ETSF15: Lecture 5
- Routing
- Network protocols
- IPv4/IPv6
- ARP/NDP

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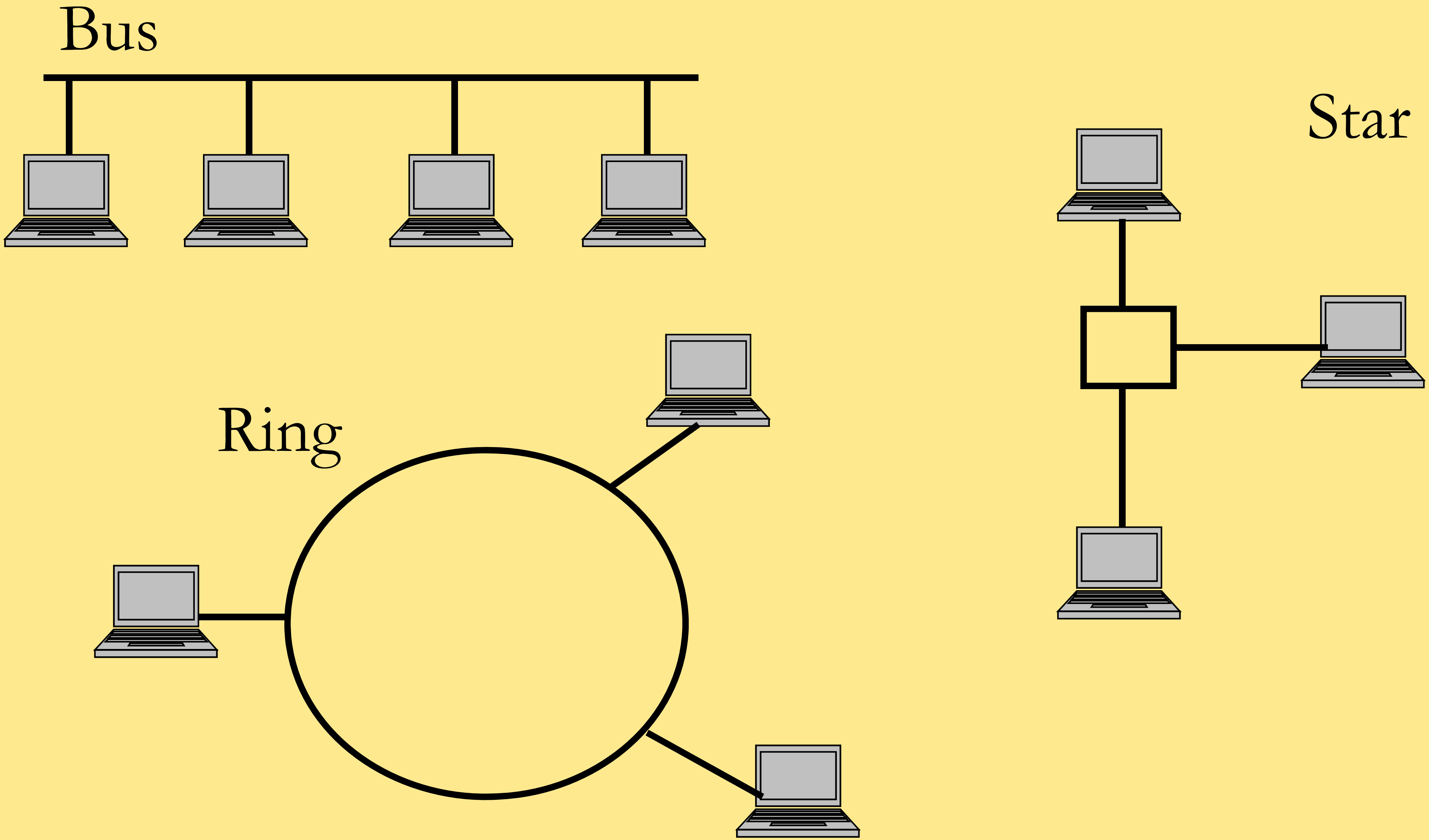
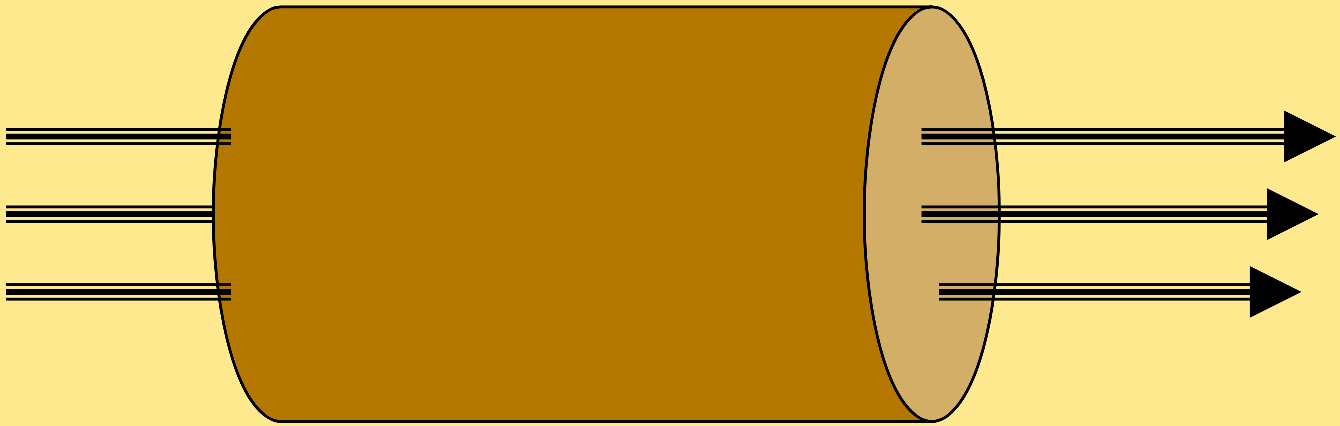
Link topologies



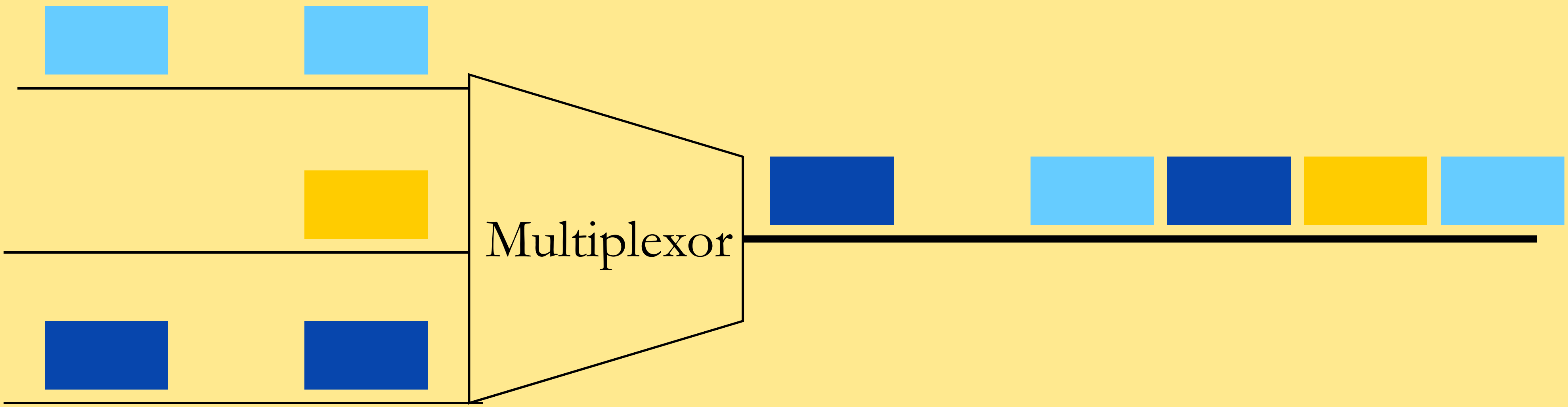
Generic multiplexing

Allocate channels in the available transmission medium



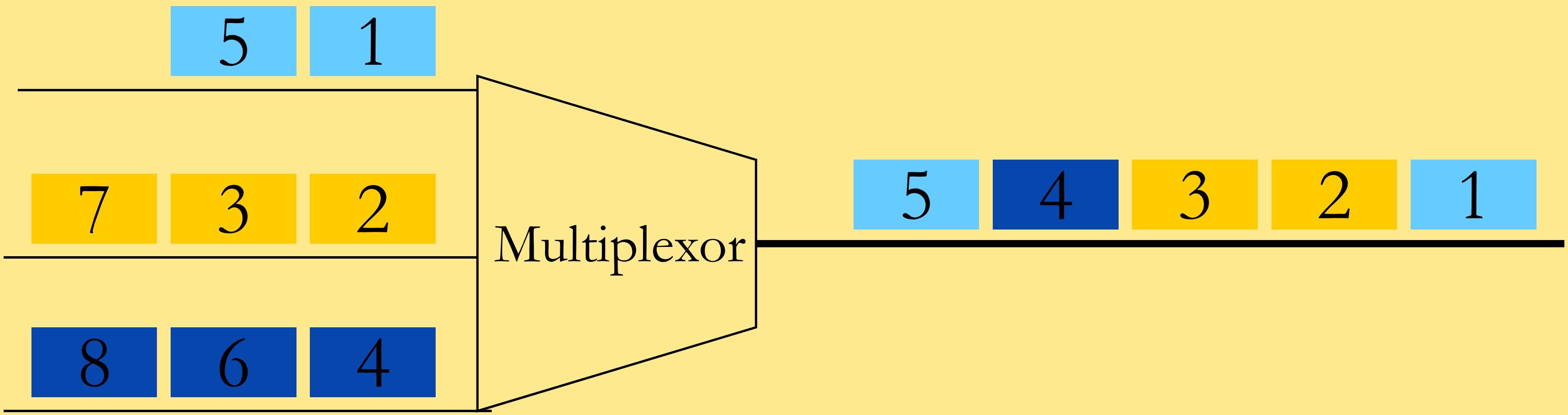
Synchronous time division multiplex

- Forwards one frame per channel in round robin
- If channel has nothing to send, corresponding time slot is i empty.

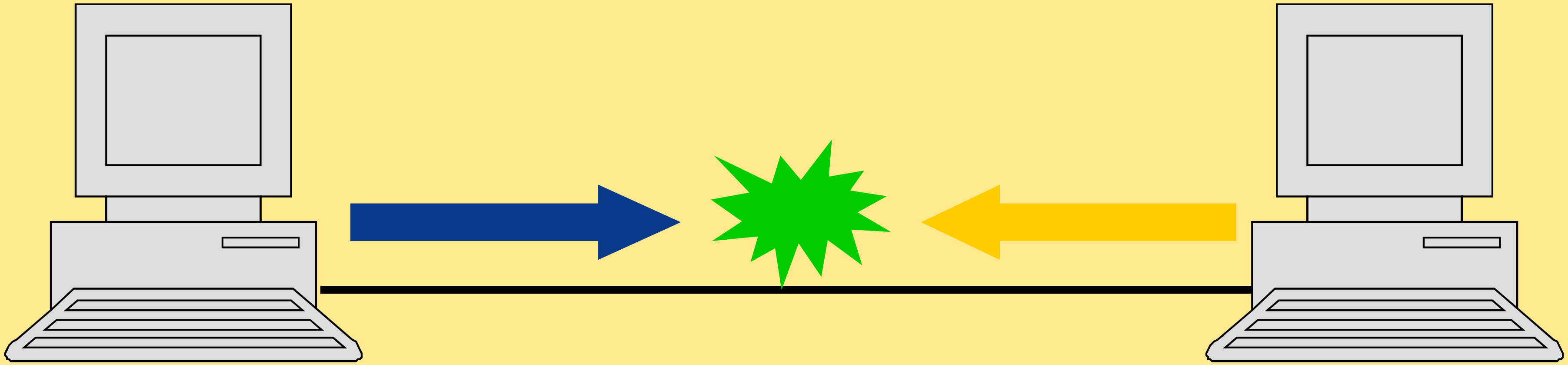


Statistical time division multiplexing

- Frames are transmitted as they arrive.
- Need buffering if outgoing link is occupied.
- Need 'address' for channel identification

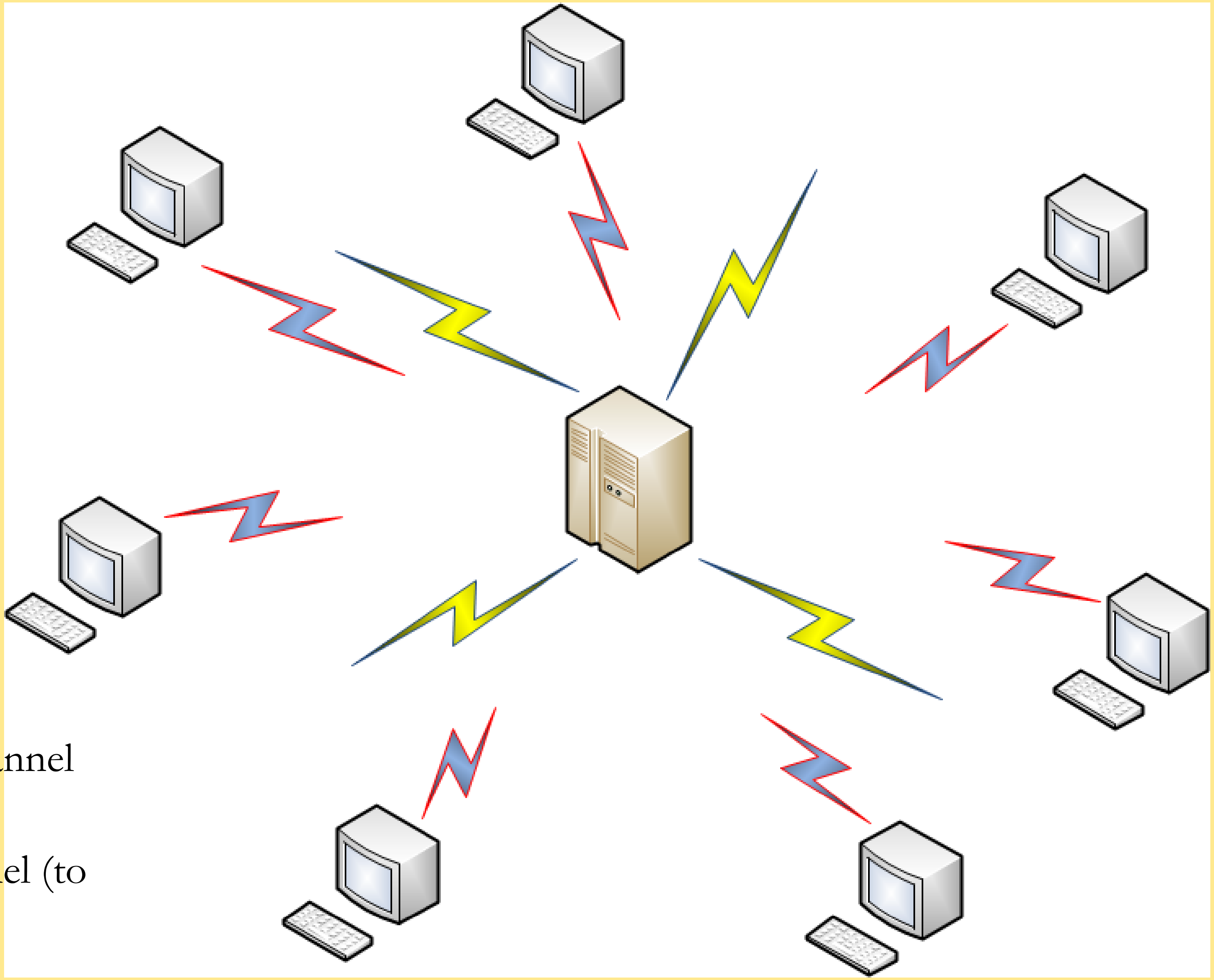


Access methods



Multiple access requires ordered access!

ALOHA



Yellow=Broadcast channel (from central node)

Blue=Common channel (to central node)

University of Hawaii (1971)

Carrier Sense Multiple Access (CSMA)

CS: Listen before transmit

- If busy, wait and try again

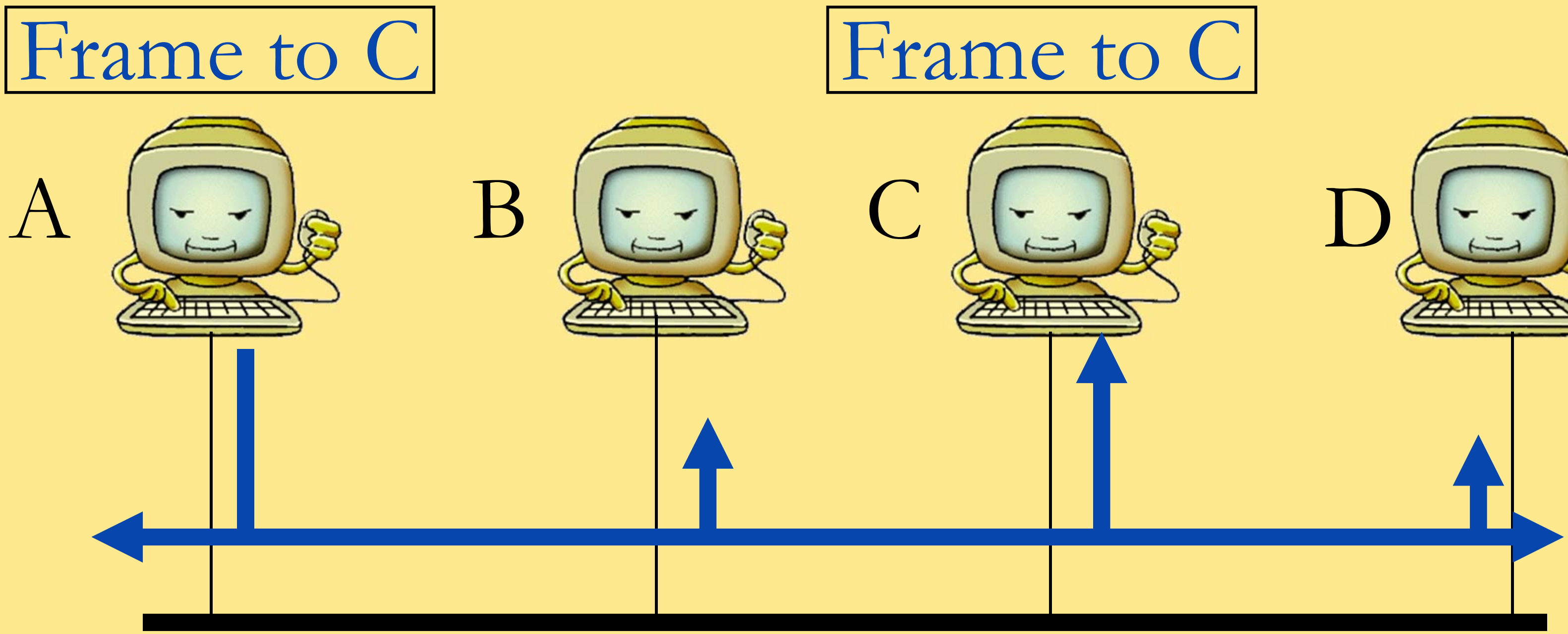
CSMA/CD

- CD: Collision Detection
- Listen for collision while transmitting
- Works only in wired environment

CSMA/CA

- CA: Collision avoidance
- Request channel before sending
- RTS/CTS (master/slave)

The need for addresses

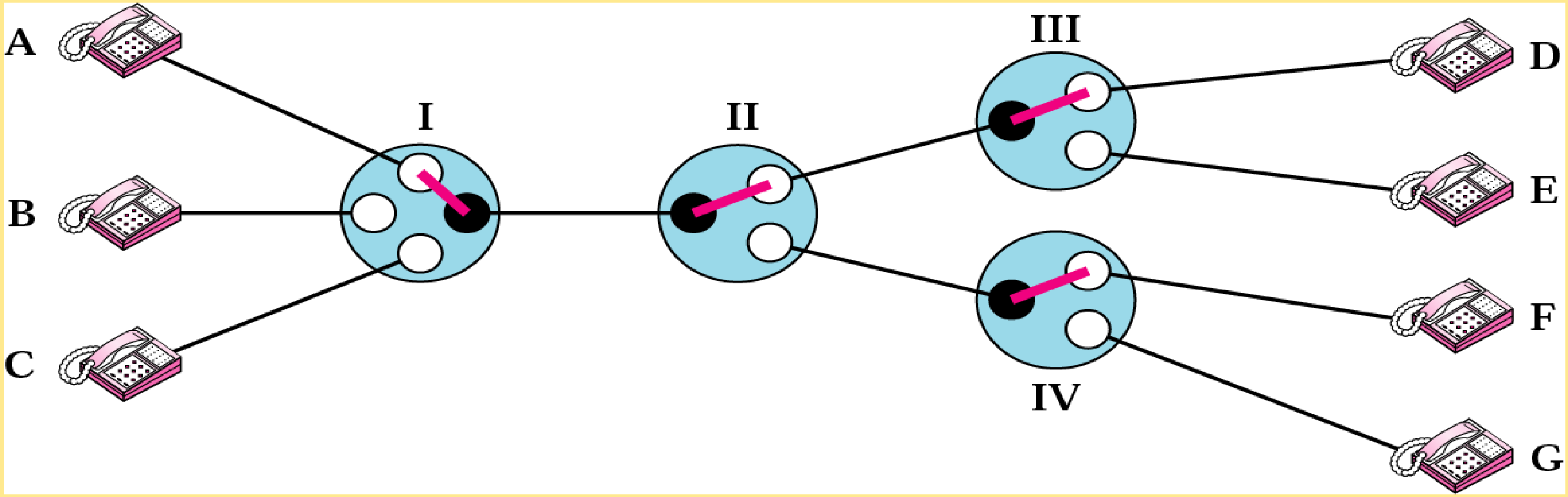


- All stations must have a unique address.
- All stations receives frame.
- Only addressed station handle the frame

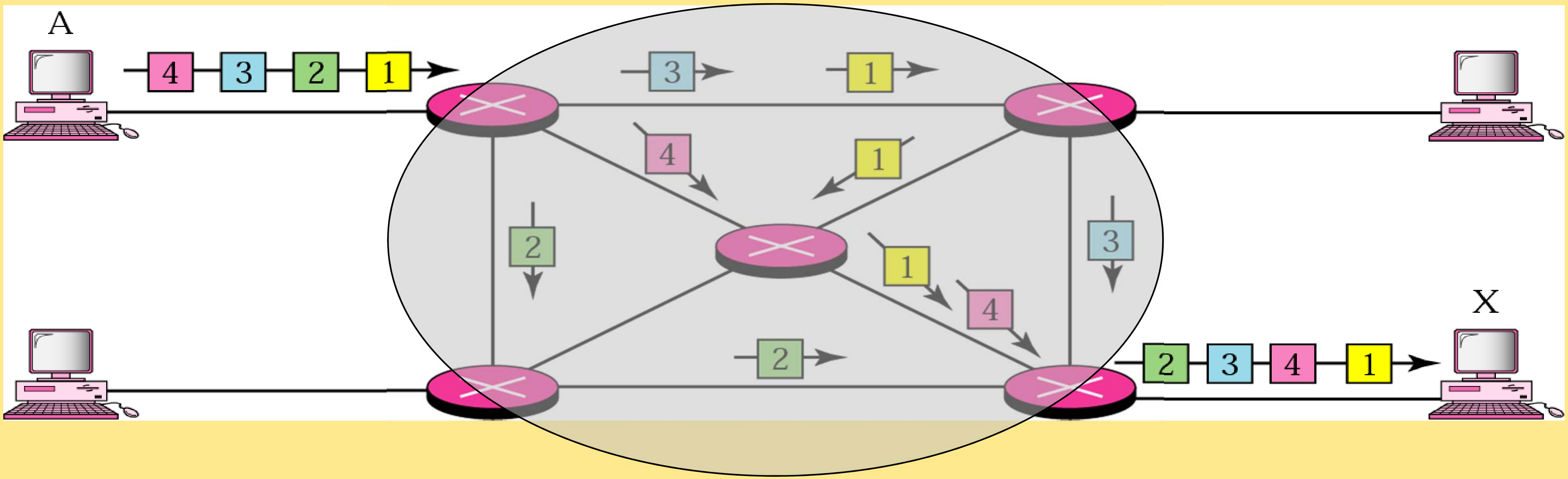
Domains

- Collision domain
  - Every station are effected by the same collision
  - Number of (busy) stations in a domain affects throughput
- Broadcast domain
  - Every station receives the same broadcast message
  - Alas: there exists a broadcast address!
  - Number of stations/broadcasts in a domain affects throughput

Circuit switching



Packet Switching



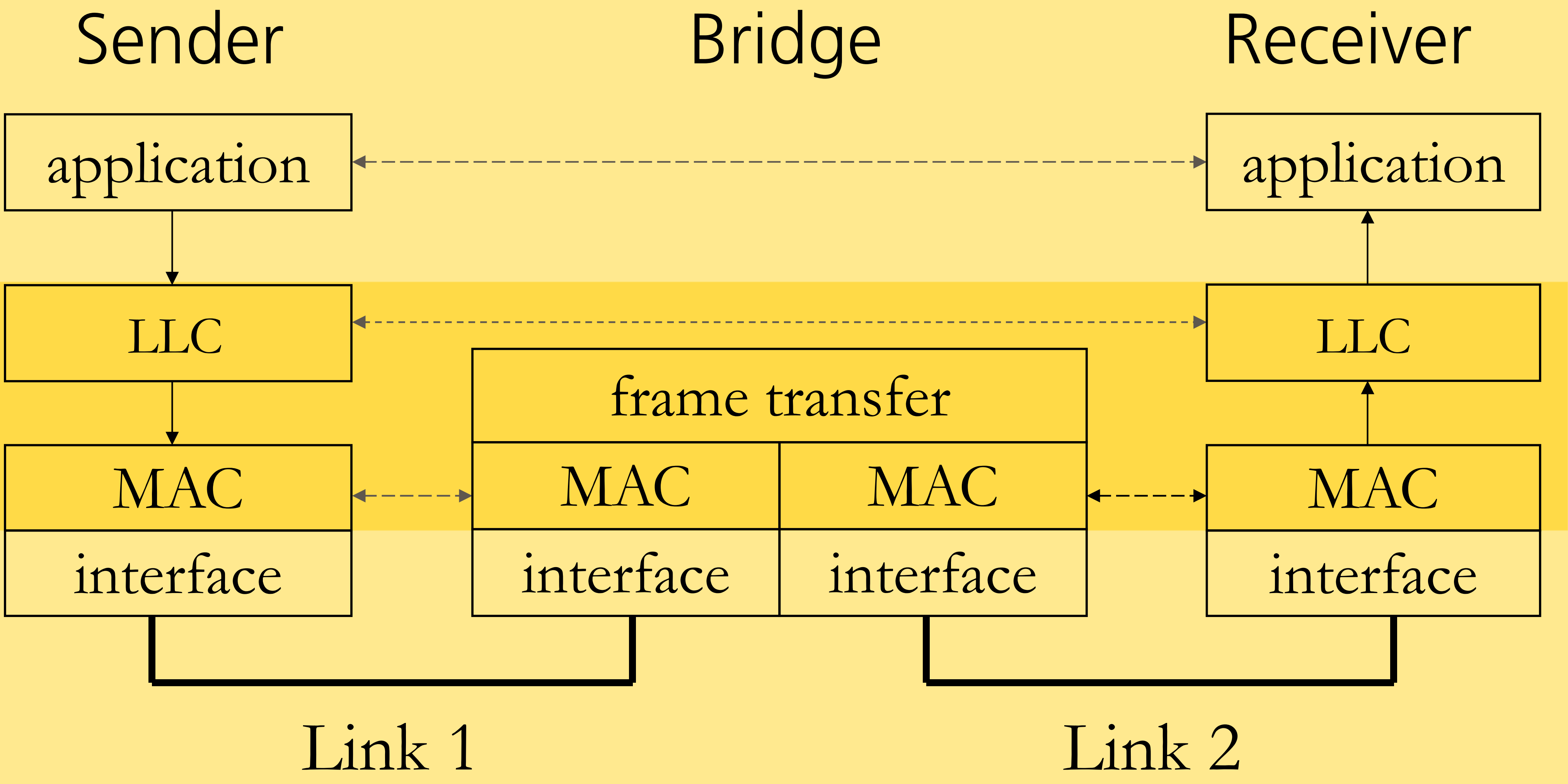
Ethernet, wired

- Ethernet developed by Xerox, Intel and DEC 1976.
- IEEE 802.3 is based on Ethernet.
  - Ethernet version II is included in IEEE802.3
  - Differences in the frame format but can co-exist on same link as 802.3.

Preamble	SFD	DA	SA	Type	Data	CRC
7	1	6	6	2	46-1500	4

SFD=Start frame delimiter DA=Destination address SA=Source address

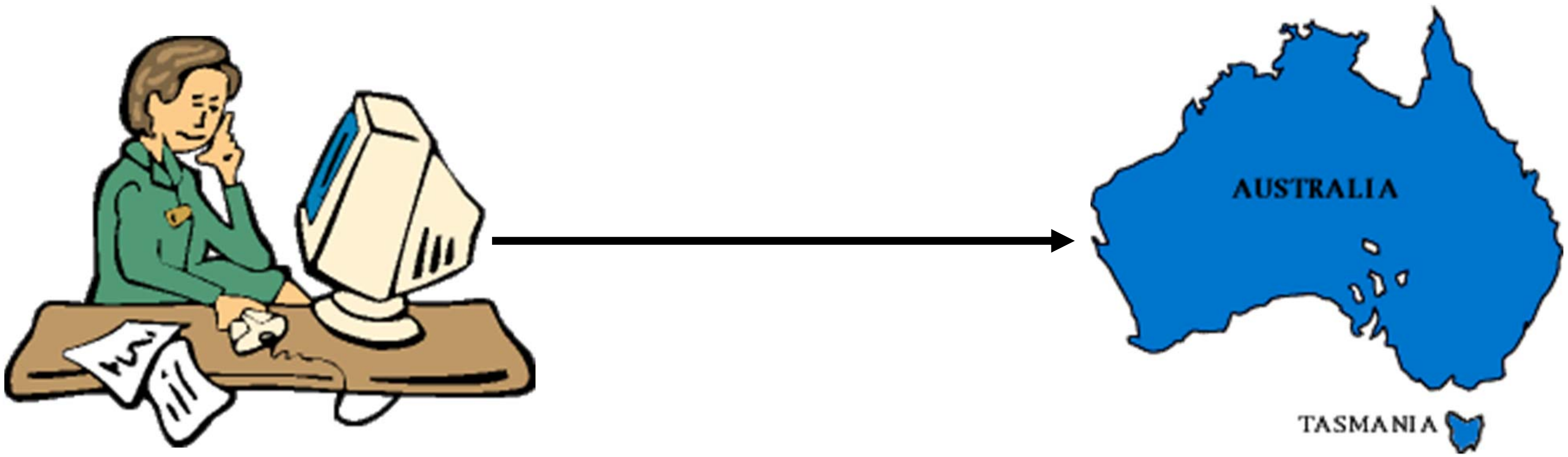
Protocol structure so far



A bridge recognises frames!

Extended Networks

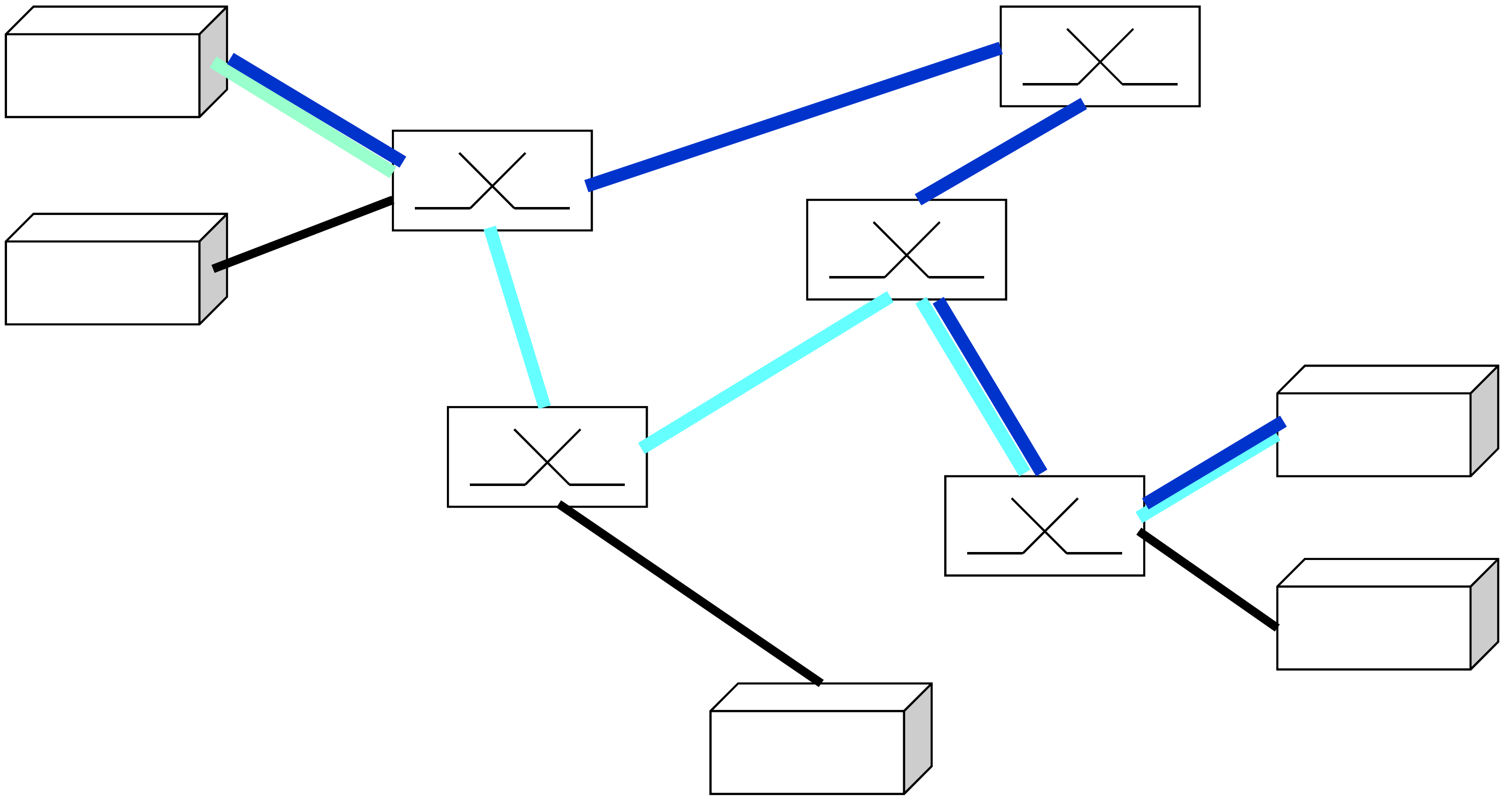
- All layer 2 networks have limitations in reach.
- There is a demand for connecting networks.



Layer 2 networks for long reach

- SONET/SDH
  - encapsulates several telephone calls (64kbps) in a hierarki of flows
  - flows can be added or dropped
- ATM
  - for telephony and data
  - cells, small equal sized frames
  - ”packet switching” over virtual circuits (label switching)
- Ethernet based networks for long distances
- WDM – Wavelength Division Multiplexing

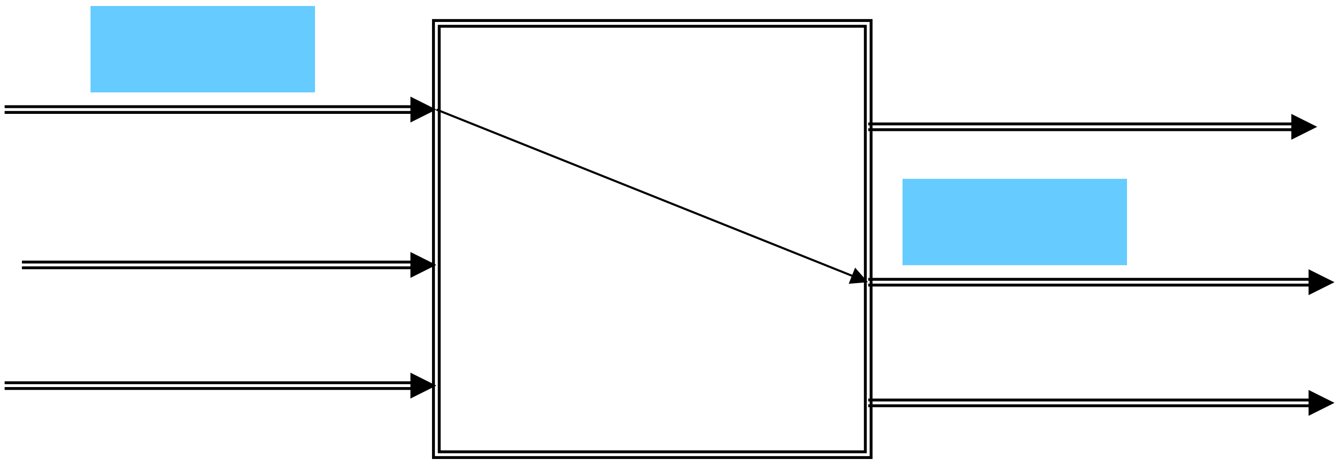
Switches selects routes?



- In networks there might (preferable) exist mutliple paths.
- Switches must keep track of all stations!

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

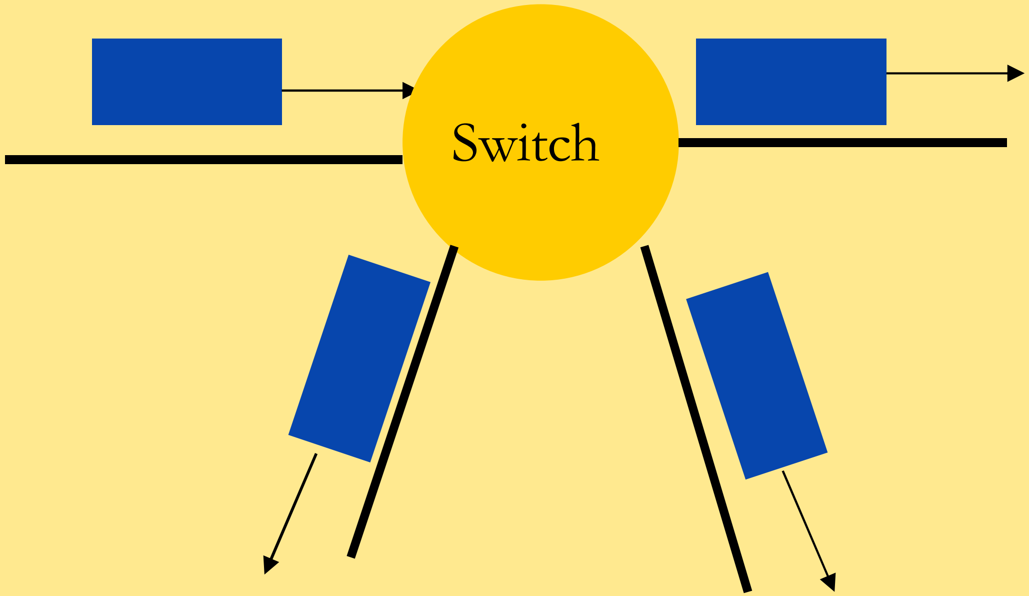
Routing (cont …)

Principles

- Centralised
  - Remote switching/forwarding nodes send network information to central node that finds best paths and pushes those to switching/forwarding nodes
- Distributed
  - All nodes share network information and find best paths

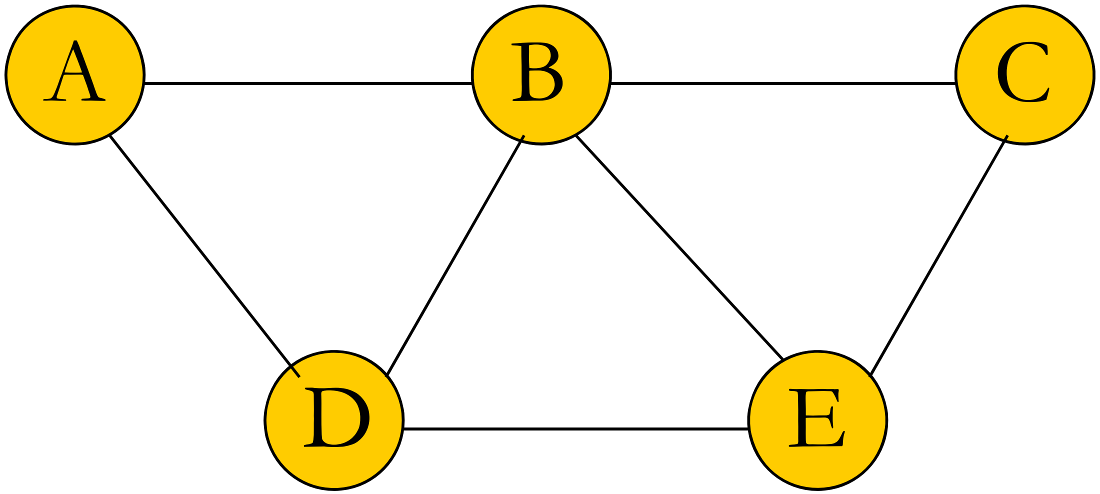
Flooding

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



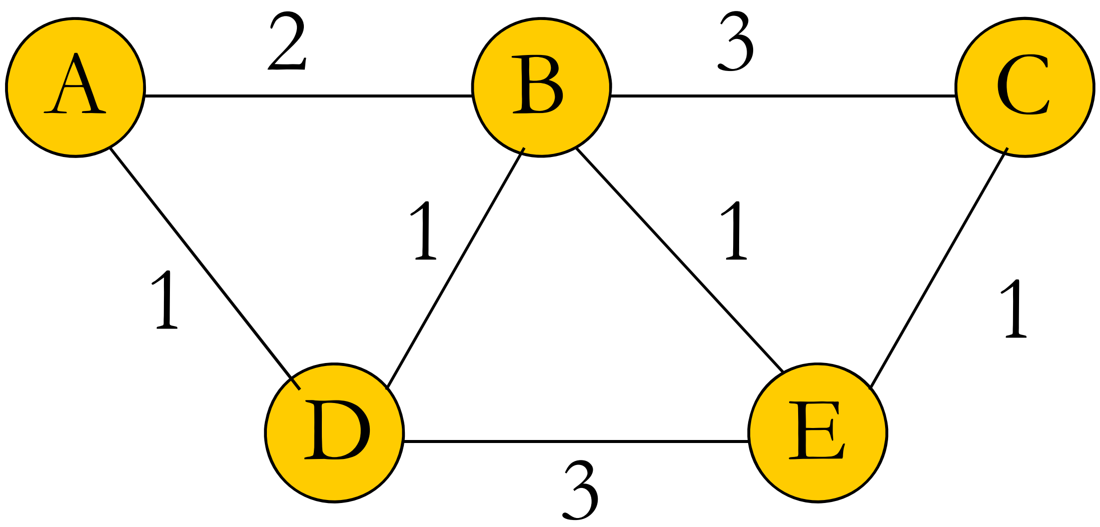
Network graphs

- A graph has nodes and edges
  - (sv noder och bågar)



Network graphs (cont …)

- Each edge is assigned a cost
- In network cost to use a link

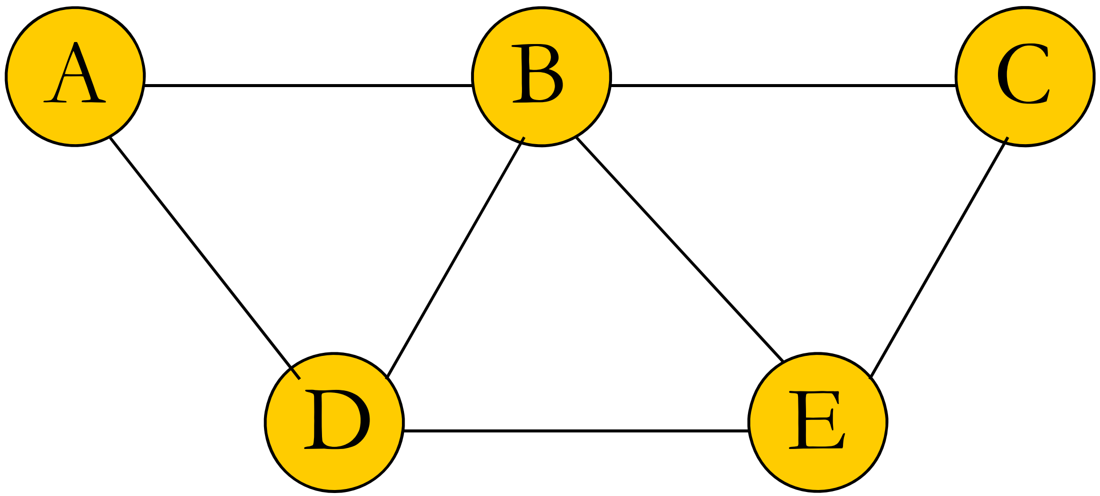


Link cost metrics

- Capacity/Bit rate
- Load
- Type of network
  - Fixed
  - Mobile
  - Wifi
- Latency
- Etc …

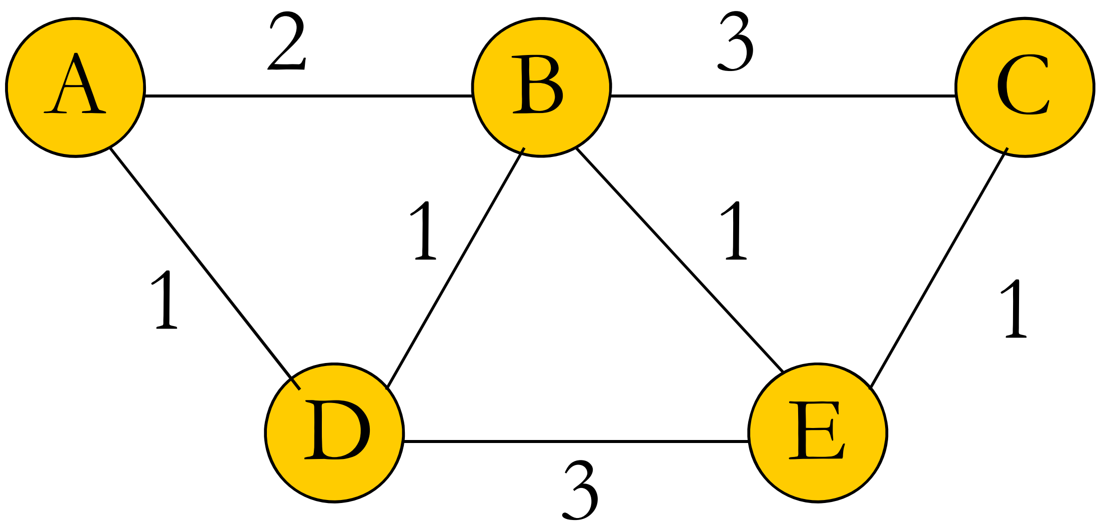
Least-hop path

- 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



Problem!

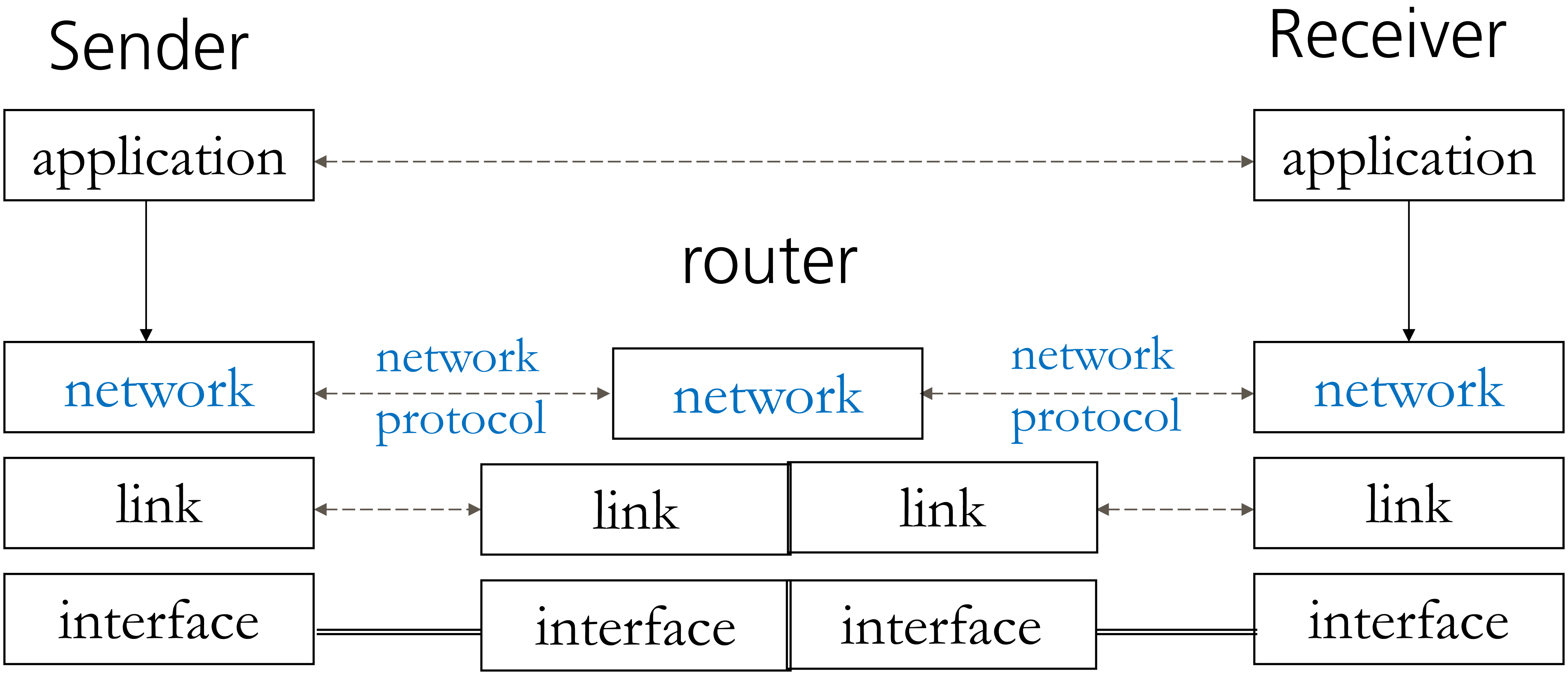
If LANs don't have same L2 protocol?

- Different propagation media
- Different signaling
- Different frame structure
- Different MAC layer address formats

Solution: Network Layer Protocol

- Rides on top of any layer 2 network
  - Encapsulation (a frame as payload of another frame)
- Global address structure
  - Network ID requirement
    - Flat structure impossible; requires all addresses known to all switches
  - Host ID is address to individual host on a network
- Global frame format

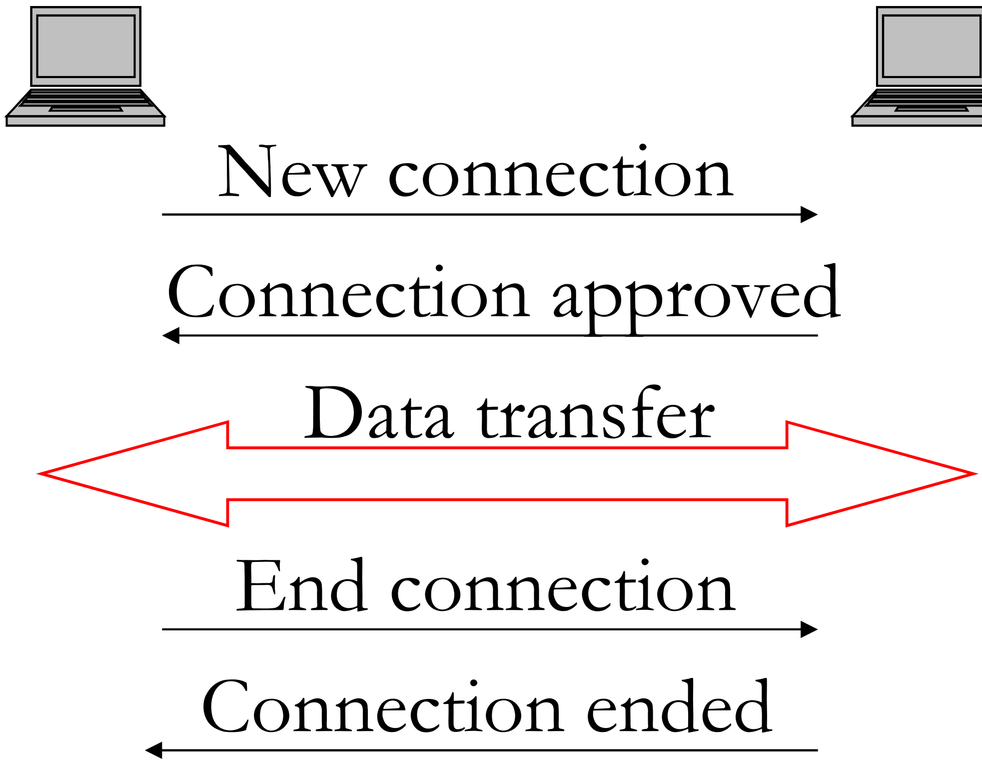
Network Protocol



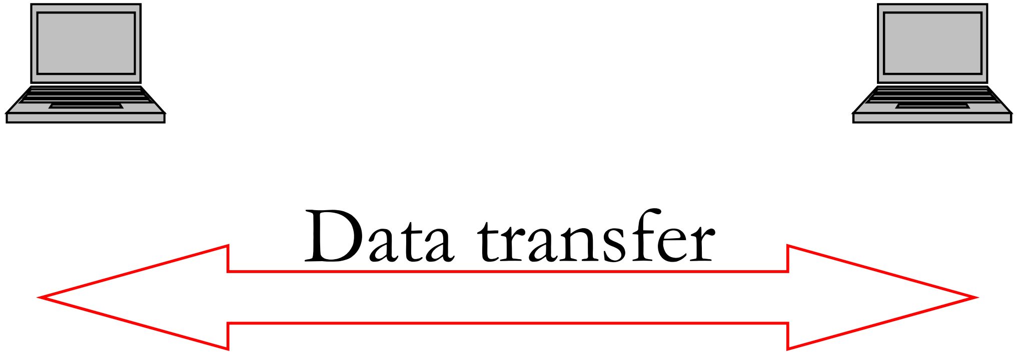
One Network Protocol: IP

- 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



Connection Free 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 datagram

header	data/payload
20-60 bytes	0-65.515 bytes

IPv4 header format

<table>
<tr><td>0</td><td>4</td><td>8</td><td>16</td><td></td><td>31</td></tr>
<tr><td>vers.</td><td>hl.</td><td>type</td><td colspan="3">datagram length</td></tr>
<tr><td colspan="3">sequence number</td><td>frg.</td><td colspan="2">fragment position</td></tr>
<tr><td colspan="2">time to live</td><td>protocol</td><td colspan="3">check sum</td></tr>
<tr><td colspan="6">source address</td></tr>
<tr><td colspan="6">destination address</td></tr>
<tr><td colspan="5">options</td><td>padding</td></tr>
</table>

IPv4 address structure

- IPv4 addresses are 32 bits long.
  - 4.3 10^9 idividual addresses
  - Only 3.8 10^9 can be used
- Printed as 4 decimal numbers; full stop as delimiter
  - Dot decimal notation
  - 4 bytes/octets

$$10000010\ 11101011\ 00010010\ 10011110_2$$
$$=$$
$$130.235.18.158_{10}$$

IPv4 address structure (2)

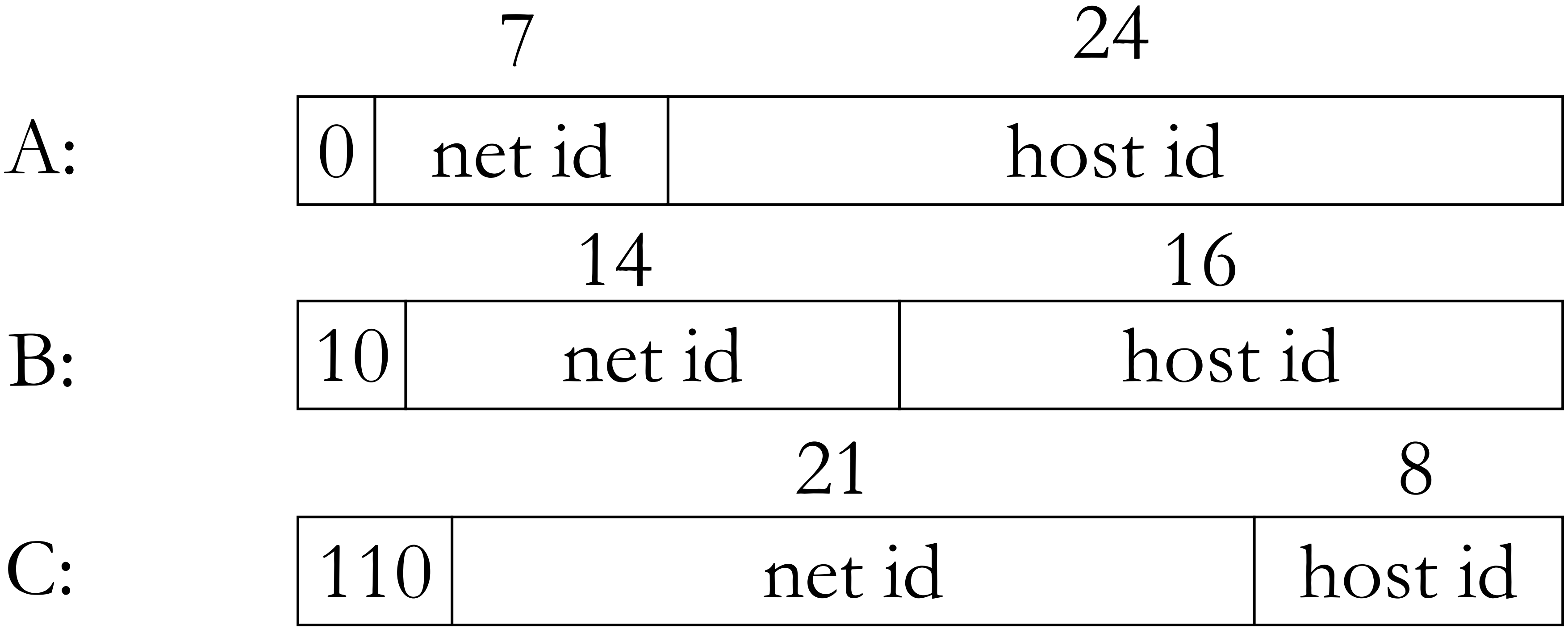
- Two parts:
  - Network identity (net id)
  - Host identity (host id)

One EIT IP address = 130.235.202.173

????

EIT network id = 130.235.200

IPv4 address structure (3)
Classful adddressing



IPv4 address structure (4) Subnetting

- Split network into subnets: Add a subnet mask
- 32 bit vector
  - Ones identify bits in net id
    - Always consecutive from the left
  - Zeros identify bits in host id
- 255.255.255.128
  - Splits one C net into two subnets
  - Splits one B net into 512 subnets

IPv4 address structure (3) Classless adddressing (CIDR)

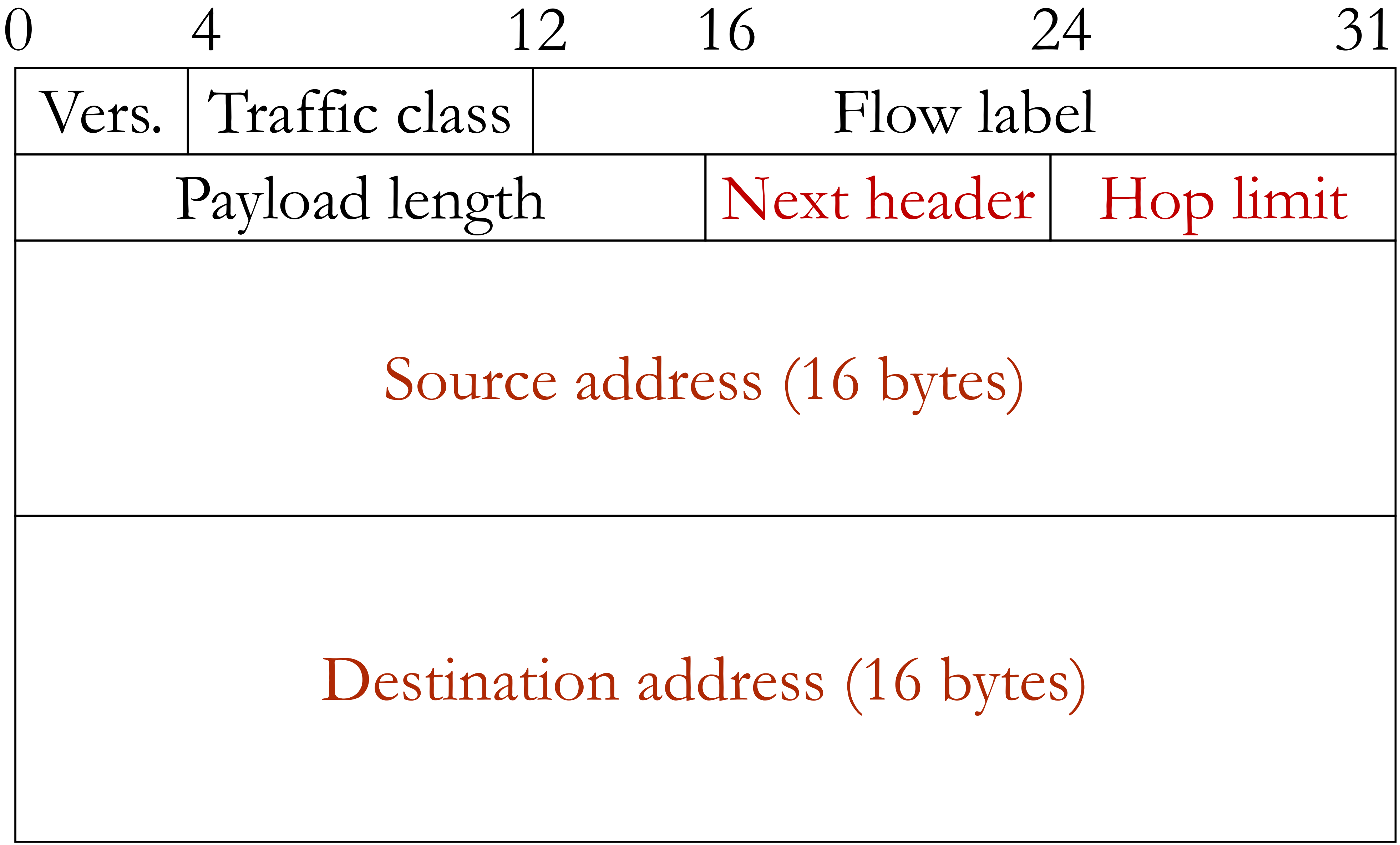
- Skip classes
- Use only (sub)net mask

Address:	11011110 00010111 01000011 01000100
Mask:	11111111 11111111 11000000 00000000
Net id:	11011110 00010111 01000000 00000000
Host id:	00000000 00000000 00000011 01000100

IPv6 datagram

header	data
40 bytes	0-65.535 bytes

IPv6 header format



IPv6 address structure

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

$010A : 1234 : E4F5 : 1003 : 4567 : BC98 : 0000 : 2341_{16}$

IPv6 address structure (2)

- Address space divided into blocks
- Each block idetified by its *block prefix*
  - 001 = *global unicast* ; host to host)
  - 1111 110 = *unique local unicast* ; corresponds to IPv4 private adresses, rfc 1918
  - 1111 1110 11 = *link local* ; used in combination with MAC address for auto configuration

IPv6 address structure (3)

- Printed as eight hexadecimal numbers; colon delimiter
  - Colon-hexadecimal notation
- Leading zeros in a group kan be omitted
- Consecutive groups with zeros only
  - Can be printed as ::
  - Only allowed once per address

IPv6 address structure (4)

FDEC : 0102 : 0000 : 0000 : 0000 : EB82 : 0013 : 14A5

can be shortened to

FDEC : 102 : : EB82 : 13 : 14A5

IPv6 address structure (5)

- Net id or host id?
- Compare IPv4 (sub)net mask
- Printed as number of consecutive ones
- Exempel prefix: FDEC::BBFF:0:FFFF/60
  - The first 60 bits gives the net id

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

Check Sum (Hash Sum) (2)

Receiver side:

- Split the bit vector into equal sized segments
  - same segments size as the sending end
- Calculate sum over all the segments
  - Remove carry bits and add to the sum
- Calculate the sum's one complement
- If complement of sum = 0 then segments are received without error

From IP address to MAC-adress

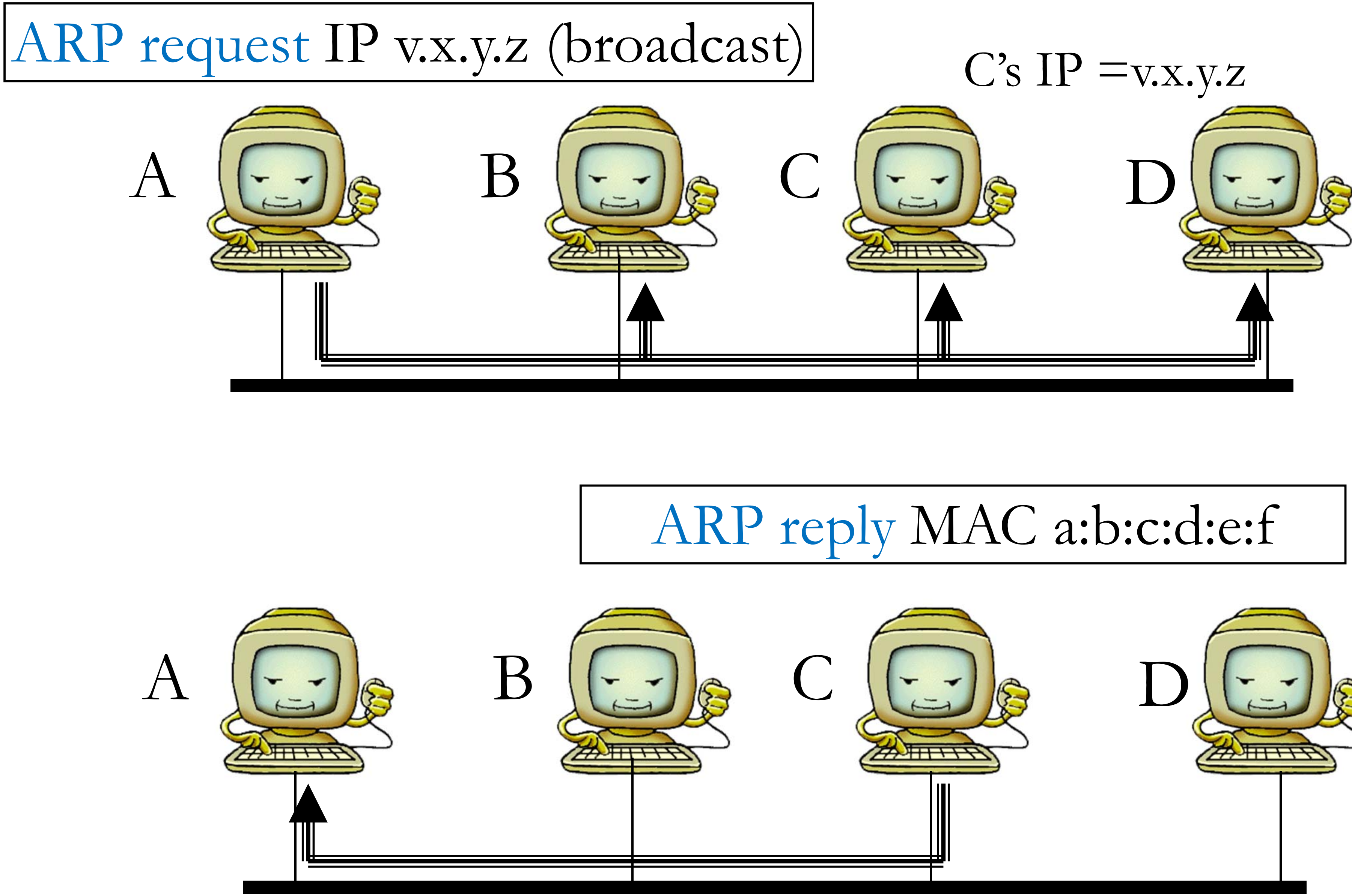
- Hosts have to know MAC addresses to be able to communicate on one LAN
- Find out the MAC/IP address mapping
  - IPv6 uses sub protocol of Neighbor Discovery Protocol (NDP)
  - IPv4 uses Address Resolution Protocol (ARP)

From IPv4 address to MAC address

ARP:

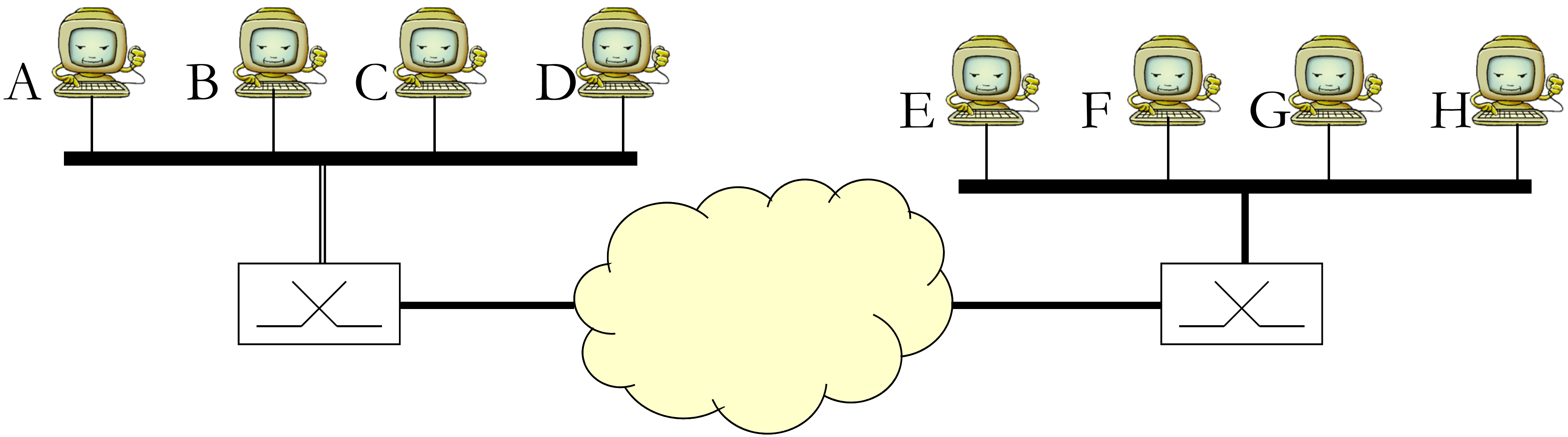
- Before transmitting an IP datagram sender must know of the corresponding MAC address on the same LAN
- ARP caches known IP/MAC address pair
- First look in ARP cache; if not found ask for it on the LAN

From IPv4 address to MAC address (2)



From IPv4 address to MAC address (3)

- If the IPv4 address is to another network the default gateway's MAC address has to be used

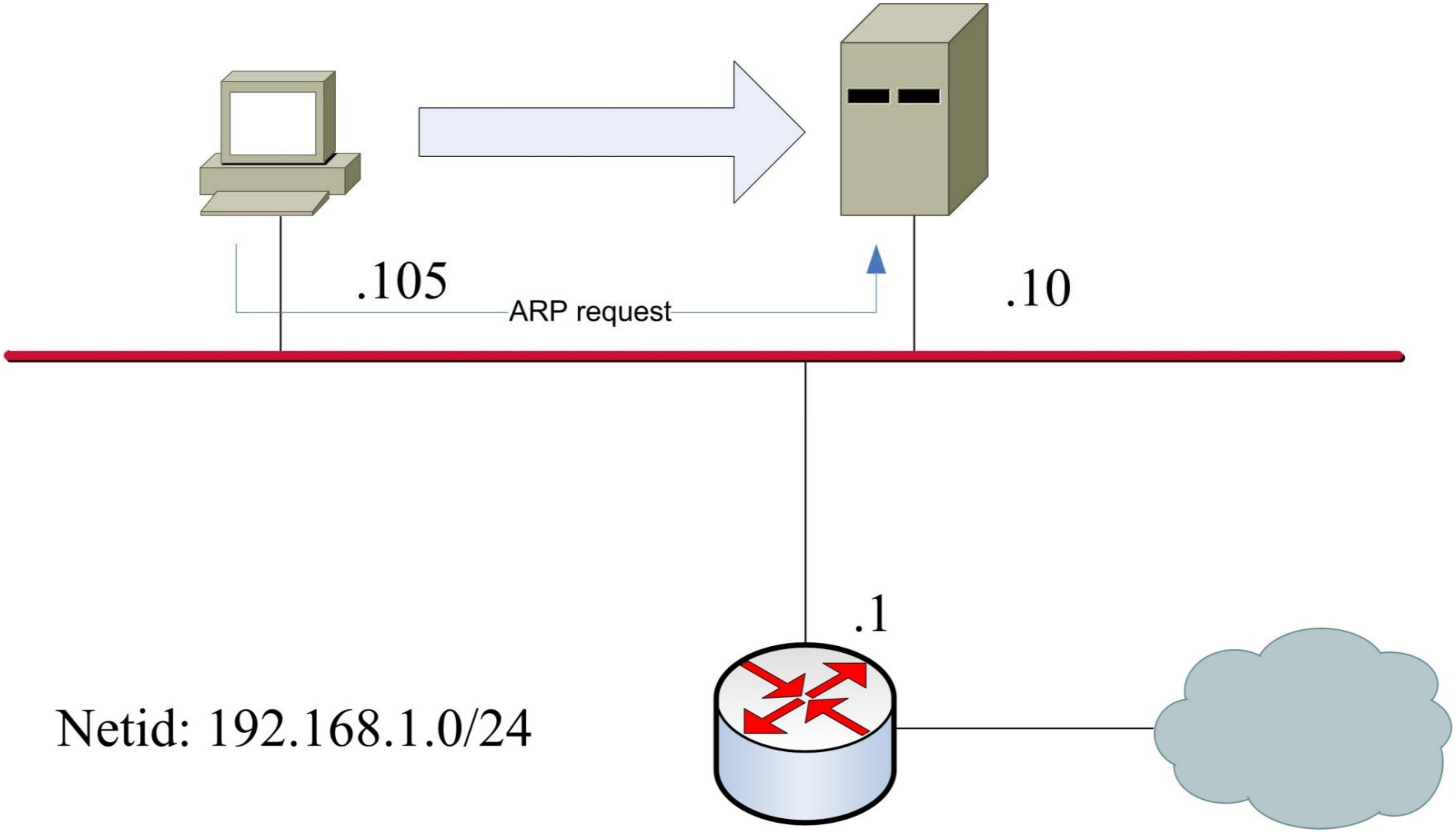


"Routing" in a host

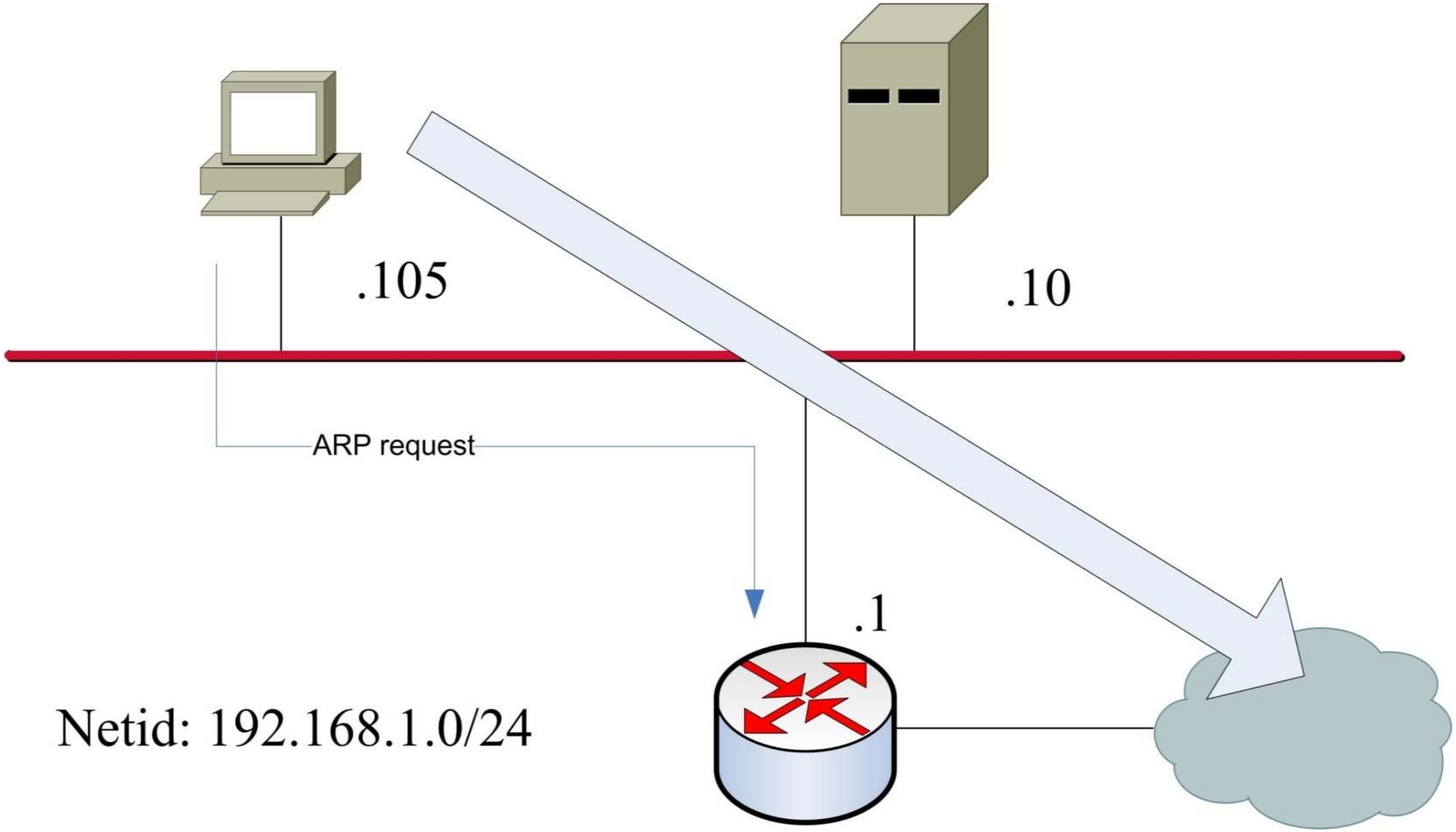
- Sending host must know
  - Is destination on same network?
  - If not, which is the path to the outside world?

- Compare own net id with destinations net id:
  - If the same: ARP request for destination's MAC address
  - If different: ARP request for default gateway's MAC address

ARP (1)



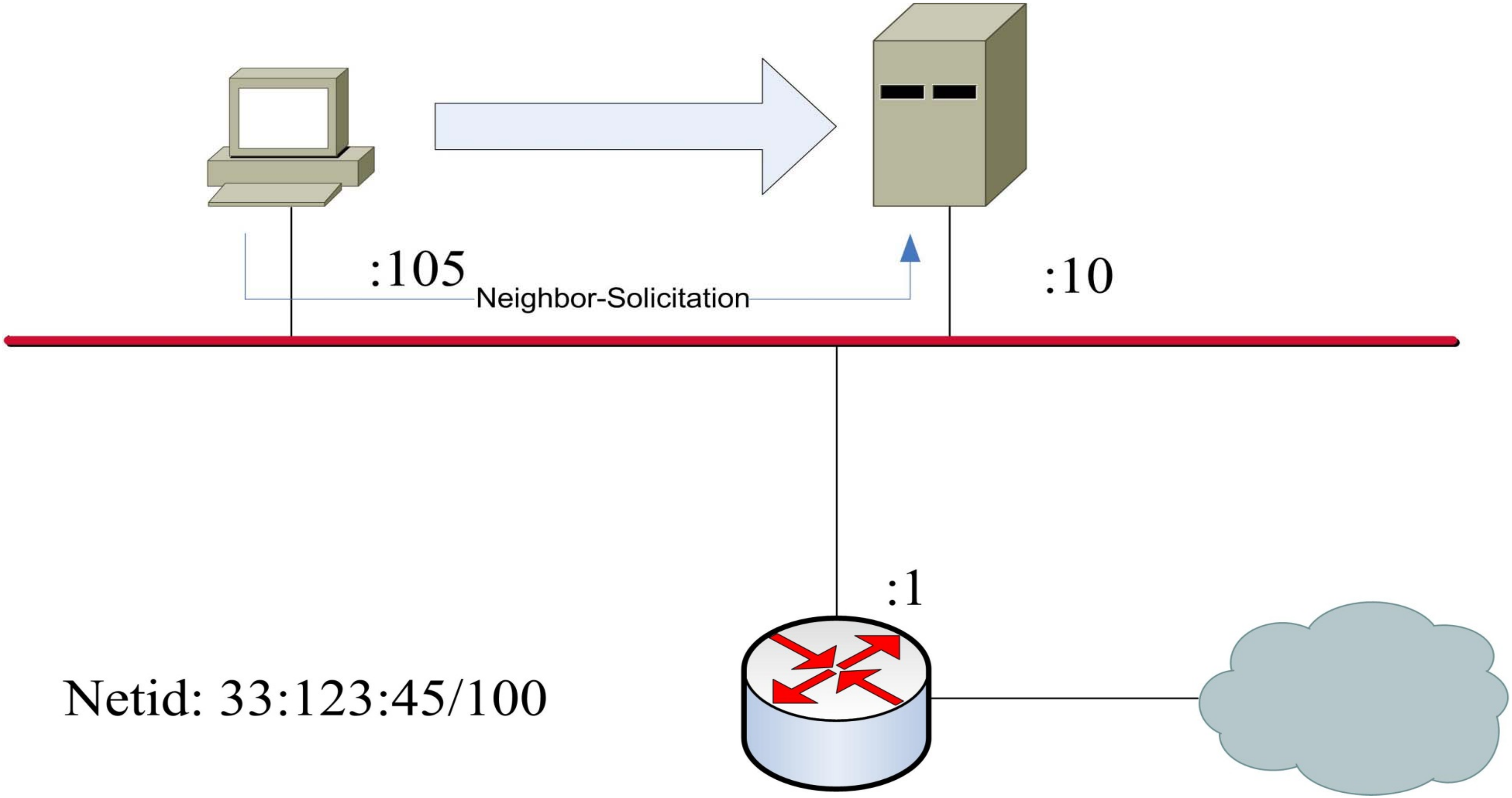
ARP (2)



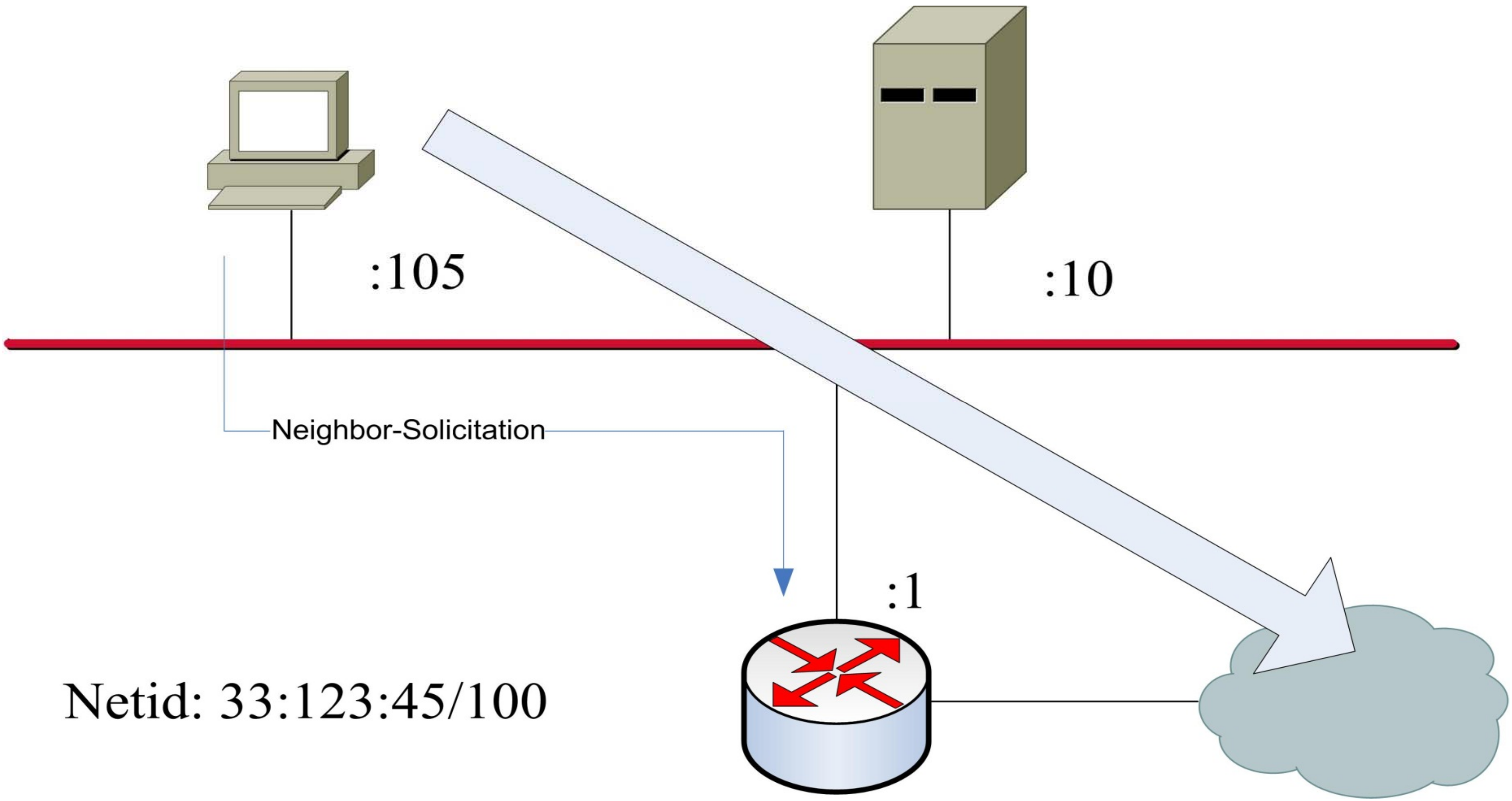
From IPv6 address to MAC address

- 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

NDP (1)



NDP (2)



NDP (3)

Also Automatic Configuration

- Network Discovery
- Host ”invents” own address
- Ask all stations on the LAN if there is a conflict
- Requests net id and default gateway’s address