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 threshholds 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 managment, 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

- http://tools.ietf.org/html/draft-ietf-bmwg-dsmterm-03 (Perser et al 2002)
  - "Congestion Definition: A condition in which one or more egress interfaces are offered more packets than are forwarded at any given instant."
- http://www.ietf.org/mail-archive/web/bmwg/current/msg00285.html (Poretsky, 2002)
  - "Congestion is a condition in which a queue is filling due to packet arrival rate exceeding packet service rate."

Four definitions from:

http://tprcweb.com/images/stories/papers/Bauer_Clark_Lehr_2009.pdf (Clark et al, 2009)

- 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'."