Comparison of Different TCP flavors

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AGENDA

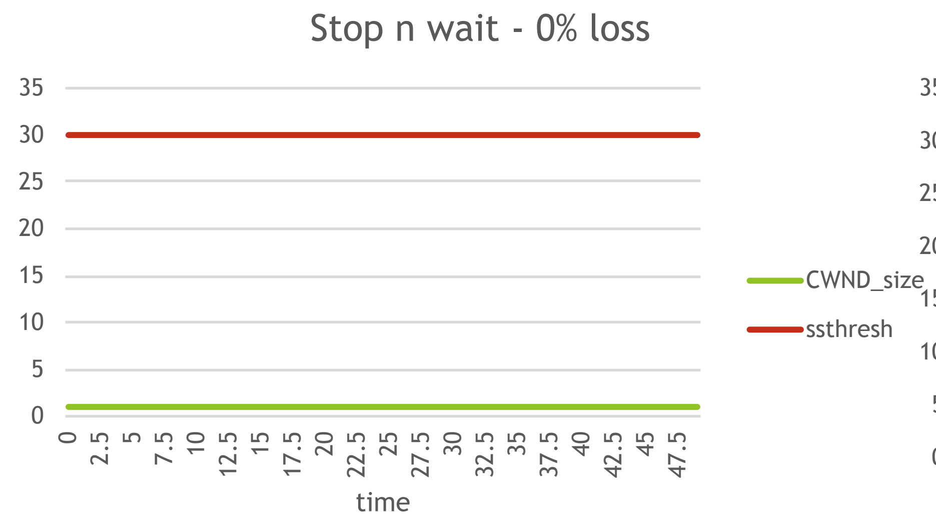
- Overview of TCP
- TCP stop-and-wait
- TCP Go-back-n
- TCP Tahoe
- TCP Reno

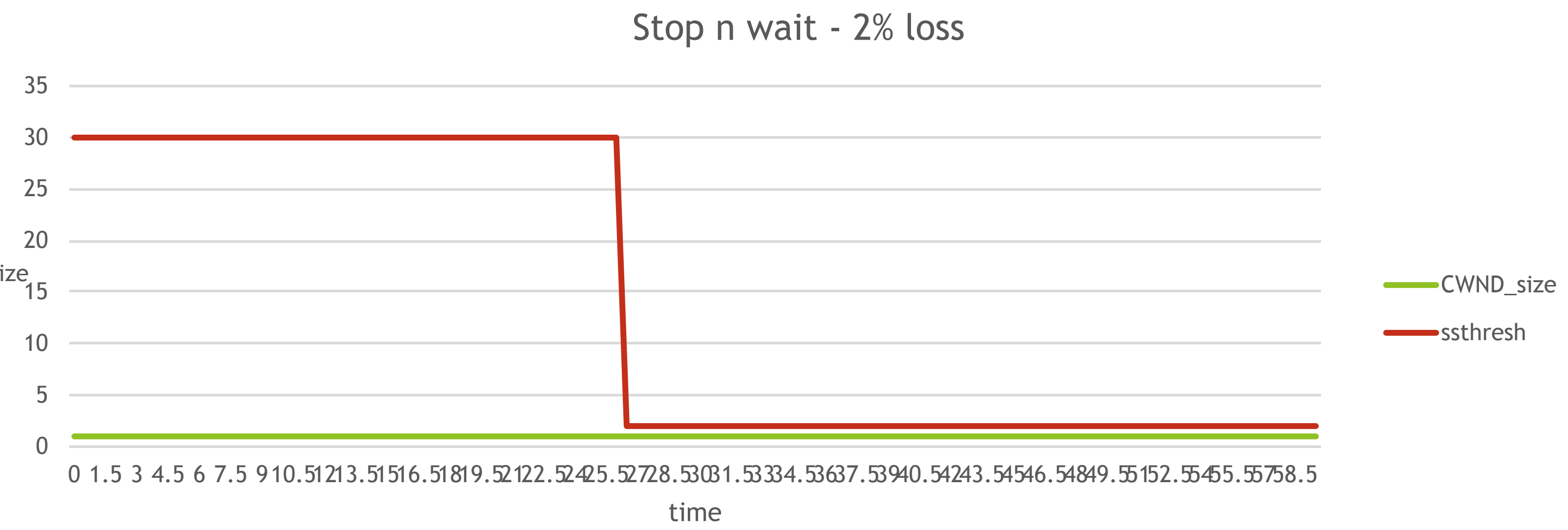
Overview of TCP

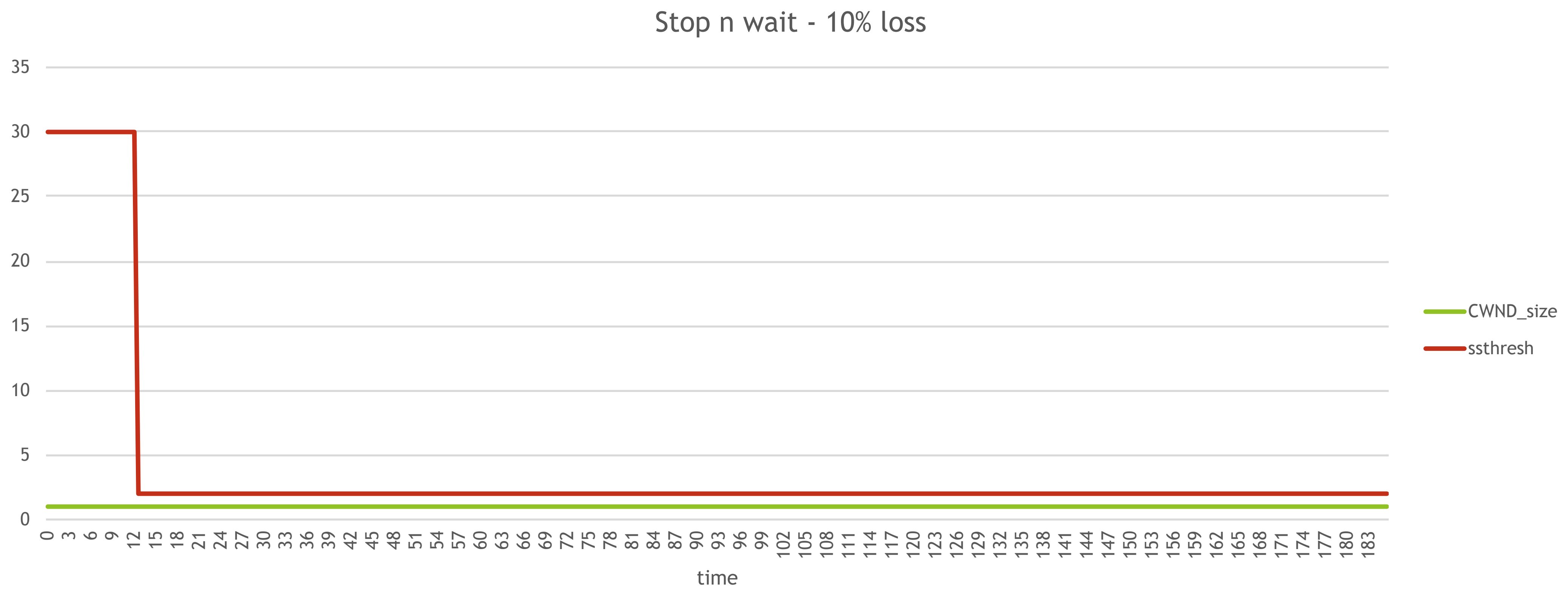
- Goals of TCP
  - Congestion Control
    - Control the sending rate as per network traffic
  - Reliable Data Transfer
    - Re-transmit lost packets effectively

TCP with Stop-n-wait

- Overview of early TCP with stop n wait
- Features:
  - Stop and wait
    - Send one packet and wait for the ACK
    - Once we receive the ACK send next packet
  - Retransmission
    - Only way to detect packet loss is TO
    - If we don’t receive the ACK after TO, resend the packet.

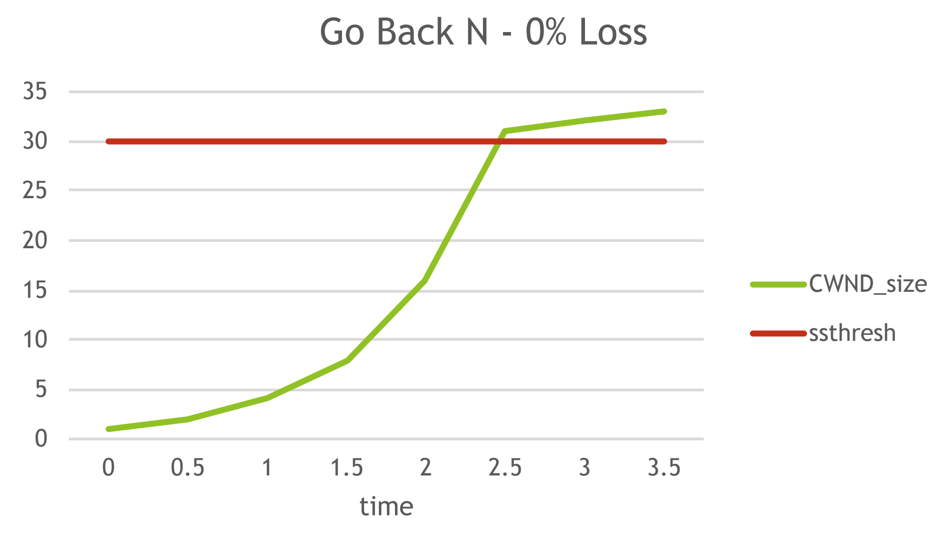

Stop n wait - 0% loss
35
30
25
20
15
10
5
0
0 2.5 5 7.5 10 12.5 15 17.5 20 22.5 25 27.5 30 32.5 35 37.5 40 42.5 45 47.5
time
CWND_size
ssthresh

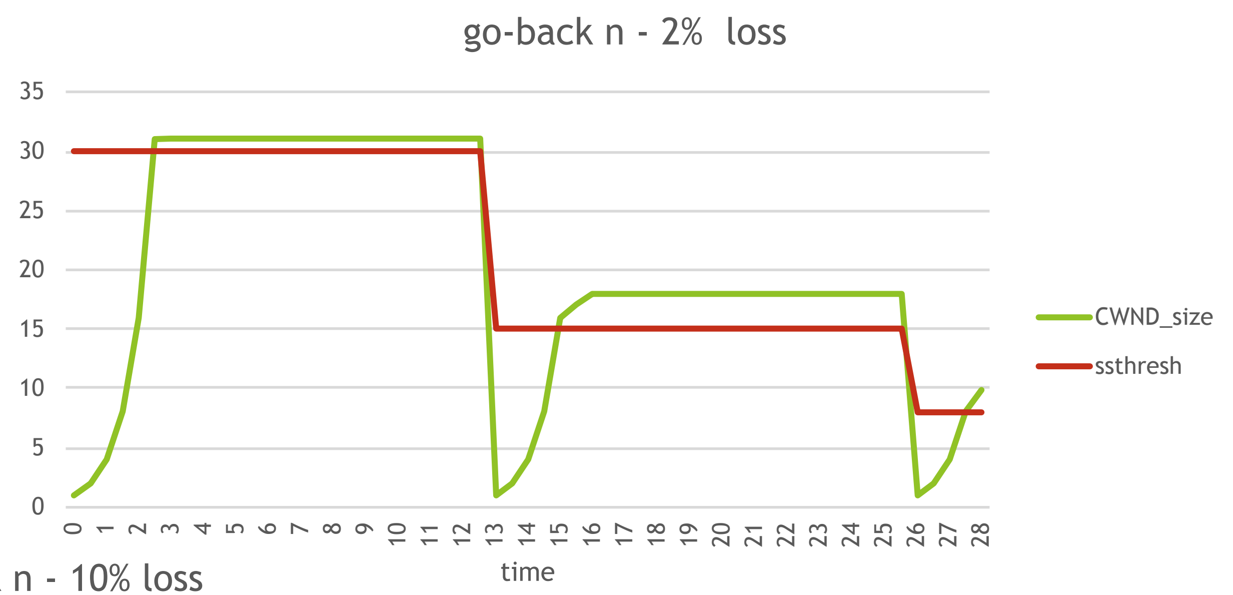

Stop n wait - 2% loss
35
30
25
20
15
10
5
0
time
CWND_size
ssthresh

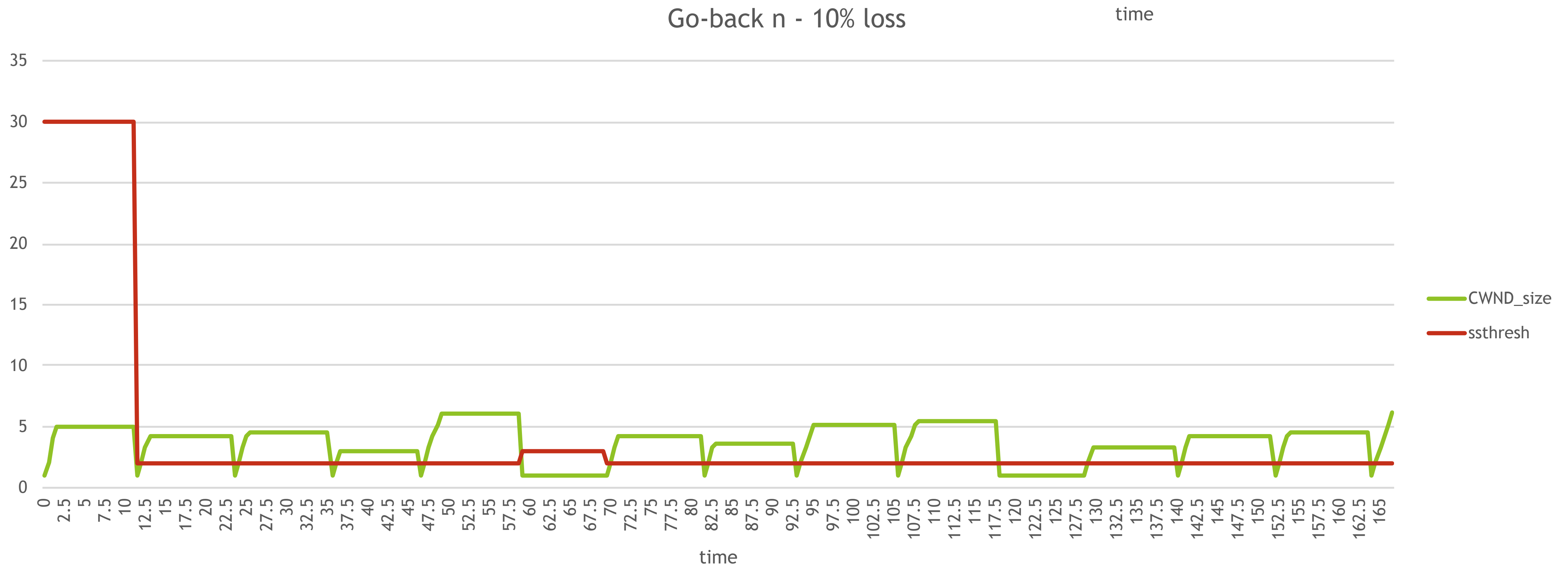

Stop n wait - 10% loss
35
30
25
20
15
10
5
0
time
CWND_size
ssthresh

TCP with Go-back-n

- Overview of early TCP with go-back-n
- Features:
  - Congestion window
    - Send more than one packets(same as the size of congestion window) in one RTT
  - Slow start and Congestion avoidance
    - Slow Start -> CWND += 1 for each ACK received
    - Congestion avoidance -> CWND = $\frac{1}{CWND}$
  - Retransmission -> Go back n approach
    - Whenever a packet loss happens, retransmit all the packets after the lost packet including lost packet in the congestion window.
    - Only way to detect a packet loss is Time Out (Time out)

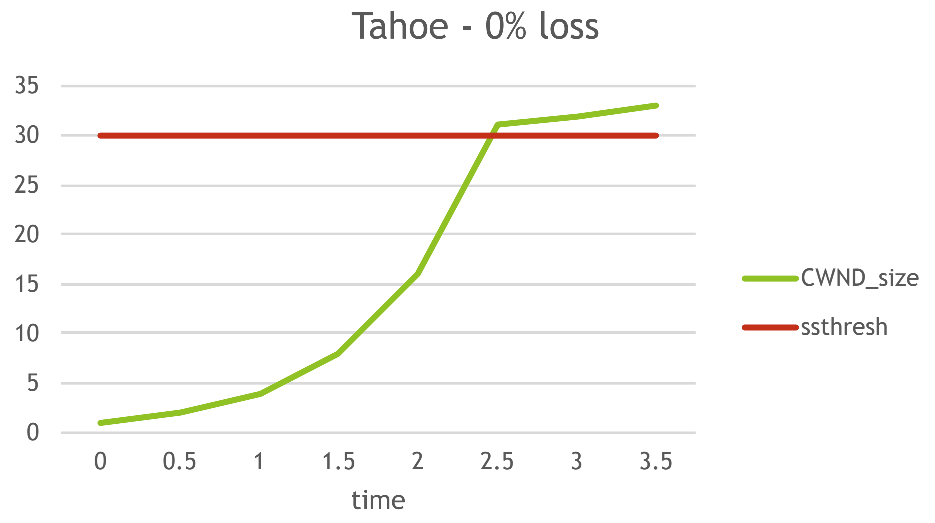

Go Back N - 0% Loss
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
time
CWND_size
ssthresh

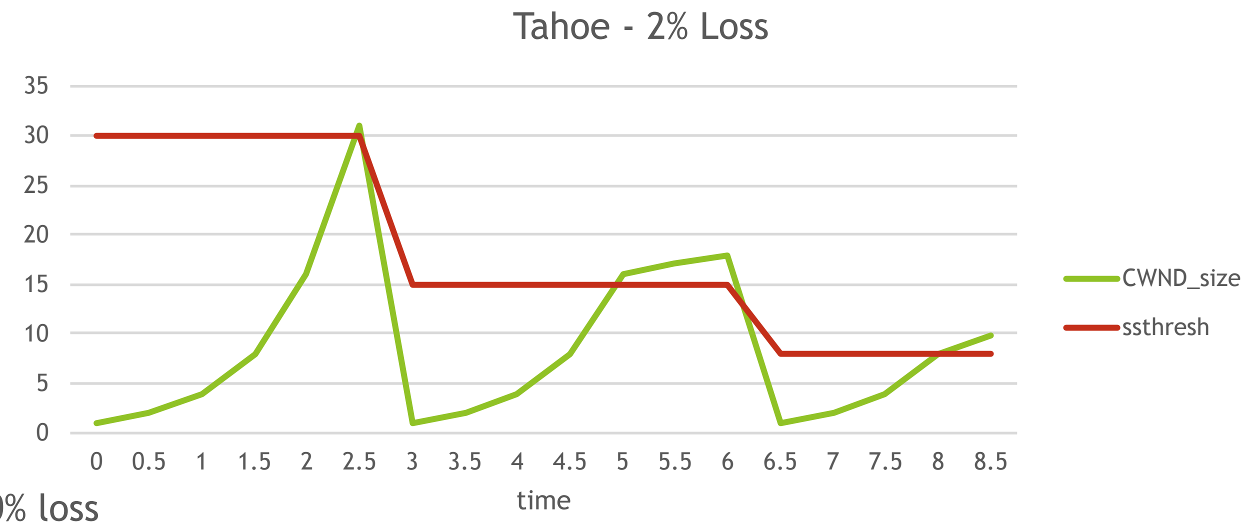

go-back n - 2% loss
35
30
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
time
CWND_size
ssthresh

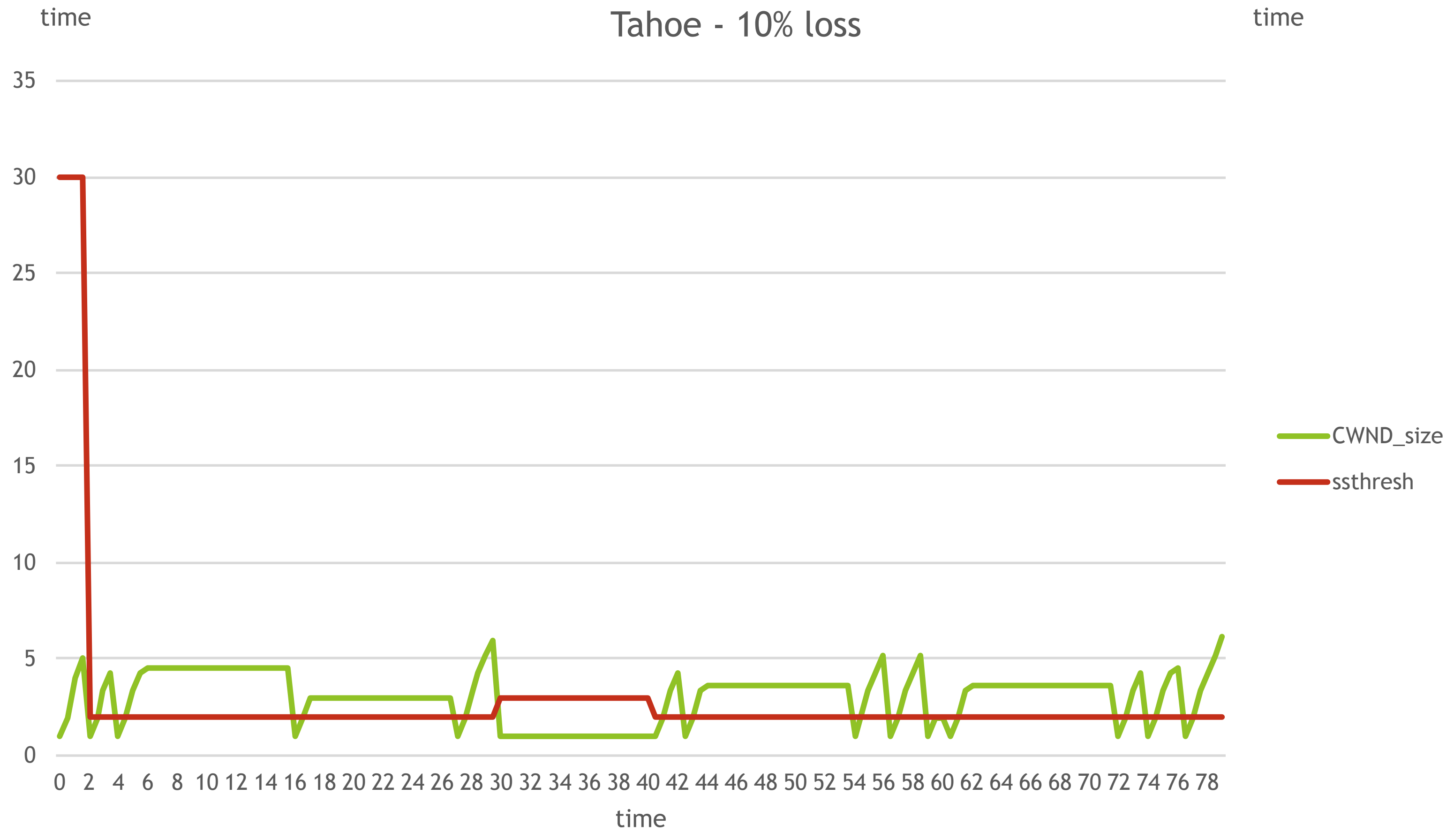

Go-back n - 10% loss
35
30
25
20
15
10
5
0
0 2.5 5 7.5 10 12.5 15 17.5 20 22.5 25 27.5 30 32.5 35 37.5 40 42.5 45 47.5 50 52.5 55 57.5 60 62.5 65 67.5 70 72.5 75 77.5 80 82.5 85 87.5 90 92.5 95 97.5 100 102.5 105 107.5 110 112.5 115 117.5 120 122.5 125 127.5 130 132.5 135 137.5 140 142.5 145 147.5 150 152.5 155 157.5 160 162.5 165
time
CWND_size
ssthresh

TCP Tahoe

- Overview of TCP Tahoe
- Features:
  - Congestion window
    - Send more than one packets(same as the size of congestion window) in one RTT
  - Slow start and Congestion avoidance
    - Slow Start -> CWND += 1 for each ACK received
    - Congestion avoidance -> CWND = $\frac{1}{CWND}$
  - Fast Retransmit
    - Retransmit the Packet as soon as we receive 3 dupAcks
    - Don’t wait for time out for packet retransmission
    - Early detection of packet loss
    - reduce the CWND to 1 and enter Slow start

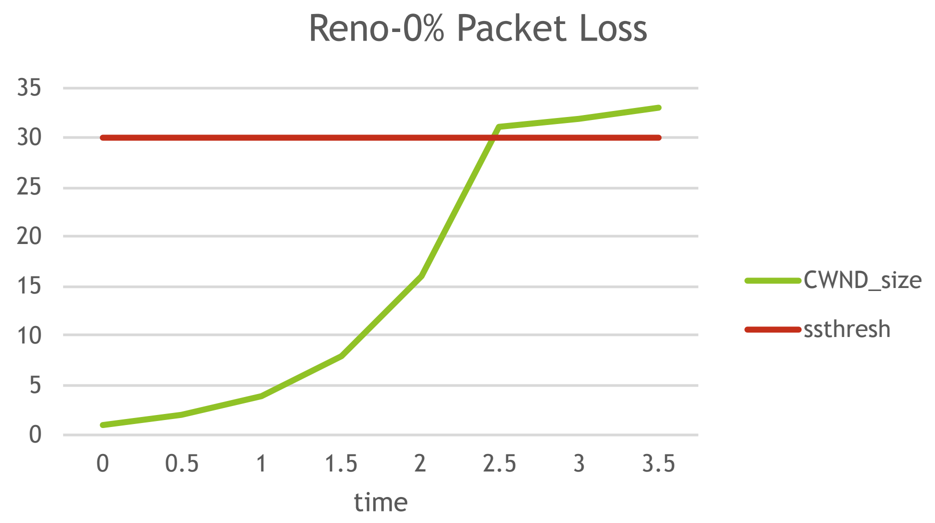

Tahoe - 0% loss
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
time
CWND_size
ssthresh

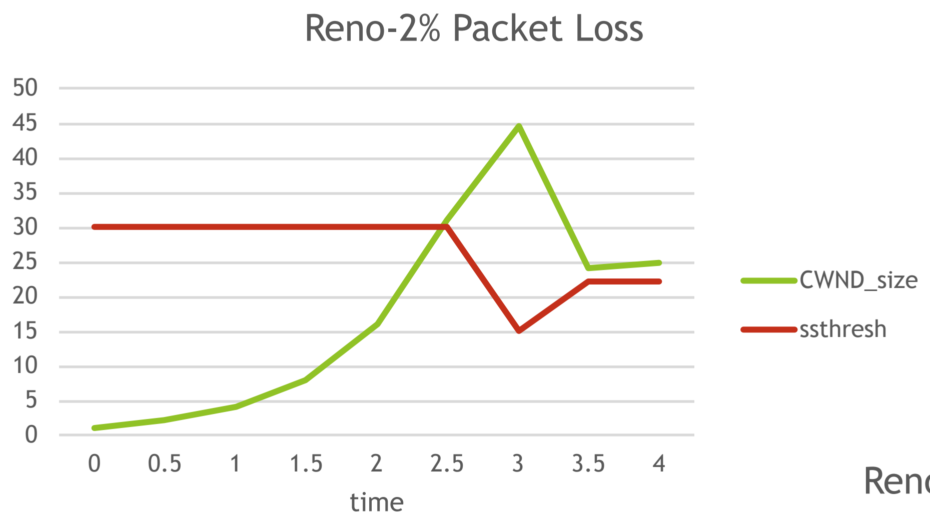

Tahoe - 2% Loss
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
8.5
time
CWND_size
ssthresh

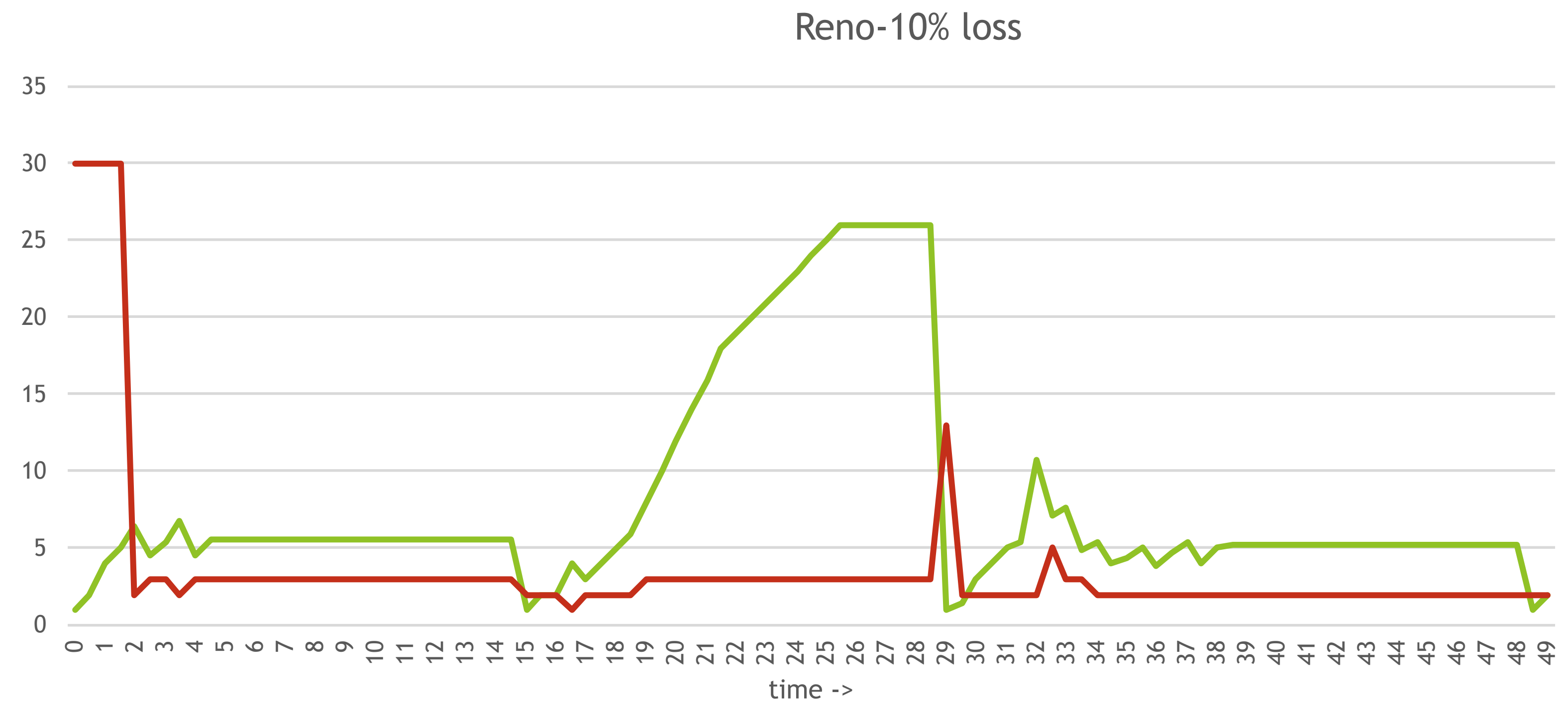

Tahoe - 10% loss
35
30
25
20
15
10
5
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78
time
CWND_size
ssthresh

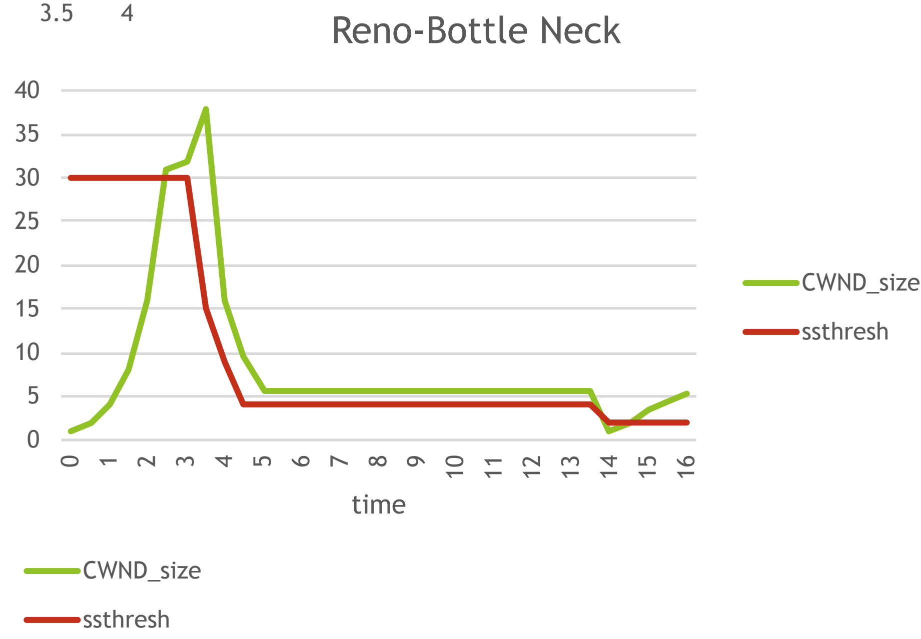
TCP Reno

- Overview of TCP Reno
- Features:
  - Congestion window
    - Send more than one packets(same as the size of congestion window) in one RTT
  - Slow start and Congestion avoidance
    - Slow Start -> CWND += 1 for each ACK received
    - Congestion avoidance -> CWND = $\frac{1}{CWND}$
  - Fast Retransmit
    - Retransmit the Packet as soon as we receive 3 dupAcks
    - Don't wait for time out for packet retransmission
    - Early detection of packet loss
    - Don't reduce the CWND to 1 and enter fast recovery
  - Fast Recovery
    - Don't reduce the CWND to 1 after fast retransmission
    - For each dupACK where dupACK count > 3;
      - Increase CWND += 1
    - When a non-dupACK is received come out of fast recovery

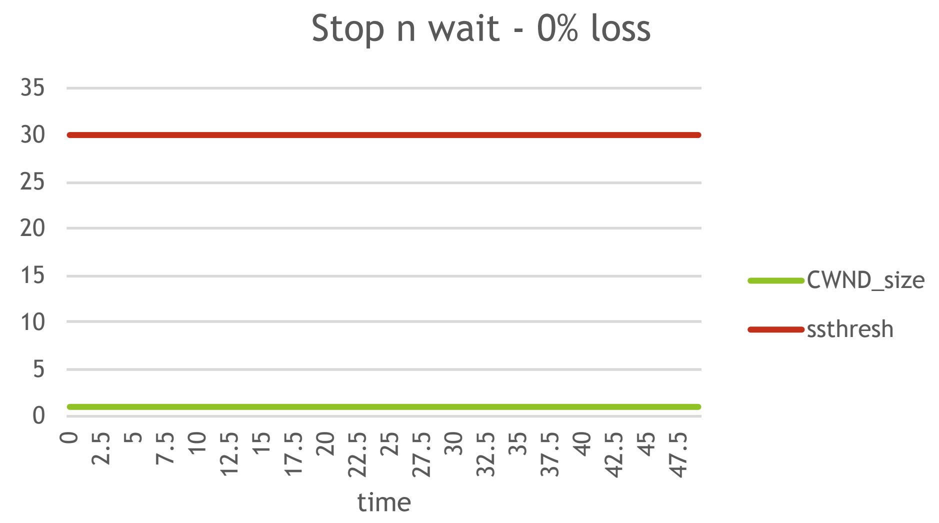

Reno-0% Packet Loss
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
time
CWND_size
ssthresh

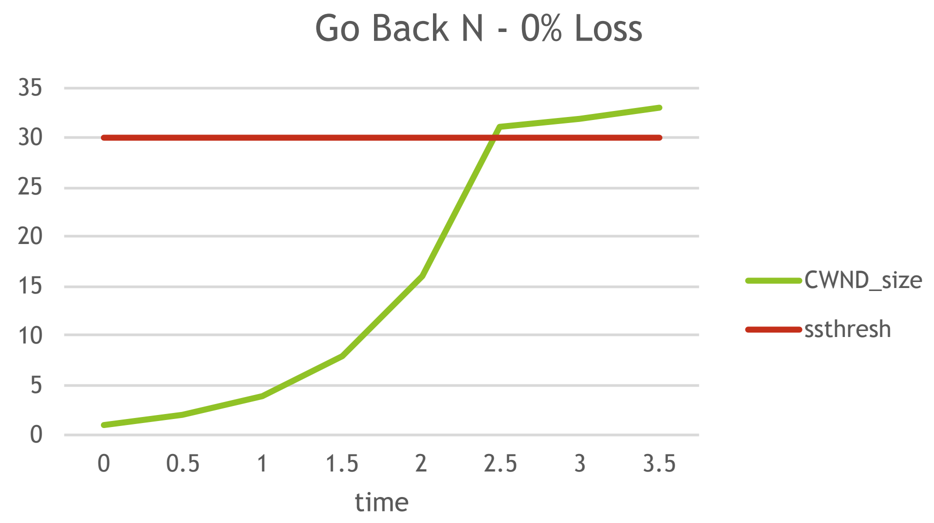

Reno-2% Packet Loss
50
45
40
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
4
time
CWND_size
ssthresh

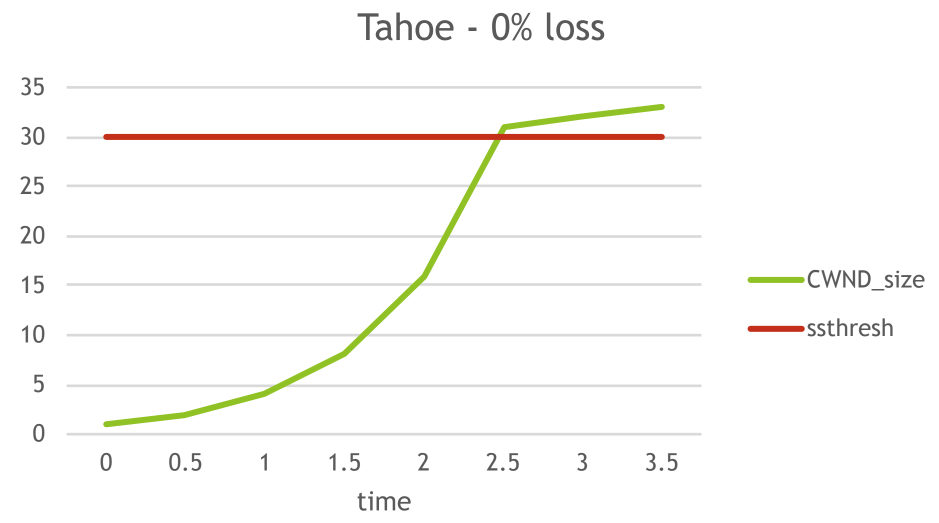

Reno-10% loss
35
30
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49
time ->

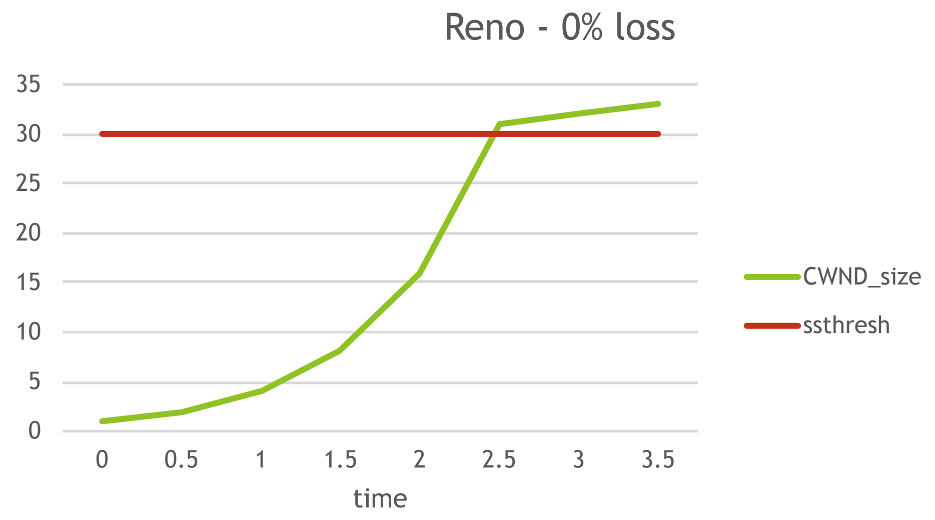

Reno-Bottle Neck
40
35
30
25
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
time
CWND_size
ssthresh
CWND_size
ssthresh

Comparison of TCP Flavors with 0% packet loss

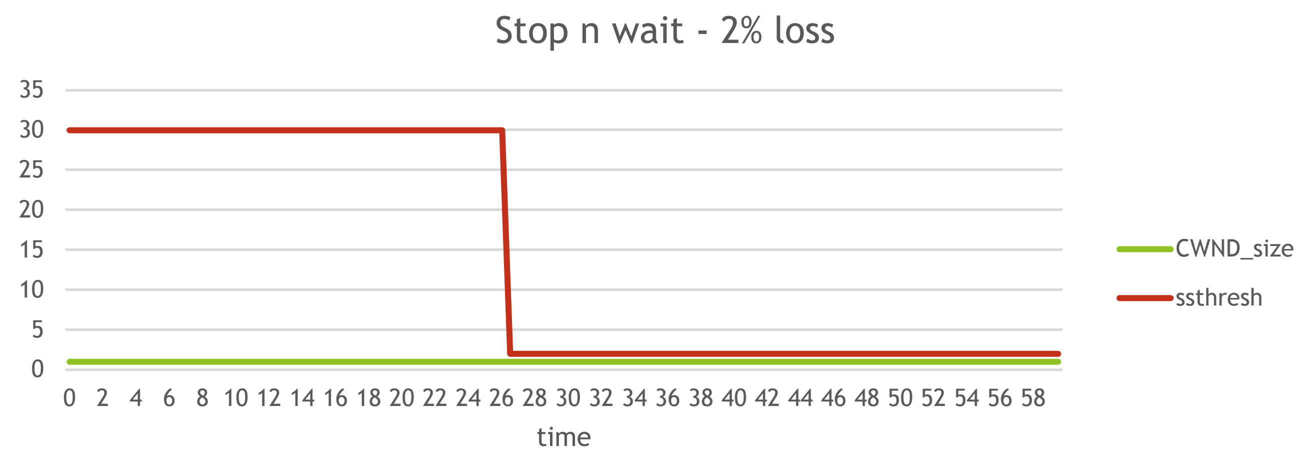

Stop n wait - 0% loss
35
30
25
20
15
10
5
0
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
25
27.5
30
32.5
35
37.5
40
42.5
45
47.5
time
CWND_size
ssthresh

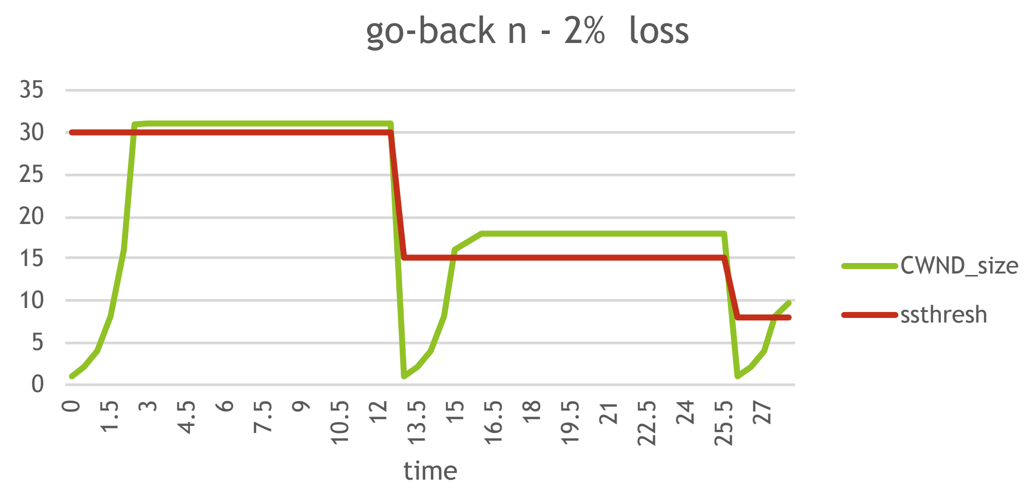

Go Back N - 0% Loss
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
time
CWND_size
ssthresh

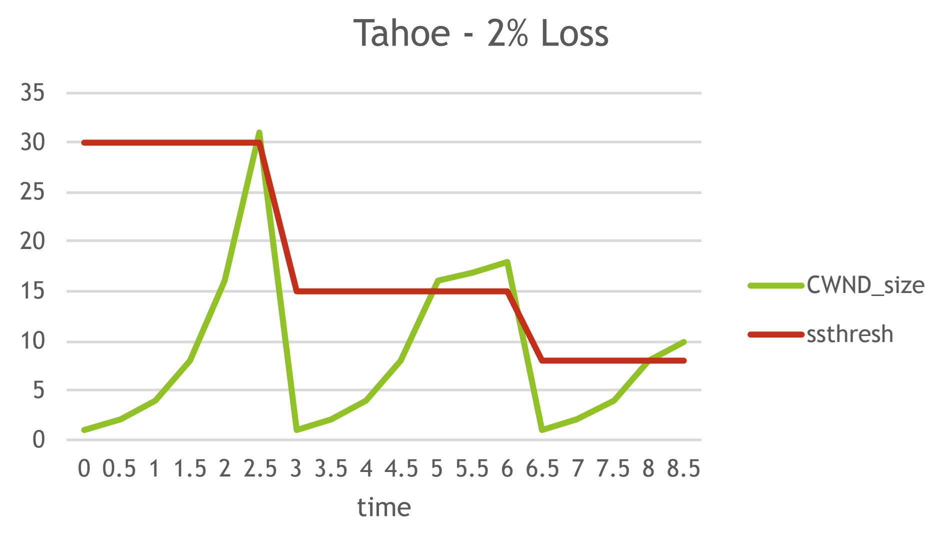

Tahoe - 0% loss
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
time
CWND_size
ssthresh

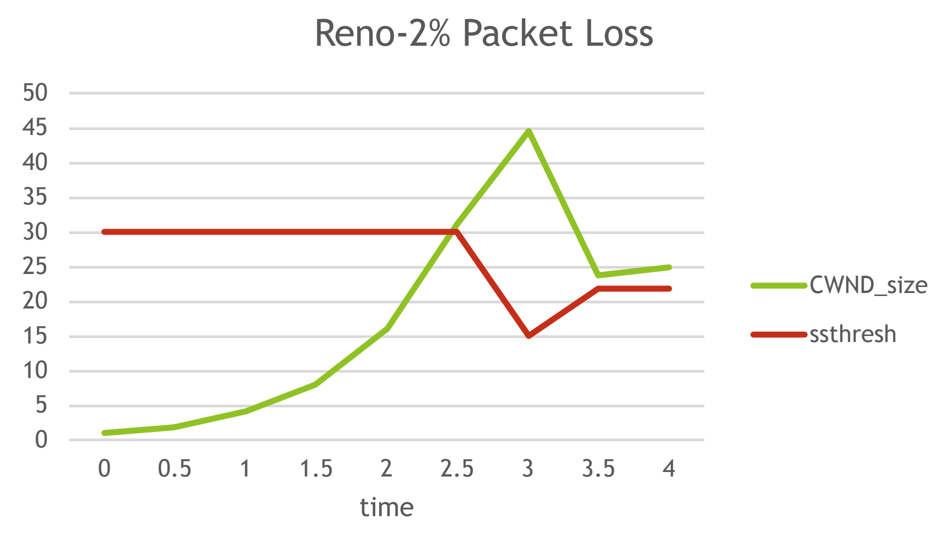

Reno - 0% loss
35
30
25
20
15
10
5
0
0
0.5
1
1.5
2
2.5
3
3.5
time
CWND_size
ssthresh

Comparison of TCP Flavors with 2% packet loss

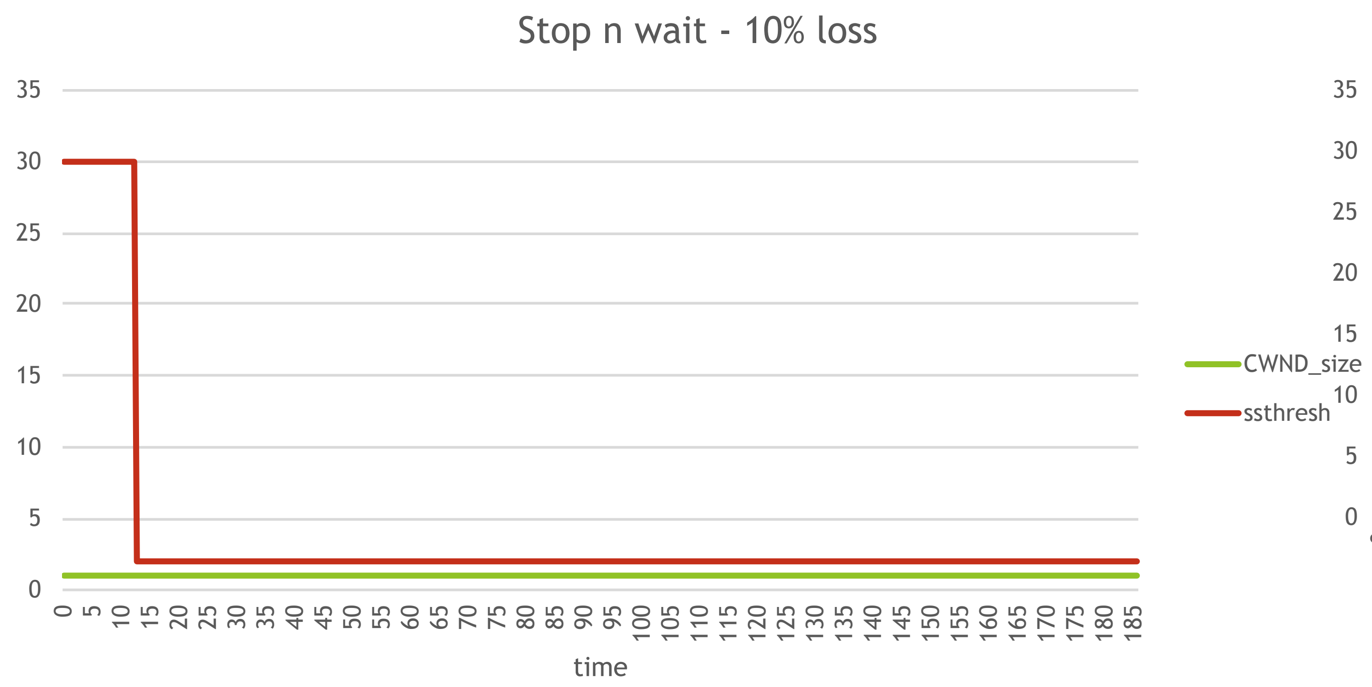

Stop n wait - 2% loss
35
30
25
20
15
10
5
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58
time
CWND_size
ssthresh

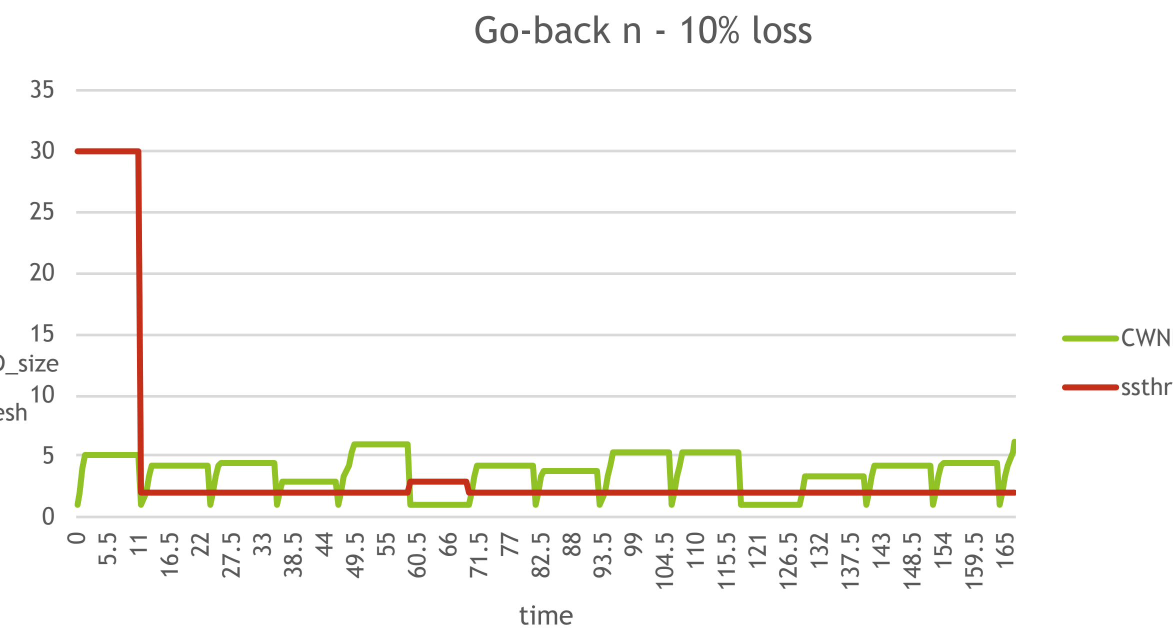

go-back n - 2% loss
35
30
25
20
15
10
5
0
0 1.5 3 4.5 6 7.5 9 10.5 12 13.5 15 16.5 18 19.5 21 22.5 24 25.5 27
time
CWND_size
ssthresh

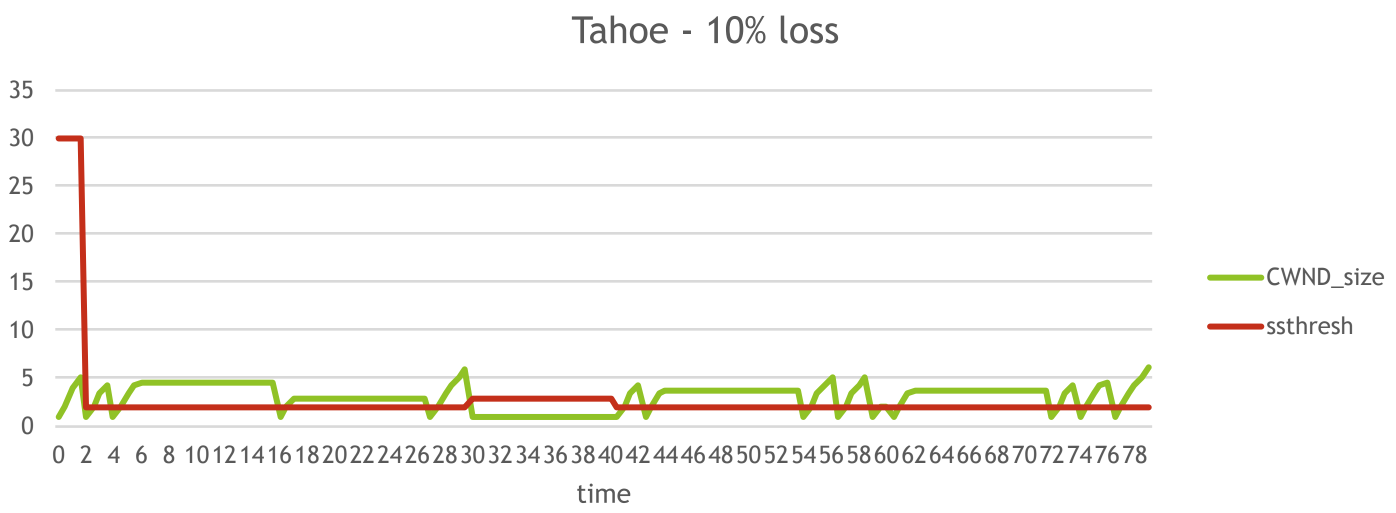

Tahoe - 2% Loss
35
30
25
20
15
10
5
0
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8 8.5
time
CWND_size
ssthresh

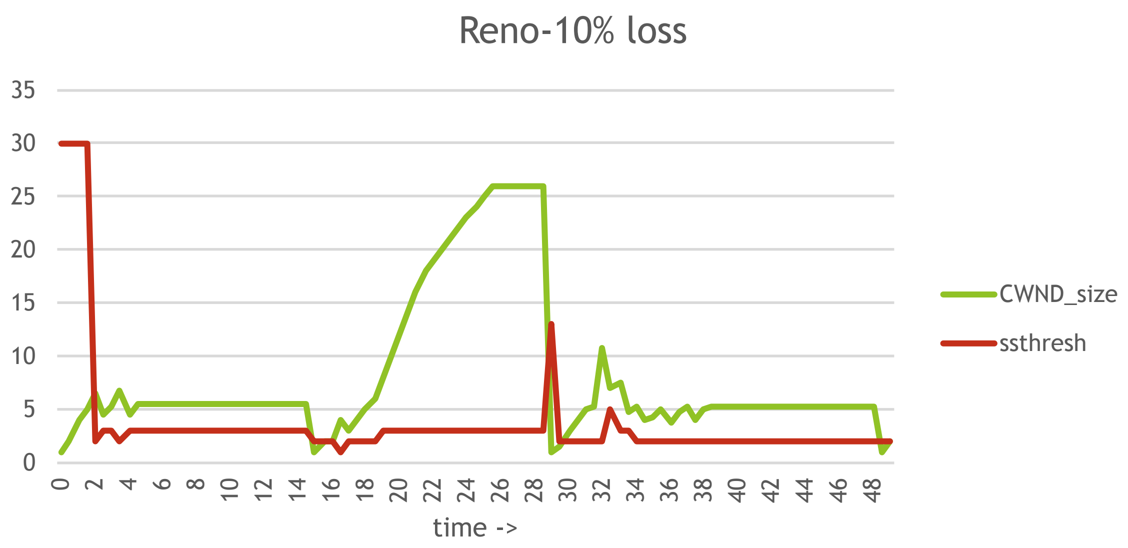

Reno-2% Packet Loss
50
45
40
35
30
25
20
15
10
5
0
0 0.5 1 1.5 2 2.5 3 3.5 4
time
CWND_size
ssthresh

Comparison of TCP Flavors with 10% packet loss


Stop n wait - 10% loss
35 30 25 20 15 10 5 0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185
time
CWND_size
ssthresh


Go-back n - 10% loss
35 30 25 20 15 10 5 0
0 5.5 11 16.5 22 27.5 33 38.5 44 49.5 55 60.5 66 71.5 77 82.5 88 93.5 99 104.5 110 115.5 121 126.5 132 137.5 143 148.5 154 159.5 165
time
CWN
ssthr


Tahoe - 10% loss
35 30 25 20 15 10 5 0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 58 60 62 64 66 68 70 72 74 76 78
time
CWND_size
ssthresh


Reno-10% loss
35 30 25 20 15 10 5 0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
time ->
CWND_size
ssthresh

Any Questions?