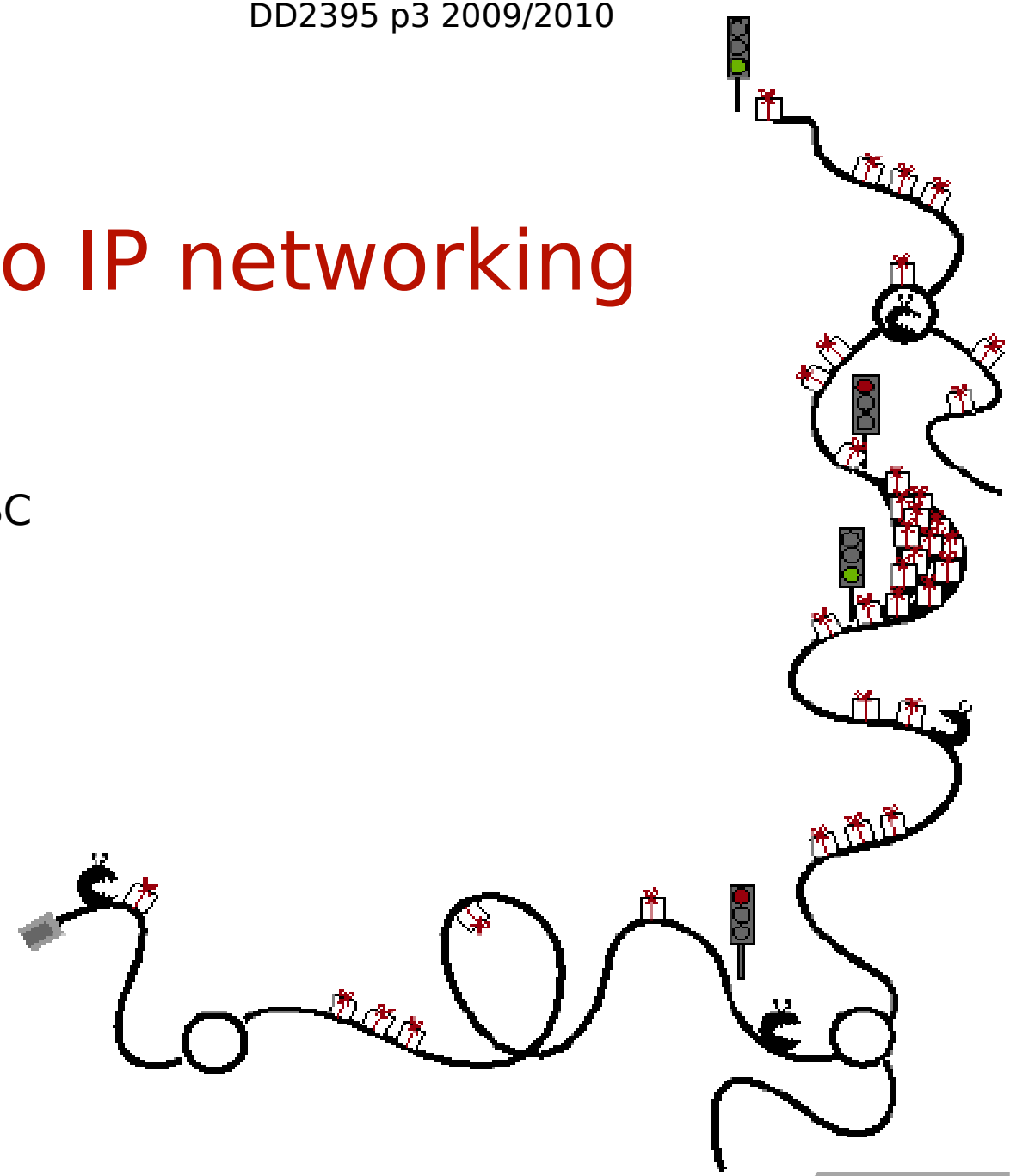
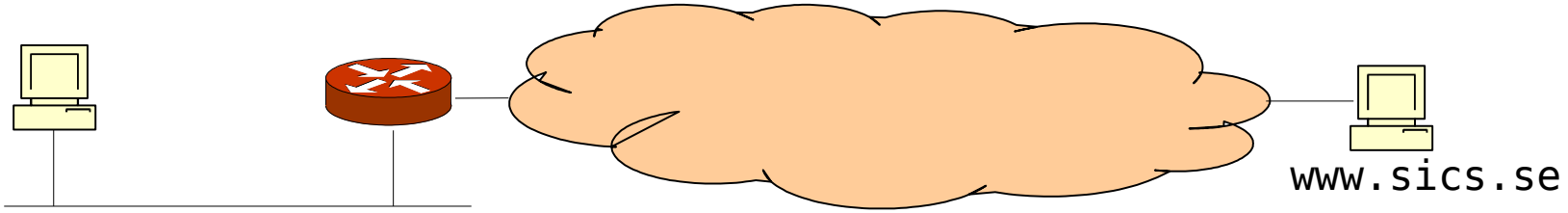
# Introduction to IP networking


Olof Hagsand KTH /CSC



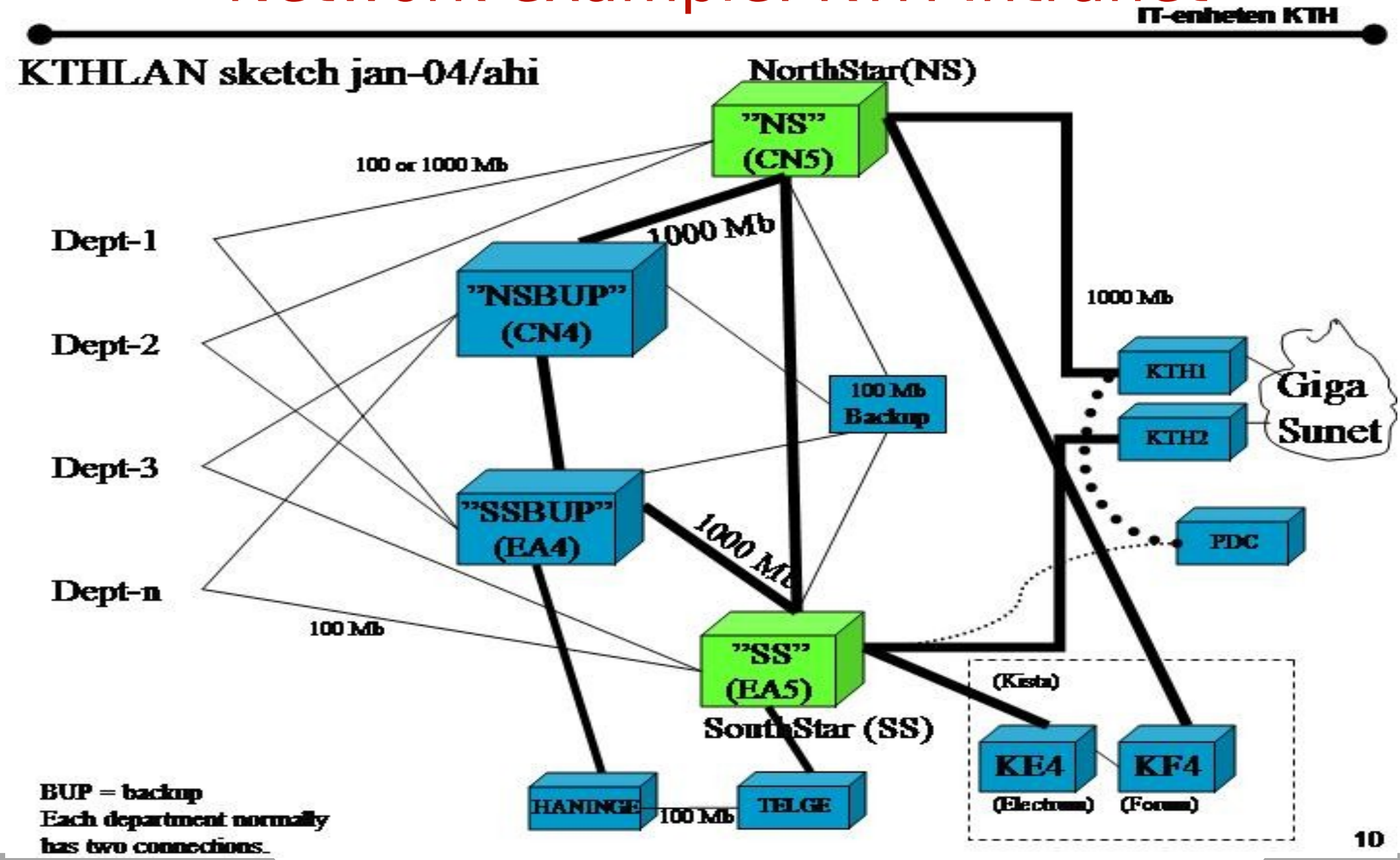
# Example: packet transfer



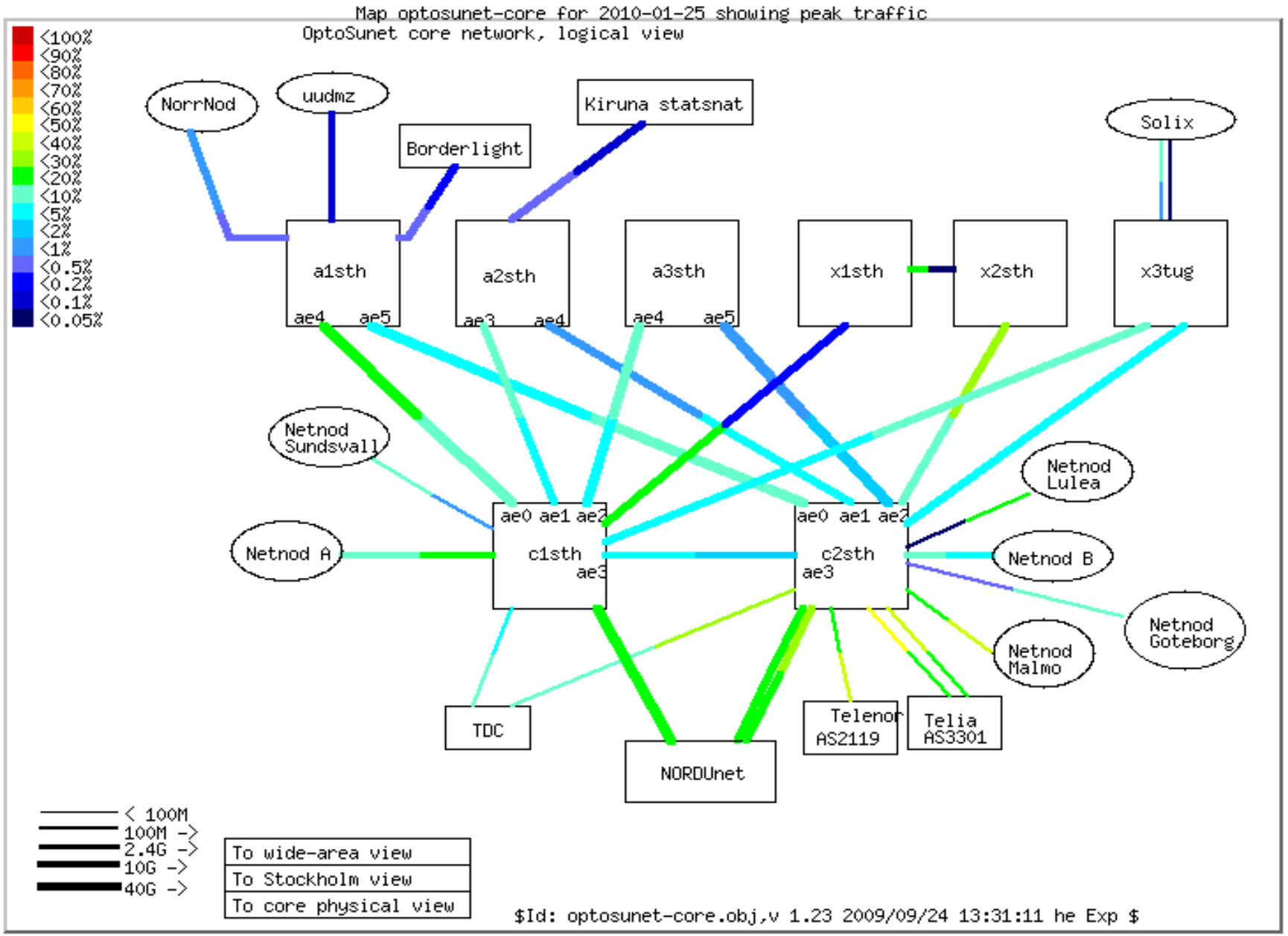


- An end host communicates requests a web-page from a server via a local-area network
- The aim of this lecture is to give an overview of how this works in practice
- So that you can configure packet filters in the ip-tables lab
- Some protocols involved:
  - Ethernet, ARP, IP, TCP, DNS, HTTP

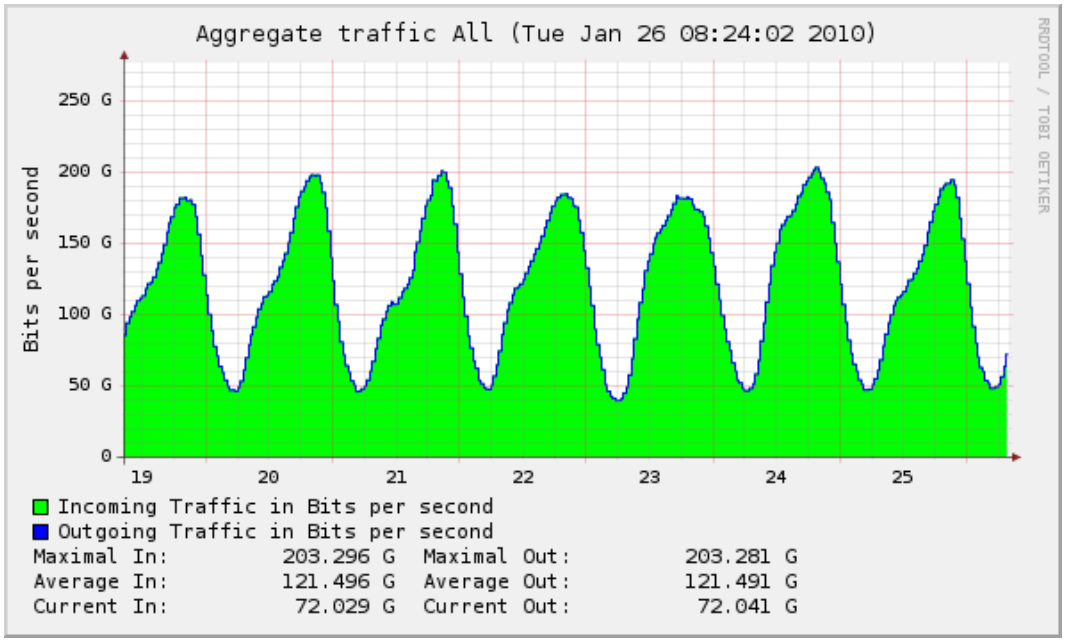
# Network example: KTH Intranet

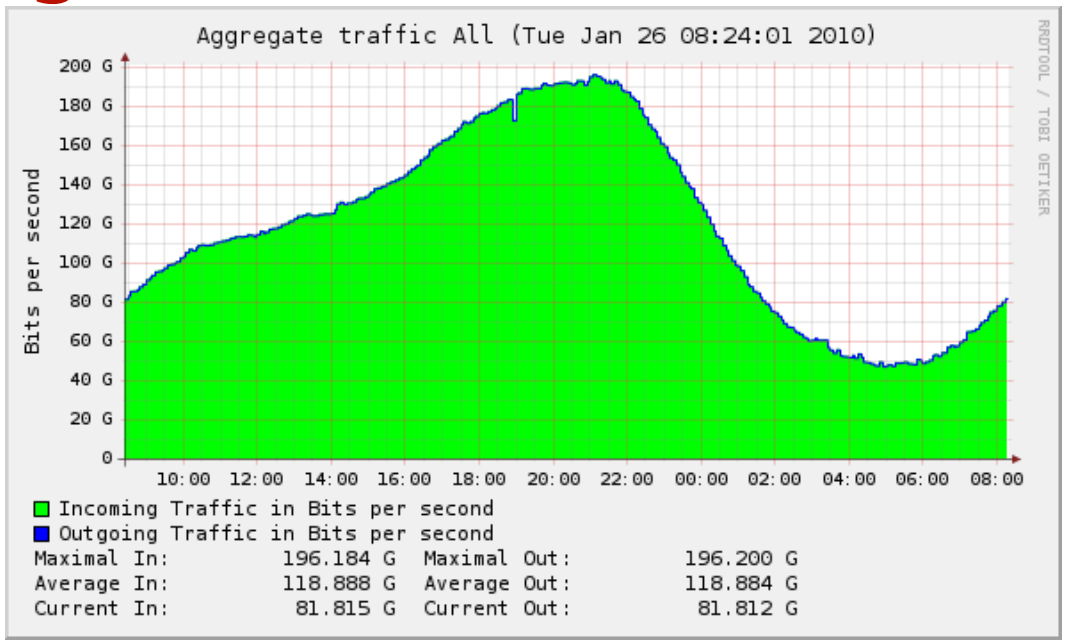


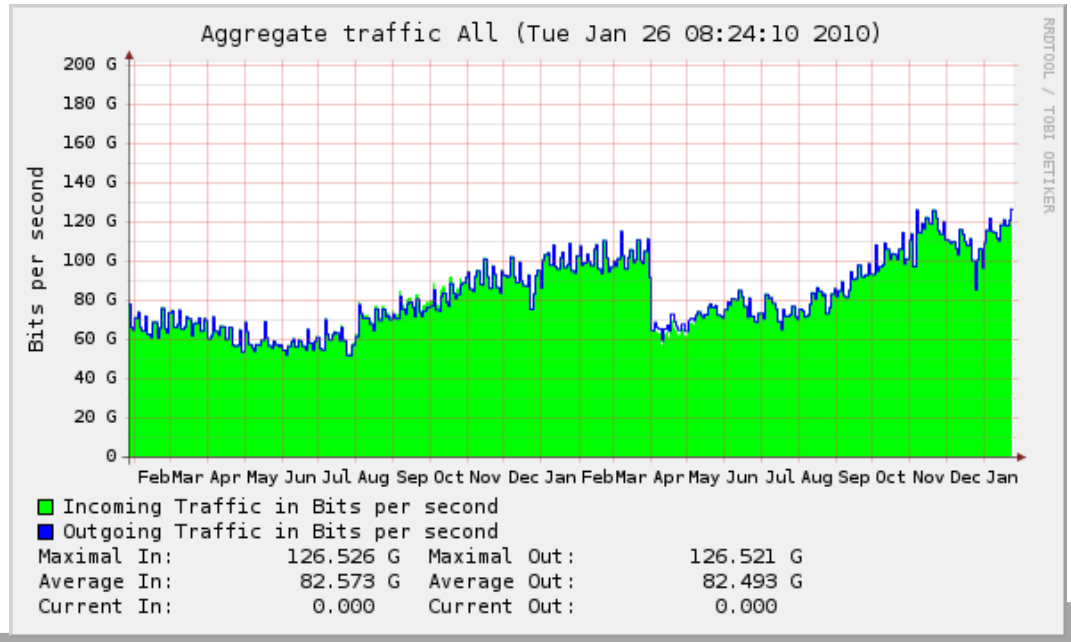
# Network example: OptoSunet core



# Netnod aggregated traffic



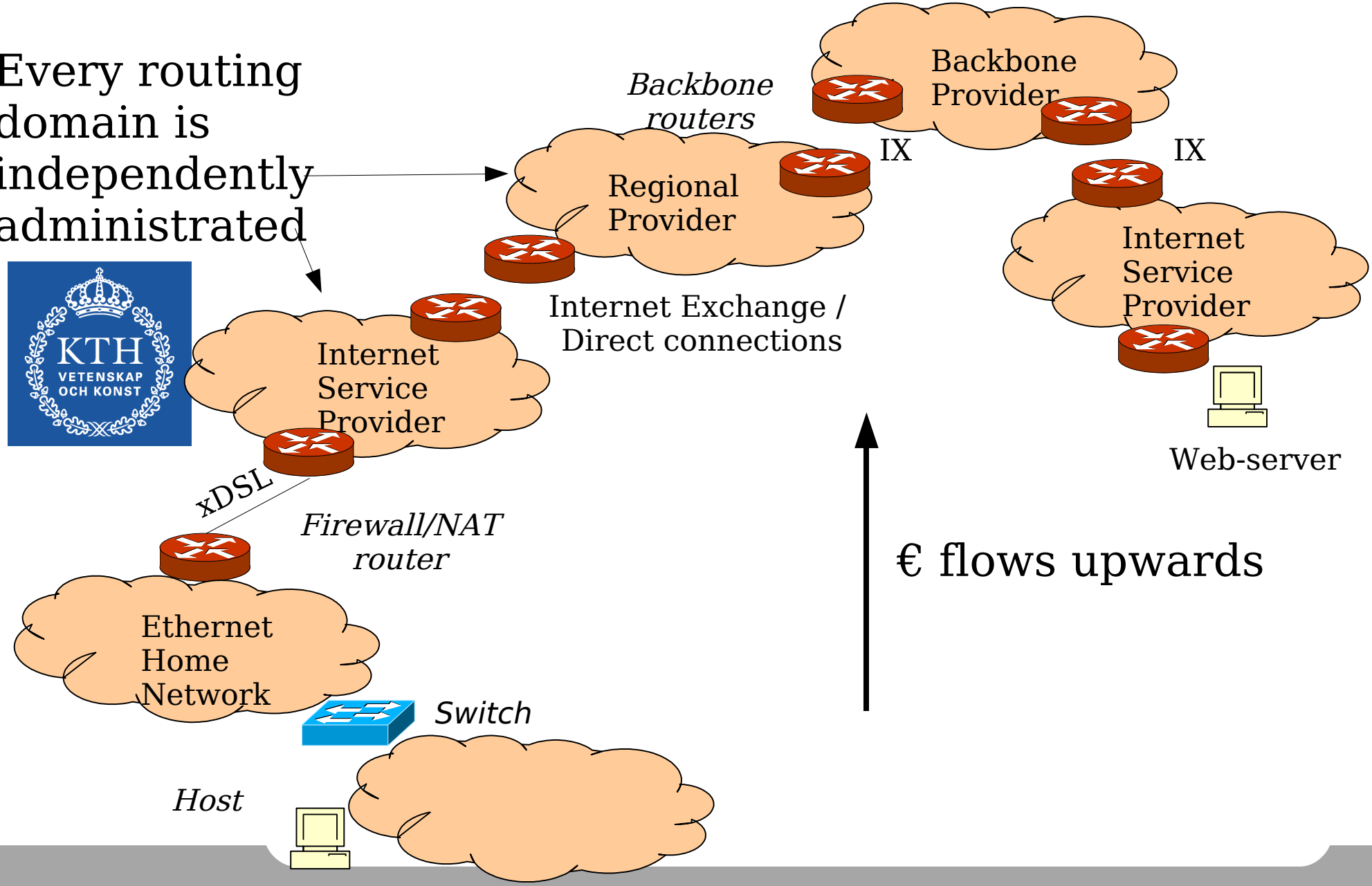




www.netnod.se

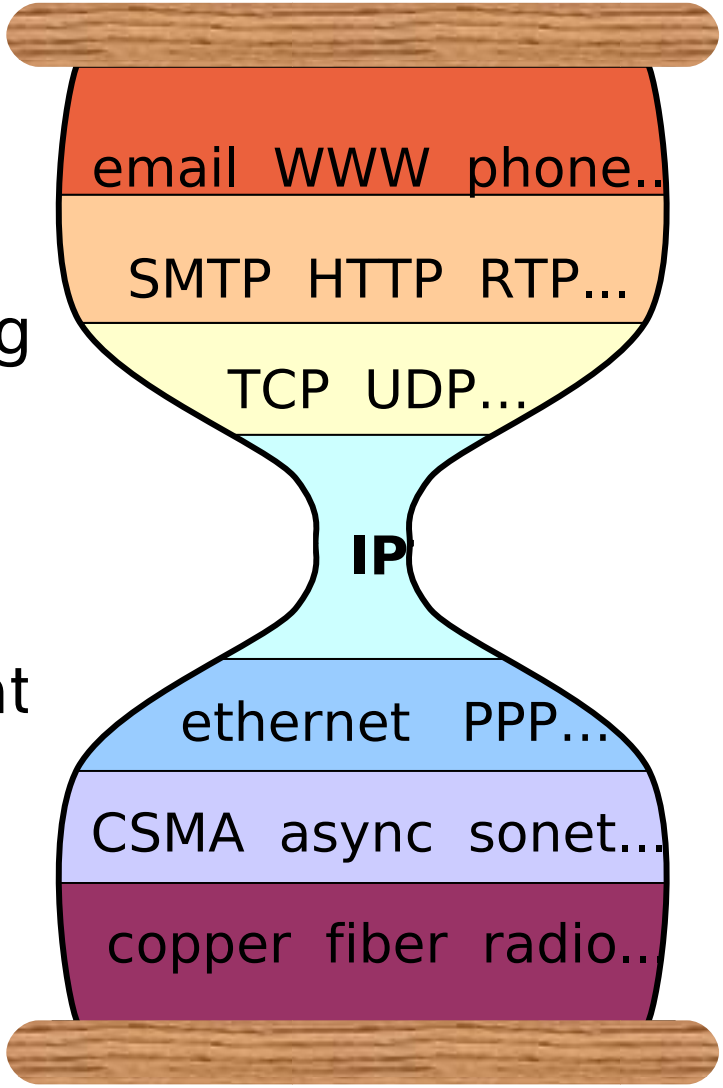
# Internet architecture: Example

Every routing domain is independently administrated



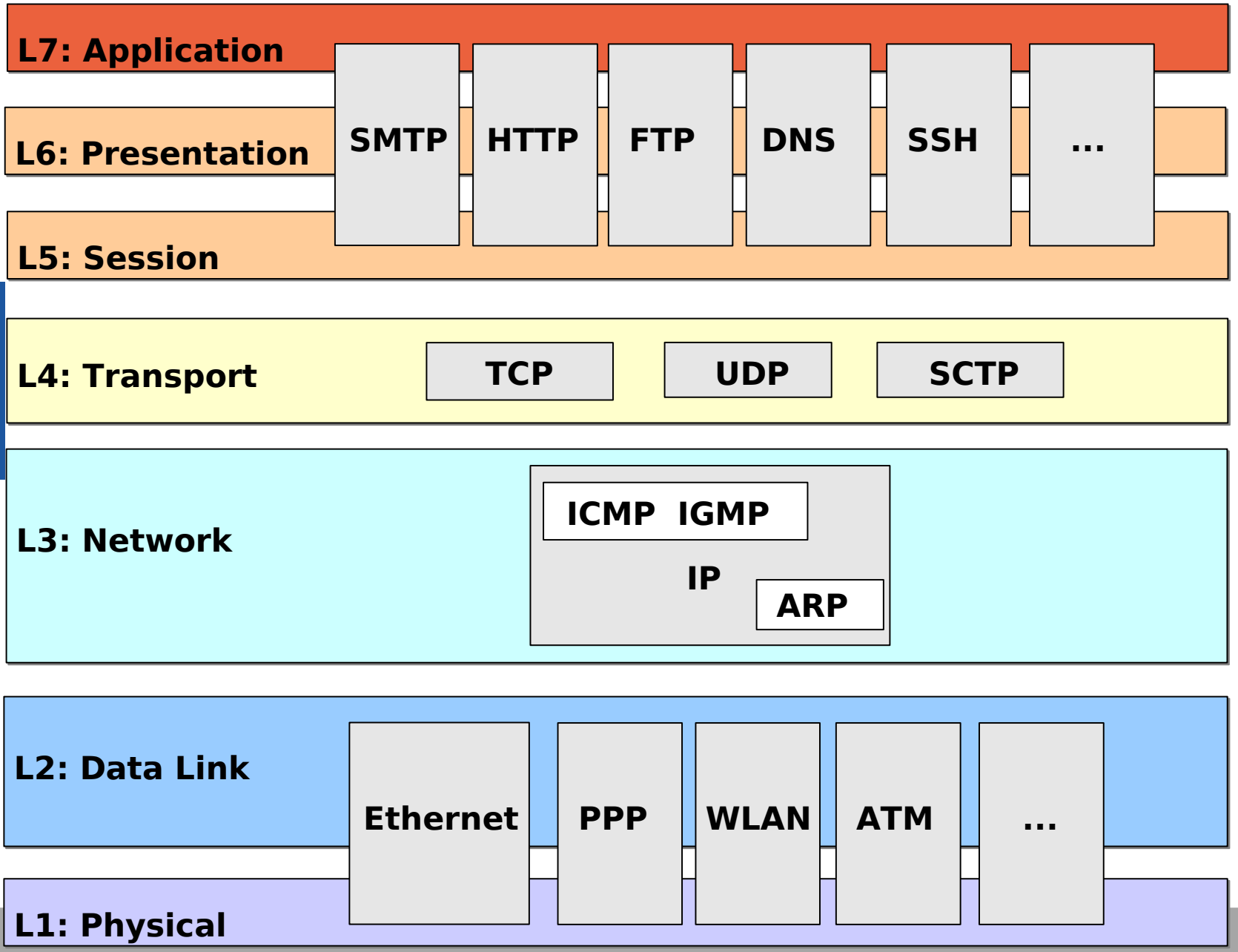
# The Hourglass Model

- Anything over IP – IP over anything
- All applications depend on IP
- IP runs over all networks
- IP is at the heart of all communicat




From Steve Deering, 2000

# The TCP/IP stack and OSI ref model

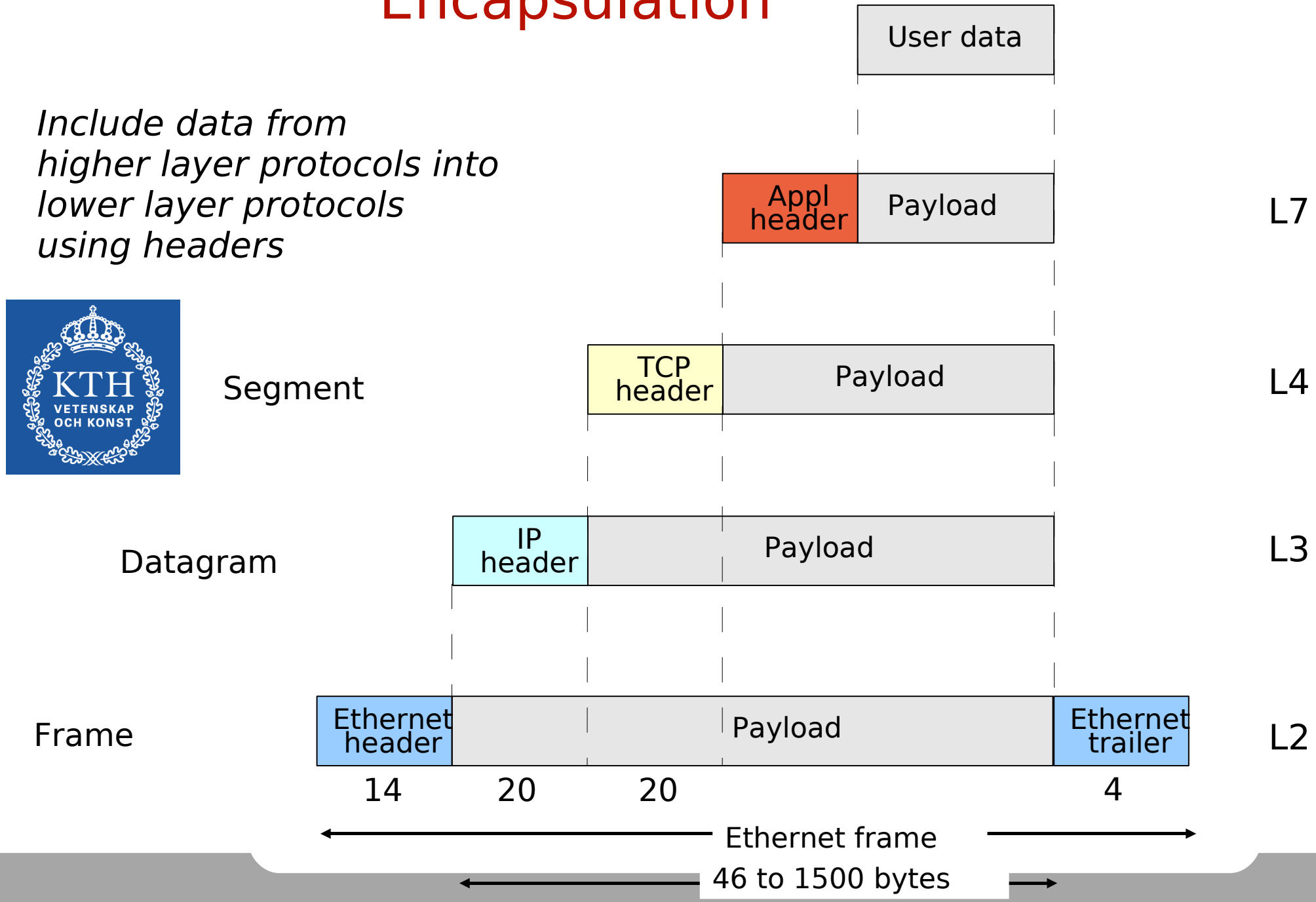



Router

Switch

# Encapsulation

*Include data from higher layer protocols into lower layer protocols using headers*



# Link-level example: Ethernet

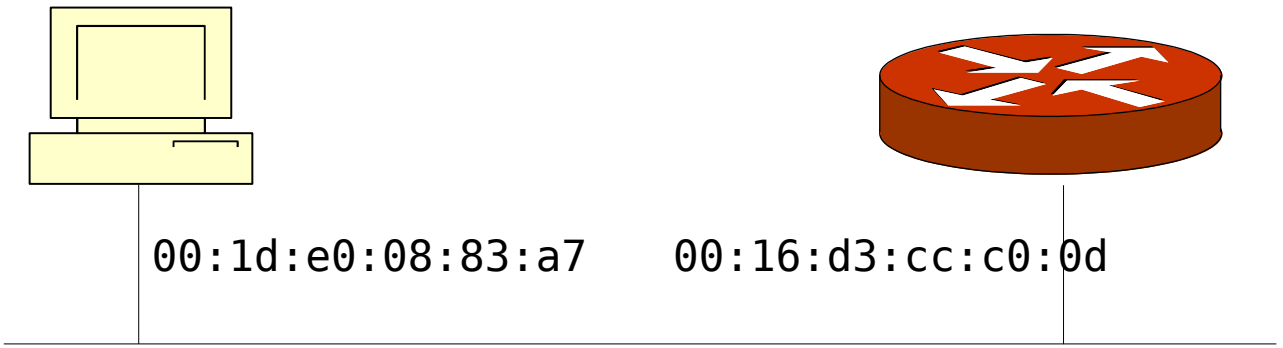
Ethernet frame:



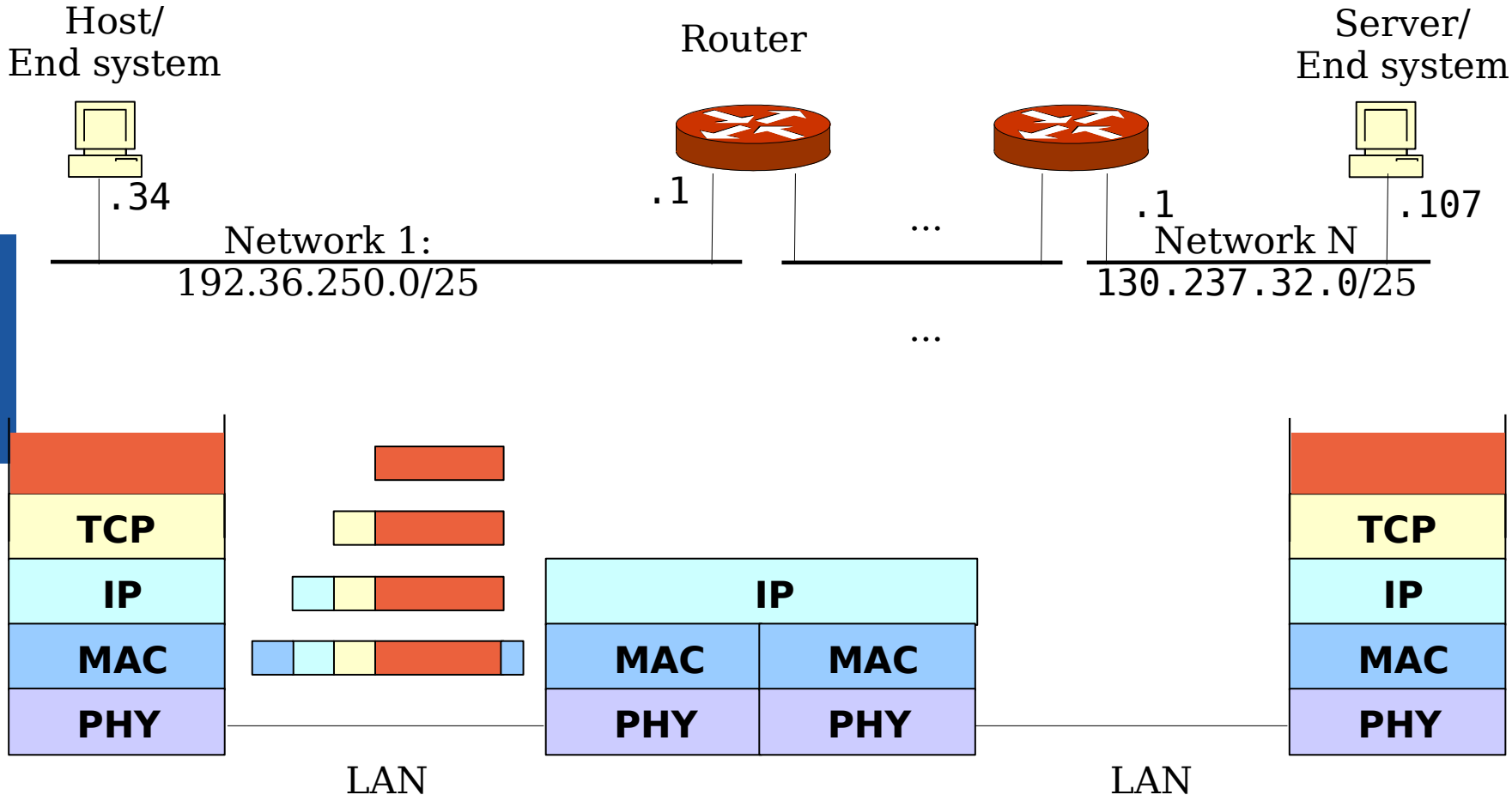
- Ethernet is an example of a link-level protocol, that uses copper or fiber. WLAN is similar to Ethernet but runs on 'air'.
- One important task of the link-layer is *framing*
  - 'create packets from the underlying physics'
- Another is detecting bit errors (cyclic redundancy check) and addressing ('MAC' addresses)
- A MAC (IEEE 802) address has a “flat” structure – they cannot be aggregated into more abstract addresses: networks
- Typically only requested on a local-area network on a *directly connected* network
  - But a “local-area” network can nowadays be very large

# Ethernet /WLAN communication

- Using a link-level protocol, you can now communicate directly over a link
- But what about communicating over several hops?



# Network layer and IP

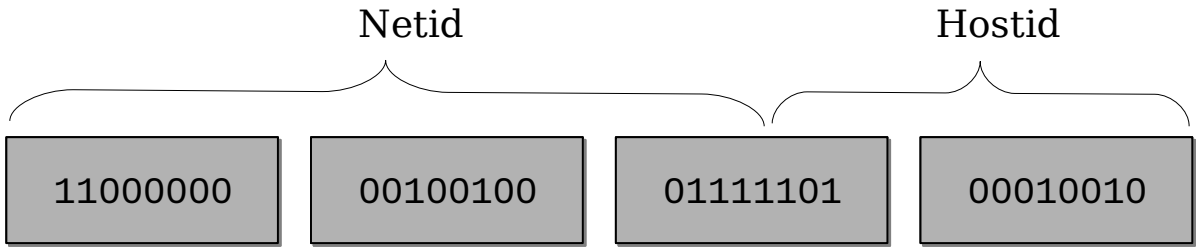



- The network layer (IP) primarily adds the ability to cross several networks using 'routing'

# IPv4 addresses

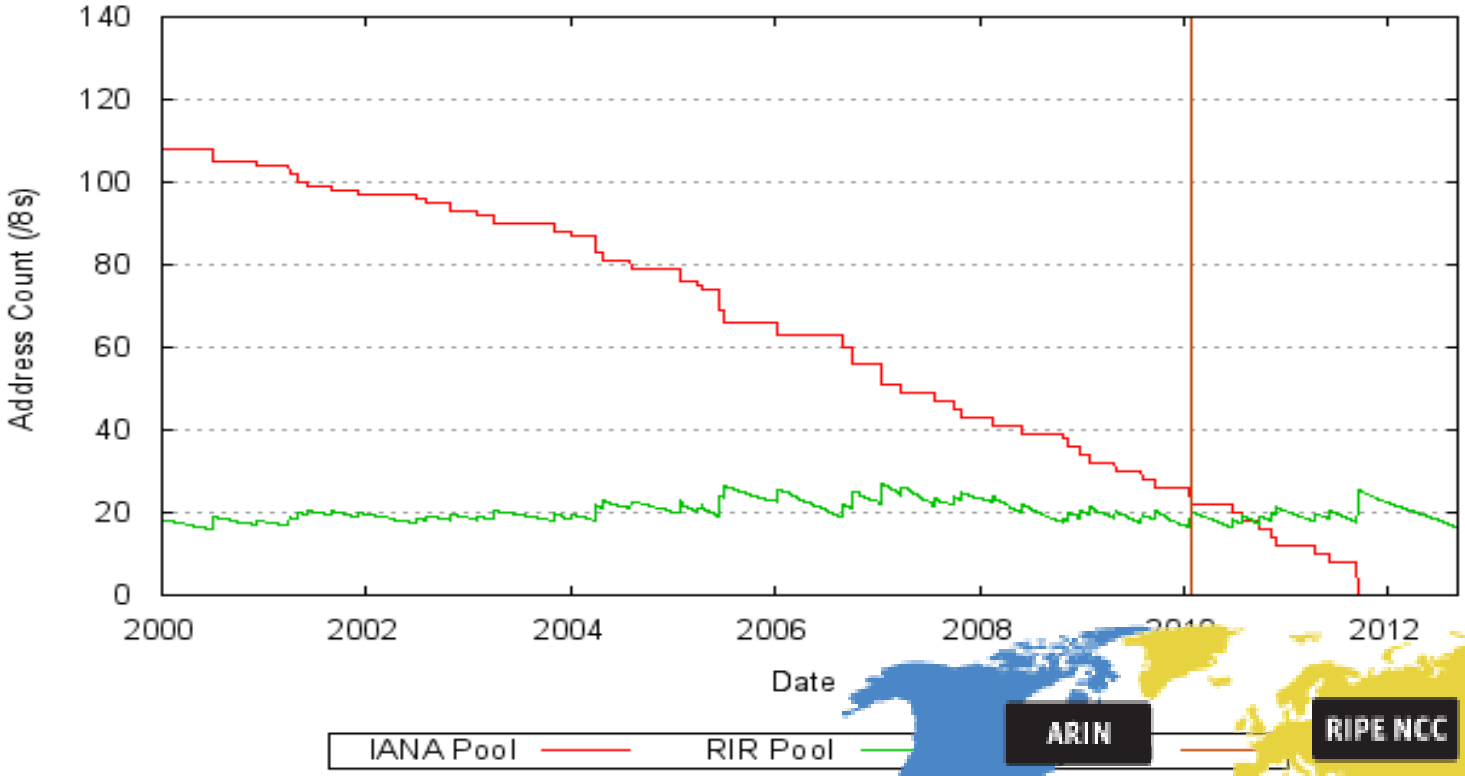
- Each *interface* in an IPv4 Internet is assigned a unique 32-bit internet address
  - –Not node addresses!
- Address types
  - –Unicast – one-to-one
  - –Anycast - one-to-any
  - –Multicast – one-to-many
  - –Broadcast – one-to-all
- Address Space
  - $-2^{32} = 4\ 294\ 967\ 296$
- Notation
  - –Dotted-decimal: 192.36.125.18

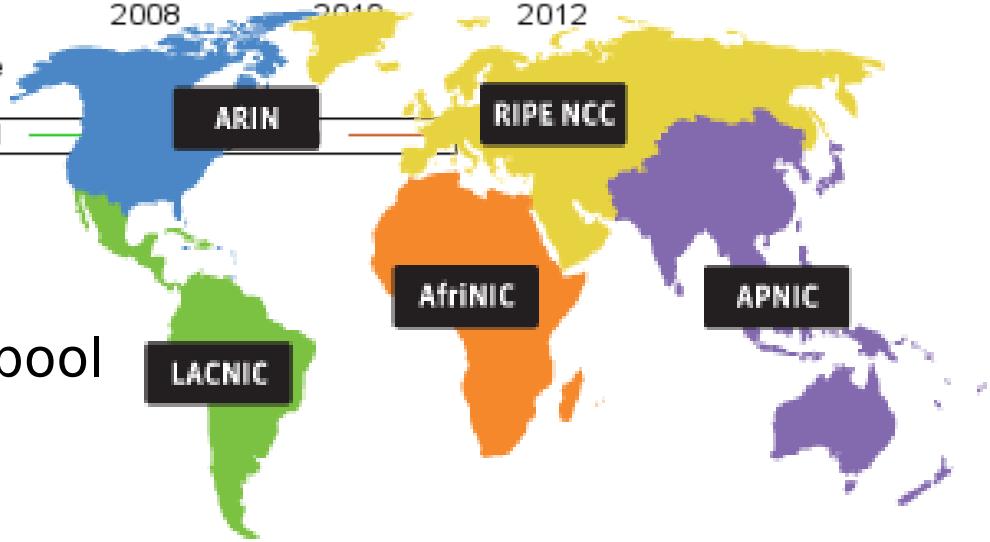

- An address has two purposes
  - –Identifier: Uniquely identify a host
  - –Locator: Give location of the host
- It therefore has two parts
  - –Netid (prefix) identifies a network
  - –Hostid identifies a node on that network
- Slash notation: <netid>/<netidlen>
  - –Example: 192.36.120.0/21




192.36.125.18

# IPv4 address exhaustion

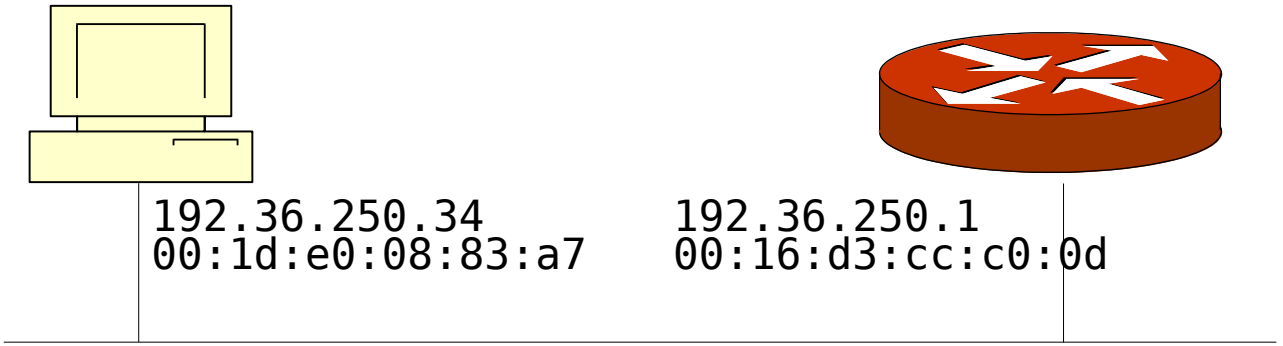


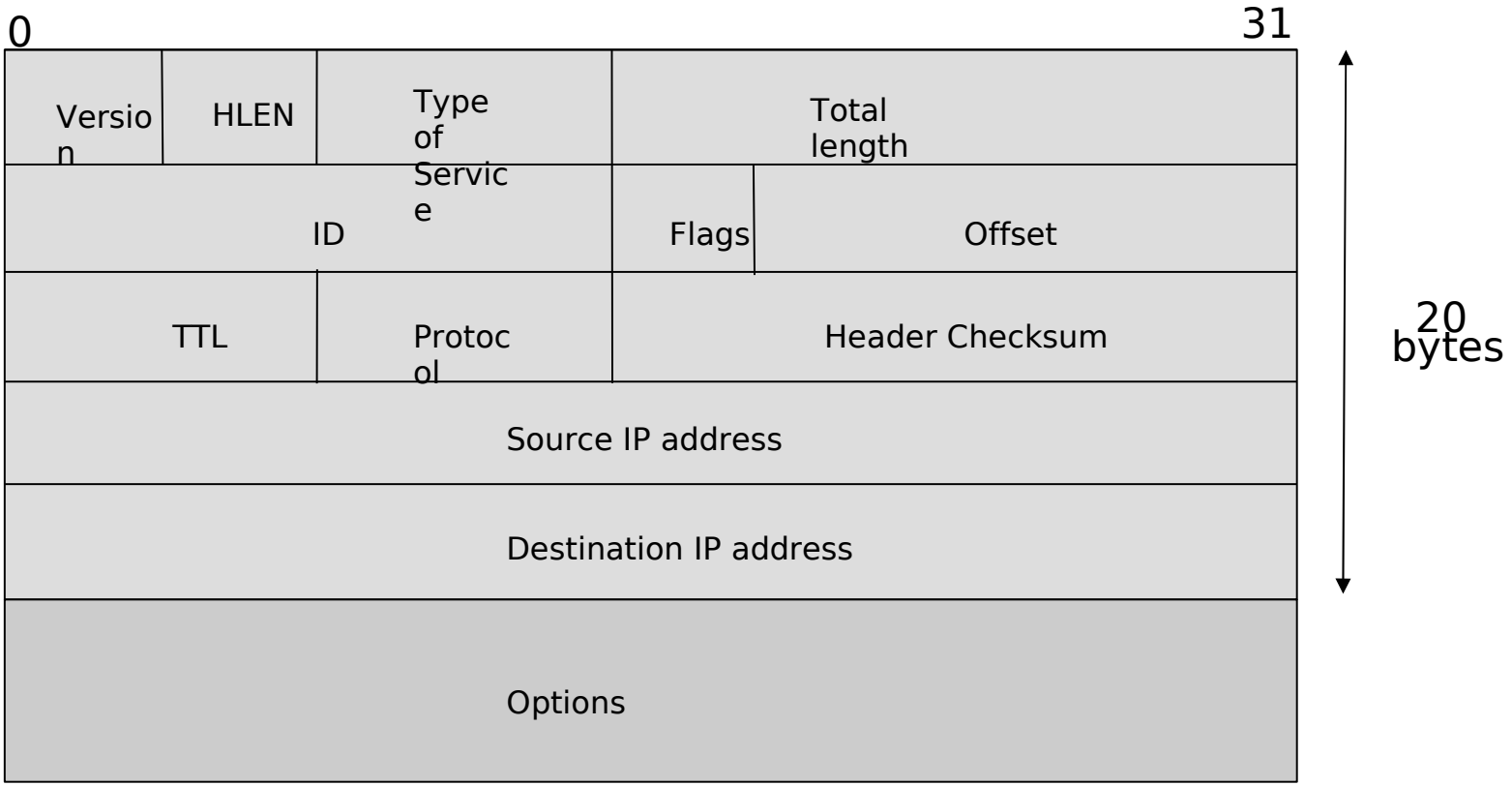

- The exhaustion of the IANA unallocated number pool will occur on 10-Sep-2011.
- The first RIR has exhausted its available pool of addresses on 03-Sep-2012.

# ARP - Address Resolution Protocol

- Problem: A source wants to send a packet to an interface on a *directly attached* broadcast network - we know the IP-address of the destination but not the MAC address.
- Idea: Broadcast a request - “On which MAC address can IP-address X be reached?”.
  - ARP request
- The host/router with the destination replies with its MAC address
  - ARP reply
- The source saves the reply in a cache
  - So you dont need to ask next time



# IPv4 Header




- Version
- HLEN – Header Length
- Type of Service
- Total Length
  - –Header + Payload
- Fragmentation
  - –ID, Flags, Offset
- TTL – Time To Live
  - –Limits lifetime
- Protocol
  - Higher level protocol
- Header checksum
- IP Addresses
  - –Source, Destination
- Options
  - –up to 40 bytes

# ICMP

ICMP is a limited signalling protocol for IPv4.

- Report IP problems back to sender
- Control and Management
- Considered a part of IP, but uses IP for transfers.


| Type | Message |
|---|---|
| 3 | Destination unreachable |
| 4 | Source quench |
| 11 | Time exceeded |
| 12 | Parameter problem |
| 5 | Redirection |

| Type | Message |
|---|---|
| 8/0 | Echo request/reply |
| 13/14 | Timestamp request/reply |
| 17/18 | Address mask request/reply |
| 10/9 | Router solicitation/advertisement |

# Transport layer

Provides service to end-applications: ports


## TCP

- Connection-oriented
- Reliable
- Full-duplex
- Data as byte-stream

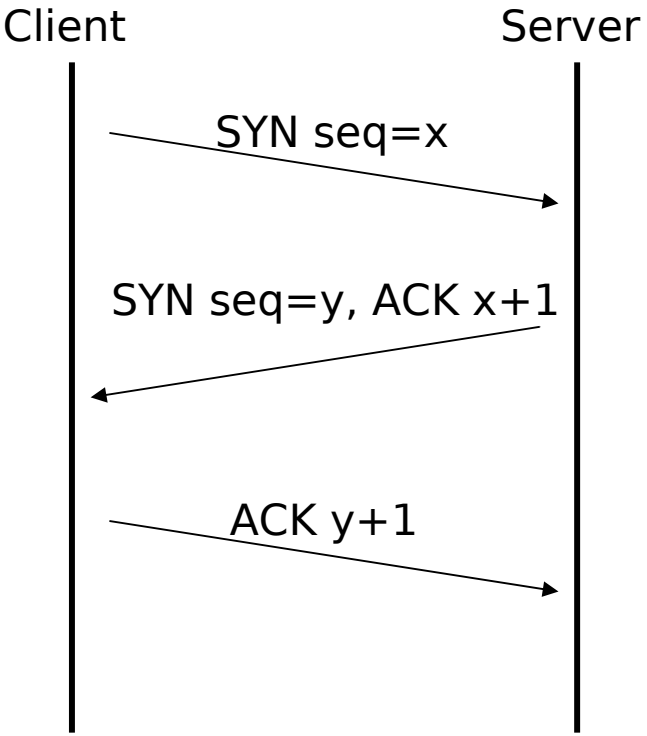
- Mostly used
- Network-friendly

## UDP

- Packet-oriented
- Unreliable
- Full-duplex
- Data in packets

- Real-time traffic
- Reliability in application

# TCP Connection Establishment




3-way handshake:

- Guarantees both sides ready to transfer data
- Allows both sides to agree on initial sequence numbers

Initial sequence number (ISN) must be chosen so that each incarnation of a specific TCP connection between two end-points has a different ISN.

Note: two well-known TCP attacks:
- SYN flooding
- Sequence number attacks

Normally, client initiates the connection

# TCP end-to-end reliability

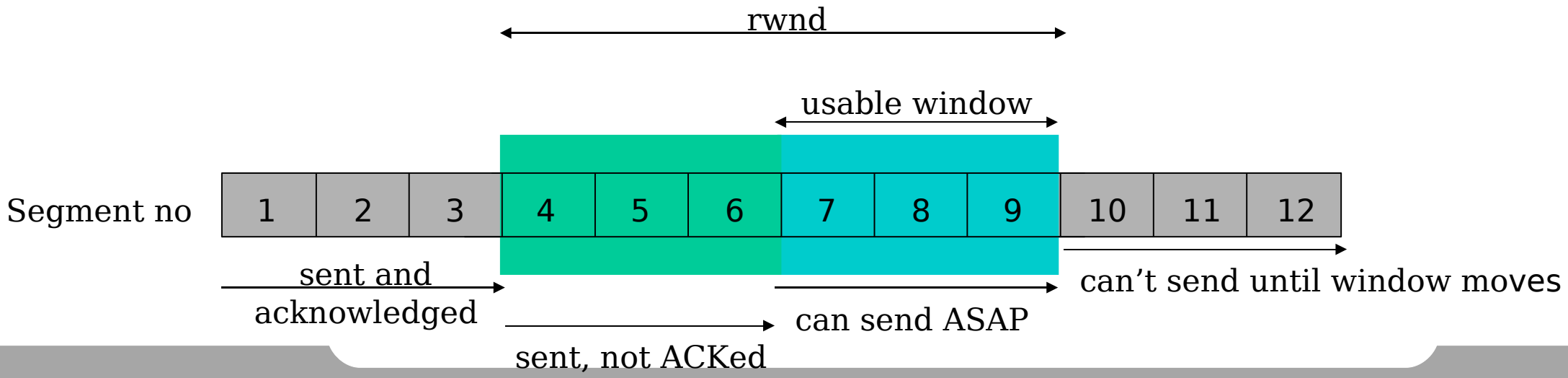

- *Flow* control : sender shall not overrun receiver
- Sliding window
- Receiver announces how much data it can receive using ACKs
- Avoid
  - –Stop and go
  - –silly windows

- *Congestion* control: Back-off when packets are lost in network
- Slow-start to quickly reach network capacity
- Congestion avoidance to slowly reach limit
- Fast retransmit
  - –Dont drop to zero at loss

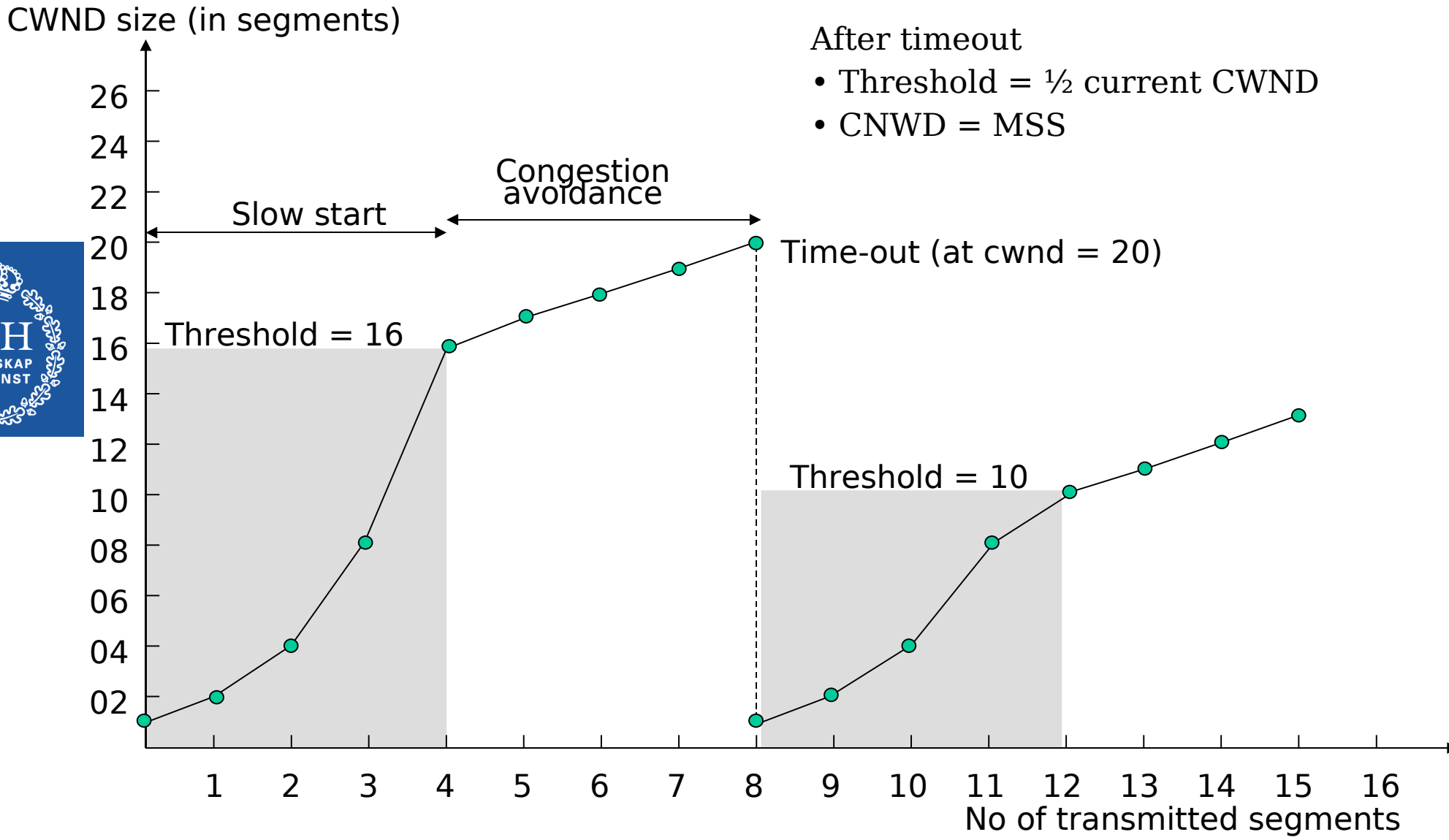
Actual window size: min(receive window, congestion window)

# Sliding window

- Receiver: receiver window – acknowledges data sent and what it is prepared to receive
- Sender window size opened and/or closed
  - –Receiving an ACK shifts the window by a constant value.
- Stop and go:
  - –Send data, wait for ACKs
- Silly window:
  - –Send one byte



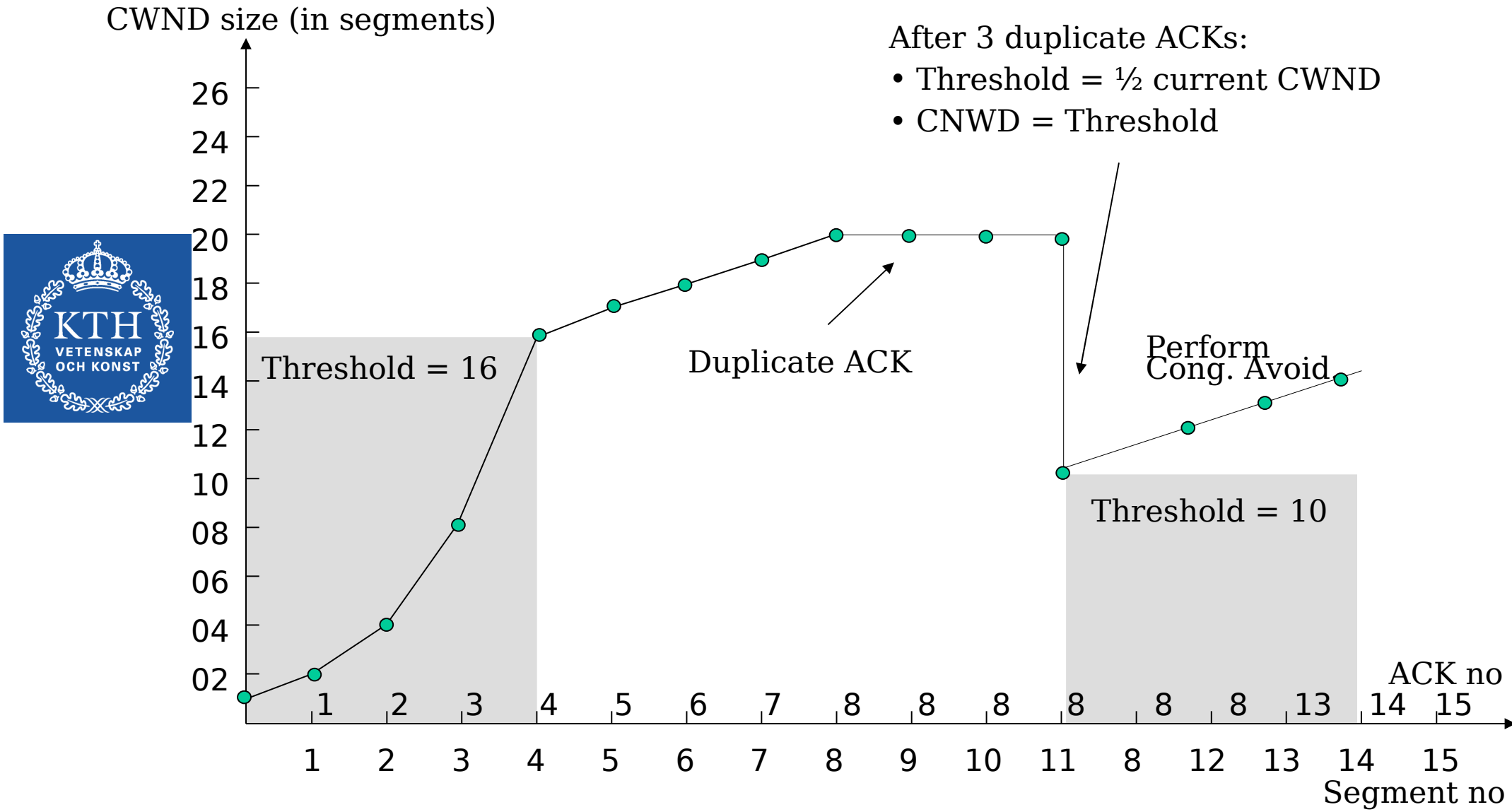
# Congestion avoidance




After timeout

- Threshold = ½ current CWND
- CNWD = MSS

# Fast Retransmit and Recovery



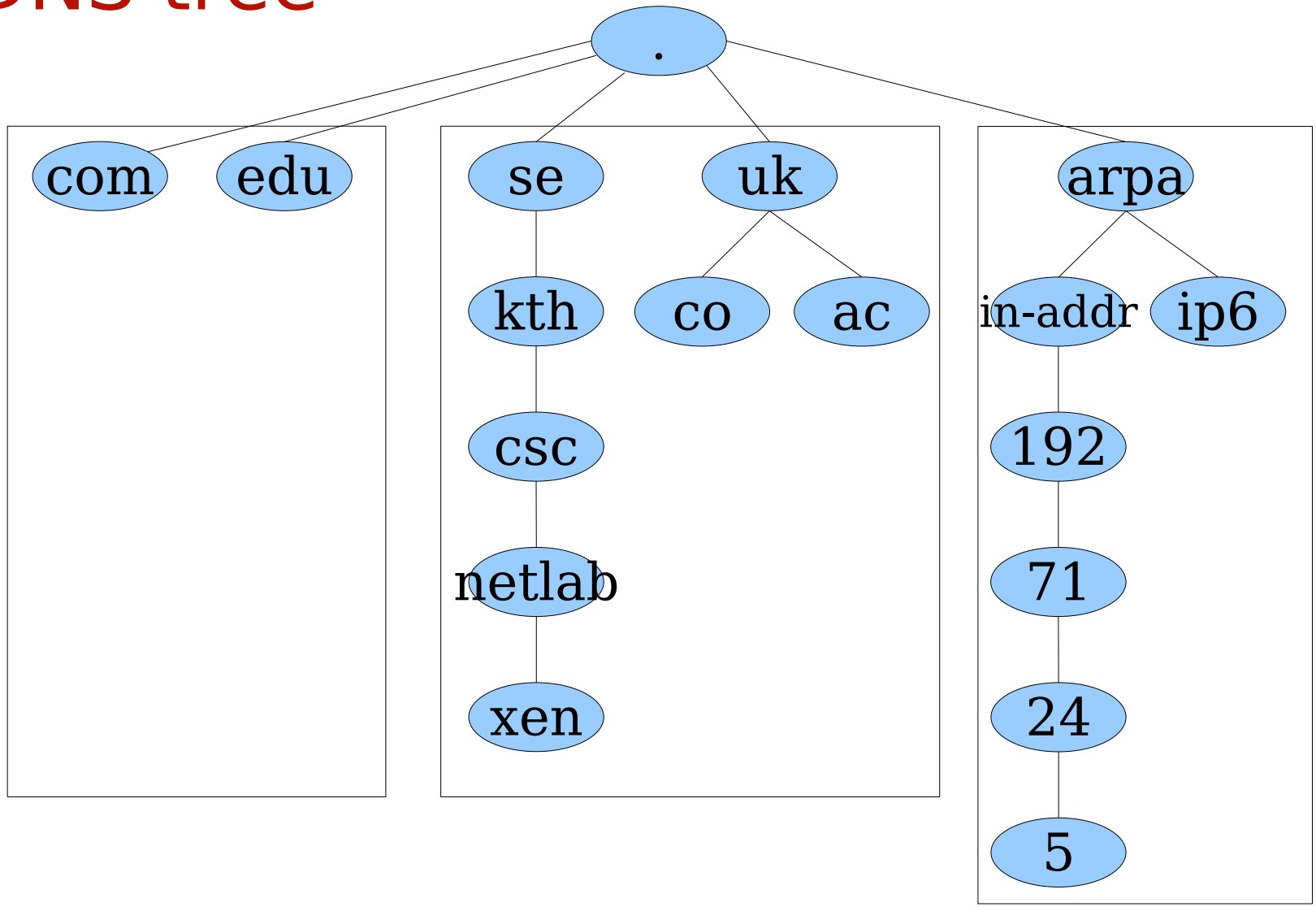
# DNS: Why do we need names?


- In the underlying network and transport layers it is all about addresses.
  - Interfaces, TCP, routing, etc.
- In IP, names are translated directly to addresses
  - And then we deal with addresses only
  - No names in the network
- Why don't we just stick with addresses?
- Names are better for humans
  - fe80::216:d3ff:fecc:c00d
- Names add another layer of indirection
  - One name can map to several logical addresses
  - One logical adress can map to several names
- Names can be used for other things than just addressing
  - load balancing, mail direction, descriptions, finding services,

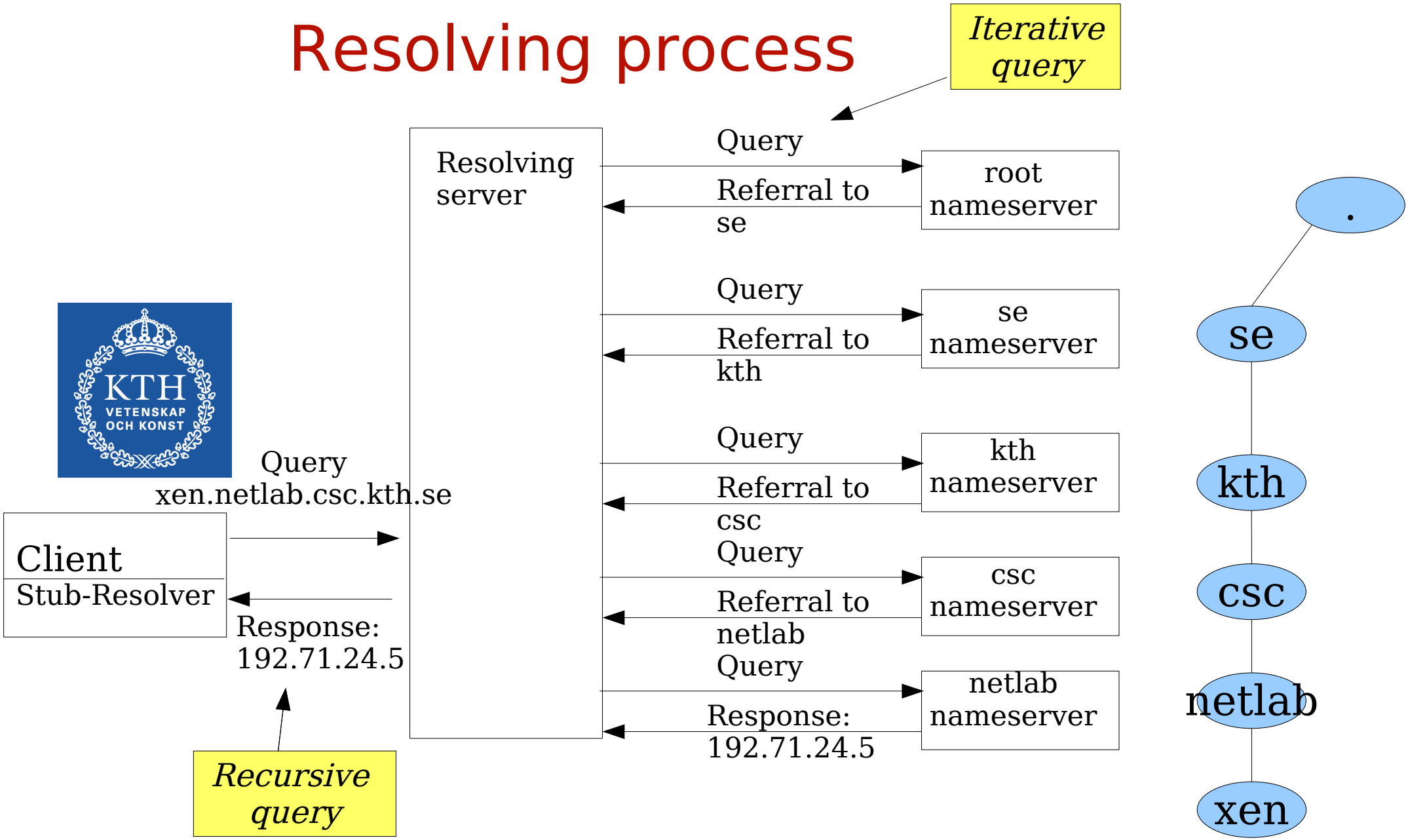
# DNS architecture

- Names are structured hierarchically - in a tree form
- The DNS architecture is client-server
  - Client is called resolver
  - Server is called name server
- The resolver queries the nameservers hierarchically
  - Ultimately, you ask one of 13 root name-servers
  - Replies are cached at several places in the system

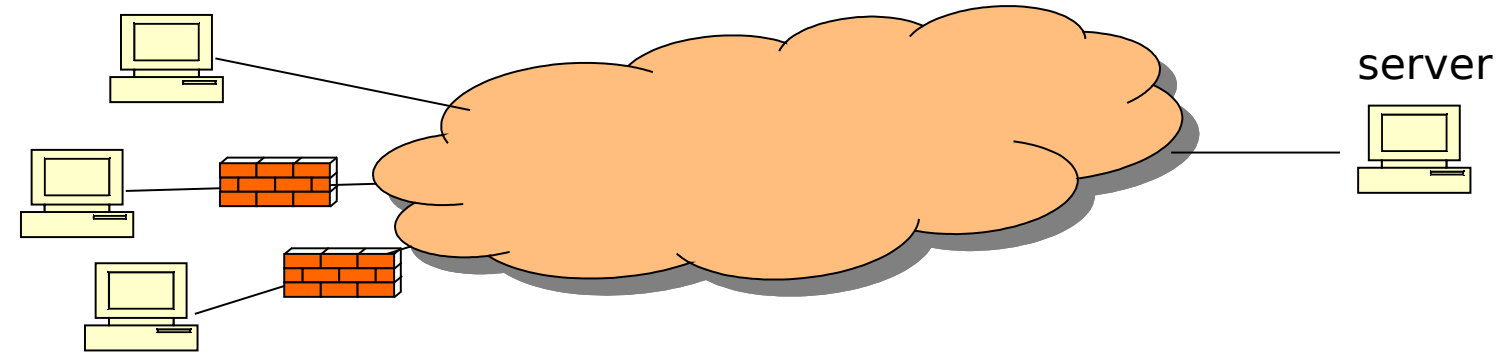
# DNS tree


.
com
edu
se
uk
arpa
kth
co
ac
in-addr
ip6
csc
192
netlab
71
xen
24
5

# Resolving process



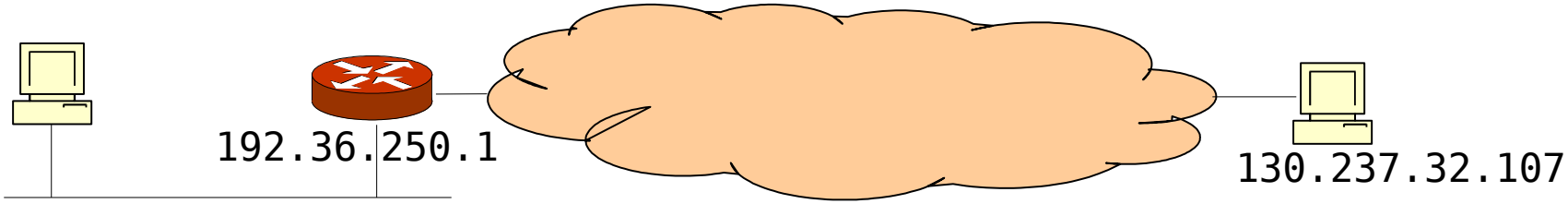
# Applications





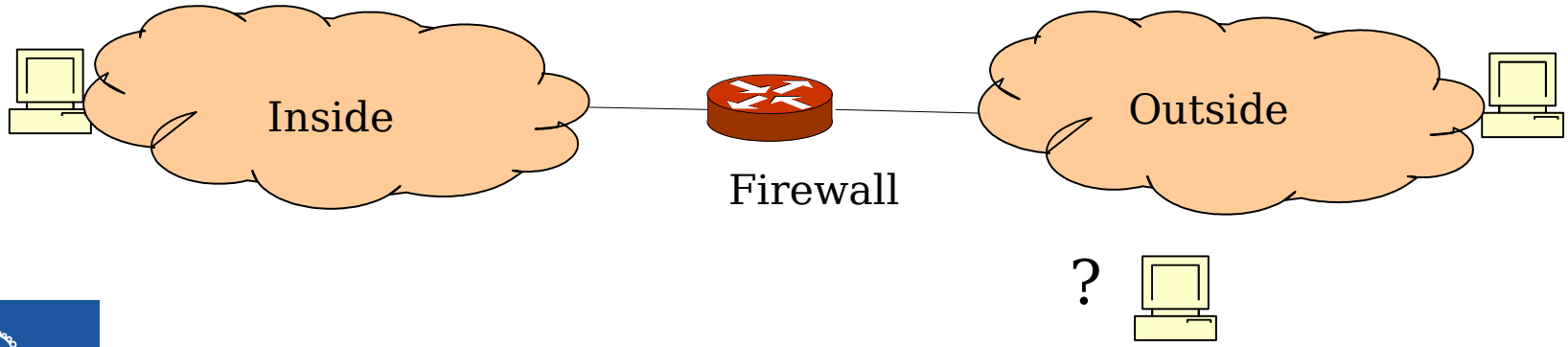
- Most applications use TCP sockets to connect between clients and servers or directly between peers - p2p
- Applications are typically end-to-end
- Anybody can create an application
  - Anybody can also attack
- Firewalls and NAT increase the security but also hinder the freedom of applications
  - Especially for peer-to-peer applications
- Firewalls are in general application-aware

# Example: packet transfer




- An end host communicating with a server via a wireless LAN
- DNS: Resolve the name to an IP address
  - –www.kth.se -> 130.237.32.107
- Make a routing lookup to get next-hop
  - –Nexthop(130.237.32.107) -> 192.36.250.1
- ARP: Translate the IP address of nexthop to MAC address
  - –192.36.250.1-> 00:e0:35:64:e9:e7
- Send TCP/IP SYN packet to 130.237.32.107 with port 80 to next hop using wireless LAN MAC address 00:e0:35:64:e9:e7
- TCP/IP SYN+ACK packet returns from remote peer
- Send HTTP Request on the TCP connection
- HTTP Response comes back with content

# DD2395 lab – packet filter firewall




- The lab configuration consists of three virtual hosts running on xen.netlab.csc.kth.se
- There is an outside host, an inside host, and a packet-filter firewall that you have control over.
- There is also an unknown server.
- Your first task is to scan the server to detect its address & capabilities
  - –You use 'nmap' for this
- Your second task is to program packet-filters on the firewall
  - –Protect internal servers and clients from access and attacks from the outside while allowing access of the outside from the inside
- You use the Linux '*ip-tables*' to acheive this.
- Read the lab instructions thoroughly,
  - –read about ip-tables and nmap!