Computer Networks

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Chapter 6. Congestion Control and QoS

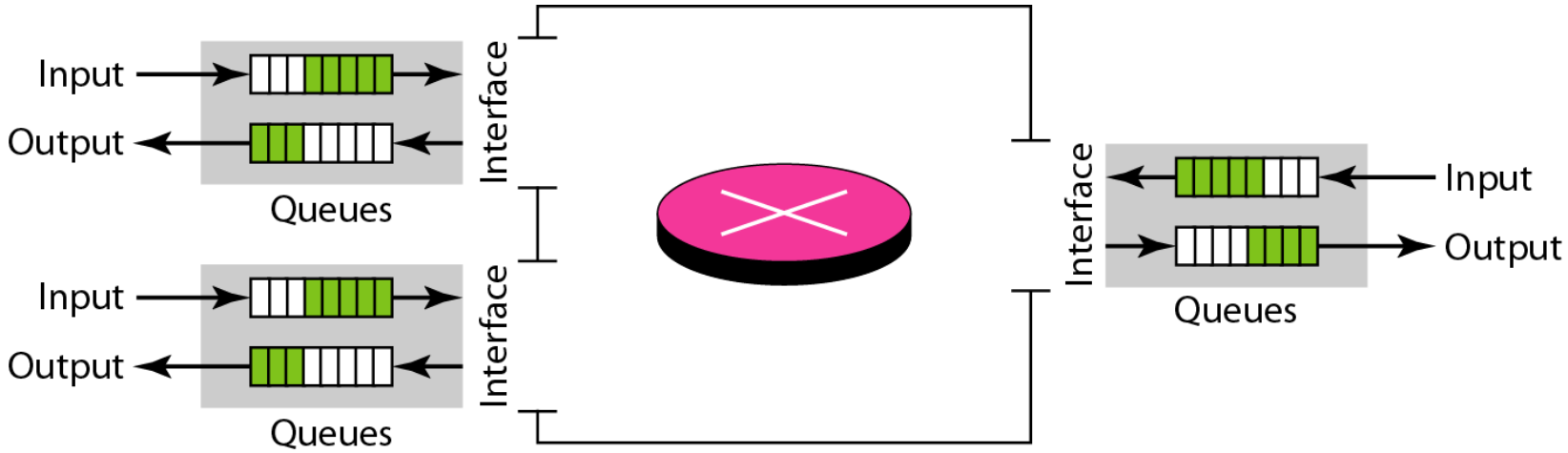
- Network Congestion
- Congestion Control in FR
- Traffic Management in ATM
- Internet QoS
- Resource Allocation and RSVP
- Differentiated Services

Network Congestion

- Congestion
  - Number of packets transmitted through the network approaches the packet handling capacity of the network
- One or more switches/routers becomes overloaded
  - Generally 80% utilization is critical
- Congestion control
  - Keep number of packets below level at which performance falls off dramatically

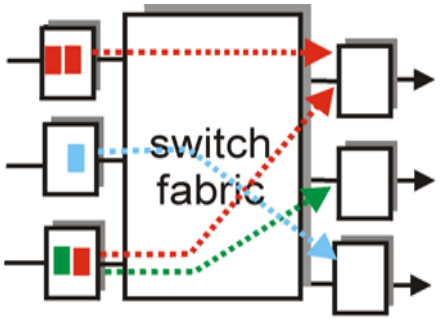
Queues at a Switch

- Switch overloads because receiving packets faster than it can forward



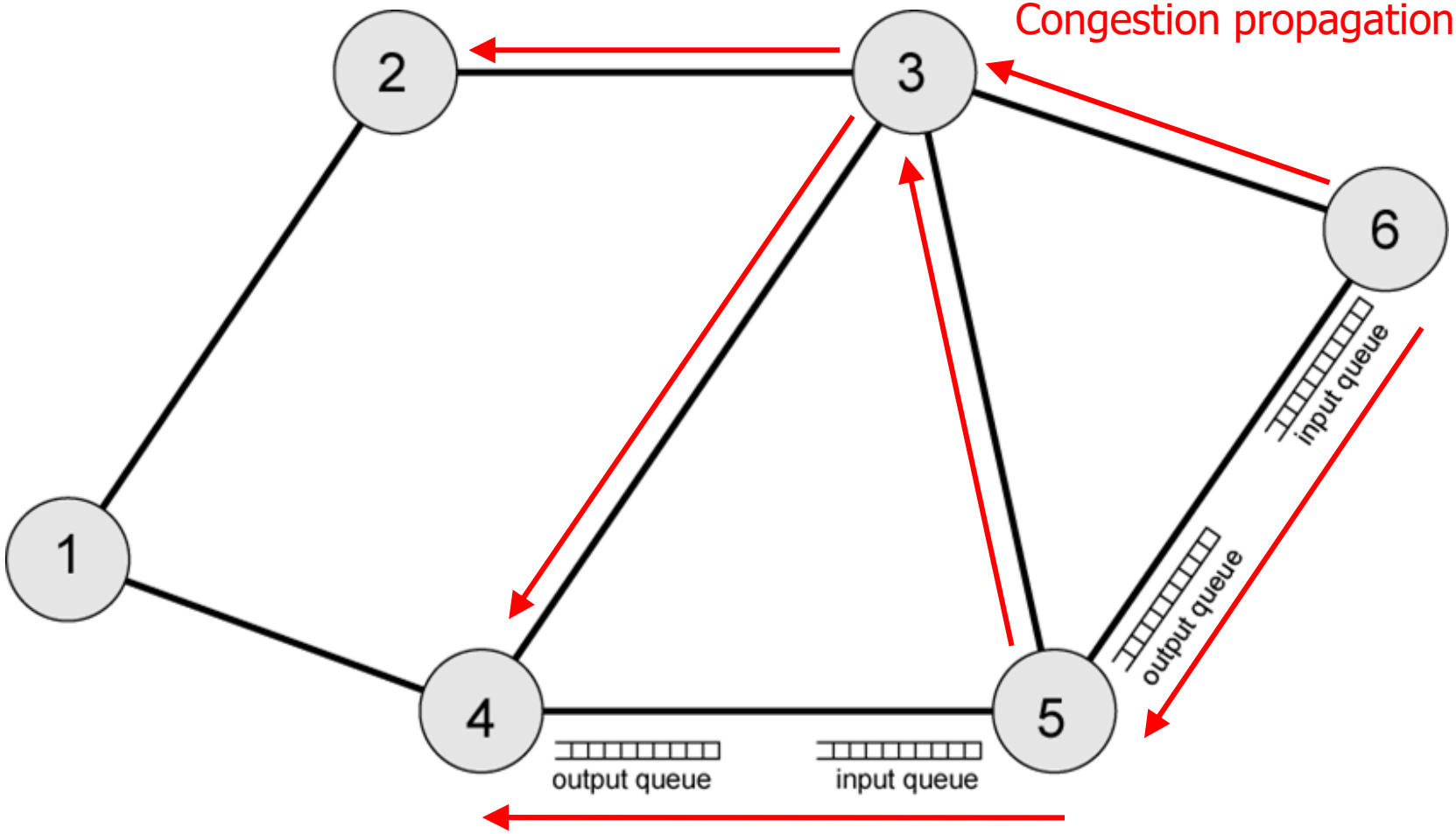
Causing Congestion

- Congestion at switch
  - Bursty traffic / poor topology
  - Packet arrival rate exceeds the outgoing link capacity
  - Packet processing rate < packet arriving rate
  - Insufficient memory to store arriving packets



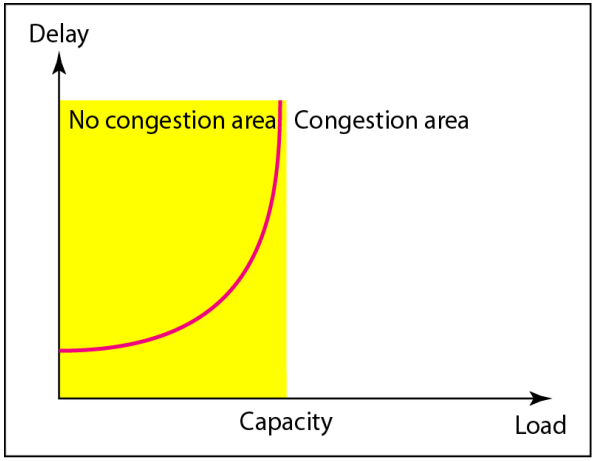
- Effects caused at congested switch
  - Discard queued packets to make room for new comings
  - Prevent additional packets from entering the congested port (link-layer flow control)

Interaction of Queues

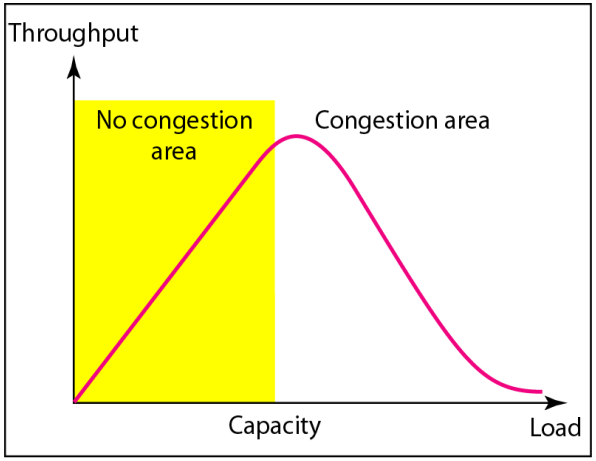


Network Utilization

- Delay and Throughput vs. Network Load



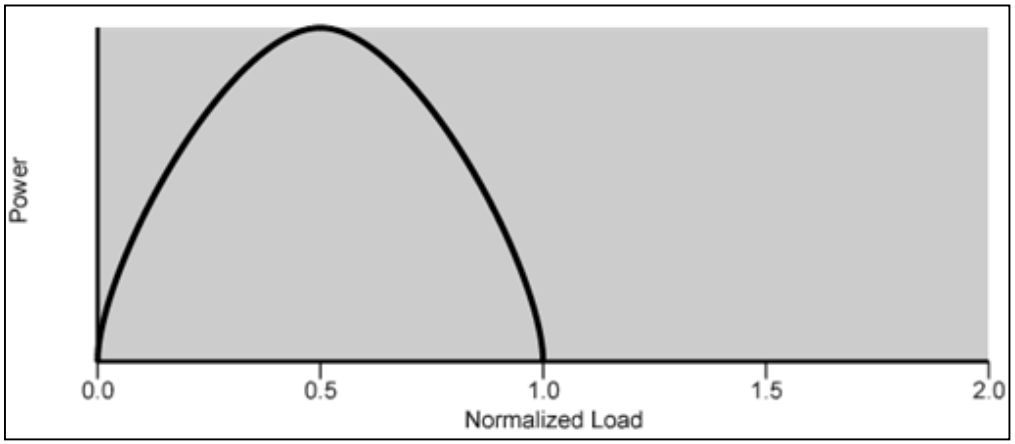
a. Delay as a function of load



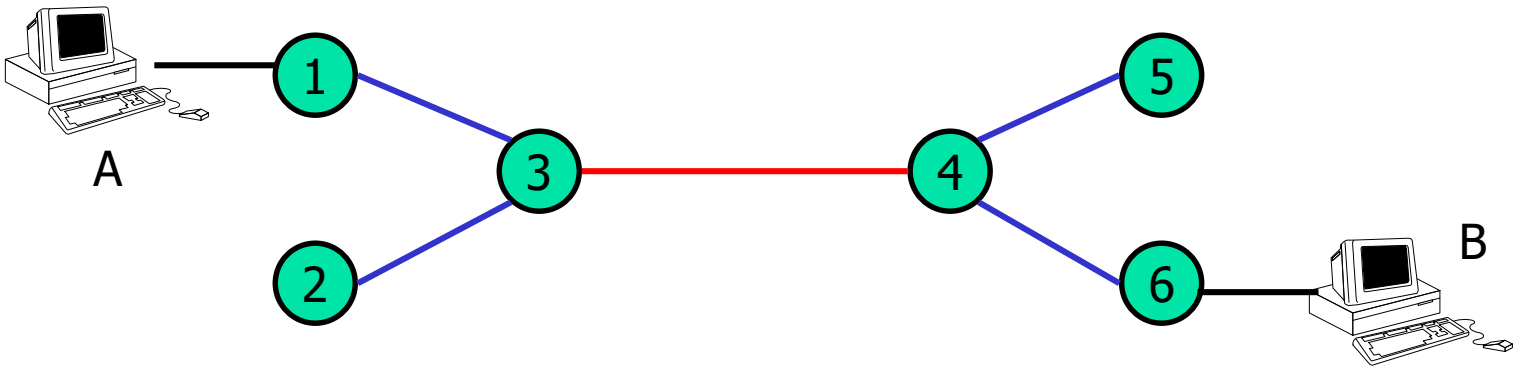
b. Throughput as a function of load

- Communication Power

$$Power = Throughput / Delay$$

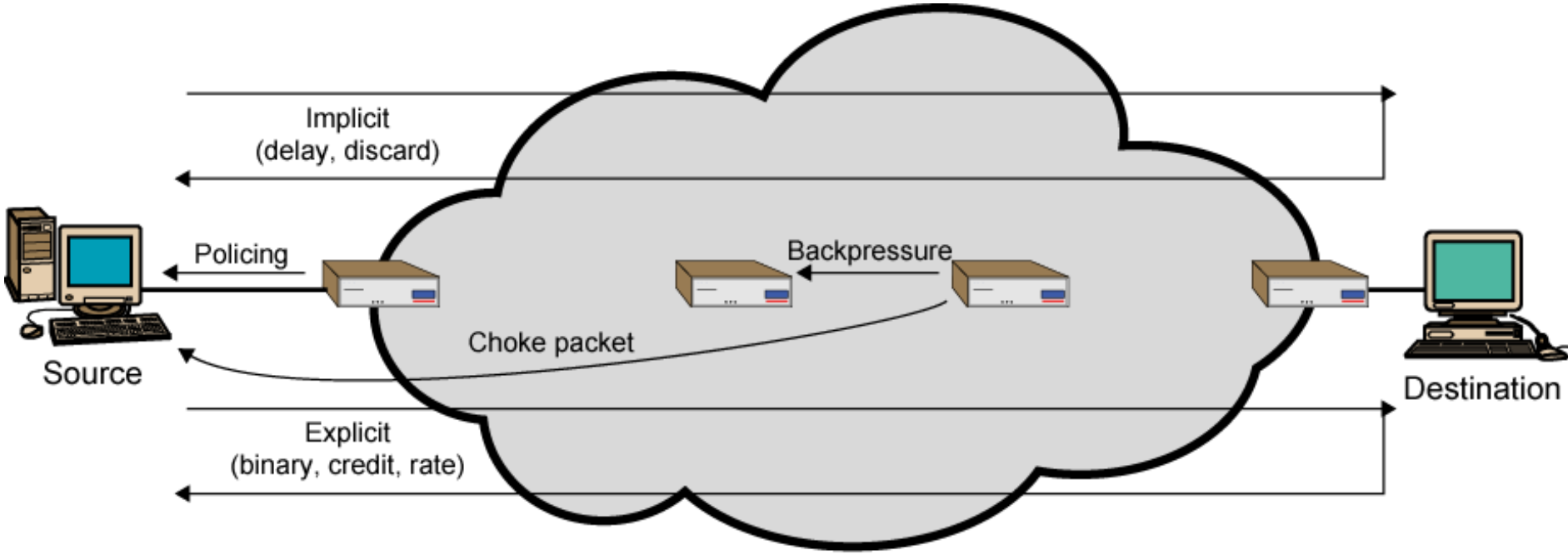


Bottleneck Effect



- Assume all the links have similar capacity, and run in full for both direction
- Then switches 3 and 4 will be in congestion

Mechanisms for Congestion Control



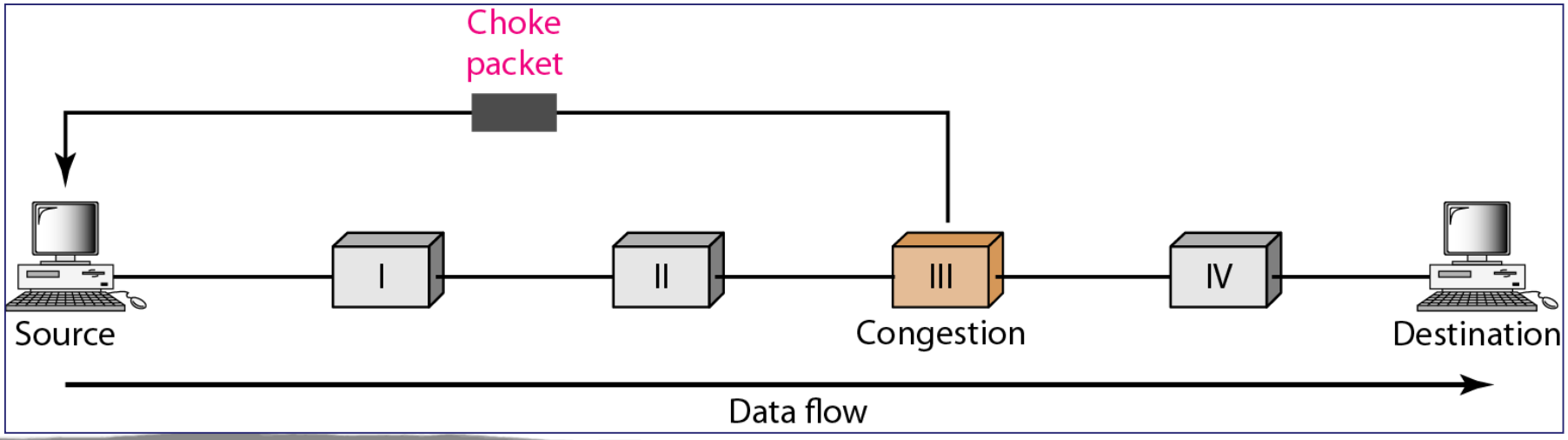
- Choke Packet
- Backpressure
- Warning bit
- Congestion window
- Random early discard
- Traffic shaping

- 抑制分组
- 反压
- 警告位
- 拥塞窗口
- 随机早期丢弃
- 流量整形

(1) Choke Packet

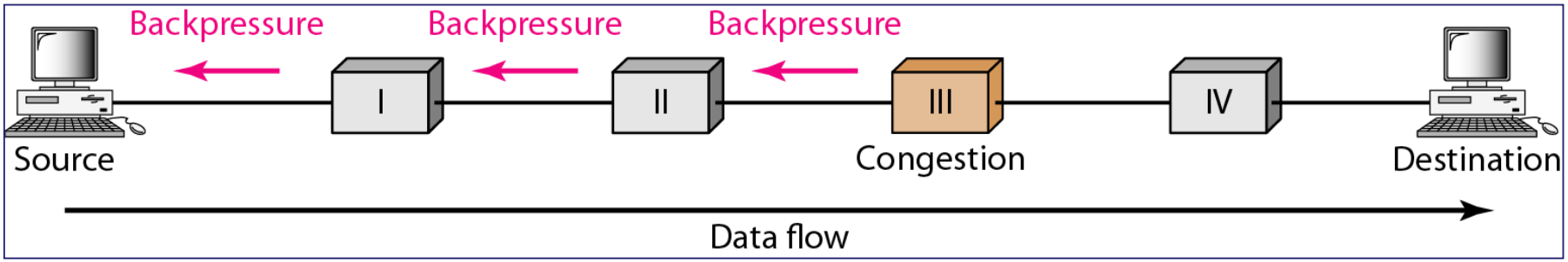
- Control packet
  - Generated at congested node
  - Sent to source node

- Source quench： using ICMP to notify source
  - From router or destination, sent for every discarded packet



(2) Backpressure

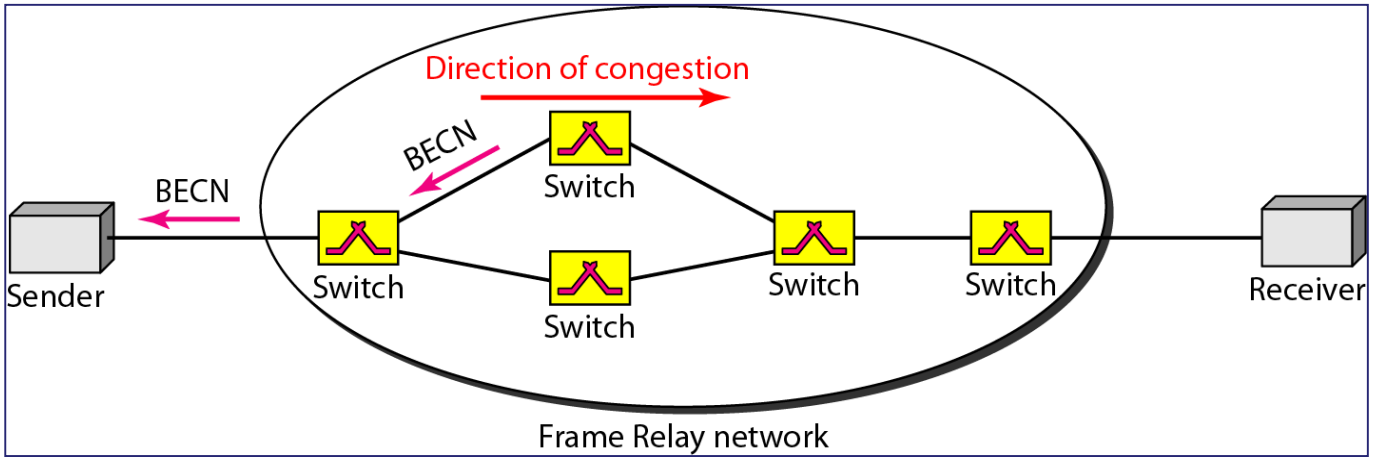
- Hop-by-Hop Choke Packets
  - Propagation time > transmission time (long distance or high speed link)
  - Choke packets from router to source are not effective
  - Require each hop to reduce its transmission

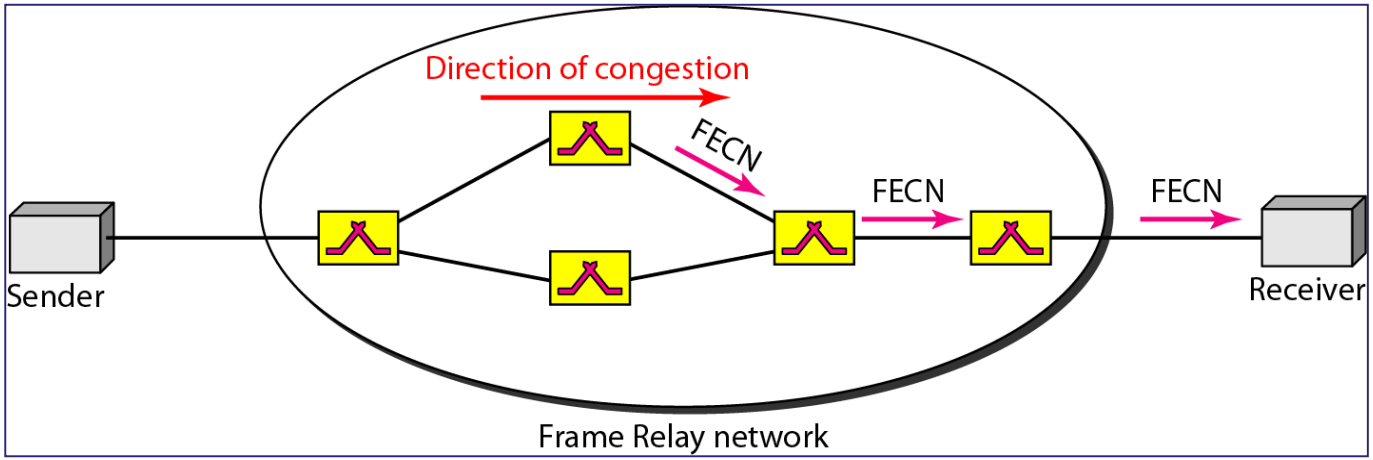


(3) Warning Bit

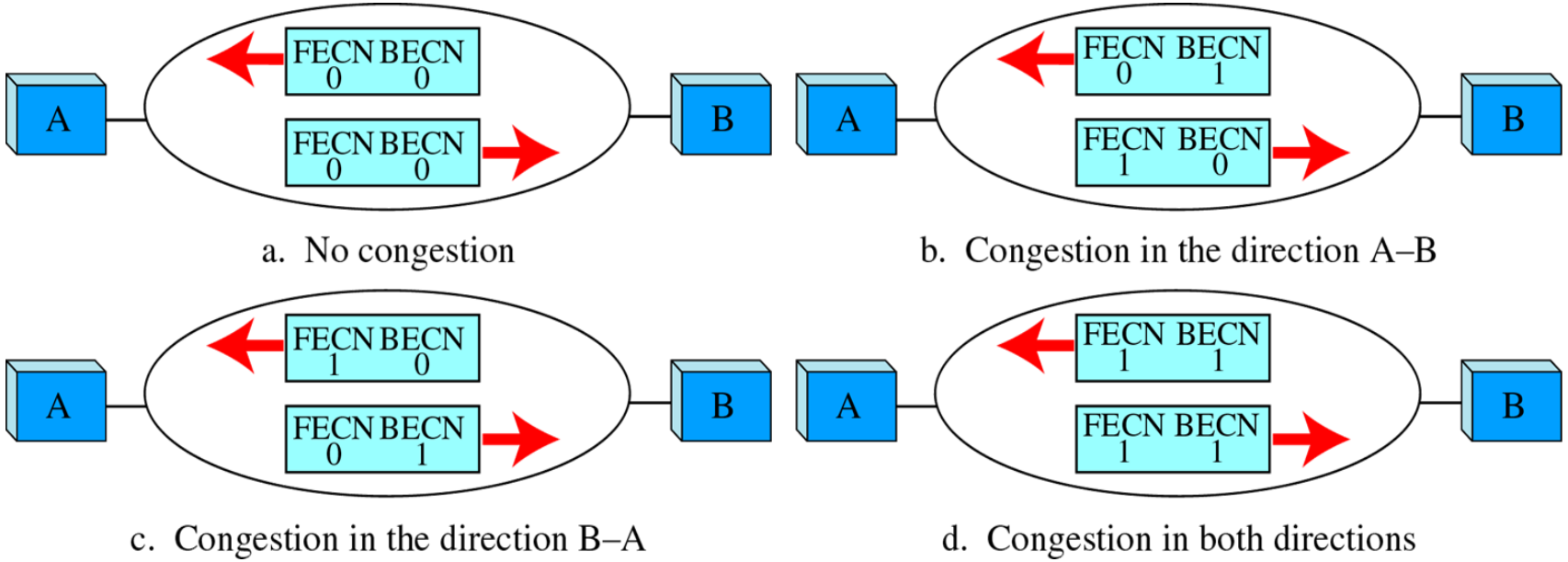
- Special bits set in the packet header by switches
  - Alerts end systems of increasing congestion
  - End systems take steps to reduce offered load
- Backwards
  - Congestion avoidance in opposite direction to congested packet
  - Assume congestion will burst up quickly
- Forwards
  - Congestion avoidance in same direction as congested packet
  - Assume congestion will cumulate slowly

BECN and FECN in FR



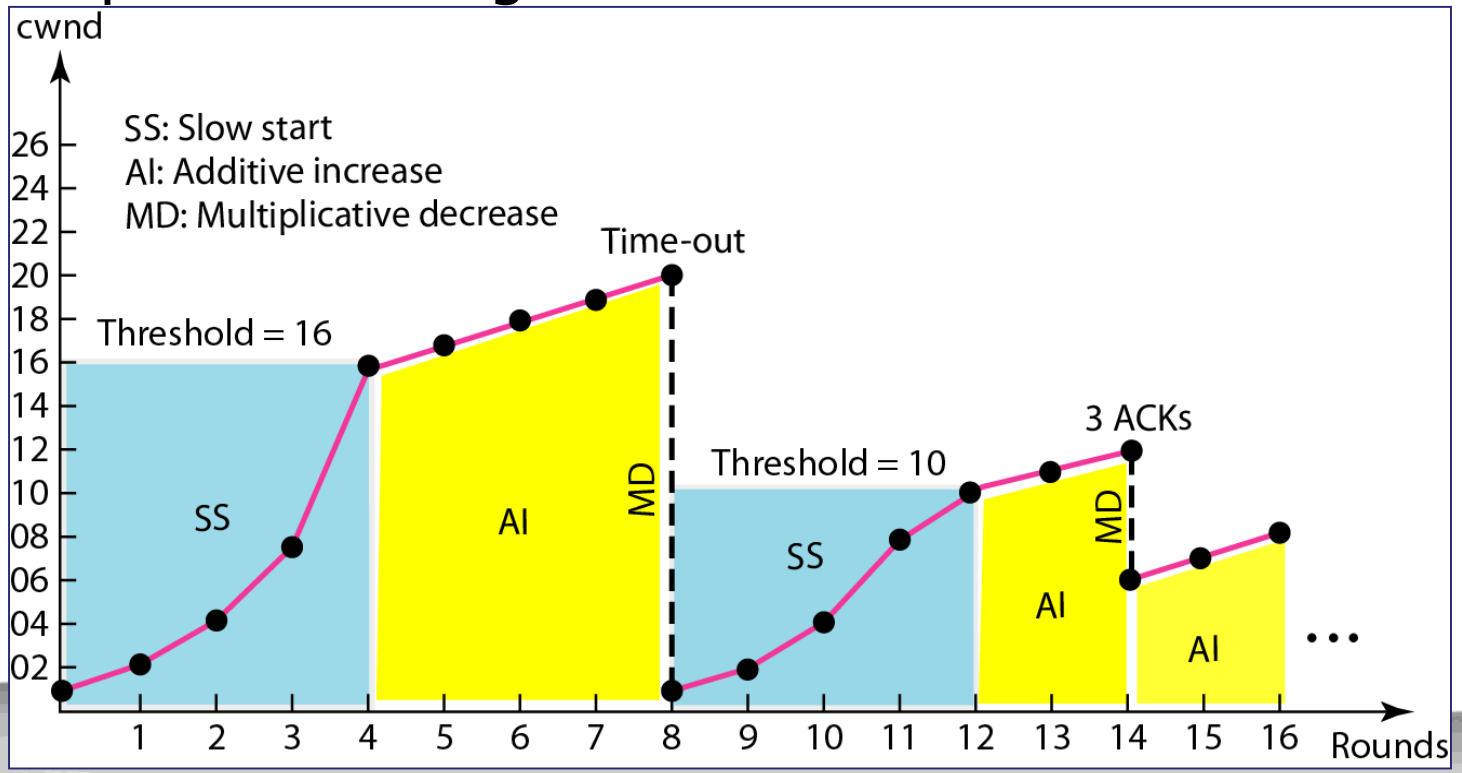


Four Cases of Congestion



(4) Congestion Window

- Control congestion at hosts
  - Packet timeout as a signal of network congestion
  - Dynamic send window management (as in TCP) to hold the packet sending



(5) Random Early Discard

- Control congestion at routers (switches)
  - Combined with congestion window at hosts
- Internet (TCP) global synchronization problem
  - Traffic burst fills queues so packets lost, TCP connections enter slow start
  - Traffic drops so network under utilized, connections leave slow start at same time causing burst again
- Handle the problem – RED
  - Router randomly discards packets before buffer becomes completely full

The RED Algorithm

- Compute average queue length

$$avgLen = (1-\omega)\times avgLen + \omega \times sampleLen$$

Calculate average queue size *avgLen*

if *avgLen* < TH_{min}

queue packet

else if $TH_{min} \le$ *avgLen* < TH_{max}

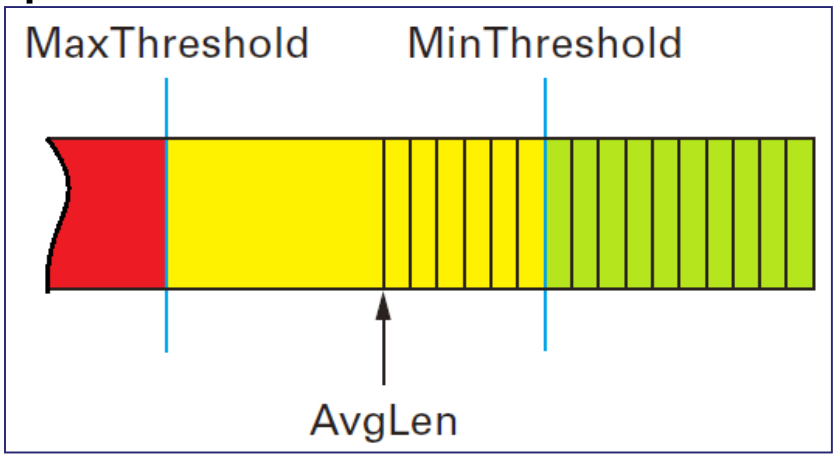
calculate probability p

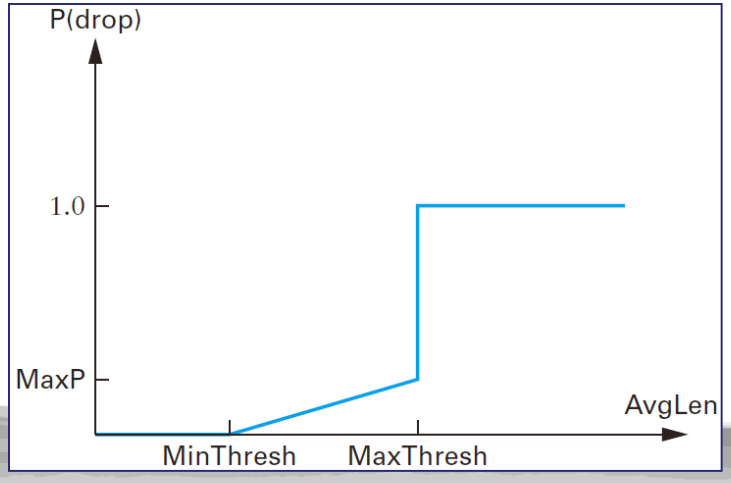
with probability p discard packet

else with probability 1-p queue packet

else if *avg* $\ge TH_{max}$

discard packet



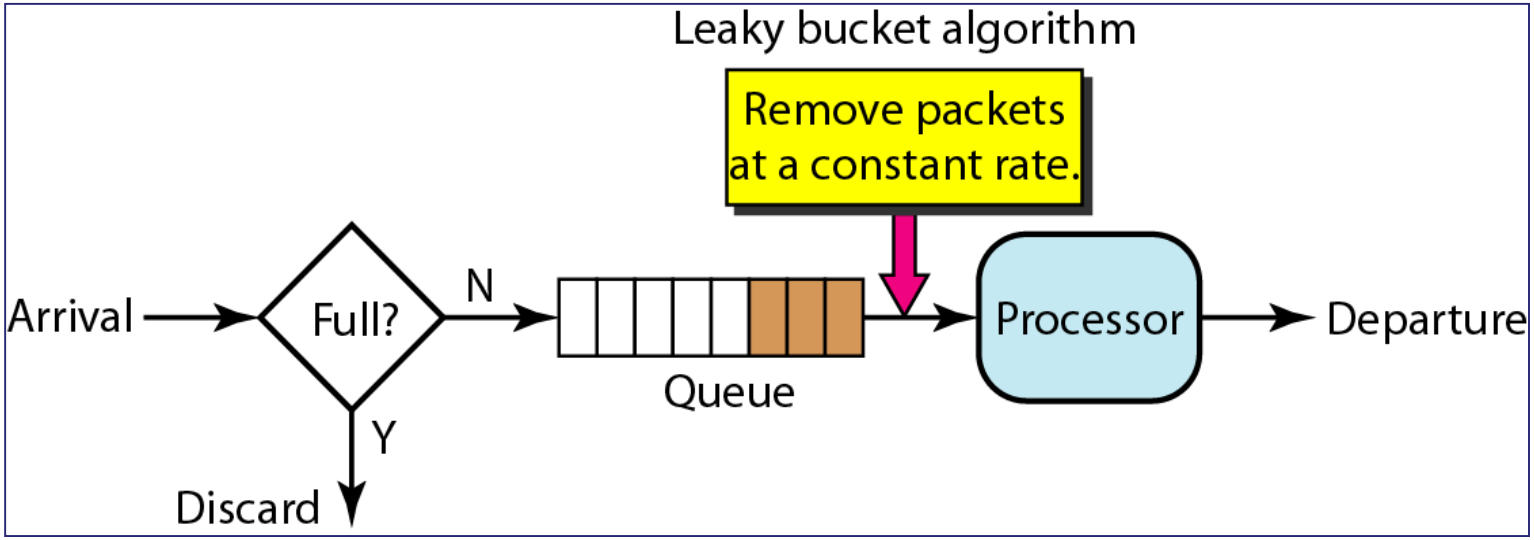


(6) Traffic Shaping

- Shape the traffic (packet flow) before it enters the network
  - Control the rate at which packets are sent
  - At connection set-up, host and end switch negotiate a traffic pattern (shape)
- Two traffic shaping algorithms
  - Leaky Bucket
  - Token Bucket

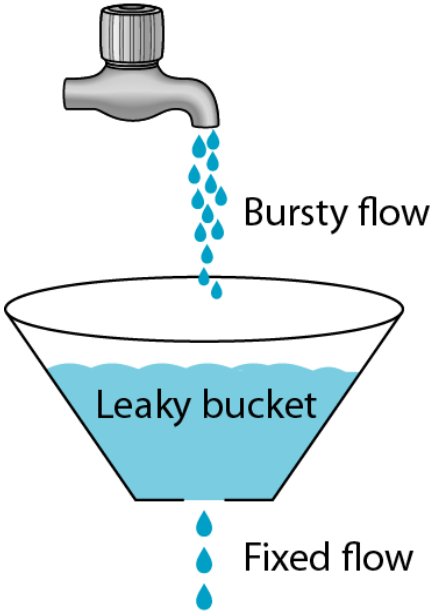
Leaky Bucket

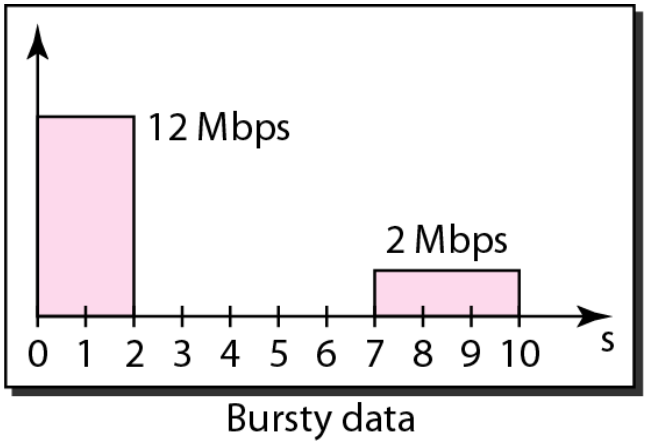
- Shape bursty traffic into fixed-rate traffic by averaging the data rate
- May drop the packets if the bucket is full



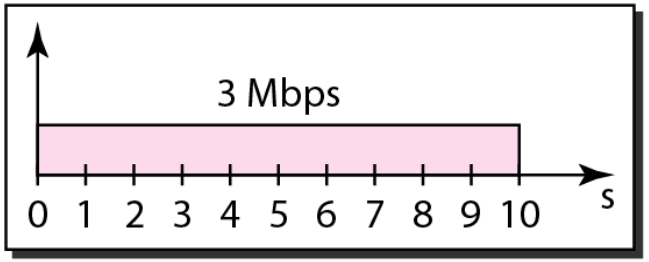
Leaky Bucket

- Do nothing when input is idle
- Packet output rate is fixed





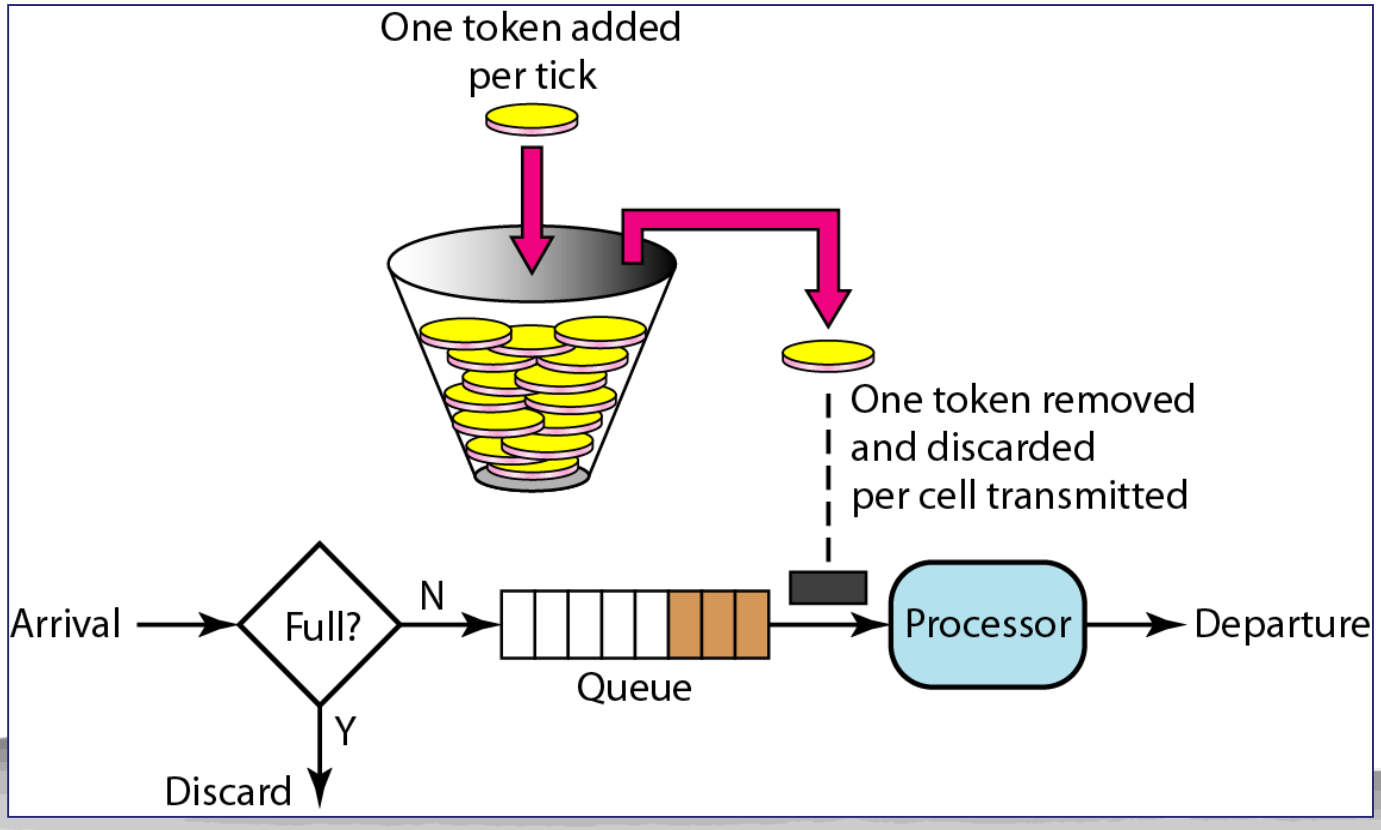
Bursty data



Fixed-rate data

Token Bucket

- Use token to control the output traffic, allowing vary output rate
- Token generation rate is fixed, may drop token (not packet) when bucket full

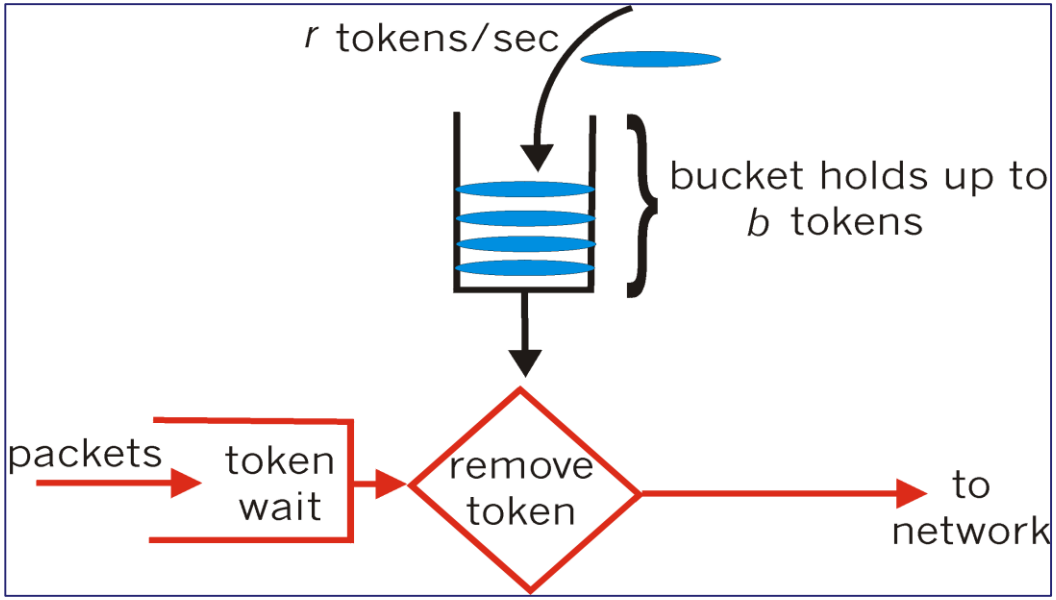


Token Bucket

- Token bucket is more powerful in traffic shaping

3 metrics defined

- Average traffic rate
- Burst traffic rate
- Maximum burst size



Summary

- Mechanisms for Network Congestion Control
  - Choke packet
  - Backpressure
  - Warning bit
  - Congestion window
  - Random early discard
  - Traffic shaping

Homework

- 第7章：R19, P18, P20