

## ETSF05/ETSF10 – Internet Protocols

SMTP

FTP

TFTP

DNS

SNMP

...

BOOTP

SCTP

TCP

UDP

## Higher Layer Protocols

IGMP

ICMP

IP

ARP

RARP

2013, Part 2, Lecture 3.1 and 3.2

Underlying LAN or WAN  
technology

Jens Andersson (Kaan Bur)



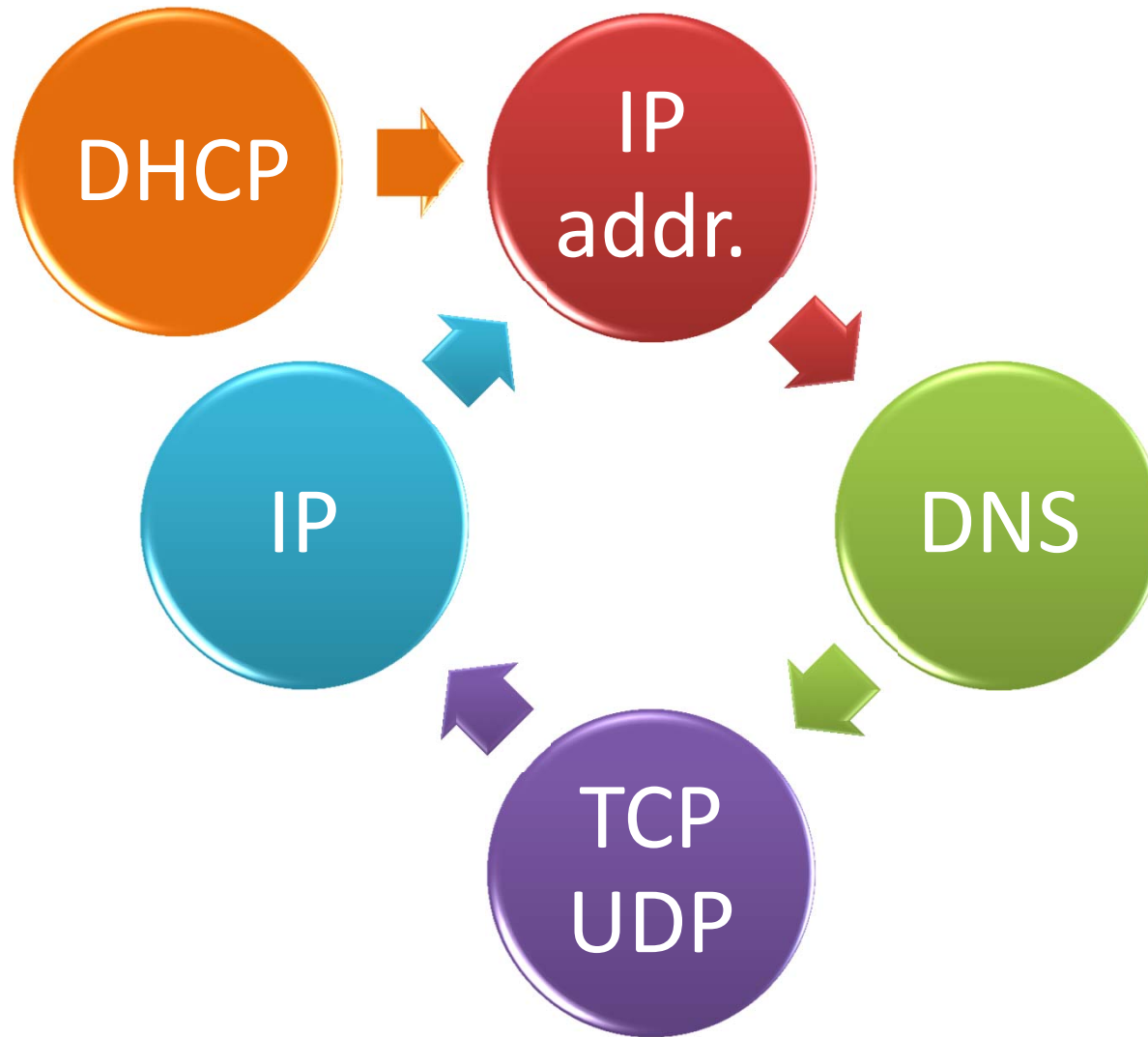
# Part 3

- Finding IP addresses: DHCP, DNS
- Network performance
- Quality of Service
- Real Time Application Considerations and Transport Layer Protocols
  
- See study guide for chapters in text book

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# *Exercise: Break this vicious cycle!*

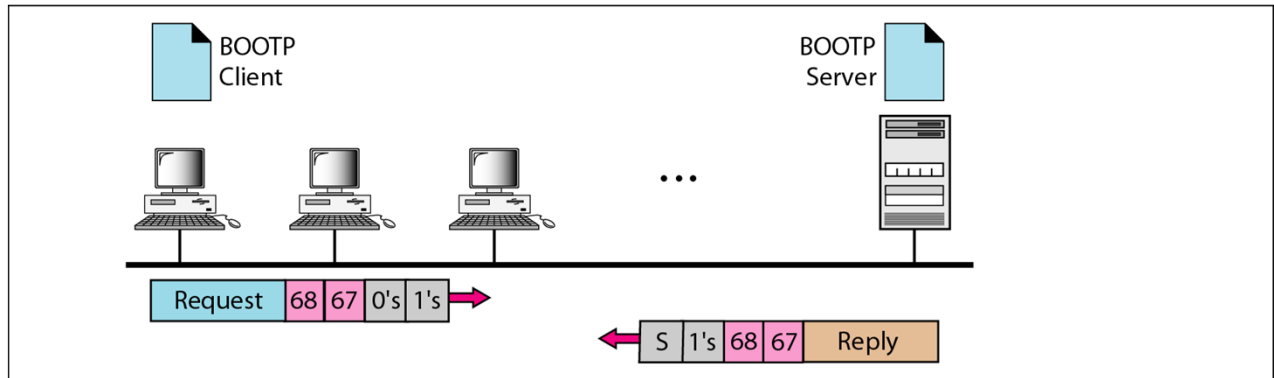


# What to configure

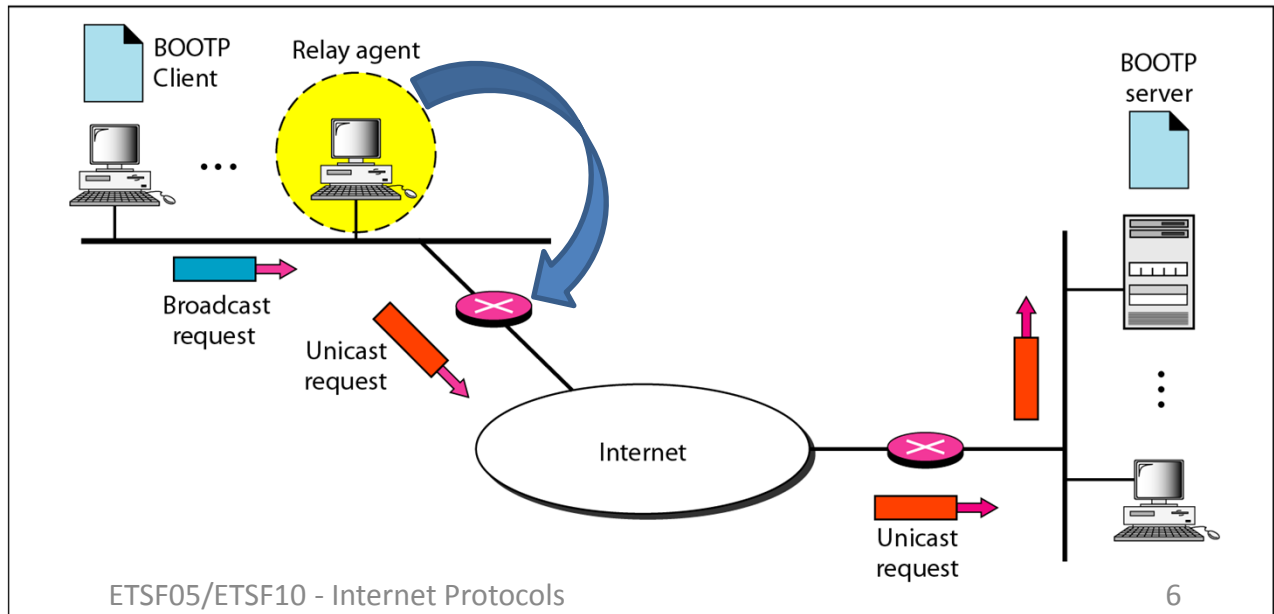
- IP address
- Net mask (specifies network id)
- Default Gateway (at least one)
- DNS server (at least one)
  - Server's ip address
- Other stuff
  - Configuration file
  - Image download

# Obtaining an IP address

- Bootstrap



a. Client and server on the same network

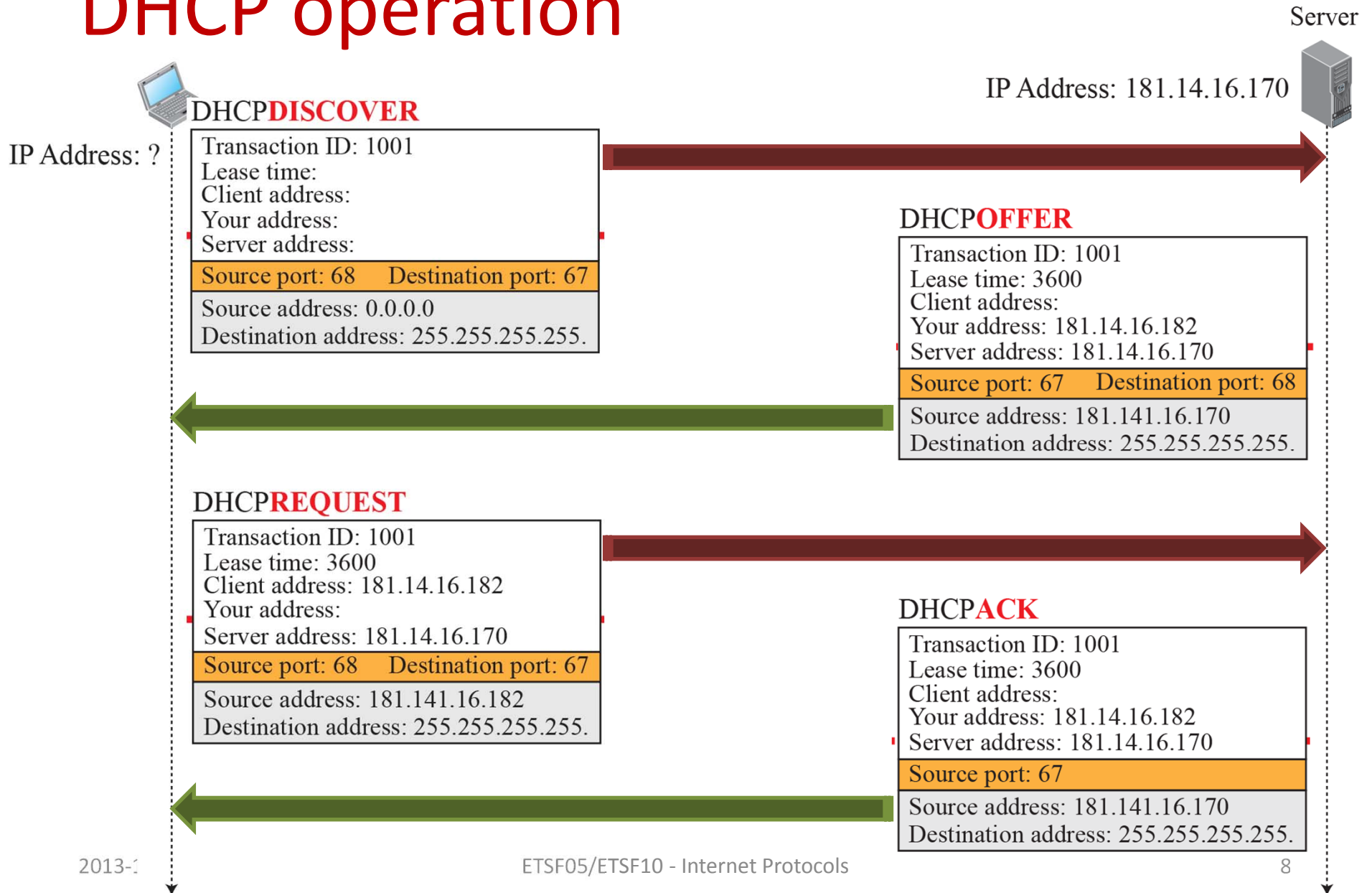


b. Client and server on different networks

# Dynamic Host Configuration Protocol

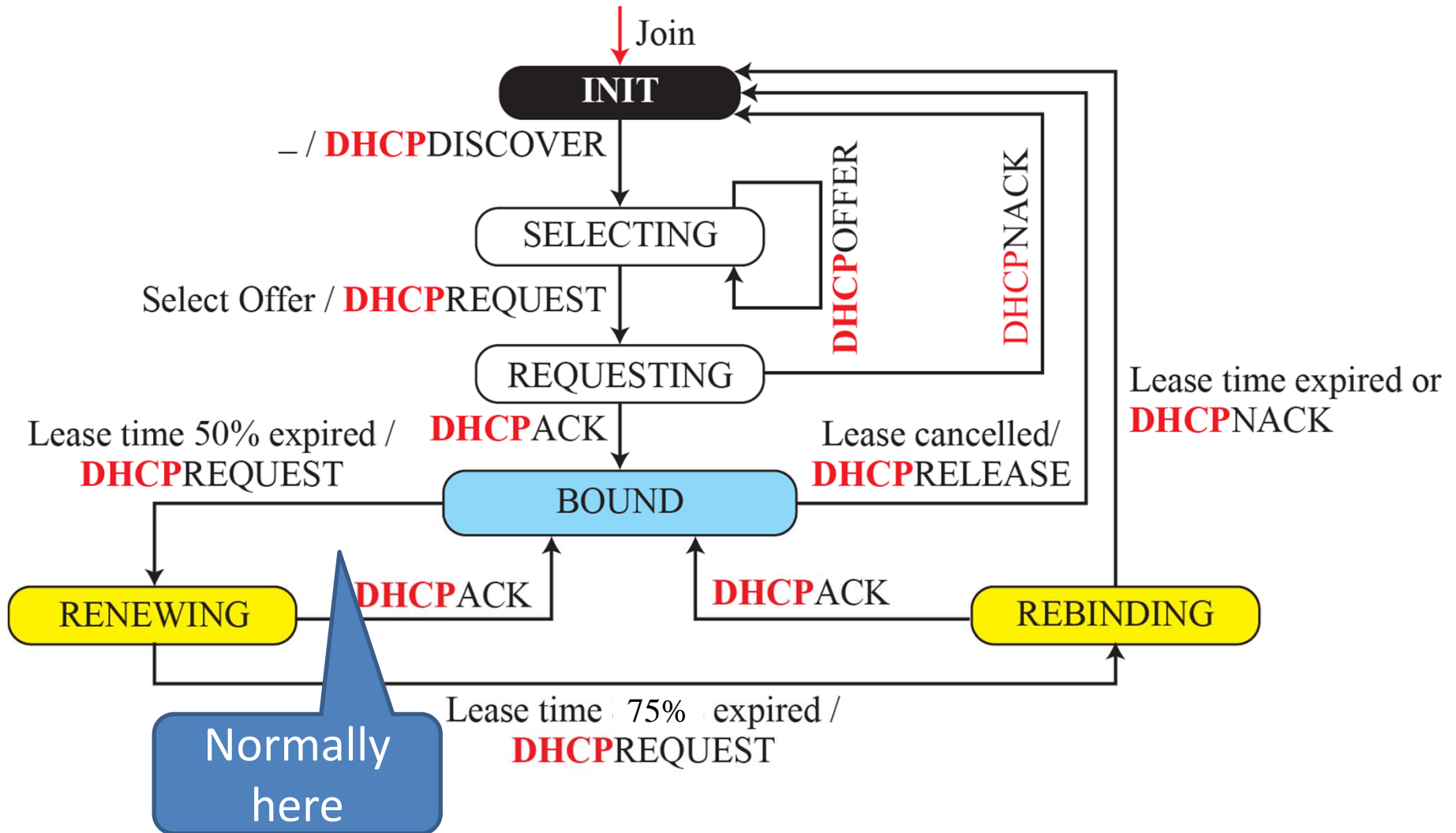
- BOOTP
  - Not dynamic!
- DHCP
  - IP address
    - Allocation from pool or static
  - Network mask
  - Default gateway
  - DNS server(s)

# DHCP operation



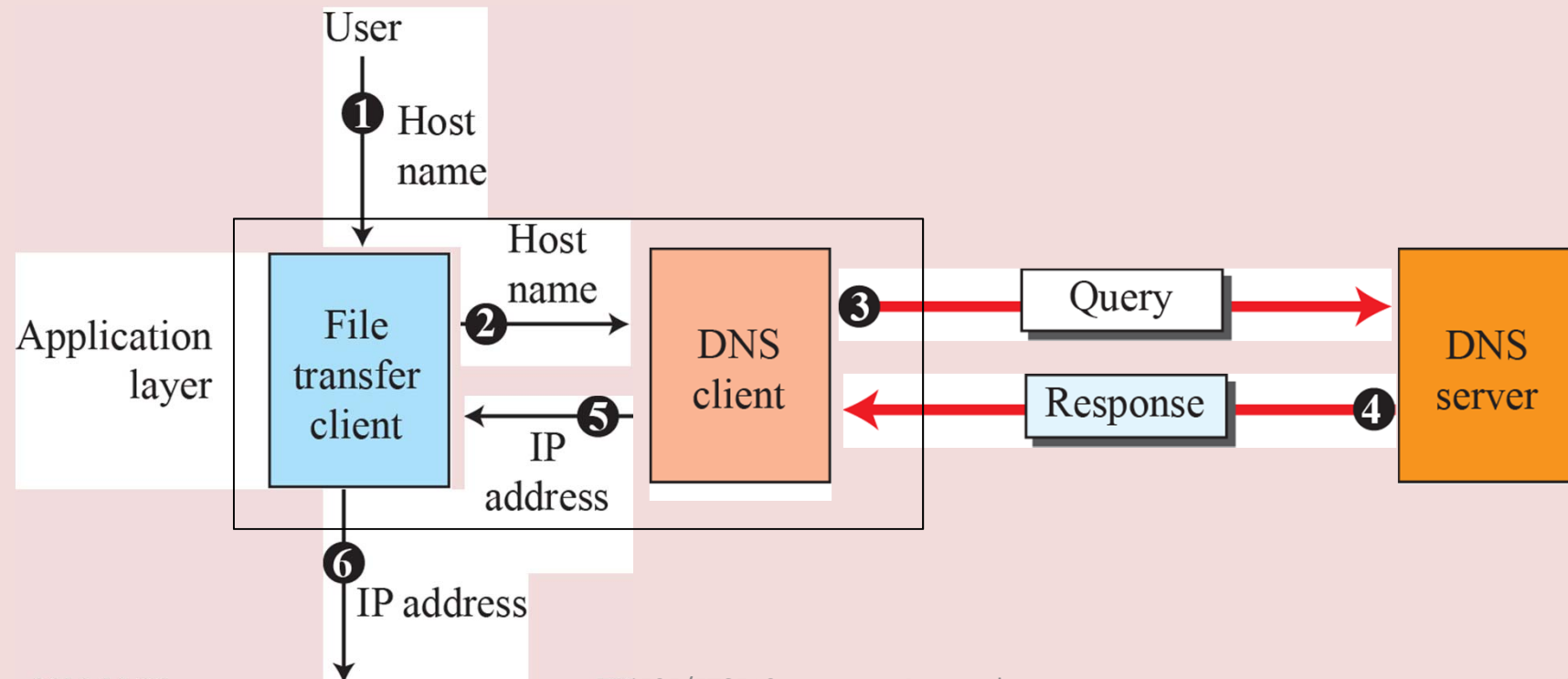


# DHCP states



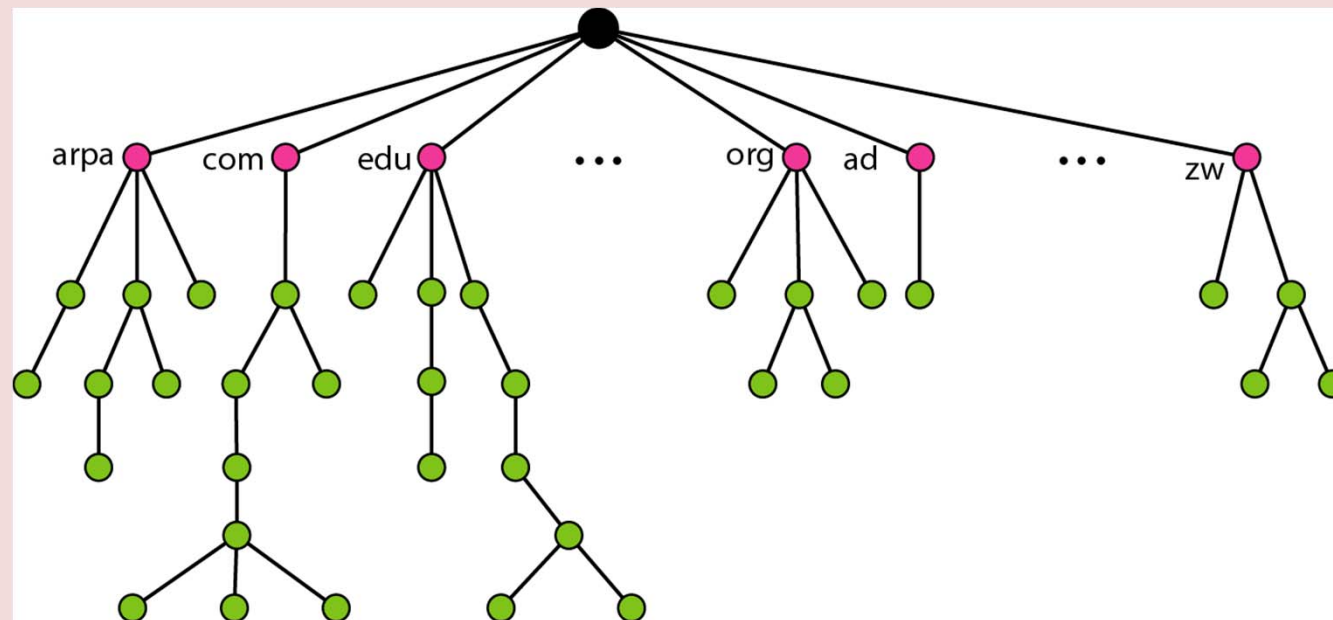
# Domain Name System (DNS)

- Internet's telephone book: Address  $\leftrightarrow$  name
  - One of the most important systems on the Internet

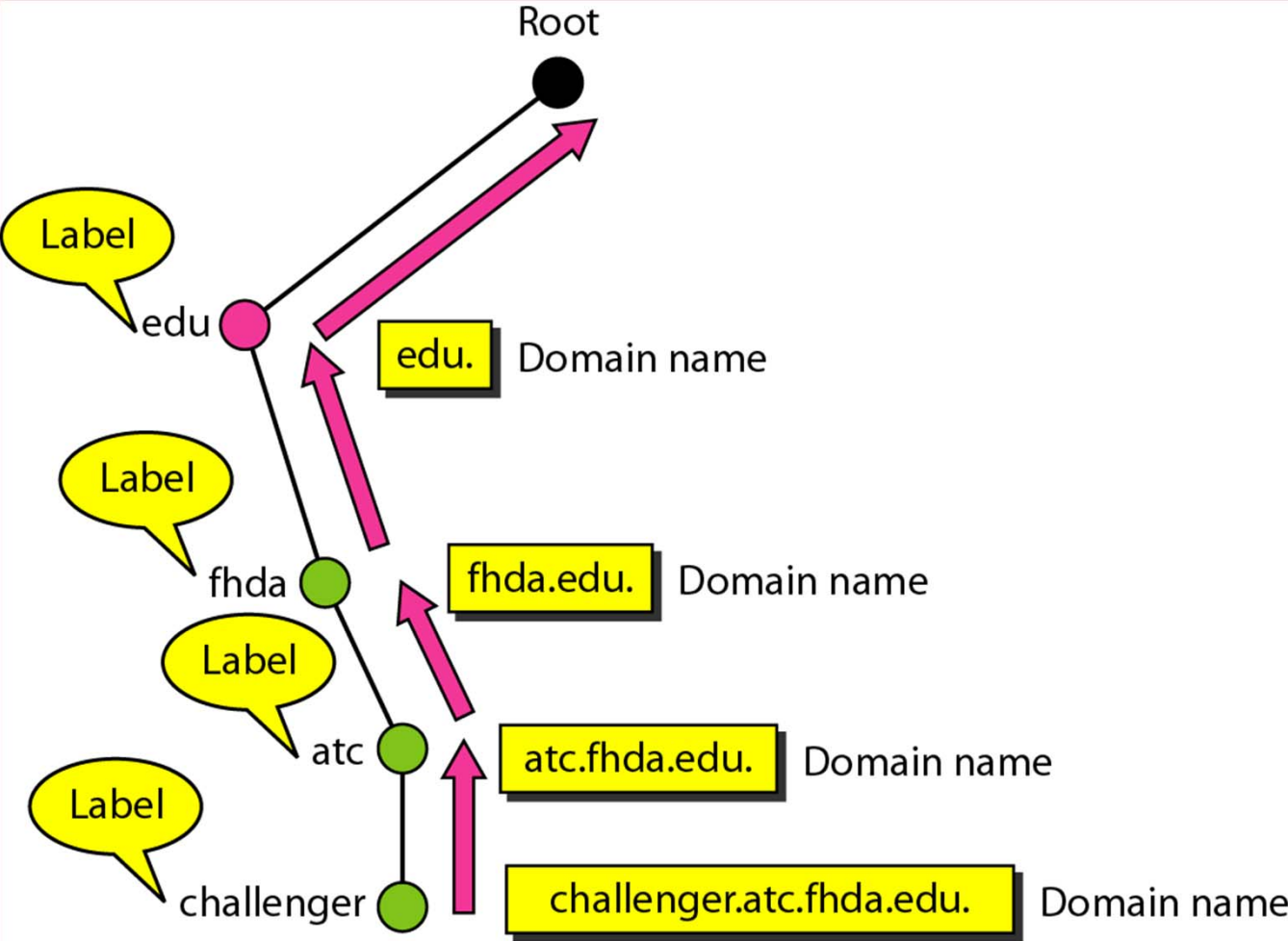


# Domain name space

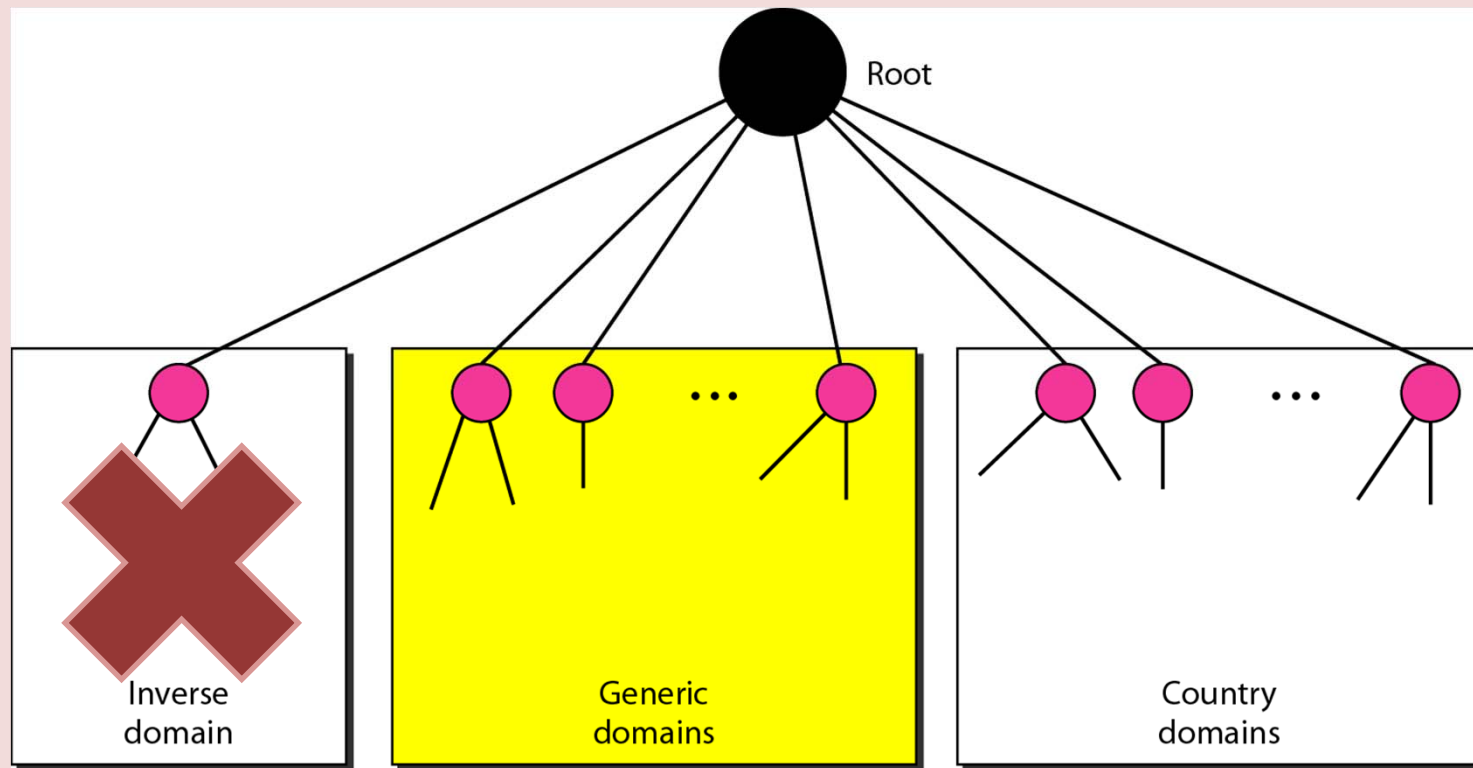
- Names must be unique
  - Complete control needed



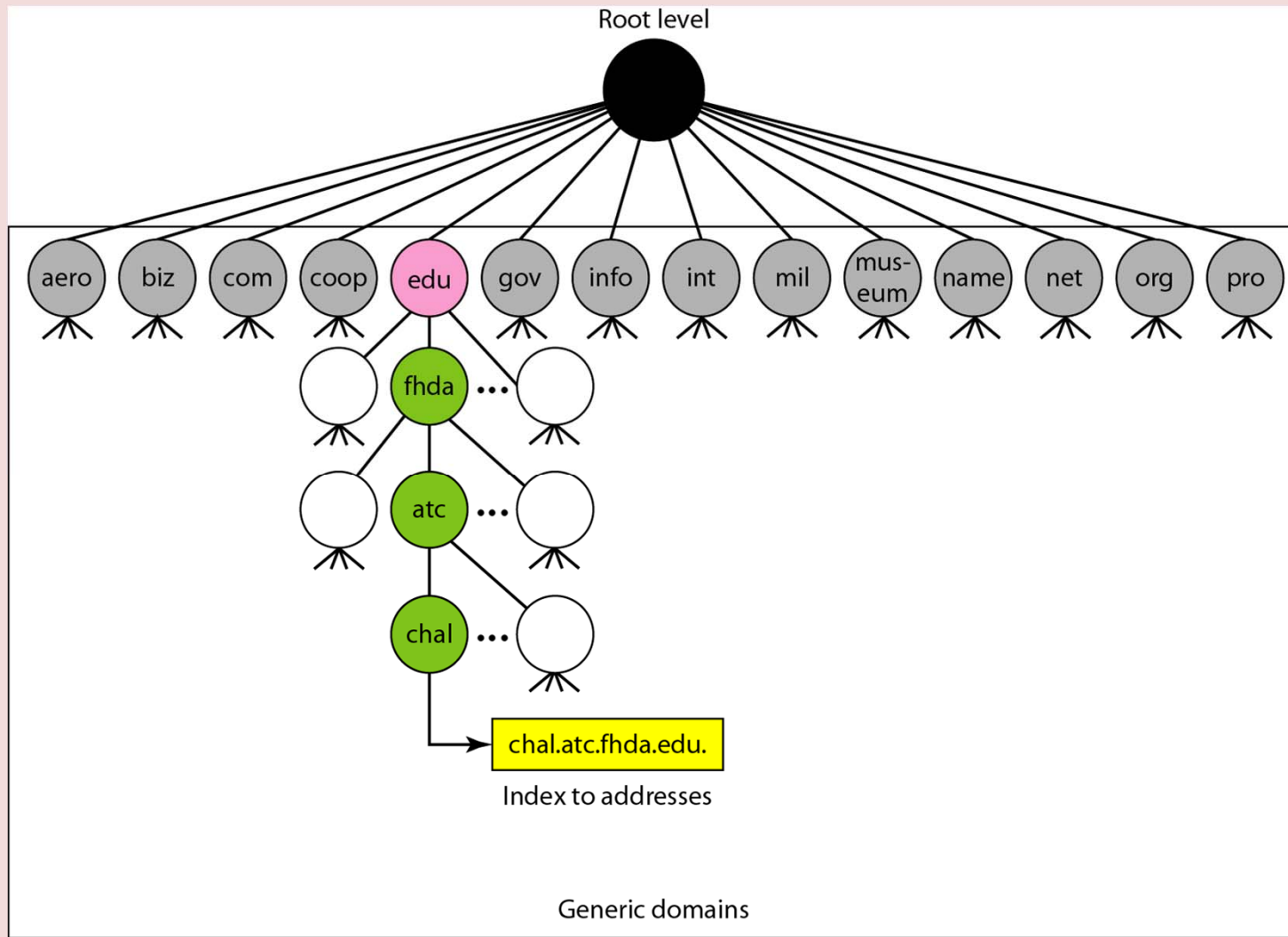
# Domain names and labels



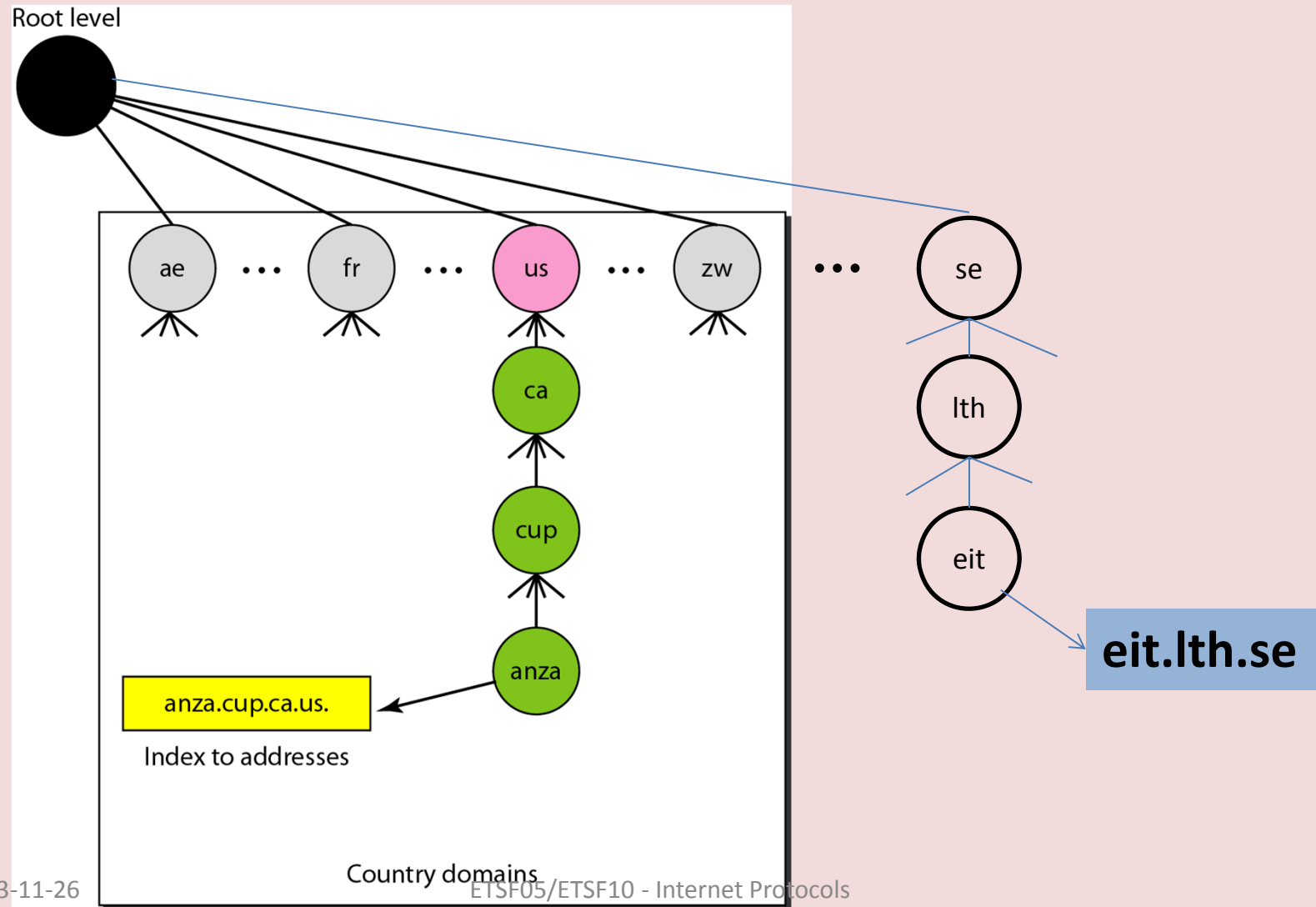
# Internet domains



# Generic domains

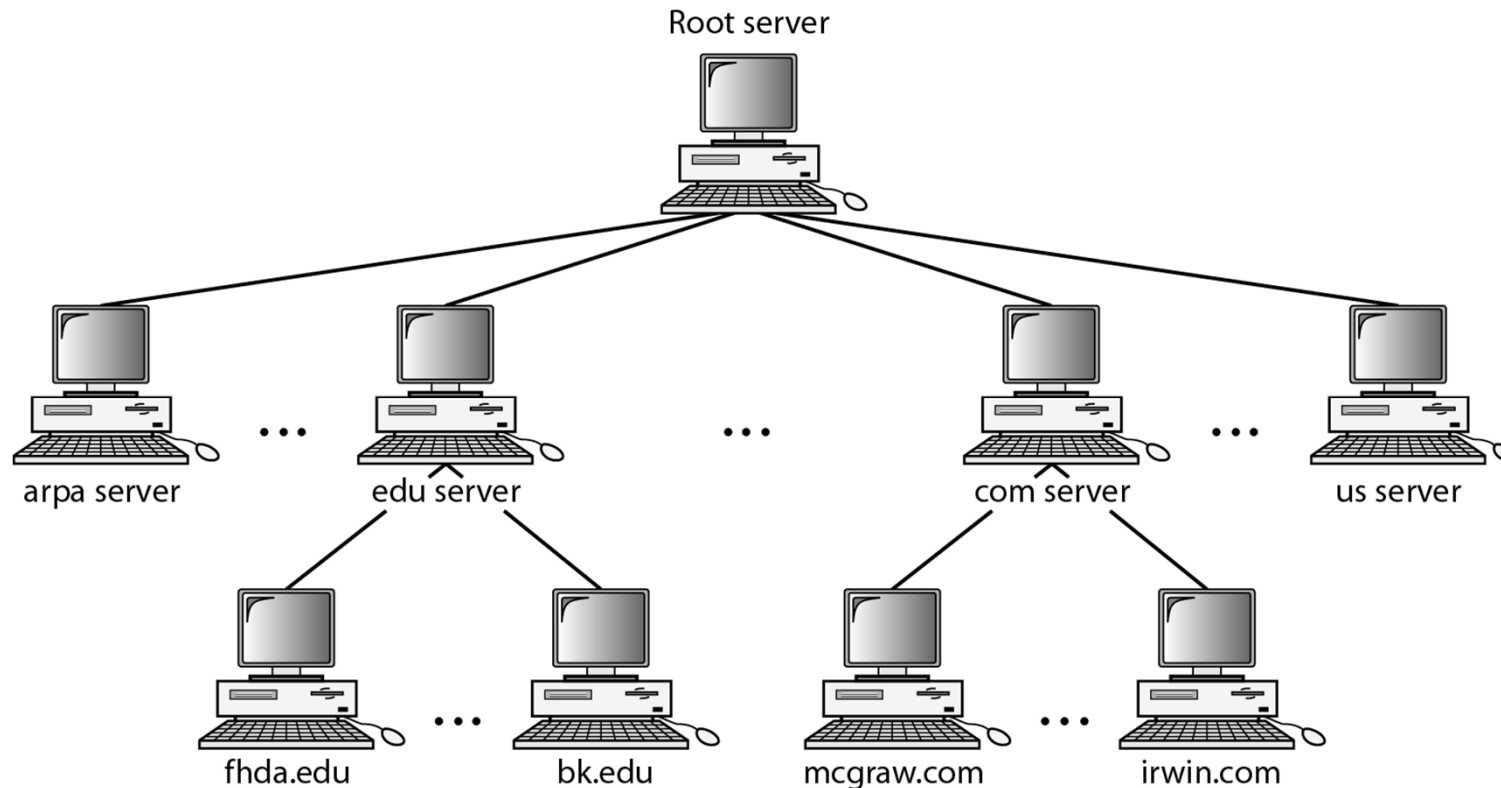


# Country domains



# Hierarchy of domain name servers

- 13 root servers impl. by 259 servers

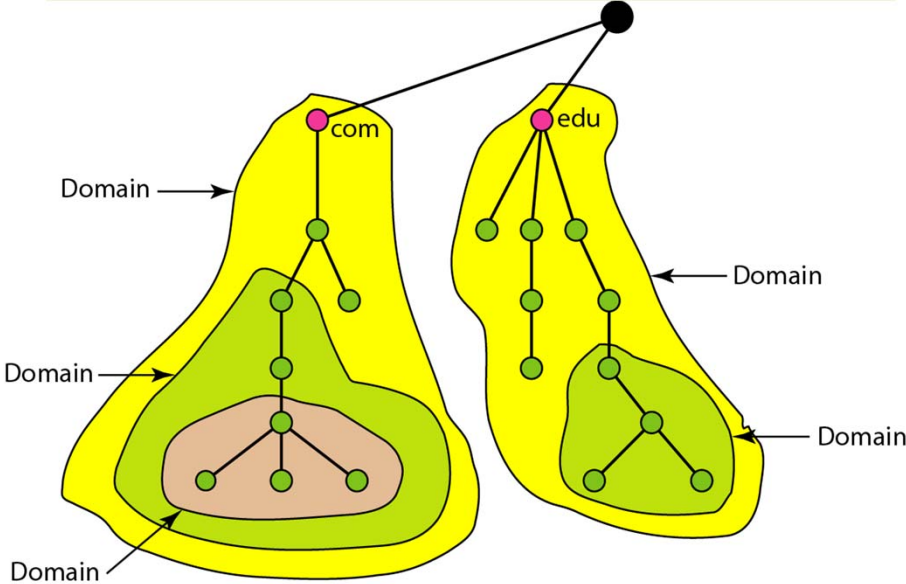




# Domains, subdomains, zones

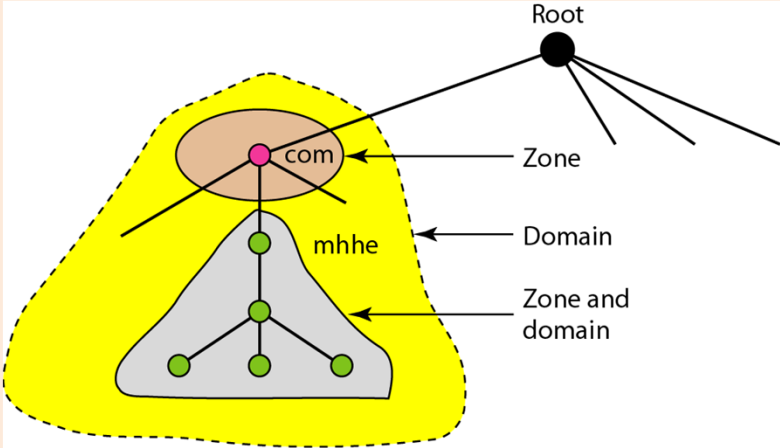
## Domain

- Subtree of DNS



## Zone

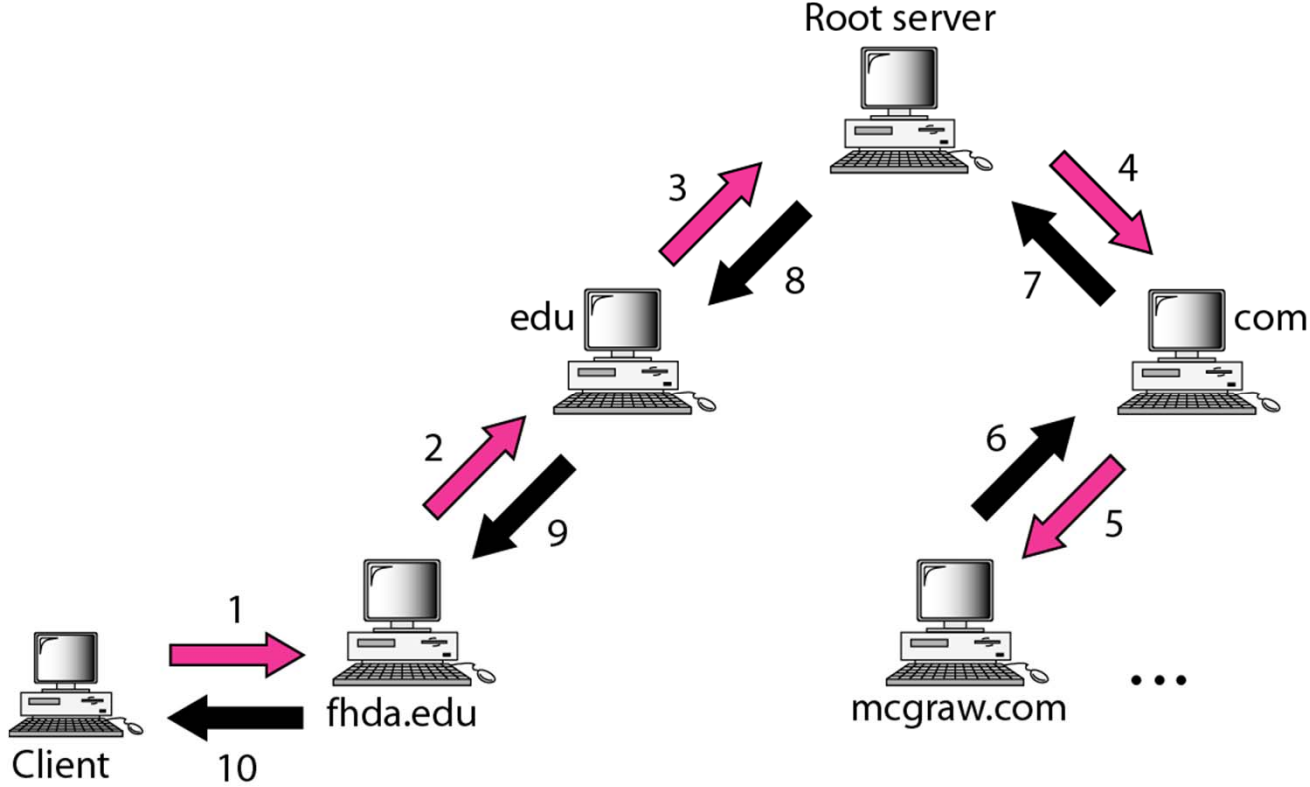
- Servers' control area



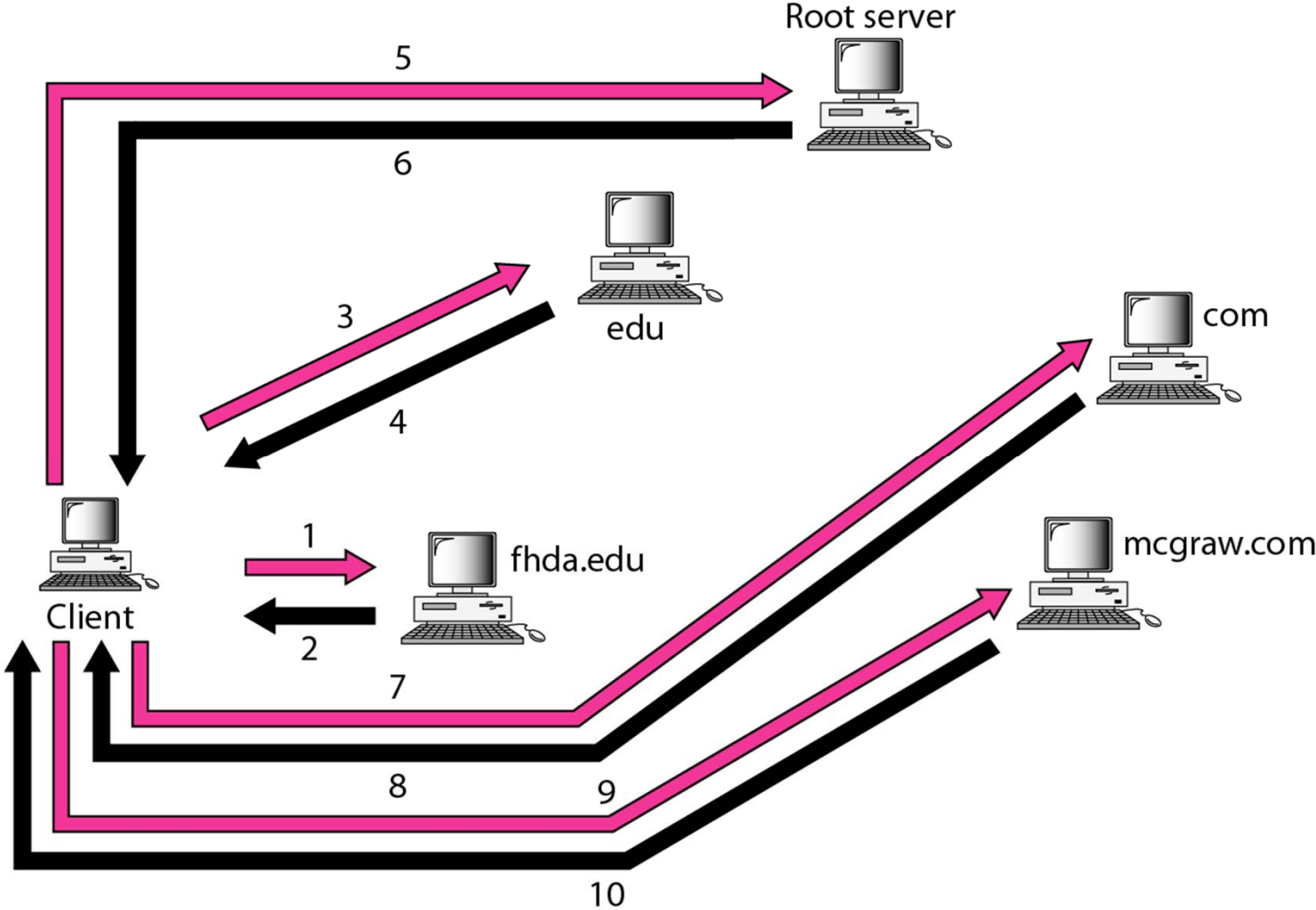
# Domain name resolution

- Action of address mapping
  - Client = resolver
  - Server = DNS
- One server cannot have all the answers!
  - How to ask others?
  - What to do with the answer?
- Caching
  - Remember what you've learned!

# Recursive resolution



# Iterative resolution



# DNS resource records

**(Domain Name, Type, Class, TTL, Value)**

<i>Type</i>	<i>Interpretation of value</i>
A	A 32-bit IPv4 address (see Chapter 4)
NS	Identifies the authoritative servers for a zone
CNAME	Defines an alias for the official name of a host
SOA	Marks the beginning of a zone
MX	Redirects mail to a mail server
AAAA	An IPv6 address (see Chapter 4)

# Dynamic DNS

- Host may move around
  - Change of IP address
- New domains may emerge
  - Binding (IP address  $\leftrightarrow$  Name)
  - DHCP updates primary DNS server
  - Primary server updates zone
  - Secondary servers notified

# DNSsec

- Provides
  - Message origin authentication
  - Message integrity
- Protect against
  - Forged or manipulated data
- No confidentiality
- Digital signature

# Part 3

- Finding IP addresses: DHCP, DNS
- **Network performance**
- Quality of Service
- Real Time Application Considerations and Transport Layer Protocols
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# Network performance

- Bandwidth
  - Bits per second (capacity)
- Throughput
  - Efficiency, always less than capacity ( $<1$ )
- Latency (Delay)
  - Transmission, propagation, processing, queueing
- Jitter → real-time data!

## *Exercise: Find the delays.*

- Given:**
- Packet size 1 MB
  - Bandwidth 200 Kbps
  - Propagation speed  $2 \times 10^8$  m/s
  - Link length 2.000 km

### *Transmission delay?*

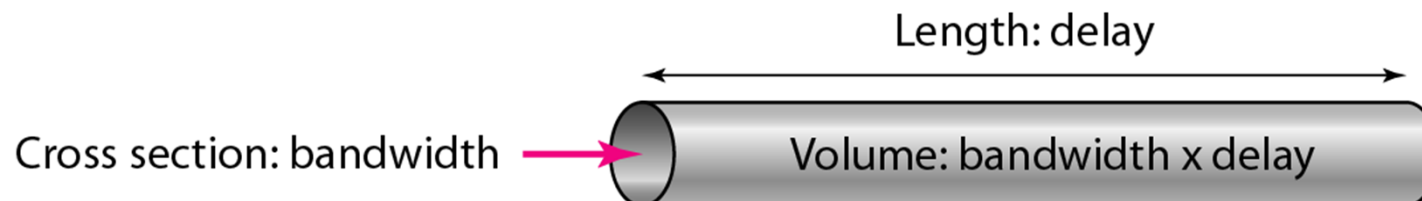
$$d_t = \frac{\textit{packet size}}{\textit{bandwidth}}$$
$$= \frac{8 \times 10^6 b}{200 \times 10^3 b/s}$$

### *Propagation delay?*

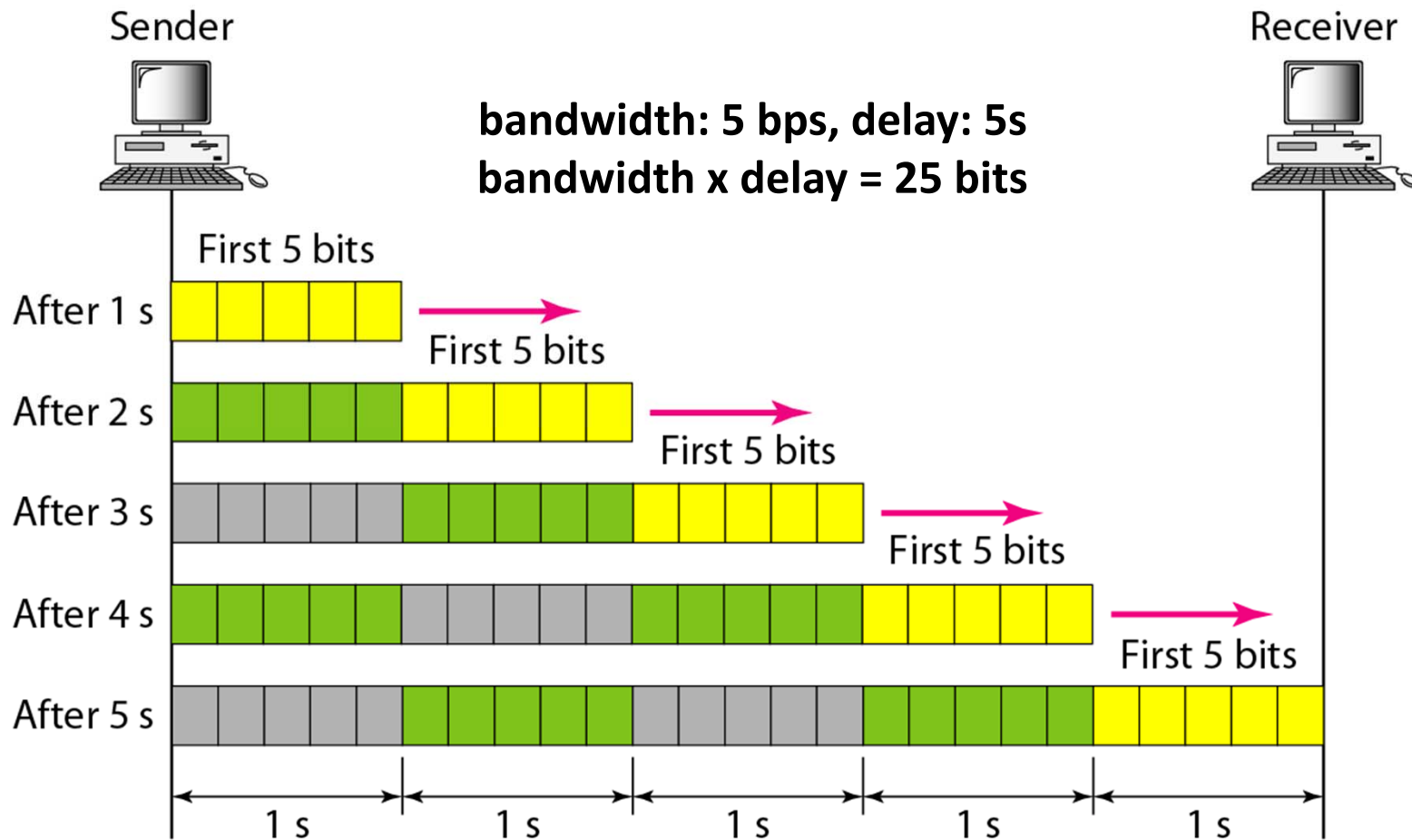
$$d_p = \frac{\textit{link length}}{\textit{speed}_p}$$
$$= \frac{2 \times 10^6 m}{2 \times 10^8 m/s}$$

# Bandwidth-delay product

- How much data fills the link
- One Way Delay
- Two Way Delay = Round Trip Time (RTT)  
Time for data + time for ACK



# Bandwidth-delay product



# Bandwidth-delay product

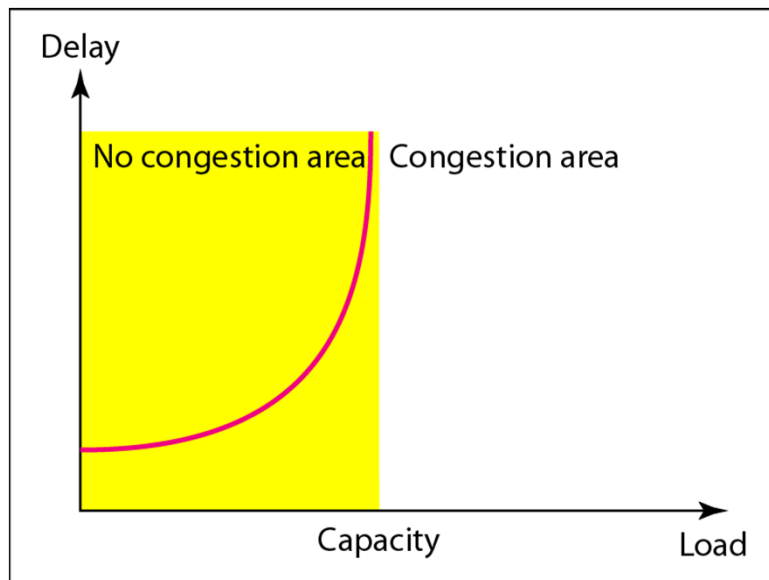
- Important for congestion avoidance
  - Don't overfill the link
- Important for efficiency
  - Keep the link filled at all times
  - For max efficiency
    - Data chunks  $> 2 * \text{bandwidth} * \text{delay}$

# Bandwidth-delay product

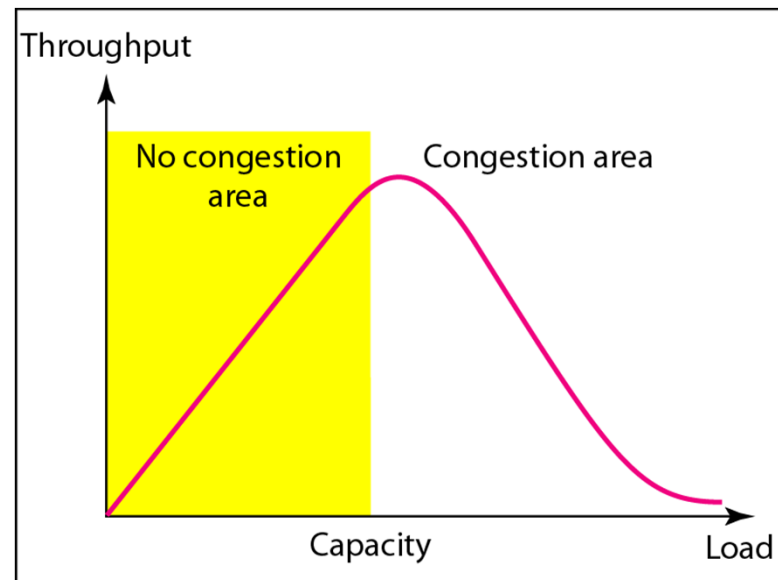
- Important for tuning (TCP)
- Long Fat Network (LFN, "elephant")  
BDP  $\gg 10^5$  bits
- Very long (high delay) links:
  - > Bandwidth = BDP/delay
  - But it takes long time before ACK arrives ...

# Delay and throughput

- Related to network load
  - Normal operation vs. congestion



a. Delay as a function of load



b. Throughput as a function of load

# Packet loss

- Due to
  - Bit error in packet
    - Discard erroneous packet
    - Link or Physical Layer?
  - Queue overflow
    - Discard packets
    - Node problems
- In real time multimedia late packets considered lost
- Packet loss ratio (%)
- Note TCP's sensitivity to packet loss



# Other parameters

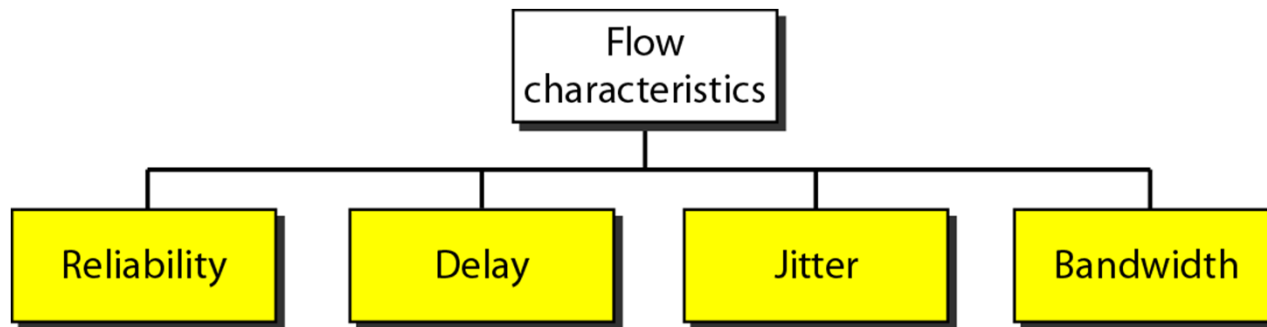
- Bit Error Rate
  - L1 parameter that heavily impacts with L3
- Packet Delay Variations
  - “Jitter”
  - Inter Packet Gap variations
- Ratio of packets out of order
  - Impact on delay in TCP

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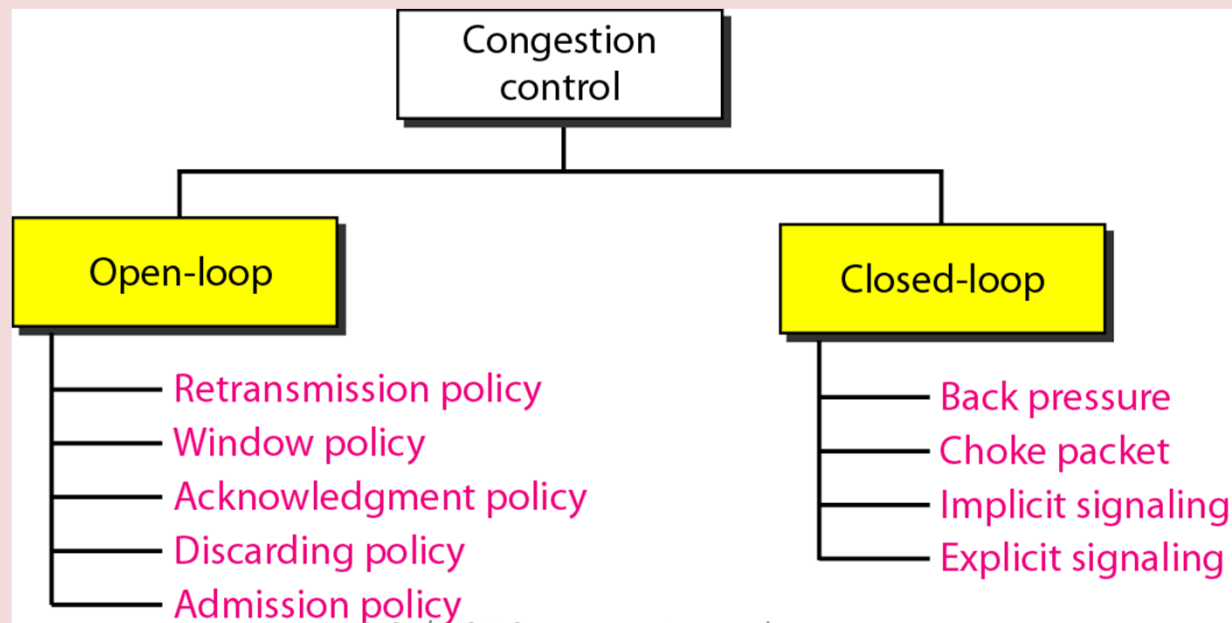
# Quality of Service (QoS)

- Maintaining a functioning network
  - Meeting applications' demands
  - Dealing with flow characteristics



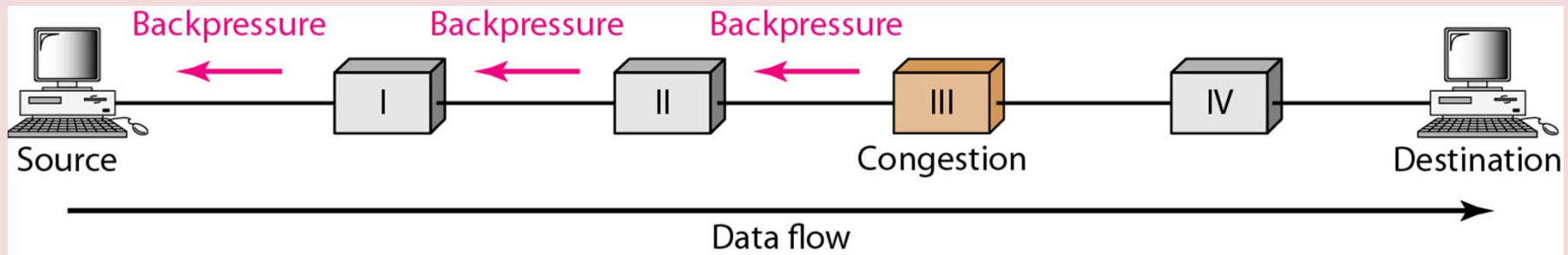
# Congestion control

- Avoiding and eliminating congestion
  - Open-loop = proactive
  - Closed-loop = reactive



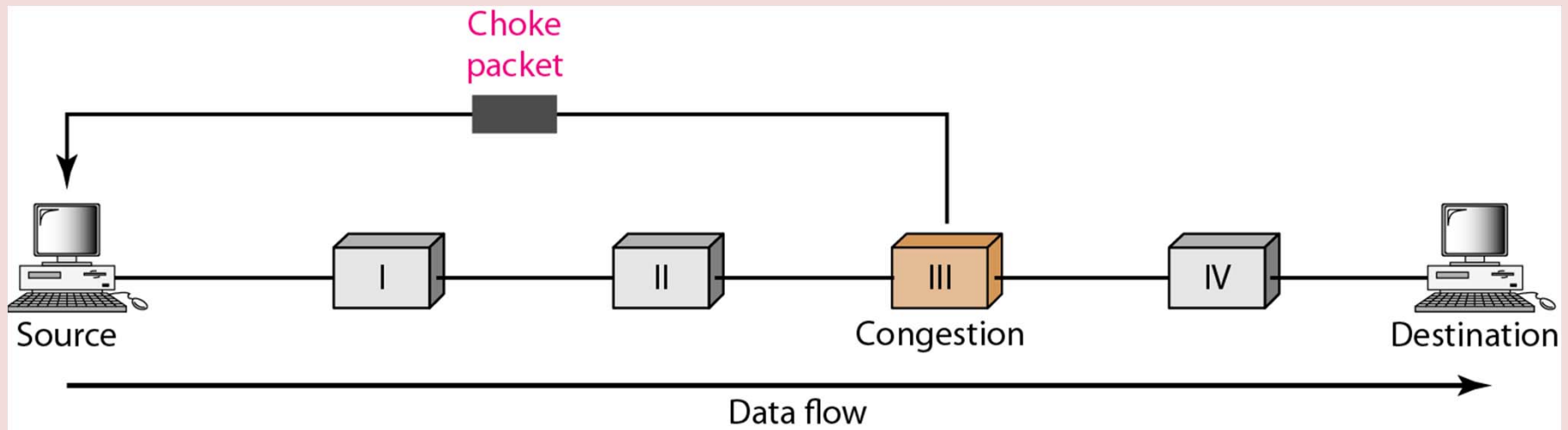
# Closed-loop congestion control (1)

- Backpressure



# Closed-loop congestion control (2)

- Choke packet



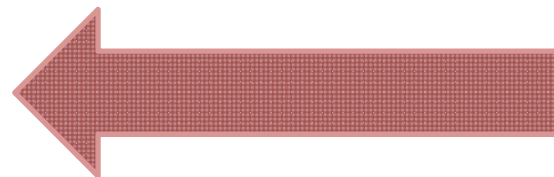
# How to improve QoS

- Admission control
- Resource reservation
- **Scheduling**
- **Traffic shaping**



**Identified during  
online discussion.  
Question: Where to  
implement them?**

- **Routing?**



# Support from routing protocols?

## *Yes!*

- Optimal path
  - Single metric
  - Multiple metrics?
- Multiple paths
  - Load sharing
  - Load balancing
- QoS routing
  - Cross-layer approaches
  - OSPF extensions (RFC2676)

## *Well, sort of!*

- Applies to all traffic
  - No differentiation between flow types
- What about inter-domain?
  - No control over network resources
- More sophisticated mechanisms needed
  - Multiprotocol Label Switching (MPLS)

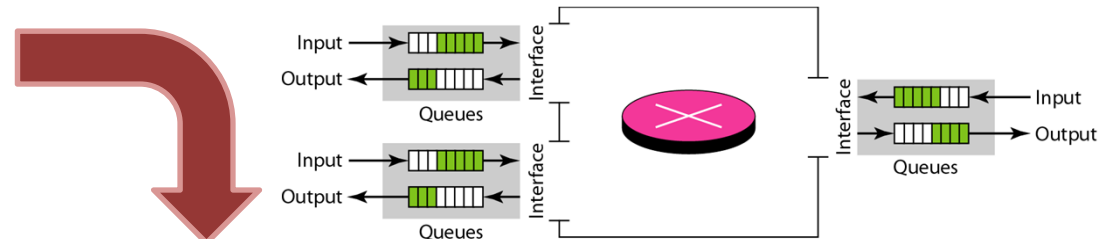


# Where to improve QoS?

- Admission control
  - INTSERV, DIFFSERV
- Resource reservation
  - RSVP

and  
underlying WAN technologies:  
**ATM**

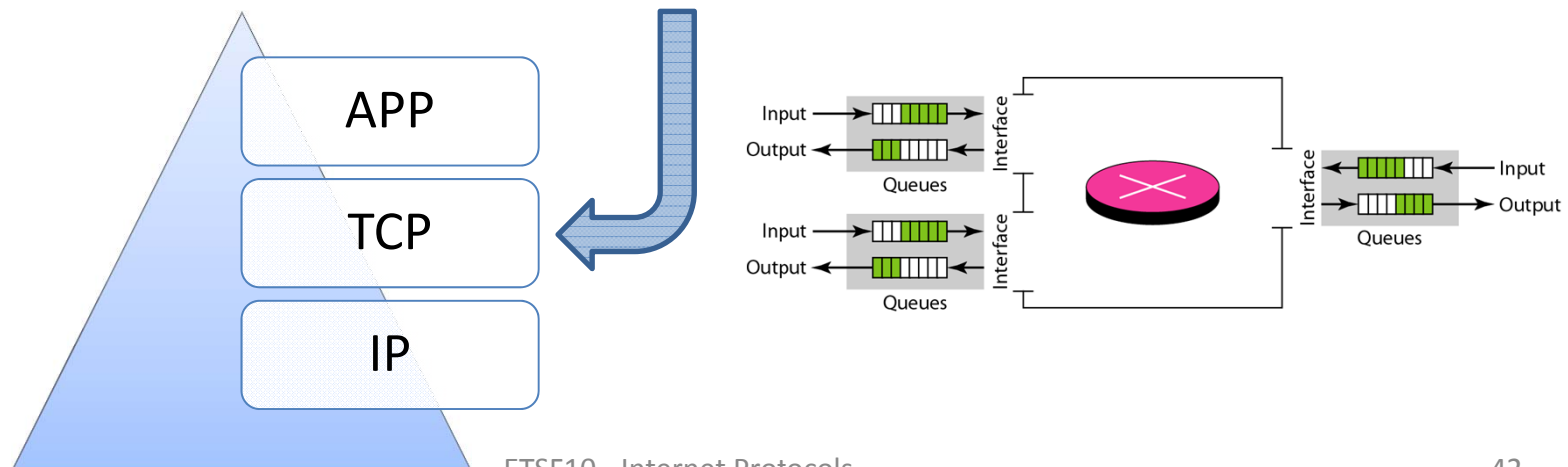
- Scheduling
- Traffic shaping



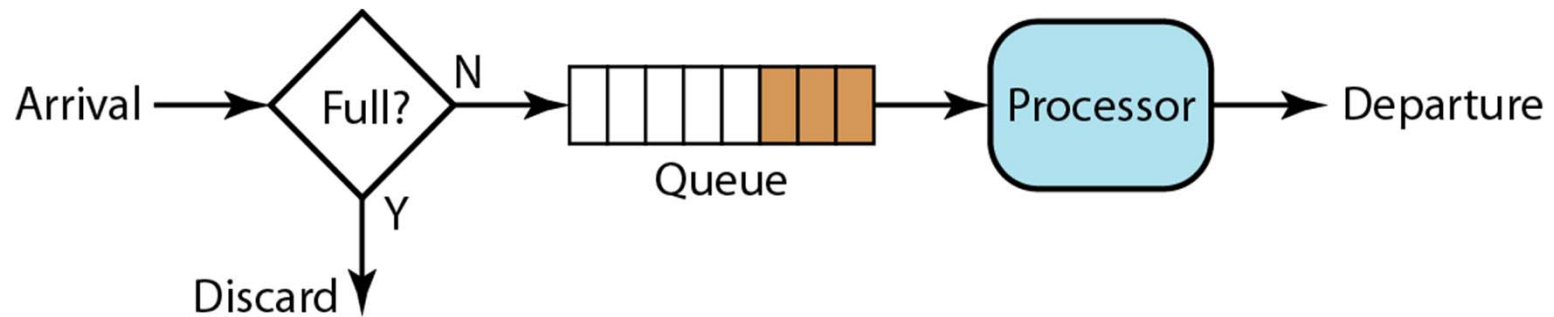
**ANYWHERE YOU FIND QUEUES!**

# Congestion avoidance

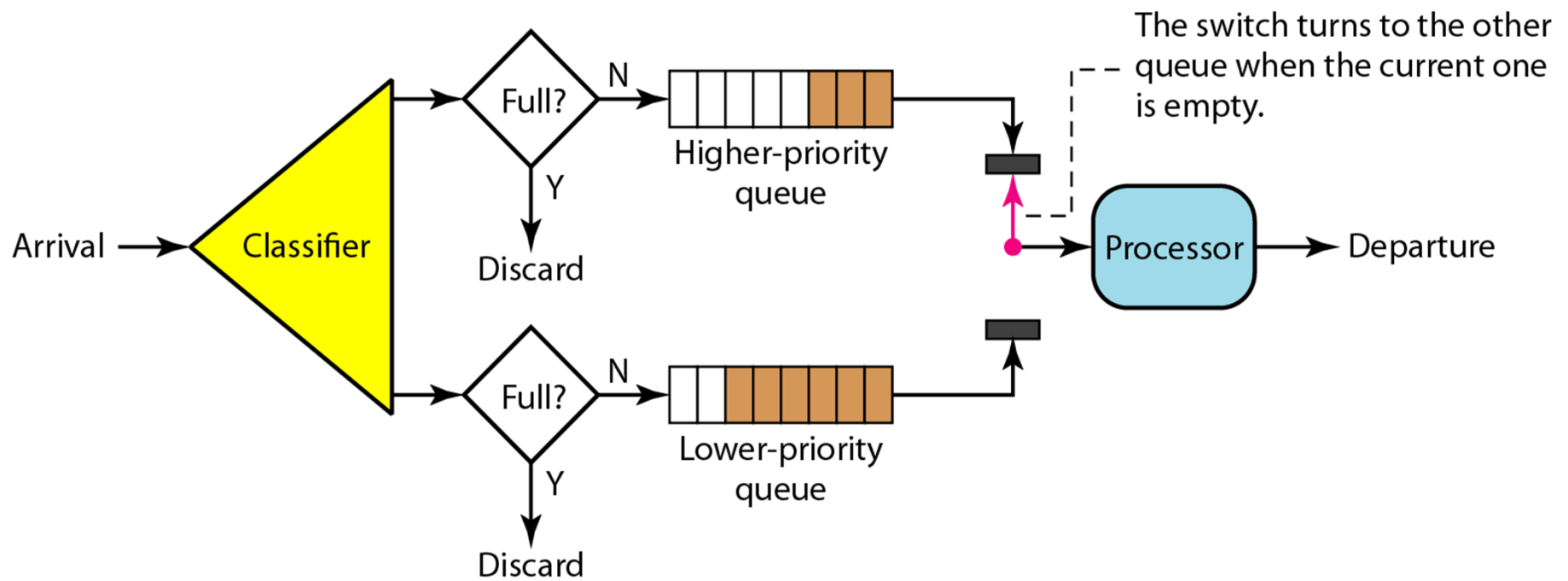
- Congestion = data load > network capacity
  - Arrival rate > processing rate
  - Processing rate > departure rate
- A simple method
  - Random early discard (RED)



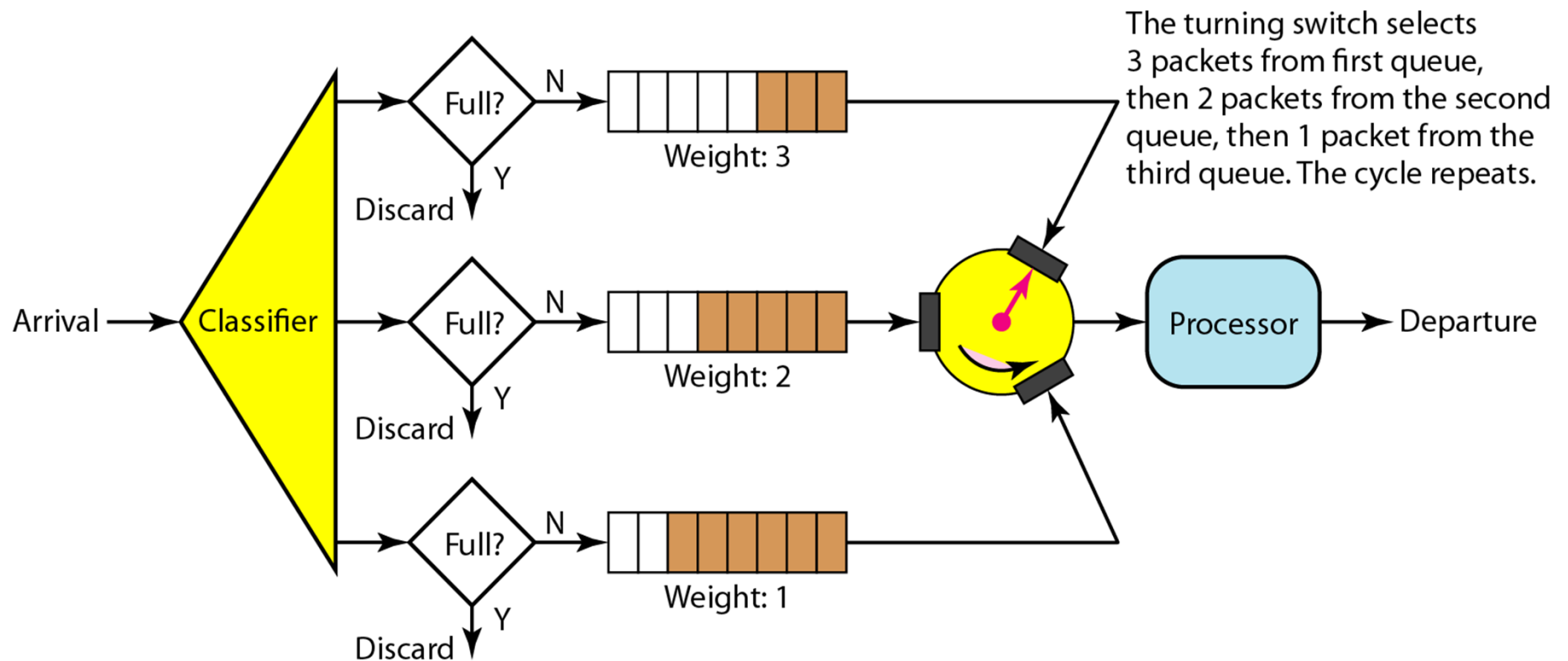
# Scheduling: *FIFO queuing*



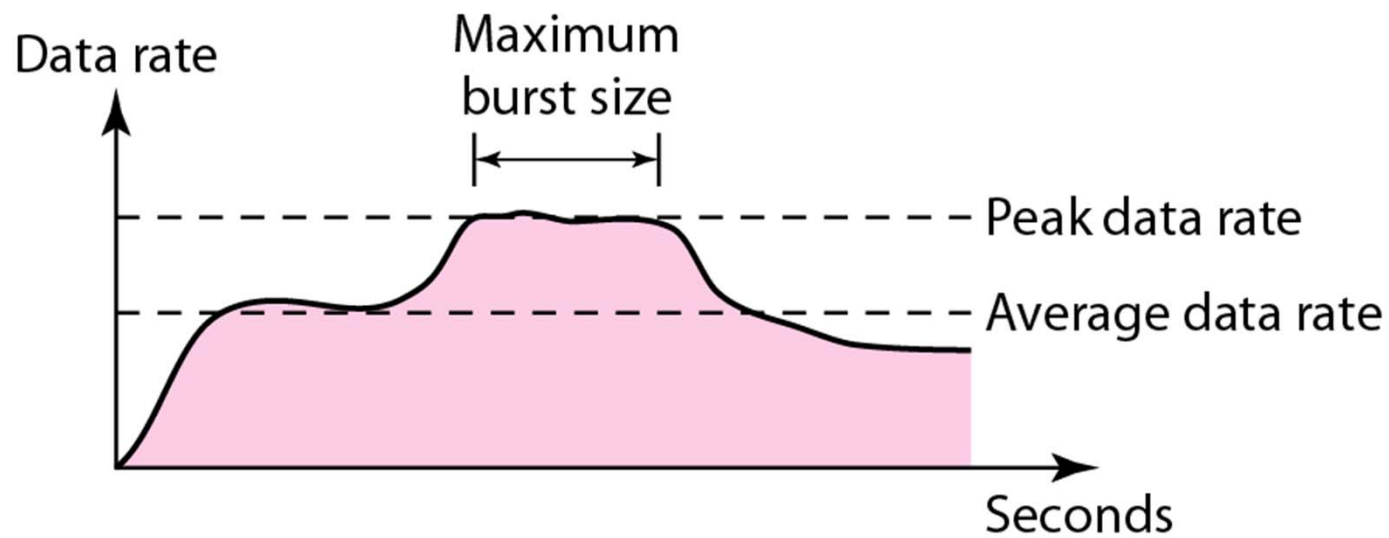
# Scheduling: *Priority queuing*



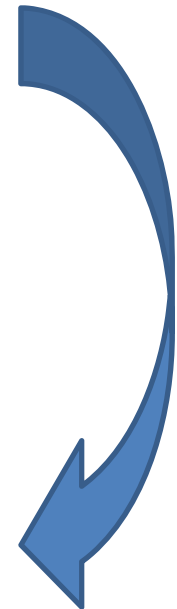
# Scheduling: *Weighted fair queuing*



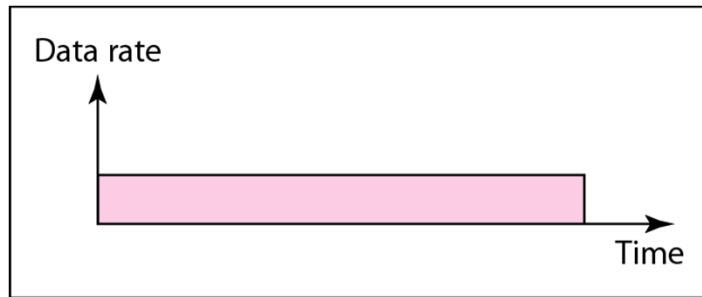
# Traffic descriptors



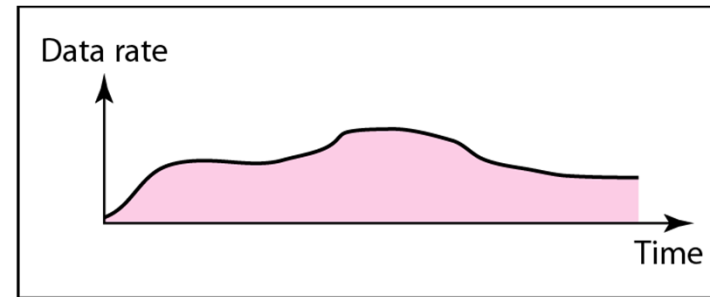
**Effective bandwidth**



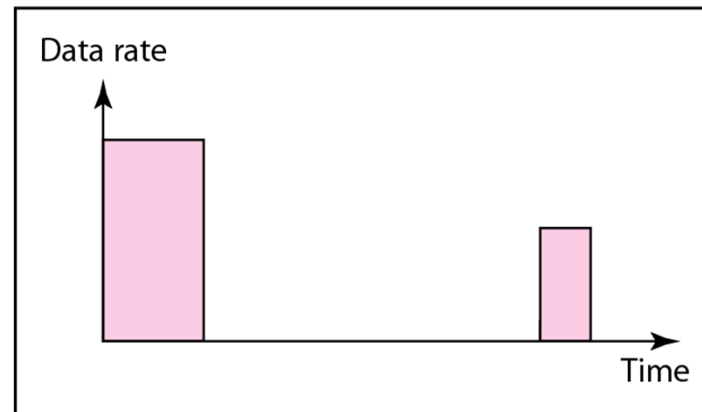
# Traffic profiles



a. Constant bit rate

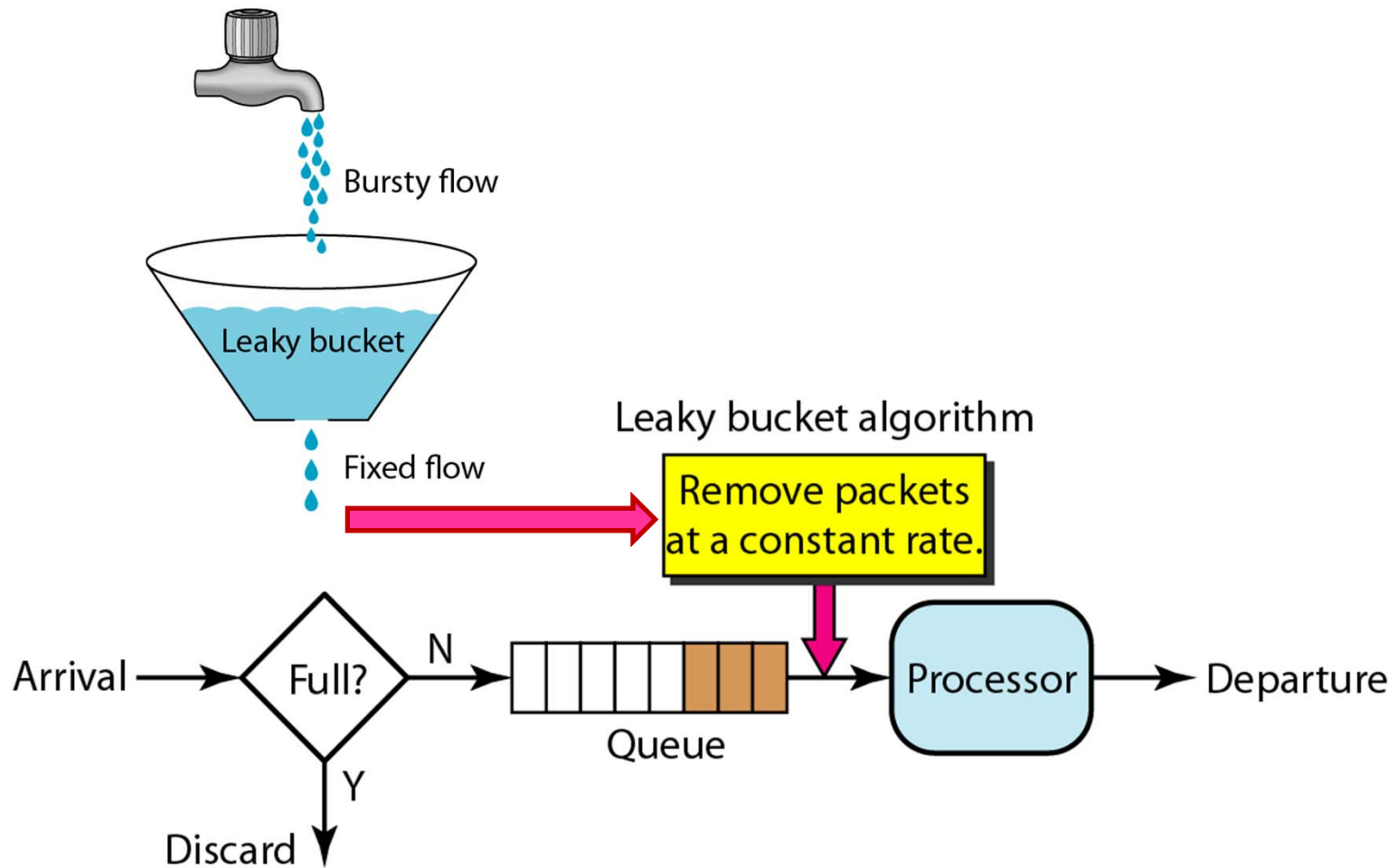


b. Variable bit rate



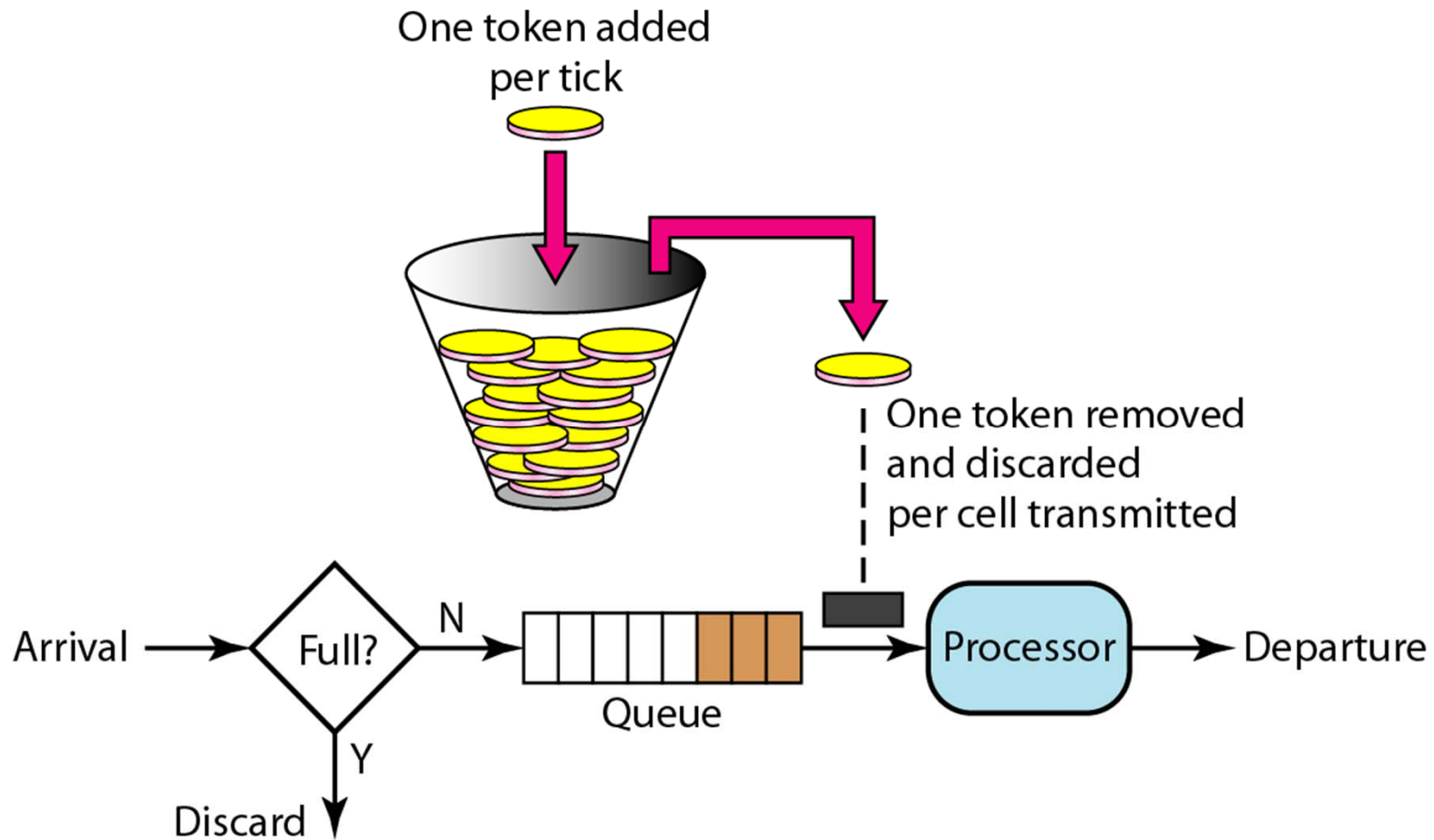
c. Bursty

# Traffic shaping: *Leaky bucket*



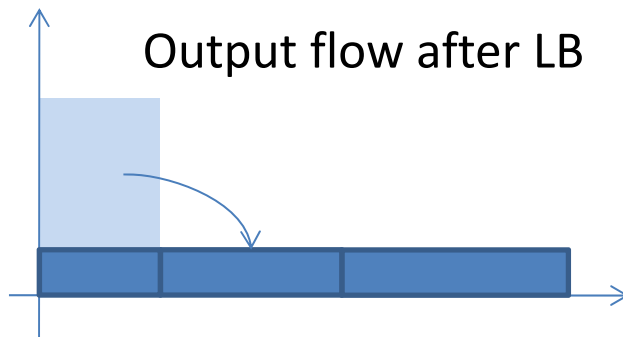
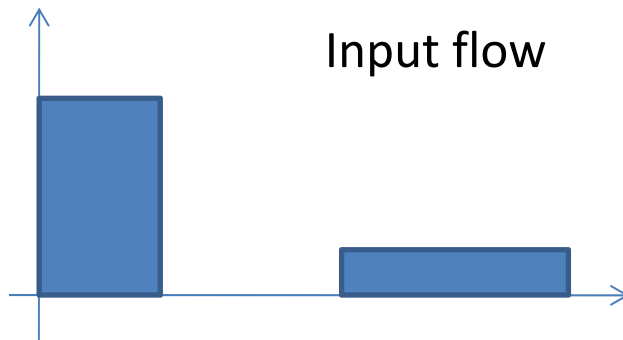


# Traffic shaping: *Token bucket*

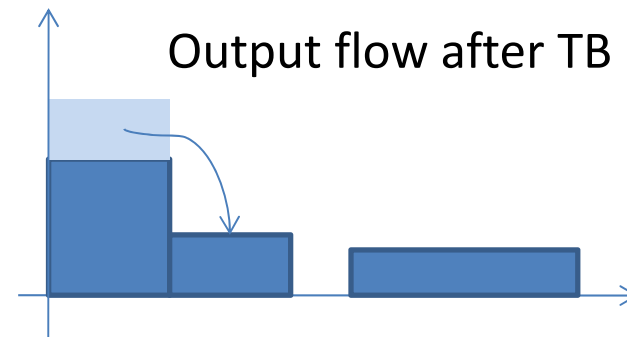
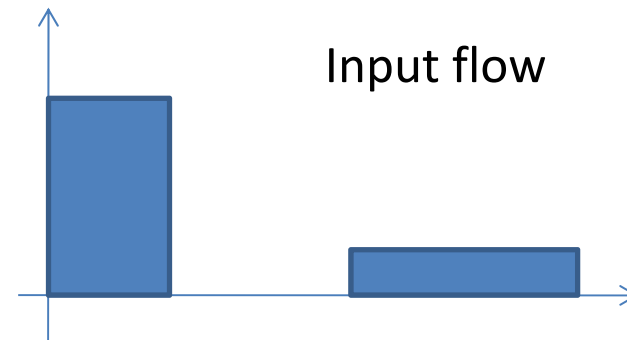


# Traffic shaping: *Two approaches*

## *Leaky bucket*



## *Token bucket*



# Bonus: QoE, Quality of Experience

- The user's subjective perception of the presentation of the content
- Mean Opinion Score
- Research for to find objective measures
  - Full reference
  - No reference
  - Hybrid
- What QoS give what QoE

# Part 3

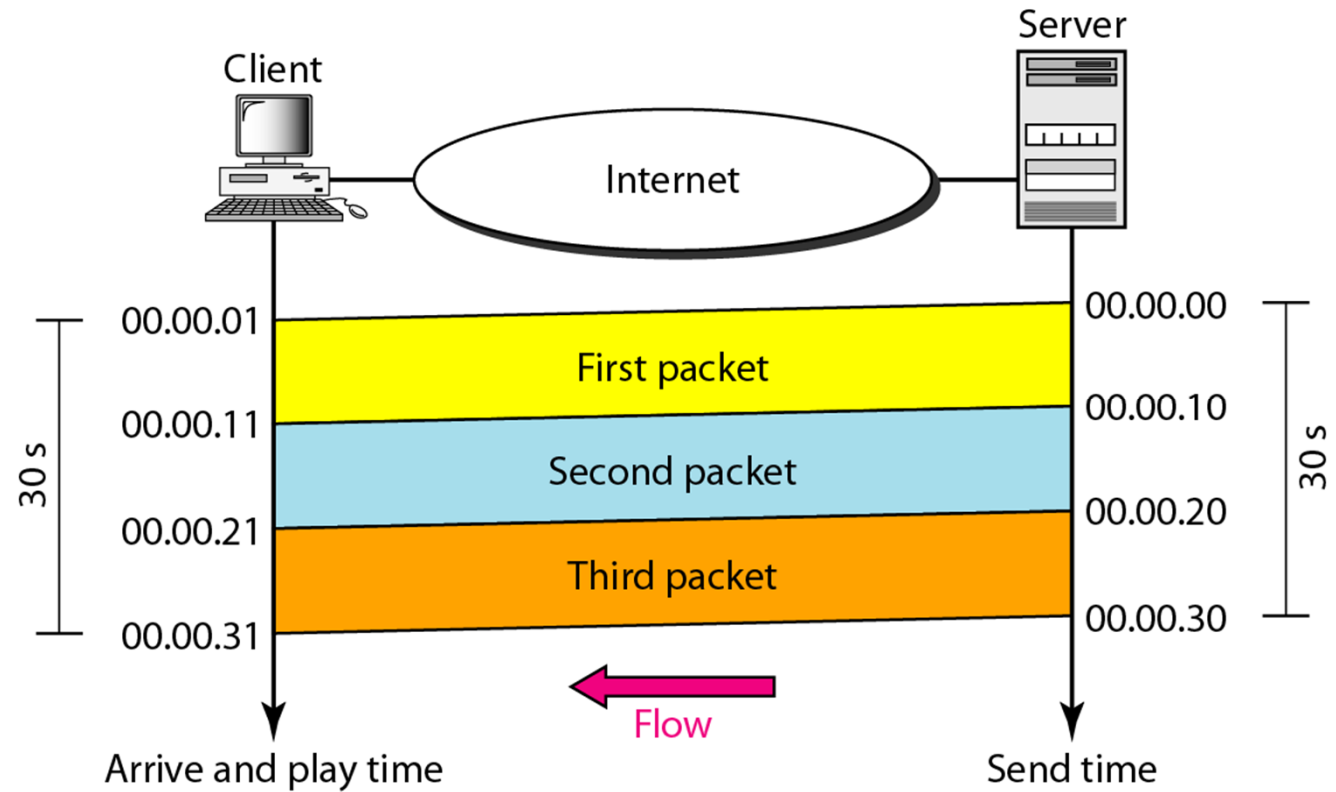
- Finding IP addresses: DHCP, DNS
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# Real-time audio/video

- One-way communication
  - IPTV, OTT (Over The Top)
  - Internet Radio
- Two-way communication (interactive)
  - Internet telephony
  - Voice over IP
  - Video conferencing

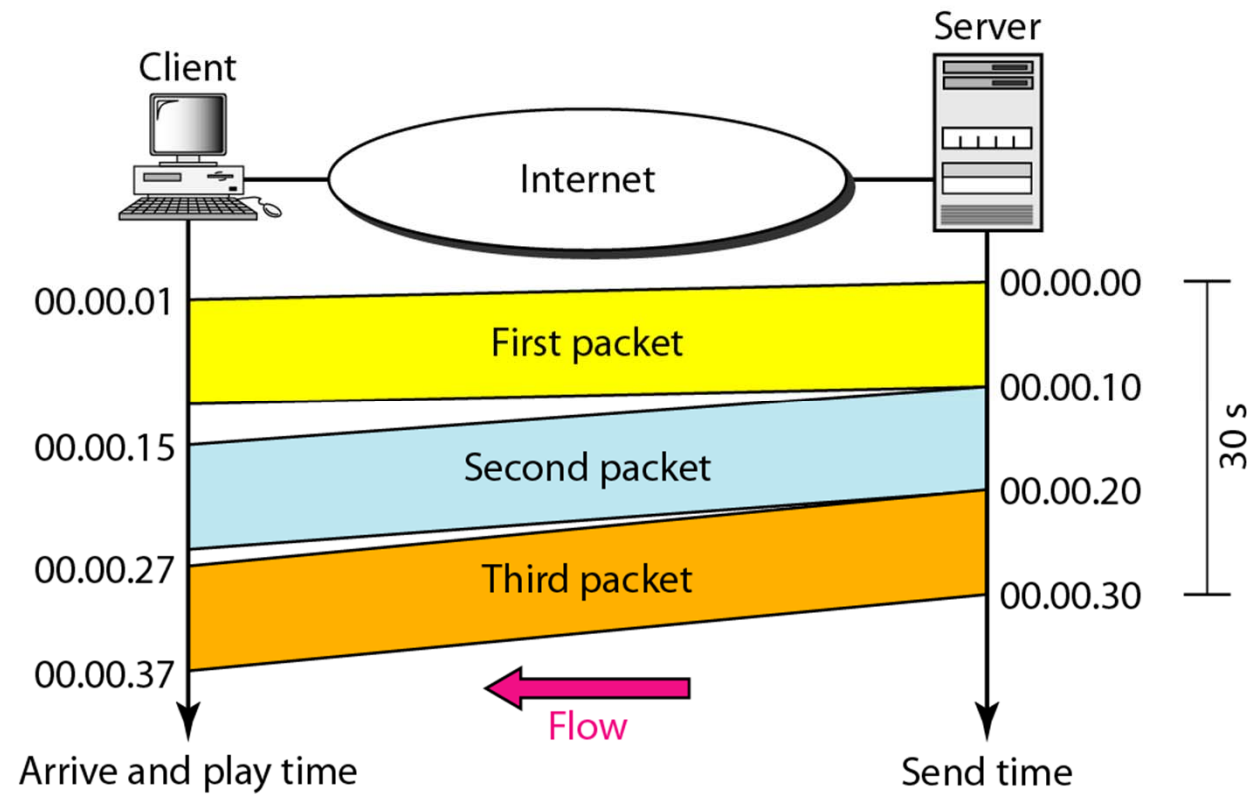
# Time relationship

- Just delay? No problem!



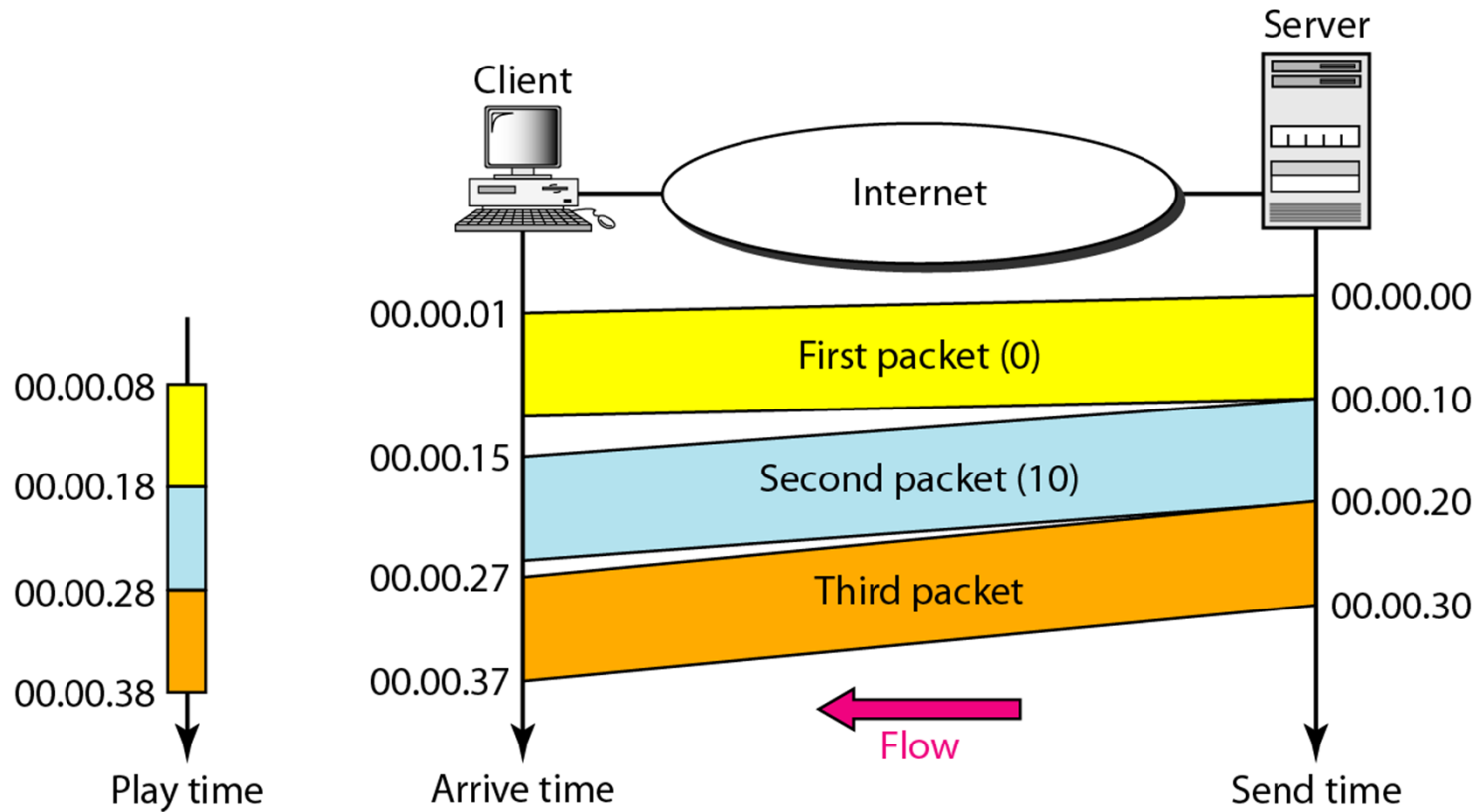
# Jitter

- Undesired variation in delay



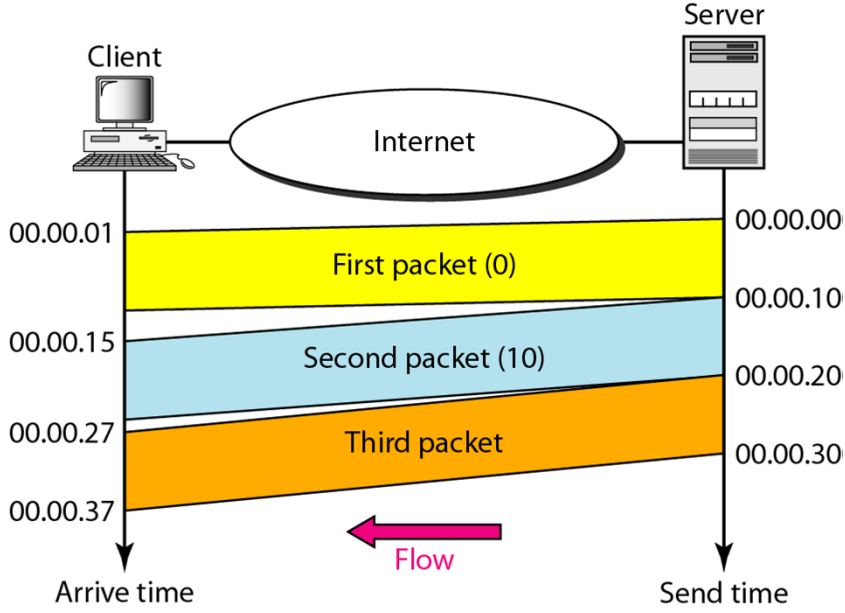
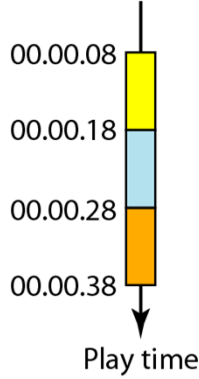
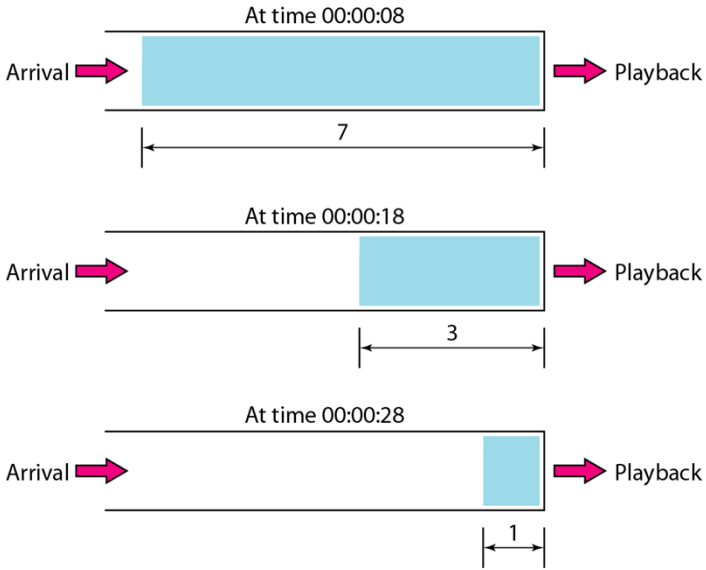
# Timestamps

- Separation of arrival time from playback time





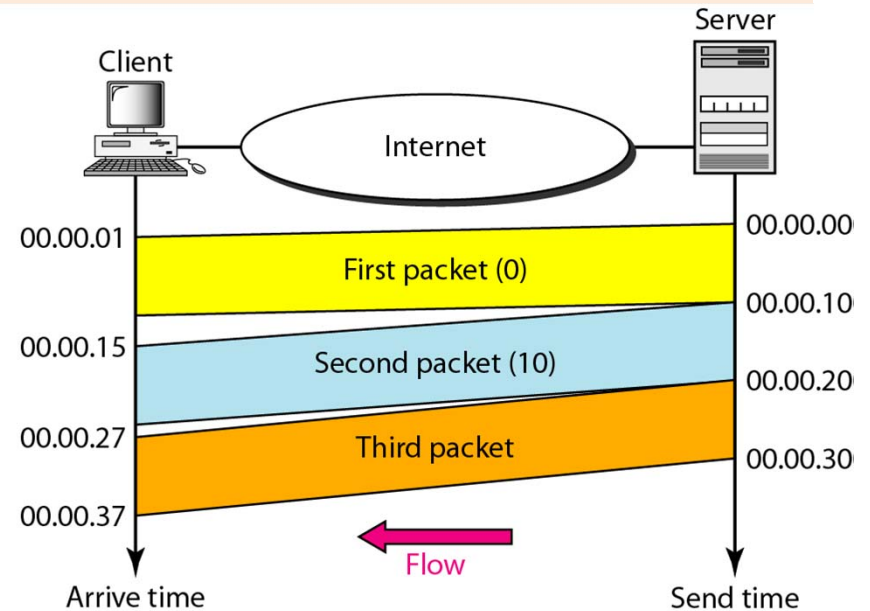
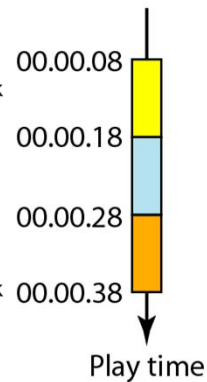
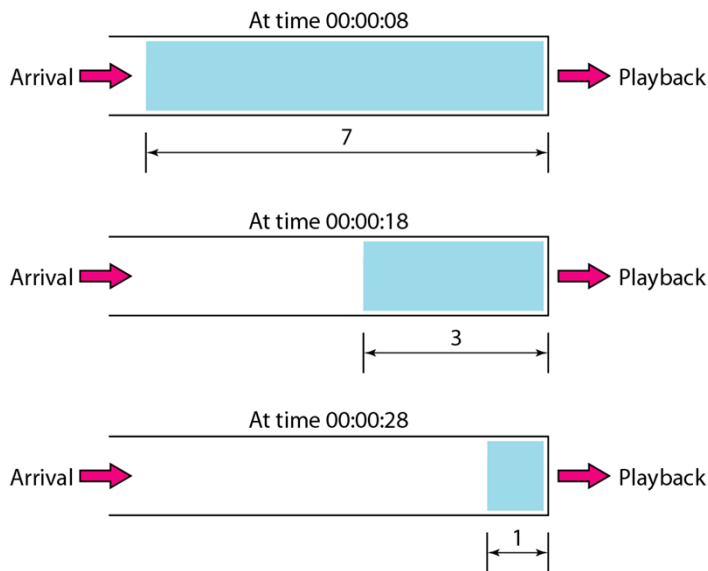
# Playback buffer



# Exercise: Find the buffer size in s.

- a) At 00:00:17
- b) At 00:00:20
- c) At 00:00:25
- d) At 00:00:30

- a) 3 s (12-9)
- b) 3 s (15-12)
- c) 3 s (20-17)
- d) 1 s (23-22)



# Still not good enough!

- Packets can be delivered out of order.
- Packets can be dropped on their way.
- Timestamps do not detect lost packets.



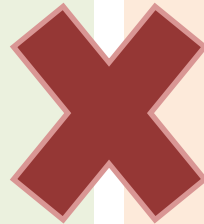
## Sequence numbers

- More support:
  - Multicast? Translation? Mixing?

# Summary and comparison

## *Performance Requirements*

- Sensitive to:
  - Delay
  - Jitter
- Not so sensitive to:
  - Packet loss
  - Corrupted packets



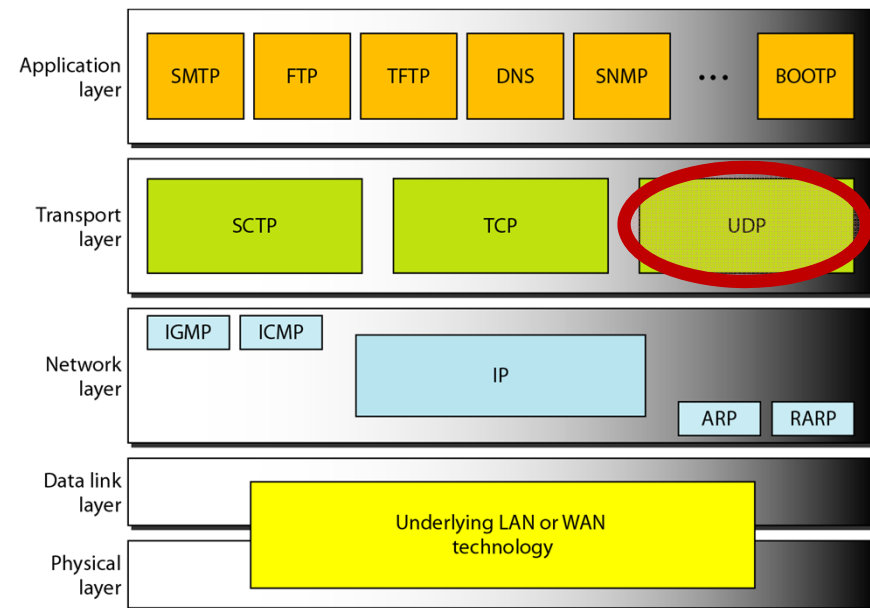
## *vs. Characteristics of TCP*

- Sensitive to:
  - Lost or corrupted packets
- Not so sensitive to:
  - Delay
- No multicasting!

*So, what about UDP?*

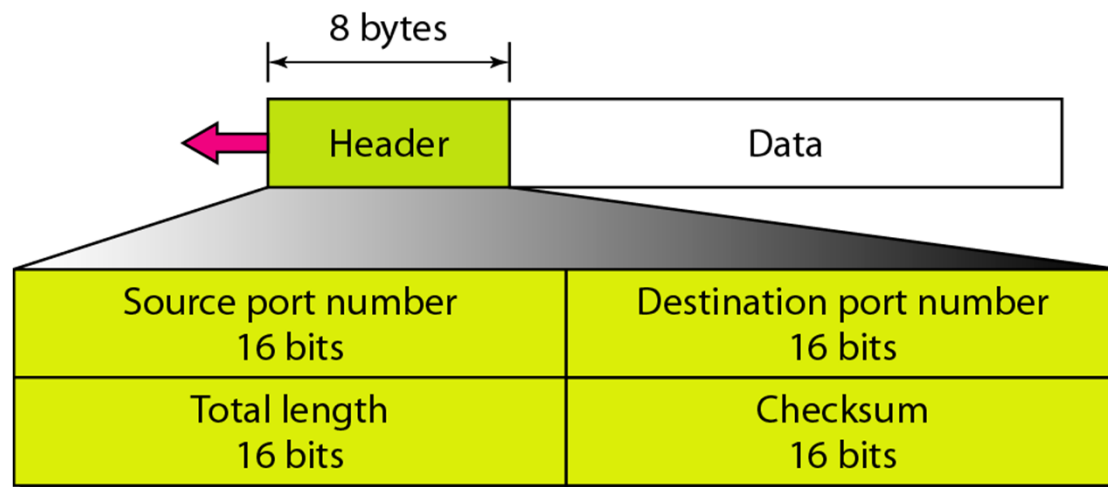
# User Datagram Protocol (UDP)

- Connectionless
  - Independent datagrams
  - No sessions
- Unreliable
  - No error control
  - No flow control

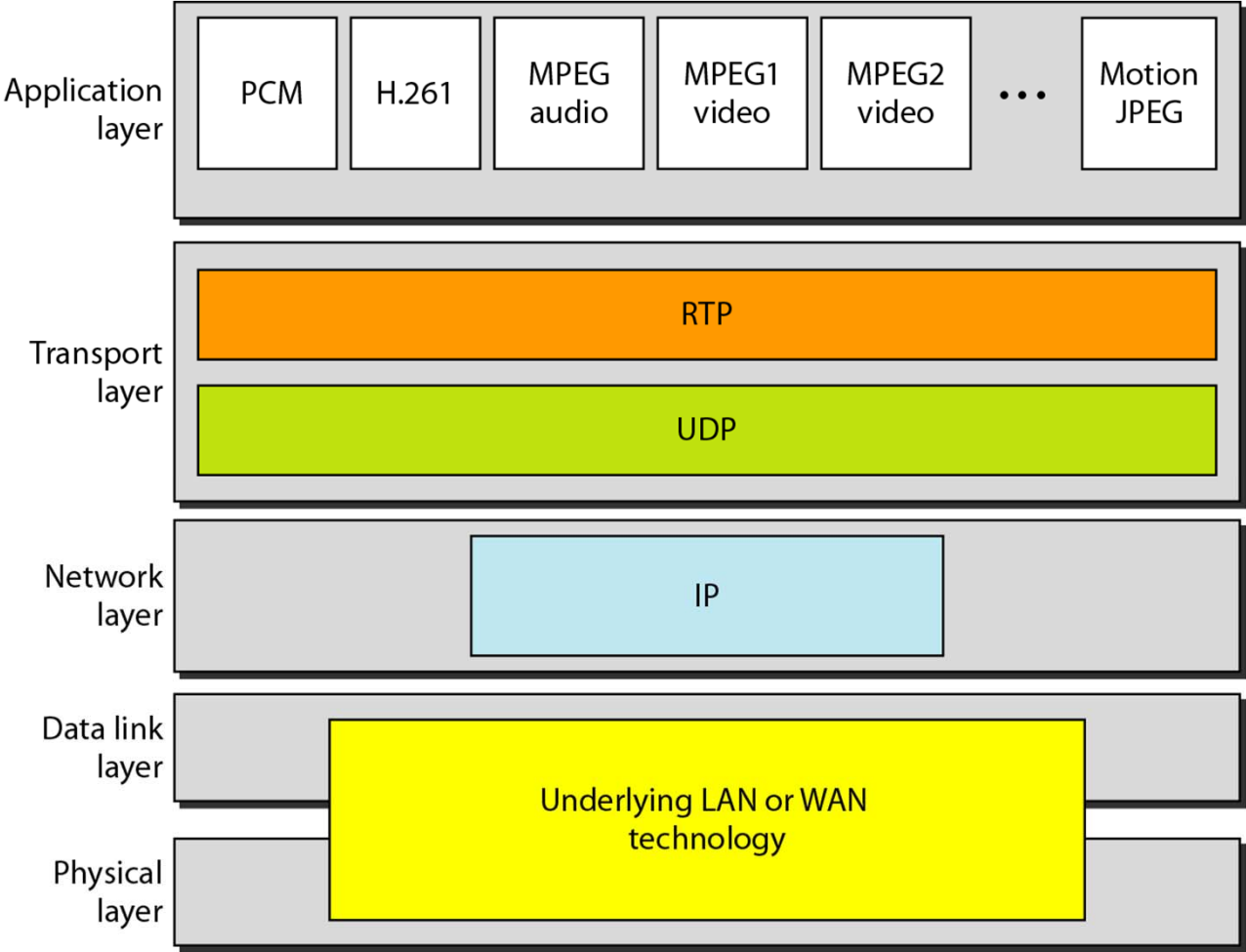


# UDP header format

- Checksum optional
- No numbering
  - No relation between datagrams



# Real-time Transport Protocol

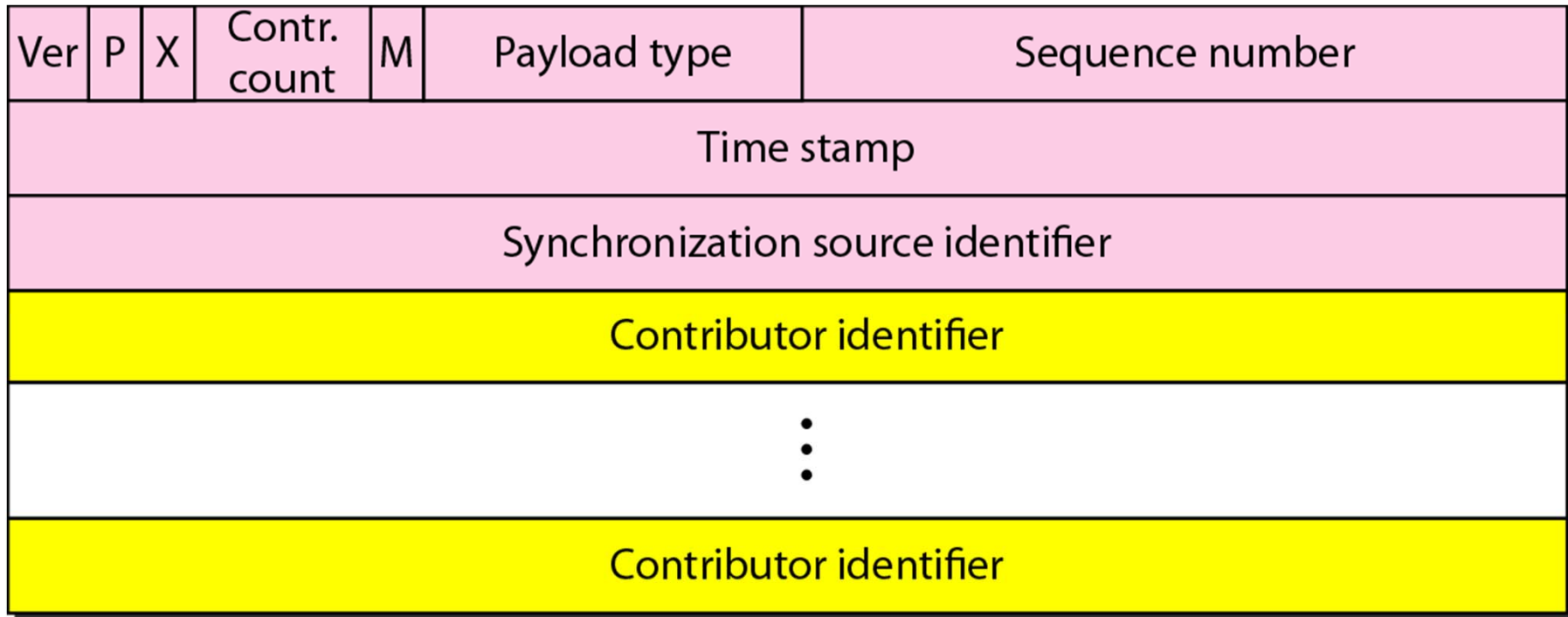


# Real-time Transport Protocol

- RTP handles real-time traffic
- No delivery mechanism
  - Uses UDP/IP
- Contributions
  - Time-stamping
  - Sequencing
  - Mixing



# RTP header format



# Real-time Transport Control Protocol

- RTP only carries data
  - Sessions initialised by SIP
- RTCP carries control messages
  - Flow control
  - Service quality
  - Feedback to source

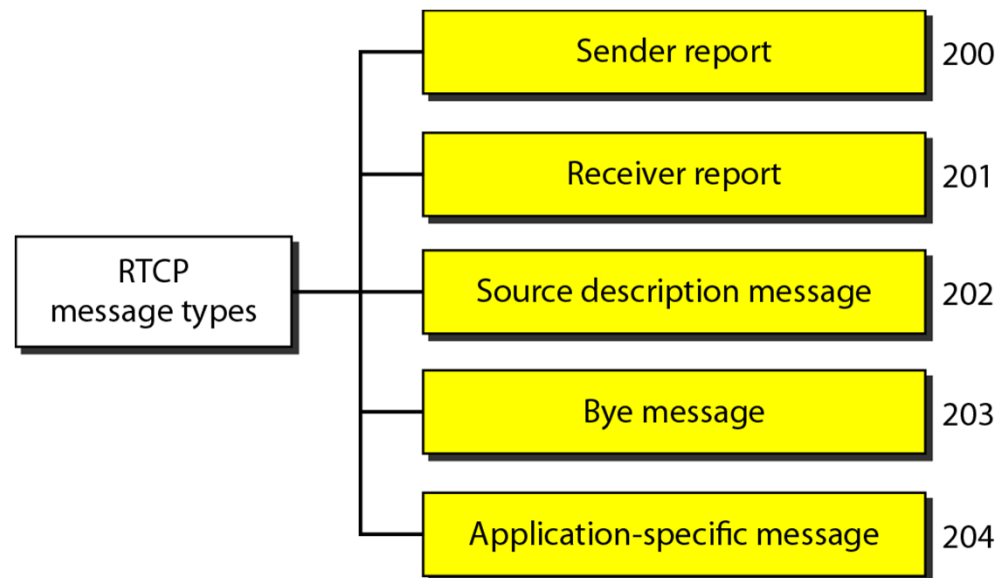
# Sender report

- Sent by active senders
  - Periodical
- Statistics
  - Transmission
  - Reception
- Absolute timestamp
  - Receivers can synch RTP messages
    - Important for audio and video

# Receiver report

- Sent by listeners
  - Not sending RTP packets
  - Feedback about QoS

## And others...



# Voice over IP (VoIP)

- Internet telephony
  - Uses two protocols

## *SIP*

- Session Initiation Protocol
- IETF standard

## *H.323*

- Communication (telephone, computer)
- ITU-T standard

# More multimedia applications

## Two-way

- Skype
- Lync
- ...

## One-way

- HBO
- Netflix
- Spotify
- Play channels
- ...

# Problem

- We expect the same or better QoE than terrestrial broadcast
- Digital transmission
- Internet based applications has to coop with
  - Best effort
  - Cramped access networks
  - Bad channels
    - DSL
    - WiFi
    - Mobile

# Want to more?

- Advanced Telecommunication
- Queueing Theory
- Discrete Event Simulations
- Master Thesis Projects