TCP
Congestion Control

TCP Congestion Control

- Essential strategy :: The TCP host sends packets into the network without a reservation and then the host reacts to observable events.
- Originally TCP assumed FIFO queuing.
- Basic idea :: each source determines how much capacity is available to a given flow in the network.
- ACKs are used to *'pace'* the transmission of packets such that TCP is "self-clocking".

AIMD
(Additive Increase / Multiplicative Decrease)

- CongestionWindow (cwnd) is a variable held by the TCP source for each connection.

MaxWindow :: min (**CongestionWindow** , AdvertisedWindow)

EffectiveWindow = MaxWindow – (LastByteSent -LastByteAcked)

- cwnd is set based on the perceived level of congestion. The Host receives *implicit* (packet drop) or *explicit* (packet mark) indications of internal congestion.

Additive Increase

- Additive Increase is a reaction to perceived available capacity.
- Linear Increase basic idea:: For each "cwnd's worth" of packets sent, increase cwnd by 1 packet.
- In practice, cwnd is incremented fractionally for each arriving ACK.

increment = MSS x (MSS /cwnd)

cwnd = cwnd + increment

Multiplicative Decrease

* The key assumption is that a dropped packet and the resultant timeout are due to congestion at a router or a switch.

  Multiplicate Decrease:: TCP reacts to a timeout by halving cwnd.

- Although cwnd is defined in bytes, the literature often discusses congestion control in terms of packets (or more formally in MSS == Maximum Segment Size).
- cwnd is not allowed below the size of a single packet.

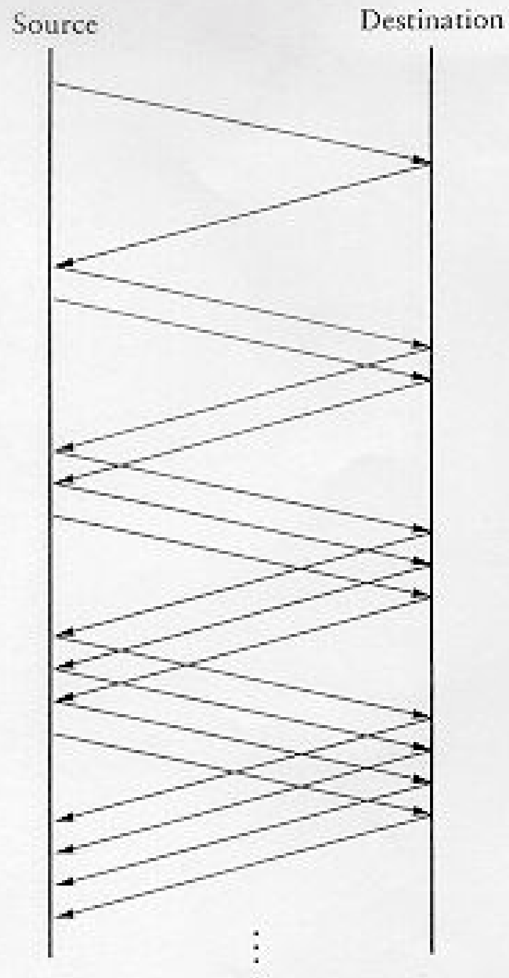


Figure 6.8 Packets in transit during additive increase, with one packet being added each RTT.

Additive Increase

AIMD
(Additive Increase / Multiplicative Decrease)

- It has been shown that AIMD is a <u>necessary</u> congestion for TCP congestion control to be stable.
- Because the simple CC mechanism involves timeouts that cause retransmissions, it is important that hosts have an accurate timeout mechanism.
- Timeouts set as a function of average RTT and standard deviation of RTT.
- However, TCP hosts only sample round-trip time once per RTT using coarse-grained clock.

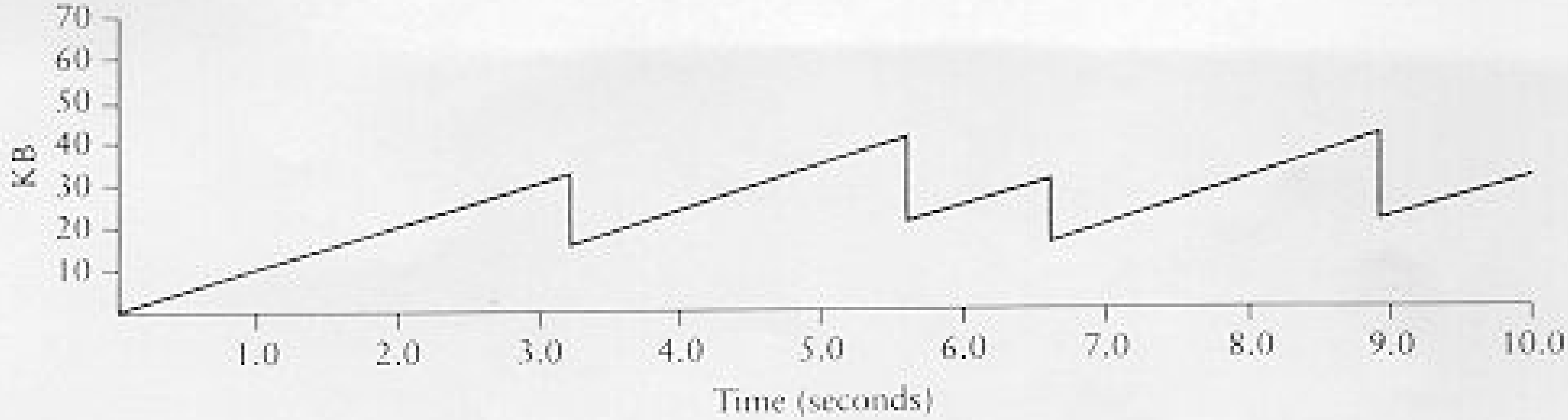


Figure 6.9 Typical TCP sawtooth pattern.

Slow Start

- Linear additive increase takes <u>too long</u> to ramp up a new TCP connection from cold start.
- Beginning with TCP Tahoe, the slow start mechanism was added to provide an initial exponential increase in the size of cwnd.

Remember mechanism by: ***slow start <u>prevents</u> a slow start. Moreover, slow start is slower than sending a full advertised window's worth of packets all at once.***

Slow Start

- The source starts with cwnd = 1.
- Every time an ACK arrives, cwnd is incremented.

➔cwnd is effectively doubled per RTT “epoch”.

- Two slow start situations:
  - At the very beginning of a connection **{cold start}**.
  - When the connection goes dead waiting for a timeout to occur (i.e, the advertized window goes to zero!)

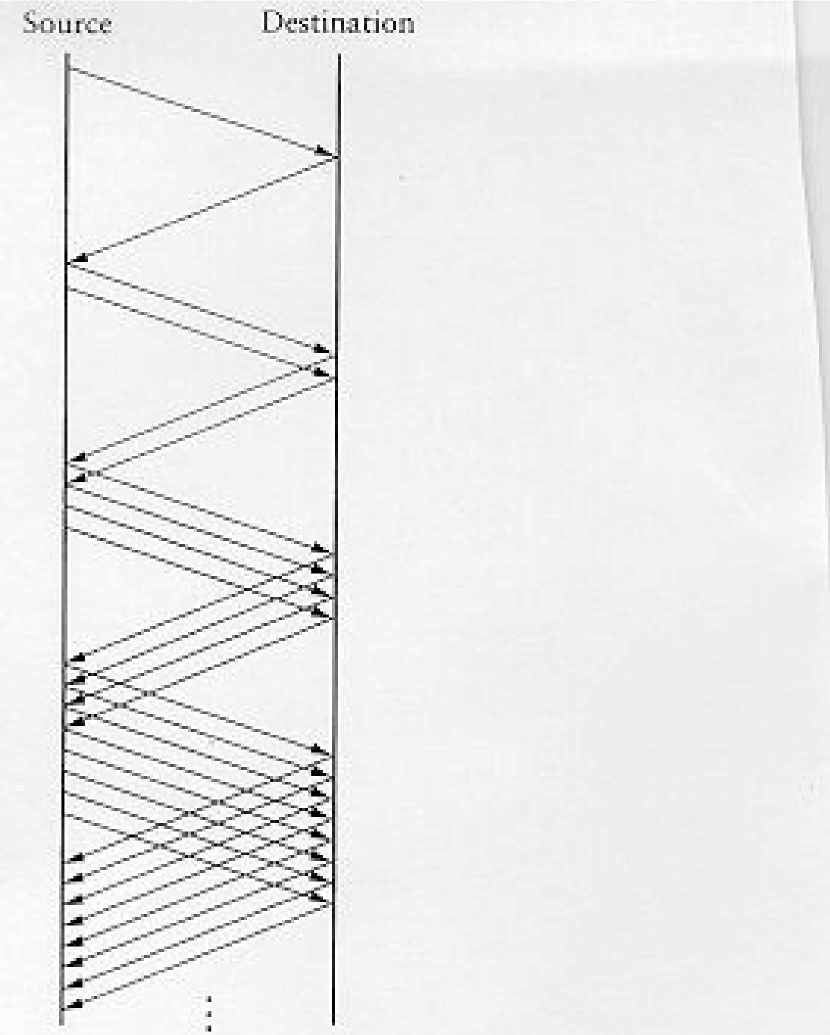


Figure 6.10 Packets in transit during slow start.

Slow Start

Slow Start

- However, in the second case the source has more information. The current value of cwnd can be saved as a **congestion threshold.**
- This is also known as the “slow start threshold” **ssthresh**.

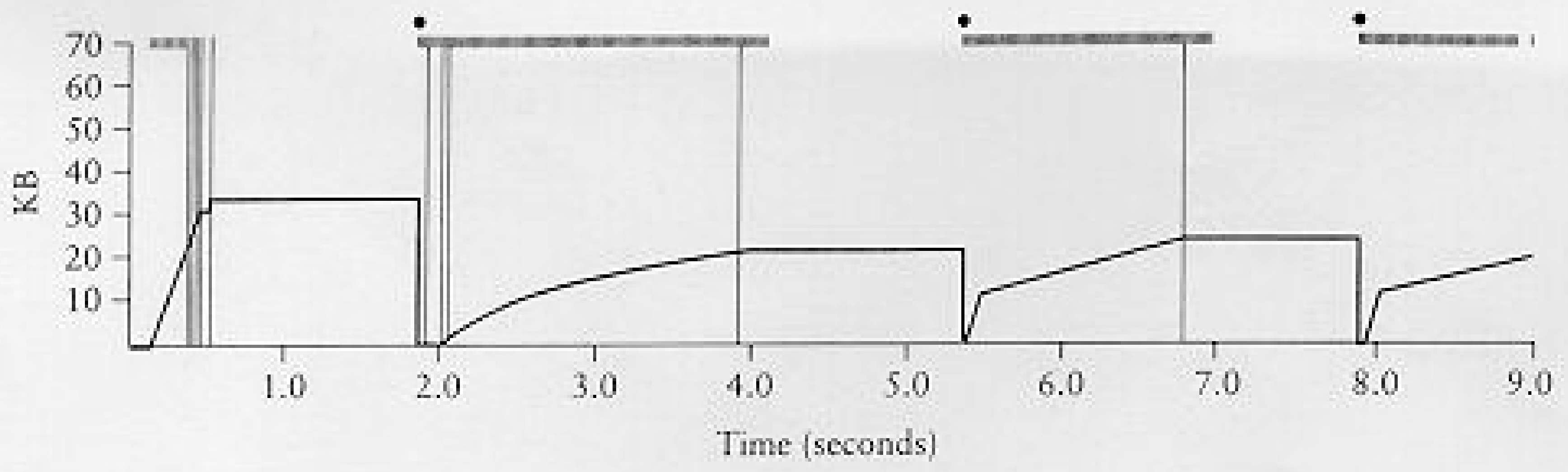


Figure 6.11 **Behavior of TCP congestion control. Colored line = value of CongestionWindow over time; solid bullets at top of graph = timeouts; hash marks at top of graph = time when each packet is transmitted; vertical bars = time when a packet that was eventually retransmitted was first transmitted.**

Fast Retransmit

- Coarse timeouts remained a problem, and Fast retransmit was added with TCP Tahoe.
- Since the receiver responds every time a packet arrives, this implies the sender will see duplicate ACKs.

Basic Idea:: *use **duplicate ACKs** to signal lost packet.*

Fast Retransmit

Upon receipt of *three* duplicate ACKs, the TCP Sender retransmits the lost packet.

Fast Retransmit

- Generally, fast retransmit eliminates about <u>half</u> the coarse-grain timeouts.
- This yields roughly a 20% improvement in throughput.
- Note – fast retransmit does not eliminate all the timeouts due to small window sizes at the source.

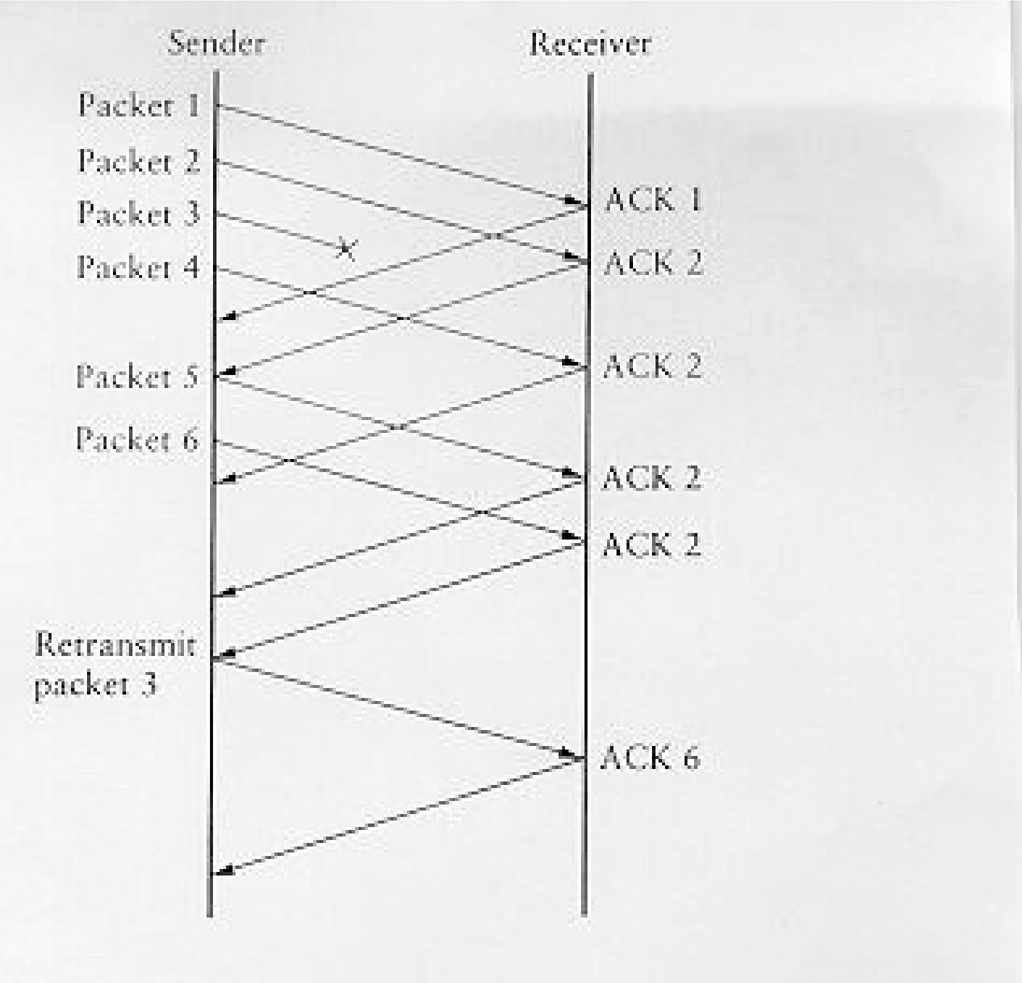


Figure 6.12 Fast retransmit based on duplicate ACKs.

Fast Retransmit

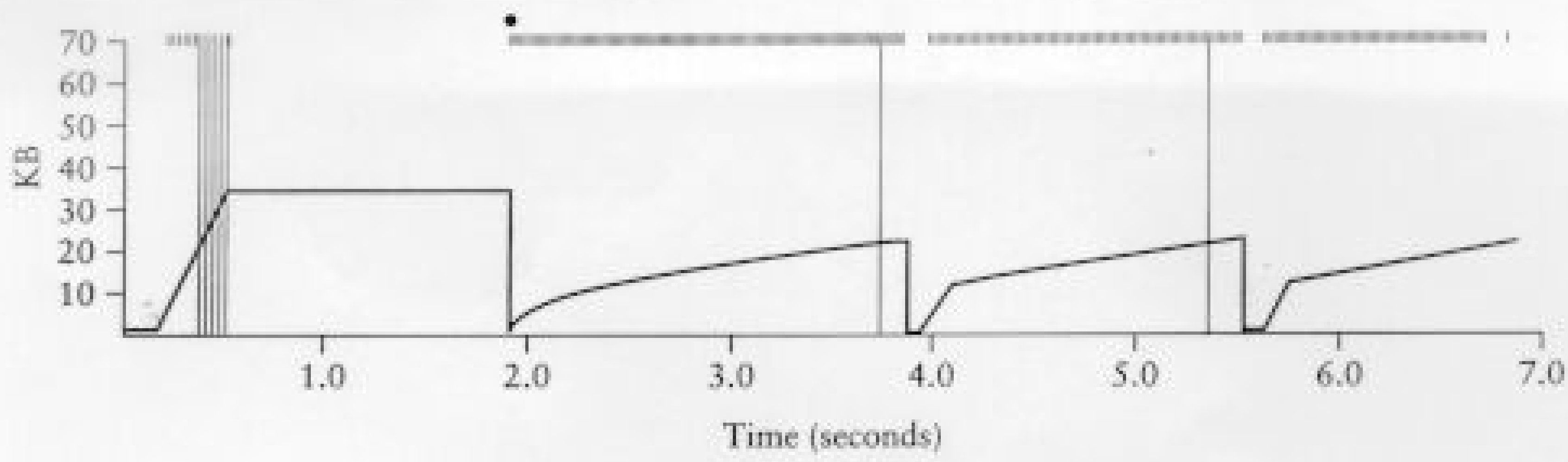


Figure 6.13 Trace of TCP with fast retransmit. Colored line = CongestionWindow; solid bullet = timeout; hash marks = time when each packet is transmitted; vertical bars = time when a packet that was eventually retransmitted was first transmitted.

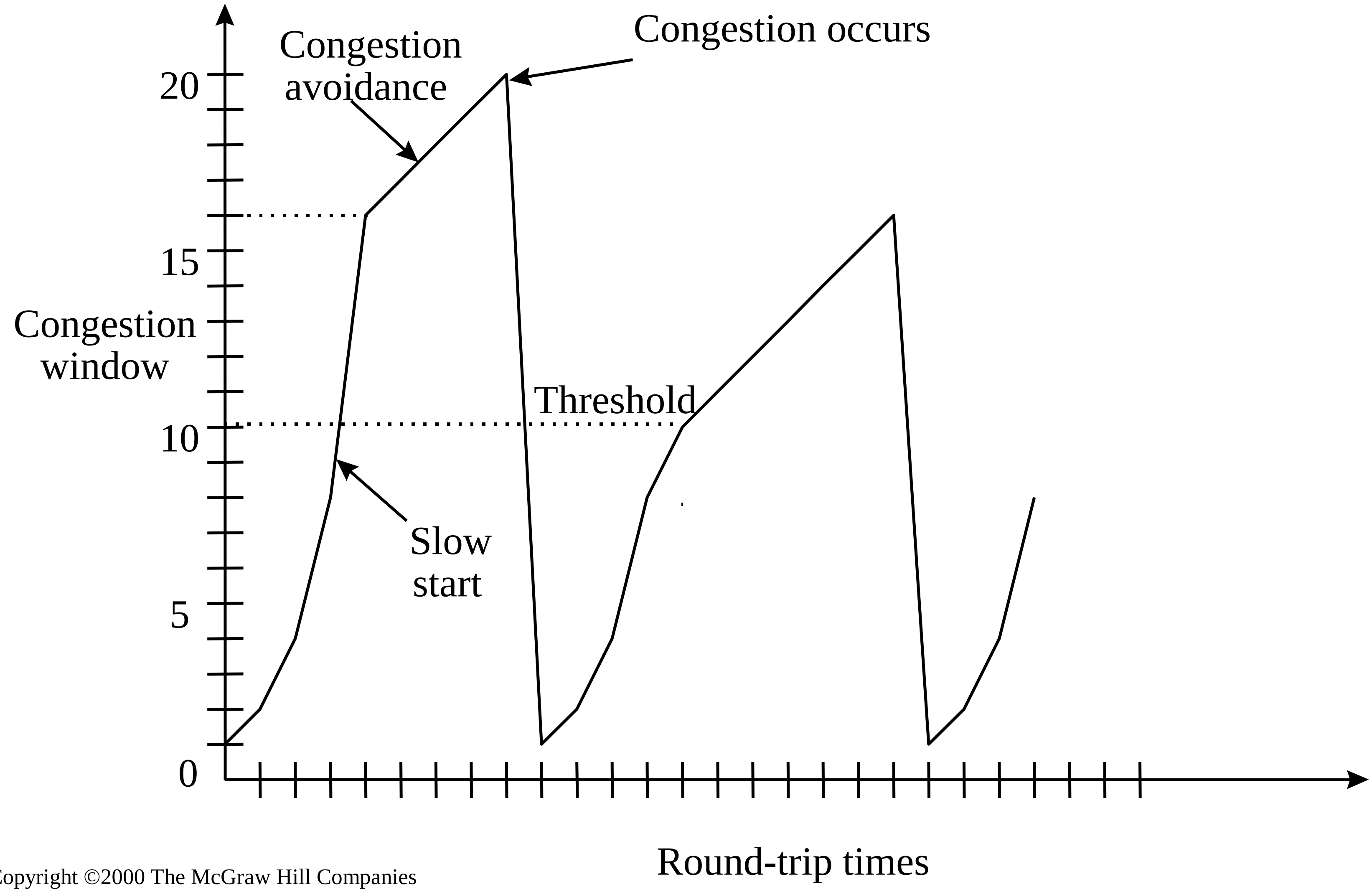
Fast Recovery

- Fast recovery was added with TCP Reno.
- Basic idea:: When fast retransmit detects three duplicate ACKs, start the recovery process from congestion avoidance region and use ACKs in the pipe to pace the sending of packets.

Fast Recovery

After Fast Retransmit, half cwnd and commence recovery from this point using linear additive increase 'primed' by left over ACKs in pipe.

TCP Congestion Control



Modified Slow Start

- With fast recovery, **slow start** only occurs:
  - At cold start
  - After a coarse-grain timeout
- *This is the difference between TCP Tahoe and TCP Reno!!*