

Chapter 3 outline

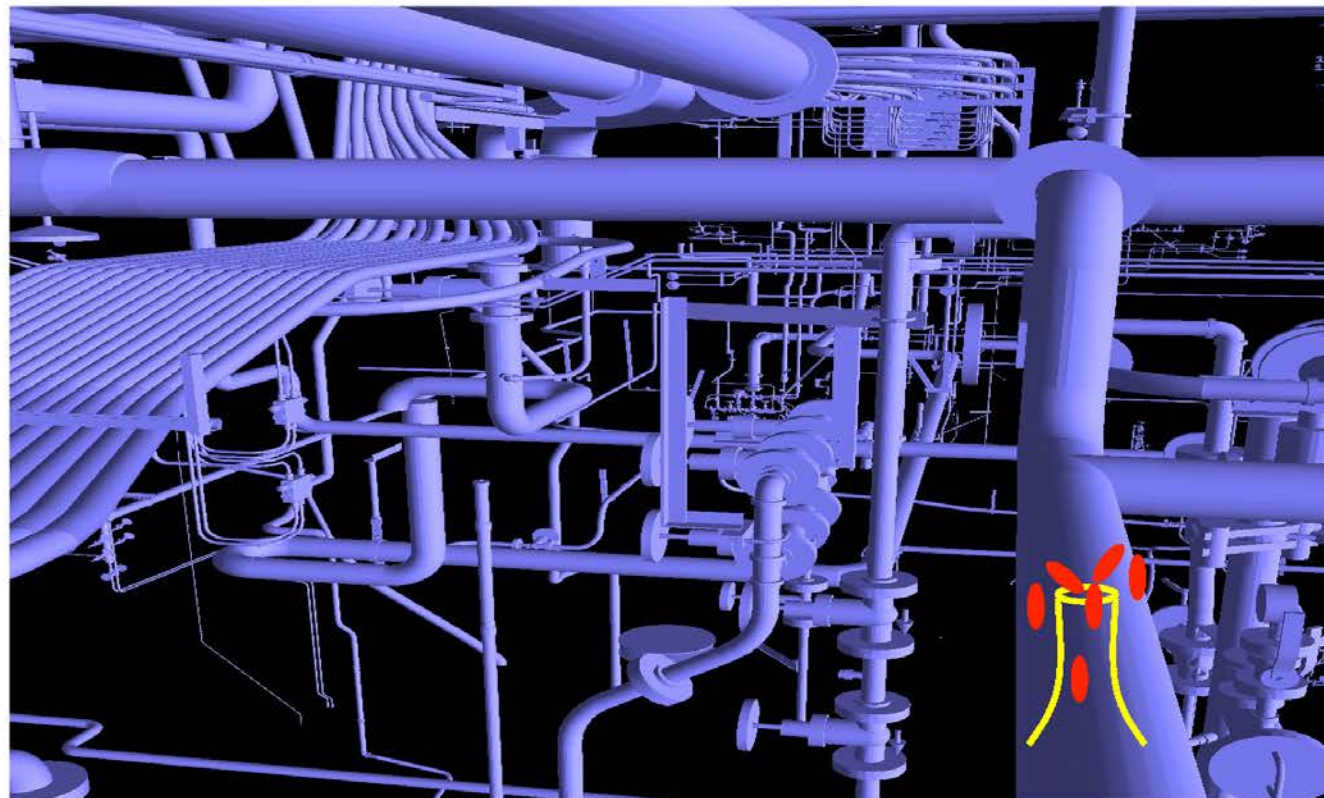
- ❑ 3.1 Transport-layer services
- ❑ 3.2 Multiplexing and demultiplexing
- ❑ 3.3 Connectionless transport: UDP
- ❑ 3.4 Principles of reliable data transfer
- ❑ 3.5 Connection-oriented transport: TCP
 - segment structure
 - reliable data transfer
 - flow control
 - connection management
- ❑ 3.6 Principles of congestion control
- ❑ 3.7 TCP congestion control

The TCP Intuition

Pour
water

너무 많이 보내면 안됨!
→ 가장 많은 데이터를 받아야 할 때
까지

∴ 조금씩 늘려가면서 보내봄
⇒ TCP의 congestion control



Collect
water

TCP Congestion Control

□ 3 main phases

1. **Slow Start** 시작할때
주목적 보내줌
→ 빠르게 증가

slow start
MSS (Maximum Segment Size) = 512 byte
= segment의 길이
→ MSS는 1024, 2048, 4096, 8192, 16384, 32768, 65536, 131072, 262144, 524288, 1048576, 2097152, 4194304, 8388608, 16777216, 33554432, 67108864, 134217728, 268435456, 536870912, 1073741824, 2147483648, 4294967296, 8589934592, 17179869184, 34359738368, 68719476736, 137438953472, 274877906944, 549755813888, 1099511627776, 2199023255552, 4398046511104, 8796093022208, 17592186044416, 35184372088832, 70368744177664, 140737488355328, 281474976710656, 562949953421312, 1125899906842624, 2251799813685248, 4503599627370496, 9007199254740992, 18014398509481984, 36028797018963968, 72057594037927936, 144115188075855872, 288230376151711744, 576460752303423488, 1152921504606846976, 2305843009213693952, 4611686018427387904, 9223372036854775808, 18446744073709551616, 36893488147419103232, 73786976294838206464, 147573952589676412928, 295147905179352825856, 590295810358705651712, 1180591620717411303424, 2361183241434822606848, 4722366482869645213696, 9444732965739290427392, 18889465931478580854784, 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TCP Congestion Control

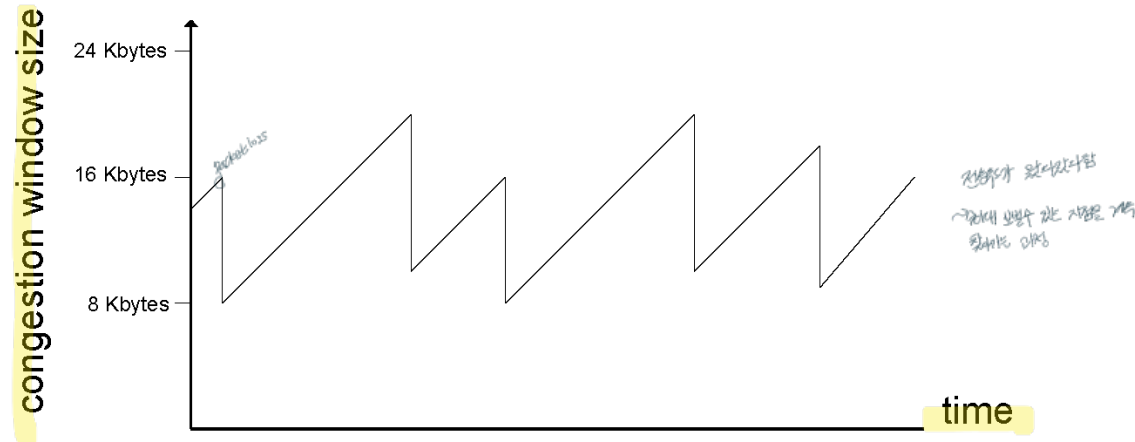
□ 3 main phases

1. Slow Start: **Do not know bottleneck bandwidth**
So start from zero and quickly ramp up
2. Additive increase: **Hey, we are getting close to capacity**
Let's be conservative and increase slow
3. Multiplicative decrease: **Oops! Packet drop**
Start over from slow start (from scratch)
Hmm! many ACKs coming, start midway

TCP congestion control: additive increase, multiplicative decrease

- *Approach*: increase transmission rate (window size), probing for usable bandwidth, until loss occurs
 - *additive increase*: increase **CongWin** by 1 MSS every RTT until loss detected
 - *multiplicative decrease*: cut **CongWin** in half after loss

Saw tooth behavior: probing for bandwidth



TCP Congestion Control: details

- sender limits transmission:

$$\text{LastByteSent} - \text{LastByteAcked} \leq \text{CongWin}$$

- Roughly,

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

- **CongWin** is dynamic, function of perceived network congestion

How does sender perceive congestion?

- loss event = timeout *or* 3 duplicate acks
- TCP sender reduces rate (**CongWin**) after loss event

three mechanisms:

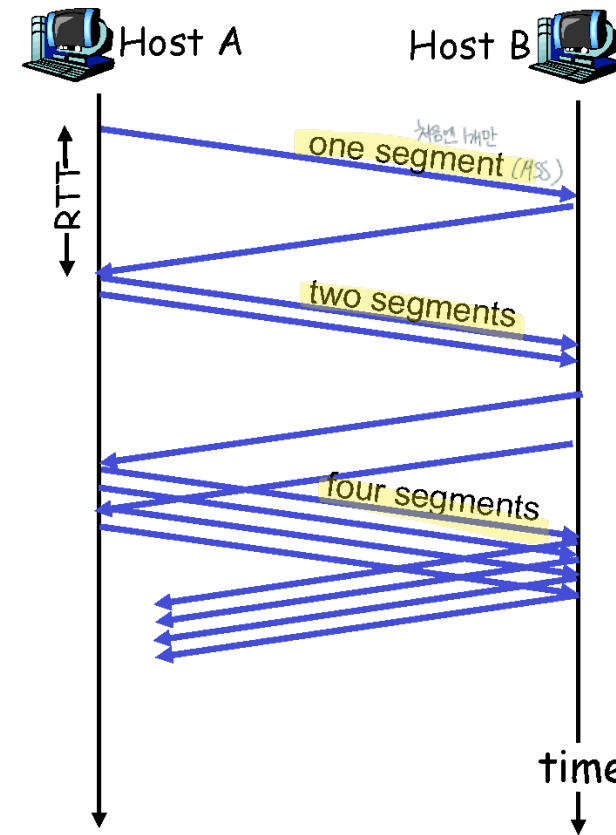
- AIMD
- slow start
- conservative after timeout events

TCP Slow Start

- ❑ When connection begins,
CongWin = 1 MSS
 - Example: MSS = 500 bytes & RTT = 200 msec
 - initial rate = 20 kbps
- ❑ available bandwidth may be
>> MSS/RTT
 - desirable to quickly ramp up to respectable rate
- ❑ When connection begins,
increase rate exponentially
fast until first loss event

TCP Slow Start (more)

- ❑ When connection begins, increase rate exponentially until first loss event:
 - double **CongWin** every RTT
 - done by incrementing **CongWin** for every ACK received
- ❑ **Summary:** initial rate is slow but ramps up exponentially fast



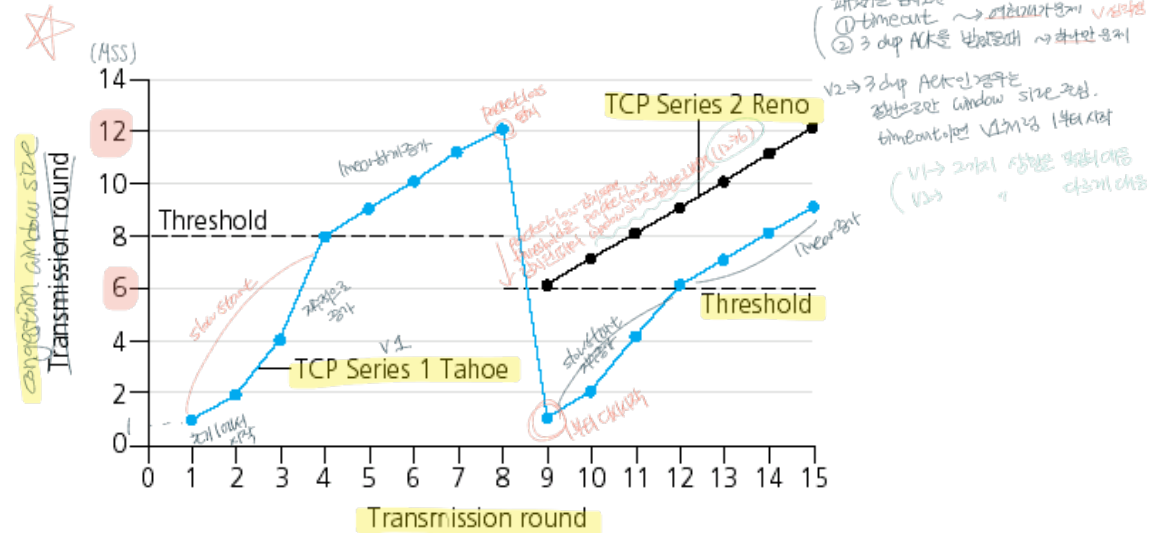
Refinement

Q: When should the exponential increase switch to linear?

A: When **CongWin** gets to 1/2 of its value before timeout.

Implementation:

- Variable Threshold
- At loss event, Threshold is set to 1/2 of CongWin just before loss event

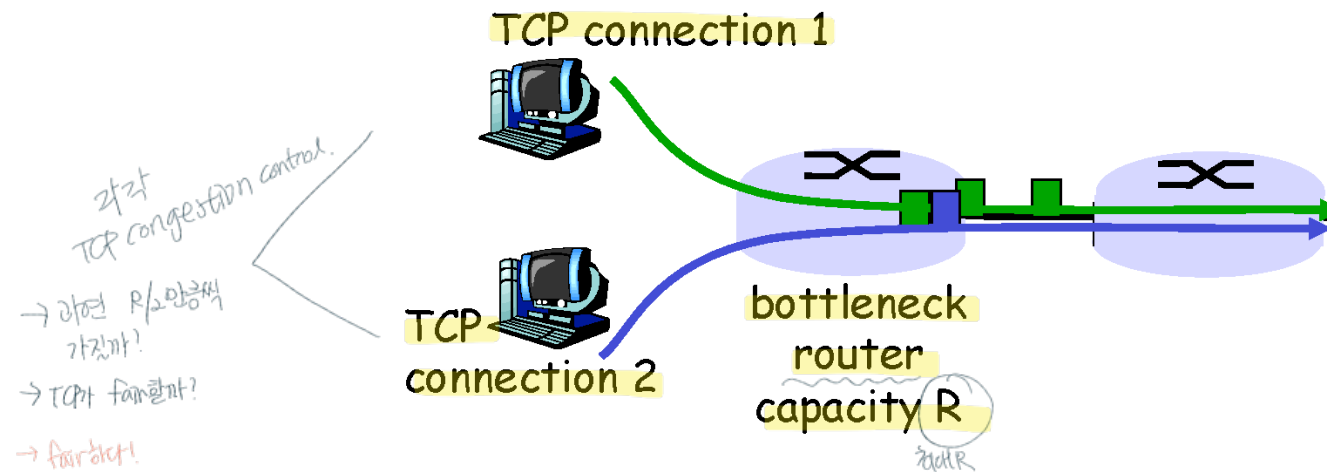


Summary: TCP Congestion Control

- ❑ 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 Fairness

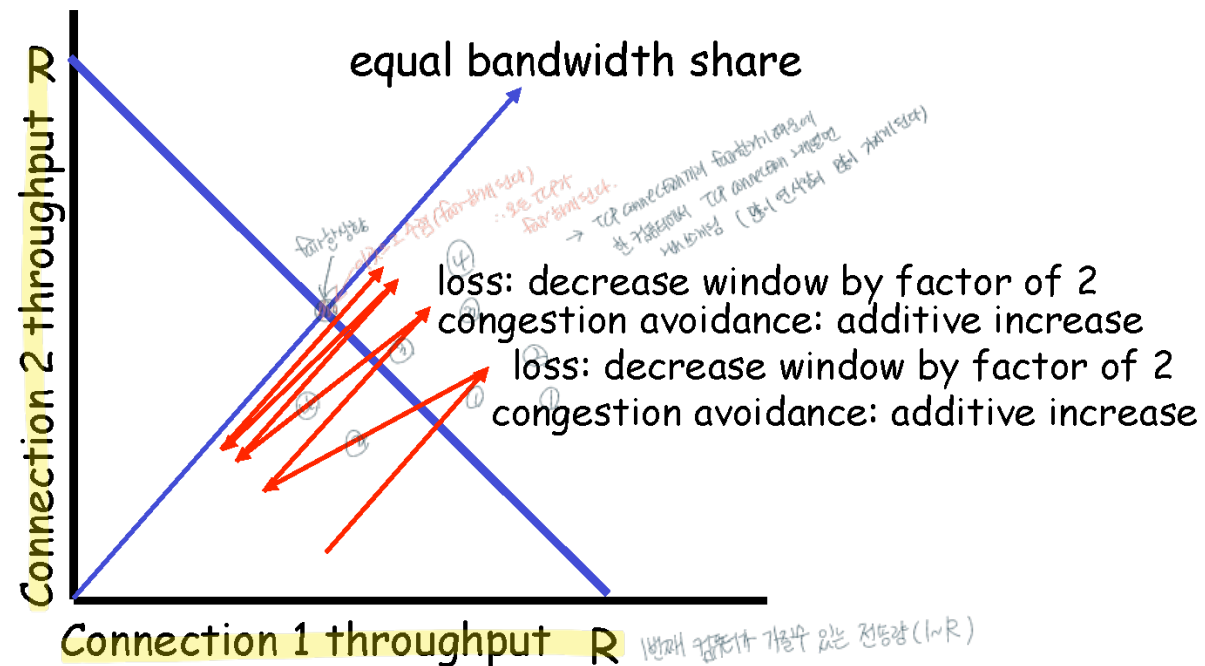
Fairness goal: if K TCP sessions share same bottleneck link of bandwidth R , each should have average rate of R/K



Why is TCP fair?

Two competing sessions:

- Additive increase gives slope of 1, as throughput increases
- multiplicative decrease decreases throughput proportionally



Chapter 3: Summary

- ❑ principles behind transport layer services:
 - multiplexing, demultiplexing
 - reliable data transfer
 - flow control
 - congestion control
- ❑ instantiation and implementation in the Internet
 - UDP
 - TCP

Next:

- ❑ leaving the network “edge” (application, transport layers)
- ❑ into the network “core”