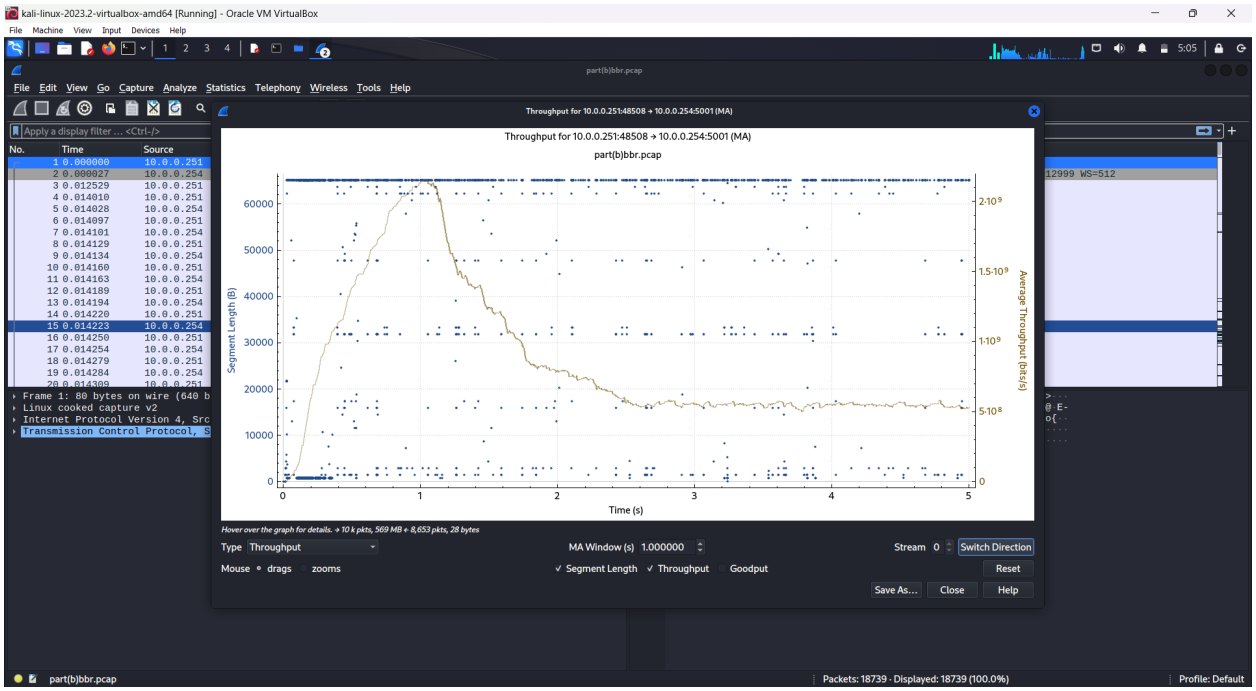
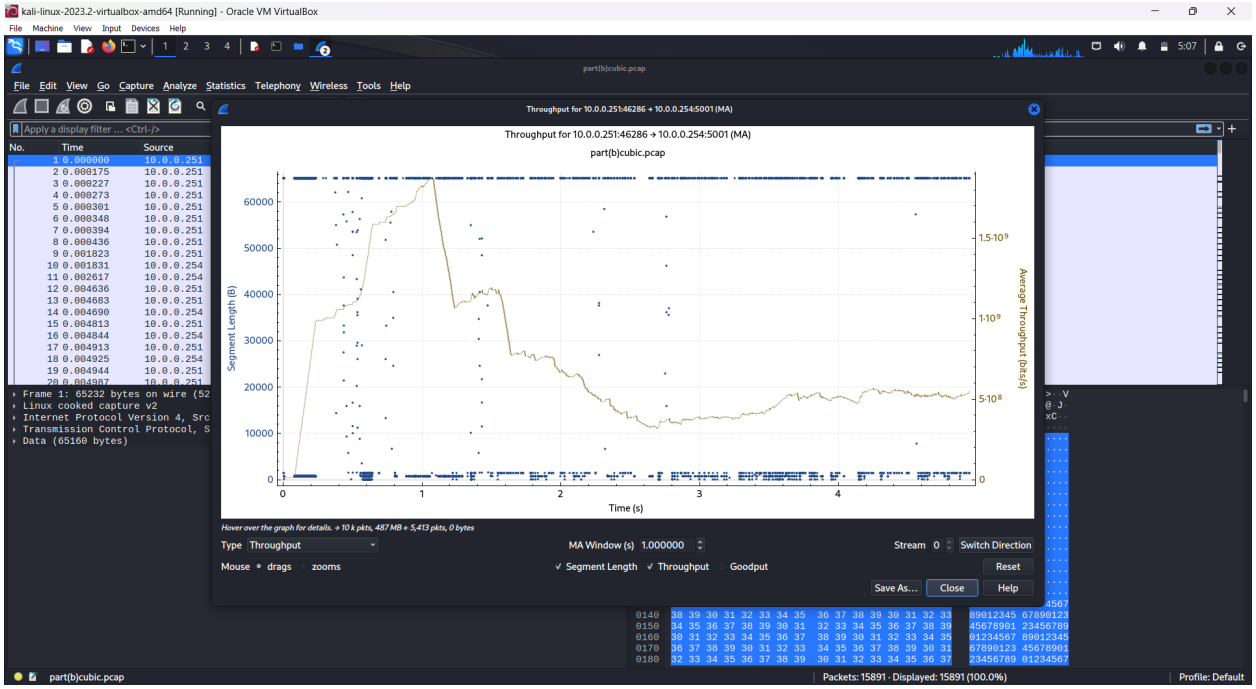
A) Implemented the topology and the required configuration. Added config, congestion, and linkloss input fields.

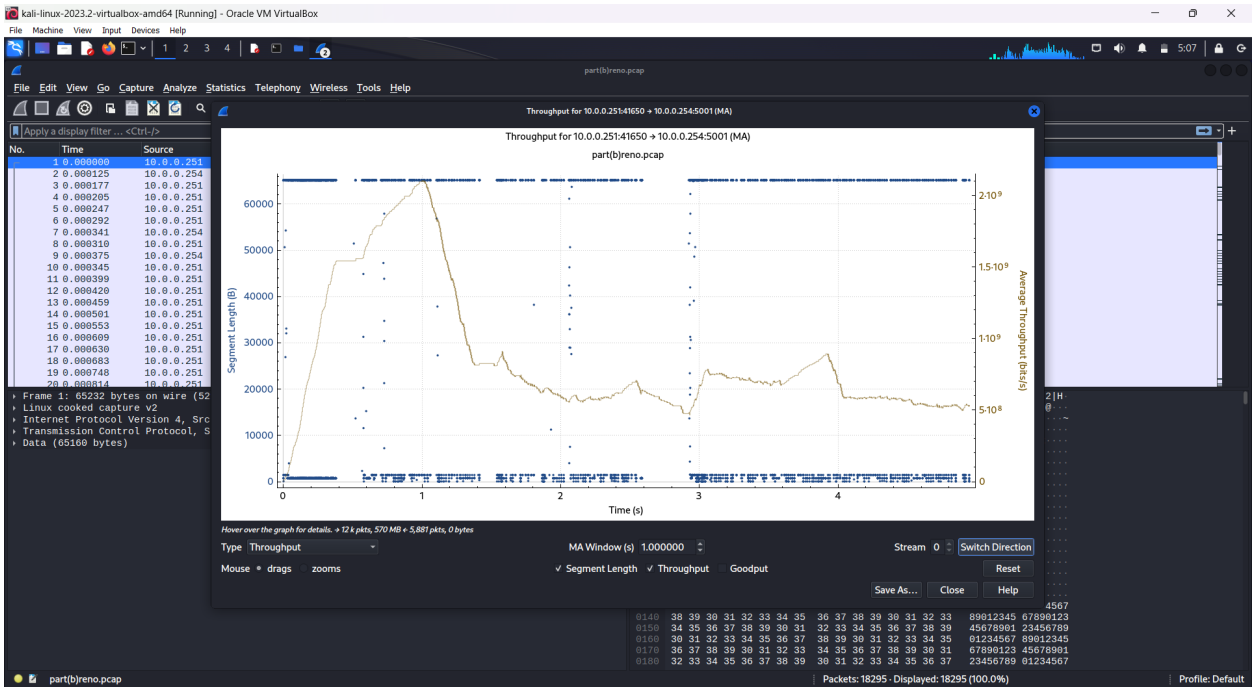
B)

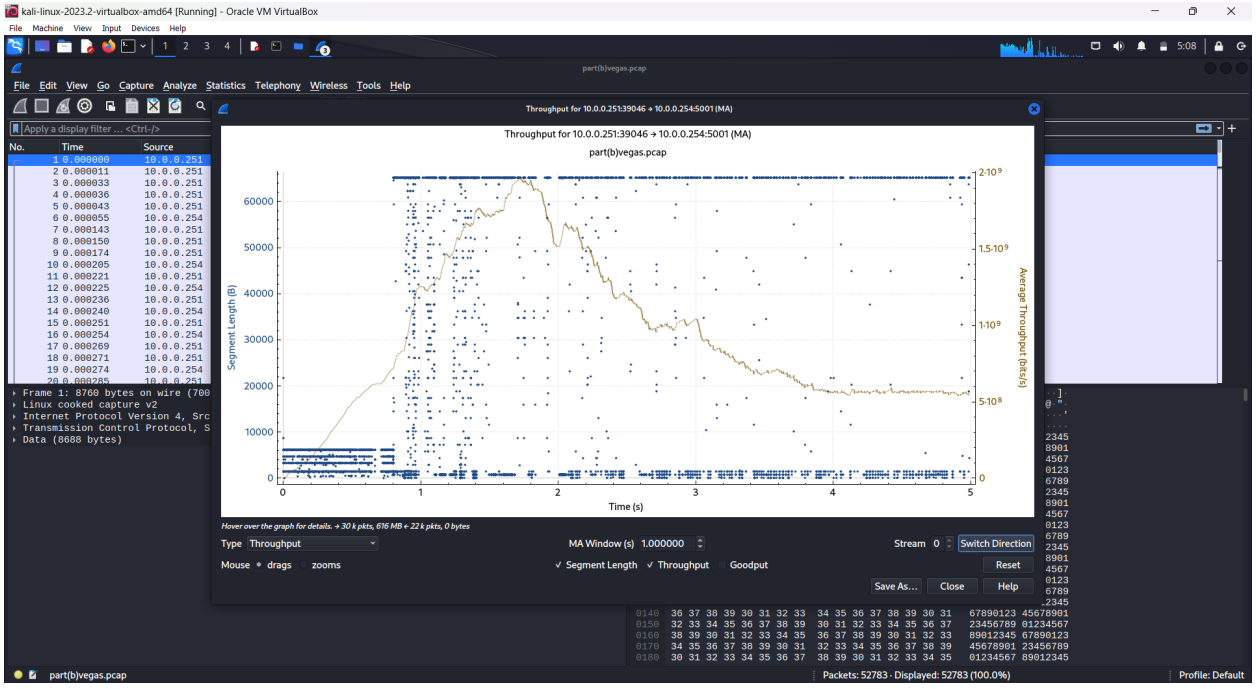
This is the throughput observed under the BBR scheme. BBR has an aggressive startup phase, where it quickly increases its sending rate to probe for the available bandwidth. This allows it to discover the network's capacity and start sending data at a rate that is close to the actual bottleneck bandwidth.





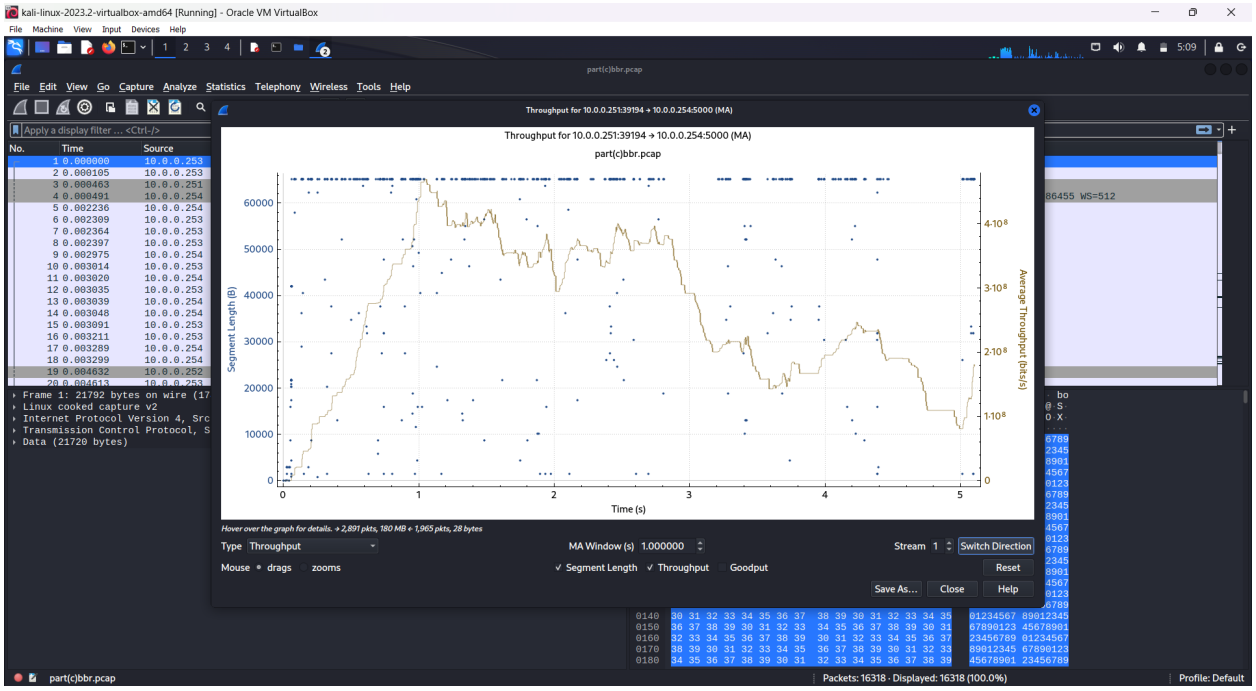
Under TCP Cubic, a very aggressive but smooth window increase should be observed. The curve we obtained doesn't actually portray that. The reasons could be system incompetency or some abnormal packet loss.
Under TCP Reno, a linear start is observed which then suddenly falls to about half. This is because of bandwidth congestion at that point.
Under TCP Vegas, gradual changes in throughput are observed rather than abrupt changes. This is a key identifier for TCP Vegas.

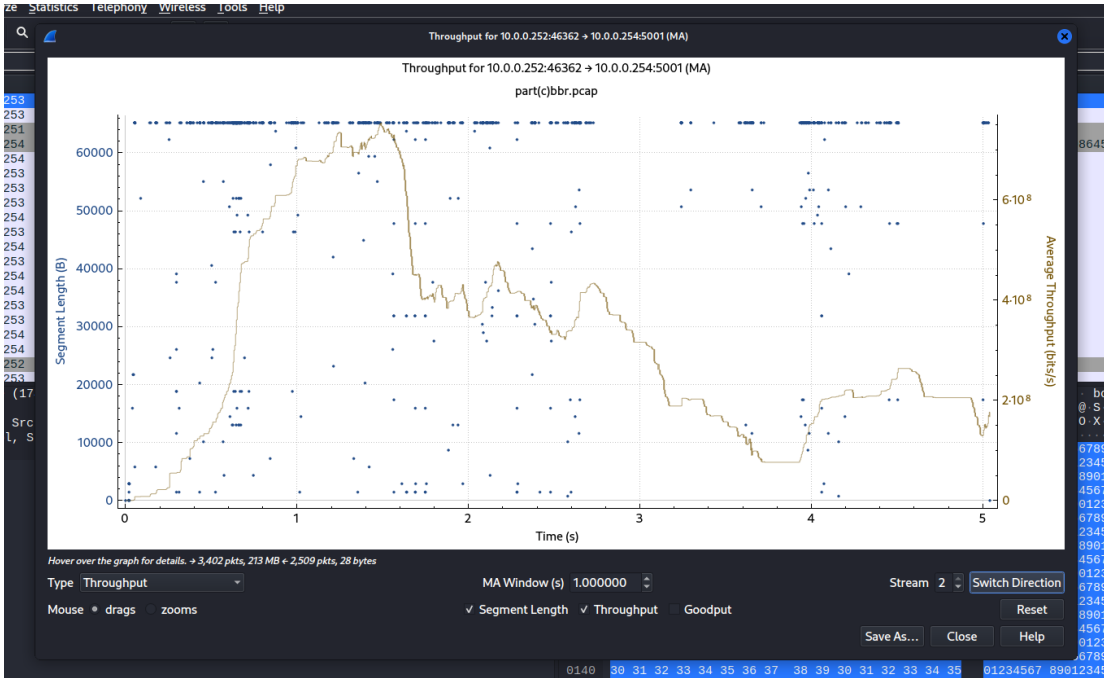


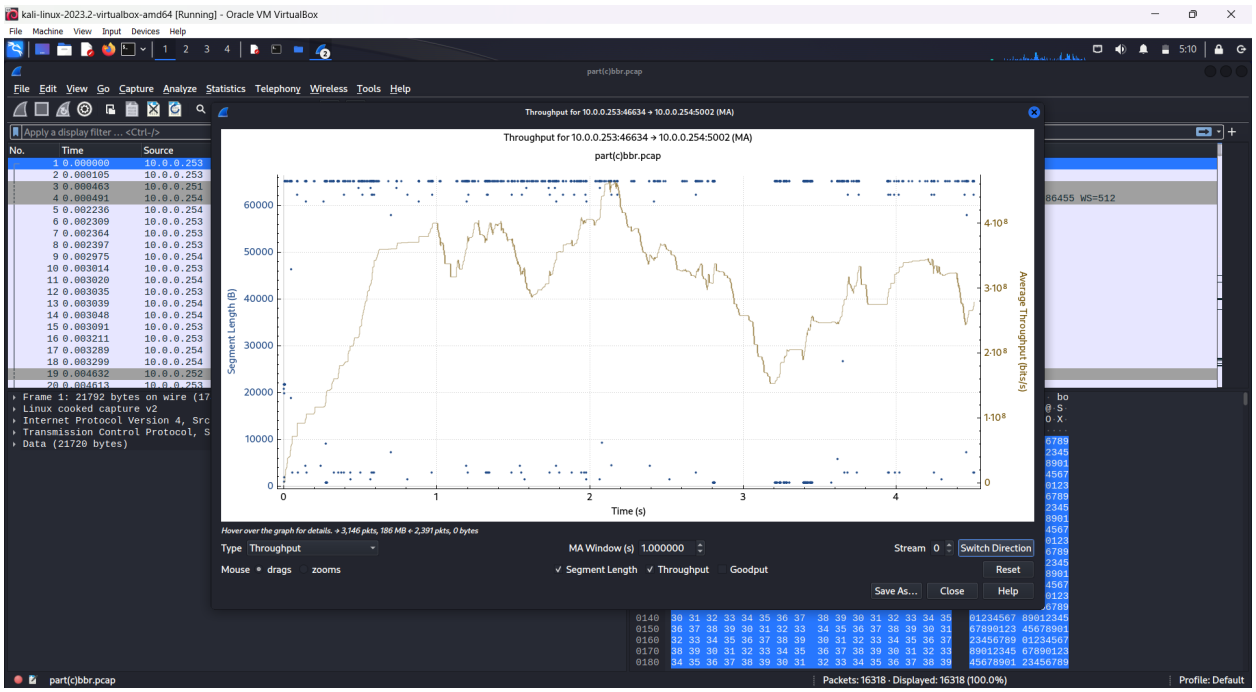


C)

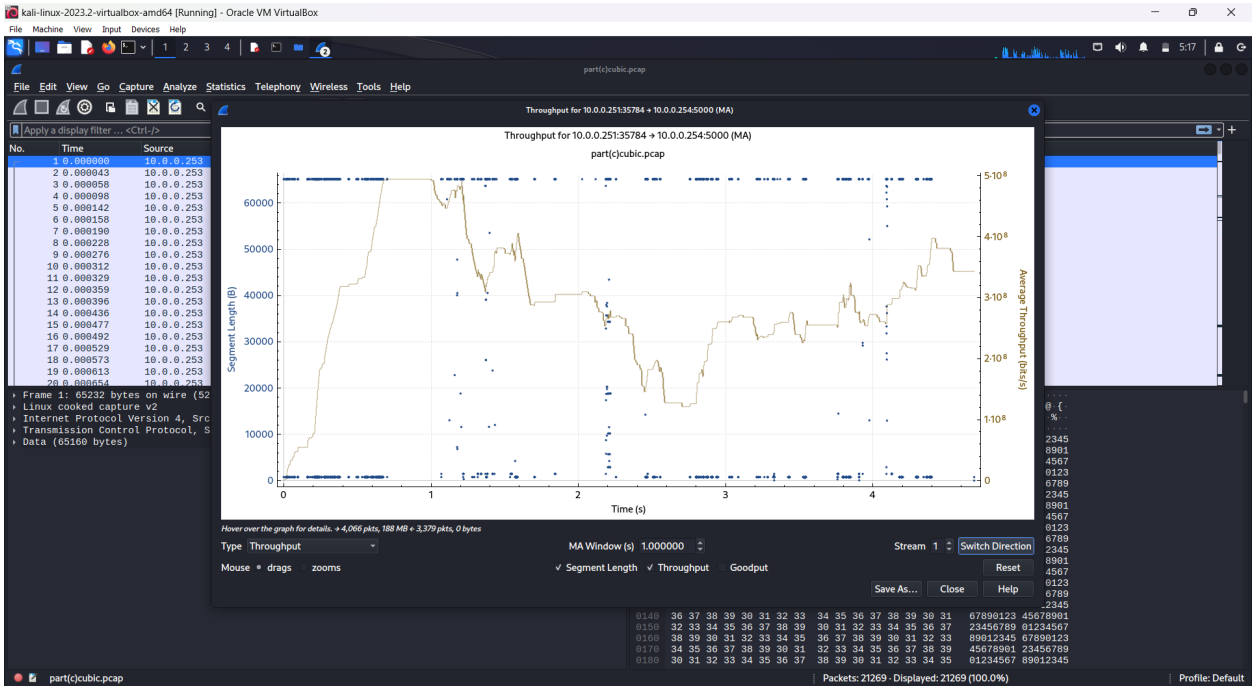
The three graphs below are for each host h1, h2, and h3 under the TCP BBR scheme. Again aggressive start phase is observed which then gradually settles down for the bottleneck value.

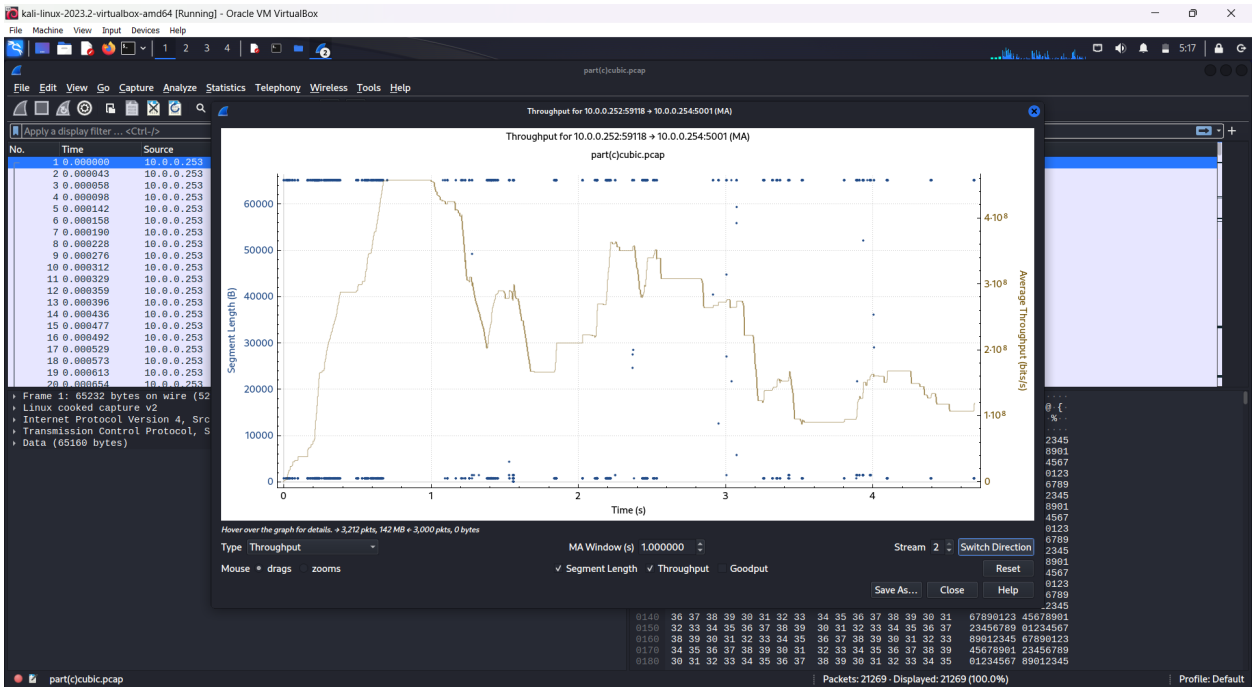


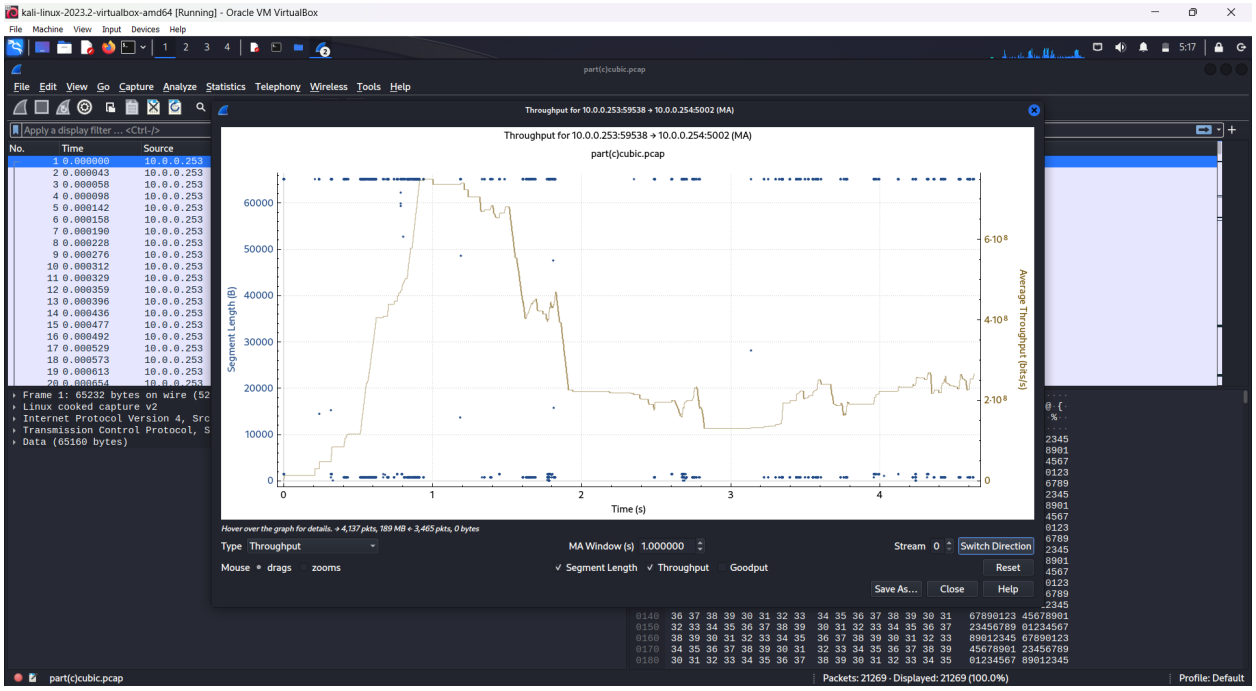




In the below-mentioned three graphs for each host h1, h2 and h3, under TCP Cubic the throughput is unexpectedly bizarre. We have observed this whenever the cubic scheme is requested.

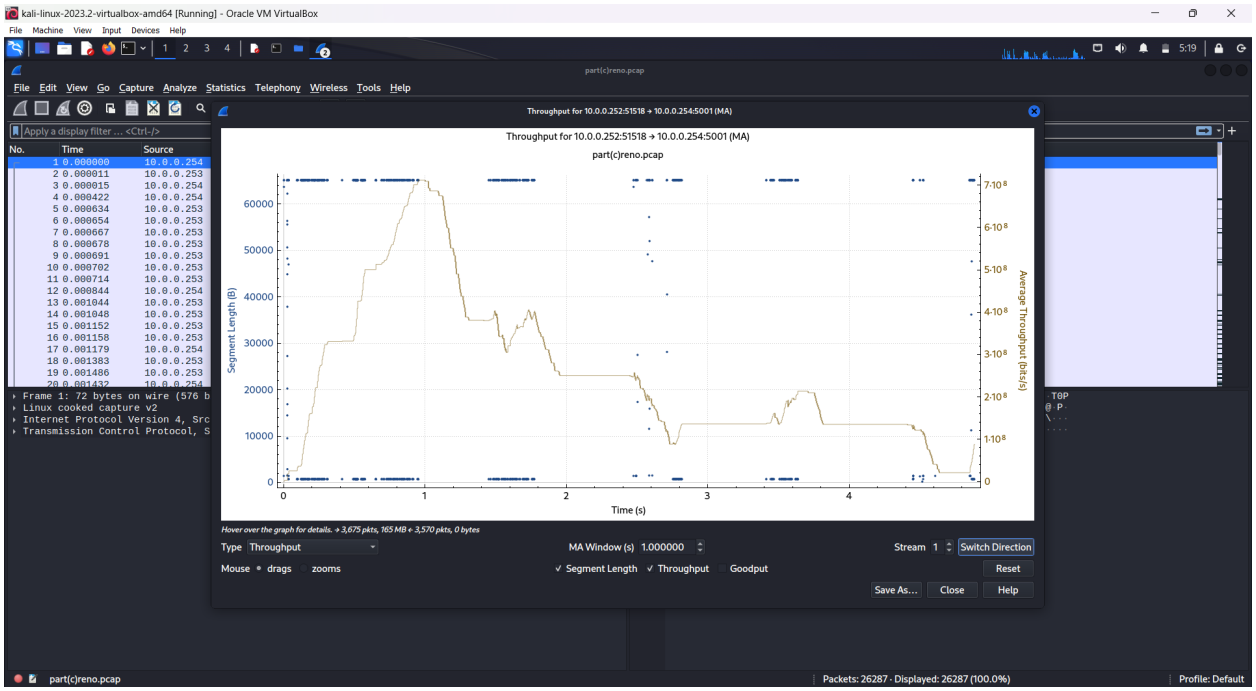

kali-linux-2023.2-virtualbox-amd64 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Throughput for 10.0.0.251:35784 → 10.0.0.254:5000 (MA)
Throughput for 10.0.0.251:35784 → 10.0.0.254:5000 (MA)
part(c)cubic.pcap
Segment Length (B)
Average Throughput (bits/s)
Time (s)
Hover over the graph for details. → 4,066 pkts, 188 MB ← 3,379 pkts, 0 bytes
Type Throughput
MA Window (s) 1.000000
Stream 1
Switch Direction
Mouse drags zooms
Segment Length
Throughput
Goodput
Reset
Save As...
Close
Help
part(c)cubic.pcap
Packets: 21269 · Displayed: 21269 (100.0%)
Profile: Default

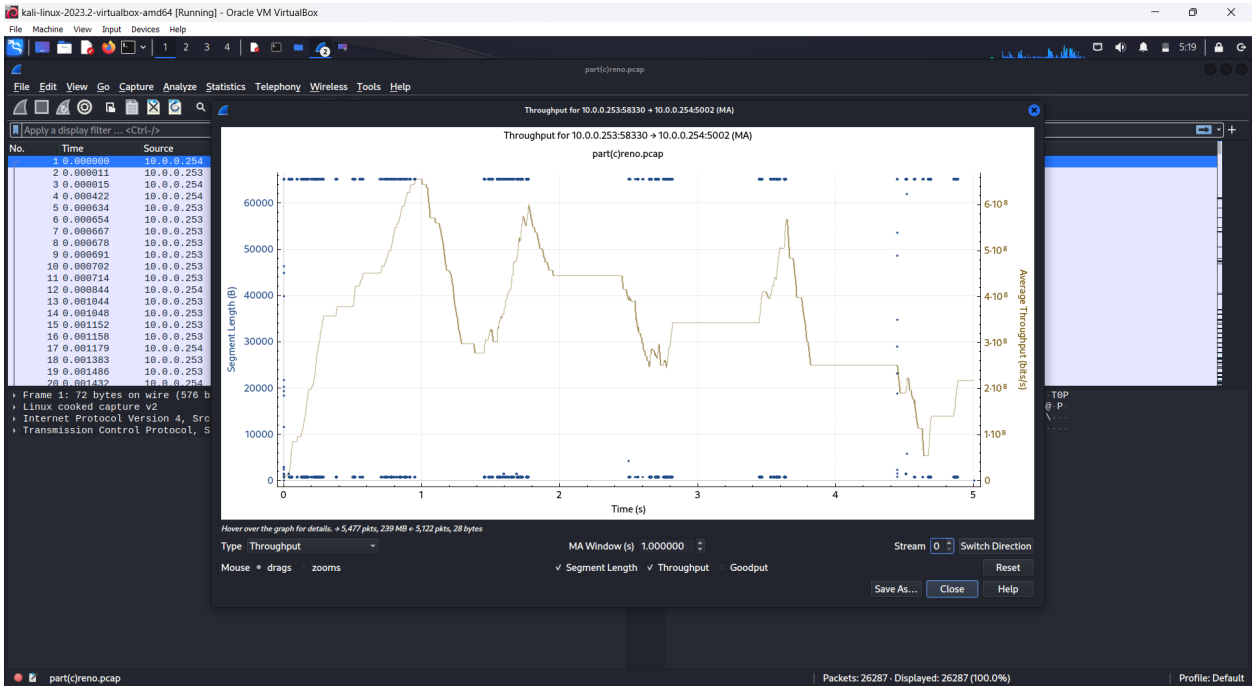

kali-linux-2023.2-virtualbox-amd64 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Throughput for 10.0.0.252:59118 → 10.0.0.254:5001 (MA)
Throughput for 10.0.0.252:59118 → 10.0.0.254:5001 (MA)
part(c)cubic.pcap
Segment Length (B)
Average Throughput (bits/s)
Time (s)
Hover over the graph for details. → 3,212 pkts, 142 MB ← 3,000 pkts, 0 bytes
Type Throughput
MA Window (s) 1.000000
Stream 2
Switch Direction
Mouse drags zooms
Segment Length
Throughput
Goodput
Reset
Save As...
Close
Help
part(c)cubic.pcap
Packets: 21269 · Displayed: 21269 (100.0%)
Profile: Default



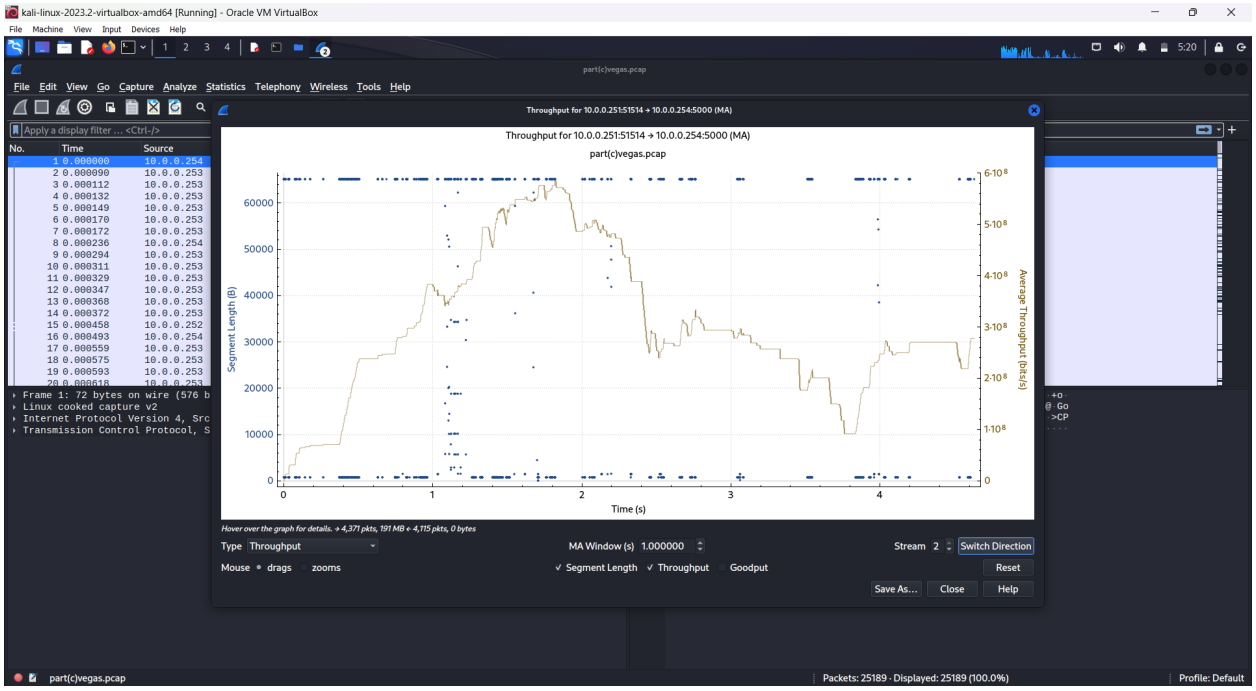
Now for TCP Reno, a slow start is the identifier here. An exponential increase is observed after the ACK is received.

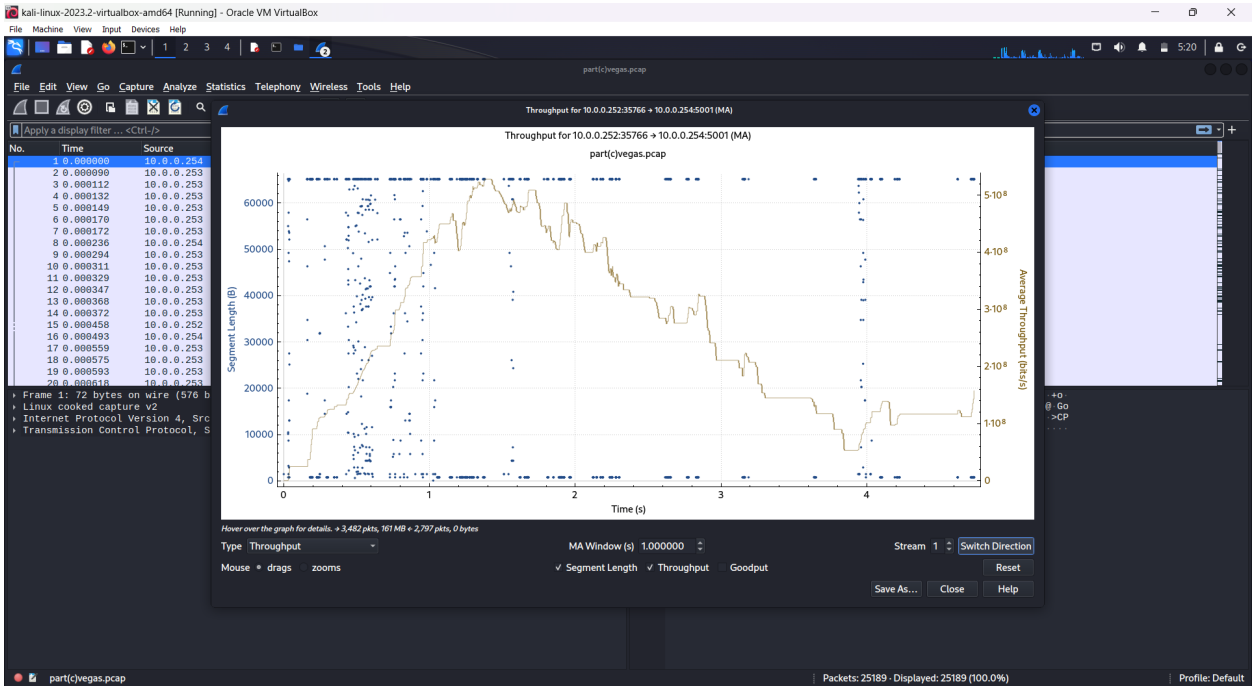

kali-linux-2023.2-virtualbox-amd64 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Throughput for 10.0.0.251:52884 → 10.0.0.254:5000 (MA)
part(c)reno.pcap
Segment Length (B)
Average Throughput (bits/s)
Time (s)
Hover over the graph for details. → 4,244 pkts, 184 MB ← 4,197 pkts, 28 bytes
Type Throughput
MA Window (s) 1.000000
Stream 2
Switch Direction
Mouse drags zooms
Segment Length
Throughput
Goodput
Reset
Save As...
Close
Help
part(c)reno.pcap
Packets: 26287 · Displayed: 26287 (100.0%)
Profile: Default

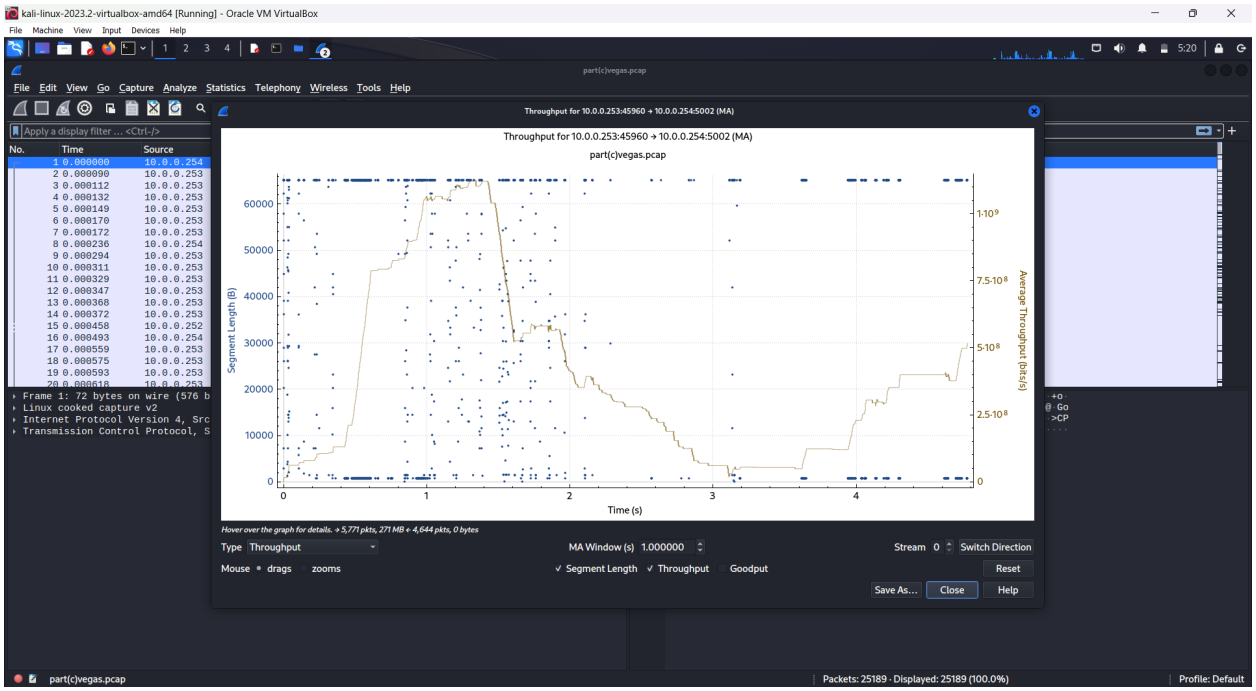

kali-linux-2023.2-virtualbox-amd64 [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Throughput for 10.0.0.252:51518 → 10.0.0.254:5001 (MA)
part(c)reno.pcap
Segment Length (B)
Average Throughput (bits/s)
Time (s)
Hover over the graph for details. → 3,675 pkts, 165 MB ← 3,570 pkts, 0 bytes
Type Throughput
MA Window (s) 1.000000
Stream 1
Switch Direction
Mouse drags zooms
Segment Length
Throughput
Goodput
Reset
Save As...
Close
Help
part(c)reno.pcap
Packets: 26287 · Displayed: 26287 (100.0%)
Profile: Default



For the below three graphs of throughput of hosts h1,h2 and h3 TCP Vegas.



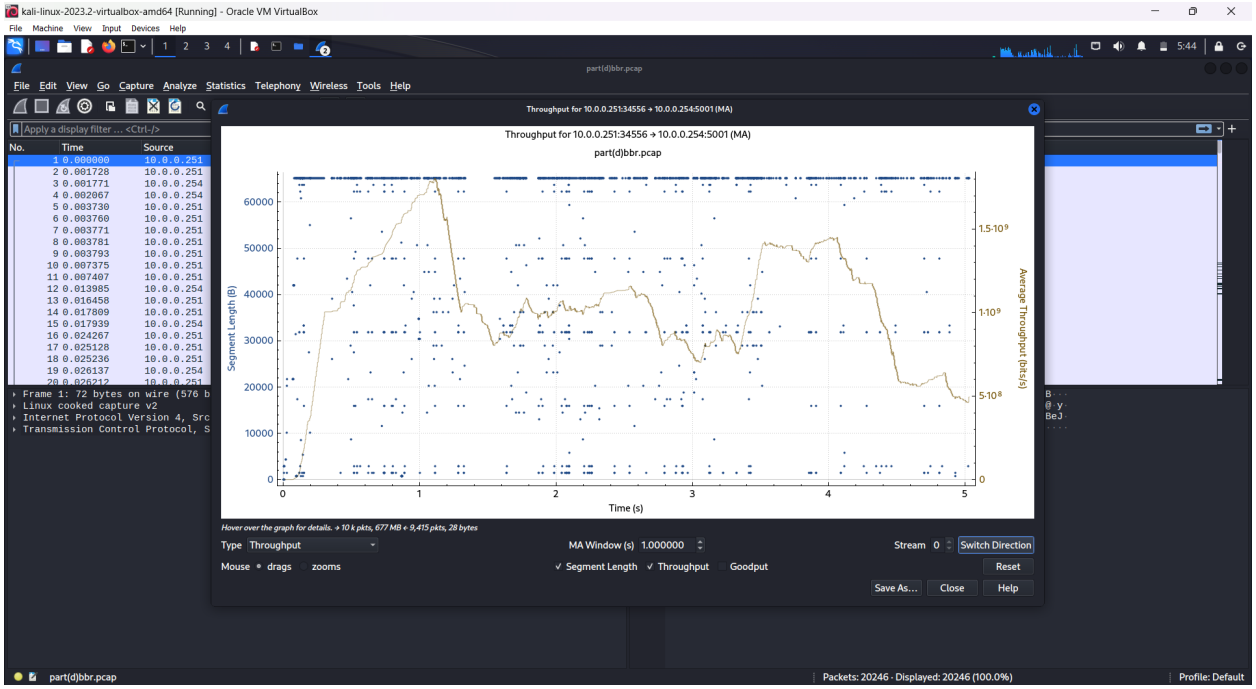




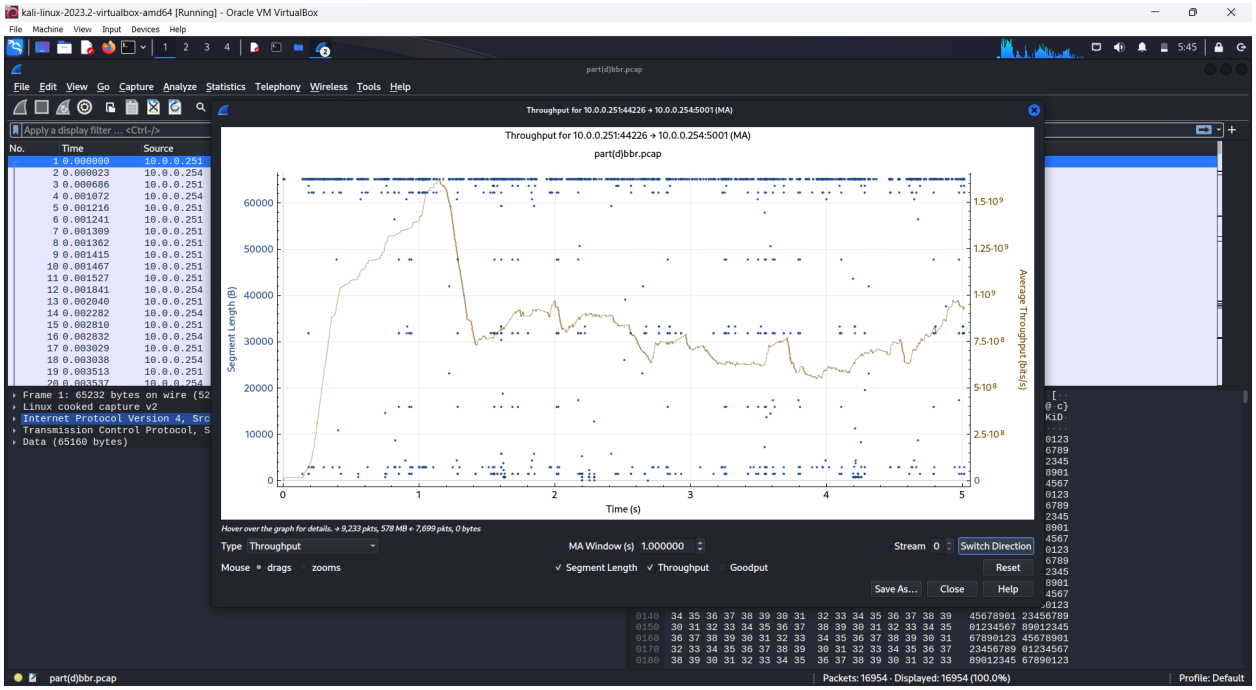
D)

When Linkloss is introduced, there is a guaranteed drop of some packages. The peak throughput would decrease when compared to no Linkloss. When comparing, the 1% loss case with the 3% loss case, the latter is more efficient as the instances of a huge peak are reduced and stable throughput is achieved faster. Hence consistency in throughput is improved.

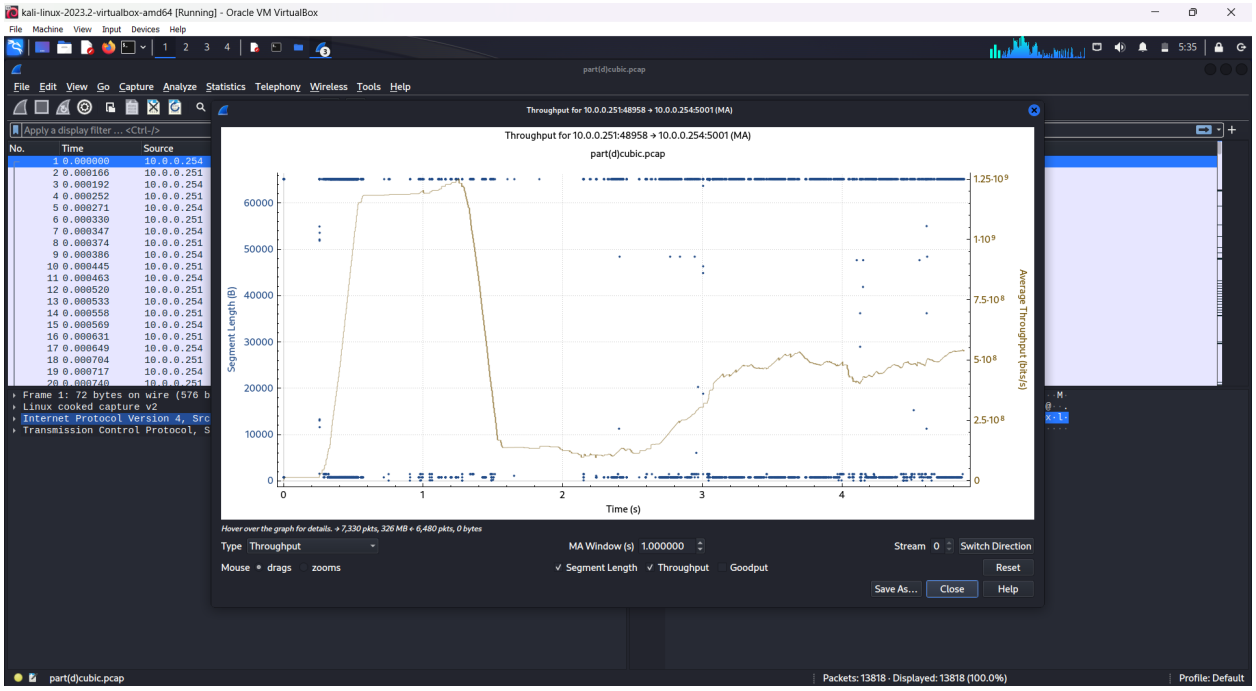
1%


kali-linux-2023.2-virtualbox-amd64 [Running] - Oracle VM VirtualBox
Throughput for 10.0.0.251:34556 → 10.0.0.254:5001 (MA)
Throughput for 10.0.0.251:34556 → 10.0.0.254:5001 (MA)
part(d)bbr.pcap
Segment Length (B)
Average Throughput (bits/s)
Time (s)
Type Throughput
MA Window (s) 1.000000
Stream 0
Switch Direction
Mouse drags zooms
Segment Length Throughput Goodput
Reset
Save As... Close Help
part(d)bbr.pcap
Packets: 20246 · Displayed: 20246 (100.0%)
Profile: Default

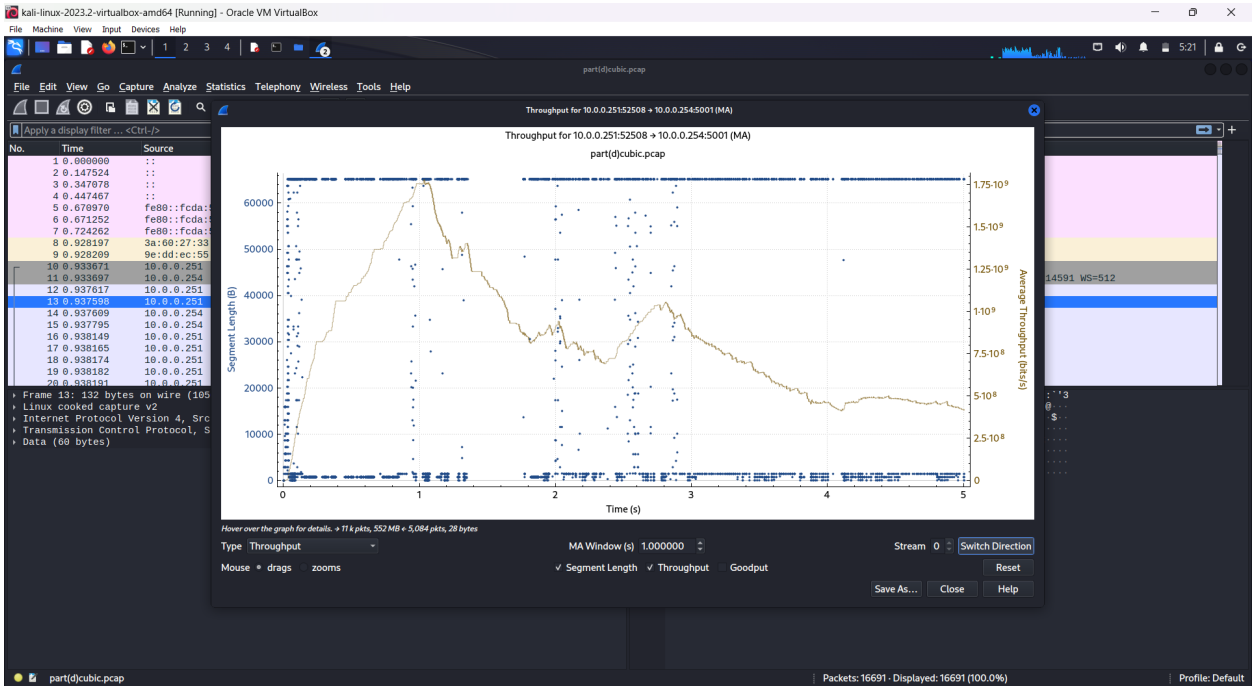
3%


kali-linux-2023.2-virtualbox-amd64 [Running] - Oracle VM VirtualBox
Throughput for 10.0.0.251:44226 → 10.0.0.254:5001 (MA)
Throughput for 10.0.0.251:44226 → 10.0.0.254:5001 (MA)
part(d)bbr.pcap
Segment Length (B)
Average Throughput (bits/s)
Time (s)
Type Throughput
MA Window (s) 1.000000
Stream 0
Switch Direction
Mouse drags zooms
Segment Length Throughput Goodput
Reset
Save As... Close Help
part(d)bbr.pcap
Packets: 16954 · Displayed: 16954 (100.0%)
Profile: Default

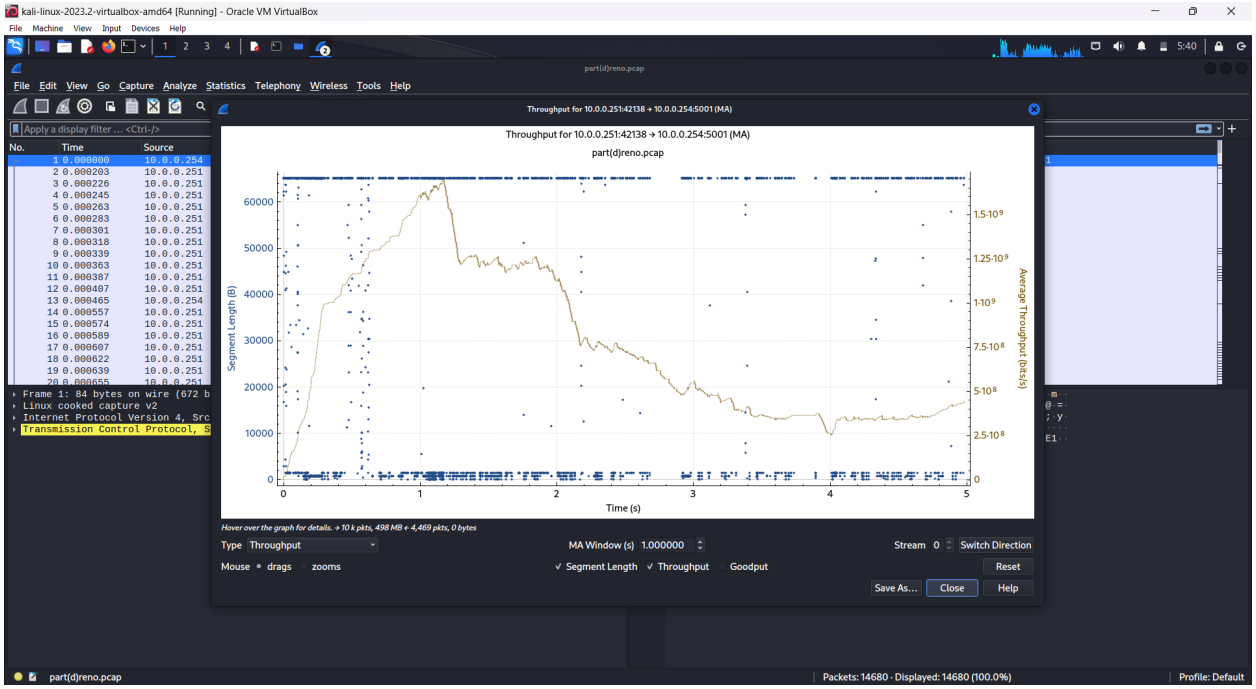
1%


kali-linux-2023.2-virtualbox-amd64 [Running] - Oracle VM VirtualBox
Throughput for 10.0.0.251:48958 → 10.0.0.254:5001 (MA)
part(d)cubic.pcap
Segment Length (B)
Average Throughput (bits/s)
Time (s)
Hover over the graph for details. → 7,330 pkts, 326 MB ← 6,480 pkts, 0 bytes
Type Throughput
MA Window (s) 1.000000
Stream 0
Switch Direction
Mouse drags zooms
Segment Length
Throughput
Goodput
Reset
Save As...
Close
Help
Packets: 13818 · Displayed: 13818 (100.0%)
Profile: Default

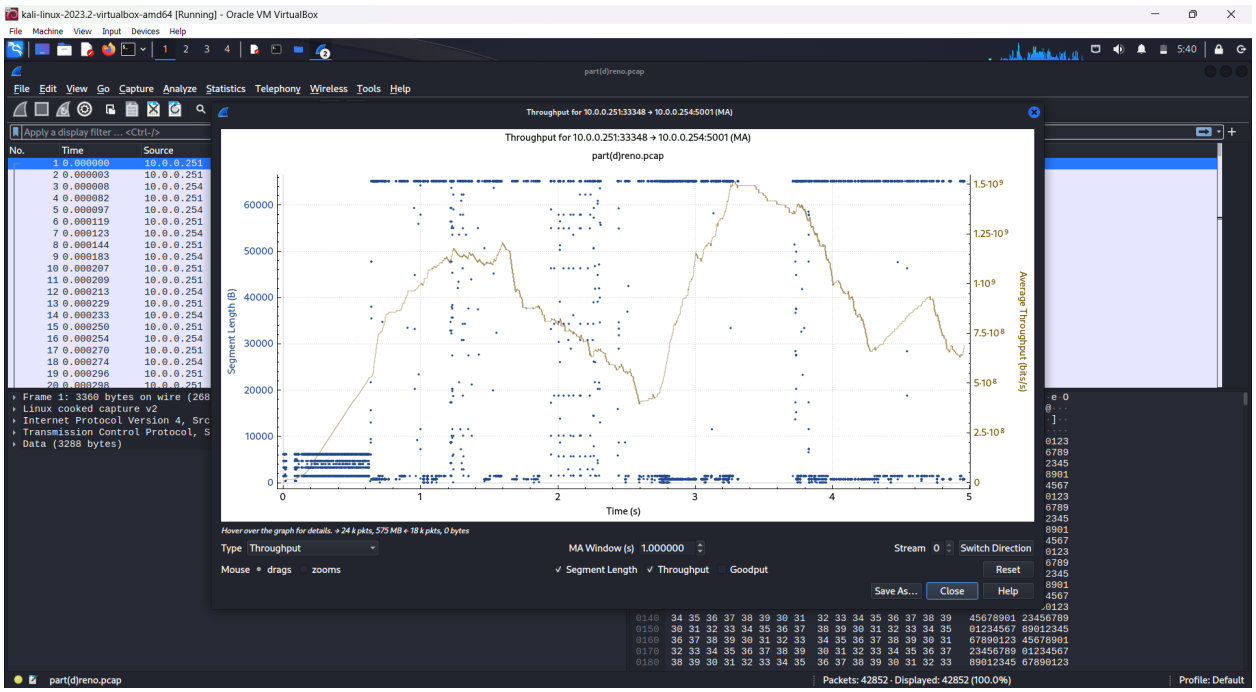
3%


kali-linux-2023.2-virtualbox-amd64 [Running] - Oracle VM VirtualBox
Throughput for 10.0.0.251:52508 → 10.0.0.254:5001 (MA)
part(d)cubic.pcap
Segment Length (B)
Average Throughput (bits/s)
Time (s)
Hover over the graph for details. → 11 k pkts, 552 MB ← 5,084 pkts, 28 bytes
Type Throughput
MA Window (s) 1.000000
Stream 0
Switch Direction
Mouse drags zooms
Segment Length
Throughput
Goodput
Reset
Save As...
Close
Help
Packets: 16691 · Displayed: 16691 (100.0%)
Profile: Default

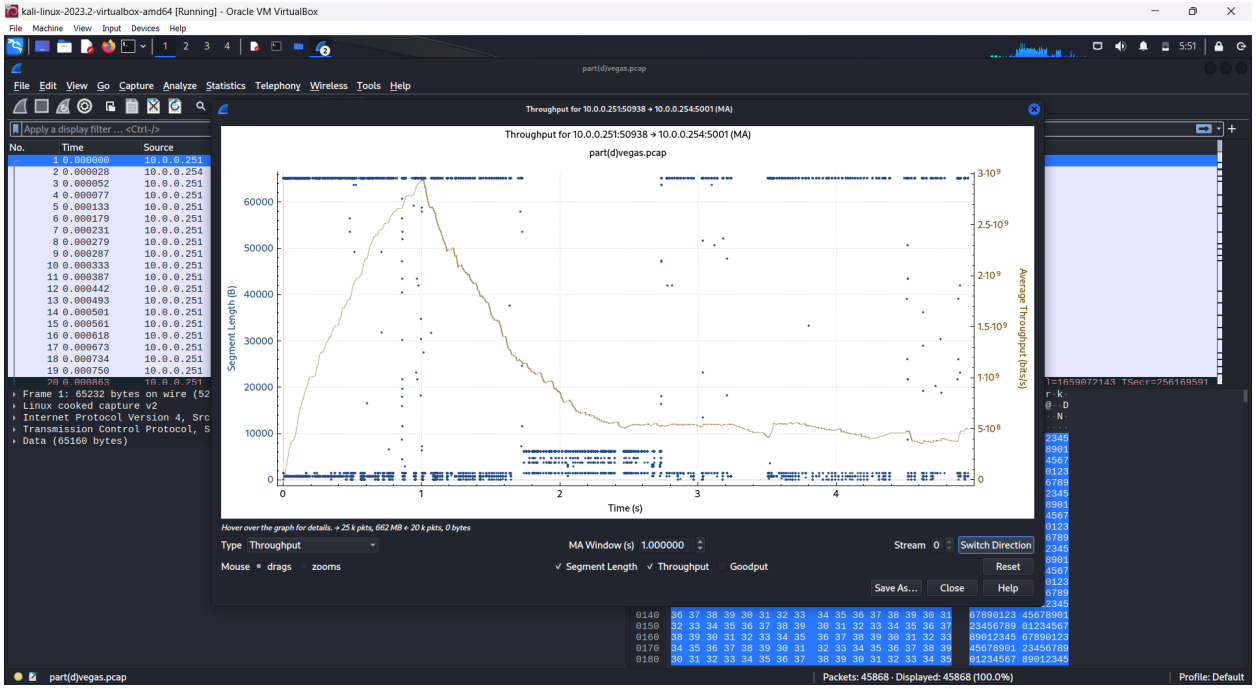
1%


kali-linux-2023.2-virtualbox-amd64 [Running] - Oracle VM VirtualBox
Throughput for 10.0.0.251:42138 → 10.0.0.254:5001 (MA)
Throughput for 10.0.0.251:42138 → 10.0.0.254:5001 (MA)
part(d)reno.pcap
Segment Length (B)
Average Throughput (bits/s)
Time (s)
Hover over the graph for details. → 10 k pkts, 498 MB ← 4,469 pkts, 0 bytes
Type Throughput
MA Window (s) 1.000000
Stream 0
Switch Direction
Mouse drags zooms
Segment Length
Throughput
Goodput
Reset
Save As...
Close
Help
part(d)reno.pcap
Packets: 14680 · Displayed: 14680 (100.0%)
Profile: Default

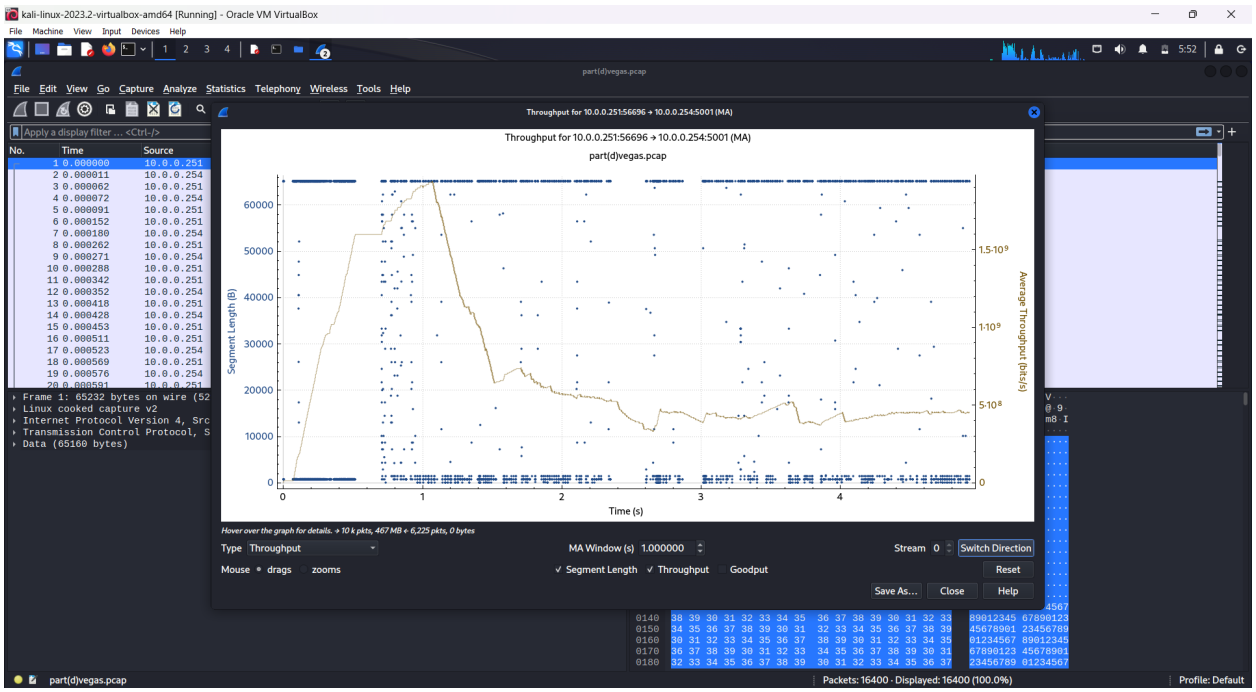
3%


kali-linux-2023.2-virtualbox-amd64 [Running] - Oracle VM VirtualBox
Throughput for 10.0.0.251:33348 → 10.0.0.254:5001 (MA)
Throughput for 10.0.0.251:33348 → 10.0.0.254:5001 (MA)
part(d)reno.pcap
Segment Length (B)
Average Throughput (bits/s)
Time (s)
Hover over the graph for details. → 24 k pkts, 575 MB ← 18 k pkts, 0 bytes
Type Throughput
MA Window (s) 1.000000
Stream 0
Switch Direction
Mouse drags zooms
Segment Length
Throughput
Goodput
Reset
Save As...
Close
Help
part(d)reno.pcap
Packets: 42852 · Displayed: 42852 (100.0%)
Profile: Default

1%



3%



REFERENCES :

1) *How to run custom topology in mininet?*, *Stack Overflow*. Available at: https://stackoverflow.com/questions/47764271/how-to-run-custom-topology-in-mininet (Accessed: 11 November 2023).