

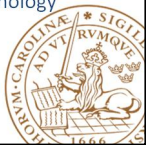
# Transport Layer

## (Part 2)

ETSF10 – Internet Protocols – 2011

Kaan Bür & Jens Andersson

Department of Electrical and Information Technology



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# Transport Layer

- “ Process-to-process delivery §23.1
- “ User Datagram Protocol (UDP) §23.2
- “ Transmission Control Protocol (TCP) §23.3
- “ **Network performance** §3.6
- “ **Congestion control** §24.1-4
- “ **Quality of Service (QoS)** §24.5-6
- “ **Real-time interactive audio/video** §29.5

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# Performance

- “ Bandwidth
  - . Hertz (frequency band)
  - . Bits per second (capacity)
- “ Throughput
  - . Efficiency
  - . Always less than capacity
- “ Latency (Delay)
  - . Transmission, propagation
  - . Processing, queueing
- “ Jitter → real-time data!

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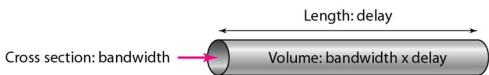
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### Bandwidth-delay product

- How much data can fill the link
- Important for congestion avoidance
  - Delay = Round Trip Time (RTT)
  - Burst = 2 \* bandwidth \* delay



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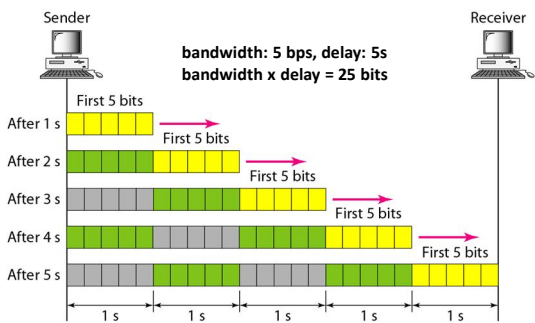
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### Bandwidth-delay product



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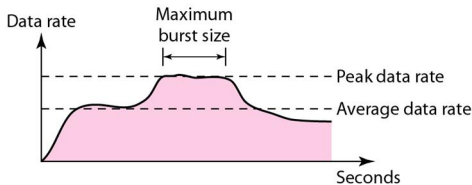
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### Traffic descriptors



- Effective bandwidth

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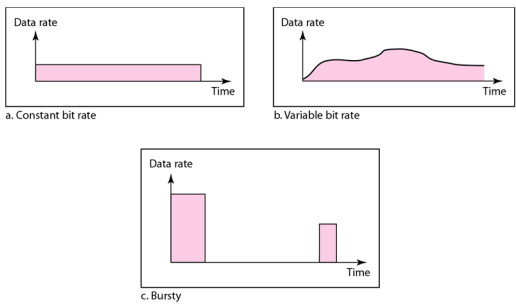
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Traffic profiles



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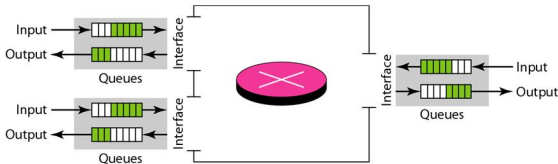
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Congestion

- “ Result of waiting
- “ When load > capacity
  - . Arrival rate > processing rate
  - . Processing rate > departure rate



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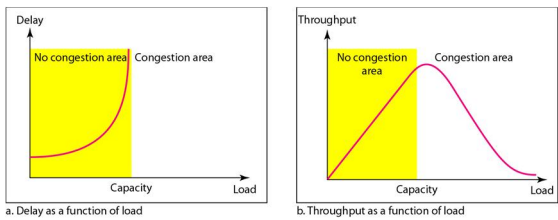
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Delay and throughput



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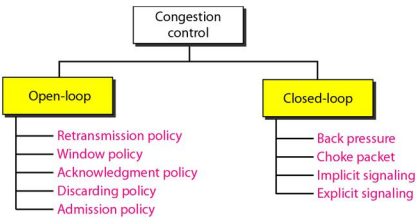
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### Congestion control

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



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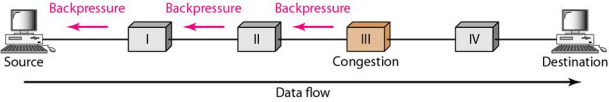
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### Closed-loop congestion control (1)

- “ Backpressure



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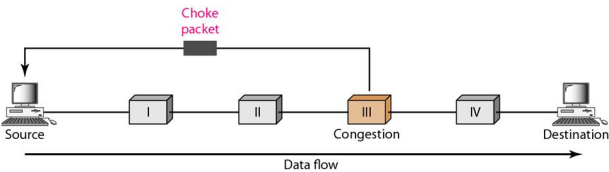
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### Closed-loop congestion control (2)

- “ Choke packet



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### Congestion Control in TCP

- ” Congestion window
  - . size = min(rwnd, cwnd)
- ” Slow start (state)
  - . Exponential increase
- ” Congestion avoidance (state)
  - . Additive increase
- ” Congestion detection (event - to act upon)
  - . Multiplicative decrease

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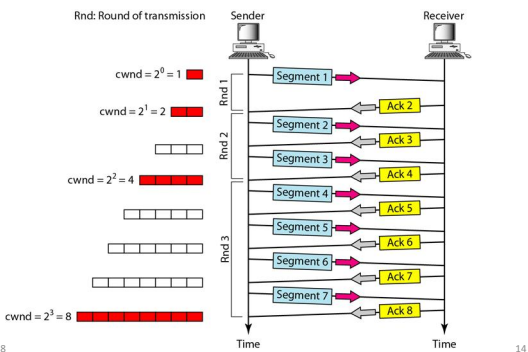
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### Slow start: Exponential increase



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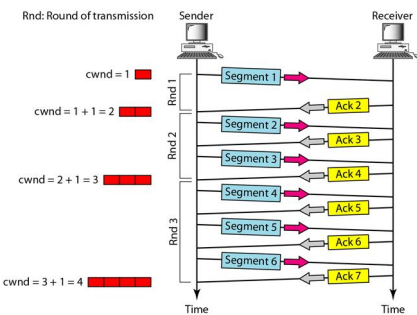
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### Congestion avoidance: Additive increase



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Reaction to congestion detection

- “ Detection by time-out
  - . Probably both channels congested
  - . New slow start phase
- “ Detection by three ACK
  - . Probably sending channel congested only
  - . New congestion avoidance phase

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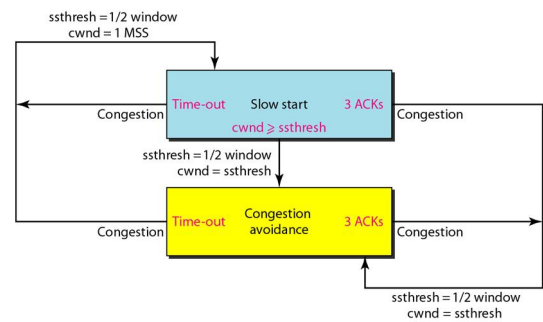
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TCP congestion policy: *Summary*



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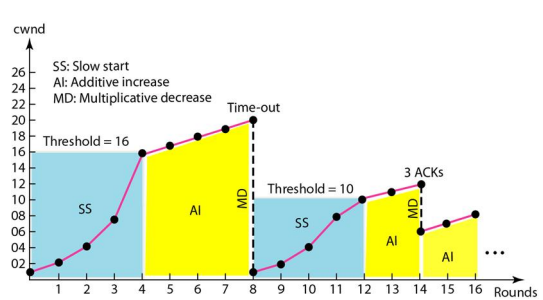
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TCP congestion policy: *Example*



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See you in 15' :)



- ” After the break
  - . Quality of Service
  - . Real-time data

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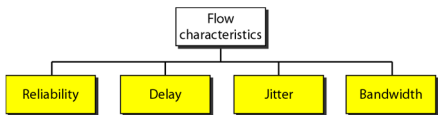
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## Quality of Service (QoS)

- ” Maintaining an appropriate environment
  - . Meeting applications’ demands
  - . Deals with flow characteristics



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## How to improve QoS

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

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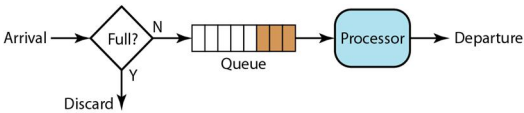
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Scheduling: *FIFO queuing*



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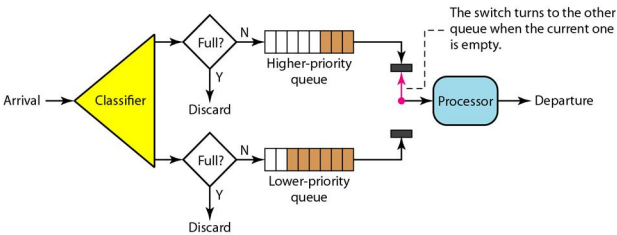
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Scheduling: *Priority queuing*



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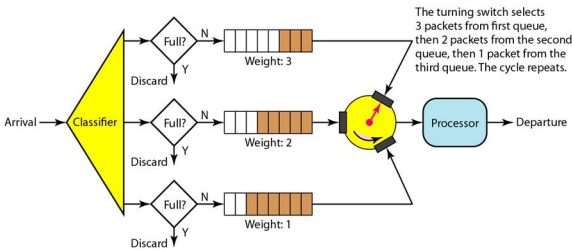
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Scheduling: *Weighted fair queuing*



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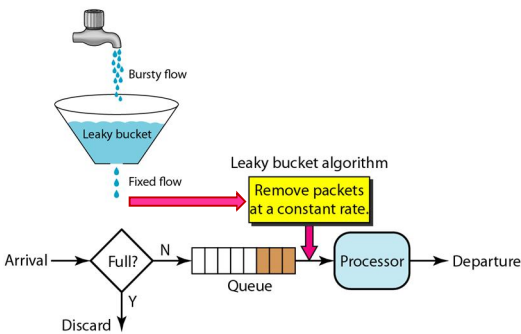
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Traffic shaping: *Leaky bucket*



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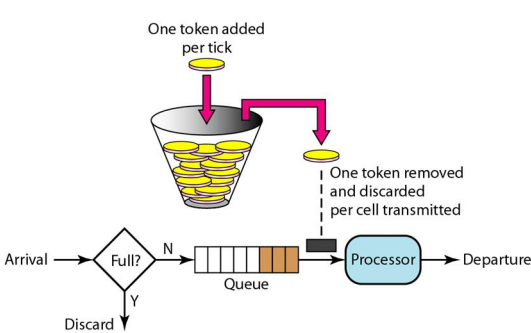
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Traffic shaping: *Token bucket*



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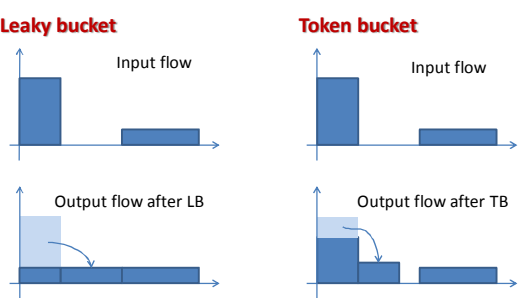
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Traffic shaping: *Two approaches*



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### Real-time interactive audio/video

- “ Two-way communication in real time
  - . Internet telephony
  - . Voice over IP
  - . Video conferencing
- “ Sensitive to delay and jitter
  - . TCP not suitable
- “ Not so sensitive to lost and corrupted packets
  - . TCP not suitable

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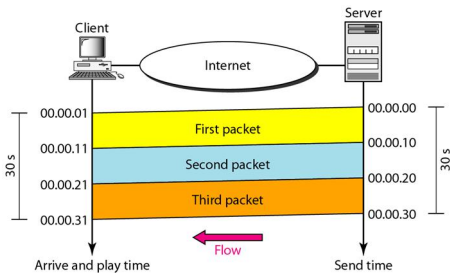
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### Real-time data: *Time relationship*



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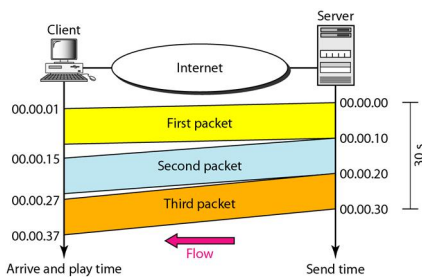
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### Real-time data: *Jitter*



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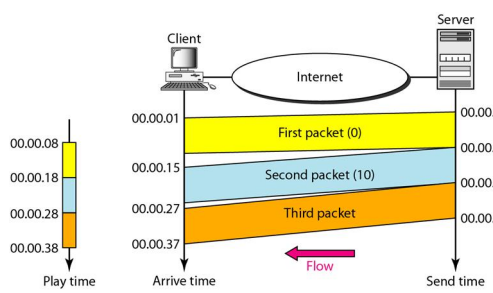
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Real-time data: *Timestamping*



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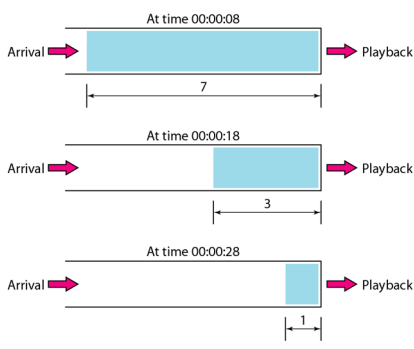
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Real-time data: *Playback buffer*



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Real-time data: *Sequence numbers*

- ” Why?
- . Packets can be delivered out of order.
  - . Packets can be dropped on their way.
  - . Time stamps do not detect lost packets.
- ” Order in the playback buffer

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