What do you mean, “Congestion”?

- some history
  - “Congestion Collapse”
  - “Congestion Avoidance”
  - “Congestion Control”
  - “Explicit Congestion Notification”
  - “Datagram Congestion Control Protocol”
- this presentation is about what “congestion” means
  - not about what’s good or bad about a protocol
- some definitions
Congestion Collapse
(ref: RFC896, Nagle 1984)

• in 1986, NFSnet throughput dropped to 40 bps
  • routers discarded packets
  • expecting senders to retransmit
  • data-send rate doubled
  • lather, rinse, repeat
Van Jacobson in ACM, 1988

• “The flow on a TCP connection should obey a ‘conservation of packets’ principle.”
• “Thus congestion control involves finding places that violate conservation and fixing them.”
• “A new packet isn’t put into the network until an old packet leaves.”
Congestion-Avoidance
(RFC2001, Stevens 1997)

• four intertwined algorithms:
  • slow start (match injection rate to ACK rate)
  • congestion avoidance (AIMD, growth limited to <= 1 segment per RTT)
  • fast retransmit (>= 3 duplicate ACKs -> retransmit lost segment)
  • fast recovery
Congestion Control
(RFC 2581, Allman et al, 1999)

• updates Stevens 1997
• details of variables
• see also Congestion Control Principles
  (RFC 2914, Floyd 2000)
• see also Random Early Detection
  (RFC 2309, Braden et al 1998)
  • defines min & max thresholds for random drops
  • estimates “average queue size”
Explicit Congestion Notification

(RFC 2481, Floyd et al 1999)

- routers set CE bit instead of dropping
  - (would drop if not ECN-capable)
- typically RED rules
- when queue size remains high, drop instead of mark
- receiver response should be essentially the same as a single dropped packet
- react at most once per RTT
- obsoleted by RFC 3168
Addition of ECN to IP  
(RFC 3168, Floyd et al, 2001)

• now Standards Track  
• various TCP rules for packet drops  
• rules for routers setting CE bit  
• considers IP tunnels, e.g. IPsec (compatibility issues)  
• active queue management, to smooth estimates  
  • router can separate policies for queueing, dropping, indicating congestion
RFC 3168, continued

- workarounds for problem middleboxes
- CE set should indicate persistent congestion,
  - not a particular queue size
- receiver of CE should inform sender of its receipt
- sender should inform receiver that CWND has been reduced
- effects of on-path modifications to ECN bits
- see http://www.icir.org/floyd/ecn.html
Datagram Congestion Control Protocol
(RFC 4340, Handley et al 2006)

- aims for bidirectional unicast unreliable datagrams
- negotiation of congestion control mechanism
- uses ECN; ACKs arbitrarily reliable
- notification to sender which packets reached receiver
- initially two congestion-control mechanisms
  - TCP-like (RFC 4341) AIMD, ACKs similar to SACK
  - TCP-friendly (RFC 5348) for smoother responses
- intent to serve streaming-media needs
Definitions

  • “Congestion Definition: A condition in which one or more egress interfaces are offered more packets than are forwarded at any given instant.”
  • “Congestion is a condition in which a queue is filling due to packet arrival rate exceeding packet service rate.”
Four definitions from:


• Queuing theory definition:
• Networking text book definition:
• Network Operator’s definition:
• Economic definition:
Queuing theory definition:

“In queuing theory, traffic congestion is said to occur if the arrival rate into a system exceeds the service rate of the system at a point in time.”
Networking text book definition:

“Congestion of a network router is said to occur if packets are dropped. The buildup of packets in a queue is instead described as ‘contention’.”
Network Operator’s definition:

“Ask a network operator how “congested” part of their network is and they will respond with the average utilization of a link over some period of time.”
Economic definition:

“When an increase in the use of a facility or service which is used by a number of people would impose a cost (not necessarily a monetary cost) on the existing users, that facility is said to be ‘congested’.”