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计算机网络之探赜索隐

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本讲主题

TCP拥塞控制

TCP拥塞控制的基本原理

- Sender限制发送速率

```
LastByteSent-LastByteAcked
                <= CongWin
```

$$\text{rate} \approx \frac{\text{CongWin}}{\text{RTT}} \text{ Bytes/sec}$$

- CongWin: (拥塞窗口)
  - 动态调整以改变发送速率
  - 反映所感知到的网络拥塞

问题：如何感知网络拥塞？

- Loss事件=timeout或3个重复ACK
- 发生loss事件后，发送方降低速率

如何合理地调整发送速率？

- 加性增—乘性减: AIMD
- 慢启动: SS

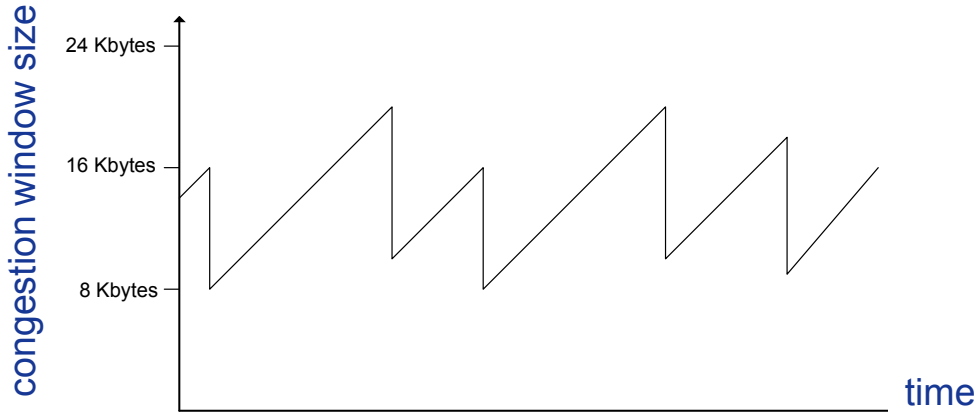
拥塞避免机制

加性增—乘性减: AIMD

- 原理：逐渐增加发送速率，谨慎探测可用带宽，直到发生loss
- 方法: AIMD
  - Additive Increase: 每个RTT将CongWin增大一个MSS——拥塞避免
  - Multiplicative Decrease: 发生loss后将CongWin减半

最大段加长度(?)

锯齿行为: 探测
可用带宽



TCP慢启动: SS

- TCP连接建立时，CongWin=1 MSS
  - 例：MSS=500 byte, RTT=200msec
  - 初始速率=20k bps
- 可用带宽可能远远高于初始速率：
  - 希望快速增长

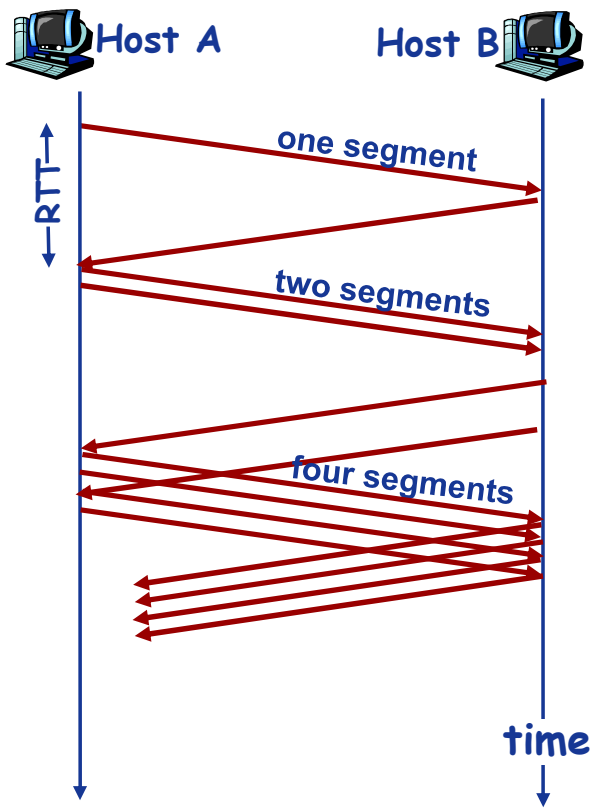
- 原理：
  - 当连接开始时，指数性增长

Slowstart algorithm

initialize: Congwin = 1
for (each segment ACKed)
    Congwin++
until (loss event OR
    CongWin > threshold)

TCP慢启动: SS

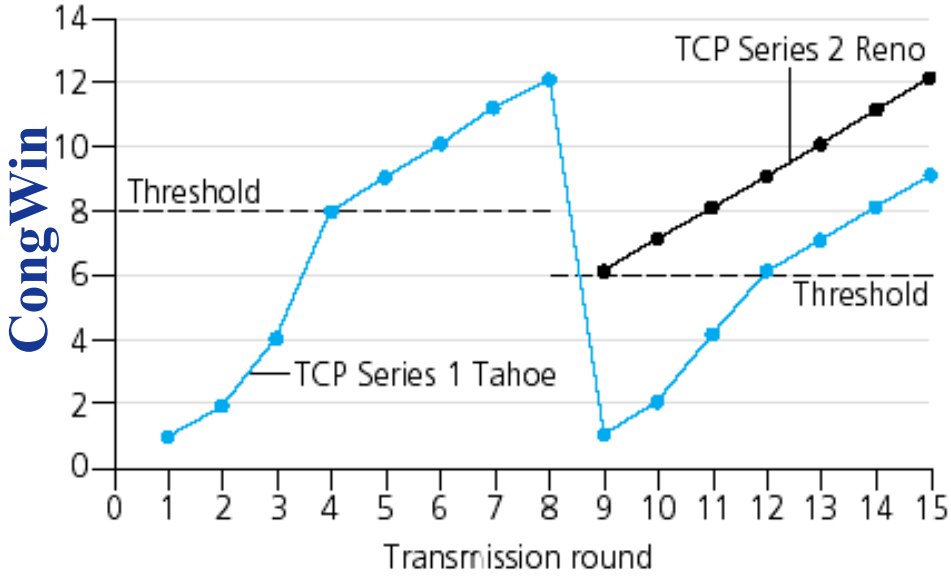
- 指数性增长
  - 每个RTT将CongWin翻倍
  - 收到每个ACK进行操作
- 初始速率很慢，但是快速攀升



Threshold变量

Q:何时应该指数性增长切换为线性增长(拥塞避免)?

A: 当CongWin达到Loss事件前值的1/2时.



实现方法:

- 变量 Threshold
- Loss事件发生时, Threshold被设为Loss事件前CongWin值的1/2。

Loss事件的处理

- 3个重复ACKs:
  - CongWin切到一半
  - 然后线性增长 Reno
- Timeout事件:
  - CongWin直接设为1个MSS
  - 然后指数增长
  - 达到threshold后，再线性增长 Tahoe

Philosophy:

- 3个重复ACKs表示网络还能够传输一些 segments
- timeout事件表明拥塞更为严重

TCP拥塞控制：总结

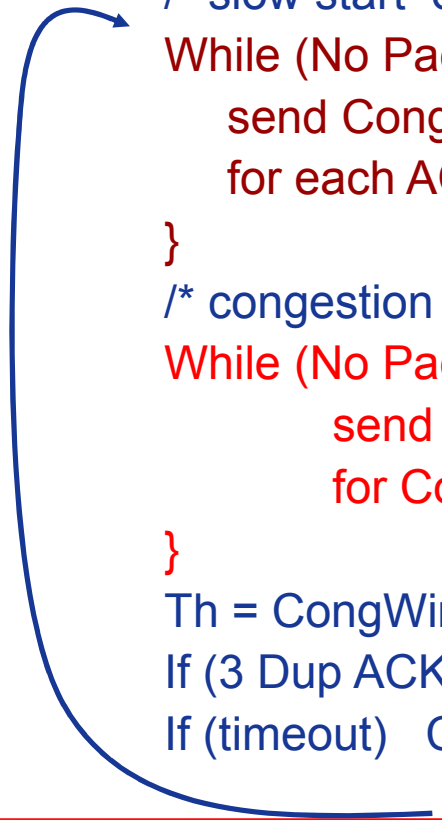
- When `CongWin` is below `Threshold`, sender in slow-start phase, window grows exponentially.
- When `CongWin` is above `Threshold`, sender is in congestion-avoidance phase, window grows linearly.
- When a triple duplicate ACK occurs, `Threshold` set to `CongWin/2` and `CongWin` set to `Threshold`.
- When timeout occurs, `Threshold` set to `CongWin/2` and `CongWin` is set to 1 MSS.

TCP拥塞控制

State	Event	TCP Sender Action	Commentary
Slow Start (SS)	ACK receipt for previously unacked data	CongWin = CongWin + MSS, If (CongWin > Threshold) set state to "Congestion Avoidance"	Resulting in a doubling of CongWin every RTT
Congestion Avoidance (CA)	ACK receipt for previously unacked data	CongWin = CongWin+MSS * (MSS/CongWin)	Additive increase, resulting in increase of CongWin by 1 MSS every RTT
SS or CA	Loss event detected by triple duplicate ACK	Threshold = CongWin/2, CongWin = Threshold, Set state to "Congestion Avoidance"	Fast recovery, implementing multiplicative decrease. CongWin will not drop below 1 MSS.
SS or CA	Timeout	Threshold = CongWin/2, CongWin = 1 MSS, Set state to "Slow Start"	Enter slow start
SS or CA	Duplicate ACK	Increment duplicate ACK count for segment being acked	CongWin and Threshold not changed

TCP拥塞控制算法

```
Th = ?
CongWin = 1 MSS
/* slow start  or exponential increase */
While (No Packet Loss and CongWin < Th) {
    send CongWin TCP segments
    for each ACK increase CongWin by 1
}
/* congestion avoidance or linear increase */
While (No Packet Loss) {
        send CongWin TCP segments
        for CongWin ACKs, increase CongWin by 1
}
Th = CongWin/2
If (3 Dup ACKs) CongWin = Th;
If (timeout)   CongWin=1;
```



例题

- 一个TCP连接总是以1 KB的最大段长发送TCP段，发送方有足够多的数据要发送。当拥塞窗口为16 KB时发生了超时，如果接下来的4个RTT（往返时间）时间内的TCP段的传输都是成功的，那么当第4个RTT时间内发送的所有TCP段都得到肯定应答时，拥塞窗口大小是多少？

- 解：threshold=16/2=8 KB, CongWin=1 KB, 1个RTT后， CongWin=2 KB ，2个RTT后， CongWin=4 KB ，3个RTT后， CongWin=8 KB ，Slowstart is over; 4个RTT后， CongWin=9 KB

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谢 谢！