Wireless Networks
(CSC-7602)
Lecture 8
(22 Oct. 2007)

Seung-Jong Park (Jay)
http://www.csc.lsu.edu/~sjpark

Fair Queueing

Today

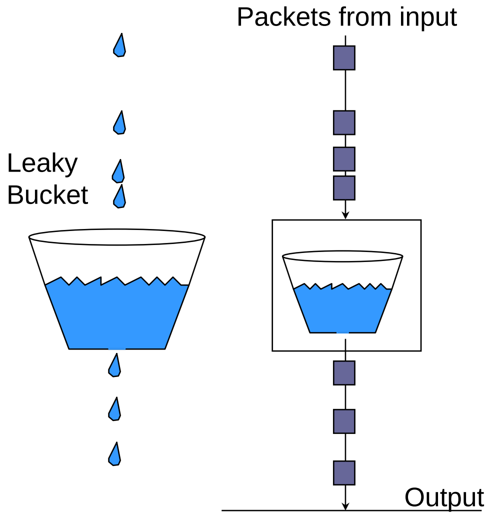
- Wireline Queue Drop
- Wireless Queue Drop

Types of Congestion Control Strategies

- Limit entry into the system
  - Packet level (layer 3)
    - Leaky Bucket, token bucket, WFQ
  - Flow/conversation level (layer 4)
    - Resource reservation
    - TCP backoff/reduce window
  - Application level (layer 7)
    - Limit types/kinds of applications
- Terminate existing resources
  - Drop packets
  - Drop circuits

Leaky Bucket: Analogy

- Across a single link, only allow packets across at a constant rate
- Packets may be generated in a bursty manner, but after they pass through the leaky bucket, they enter the network evenly spaced
- If all inputs enforce a leaky bucket, its easy to reason about the total resource demand on the rest of the system



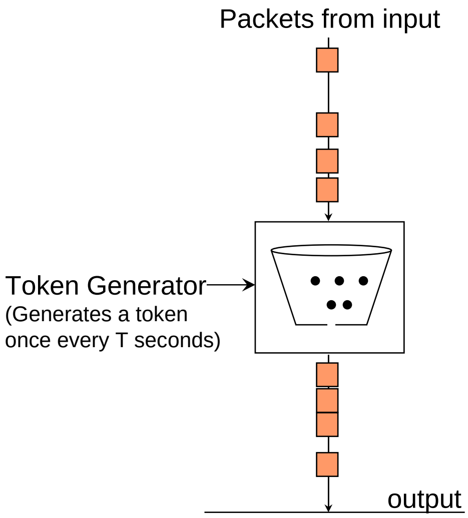
Leaky Bucket *(cont'd)*

- The leaky bucket is a "traffic shaper": It changes the characteristics of a packet stream
- Traffic shaping makes the network more manageable and predictable
- Usually the network tells the leaky bucket the rate at which it may send packets when a connection is established

- **Leaky Bucket: Doesn't allow bursty transmissions**
  - In some cases, we may want to allow short bursts of packets to enter the network without smoothing them out
  - For this purpose we use a token bucket, which is a modified leaky bucket

Token Bucket

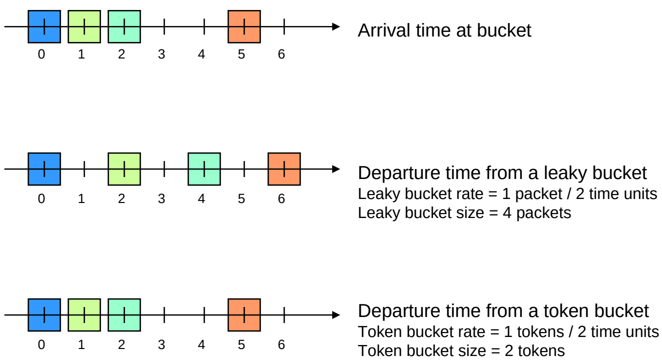
- The bucket holds logical tokens instead of packets
- Tokens are generated and placed into the token bucket at a constant rate
- When a packet arrives at the token bucket, it is transmitted if there is a token available. Otherwise it is buffered until a token becomes available.
- The token bucket holds a fixed number of tokens, so when it becomes full, subsequently generated tokens are discarded
- Can still reason about total possible demand



CSC7602 – S.J. Park

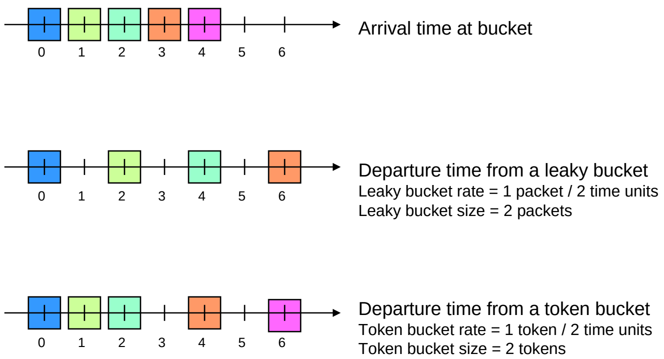
Token Bucket vs. Leaky Bucket

Case 1: Short burst arrivals



Token Bucket vs. Leaky Bucket

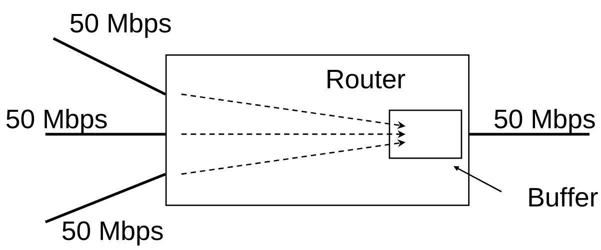
Case 2: Large burst arrivals



Queue Drop Policy for Wire Link

Packet dropping

- Packets that cannot be served immediately are buffered
- Full buffers => *packet drop strategy*
- Packet losses happen almost always from best-effort connections (why?)
- Shouldn't drop packets unless imperative
  - packet drop wastes resources (why?)



Early vs. late drop

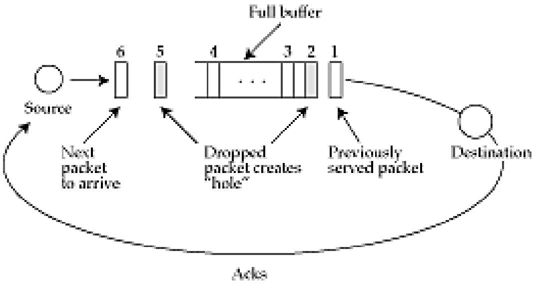
- Early drop => drop even if space is available
  - signals endpoints to reduce rate
  - cooperative sources get lower overall delays, uncooperative sources get severe packet loss
- Early random drop
  - drop arriving packet with fixed drop probability if queue length exceeds threshold
  - intuition: misbehaving sources more likely to send packets and see packet losses
  - doesn't work!

Early vs. late drop: RED

- Random early detection (RED) makes three improvements
- Metric is moving average of queue lengths
  - small bursts pass through unharmed
  - only affects sustained overloads
- Packet drop probability is a function of mean queue length
  - prevents severe reaction to mild overload
- Can mark packets instead of dropping them
  - allows sources to detect network state without losses
- RED improves performance of a network of cooperating TCP sources
- No bias against bursty sources
- Controls queue length regardless of endpoint cooperation

Drop position

- Can drop a packet from head, tail, or random position in the queue
- Tail
  - easy
  - default approach
- Head
  - harder
  - lets source detect loss earlier

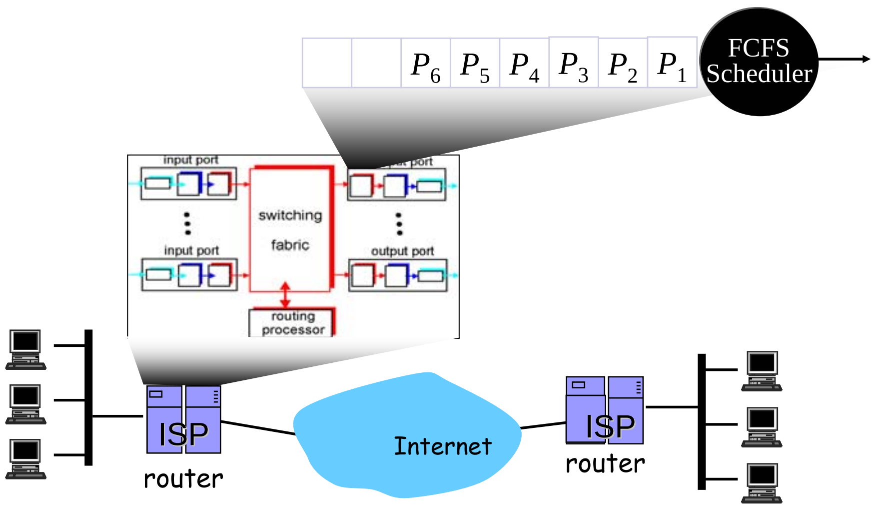


Drop position (contd.)

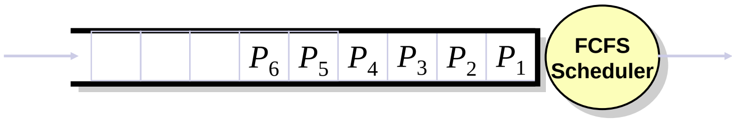
- Random
  - hardest
  - unlikely to make it to real routers
- Drop entire longest queue
  - easy
  - almost as effective as drop tail from longest queue

Randomization in Router Queue Management

- normally, packets dropped only when queue overflows
  - "drop-tail" queueing

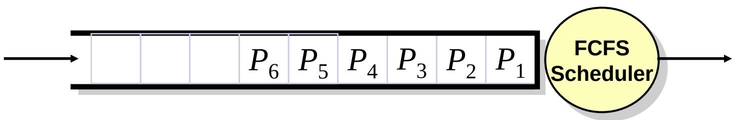


The case against drop-tail queue management



- large queues in routers are "a bad thing"
  - end-to-end latency dominated by length of queues at switches in network
- allowing queues to overflow is "a bad thing"
  - connections transmitting at high rates can starve connections transmitting at low rates
  - connections can *synchronize* their response to congestion
    - Global synchronization

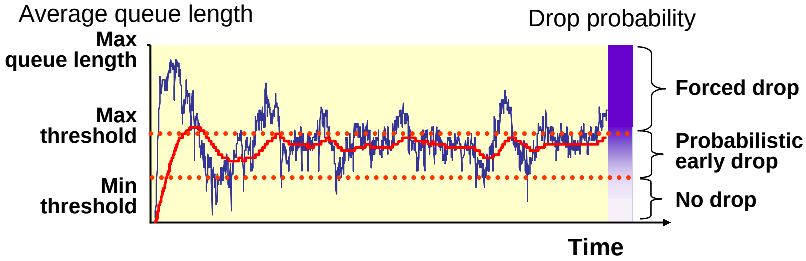
Idea: early random packet drop



when queue length exceeds threshold, drop packets with queue length dependent *probability*

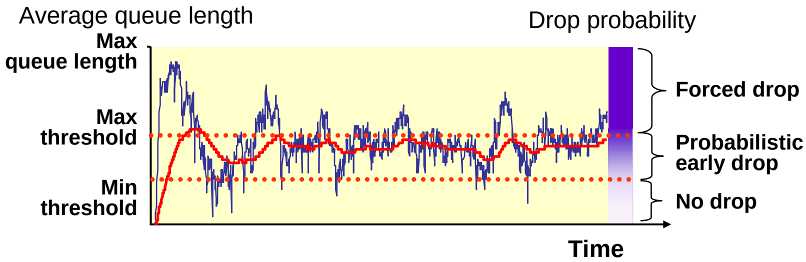
- probabilistic packet drop: flows see same loss *rate*
- problem: bursty traffic (burst arrives when queue is near threshold) can be over penalized

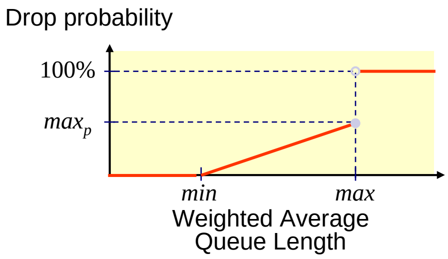
Random early detection (RED) packet drop



- use exponential *average* of queue length to determine when to drop
  - avoid overly penalizing short-term bursts
  - react to longer term trends
- tie drop prob. to weighted avg. queue length
  - avoids over-reaction to mild overload conditions

Random early detection (RED) packet drop





New Queue Drop for Wireless Networks:

Enhancing TCP Fairness in Ad Hoc Wireless Networks using Neighborhood RED

Kaixin Xu, Mario Gerla
UCLA Computer Science Department
{xkx,gerla}@cs.ucla.edu

21

Three different types of challenges are posed to TCP in MANET

- 1. Mobility causes changing of topology and route change, cause TCP goes to exponentially back-off
- 2. The second problem deal with congestion window in use.
- 3. The third problem is significant TCP unfairness.
- This paper focuses on the third problem.

22

RED can improve congestion control and fairness in wired network

- Suppose the current queue size is q
- The avg queue size is computed as

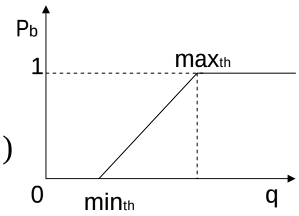
$$avg = (1 - w_q) * avg + w_q * q$$

w_q *is the queue weight*

$$p_b = \max_p (avg - \min_{th}) / (\max_{th} - \min_{th})$$

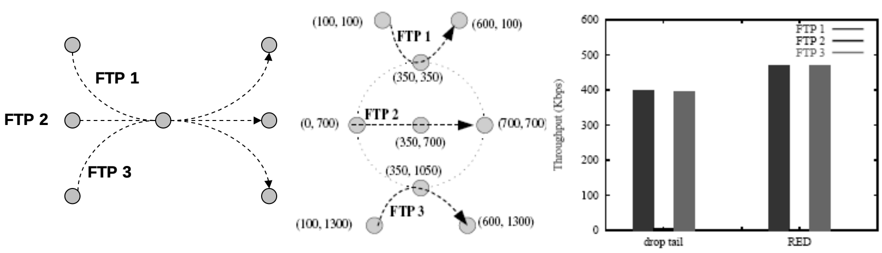
$$p_a = p_b / (1 - count * p_b)$$

$\max_p$ *is the maximum packet drop probability and count is the number of packets arrived since last packet drop.*



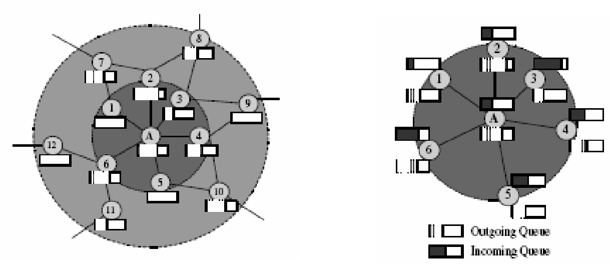
TCP UNFAIRNESS AND RED IN MANET

- FTP 2 is always starved. RED does not improve fairness.
  This is because congestion does not happens in a single node, but in an entire area.



Neighborhood and its Distributed Queue

- Neighborhood: A node's neighborhood consists of the node itself and the nodes which can interfere with this node's signal, which includes 1-hop neighbors and 2-hop neighbors.
- (normally interference range is much larger than data transmission ra nge, which is simplified in this paper).



Neighborhood and its Distributed Queue

- The main idea of this paper is to treat this distributed queue of a neighborho od in an manet the same way as we would on a single link queue in the wire d net and apply RED to it.
- 1. A neighborhood queue consists of multiple queues located at the neighbo ring nodes that are part of the same spatial reuse constraint set.
- 2. Multiple sub-queues have different relative priorities in terms of acquiring the wireless channel due to various factors including MAC unfairness, chan nel capture, hidden and exposed terminal etc.
- 3. The priority of a sub-queue may change dynamically due to topology or tr affic pattern changes.

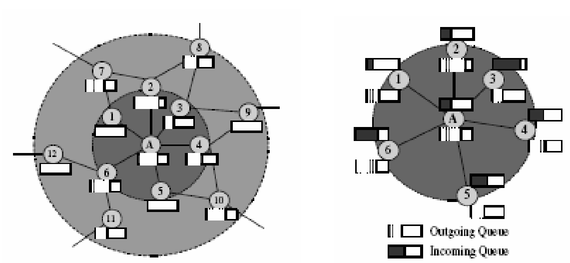
NEIGHBORHOOD RANDOM EARLY DETECTION

- Make packet drop probability and packet delay proportional to the s hare of bandwidth used by each TCP flow.

- 1. Neighborhood Congestion Detection (NCD)
- 2. Neighborhood congestion Notification (NCN)
- 3. Distributed Neighborhood Packet Drop (DNPD)

Neighborhood Congestion Detection (NCD)

- When a packet in any outgoing queue is transmitted, node A will detect the medium as busy.
- When a packet is received to any incoming queue, node A can al so learn this through the CTS packet.



Neighborhood Congestion Detection (NCD)

- A node will monitor 5 different radio state
- 1. Transmitting
- 2. Receiving
- 3. Carrier sensing busy (RTS, CTS)
- 4. Virtual carrier sensing busy
- 5. Idle
- State 1&2 is for current node, 3&4 is for its neighbors. The authors ass ume state 5 means empty queue.

Neighborhood Congestion Detection (NCD)

$$(1)\ U_{busy} = \frac{T_{interval} - T_{idle}}{T_{interval}};\ (2)\ U_{tx} = \frac{T_{tx}}{T_{interval}};\ (3)\ U_{rx} = \frac{T_{rx}}{T_{interval}};$$

$$T_{interval} = T_{tx} + T_{rx} + T_{cs} + T_{vcs} + T_{idle}$$

Assume W is channel bandwidth and the average packet size is C bits

$$q = \frac{U_{busy} * W}{C}; avg = (1 - w_q) * avg + w_q * q$$

We can use the same way to calculate avg_{tx} *and* avg_{rx}

Distributed Neighborhood Packet Drop

- When a node received a NCN with a none zero normalizedPb, the local drop prob pb is caculated as normalizedPb*(avg_tx+avg_rx).

Algorithm 5.2: RANDOMDROP()

comment: Actions performed at the outgoing queue

Saved Variables:

$count_{tx}$: *outgoing pkts arrived since last drop*

avg_{tx}: *average outgoing queue size*

Other Parameters:

p_a: *current packet dropping probability*

for each *packet arrival*
  $count_{tx} \leftarrow count_{tx} + 1$
  if $normalizedP_b < 1$
    $p_b \leftarrow normalizedP_b * avg_{tx}$
    $p_a \leftarrow p_b/(1 - count_{tx} * p_b)$
  else $p_a \leftarrow 1$
  if $p_a > 0$
    $aRandomNumber \leftarrow random([0,1])$
    if $aRandomNumber \leq p_a$
      drop the arriving pkt
      $count_{tx} \leftarrow 0$
  else $count_{tx} \leftarrow -1$

VERIFICATION AND PARAMETER TUNING

- Verification of Queue Size Estimation

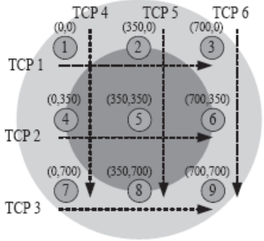


Figure 5: Scenario for verifying queue size estimation algorithm.

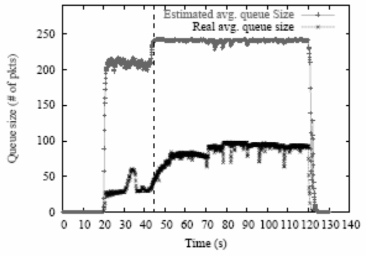


Figure 6: Estimated average queue size and the real average queue size of Node 5's neighborhood under FTP/TCP connections.

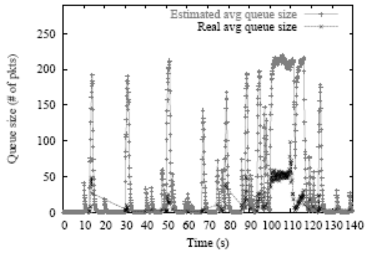


Figure 7: Estimated average queue size and the real average queue size of Node 5's neighborhood under HTTP/TCP connections.

VERIFICATION AND PARAMETER TUNING

- Parameter Tuning with Basic Scenarios with hidden and exposed t erminal scenario.

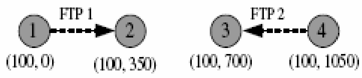
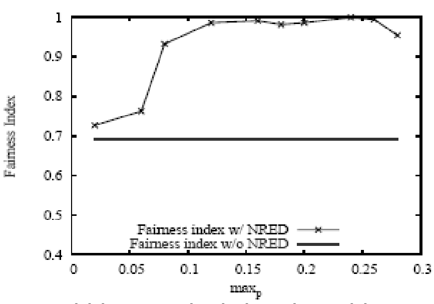


Figure 8: The hidden terminal scenario, where Node 2 is hidden by transmission from node 4 to node 3 and Node 3 is hidden by transmission from node 1 to node 2.

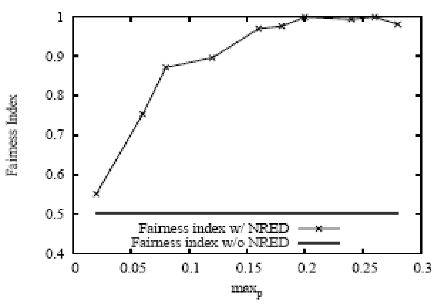
Figure 9: The exposed terminal scenario, where node 2 is exposed to transmissions from node 3 to node 4.

VERIFICATION AND PARAMETER TUNING

- Fairness index $$F(X_1, X_2) = \frac{(X_1 + X_2)^2}{2(X_1{}^2 + X_2{}^2)}$$
- MAXMin fairness is bounded between 0 and 1



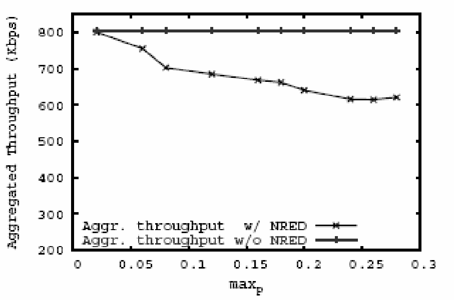
Hidden terminal situation with various max_p values

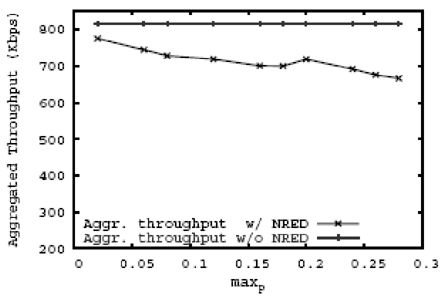


Exposed terminal situation with various max_p values

VERIFICATION AND PARAMETER TUNING

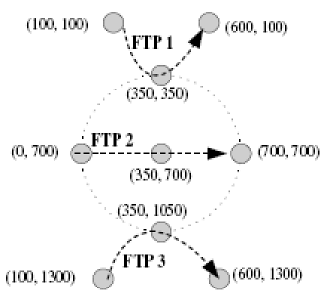
- Aggregated Throughput (kbps) under hidden and exposed terminal s ituation

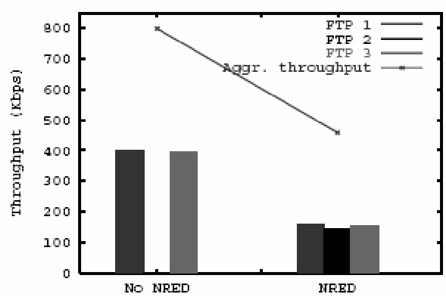




PERFORMANCE EVALUATION OF NRED

- Overall throughput of the 3 flows.





PERFORMANCE EVALUATION OF NRED

- Multiple Congested Neighborhood

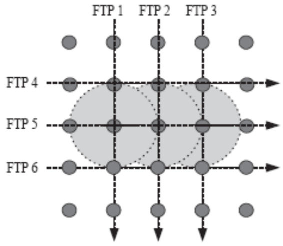


Figure 15: Scenario of the multiple congested neighborhood topology.

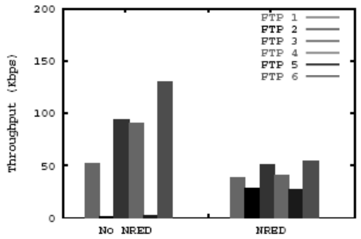


Figure 16: Overall throughput of each flow with and without NRED.

PERFORMANCE EVALUATION OF NRED

- More Realistic Scenario. 50 nodes randomly deployed in 1000X1000m. 5FTP/TCP are randomly selected.