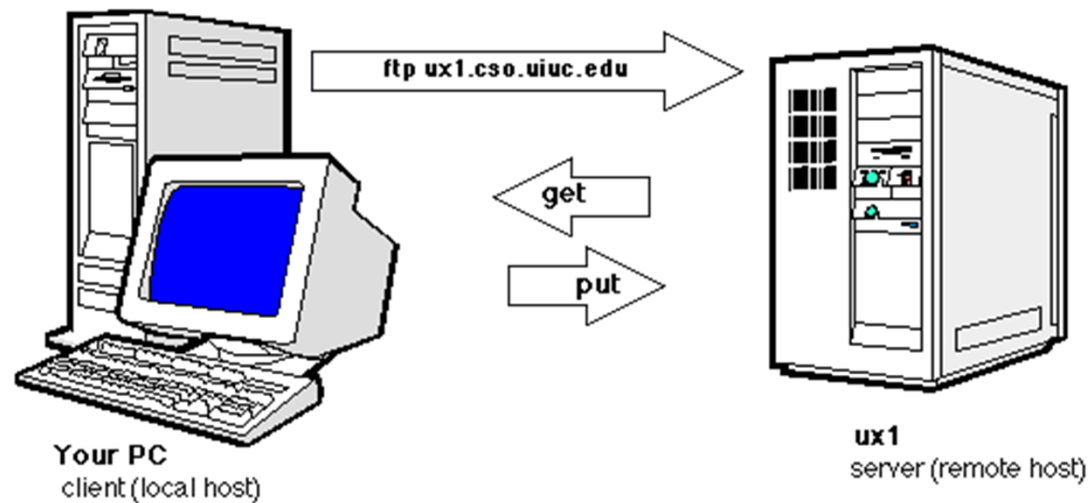
Email

- Today, email basically works the same way:

File Transfer Protocol (FTP)

- Another original application was FTP, which was developed in 1971, and that enabled file transfer between two host computers.

Source: http://opcenter.cites.uiuc.edu

Internet protocol

- In 1973, Robert E. Kahn and Vincent Cerf at DARPA developed the ideas of an internetwork protocol that made it possible for hosts on different networks to communicate with each other.

- The ideas were defined as the Transmission Control Protocol (TCP) protocol in 1974, where the term "Internet" was introduced.

- Later, some parts of the TCP protocol were moved to the Internet protocol (IP), creating the TCP/IP protocol suite.

Basic idea of Kahn and Cerf's internetworking

- Host identification (Addresses)

- Forwarding of messages between networks (routing)

- End-to-end reliability (error and flow control)

Network
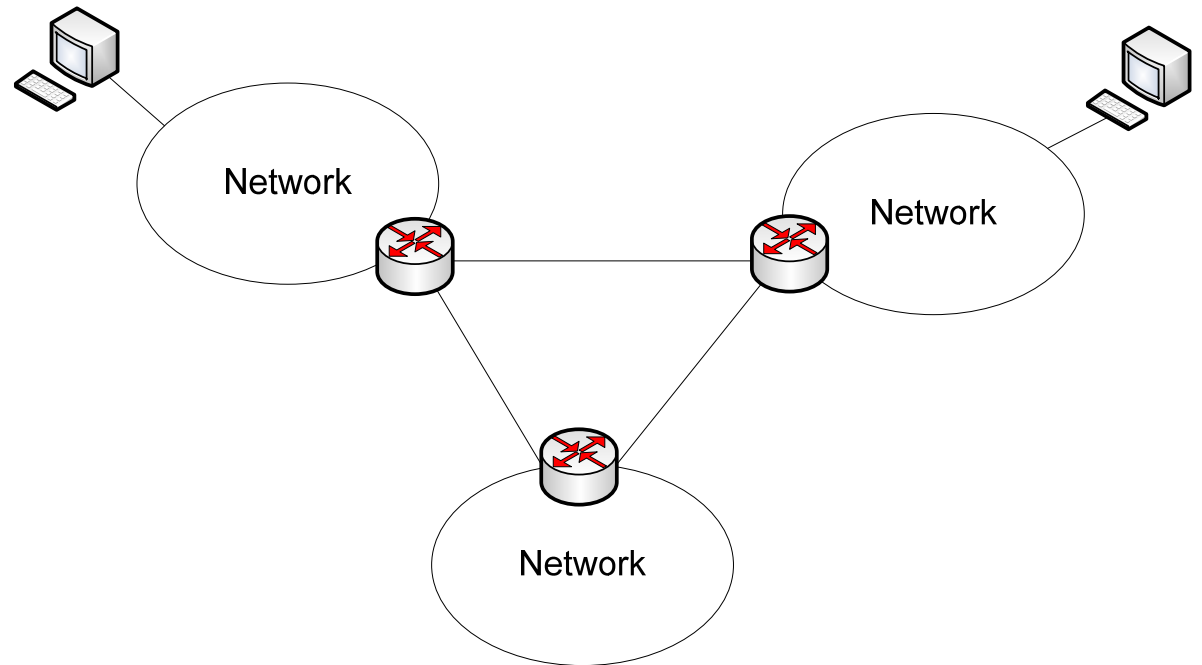
Network

Network

Internet was born

- The Internet protocol suite was formalized in 1982.
- Jan 1 1983, all networks connected to the Internet had to use the TCP/IP protocol suite.

Internet hosts 1981-2012

https://www.isc.org/solutions/survey/history
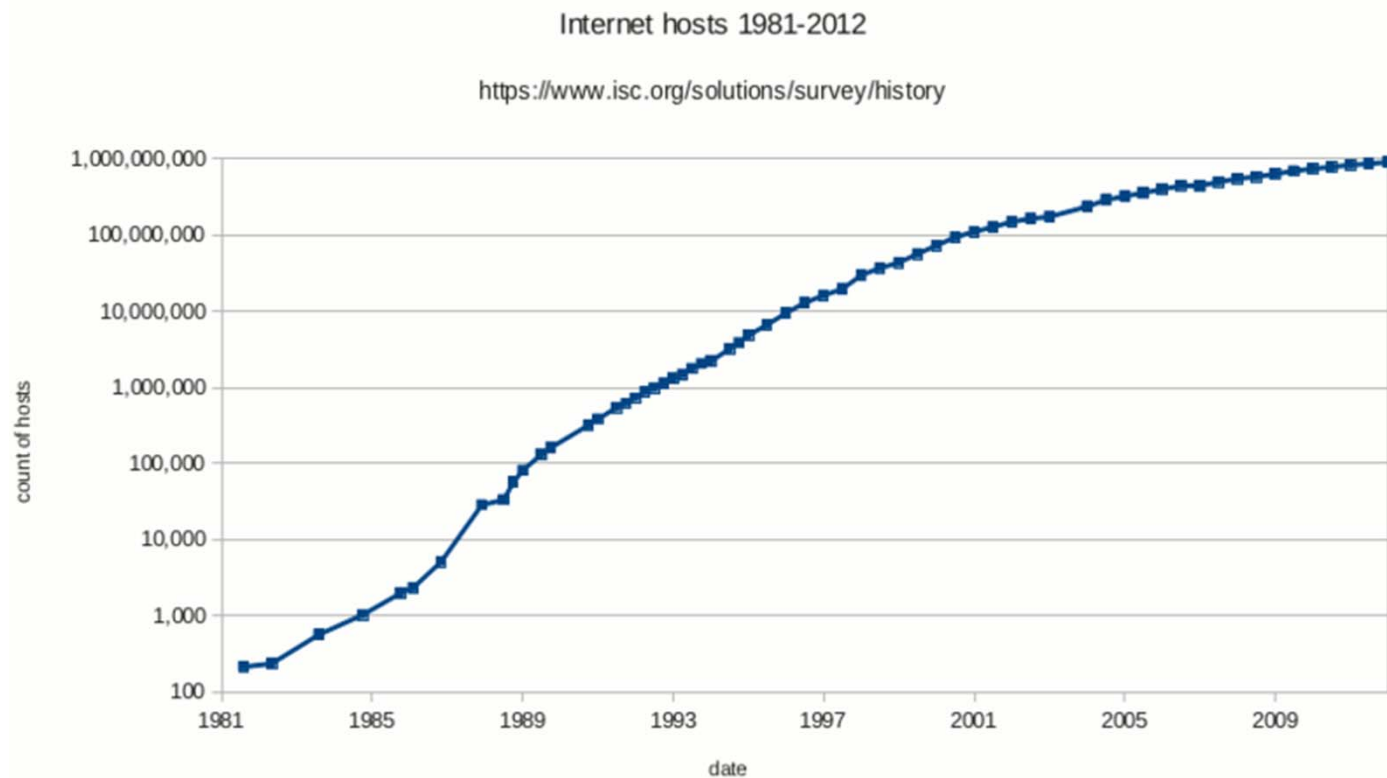
1991: World Wide Web (WWW)

- 1984-1990: Tim Berners-Lee and his group at CERN worked on the ideas of information presentation and sharing.

- 1990: HyperText Transfer Protocol (HTTP), HyperText Markup Language (HTML), a web browser, and server software were presented at CERN.

- 1991: WWW goes public

- 1993: Mosaic, the first public web browse

First web site: http://info.cern.ch

■The first web site is still working.

■WWW is based on a simple client/server protocol HTTP, where clients send requests for pages to the server.

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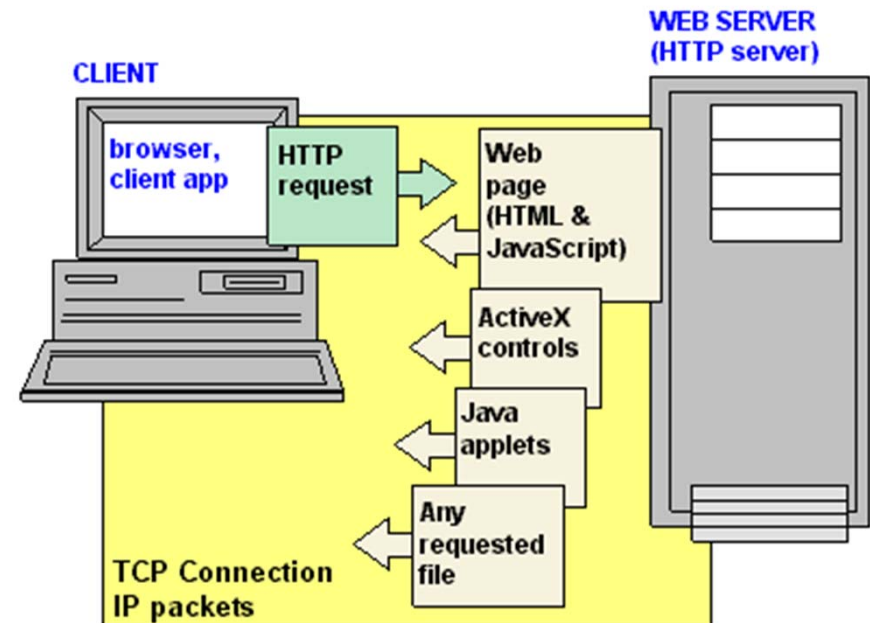
1991: The Trojan Coffee room pot

- The people working at the Computer Laboratory at the University of Cambridge implemented the first real-time Internet video application for their coffee pot.

- The application server sent real-time images of the coffee pot to the clients.

Source: http://www.cl.cam.ac.uk/coffee/coffee.html

The rest is almost not history

- 1994: Pizza Hut started first online webshop
- 1997: AOL instant messenger
- 1997: Sixdegrees.com (first modern social network)
- 1997: Google.com
- 1999: Napster
- 2001: BitTorrent
- 2003: Skype
- 2005: YouTube
- 2005: Facebook.com
- 2008: Spotify