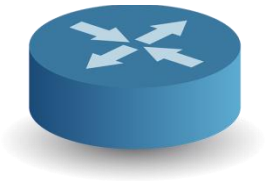
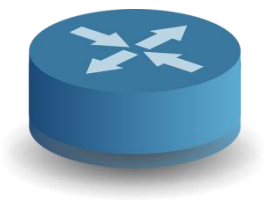


CMPN415
Computer Networks

Part Five

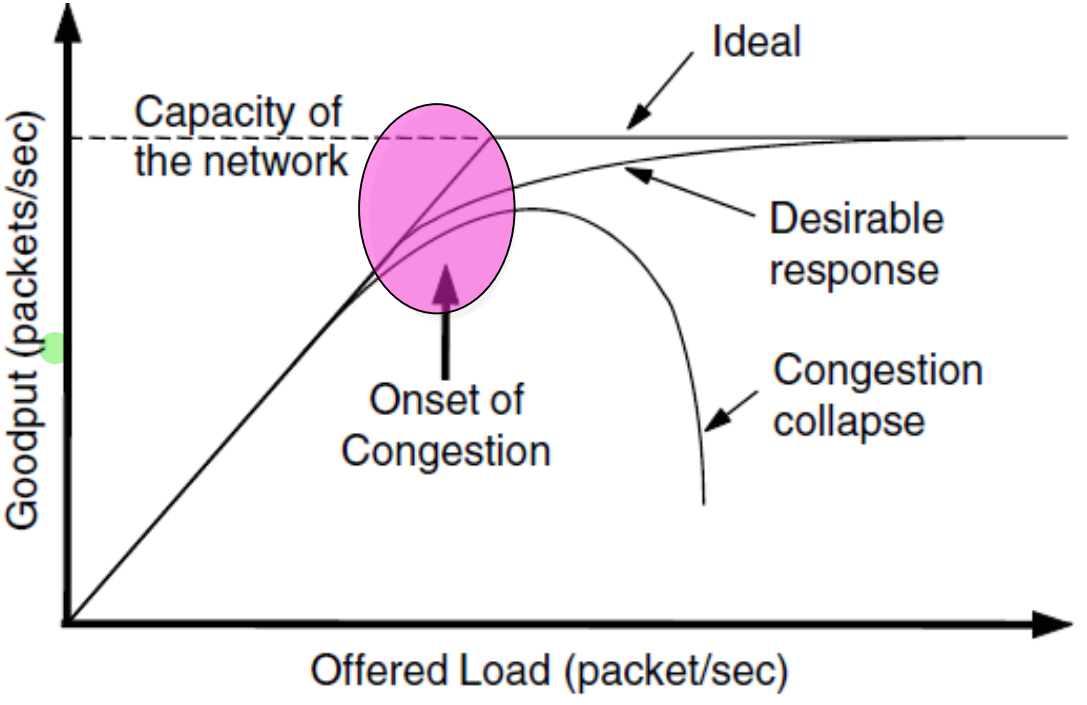
Congestion Control



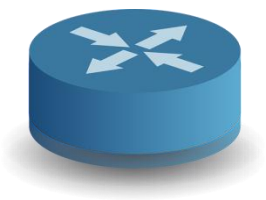
Congestion Control Algorithms

- General Principles of Congestion Control
- Congestion Control Techniques

A. What is Congestion ?



- Congestion means there is more traffic in the network than it can carry
  - May be temporary or permanent
- When too much traffic is offered, congestion sets in and performance degrades sharply.
- Congestion occurs when the network is unable to deliver incoming packets to appropriate destinations



Difference between Congestion and Flow Control

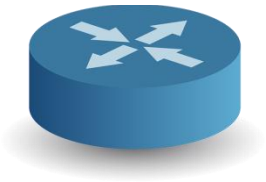
Congestion control

- Making sure that the network can carry the generated traffic
- Involves all network components, including hosts
- Global problem requiring network wide algorithm and co-operation between all components

Flow control

- Making sure that the receiver can consume the traffic generated by the sender
- Confined to the sender and receiver only
  - Point-to-point or point to multipoint problem
- Usually only sender and receiver(s) are involved
- Feedback, re-negotiation, or upfront agreement between sender and receiver are usually used

Confusion because many congestion control algorithm operate by sending feedback to the sender(s) to slow it (them) down



Congestion: principles

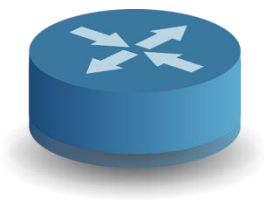
Control theory viewpoint

Open Loop

- How? Good design
  - Make sure the problem does not occur
- Techniques
  - Decide when to accept traffic CALL ADMISSION
  - Decide when to discard packets and which ones
  - Make scheduling decisions in the subnet
- Congestion Prevention Techniques

Closed Loop

- Monitor: where and when congestion?
  - % packets discarded
  - average queue length
  - number of packets that time out
  - average packet delay
- Deliver Congested notification to places where actions can be taken = source of traffic
- Adjust system operation
  - Increase resources: bandwidth
  - Decrease load: deny, degrade service
- Congestion Control Techniques

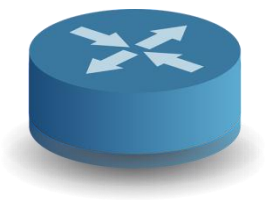


General Principles of Congestion Control
Delivering Congestion Notification

- Need to deliver knowledge about congestion to the places where action can be taken
  - End-points
  - Routers (e.g. routers can re-route traffic)

- Two general categories for delivering congestion information
  - **Explicit feedback**: information sent from congestion points to sources
  - **Implicit feedback**: Local observation e.g. sources detects that RTT has increased

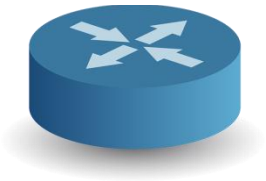
    - **Send special packets**
      - Adds more packets to the system ⇒ more congestion (***but not much***)
    - **Routers mark passing packets**
      - e.g. **set congestion bit**



General Principles of Congestion Control

Relieving Congestion

- Congestion means (possibly temporary) *excess load* beyond resources
- Thus there are two basic solutions
- Increase capacity
  - Use redundant resources $\Rightarrow$ network is not fault tolerant
  - Use more expensive or slower resources
    - » E,g. dialup lines or increase transmission power in satellites
- Reduce load
  - Use CAC (admission control)
  - Degrade service



B. Congestion Control Techniques

Handling congestion is the responsibility of the **Network and Transport layers** working together

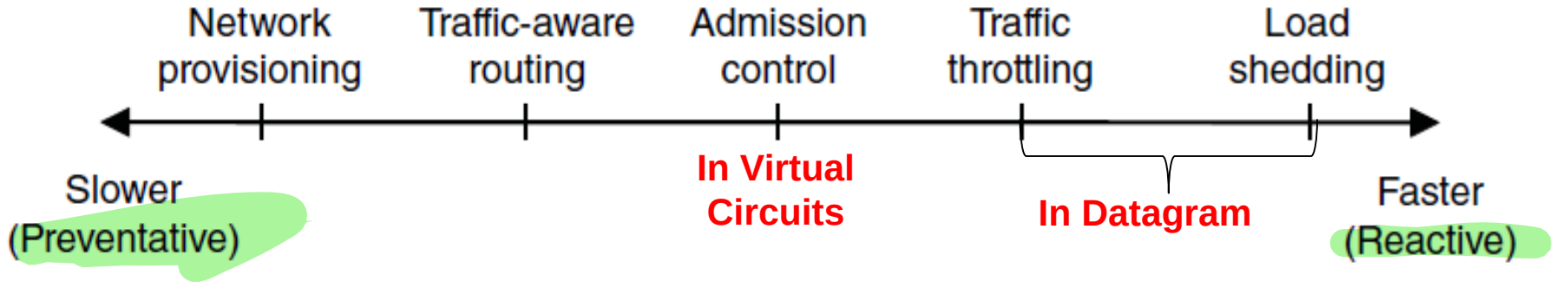
- Focus on Network layer here

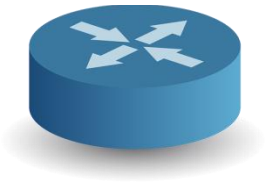
1. Traffic-aware routing
2. Admission control
3. Traffic throttling
4. Load shedding
   - Random Early Detection

Congestion Control – Approaches

Network must do its best with the offered load

- Different approaches at different timescales
- Nodes should also reduce offered load (Transport)

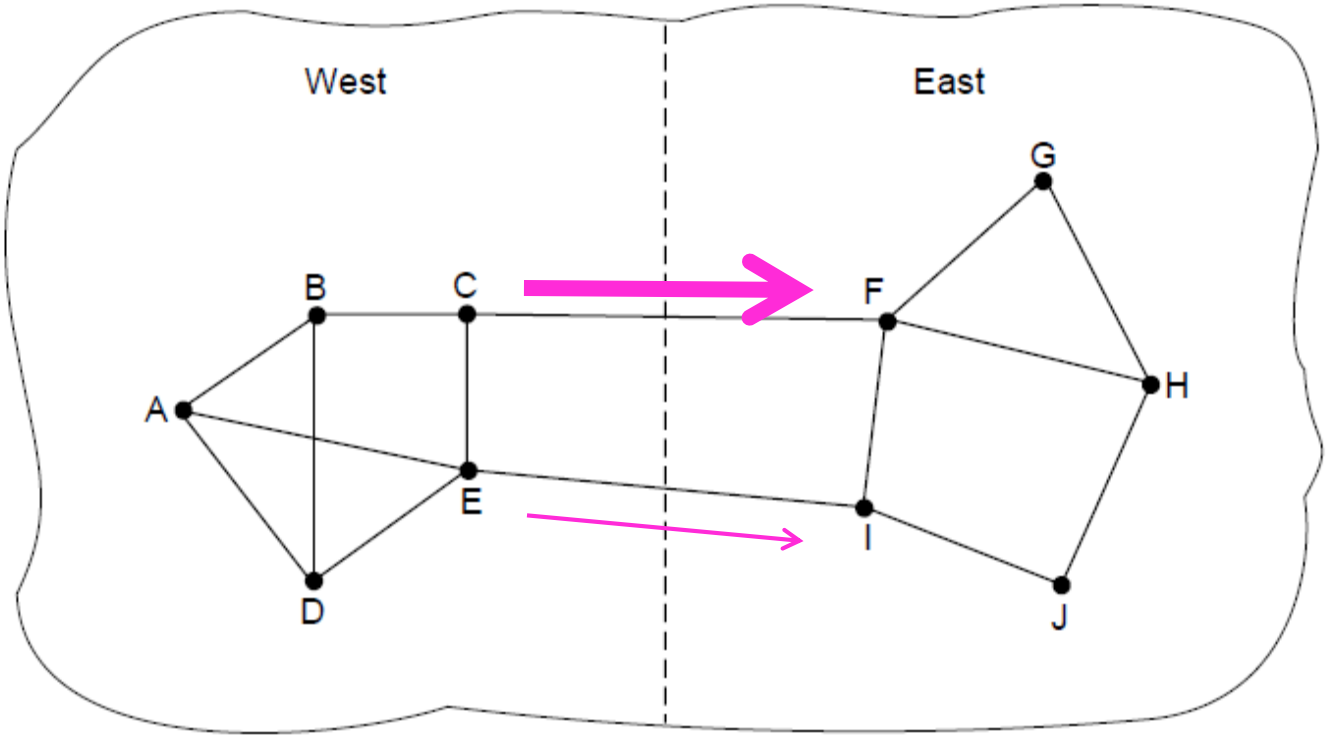


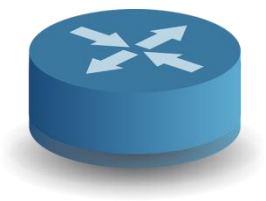


1. Traffic-Aware Routing

Choose routes depending on traffic, not just topology

- E.g., use *EI* for West-to-East traffic if *CF* is loaded
- But take care to avoid oscillations

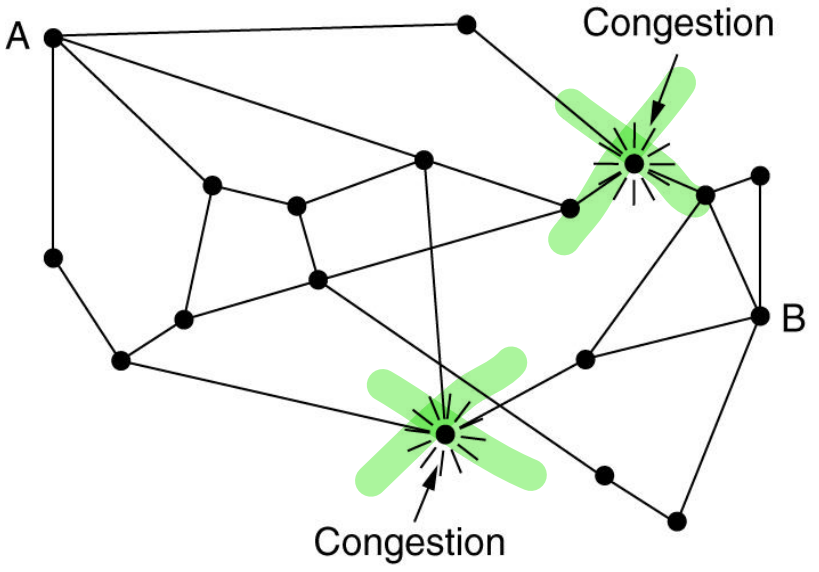




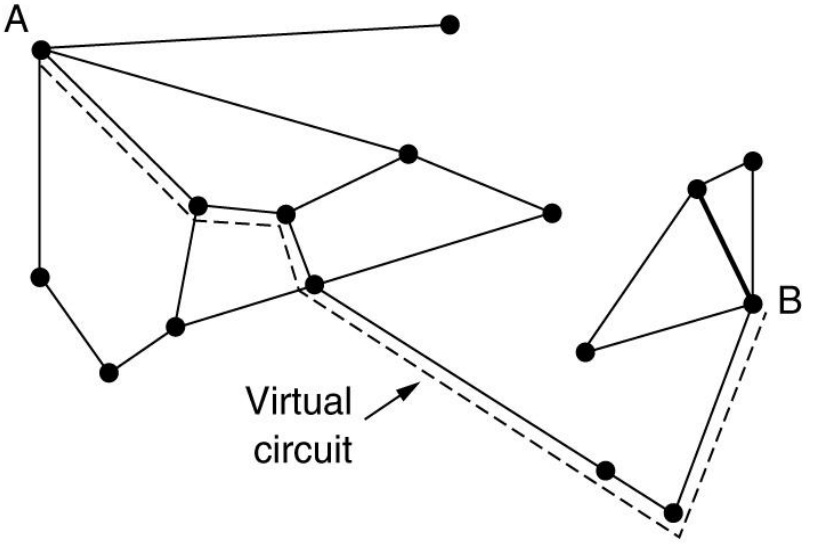
Congestion Control in Virtual-Circuit 2. Admission Control

- Resource reservation RSVP
  - Works with VCs because we know the route for every flow
  - Wastes resources
- Admission control (A.K.A Call Admission Control)
  - Do not allow new VCs until congestion is relieved
  - Simple and crude but *it works !!*
  - Used in telephone systems (e.g. not getting a dial tone)
- Limiting input traffic
  - Agreement with end user on traffic shape

Congestion Control in Virtual-Circuit Routing Around congestion*



(a)

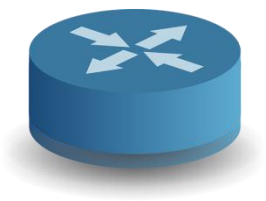


(b)

(a) A congested subnet.

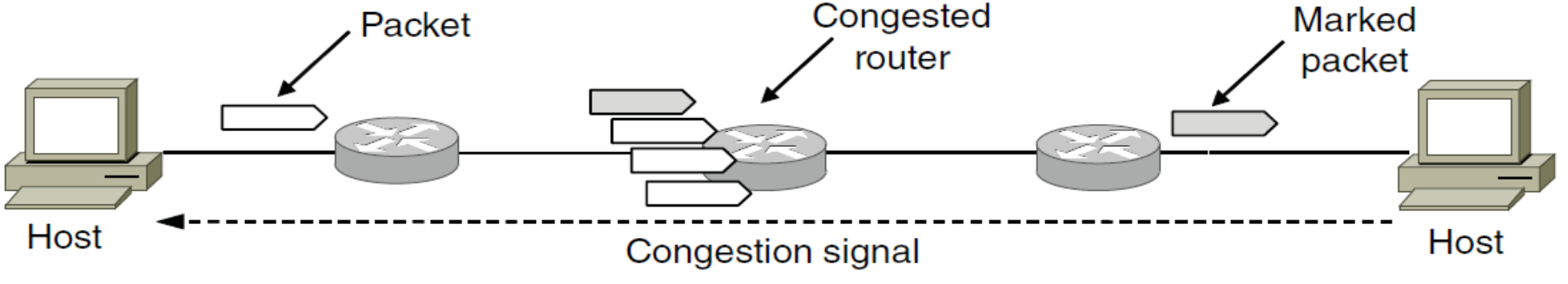
(b) Don't allow routing through congestion points. E.g. assume that congested nodes do not exist

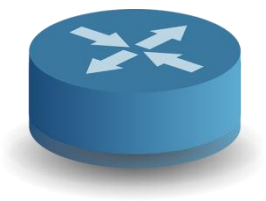
(c) A redrawn subnet, eliminates congestion and establish a virtual circuit from A to B.



Congestion Control in Datagram
3. Traffic Throttling

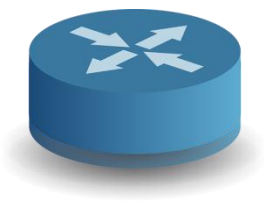
- Detect congestion at congestion point (ex: based on buffers utilization)
- Congestion notification is sent from the congested router to the traffic source directly or indirectly through marking the packets to the destination
- Source listens to congestion notification and reduces generated traffic as long congestion notification is coming
- Source increases traffic (*gradually*) when congestion notifications no longer arrive





Datagram: Traffic Throttling Warning Bit – Choke Packets

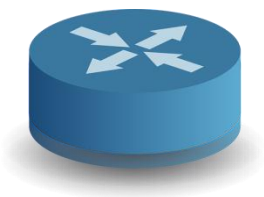
- Warning bit (Explicit congestion notification)
  - Congested router sets a **warning bit** in forward traffic to Destination
  - Destination sets the warning bit in **ACK packets**
  - Sources are required to react to warning bit in ACK by reducing traffic to the destination that sent the ACK containing warning bit
- Choke packet
  - Generated at congested router/node send choke packet to source
  - Choke packet contains destination in the packet
  - Source is required to reduce traffic to this destination
  - Most likely first few choke packet will be sent first to sources with largest amount of traffic



Datagram: Traffic Throttling

Hop-by-Hop Choke Packets

- Faster relief
- Requires additional resources in the network
- Need to generate more packets
  - Each intermediate router along the reverse path has to receive the choke packet, process it, and then generate another choke packet to its upstream neighbor
  - Not much additional traffic
- Most likely very hard to implement in hardware



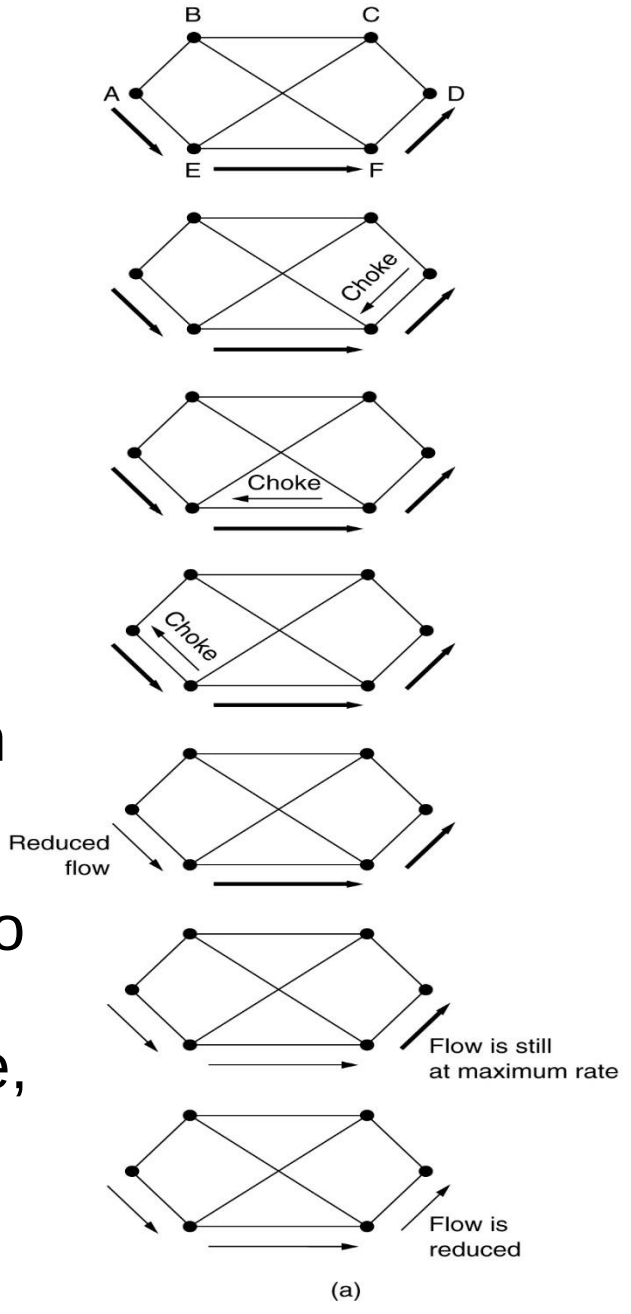
Network Based Reaction Hop-by-Hop Choke Packets

Idea:

(a) Choke packet that affects ONLY the source

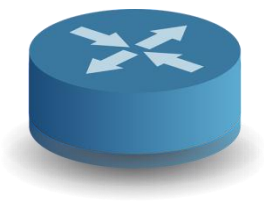
(b) Choke packet affects each hop it passes through.

Upstream hops are required to relieve congested node by allocating more buffer, reroute, drop traffic,…,



Choke packet sent to heavy sources

Hop-By-Hop Choke packet



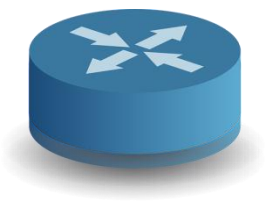
Congestion Control in Datagram
4. Load Shedding

Basic Idea

- Overloaded routers can drop packets
- It is good to be *smart* when dropping packets

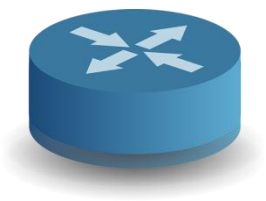
Example drop policies (*How smart can packet dropping be*)

- Tail drop
- Random drop
- Drop new packets (*when it is good to drop new packets?*)
- Drop old packets (*Example of when it is good to drop old packets?*)
- Rely on information from the sources to drop packets
  - Sources can mark packets as important
  - Give incentive to unimportant packets (e.g. discount)
  - E.g. Text packets are very important but video packets are not



Datagram, Load Shedding Random Early Detection (RED)

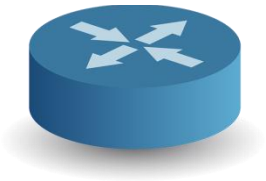
- Proposed by Floyd and Jacobson in 1993
- Idea
  - Detect congestion early
  - When queue exceeds a certain threshold, router declares congestion
  - Router need **not** to know which source caused congestion
  - Pick a packet at random (i.e. a source at random) is a good enough action
  - *Inform* (how?) the randomly chosen source about congestion
  - Source is expected to reduce generated traffic



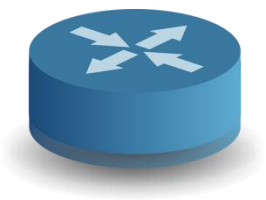
Datagram, Load Shedding : Random Early Detection (RED)

- How to tell the random source about congestion?

- Drop packet at random
  - ACK does not come or *duplicate* ACK is sent to source
  - Source reacts to dropped packet by reducing traffic
  - Thus we effectively did the following
    - » Notified the source
    - » Source assumes that dropping the packets is because of congestion
    - » The source reacted appropriately by reducing traffic



End of Congestion Control



Congestion Control in Datagram Source-based Reaction

- *Which one is better, warning bit or choke packet?*
- *How does host based reaction eventually relieve network wide congestion?*
- *Can you give examples of how a source can reduce traffic?*