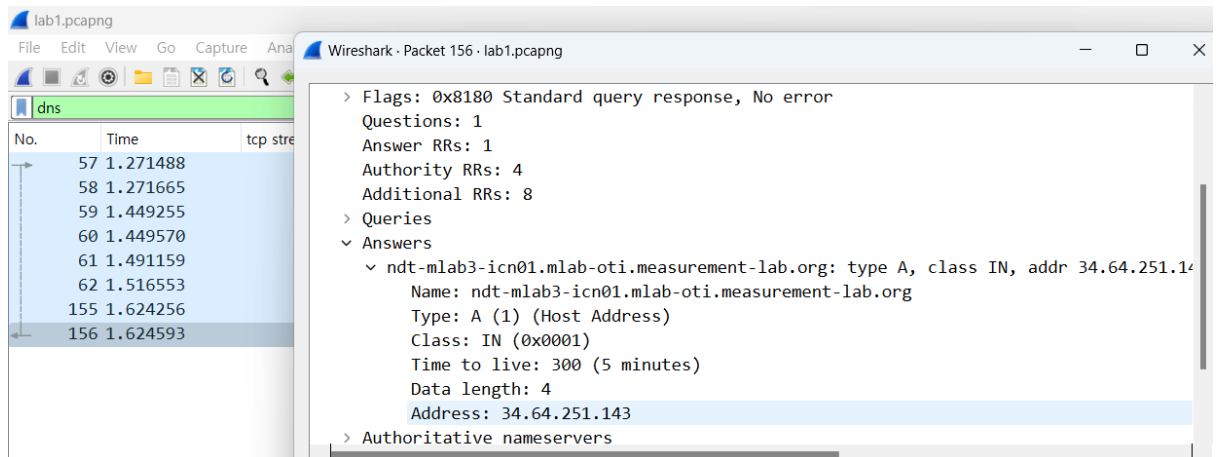


24-1 IoT실습 Lab1

22100579 이진주

1. Throughput 측정을 위해 사용되는 서버의 호스트명과 IP주소는 무엇인가요?



DNS와 주고받은 마지막 response의 answers를 확인한다.

호스트명: ndt-mlab3-icn01.mlab-oti.measurement-lab.org

IP 주소: 34.64.251.143

2. Throughput 측정을 위해 몇 개의 TCP Stream이 사용되나요? 또한 각 TCP Stream의 Source와 Destination은 무엇이고, 전송하는 데이터의 양은 얼마인가요?

tcp && ip.addr == 34.64.251.143				Name:		C:\Munjeonbakdea\Assignments\2024-1\lab1.pcapng	
No.	Time	tcp stream	Source	Length:	199 MB		
30027	12.406524	3	192.168.0.69	Hash (SHA256):	b23383ff7f43aade837eaea728b2e8a087dfd7cec6ceb3ffa0eb52895d10fe7		
30028	12.410047	3	34.64.251.143	Hash (SHA1):	8233072baaf03ebb9a76db72067d09769c49cb7a		
30029	12.410047	3	34.64.251.143	Format:	Wireshark/... - pcapng		
30030	12.410087	3	192.168.0.69	Encapsulation:	Ethernet		
30031	12.410113	3	192.168.0.69				
30032	12.410826	3	34.64.251.143				
30033	12.410826	3	34.64.251.143				
30034	12.410826	3	34.64.251.143				
30035	12.410864	3	192.168.0.69				
30036	12.410906	3	192.168.0.69				
30037	12.410932	3	192.168.0.69				
30038	12.411073	3	192.168.0.69				
30039	12.422857	3	34.64.251.143				
30040	12.422857	3	34.64.251.143				
30041	12.422897	3	192.168.0.69				
30042	12.423072	3	192.168.0.69				
30043	12.428563	15	192.168.0.69				
30044	12.432828	3	34.64.251.143				
30045	12.438381	15	34.64.251.143				
30046	12.438436	15	192.168.0.69				
30047	12.438981	15	192.168.0.69				
30048	12.438981	15	192.168.0.69				
30049	12.441048	15	34.64.251.143				
30050	12.441048	15	34.64.251.143				
30051	12.450124	15	34.64.251.143				
30052	12.450586	15	192.168.0.69				
30053	12.450819	15	192.168.0.69				

Time	
First packet:	2024-03-15 15:18:52
Last packet:	2024-03-15 15:19:17
Elapsed:	00:00:25

Capture	
Hardware:	Intel(R) Core(TM) i5-8250U CPU @ 1.60GHz (with SSE4.2)
OS:	64-bit Windows 11 (23H2), build 22631
Application:	Dumpcap (Wireshark) 4.2.3 (v4.2.3-0-ga15d7331476c)

Interfaces			
Interface	Dropped packets	Capture filter	Link type
Wi-Fi	0 (0.0%)	none	Ethernet

Statistics		
Measurement	Captured	Displayed
Packets	126831	126679 (99.9%)
Time span, s	25.197	21.432
Average pps	5033.6	5910.7
Average packet size, B	1539	1541
Bytes	195205026	195176705 (100.0%)
Average bytes/s	7747 k	9106 k
Average bits/s	61 M	72 M

3와 15, 2개의 stream이 사용되고 있다.

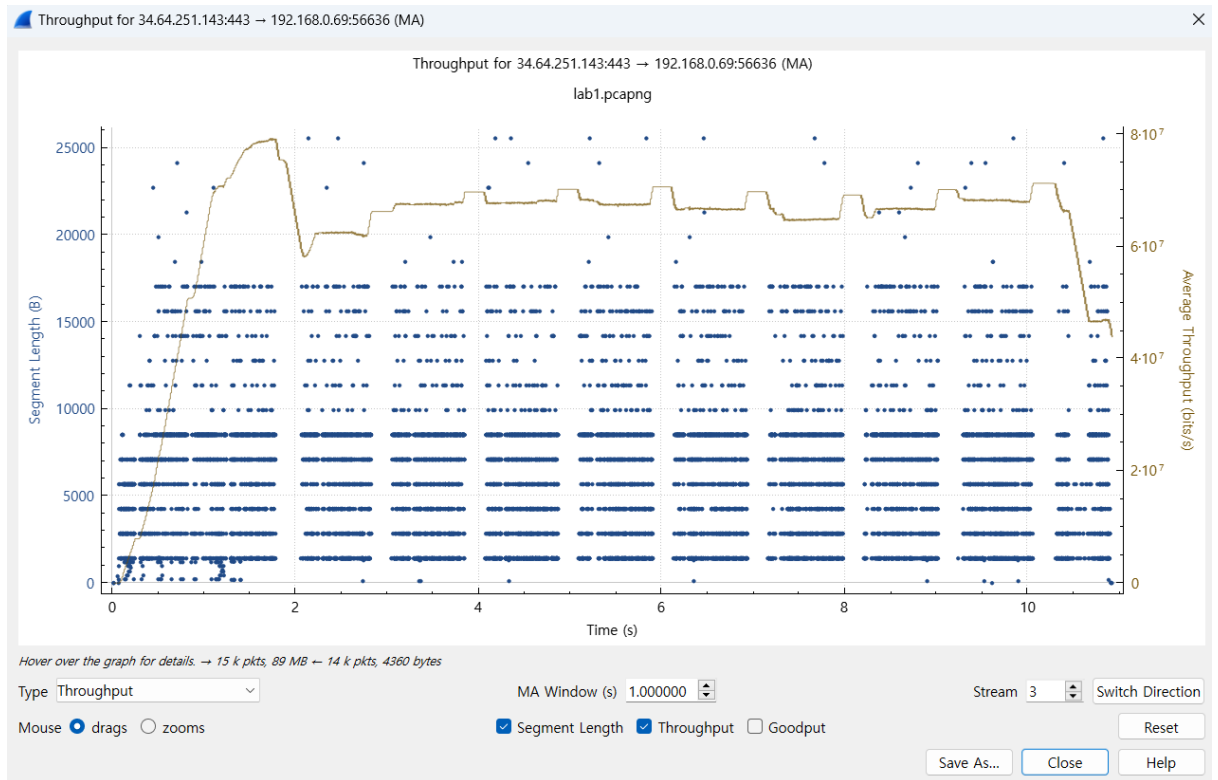
Stream 3의 src는 192.168.0.69, dest는 34.64.251.143인 경우가 있고, src와 dest가 반대인

경우도 있다.

Stream 15 에서도 위와 동일하다.

총 195176705 byte가 전송되었다.

3. Wireshark으로 측정된 TCP Throughput에서 Throughput이 증가하다가 감소하는 주요 원인은 무엇인가요? 반드시 근거를 들어 설명하세요.



Stream 3는 throughput 측정 서버로부터 내 컴퓨터로 보내는 throughput이 유의미하게 변동되므로 downstream인 것 같다. 그래프를 확인하면 중간중간 throughput이 감소하는 구간이 있는데, 해당 구간의 기록을 살펴보면 다음과 같은 공통적인 양상을 확인할 수 있었다.

No.	Time	tcp stream	Source	Destination	Protocol	Length	Info
4938	3.573405	3	192.168.0.69	34.64.251.143	TCP	66	[TCP Dup ACK 4931#1] 56636 -> 443 [ACK] Seq=3285 Ack=15779189 Win=528128 Len=0 SLE=15709609
4939	3.583065	3	34.64.251.143	192.168.0.69	TLSv1.3	8574	[TCP Previous segment not captured], Continuation Data
4940	3.583099	3	192.168.0.69	34.64.251.143	TCP	66	[TCP Dup ACK 4931#2] 56636 -> 443 [ACK] Seq=3285 Ack=15779189 Win=528128 Len=0 SLE=16095849
4941	3.584348	3	34.64.251.143	192.168.0.69	TLSv1.3	17094	Continuation Data
4942	3.584381	3	192.168.0.69	34.64.251.143	TCP	66	[TCP Dup ACK 4931#3] 56636 -> 443 [ACK] Seq=3285 Ack=15779189 Win=528128 Len=0 SLE=16095849
4943	3.585273	3	34.64.251.143	192.168.0.69	TLSv1.3	8574	Continuation Data
4944	3.585287	3	192.168.0.69	34.64.251.143	TCP	66	[TCP Dup ACK 4931#4] 56636 -> 443 [ACK] Seq=3285 Ack=15779189 Win=528128 Len=0 SLE=16095849
4945	3.585666	3	34.64.251.143	192.168.0.69	TLSv1.3	8574	Continuation Data
4946	3.585683	3	192.168.0.69	34.64.251.143	TCP	66	[TCP Dup ACK 4931#5] 56636 -> 443 [ACK] Seq=3285 Ack=15779189 Win=528128 Len=0 SLE=16095849
4947	3.587081	3	34.64.251.143	192.168.0.69	TLSv1.3	8574	Continuation Data
4948	3.587094	3	192.168.0.69	34.64.251.143	TCP	66	[TCP Dup ACK 4931#6] 56636 -> 443 [ACK] Seq=3285 Ack=15779189 Win=528128 Len=0 SLE=16095849
4949	3.587443	3	34.64.251.143	192.168.0.69	TLSv1.3	8574	Continuation Data
4950	3.587461	3	192.168.0.69	34.64.251.143	TCP	66	[TCP Dup ACK 4931#7] 56636 -> 443 [ACK] Seq=3285 Ack=15779189 Win=528128 Len=0 SLE=16095849
4951	3.587822	3	34.64.251.143	192.168.0.69	TLSv1.3	5734	Continuation Data
4953	3.587836	3	192.168.0.69	34.64.251.143	TCP	66	[TCP Dup ACK 4931#8] 56636 -> 443 [ACK] Seq=3285 Ack=15779189 Win=528128 Len=0 SLE=16095849
4954	3.593070	3	192.168.0.69	34.64.251.143	TLSv1.3	1474	[TCP Fast Retransmission], Continuation Data
4955	3.593070	3	34.64.251.143	192.168.0.69	TCP	1474	[TCP Out-Of-Order] 443 -> 56636 [ACK] Seq=15780609 Ack=3285 Win=64128 Len=1420
4956	3.593070	3	34.64.251.143	192.168.0.69	TCP	5734	[TCP Out-Of-Order] 443 -> 56636 [PSH, ACK] Seq=15782029 Ack=3285 Win=64128 Len=5680
4957	3.593113	3	192.168.0.69	34.64.251.143	TCP	66	56636 -> 443 [ACK] Seq=3285 Ack=15780609 Win=528128 Len=0 SLE=16095849 SRE=16161169
4958	3.593156	3	192.168.0.69	34.64.251.143	TCP	66	56636 -> 443 [ACK] Seq=3285 Ack=15782029 Win=528128 Len=0 SLE=16095849 SRE=16161169
4959	3.593178	3	192.168.0.69	34.64.251.143	TCP	66	56636 -> 443 [ACK] Seq=3285 Ack=15787709 Win=528128 Len=0 SLE=16095849 SRE=16161169
4960	3.594038	3	34.64.251.143	192.168.0.69	TCP	8574	[TCP Out-Of-Order] 443 -> 56636 [PSH, ACK] Seq=15787709 Ack=3285 Win=64128 Len=8520
4961	3.594078	3	192.168.0.69	34.64.251.143	TCP	66	56636 -> 443 [ACK] Seq=3285 Ack=15796229 Win=528128 Len=0 SLE=16095849 SRE=16161169
4962	3.594902	3	34.64.251.143	192.168.0.69	TCP	8574	[TCP Out-Of-Order] 443 -> 56636 [PSH, ACK] Seq=15796229 Ack=3285 Win=64128 Len=8520
4963	3.594937	3	192.168.0.69	34.64.251.143	TCP	66	56636 -> 443 [ACK] Seq=3285 Ack=15804749 Win=528128 Len=0 SLE=16095849 SRE=16161169
4964	3.595292	3	34.64.251.143	192.168.0.69	TCP	8574	[TCP Out-Of-Order] 443 -> 56636 [PSH, ACK] Seq=15804749 Ack=3285 Win=64128 Len=8520
4965	3.595315	3	192.168.0.69	34.64.251.143	TCP	66	56636 -> 443 [ACK] Seq=3285 Ack=15813269 Win=528128 Len=0 SLE=16095849 SRE=16161169
4966	3.595845	3	34.64.251.143	192.168.0.69	TCP	7154	[TCP Out-Of-Order] 443 -> 56636 [PSH, ACK] Seq=15813269 Ack=3285 Win=64128 Len=7100
4967	3.595865	3	192.168.0.69	34.64.251.143	TCP	66	56636 -> 443 [ACK] Seq=3285 Ack=15820369 Win=528128 Len=0 SLE=16095849 SRE=16161169
4968	3.598048	3	34.64.251.143	192.168.0.69	TCP	1474	[TCP Out-Of-Order] 443 -> 56636 [PSH, ACK] Seq=15820369 Ack=3285 Win=64128 Len=1420
4969	3.598048	3	34.64.251.143	192.168.0.69	TCP	8574	[TCP Out-Of-Order] 443 -> 56636 [PSH, ACK] Seq=15821789 Ack=3285 Win=64128 Len=8520
4970	3.598120	3	192.168.0.69	34.64.251.143	TCP	66	56636 -> 443 [ACK] Seq=3285 Ack=15821789 Win=528128 Len=0 SLE=16095849 SRE=16161169

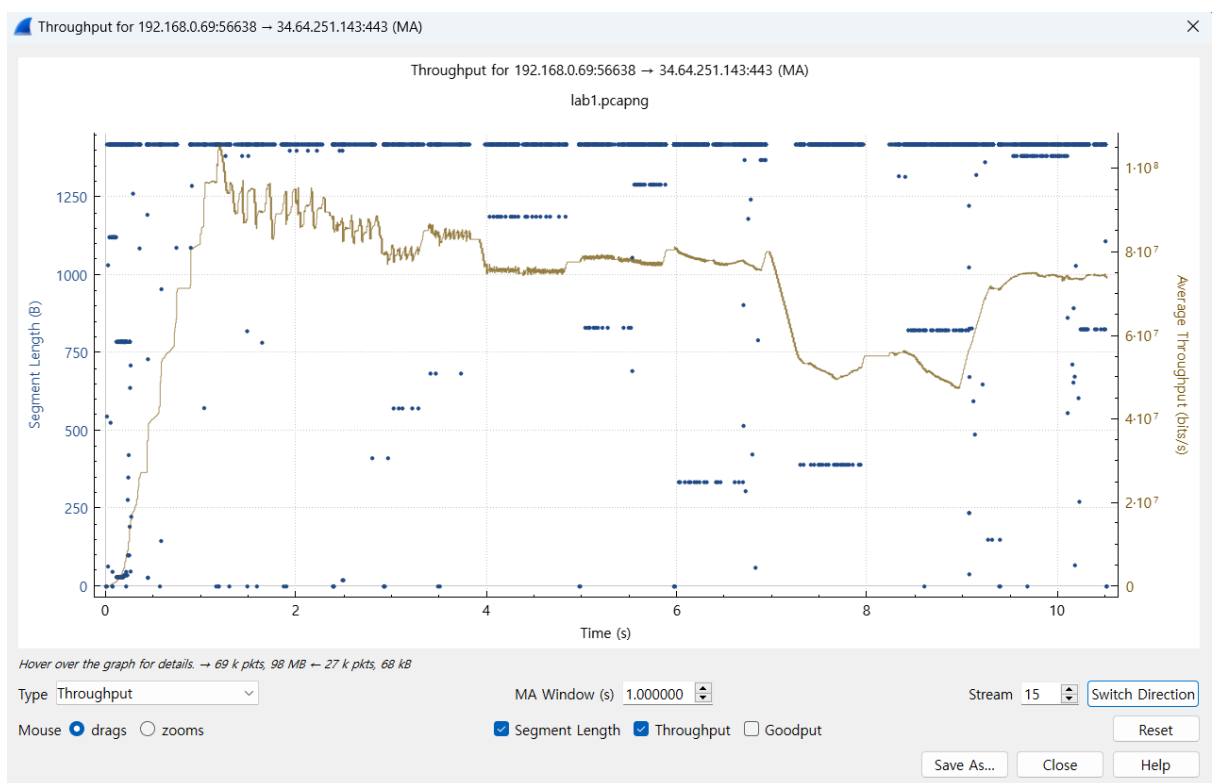
그래프상에서 throughput이 감소하기 시작한 지점의 패킷 기록들.

검은 색으로 표시된 패킷은 Retransmission, duplicate된 패킷으로, 이전 전송에서 loss가 되거나 내용이 변조되는 등 문제가 생겨 재전송된 결과이다.

- ▼ [TCP Analysis Flags]
 - > [Expert Info (Note/Sequence): This frame is a (suspected) spurious retransmission]
 - > [Expert Info (Note/Sequence): This frame is a (suspected) retransmission]
- ▼ [SEQ/ACK analysis]
 - [iRTT: 0.010594000 seconds]
 - ▼ [TCP Analysis Flags]
 - [This is a TCP duplicate ack]
 - [Duplicate ACK #: 1]
 - ▼ [Duplicate to the ACK in frame: 4931]
 - > [Expert Info (Note/Sequence): Duplicate ACK (#1)]

이 상황으로 인해 throughput이 감소되었던 것으로 보인다.

Stream 15는 stream 3와 반대로 내 컴퓨터에서 측정 서버로 보내는, upstream으로 생각된다.



그래프를 보면 큰 폭으로 throughput이 감소하는 구간이 있는데, 해당 구간의 패킷 기록은 다음과 같다.

No.	Time	tcp stream	Source	Destination	Protocol	Length	Info
99484	19.361745		15 192.168.0.69	34.64.251.143	TCP	1474	56638 → 443 [PSH, ACK] Seq=66017435 Ack=45090 Win=130816 Len=1420 [TCP segment of a reassembled
99485	19.674346		15 192.168.0.69	34.64.251.143	TCP	1474	[TCP Retransmission] 56638 → 443 [ACK] Seq=65892525 Ack=45090 Win=130816 Len=1420 [TCP segm
99486	19.681377		15 34.64.251.143	192.168.0.69	TLSv1.3	1189	Application Data
99487	19.681377		15 34.64.251.143	192.168.0.69	TLSv1.3	97	Application Data
99488	19.681431		15 192.168.0.69	34.64.251.143	TCP	1474	[TCP Retransmission] 56638 → 443 [PSH, ACK] Seq=65981935 Ack=46268 Win=131840 Len=1420 [TCP
99489	19.681431		15 192.168.0.69	34.64.251.143	TCP	1474	[TCP Retransmission] 56638 → 443 [ACK] Seq=65983355 Ack=46268 Win=131840 Len=1420 [TCP segm
99490	19.681431		15 192.168.0.69	34.64.251.143	TCP	1474	[TCP Retransmission] 56638 → 443 [PSH, ACK] Seq=65984775 Ack=46268 Win=131840 Len=1420 [TCP
99491	19.681431		15 192.168.0.69	34.64.251.143	TCP	1474	[TCP Retransmission] 56638 → 443 [ACK] Seq=65986195 Ack=46268 Win=131840 Len=1420 [TCP segm
99492	19.681431		15 192.168.0.69	34.64.251.143	TCP	1474	[TCP Retransmission] 56638 → 443 [ACK] Seq=65987615 Ack=46268 Win=131840 Len=1420 [TCP segm
99493	19.681431		15 192.168.0.69	34.64.251.143	TCP	1474	[TCP Retransmission] 56638 → 443 [ACK] Seq=65989035 Ack=46268 Win=131840 Len=1420 [TCP segm
99494	19.681431		15 192.168.0.69	34.64.251.143	TCP	1474	[TCP Retransmission] 56638 → 443 [ACK] Seq=65990455 Ack=46268 Win=131840 Len=1420 [TCP segm
99495	19.681431		15 192.168.0.69	34.64.251.143	TCP	1474	[TCP Retransmission] 56638 → 443 [ACK] Seq=65991875 Ack=46268 Win=131840 Len=1420 [TCP segm
99496	19.681431		15 192.168.0.69	34.64.251.143	TCP	1474	[TCP Retransmission] 56638 → 443 [ACK] Seq=65993295 Ack=46268 Win=131840 Len=1420 [TCP segm
99497	19.684028		15 34.64.251.143	192.168.0.69	TCP	66	[TCP Dup ACK 99486#1] 443 → 56638 [ACK] Seq=46268 Ack=65981935 Win=3145728 Len=0 SLE=658925
99498	19.690722		15 34.64.251.143	192.168.0.69	TCP	60	443 → 56638 [ACK] Seq=46268 Ack=65983355 Win=3144704 Len=0
99499	19.690722		15 34.64.251.143	192.168.0.69	TCP	60	443 → 56638 [ACK] Seq=46268 Ack=65984775 Win=3144704 Len=0
99500	19.690722		15 34.64.251.143	192.168.0.69	TCP	60	443 → 56638 [ACK] Seq=46268 Ack=65986195 Win=3144704 Len=0
99501	19.690722		15 34.64.251.143	192.168.0.69	TCP	60	443 → 56638 [ACK] Seq=46268 Ack=65987615 Win=3144704 Len=0
99502	19.690774		15 192.168.0.69	34.64.251.143	TCP	1474	[TCP Retransmission] 56638 → 443 [ACK] Seq=65994715 Ack=46268 Win=131840 Len=1420 [TCP segm
99503	19.690774		15 192.168.0.69	34.64.251.143	TCP	1474	[TCP Retransmission] 56638 → 443 [ACK] Seq=65996135 Ack=46268 Win=131840 Len=1420 [TCP segm
99504	19.690774		15 192.168.0.69	34.64.251.143	TCP	1474	[TCP Retransmission] 56638 → 443 [ACK] Seq=65997555 Ack=46268 Win=131840 Len=1420 [TCP segm
99505	19.690774		15 192.168.0.69	34.64.251.143	TCP	1474	[TCP Retransmission] 56638 → 443 [PSH, ACK] Seq=65998975 Ack=46268 Win=131840 Len=1420 [TCP
99506	19.690774		15 192.168.0.69	34.64.251.143	TCP	1474	[TCP Retransmission] 56638 → 443 [ACK] Seq=66000395 Ack=46268 Win=131840 Len=1420 [TCP segm
99507	19.690774		15 192.168.0.69	34.64.251.143	TCP	1474	[TCP Retransmission] 56638 → 443 [PSH, ACK] Seq=66001815 Ack=46268 Win=131840 Len=1420 [TCP
99508	19.690774		15 192.168.0.69	34.64.251.143	TCP	1474	[TCP Retransmission] 56638 → 443 [ACK] Seq=66003235 Ack=46268 Win=131840 Len=1420 [TCP segm
99509	19.690774		15 192.168.0.69	34.64.251.143	TCP	1474	[TCP Retransmission] 56638 → 443 [ACK] Seq=66004655 Ack=46268 Win=131840 Len=1420 [TCP segm
99510	19.691508		15 34.64.251.143	192.168.0.69	TCP	60	443 → 56638 [ACK] Seq=46268 Ack=65989035 Win=3144704 Len=0
99511	19.691508		15 34.64.251.143	192.168.0.69	TCP	60	443 → 56638 [ACK] Seq=46268 Ack=65990455 Win=3144704 Len=0
99512	19.691508		15 34.64.251.143	192.168.0.69	TCP	60	443 → 56638 [ACK] Seq=46268 Ack=65991875 Win=3144704 Len=0
99513	19.691508		15 34.64.251.143	192.168.0.69	TCP	60	443 → 56638 [ACK] Seq=46268 Ack=65993295 Win=3144704 Len=0
99514	19.691508		15 34.64.251.143	192.168.0.69	TCP	60	443 → 56638 [ACK] Seq=46268 Ack=65994715 Win=3144704 Len=0
99515	19.692452		15 192.168.0.69	34.64.251.143	TCP	1474	[TCP Retransmission] 56638 → 443 [ACK] Seq=66006075 Ack=46268 Win=131840 Len=1420 [TCP segm

위와 마찬가지로 재전송, 중복된 패킷들이 밀집되어 있다.

▼ [SEQ/ACK analysis]

[\[This is an ACK to the segment in frame: 99487\]](#)

[The RTT to ACK the segment was: 0.000054000 seconds]

[iRTT: 0.009873000 seconds]

[Bytes in flight: 36920]

[Bytes sent since last PSH flag: 2840]

▼ [TCP Analysis Flags]

➢ [Expert Info (Note/Sequence): This frame is a (suspected) retransmission]

[The RTO for this segment was: 0.322291000 seconds]

[\[RTO based on delta from frame: 99449\]](#)

TCP payload (1420 bytes)

➢ [Timestamps]

▼ [SEQ/ACK analysis]

[iRTT: 0.009873000 seconds]

▼ [TCP Analysis Flags]

[This is a TCP duplicate ack]

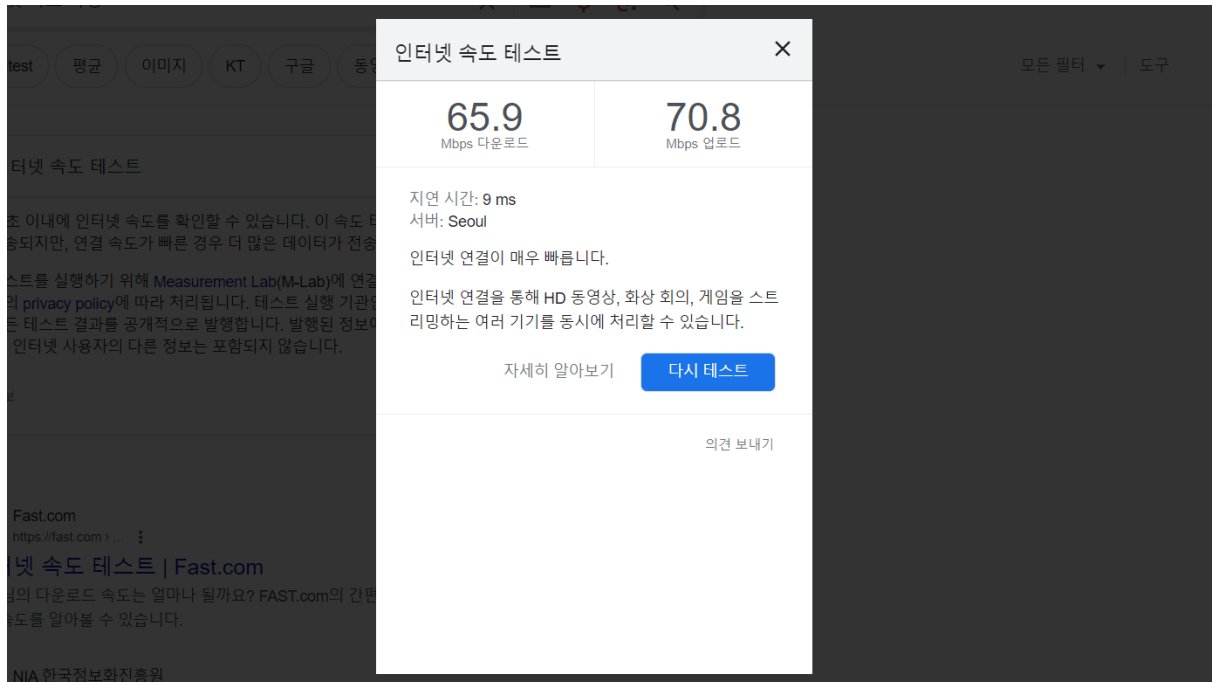
[Duplicate ACK #: 1]

➢ [\[Duplicate to the ACK in frame: 99486\]](#)

이 또한 어떠한 원인으로 인하여 시간 안에 패킷이 도착하지 못하고, 재전송되거나 중복된 패킷들이 발생하며 해당 구간의 throughput을 크게 감소시킨 것으로 보인다.

4. 웹 브라우저에 출력된 Throughput과 Wireshark을 통해 측정된 Throughput을 비교하고 차이가 발생한 이유에 대해 설명하세요.

웹 브라우저에 출력된 Throughput은 다음과 같고,



Wireshark의 분석으로 얻은 throughput은 다음과 같다.

tcp && ip.addr == 34.64.251.143 && tcp.stream == 3			tcp && ip.addr == 34.64.251.143 && tcp.stream == 15		
Statistics			Statistics		
Measurement	Captured	Displayed	Measurement	Captured	Displayed
Packets	126831	29938 (23.6%)	Packets	126831	96741 (76.3%)
Time span, s	25.197	10.916	Time span, s	25.197	10.521
Average pps	5033.6	2742.6	Average pps	5033.6	9195.4
Average packet size, B	1539	3049	Average packet size, B	1539	1074
Bytes	195205026	91269259 (46.8%)	Bytes	195205026	103907446 (53.2%)
Average bytes/s	7747 k	8361 k	Average bytes/s	7747 k	9876 k
Average bits/s	61 M	66 M	Average bits/s	61 M	79 M
다운로드			업로드		

웹에서 측정한 결과보다 Wireshark로 측정한 결과가 더 높게 나왔다.

웹을 한 차례 거치는 과정에서 패킷 교환이 더 필요해 그렇게 된 것이 아닐까...?