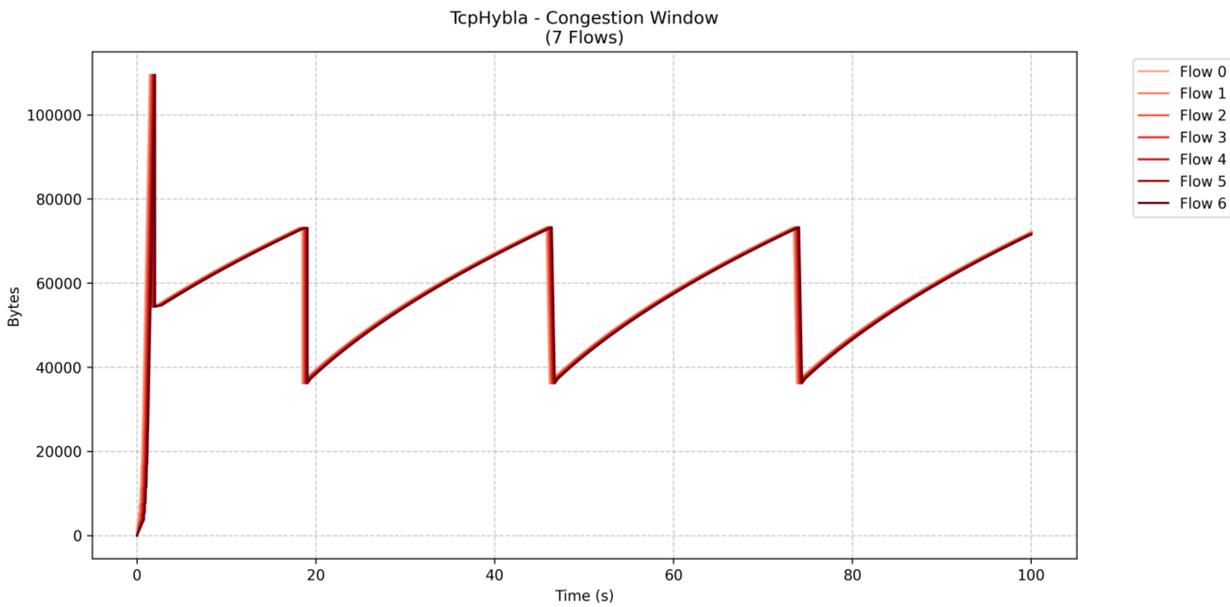
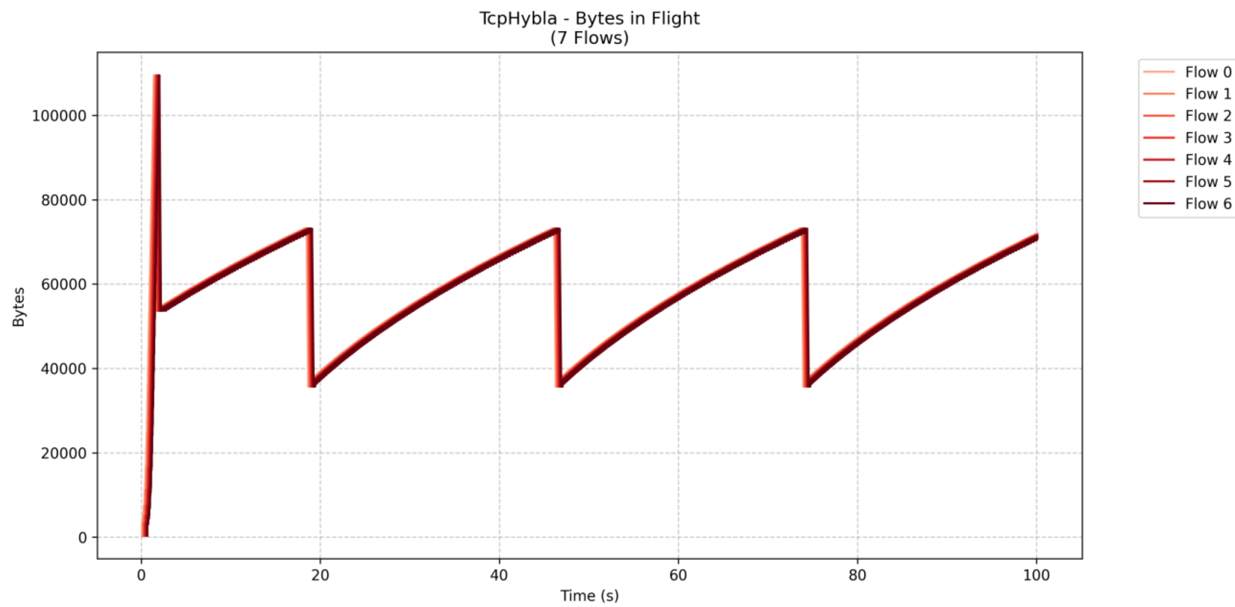
2005013

Al Muhit Muhtadi

TCP HYBLA:

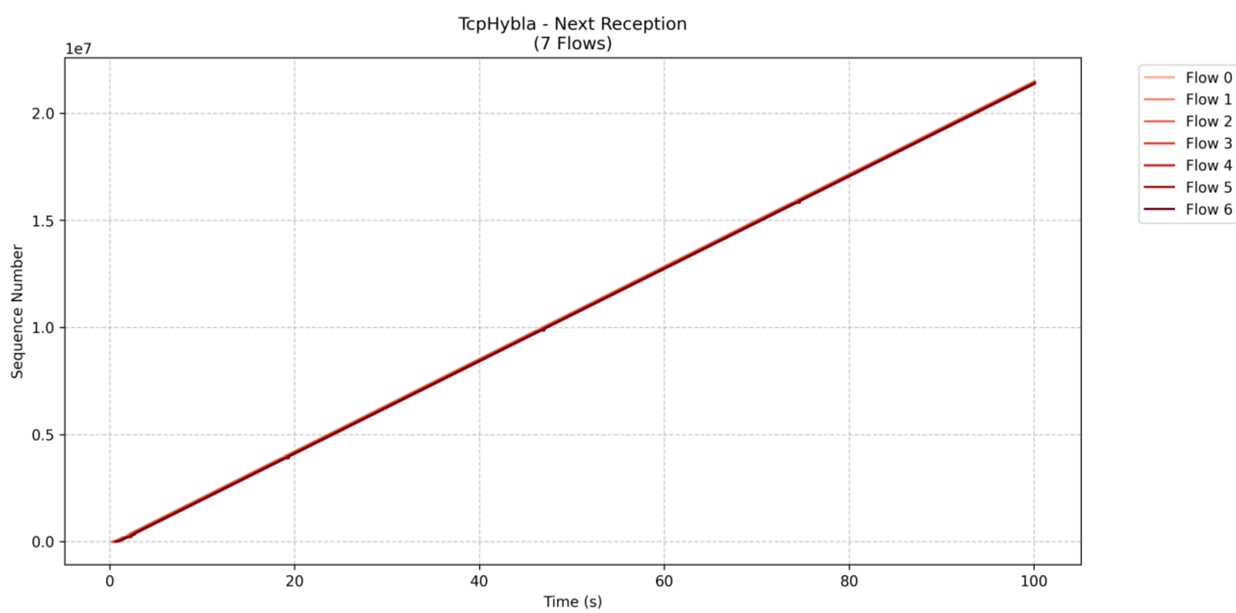


- The congestion window jumps sharply from 0. This is due to TCP Hybla's initial rapid cwnd growth, which mimics the growth rate of a low-latency network.
- **Sharp drops**: These represent packet loss events. When packet loss occurs, TCP interprets it as congestion and reduces the cwnd size to half of ssth to avoid further congestion.
- **Linear growth**: After a loss, TCP enters the Congestion Avoidance phase, where the cwnd grows as power of 2 over time.



Bytes in Flight is the sum of all unacknowledged bytes in the network. It represents the total data currently "in transit" between the sender and receiver. This is critical for understanding network utilization and congestion control.

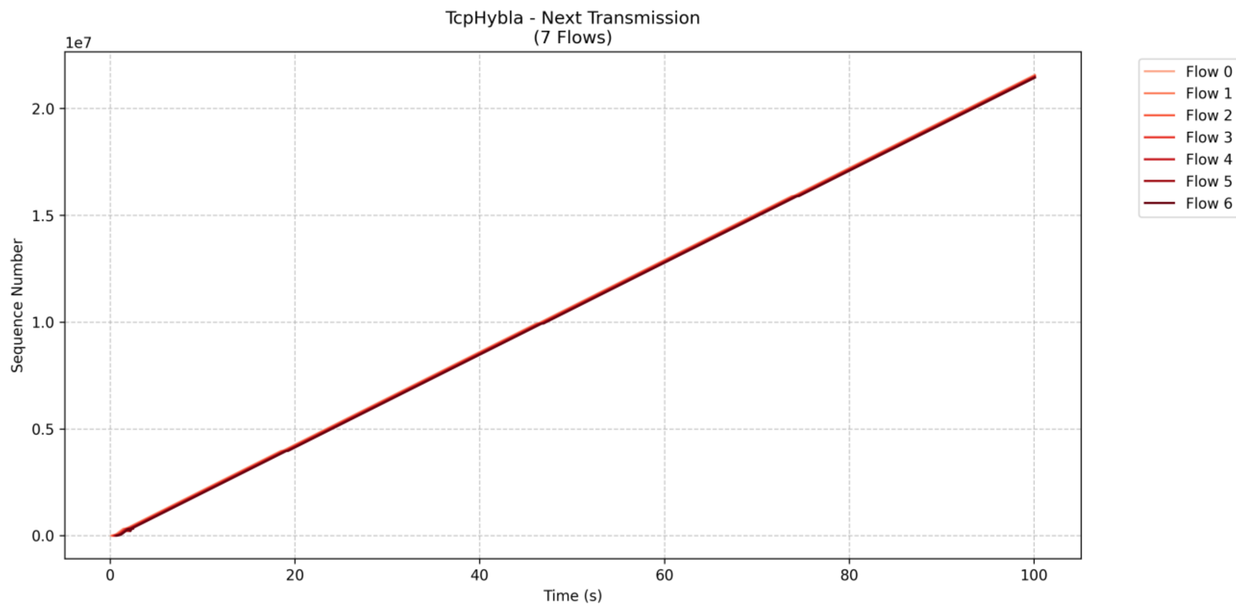
The **congestion window** limits how much data can be sent without waiting for acknowledgments.so graphs are similar



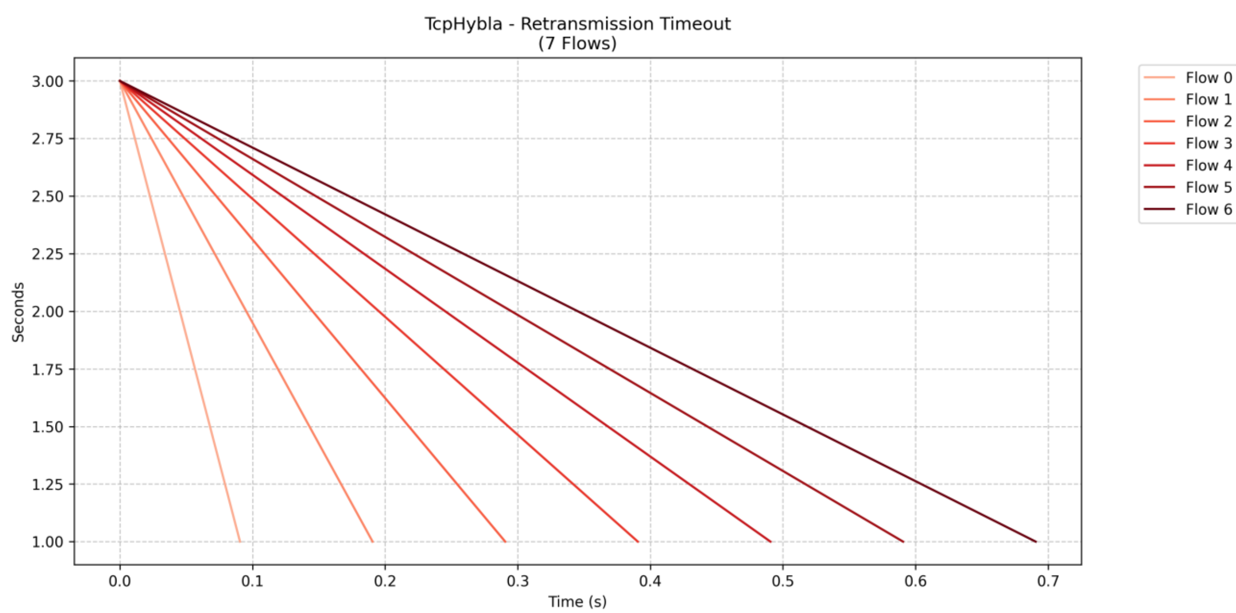
Sequence Number in TCP represents the **position of the data byte** in the overall stream. A linear increase in sequence numbers signifies:

Consistent packet delivery.

High throughput, as no significant interruptions are observed.
The network is stable, and packet loss is minimal or well-managed.
Because error_p=0.



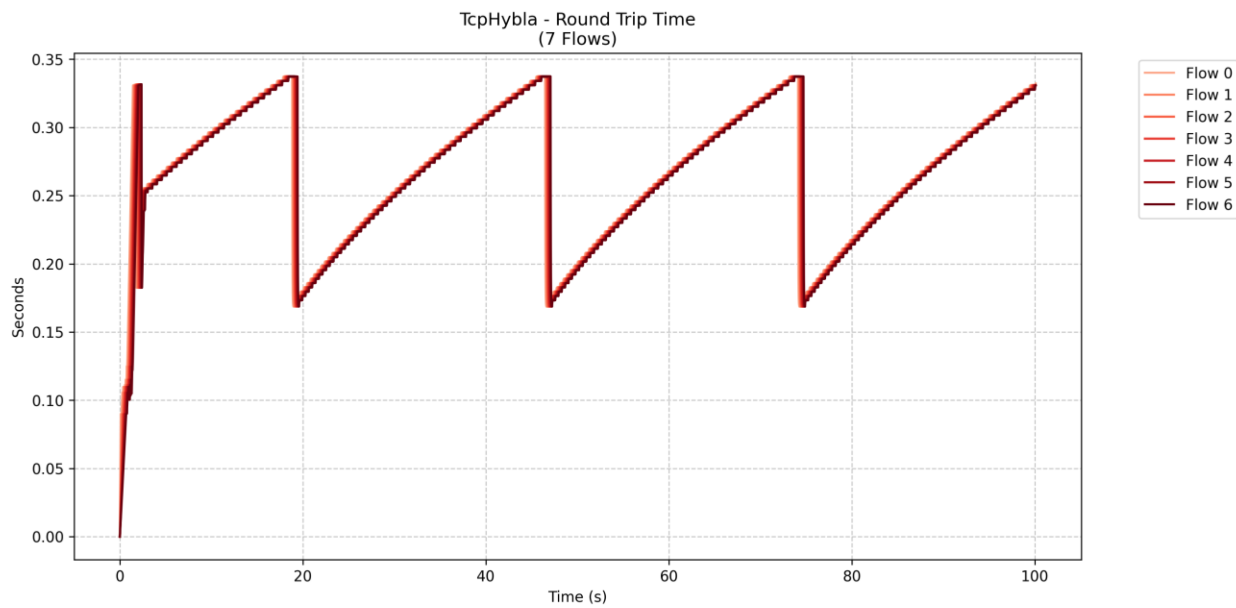
Same as Rx.This linear growth happens due to the **Additive Increase** mechanism of TCP.



The **Retransmission Timeout (RTO)** depends on each flow because it is dynamically calculated based on the **Round-Trip Time (RTT)**

RTO=SRTT+4×RTTVar

A factor of 4 times the RTT variance ensures that **RTO** covers 99.99% of RTT fluctuations in typical networks.

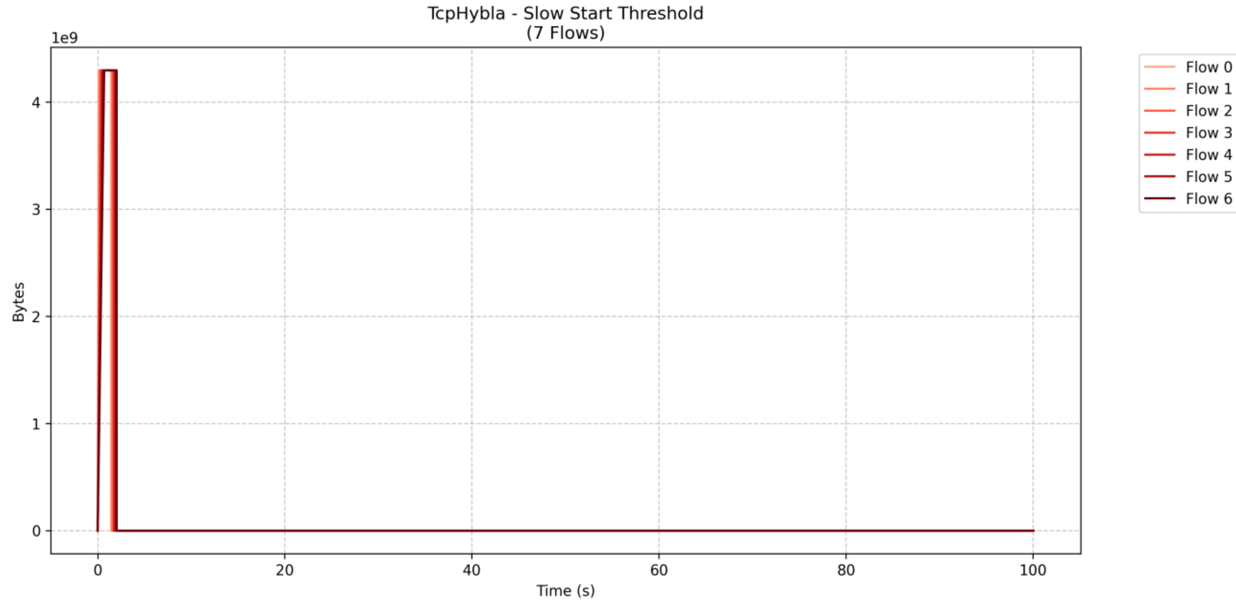


RTT measures the time taken for a packet to:

1. Travel from the sender to the receiver.
2. Return an acknowledgment (ACK) back to the sender.

RTT is a dynamic value influenced by:

Network Latency: Time it takes for packets to propagate through the network.
Congestion: Queues and delays in the network cause RTT to increase

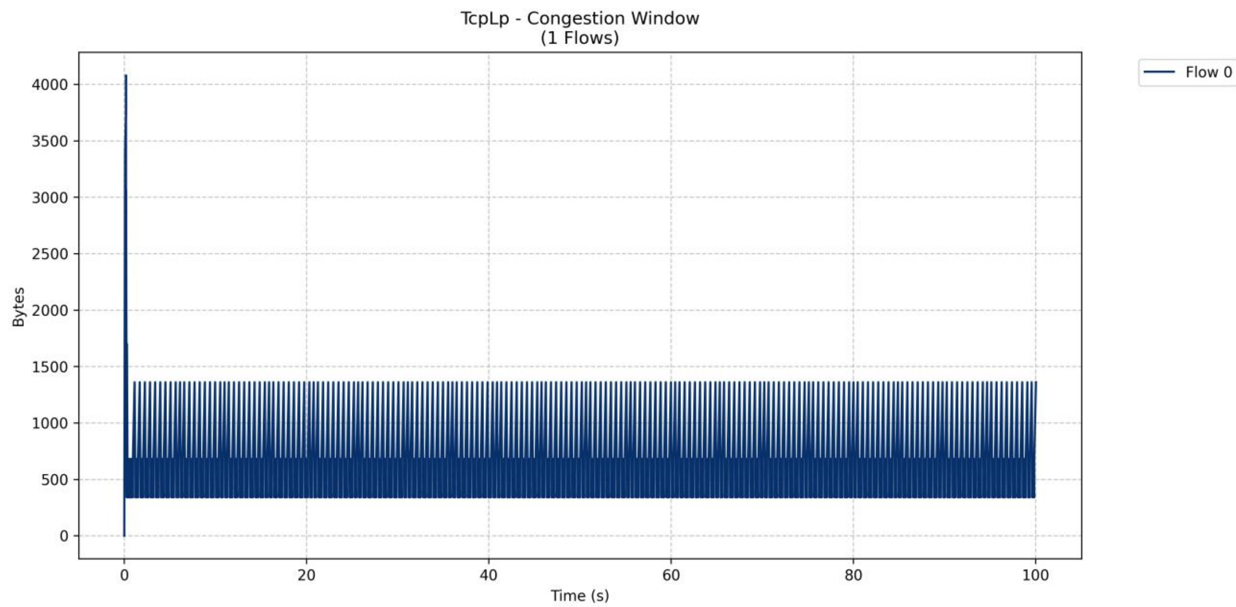


ssthresh is set to an initially high value, such as the maximum buffer size or infinity, to allow the network to test its capacity.

This is not 0 on the later part , but small compared to the initial value . I saw 3 distinct value.

Ssth not necessarily the avg time for a pkt loss. avg time can be higher .

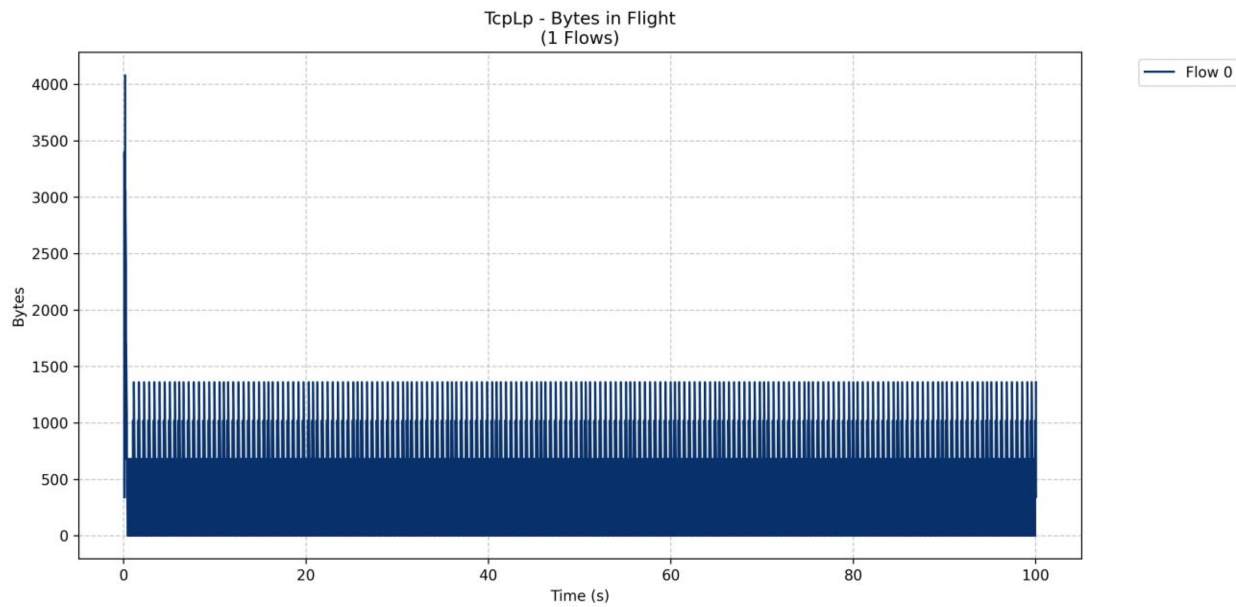
TCP-LP:



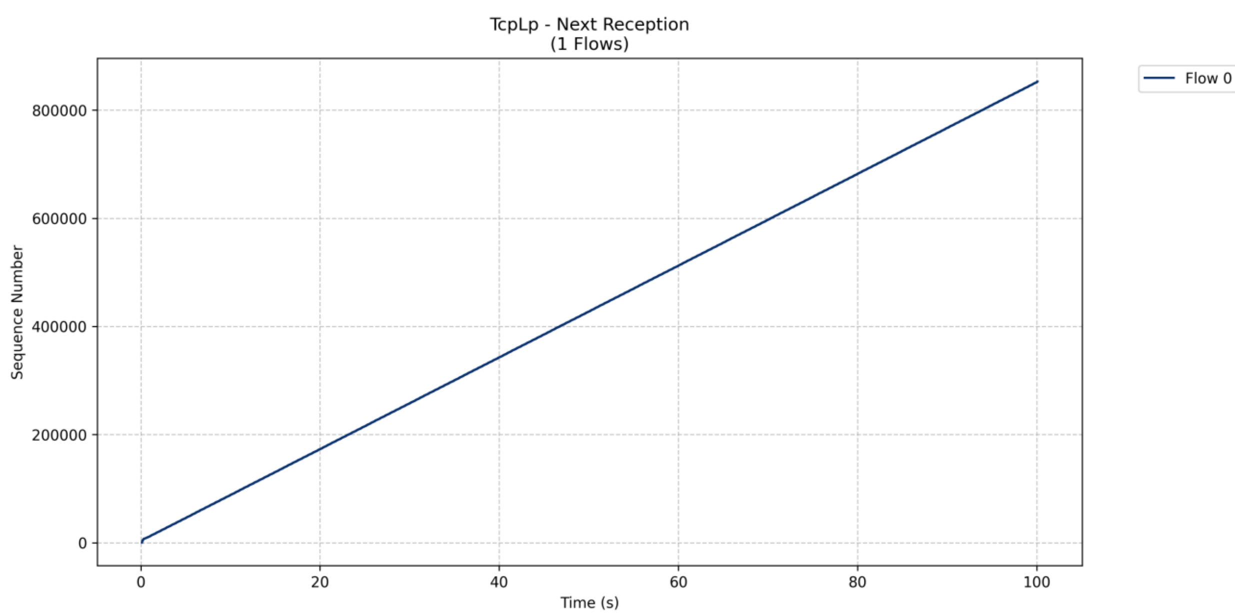
it exhibits frequent **oscillations** (small peaks and troughs).

Because it is a **background congestion control protocol** designed to:

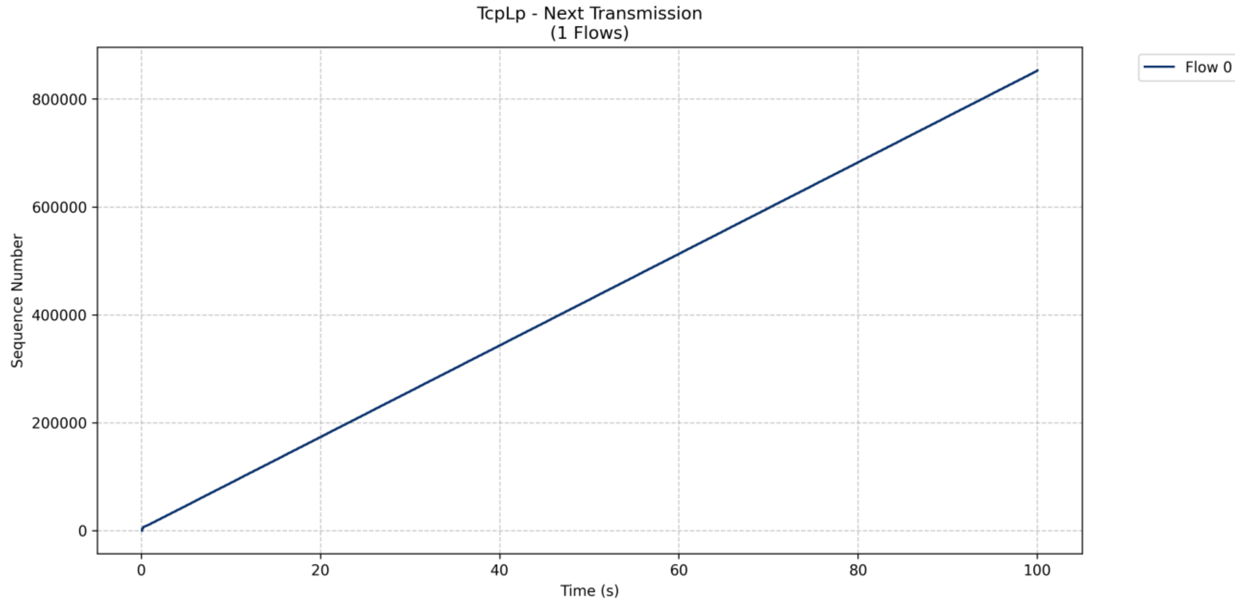
1. **Yield to Higher-Priority Traffic**:
   TCP-LP detects congestion early and aggressively reduces its congestion window to avoid competing with other traffic.
2. **Probe for Available Bandwidth**:
   It periodically increases the congestion window to test if additional bandwidth becomes available.If congestion is detected, it quickly reduces the congestion window again.



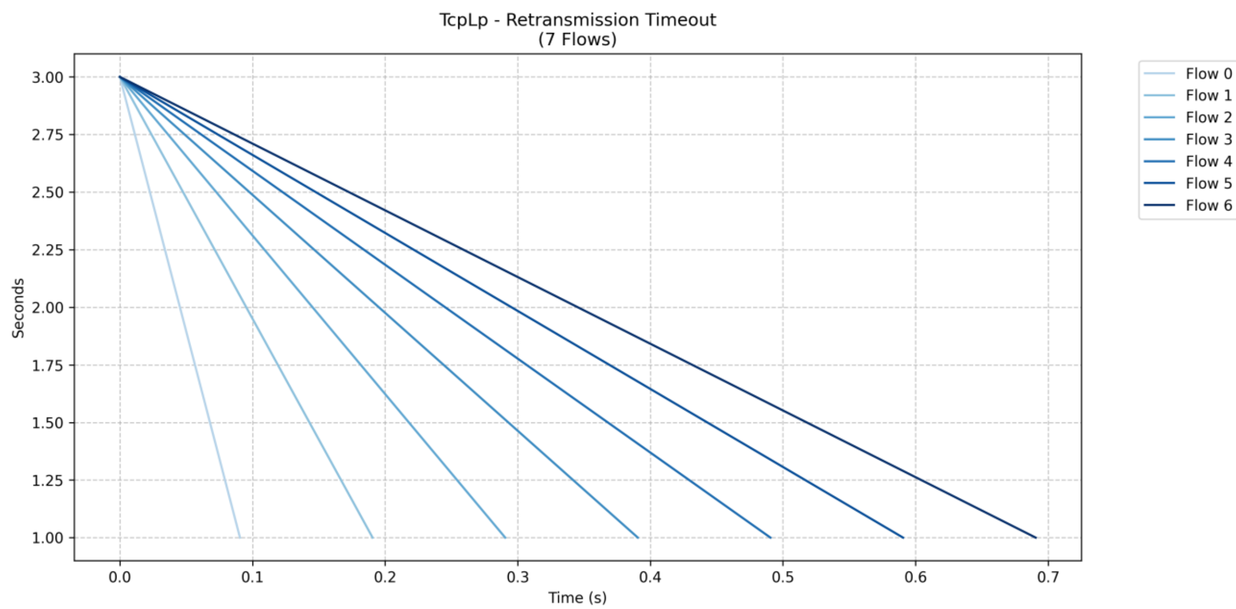
Same as cwnd .But if ACKs are delayed, Bytes in Flight may appear higher for a short time.



Packet loss or congestion can be seen comparing slopes of next-rx and next-tx sequence .

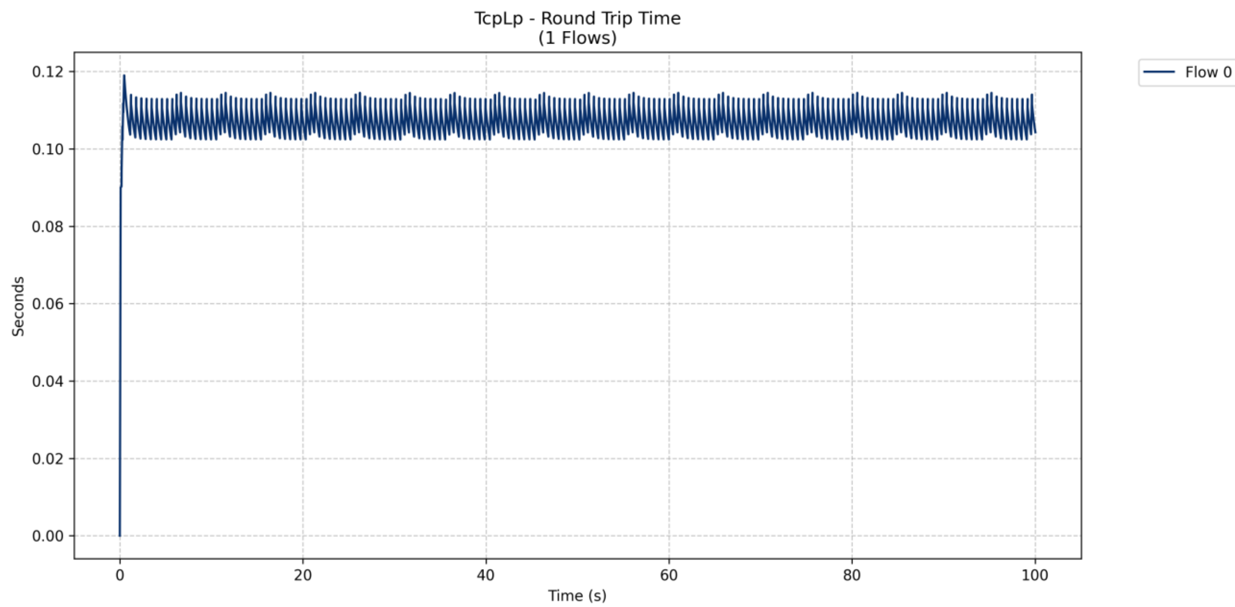


It consistently sends packets without overloading the network.

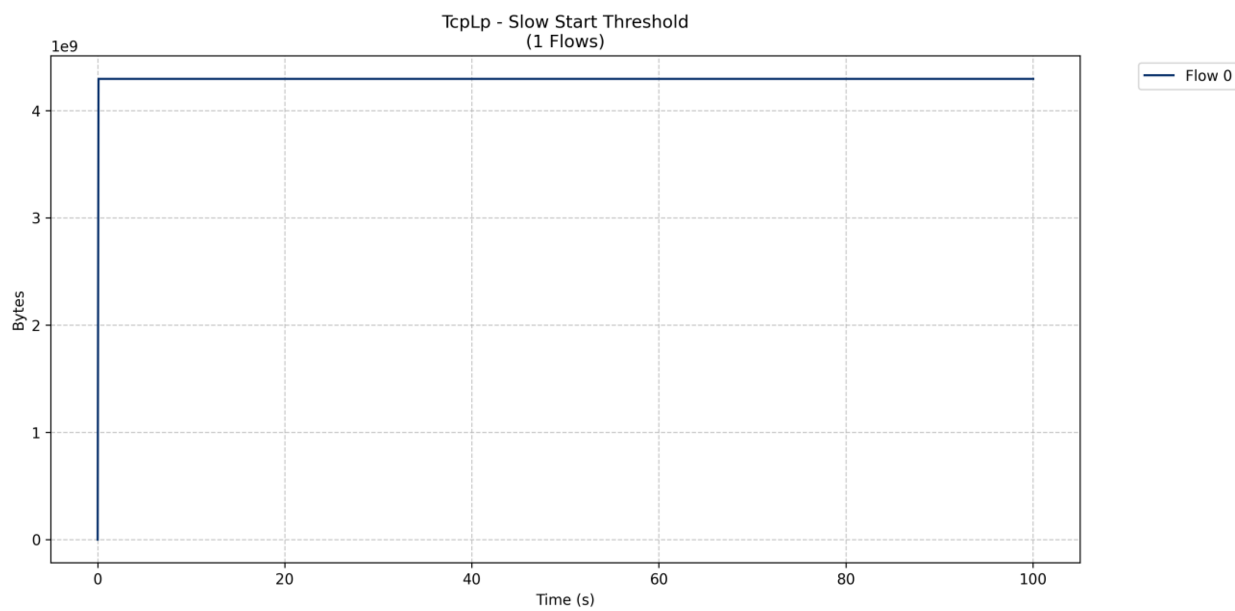


Different for each flow because

- **RTT Differences**: Flows with shorter RTTs observe a faster reduction in RTO.
- **Network Congestion**: Higher RTT variance can slow down the RTO adjustment process.

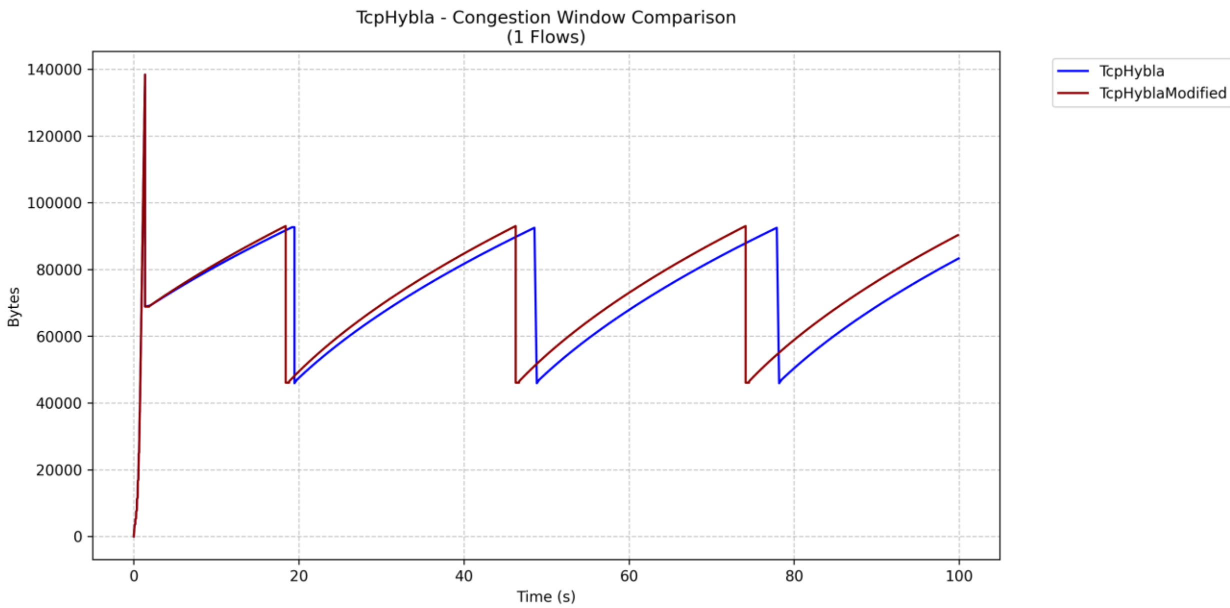


- TCP-LP periodically increases its sending rate to **probe for available bandwidth**.
- When slight delays occur (due to queuing or congestion), TCP-LP backs off, reducing the sending rate.
- This behavior aligns with TCP-LP's **delay-based congestion control** mechanism, where RTT variations help detect network congestion.



Ssth updates only for high priority packets . So TCP-LP never encounters a condition requiring the **ssthresh** to be updated.

TCP-HYBLA and MODIFIED TCP-HYBLA:



the modified version increases the congestion window more aggressively by allowing increment to be a function of cwnd . multiplier=1+1/sqrt(cwnd) . Increment=multiplier*increment.

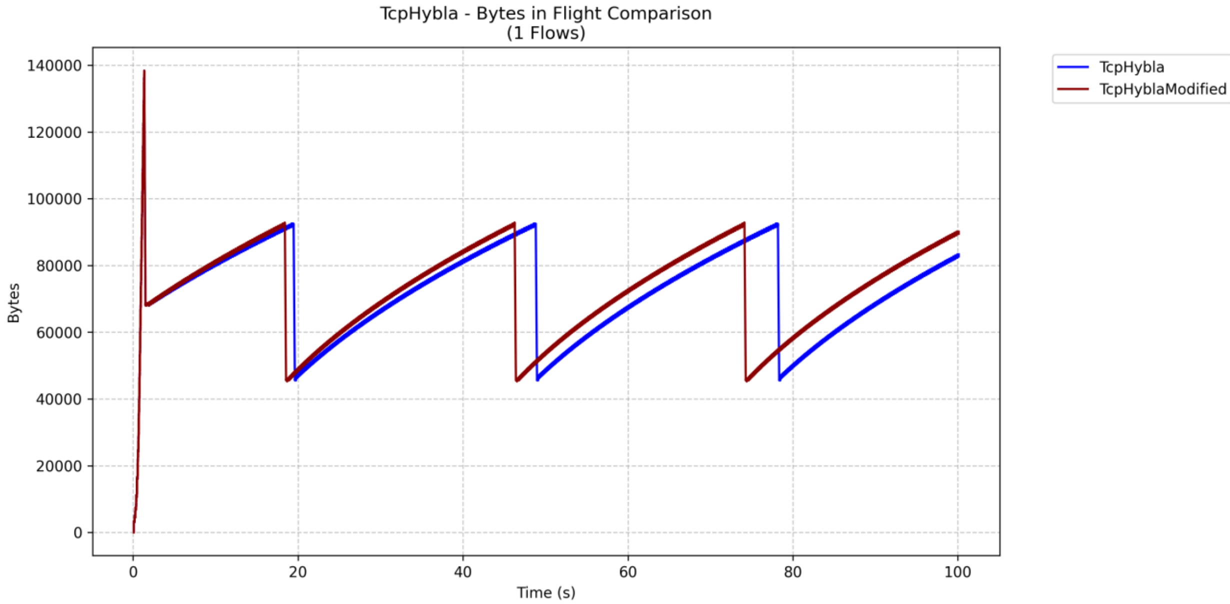
Slope increases

Higher cwnd values indicate that the modified version of TCP Hybla is able to send more data (higher throughput) during the same time.

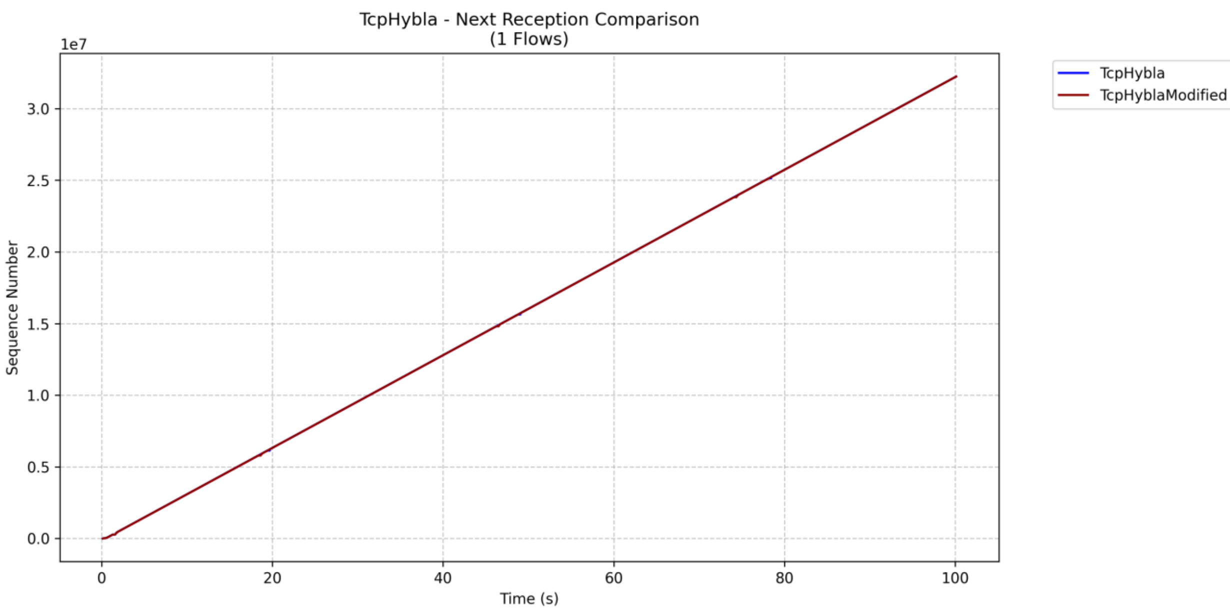
However, this comes at a potential **cost**:

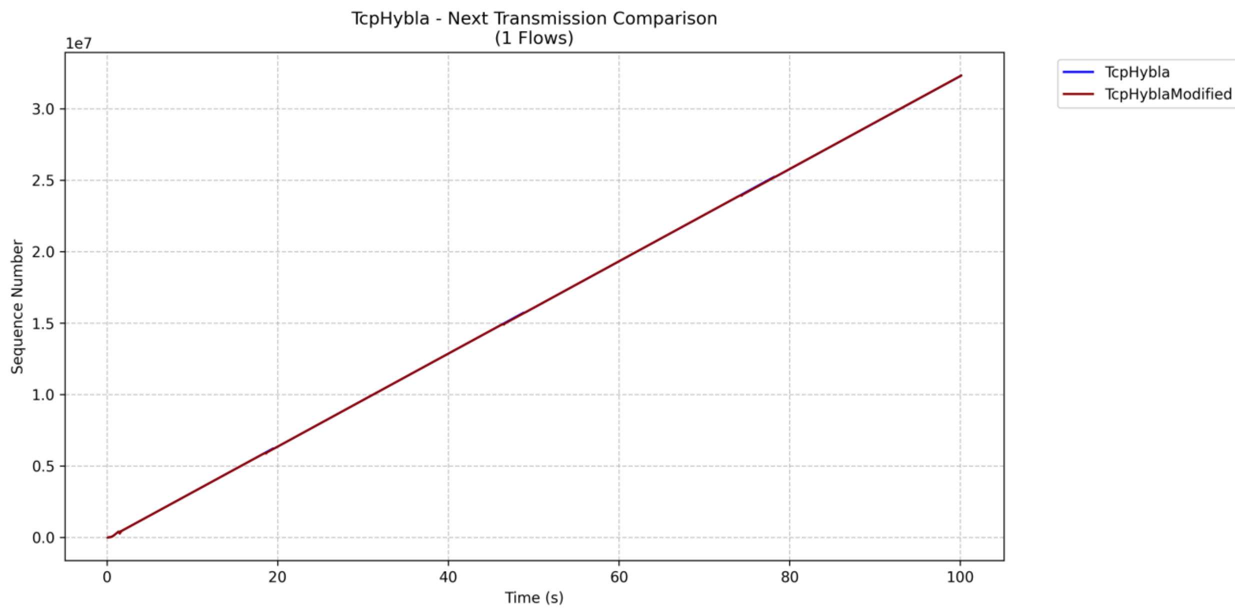
Faster cwnd growth can result in **higher network utilization**, which may lead to increased congestion in shared networks.

Cubic growth is used in recovery.

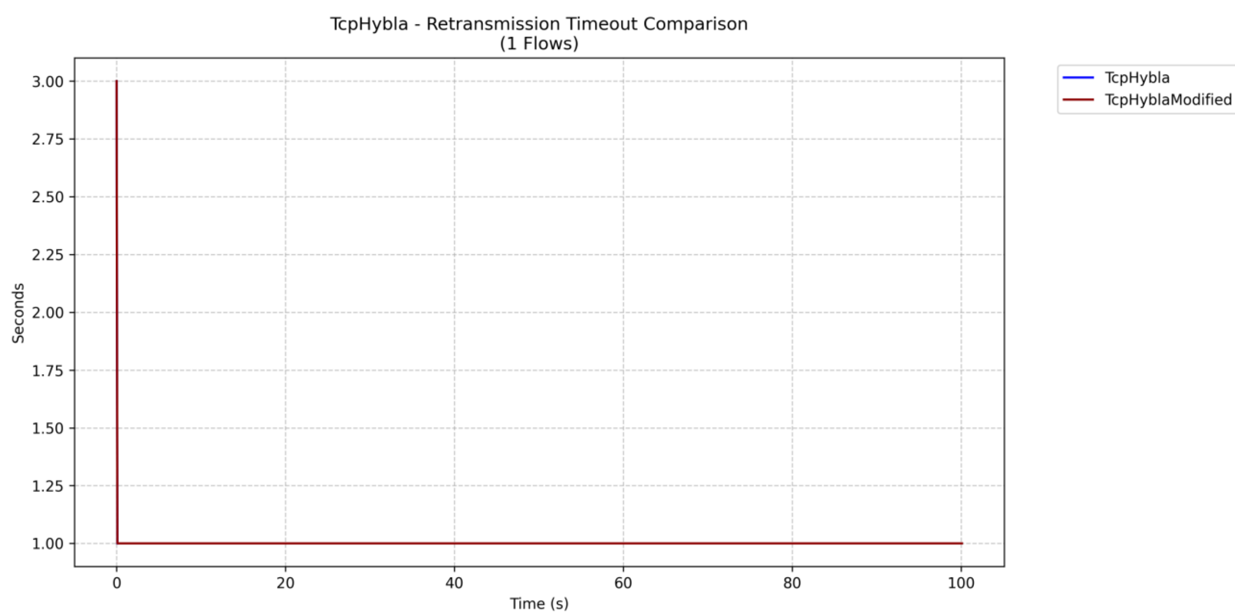


The modified version increases cwnd faster than the original, leading to higher Bytes in Flight.





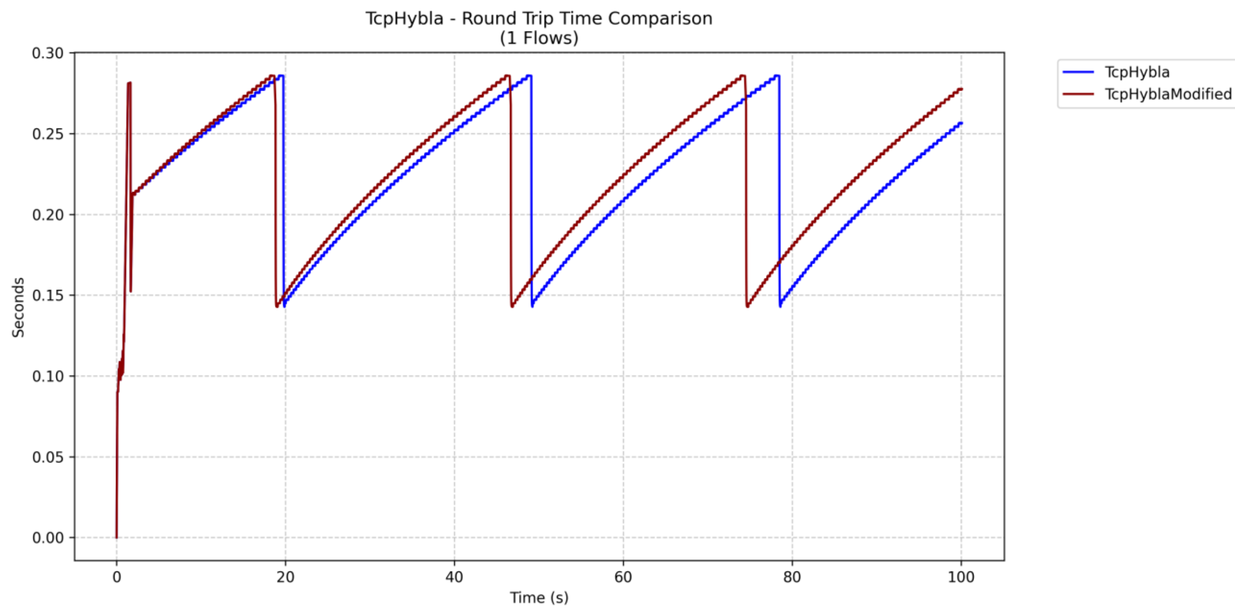
Received and transmitted sequence number remains same.



Rto calculations remained same.

Because although rtt changed . Smoothed rtt + 4 * rtt_variance resulted same .

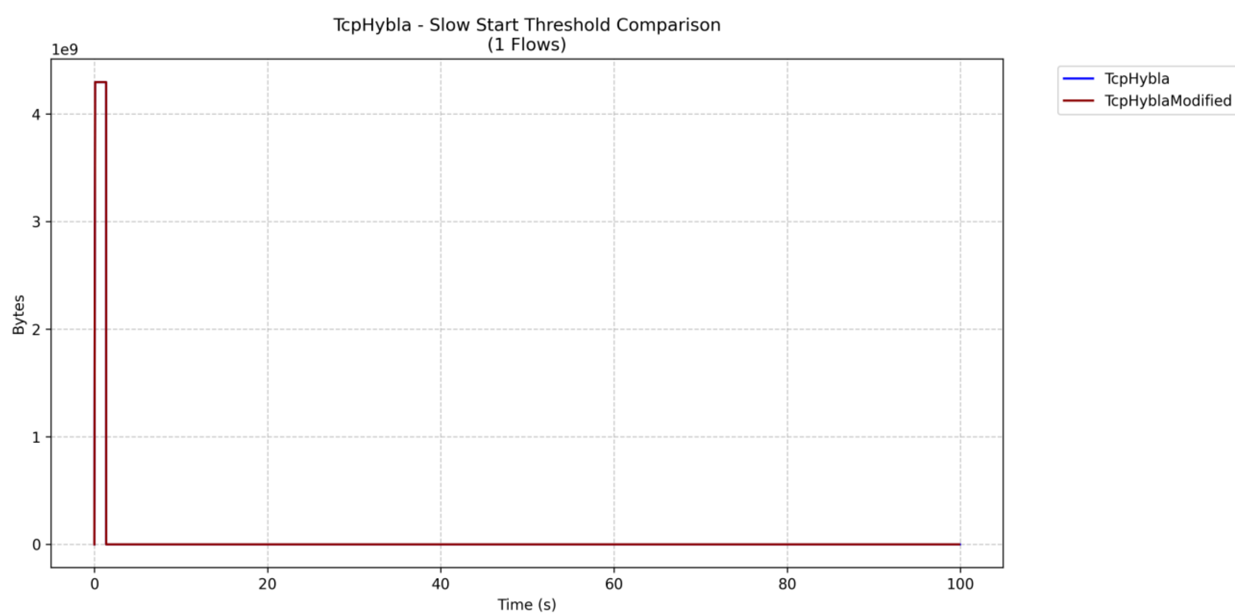
When RTT variation (jitter) is low, the RTO calculation yields a consistent and low value(minimum rto is 1).



-

The modified version of TCP Hybla has a **more aggressive cwnd growth**. This leads to:

- More packets being injected into the network.
- Higher queue occupancy in routers, causing slight delays.
- As a result, the RTT increases more rapidly than in the original version.



Overall Comparison Summary

Metric	Original TCP Hybla	Modified TCP Hybla
Congestion Window	Conservative growth, lower peak.	Faster growth, higher peak CWND.
Bytes in Flight	Lower pipeline utilization.	Higher pipeline utilization.
RTT	Lower RTT, less aggressive.	Slightly higher RTT, aggressive.