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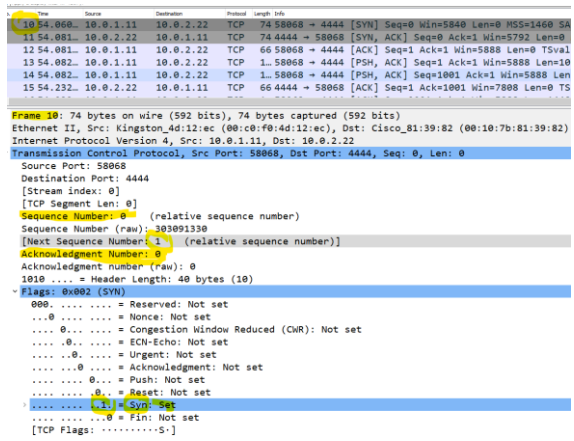
ECE 6321 - TAKE HOME EXAM - 1

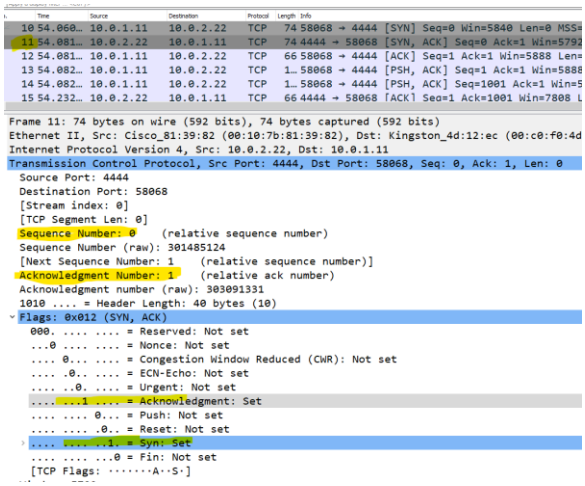
1. *Identify, by number, the frames involved with the 3-way handshake as viewed by the client and by the server. List the synchronization data that is exchanged and agreed upon (ACKED) for this connection.*

- **3-Way handshake is the Connection Establishment Phase. It includes 3 steps in order:**
  a. Frame # 10: SYN
  b. Frame # 11: SYN/ACK
  c. Frame # 12: ACK
- **Synchronization Data:**

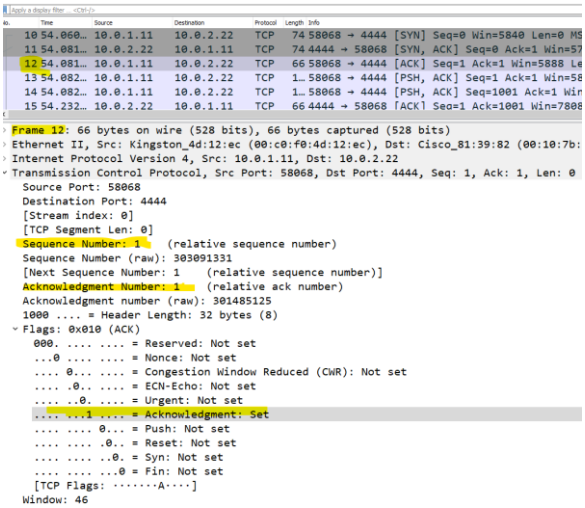
  Frame # 10: PC-1 (Sender) sends a TCP segment with SYN = 1, ACK = 0 and Relative Sequence #: 0



  Frame # 11: PC-2 (Receiver) sends a TCP segment with SYN = 1, ACK = 1 and Rel. Sequence #: 0



  Frame # 12: PC-1 (Sender) sends a TCP segment with SYN = 0, ACK = 1 and Rel. Sequence #:**1**



2. *The initial size of the sender's congestion window is **2 MSS**. After the first 2 segments (numbers 1 &1001), transmission is <u>suspended</u> until the first ACK (#1001) is received. What is the time interval between the receipt of the first ACK and the transmission of the third segment (# 2001)?*

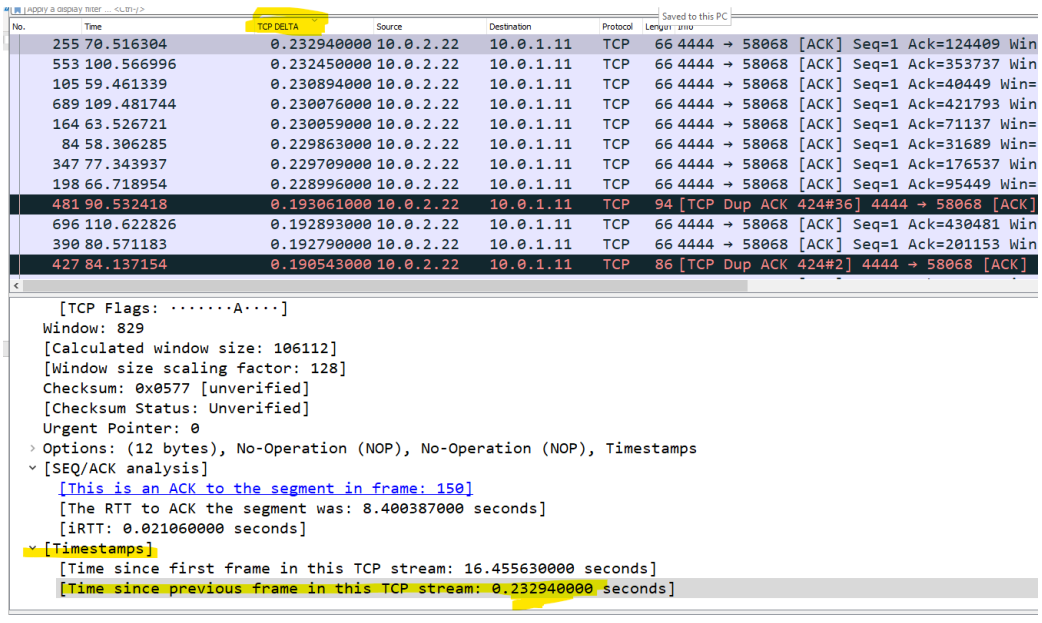
   Time on ACK (#1001): 54.232418 (frame 15)
   3rd Segment Transmission (#2001): 54.232493 (frame 16)
   So, time interval is: (54.232493-54.232418) = **0.000075 sec = 75 µs**

3. *What the time interval between the time that segment #1001 arrives at the receiver and the time that its ACK (ACK # 2001) is transmitted?*

   Time: Arrival of segment #1001 at the Receiver (PC2): 54.082067 (frame 14)
   Time: ACK of ACK #2001 transmission: 54.366366 (frame 18)
   So, time interval is: (54.366366-54.082067)= **0.284299 sec = 284.299 ms**

4. *Determine the round trip time(RTT) for segment 1.*
   Identify, based on numerical analysis, the primary sources of the delay. Discuss the other components of delay. Assume that the bit rates on the Ethernet networks are 10 Mbps.

   - RTT of Segment 1: It is given on the SEQ/ACK analysis of Frame 15 (ACK to the segment in frame 13) : **0.150383 sec = 15.383 ms**
   - Primary sources of the delay: ***Data rate between R1 and R2 (64 kbps) is significantly (156 times) less*** than between R1 & PC1 (10 Mbps) and R2&PC2 (10 Mbps). Even we can ignore the transmission delays on the 10Mbps networks.
   - Other components of delay: frequency of Packet loss, the speed at which new data can be made available for transmission, the maximum possible size of the TCP receive window etc. can be reasons of delay. At wireshark; **Timestamps** can tell us delays too. [Time since previous frame in the TCP stream]

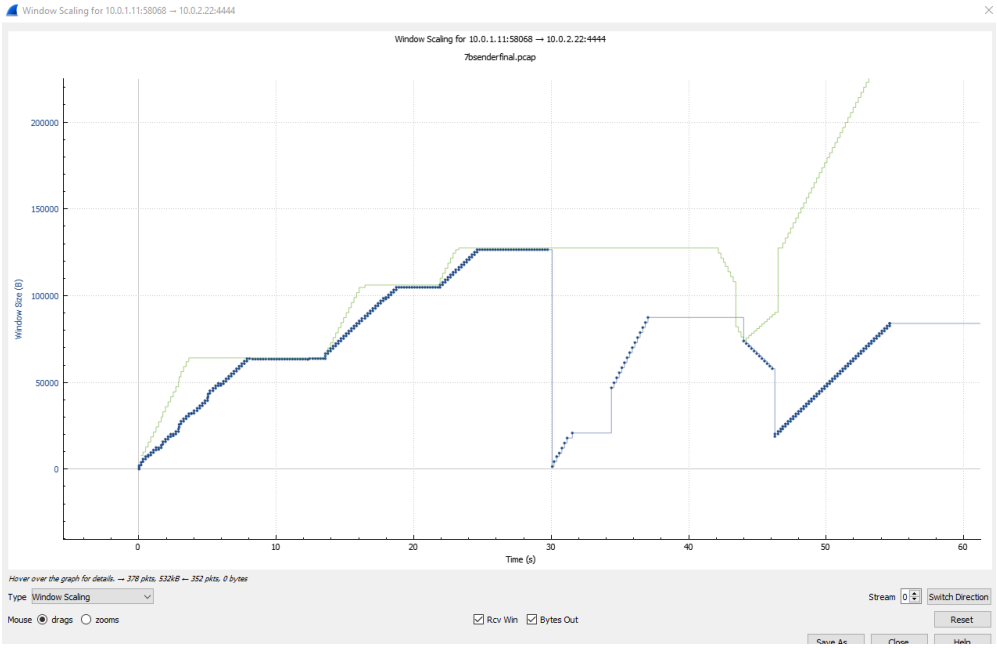


5. *Measure the round-trip-time (RTT) for the first 10 segments. Provide a quantitative explanation for the increase.*

   - The RTT for first segment (frame 13) is: 0.150383000 seconds.
   - The RTT for second segment (frame 14) is: 0.284299000 seconds.
   - The RTT for third segment (frame 16) is: 0.323242000 seconds.
   - The RTT for the fourth segment (frame 17) is: 0.512908000 seconds.
   - The RTT for the fifth segment (frame 19) is: 0.568492000 seconds
   - The RTT for the sixth segment (frame 20) is: 0.758270000 seconds.

- The RTT for the seventh segment (frame 22) is: 0.758610000 seconds
- The RTT for the eighth segment (frame 23) is: 0.948259000 seconds
- The RTT for the ninth segment (frame 25) is: 0.94825000 seconds
- The RTT for the tenth segment (frame 26) is: 1.064053000 seconds

RTT is increasing because congestion window is growing. If we ignore the slow-start phase, we see that TCP essentially increases its window size by 1 each RTT (and thus increases its transmission rate by an additive factor) when its network path is not congested and decreases its window size by a factor of two each RTT when the path is congested. For this reason, TCP is often referred to as an additive-increase, multiplicative-decrease (AIMD) algorithm.



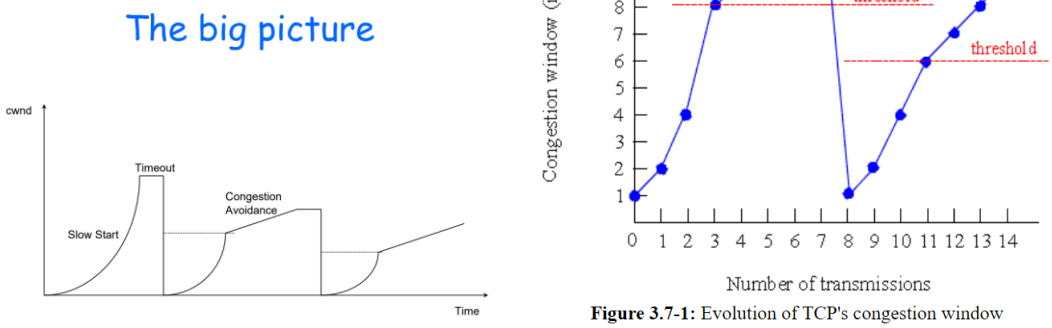


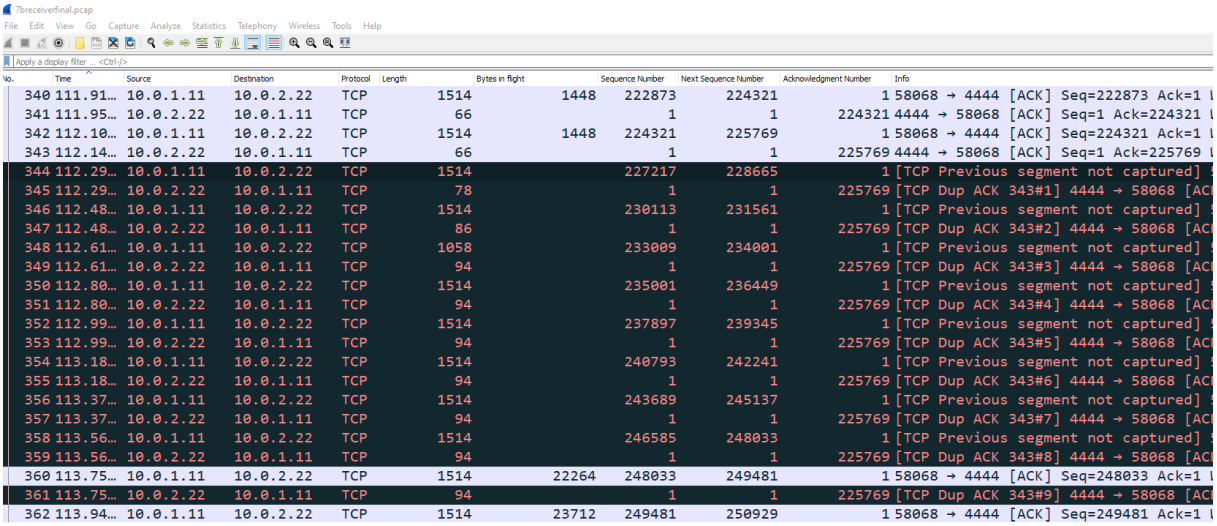
Figure 3.7-1: Evolution of TCP's congestion window

6. *Compute the number of bytes "in-flight" (unacknowledged bytes) when the first segment is lost. Where are these segments being stored? Provide upper and lower bounds on the storage capacity of the network.*

Bytes-out, server side of the computation. That's why 7receiver.pcap files is used here in below:

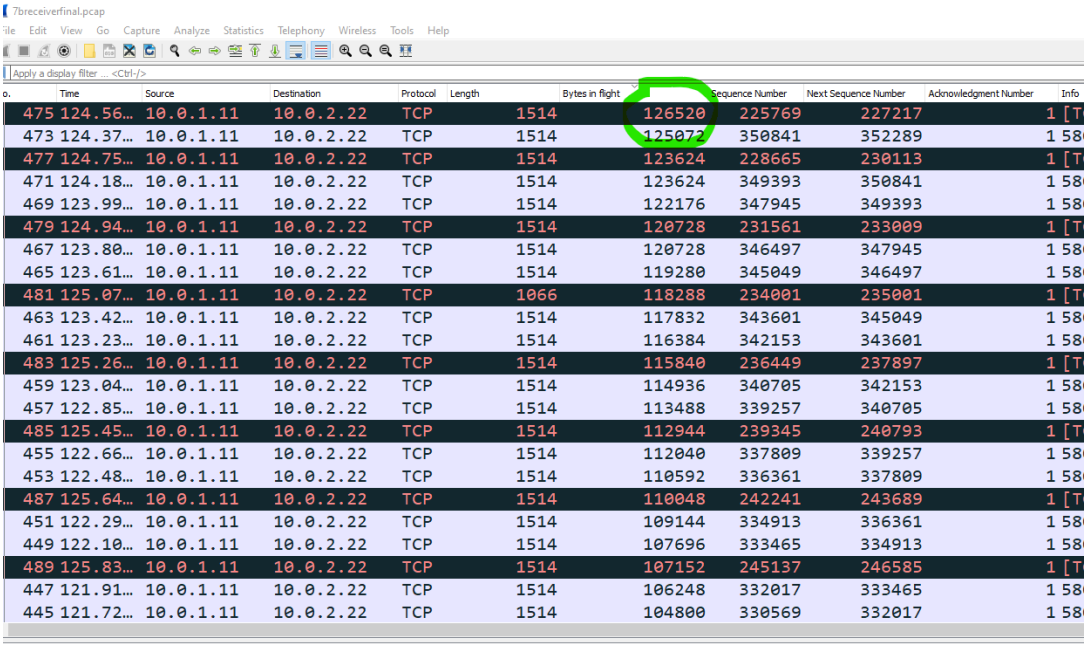
Selective ACKs (SACKs) will provide a bit more information about what segments have been received and make this all more efficient.

First segment lost is seen on the **Frame 344**. So, at frame 341 the In-Flight bytes is **1448**. Next sequence number is mentioned at the Frame 342 which is 225769, however, only at **frame 475** we see the sequence number as 225769. The In-flight bytes is **126520.**

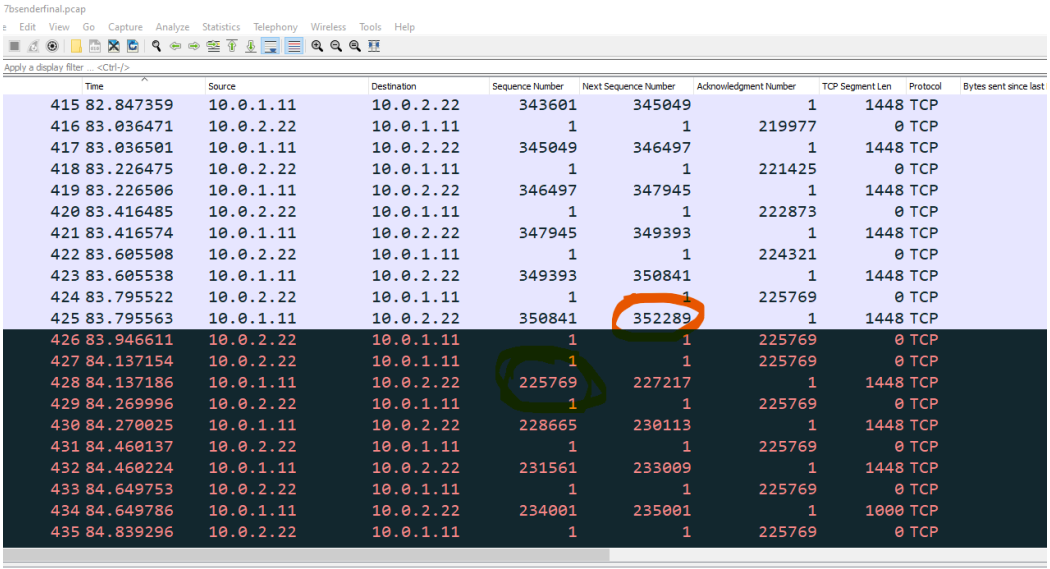


No.	Time	Source	Destination	Protocol	Length	Bytes in flight	Sequence Number	Next Sequence Number	Acknowledgment Number	Info
340	111.91…	10.0.1.11	10.0.2.22	TCP	1514	1448	222873	224321	1	58068 → 4444 [ACK] Seq=222873 Ack=1
341	111.95…	10.0.2.22	10.0.1.11	TCP	66		1	1	224321	4444 → 58068 [ACK] Seq=1 Ack=224321
342	112.10…	10.0.1.11	10.0.2.22	TCP	1514	1448	224321	225769	1	58068 → 4444 [ACK] Seq=224321 Ack=1
343	112.14…	10.0.2.22	10.0.1.11	TCP	66		1	1	225769	4444 → 58068 [ACK] Seq=1 Ack=225769
344	112.29…	10.0.1.11	10.0.2.22	TCP	1514		227217	228665	1	[TCP Previous segment not captured]
345	112.29…	10.0.2.22	10.0.1.11	TCP	78		1	1	225769	[TCP Dup ACK 343#1] 4444 → 58068 [AC
346	112.48…	10.0.1.11	10.0.2.22	TCP	1514		230113	231561	1	[TCP Previous segment not captured]
347	112.48…	10.0.2.22	10.0.1.11	TCP	86		1	1	225769	[TCP Dup ACK 343#2] 4444 → 58068 [AC
348	112.61…	10.0.1.11	10.0.2.22	TCP	1058		233009	234001	1	[TCP Previous segment not captured]
349	112.61…	10.0.2.22	10.0.1.11	TCP	94		1	1	225769	[TCP Dup ACK 343#3] 4444 → 58068 [AC
350	112.80…	10.0.1.11	10.0.2.22	TCP	1514		235001	236449	1	[TCP Previous segment not captured]
351	112.80…	10.0.2.22	10.0.1.11	TCP	94		1	1	225769	[TCP Dup ACK 343#4] 4444 → 58068 [AC
352	112.99…	10.0.1.11	10.0.2.22	TCP	1514		237897	239345	1	[TCP Previous segment not captured]
353	112.99…	10.0.2.22	10.0.1.11	TCP	94		1	1	225769	[TCP Dup ACK 343#5] 4444 → 58068 [AC
354	113.18…	10.0.1.11	10.0.2.22	TCP	1514		240793	242241	1	[TCP Previous segment not captured]
355	113.18…	10.0.2.22	10.0.1.11	TCP	94		1	1	225769	[TCP Dup ACK 343#6] 4444 → 58068 [AC
356	113.37…	10.0.1.11	10.0.2.22	TCP	1514		243689	245137	1	[TCP Previous segment not captured]
357	113.37…	10.0.2.22	10.0.1.11	TCP	94		1	1	225769	[TCP Dup ACK 343#7] 4444 → 58068 [AC
358	113.56…	10.0.1.11	10.0.2.22	TCP	1514		246585	248033	1	[TCP Previous segment not captured]
359	113.56…	10.0.2.22	10.0.1.11	TCP	94		1	1	225769	[TCP Dup ACK 343#8] 4444 → 58068 [AC
360	113.75…	10.0.1.11	10.0.2.22	TCP	1514	22264	248033	249481	1	58068 → 4444 [ACK] Seq=248033 Ack=1
361	113.75…	10.0.2.22	10.0.1.11	TCP	94		1	1	225769	[TCP Dup ACK 343#9] 4444 → 58068 [AC
362	113.94…	10.0.1.11	10.0.2.22	TCP	1514	23712	249481	250929	1	58068 → 4444 [ACK] Seq=249481 Ack=1

Maximum number of bytes in flight is : **126520** as in the .pcap below. Must be less than receiver window size.



No.	Time	Source	Destination	Protocol	Length	Bytes in flight	Sequence Number	Next Sequence Number	Acknowledgment Number	Info
475	124.56…	10.0.1.11	10.0.2.22	TCP	1514	126520	225769	227217	1	[T
473	124.37…	10.0.1.11	10.0.2.22	TCP	1514	125072	350841	352289	1	58
477	124.75…	10.0.1.11	10.0.2.22	TCP	1514	123624	228665	230113	1	[T
471	124.18…	10.0.1.11	10.0.2.22	TCP	1514	123624	349393	350841	1	58
469	123.99…	10.0.1.11	10.0.2.22	TCP	1514	122176	347945	349393	1	58
479	124.94…	10.0.1.11	10.0.2.22	TCP	1514	120728	231561	233009	1	[T
467	123.80…	10.0.1.11	10.0.2.22	TCP	1514	120728	346497	347945	1	58
465	123.61…	10.0.1.11	10.0.2.22	TCP	1514	119280	345049	346497	1	58
481	125.07…	10.0.1.11	10.0.2.22	TCP	1066	118288	234001	235001	1	[T
463	123.42…	10.0.1.11	10.0.2.22	TCP	1514	117832	343601	345049	1	58
461	123.23…	10.0.1.11	10.0.2.22	TCP	1514	116384	342153	343601	1	58
483	125.26…	10.0.1.11	10.0.2.22	TCP	1514	115840	236449	237897	1	[T
459	123.04…	10.0.1.11	10.0.2.22	TCP	1514	114936	340705	342153	1	58
457	122.85…	10.0.1.11	10.0.2.22	TCP	1514	113488	339257	340705	1	58
485	125.45…	10.0.1.11	10.0.2.22	TCP	1514	112944	239345	240793	1	[T
455	122.66…	10.0.1.11	10.0.2.22	TCP	1514	112040	337809	339257	1	58
453	122.48…	10.0.1.11	10.0.2.22	TCP	1514	110592	336361	337809	1	58
487	125.64…	10.0.1.11	10.0.2.22	TCP	1514	110048	242241	243689	1	[T
451	122.29…	10.0.1.11	10.0.2.22	TCP	1514	109144	334913	336361	1	58
449	122.10…	10.0.1.11	10.0.2.22	TCP	1514	107696	333465	334913	1	58
489	125.83…	10.0.1.11	10.0.2.22	TCP	1514	107152	245137	246585	1	[T
447	121.91…	10.0.1.11	10.0.2.22	TCP	1514	106248	332017	333465	1	58
445	121.72…	10.0.1.11	10.0.2.22	TCP	1514	104800	330569	332017	1	58



	Time	Source	Destination	Sequence Number	Next Sequence Number	Acknowledgment Number	TCP Segment Len	Protocol	Bytes sent since last
415	82.847359	10.0.1.11	10.0.2.22	343601	345049	1	1448	TCP	
416	83.036471	10.0.2.22	10.0.1.11	1	1	219977	0	TCP	
417	83.036501	10.0.1.11	10.0.2.22	345049	346497	1	1448	TCP	
418	83.226475	10.0.2.22	10.0.1.11	1	1	221425	0	TCP	
419	83.226506	10.0.1.11	10.0.2.22	346497	347945	1	1448	TCP	
420	83.416485	10.0.2.22	10.0.1.11	1	1	222873	0	TCP	
421	83.416574	10.0.1.11	10.0.2.22	347945	349393	1	1448	TCP	
422	83.605508	10.0.2.22	10.0.1.11	1	1	224321	0	TCP	
423	83.605538	10.0.1.11	10.0.2.22	349393	350841	1	1448	TCP	
424	83.795522	10.0.2.22	10.0.1.11	1	1	225769	0	TCP	
425	83.795563	10.0.1.11	10.0.2.22	350841	352289	1	1448	TCP	
426	83.946611	10.0.2.22	10.0.1.11	1	1	225769	0	TCP	
427	84.137154	10.0.2.22	10.0.1.11	1	1	225769	0	TCP	
428	84.137186	10.0.1.11	10.0.2.22	225769	227217	1	1448	TCP	
429	84.269996	10.0.2.22	10.0.1.11	1	1	225769	0	TCP	
430	84.270025	10.0.1.11	10.0.2.22	228665	230113	1	1448	TCP	
431	84.460137	10.0.2.22	10.0.1.11	1	1	225769	0	TCP	
432	84.460224	10.0.1.11	10.0.2.22	231561	233009	1	1448	TCP	
433	84.649753	10.0.2.22	10.0.1.11	1	1	225769	0	TCP	
434	84.649786	10.0.1.11	10.0.2.22	234001	235001	1	1000	TCP	
435	84.839296	10.0.2.22	10.0.1.11	1	1	225769	0	TCP	

```
Total Length: 1500
Identification: 0xb5cc (46540)
> Flags: 0x40, Don't fragment
Fragment Offset: 0
Time to Live: 64
Protocol: TCP (6)
Header Checksum: 0x682f [validation disabled]
[Header checksum status: Unverified]
Source Address: 10.0.1.11
```