CEN445 – Network Protocols and Algorithms

Chapter 5 – Network Layer

5.3 Congestion Control Algorithms

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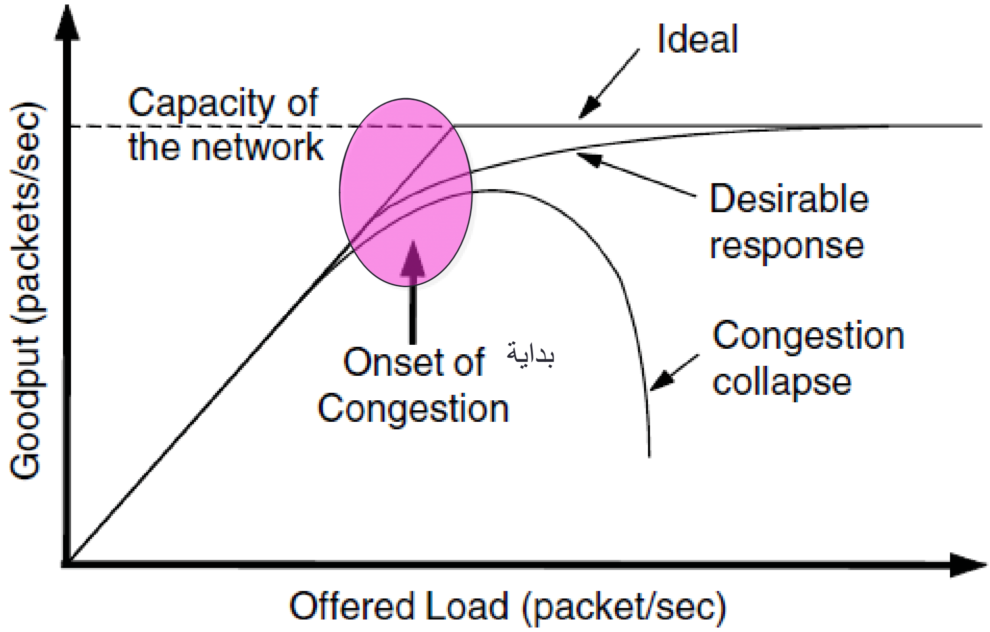
Congestion

- When number of packets sent is within subnet carrying capacity, all are delivered
- As traffic increases, packet loss happens
- At very high traffic, performance collapses
- Both transport and network layers share responsibility of handling congestion
- Network layer is directly affected
- In that chapter, we look at network aspect

Congestion



Goodput: rate at which *useful* packets are delivered by the network.

How Congestions Happens

- Incoming packets from multiple inputs need to go to same output line; queue builds up
- If insufficient memory, packets lost
- Adding memory helps to some point
- Even with ∞ memory, congestion gets worse
  - delayed packets timeout, retransmitted
  - duplicates increase load
- Congestion collapse: load exceeds capacity

How Congestions Happens

- Slow processors
  - CPU slow in doing bookkeeping tasks
  - queues build up
- Low bandwidth lines
  - can't forward packets same as arriving speeds
- Mismatch between system parts
  - upgrading some parts only shifts bottleneck

Congestion VS Flow Control

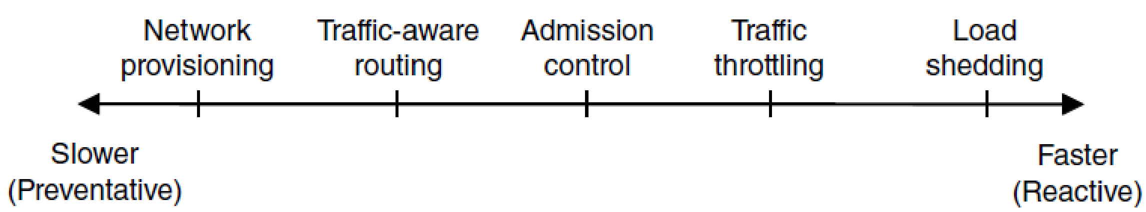
- Congestion control
  - make sure subnet is able to carry offered traffic
  - global, involve behavior of all hosts
  - all factors that diminish carrying capacity
- Flow control
  - traffic between a given sender & given receiver
  - ensure fast sender not overwhelm slow receiver
  - involve feedback from receiver to sender

Example: Congestion VS Flow Control

- Flow control
  - fiber optic network with 1000 Gbps
  - S.Computer try to transfer file to a PC @ 1Gbps
  - no congestion
  - flow control needed to slow SC
- Congestion control
  - network with 1 Mbps lines, 1000 computers
  - half of them trying to transfer @ 100 kbps
  - no overpowering problem
  - but total traffic exceed network capacity

Approaches to Congestion Control

- Congestion: load (temporarily) > resources
- Two solutions come to mind:
  - increase resources ⟶ (avoid congestion)
  - decrease load ⟶ (react to congestion)
- Solutions are supplied in different time scales



Network Provisioning

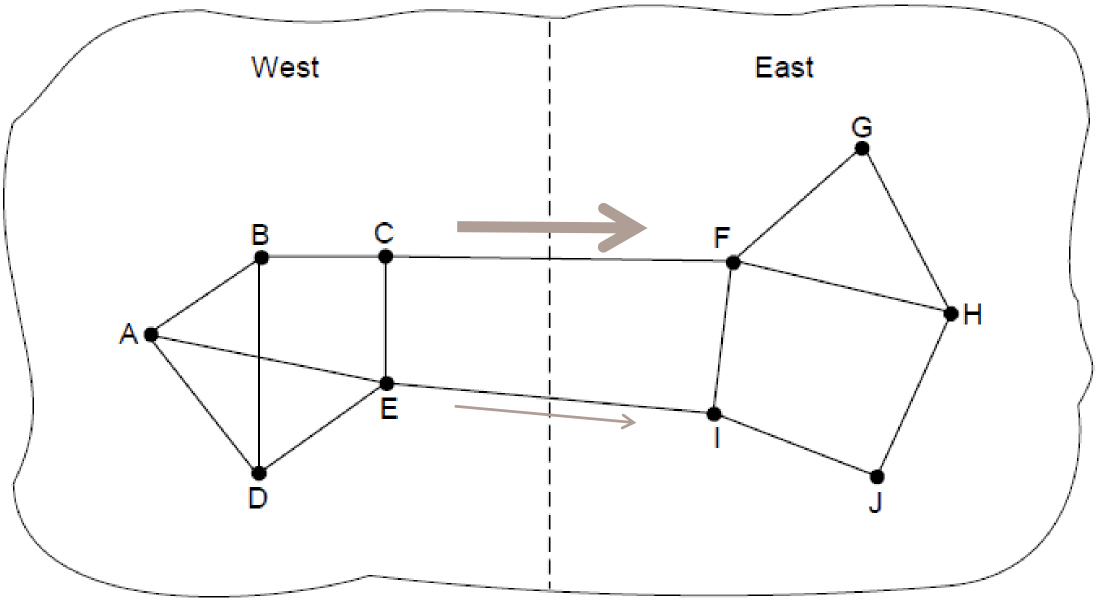
- Build network well matched to traffic
- Turn on spare resources as needed
- Upgrade heavily utilized routers and links

- Scale of months: long term trends of traffic

Traffic-Aware Routing

- Compute routes: take traffic into account
- Shift traffic away from congestion hotspots
- Used in early Internet
- Can cause routing oscillations
- Adding weight only slows down oscillations
- Solutions?
  - Multipath routing
  - Shift traffic slowly enough that it can converge

Traffic-Aware Routing

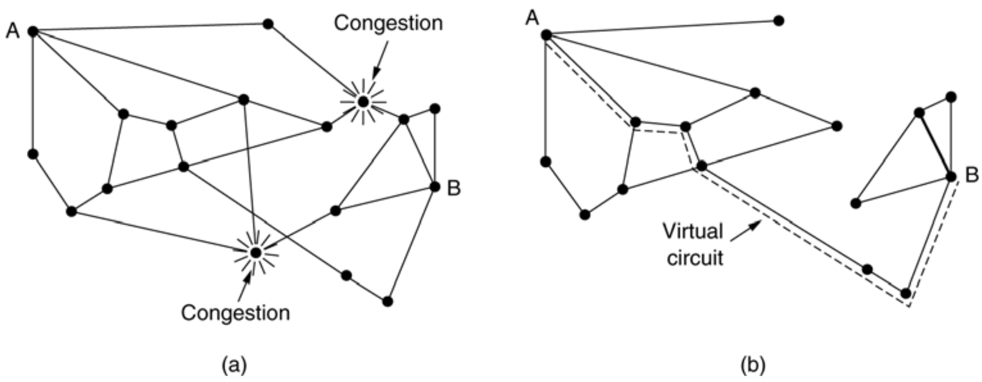


Admission Control

- Once there's congestion, no more VCs setup
- In telephone: no dial tone
- In data networks: traffic is variable (bursts)
- Reserve resources: wasteful
- Use statistics of previous behavior
- Trade performance for acceptable risk
- More details in "Quality of Service"

Admission Control

- Combined with traffic-aware routing
- Redraw network without congested links



Traffic Throttling

- Slow down when congestion is approaching
- Monitor resource usage
  - utilization of output links
  - buffering of queued packets inside router
  - number packets lost for lack of buffer space
- Packet loss: too late
- Average utilization: not account for bursts
- Queue delay directly captures congestion

Traffic Throttling

- Maintain good estimate of queue length: d
- $d_{new} = \alpha d_{old} + (1 - \alpha)s$
  - s: sample of instantaneous queue length
  - $\alpha < 1$: how fast router forgets recent history
- EWMA: Exponentially Weighted Moving Average
  - smooth fluctuations
  - equivalent to low-pass filter
- When $d > threshold$: report congestion

Example

Suppose measured delays are 20, 40, 25, 31 ms, respectively.
The current estimated delay is 30 ms.
Calculate the estimated delay

(a) if $\alpha = 0.2$

$$d_{new} = 0.2 \times 30 + 0.8 \times 20 = 22\ ms$$
$$d_{new} = 0.2 \times 22 + 0.8 \times 40 = 36.4\ ms$$
$$d_{new} = 0.2 \times 36.4 + 0.8 \times 25 = 27.28\ ms$$
$$d_{new} = 0.2 \times 27.28 + 0.8 \times 31 = 30.256\ ms$$

(b) if $\alpha = 0.6$

$$d_{new} = 0.6 \times 30 + 0.4 \times 20 = 26\ ms$$
$$d_{new} = 0.6 \times 26 + 0.4 \times 40 = 31.6\ ms$$
$$d_{new} = 0.6 \times 31.6 + 0.4 \times 25 = 28.96\ ms$$
$$d_{new} = 0.6 \times 28.96 + 0.4 \times 31 = 29.776\ ms$$

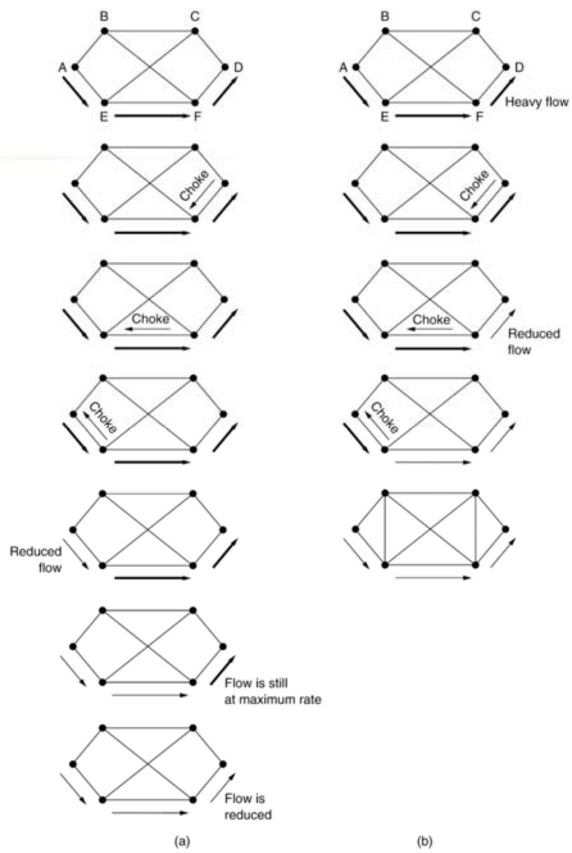
Traffic Throttling

- Choke Packets
  - most direct way, tell sender directly
  - send choke packet back to source host
  - original packet is tagged, so will not generate another choke packet, then forwarded as usual
- Hop-by-hop backpressure
  - affect every hop it passes through
  - provide quick relief at the point of congestion

Traffic Throttling

a) A choke packet that affects only the source

b) A choke packet that affects each hop it passes through



Load Shedding

- When other methods fail
- Throw excess packets away
- Term taken from electricity
  - blacking certain areas to save entire grid
  - on hot summer days with high demand
- Choosing packets to discard
  - random, may cause retransmissions
  - priority-based, required coop from senders

Load Shedding

- Random Early Detection (RED)
  - drop packets before situation become hopeless
  - routers maintain average queue length
  - if exceeds threshold, line said to be congested
  - router can’t tell which source most trouble
  - pick packet randomly from congested queue
- TCP responds to lost packets by slowing
  - in wired networks, loss is result of congestion
  - form of indirect feedback
  - in wireless networks, cannot be used