Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Networked Systems
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Communication Networks

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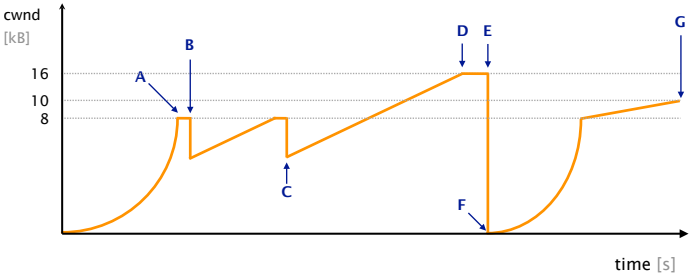
Solution: Exercise 9 – Congestion Control & DNS part I

9.1 Congestion Window

Consider the following plot which depicts the evolution of the size of the TCP congestion window of the sender.



What kind of network conditions is this flow seeing?

Describe briefly:

a) What happens at point B?
Solution: Triple duplicate ACKs.

b) Does the event happening at point B require the network to discard packets? Why or why not?
Solution: No. This could be caused by packet reordering (e.g., due to queuing or asymmetric paths).

c) What happens at point E?
Solution: A timeout event which causes the sender to decrease its window.

d) Does the event happening at point E require the network to discard packets? Why or why not?
Solution: No. Congestion (queuing delay) in the forward or backward direction could cause the round-trip time to be higher than the retransmission timeout.

Consider that the Maximum Segment Size (MSS) of the connection is 1 kB and the Round-Trip Time (RTT) between the two end points is 100 milliseconds. The sender opens the connection at time $t = 0$. Transmission delay in this network is negligible, so you should only consider the propagation delay in the following.

e) How much time has elapsed at point A?
Solution: Total time: 1 RTT for the TCP handshake + 3 RTT in slow-start ($1 \rightarrow 2 \rightarrow 4 \rightarrow 8$ MSS) = 4 RTT, i.e. 400 ms.

f) How much time has elapsed *between* point C and D?
Solution: The congestion window grows from 4 MSS to 16 MSS linearly at a growth of 1 MSS per RTT, translating to 12 periods of RTT or 1.2 s.

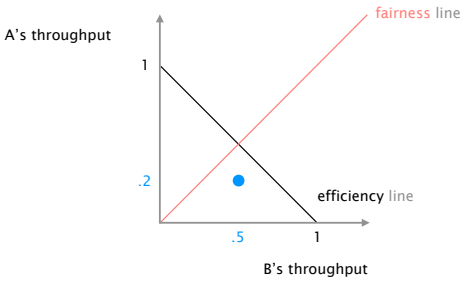
g) How much time has elapsed *between* point F and point G?

Solution: From F, we start with slow start phase to an 8K window size which takes 3 RTT ($1 \rightarrow 2 \rightarrow 4 \rightarrow 8$ MSS). After that we flip to congestion avoidance and follow an additive increase from a 8 to a 10 MSS window size (8, 9, 10 MSS) which takes 2 RTTs. In total 5 RTTs, i.e. 500 ms, elapsed from point F to G.

Briefly explain how come point D is higher than point B. Would you expect this to happen often?

Solution: D's height can vary as a consequence of other concurrent flows being sent along the same link. This is therefore likely to happen all the time.

9.2 Fairness



Are you getting a fair share?

Consider the situation in which two hosts, A and B, are concurrently using a 1 Mbps link with a Maximum Segment Size (MSS) of 100 kb.

Assuming that B starts with 500 kbps and A with 200 kbps (see left picture). Describe the evolution of the throughput of the two hosts when:

a) A and B rely on Additive Increase Multiplicate Decrease (AIMD).

Solution: By drawing on the left picture, you can show that AIMD eventually converges to the fairness state. For instance, assuming that both sender increase their CWND by 1 MSS when there is no congestion and divide it by 2 upon congestion, the following points can be drawn:

- (.2, .5)
- (.3, .6)
- (.4, .7) > congestion!
- (.2, .35)
- (.3, .45)
- (.4, .55)
- (.5, .65) > congestion!
- (.25, .325)
- ...

It can be seen that, because of its bigger share, B looses more than A because of the halving, eventually the system evolves along the fairness line.

b) A and B rely on Multiplicative Increase Additive Decrease (MIAD).

Solution: Again, by drawing on the left picture, you can show that MIAD does not converge to the fairness state at all, but rather to one in which A is completely shut down. For instance, assuming that both sender double their CWND when there is no congestion and decrease it by 1 MSS upon congestion, the following points can be drawn:

- (.2, .5)
- (.4, 1) > congestion!
- (.3, .9) > congestion!
- (.2, .8)
- (.4, 1.6) > congestion!
- (.3, 1.5) > congestion!
- (.2, 1.4) > congestion!
- (.1, 1.3) > congestion!
- (0, 1.2) > congestion!
- (0, 1.1) > congestion!
- (0, 1)
- ...

It can be seen that the sender which benefits from a bigger initial share will end up using the entire link.

Assume now that only A is malicious, and wants to cheat congestion control to get more throughput. Describe two distinct ways A could do so and what would be the net effect on B's throughput.

Solution: There are many ways A could cheat congestion control. Two simple ones would be: *i)* increase its congestion window faster than what is prescribed, e.g. instead of increasing its CWND by 1 per RTT, it could increase it by 2 or 3 per RTT; *ii)* opening up many connections and therefore profit from more overall throughput as TCP tends to allocate throughput equally across all connections.

It is worth noting that detecting cheating is hard as controlling all end-points in the Internet is rather hopeless. Yet, the Internet continues to work and we haven't faced a new congestion collapse event since the 80s.

9.3 Multiple answers

Whenever a client (e.g., your computer) receives multiple IP addresses as answer to a DNS lookup, it picks the very first one. Only if that one does not work, it tries the next one in order.

When you run `dig yahoo.com`, you receive multiple IP addresses as an answer compared to, for example, `dig google.com`.

Can you think of a reason for providing multiple IP addresses? Run the lookup for `yahoo.com` multiple times.

Solution: (i) Resiliency: Should the first IP addresses not be reachable, you can try with the second one without having to do another DNS request.

(ii) Load of the authoritative DNS server: By giving multiple answers, you have a higher chance that one of the answers works for the entire lifetime of the reply (defined TTL value). Your DNS server will therefore get less frequent requests compared to a DNS server which only answers with one entry and a low TTL value.

(iii) Load balancing: You can use it as one way to do load balancing.