CS3200: Computer Networks

Lecture 29

IIT Palakkad

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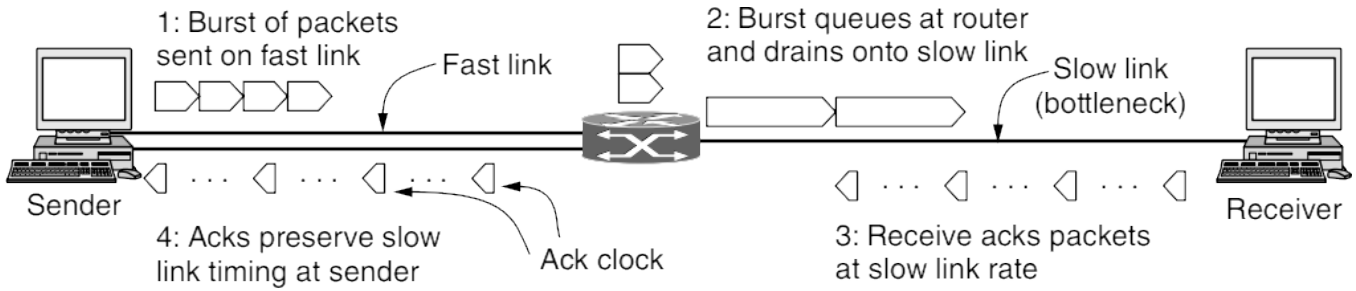
TCP Congestion Control

- AIMD (Additive Increase Multiplicative Decrease) control law in response to binary congestion signals from the network would converge to a fair and efficient bandwidth allocation.

- TCP maintains a **congestion window** whose size is the number of bytes the sender may have in the network at any time. TCP adjusts the window size according to the AIMD rule.



ACK clock

- Acknowledgements return to the sender at about the rate that packets can be sent over the slowest link in the path.
- If the sender injects new packets into the network at this rate, they will be sent as fast as the slow link permits, but they will not queue up and congest any router along the path.
- This timing is known as an **ACK clock**. It is an essential part of TCP. By using an ack clock, TCP smoothes out traffic and avoids unnecessary queues at routers.

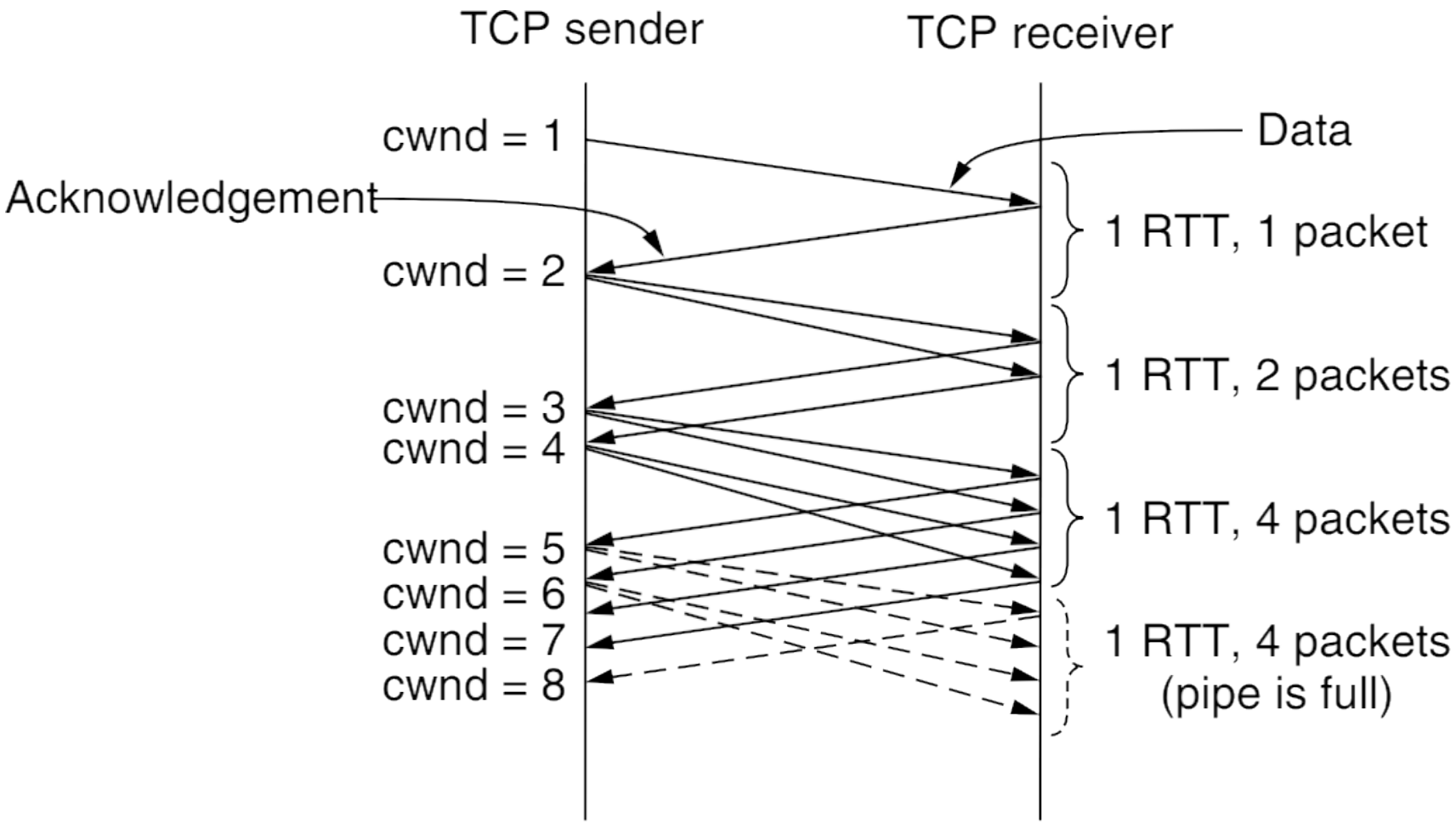
How fast to increase the CWND?

- Consider a modest network path that can support 10 *Mbps* with an RTT of 100 *msec*
- The appropriate congestion window is the bandwidth-delay product, which is 1 *Mbit* or 100 packets of 1000 *bytes* each.
- If the congestion window starts at 1 packet and increases by 1 packet every RTT, it will be 100 RTTs or 10 seconds.
- We could reduce this startup time by starting with a larger initial window, say of 50 packets. But this window would be far too large for slow or short links.

How fast to increase the CWND?

- When a connection is established, the sender initializes the congestion window to a small initial value of at most four segments.
- The sender then sends the initial window. The packets will take a round-trip time to be acknowledged.
- For each segment that is acknowledged before the retransmission timer goes off, the sender increments the the congestion window by 1.
- This algorithm is called **slow start**.

TCP Slow Start



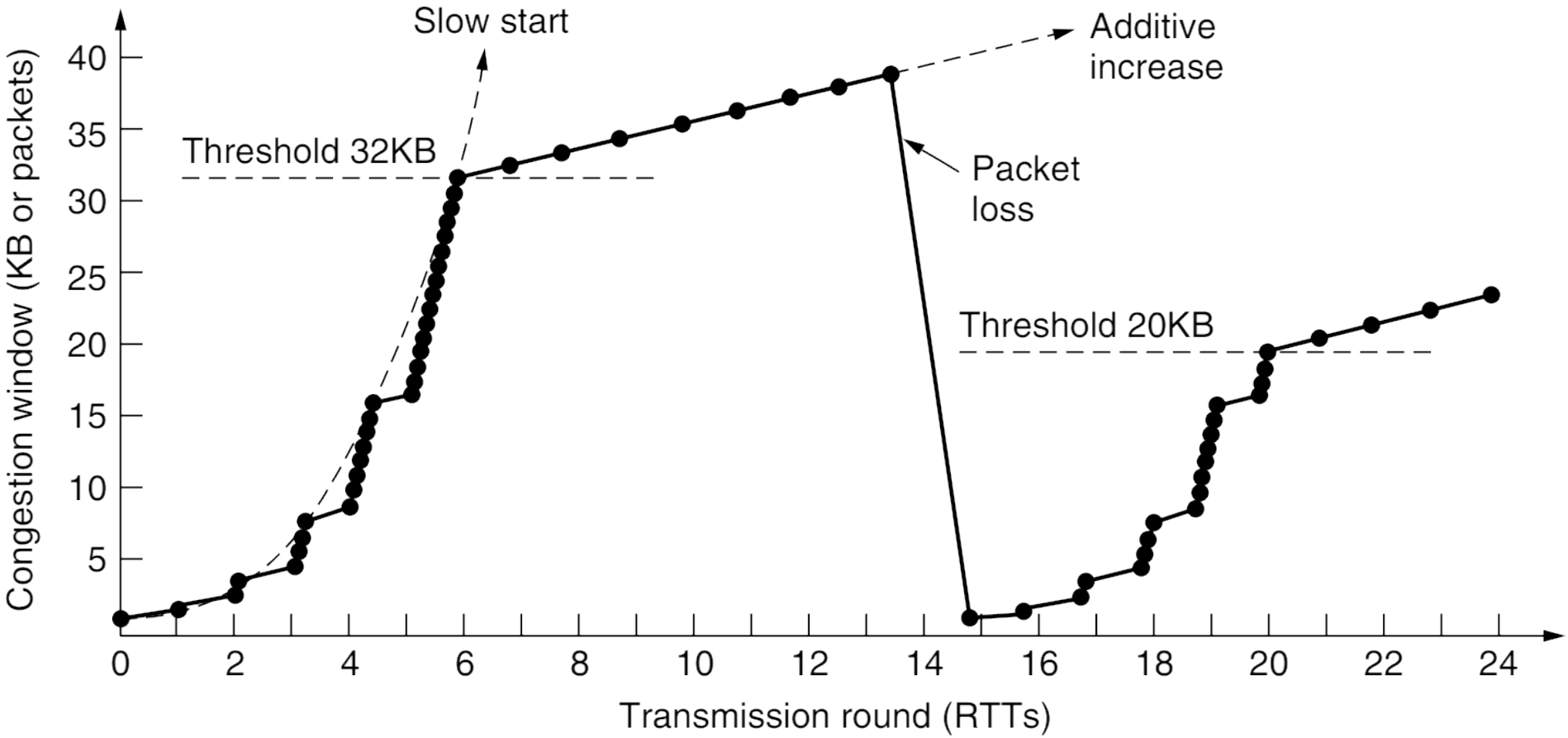
Slow Start Threshold

- Because slow start causes exponential growth, eventually (and sooner rather than later) it will send too many packets into the network too quickly.
- When the queues are full, one or more packets will be lost. After this happens, the TCP sender will time out when an acknowledgement fails to arrive in time.
- To keep slow start under control, the sender keeps a threshold for the connection called the **slow start threshold**.
- TCP keeps increasing the congestion window in slow start until a timeout occurs or the congestion window exceeds the threshold.

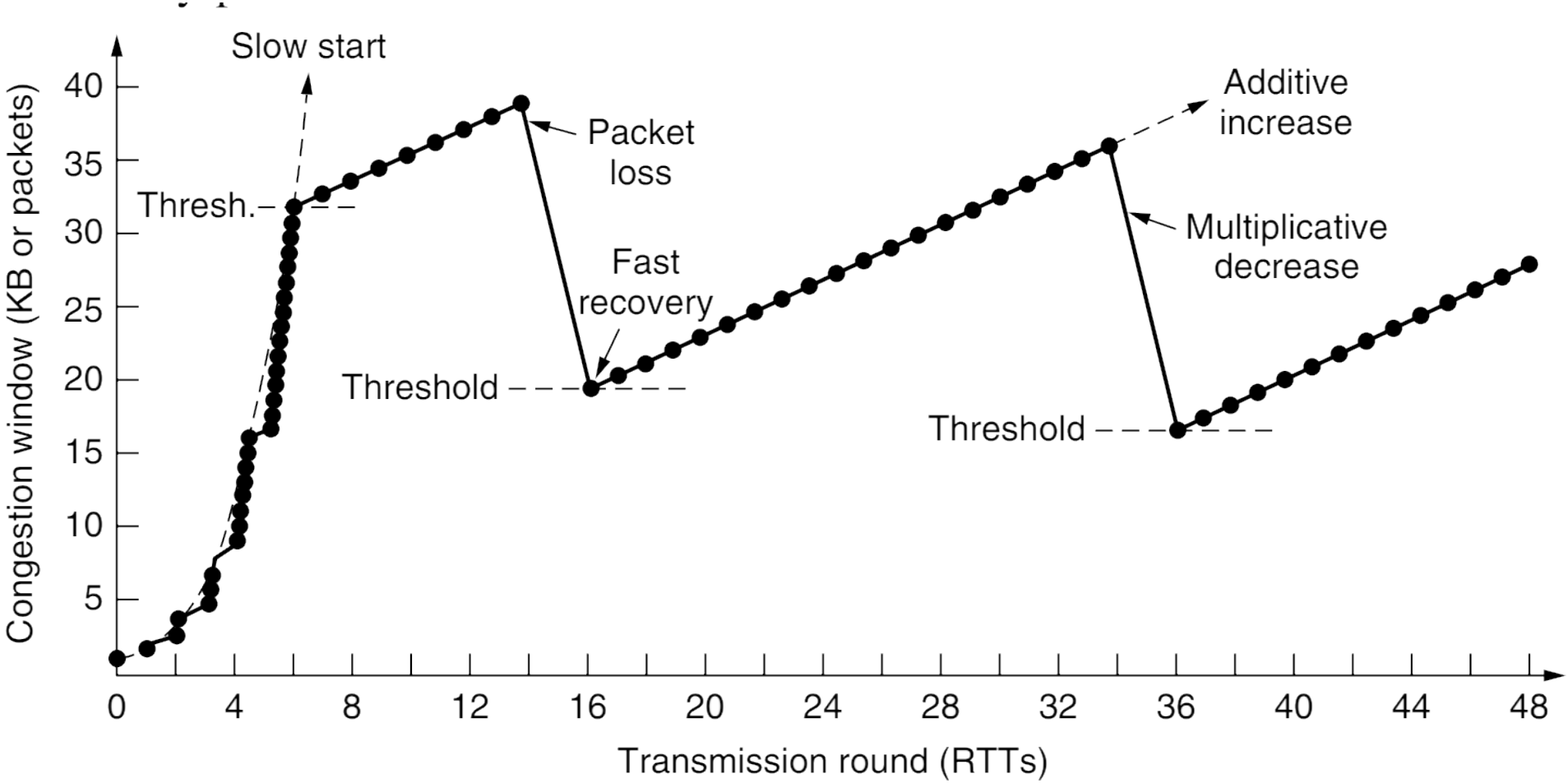
Slow Start Threshold

- Whenever a packet loss is detected, for example, by a timeout, the slow start threshold is set to be half of the congestion window and the entire process is restarted.
- Whenever the slow start threshold is crossed, TCP switches from slow start to additive increase. In this mode, the congestion window is increased by one segment every round-trip time.

CWND evolution of TCP Tahoe



CWND evolution of TCP Reno



Delay Tolerant Networking

- In occasionally connected networks, data can still be communicated by storing them at nodes and forwarding them later when there is a working link.
- This technique is called **message switching**. Eventually the data will be relayed to the destination.
- A network whose architecture is based on this approach is called a **DTN (Delay-Tolerant Network**, or a **Disruption-Tolerant Network**).
- **Read Section 6.7 of Tanenbaum**.