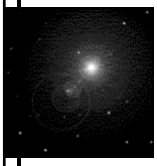
CS 4/54201 Computer

Communication Network

Kent State University

Dept. of Computer Science

www.mcs.kent.edu/~javed/class-NET06F/



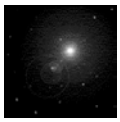
A Course on Networking and

Computer Communication

Congestion Control

Congestion Control

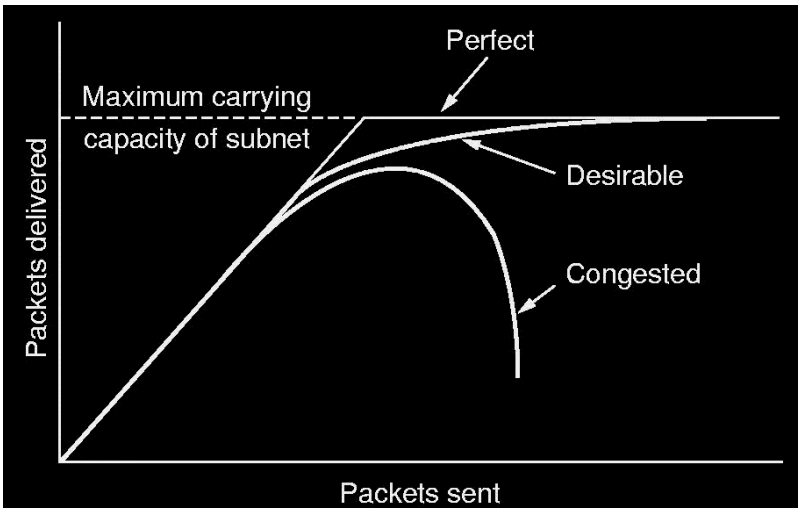
Quiz

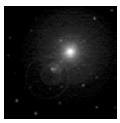


COMPUTER COMMUNICATION NETWORK

- QUIZ 701: What is the main advantage of token bucket over leaky bucket?
- QUIZ 702: What additional router capability is needed to implement hop-by-hop instead of the choke packet algorithm?
- QUIZ 704: Why in the world a router may want to drop packets intentionally even when its queue is still 20% empty?
- QUIZ 705: What is the objective of fair queuing?

Congestion Control

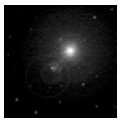




COMPUTER COMMUNICATION NETWORK

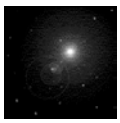
Taxonomy of Congestion Control Algorithms

- Router Centric vs. Host Centric
  - RC can address congestion inside network.
  - Most mechanisms need help from both. The question is therefore, who has the major share of burden.
- Reservation-Based vs. Feedback Based
  - Reservation based is also a congestion avoidance scheme.
  - Reservation protocols works better with virtual circuits.
  - Feedback can be *implicit* or *explicit*.
- Window-Based vs. Rate-Based
  - window-based works better for relative adjustment.
  - Rate-based works better for fast adjustment in high-speed networks.

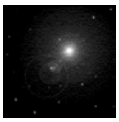


Policies Affecting CC

Layer	Policies
Transport	• Retransmission policy • Out-of-order caching policy • Acknowledgement policy • Flow control policy • Timeout determination
Network	• Virtual circuits versus datagram inside the subnet • Packet queueing and service policy • Packet discard policy • Routing algorithm • Packet lifetime management
Data link	• Retransmission policy • Out-of-order caching policy • Acknowledgement policy • Flow control policy



Evaluation Criteria

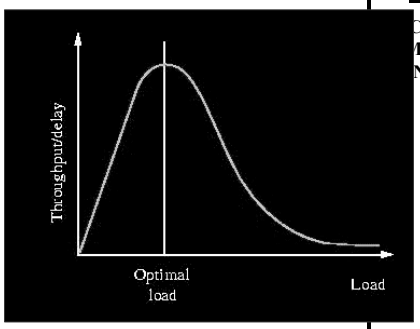


- Power

$$\frac{Throughput}{Delay}$$

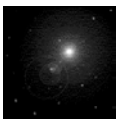
- Fairness Index:

$$f = \frac{(\sum_{i=1}^{n} x_i)^2}{n\sum_{i=1}^{n} x_i^2}$$



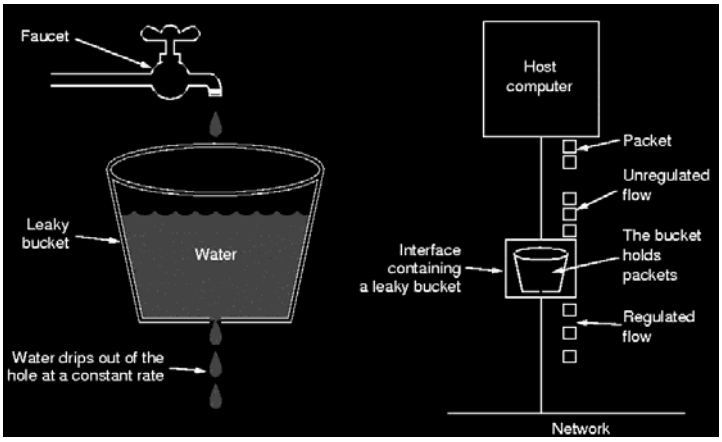
F=1 if all loads are equal.
F=k/n if (n-k) users get 0 service.

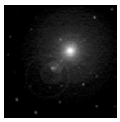
Traffic Shaping



- One of the main reason for congestion is burst traffic.
- One of the open loop method is to shape the traffic.
- Traffic shaping means smooth the output flow.
- It works well if there is a traffic police.
- Monitoring and policing is easier with virtual circuits.
- A mechanism for traffic shaping even with data-grams is Leaky Bucket Algorithm.

Leaky Bucket Algorithm (Turner 69)





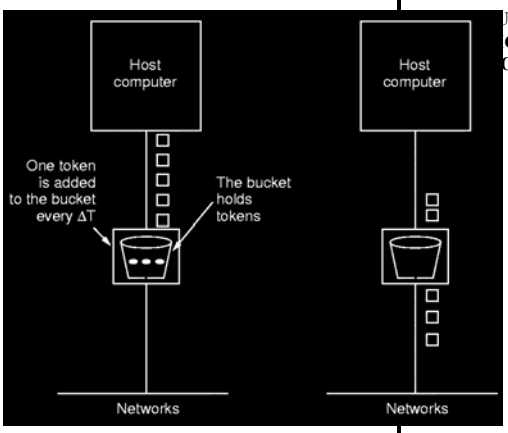
COMPUTER COMMUNICATION NETWORK

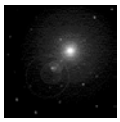
Leaky Bucket makes output flat irrespective of the burstiness of input. Some time, it is prudent to send fast when lot of data arrives.

- The host is allowed to output one packet per time tick.
- Excess packets are dropped.
- Enforced at NIC.
- For variable sized packets, it is better to count bytes rather than packets.

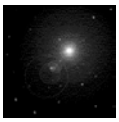
Token Bucket Algorithm

- The leaky bucket hold token generated at fixed rate.
- With 3 tokens it can send 3 out of 5 packets immediately.
- It allows idle hosts to save permissions to send (up to maximum of n).
- Here, tokens are discarded, when overflow occurs not the packets.
- A variation of the algorithm can count bytes, rather than packets.



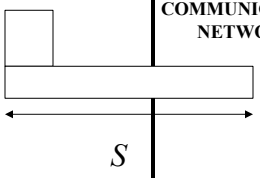


Maximum Burst Length in Token Bucket



COMPUTER COMMUNICATION NETWORK

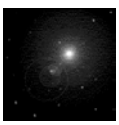
- $C + r.S = M.S$
  - C=Token bucket capacity in bytes.
  - S=Burst length is seconds.
  - r=Rate of token arrival in bytes/sec.
  - M=maximum output rate in bytes/sec.



$$S = \frac{C}{M - r}$$

QUIZ 703: A Token bucket has a capacity (C) of 250 KB. It has a maximum outputting capacity (M) of 25 MB/sec. Token is released at a rate (r) of 2 MB/sec. What is the maximum duration of time (S) we can see a burst to sustain?

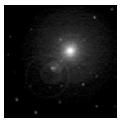
Traffic Shaping



COMPUTER COMMUNICATION NETWORK

- Description of Input
  - Maximum packet size (S bytes)
  - Token arrival rate (r bytes/second)
  - Token bucket capacity (C bytes)
  - Maximum transmission rate (S bytes/sec)
- Description of Desired Service
  - Loss sensitivity (bytes)
  - Loss interval (sec)
  - Minimum delay noticed (sec)
  - Maximum delay variation (sec)
  - Quality of guarantee

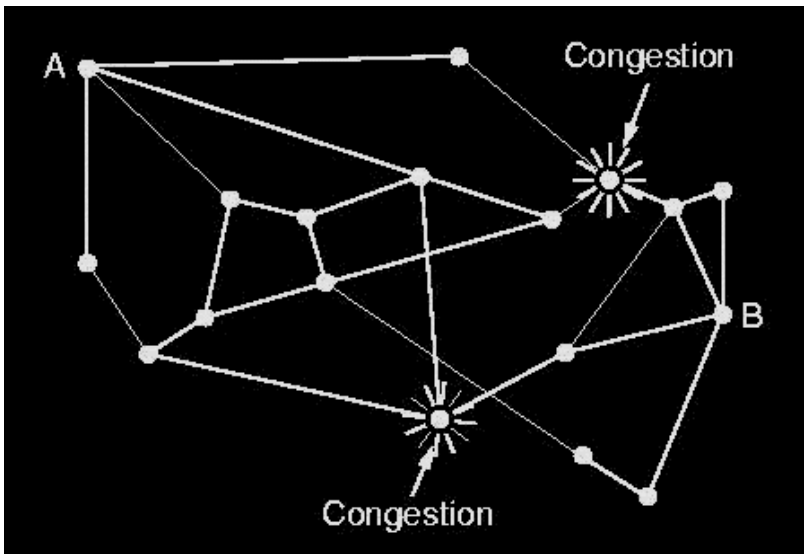
Congestion Control in Virtual Circuit Subnet

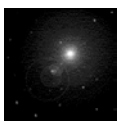


COMPUTER COMMUNICATION NETWORK

- Admission Control:
  - once congestion has been signaled, do not take in any more connection.
  - Easy to implement and enforce.
- Avoidance of Congested Subnet:
  - New connections are accepted
  - but they are routed avoiding traffic jams.

Congestion Control in VC Subnets

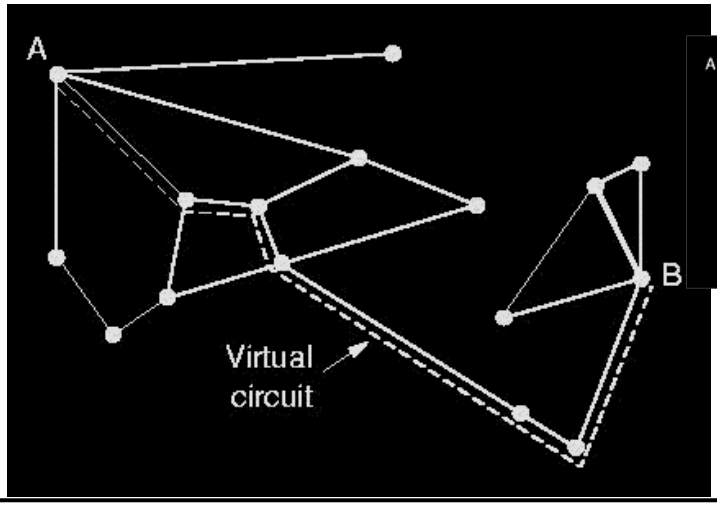


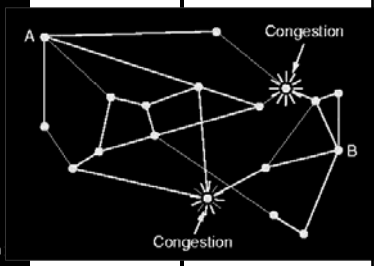


COMPUTER COMMUNICATION NETWORK

Congestion Control in VC Subnets

COMPUTER COMMUNICATION NETWORK





- Cannot be used in TCP/IP network as there is no concept of circuit!

Choke Packets

COMPUTER COMMUNICATION NETWORK

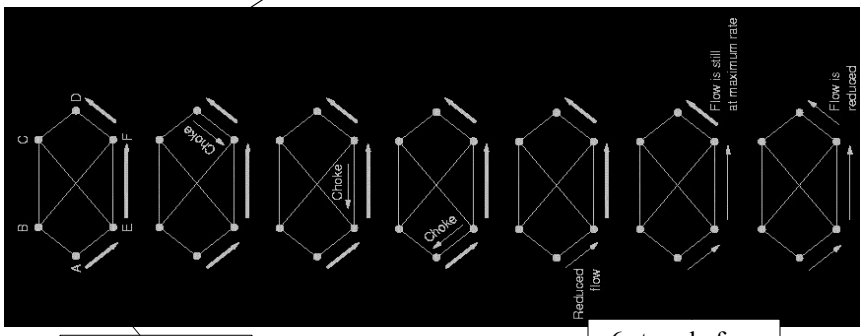
- This approach can be used both for VC's and datagrams!
- Each router monitors the utilization u of its output line. Let it takes a sample f in a regular interval:

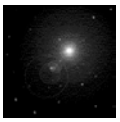
$$U = \alpha \cdot U + (1 - \alpha) \cdot f$$

- When u exceeds some threshold, it sends "warning".
- If the destination of a packet is in a jammed line, it send a 'warning' message back to the originator of the packets.
- The host is required to reduce sending rate upon receiving the warning.
  - It sets up a timer, and ignores other choke packets within that specified time to avoid the series of choke packets.
  - If new choke packets comes after the timer interval, it again reduces the rate.

- What if the router is a host is SF is sending to a router in NY at 155 MB/sec?
- It will take 30ms.
- By that time the host will send another 4.6 Mbits of data in the pipe.

Choke Packet

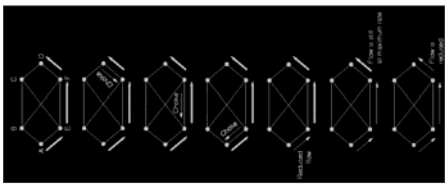


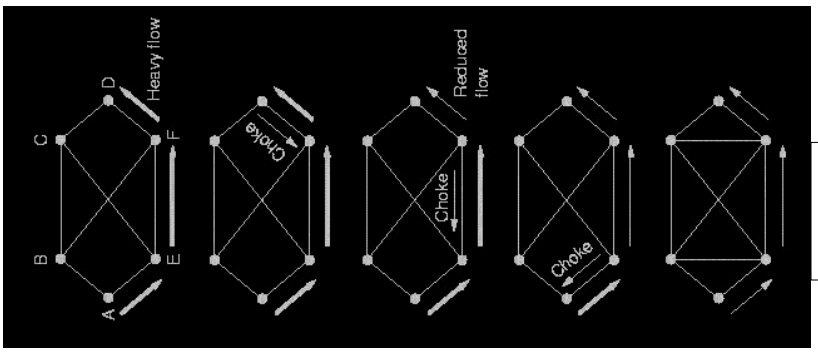


COMPUTER COMMUNICATION NETWORK

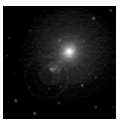
Hop-by-Hop Choke Packet

Each upstream router responds immediately.





All routers shares the pain by spending buffer.

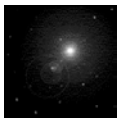


COMPUTER COMMUNICATION NETWORK

Other Variations

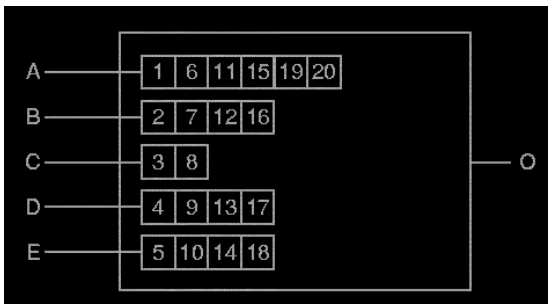
- Drop packets instead as warning to sender!
- Routers can maintain several thresholds.
  - "mild warning",
  - "stern warning",
  - "ultimatum".
- Instead of line utilization other triggers can be used:
  - queue length.
  - Buffer utilization.
  - Growth of queue length.
- There are many ways how senders can cut back.

4 Hosts are swamping the same output line.
Router sends choke packet to all of them.
Only one reduces the rate, 3 others keeps on blasting away.
What happens to the honest host?

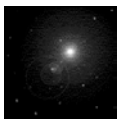


Fair Queuing (Nagle 1987, Demers 1990)

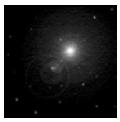
- Routers maintain separate queue for each hosts.
- It scans byte-by-byte each queue.
- A modified scheme weights the queues based on number of VC from each hosts.



Packet	Finishing time
C	8
B	16
D	17
E	18
A	20



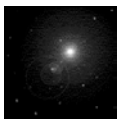
A Fair Queuing Logic for Time Stamping



COMPUTER COMMUNICATION NETWORK

- For a Single Flow
  - Clock ticks each time a bit is transmitted.
  - P(i) = length of the packet i.
  - S(i) = clock time when we start transmitting packet i.
  - F(i) = finish time to transmit packet i.
  - F(i)=S(i)+P(i)
  - When does router start transmitting packet i?
    - If router has not finished packet i-1, then immediate after sending packet i-1.
    - Otherwise, right after its arrival time A(i)
  - Thus F(i)=MAX[F(i-1), A(i)] + P(i)
- Multiple Flow
  - Calculate F(i) for each packet in each flow.
  - Transmit the one with lowest F(i)

Characteristics of Fair Queuing



COMPUTER COMMUNICATION NETWORK

- Work Conserving:
  - Router never idle:
  - If one flow is empty then it immediately transmits from other.
- Fair:
  - If one flow is sending too much of large packets its packets gets large time stamps.
- Weighted fair Queuing:
  - A modified scheme weights the queues based on number of VC from each hosts.
  - Based on flow one bit might be counted as 2 or 3.

TCP Congestion Control