Chapter 6

Congestion Control and Resource Allocation
FIGURE 6.1 A potential bottleneck router.
FIGURE 6.2 Multiple flows passing through a set of routers.
FIGURE 6.3 Ratio of throughput to delay as a function of load.
FIGURE 6.4 One four-hop flow competing with three one-hop flows.
FIGURE 6.5 (a) FIFO queuing; (b) tail drop at a FIFO queue.
FIGURE 6.6 Round-robin service of four flows at a router.
FIGURE 6.7 Example of fair queuing in action: (a) Packets with earlier finishing times are sent first; (b) sending of a packet already in progress is completed.
FIGURE 6.8 Packets in transit during additive increase, with one packet being added each RTT.
FIGURE 6.9 Typical TCP sawtooth pattern.
FIGURE 6.10 Packets in transit during slow start.
FIGURE 6.11 Behavior of TCP congestion control. Colored line = value of CongestionWindow over time; solid bullets at top of graph = timeouts; hash marks at top of graph = time when each packet is transmitted; vertical bars = time when a packet that was eventually retransmitted was first transmitted.
FIGURE 6.12 Fast retransmit based on duplicate ACKs.
FIGURE 6.13 Trace of TCP with fast retransmit. Colored line = CongestionWindow; solid bullet = timeout; hash marks = time when each packet is transmitted; vertical bars = time when a packet that was eventually retransmitted was first transmitted.
FIGURE 6.14 Computing average queue length at a router.
FIGURE 6.15 Weighted running average queue length.
FIGURE 6.16 RED thresholds on a FIFO queue.
FIGURE 6.17 Drop probability function for RED.
FIGURE 6.18 Congestion window versus observed throughput rate (the three graphs are synchronized). Top, congestion window; middle, observed throughput; bottom, buffer space taken up at the router. Colored line = CongestionWindow; solid bullet = timeout; hash marks = time when each packet is transmitted; vertical bars = time when a packet that was eventually retransmitted was first transmitted.
FIGURE 6.19 Trace of TCP Vegas congestion-avoidance mechanism. Top, congestion window; bottom, expected (colored line) and actual (black line) throughput. The shaded area is the region between the $\alpha$ and $\beta$ thresholds.
FIGURE 6.20 An audio application.
FIGURE 6.21 A playback buffer.
FIGURE 6.22 Example distribution of delays for an Internet connection.
FIGURE 6.23 Taxonomy of applications.
FIGURE 6.24 Two flows with equal average rates but different token bucket descriptions.
FIGURE 6.25 Making reservations on a multicast tree.
FIGURE 6.26 RED with In and Out drop probabilities.
FIGURE 6.27 Diagram for Exercise 6.
FIGURE 6.28 TCP trace for Exercise 27.