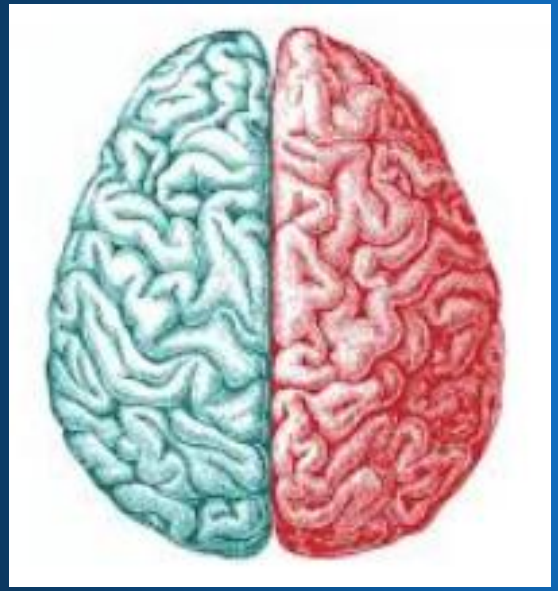
SharkFest '19 Europe

Session #11 - TCP Split Brain - Part I



Using Wireshark to Compare & Contrast behavior and TCP state of client vs. server

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Performance Management Strategist
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Premise: TCP Split Brain

- When troubleshooting TCP, you often have to consider both the sender's unique perspective and the receiver's unique perspective
- Both endpoints are independent, but at the same time, they do react to packets from the other end
- The joint behavior gets even more interesting when there's "high" latency in the path

Upfront Contract

- 75 Minutes x 2
- Your Agenda
- My Agenda

Your Agenda

- Fine tune your Wireshark Skills
- Fine tune your TCP Skills
- Learn more about what you can expect to see in Sender vs. Receiver captures
- Improve your performance troubleshooting skills

My Agenda

- Compare and contrast TCP end point behavior
- Drill down into the “what is it doing?” and “why is it doing that?”
- Promote Wireshark Profiles Feature
- Share experience and ideas
- Expose you to advanced visualizations that help reinforce the end point behavior we will be discussing

About me?

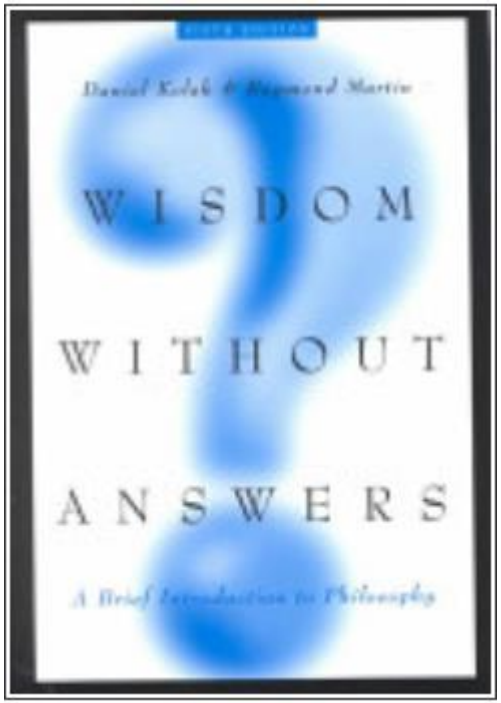
- Performance Engineering since 1980
- Protocol Analysis since 1991
- Performance Consultant with OPNET / Riverbed since 2005
- Love the mystery of a complicated performance issue
- Shaved off beard in 2003…

One of my Favorite Quotes

Education is not the filling of a pail, but the lighting of a fire.

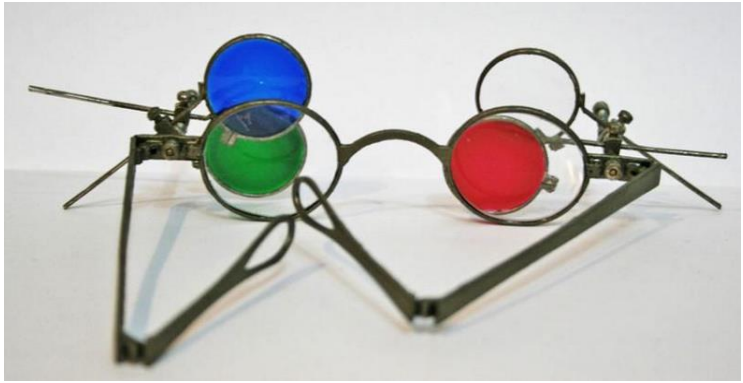
William Butler Yeats

One of my Favorite Books



My Ask of You

- Engage
- Participate
- We have a lot of detailed material
- We will explore conflicting, contradictory, and possibly confusing details
- Ask Questions
- Question Answers



Session Resources

- Pre-filtered end point capture files for the TCP connection of interest
- Wireshark Profiles
- Comparison Summary Spreadsheet
- Wireshark 2.6.3
- Riverbed Transaction Analyzer 17.6 - for Visualization and Advanced Analytics

Comparison Summary

TCP Split Brain Comparison Summary (Sender vs. Receiver)

Item	Topic	Summary	Sender	Receiver

Part I Topics

- Background on app, topology, and symptoms
- Compare and Contrast (aka Split Brain)
  - 3-way Handshake
  - Latency
  - TCP State
  - Expert Info
  - Fragment Overlaps (Part I)

Part II Topics

- Continue where we left off
- Compare and contrast…
  - Fragment Overlaps (Part II)
  - Bytes in Flight
  - Bonus – If time is available
- Session Wrap-Up


IT'S GO TIME

Troubleshooting Scenario

- HTTPS Web Application
- Private key is not available
- Host based captures on web server and my laptop

Symptoms to Analyze

- Downloading files take *forever*
- 16 seconds to download a 1.4MB file
- One TCP connection has been isolated as the connection of interest – TCP/52942-443

Very Simple Topology

Web Server
San Francisco, CA

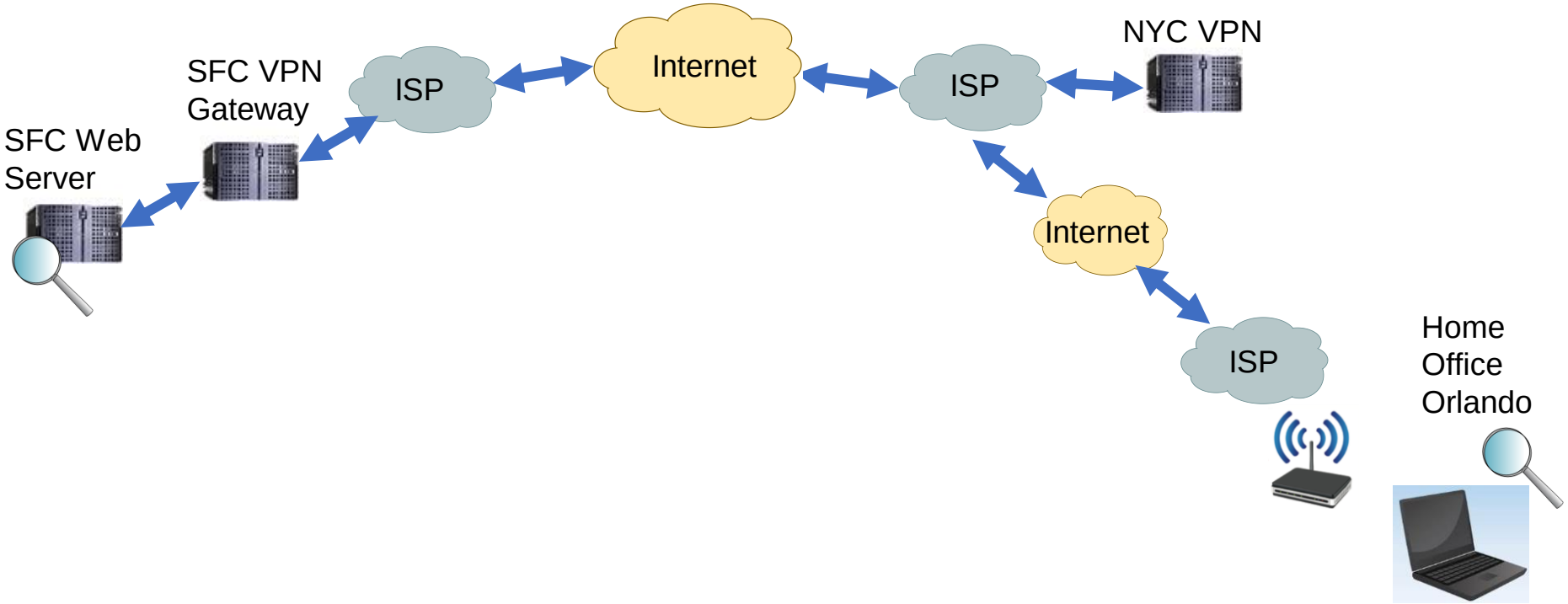
Home Office
Orlando, FL

Approx. 111ms RTT

10.16.1.251

10.36.9.27

Actual Topology

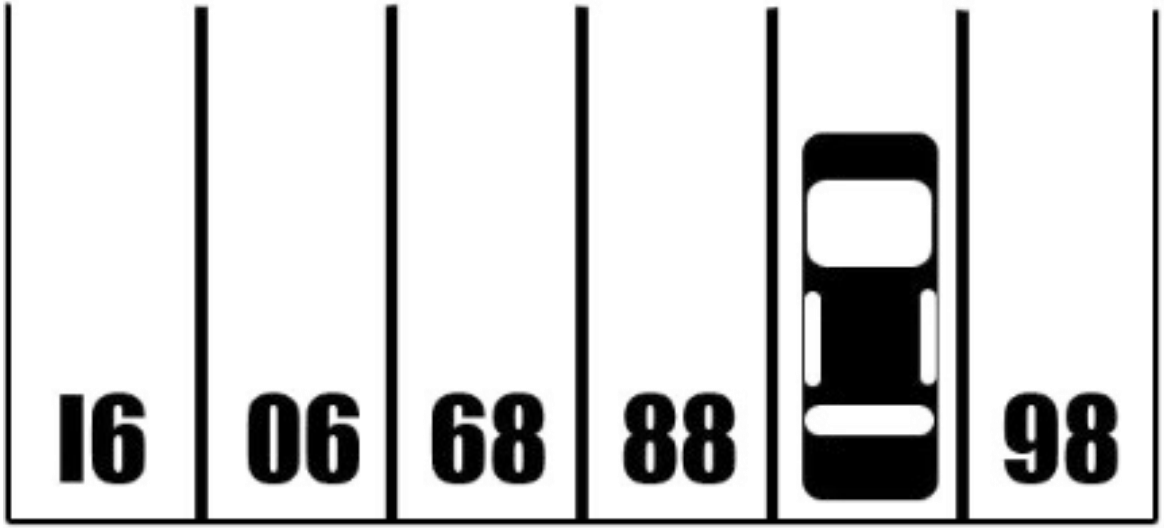


Pop Quiz #1

- Ready for our first Quiz?

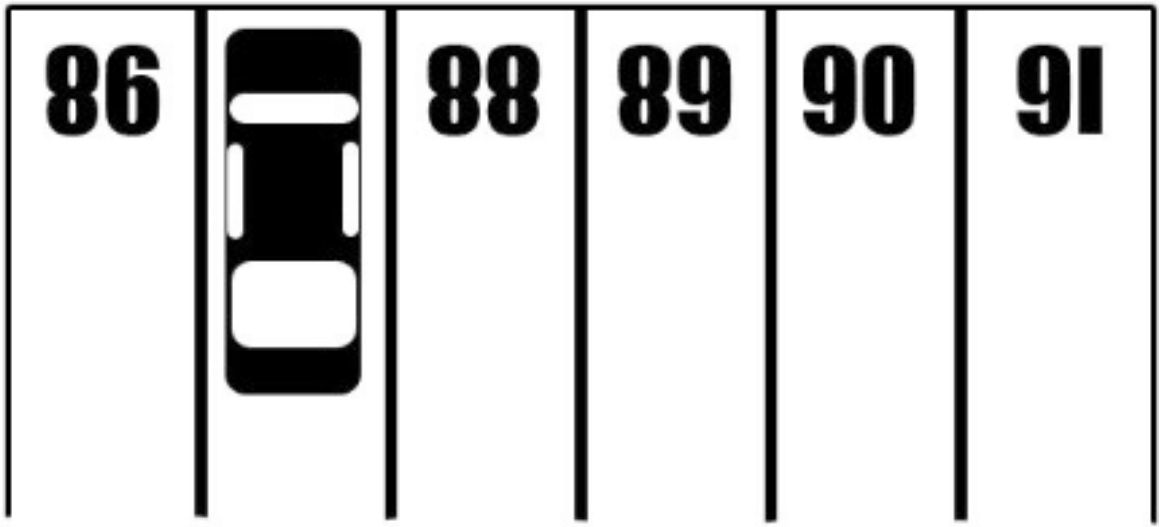
Pop Quiz

What parking slot # is the car in?
Can you do the math?



Perspective

How about now?



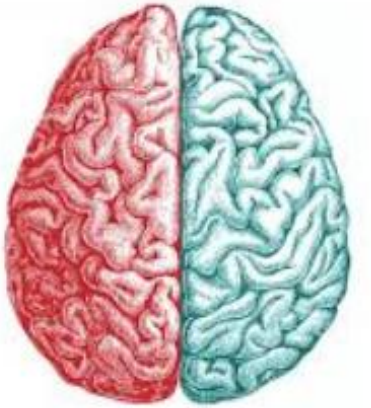
TCP End Point Behavior

- Each end point has a unique perspective
- Independent, yet influenced by the other
- Often during the traffic exchange, TCP stack decisions and actions can be occurring in parallel on each host
- 3rd party actors can also have an affect on behavior

Sixth Sense (1999)

Comparisons

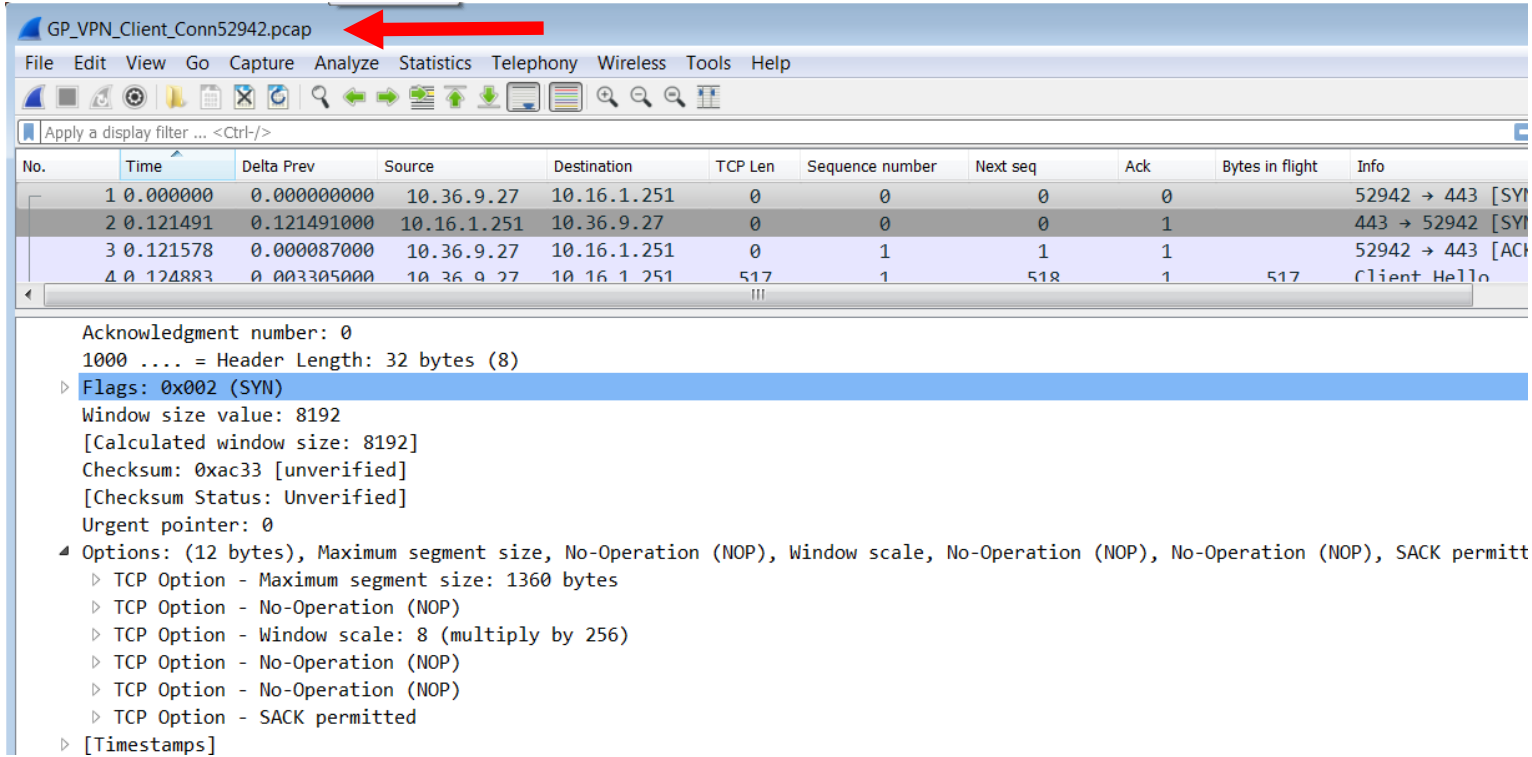
- 3-way handshake
- Latency
- TCP State
- Expert Info
- Fragment Overlaps / OOS / Retransmissions



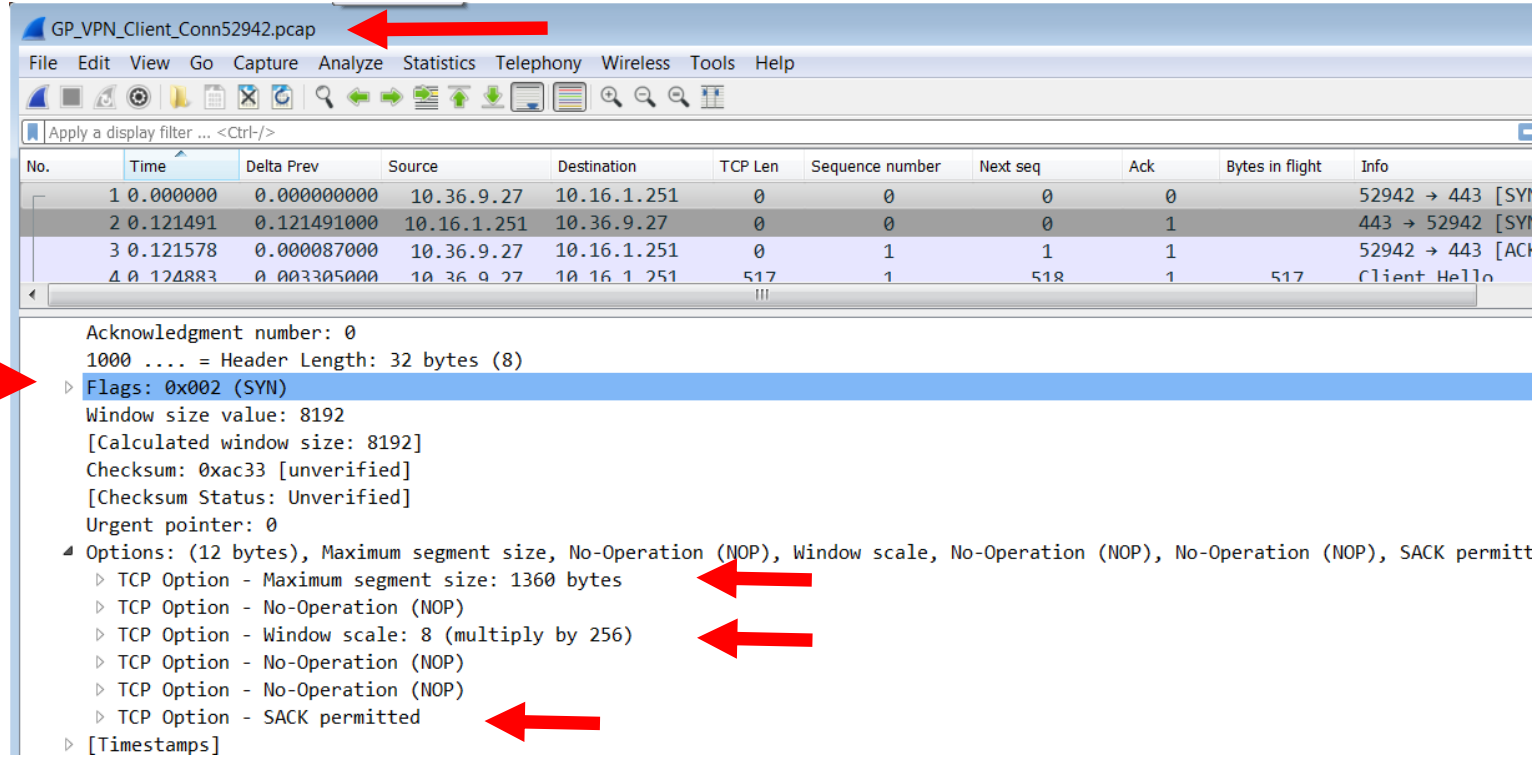
Split Brain Comparisons

- We'll start with the 3-way handshake signaling

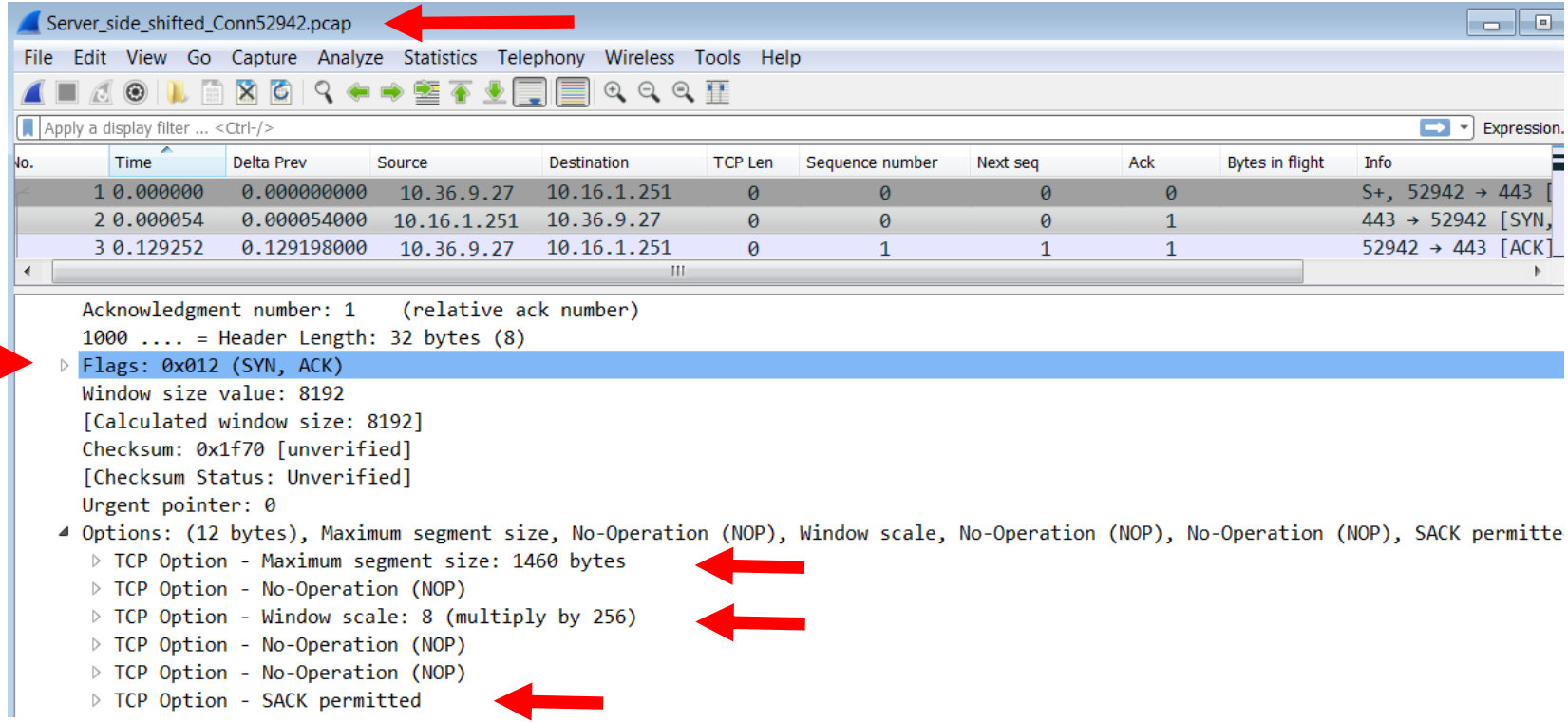
3-Way Handshake - Client



3-Way Handshake - Client



3-Way Handshake - Server



Comparison Chart

TCP Split Brain Comparison Summary (Sender vs. Receiver)				
Item	Topic	Summary	Sender	Receiver
1	SYN Options	MSS, Scaling, TimeStamps, SACK	Negotiation & Adapt, MSS=1460, WS=8, SACK	Negotiation & Adapt, MSS=1360, WS=8, SACK

Learn More about MSS

Google

tcp mss

All Images Videos News Maps More Settings Tools

About 1,330,000 results (0.53 seconds)

The maximum segment size (**MSS**) is a parameter of the options field of the **TCP** header that specifies the largest amount of data, specified in bytes, that a computer or communications device can receive in a single **TCP** segment.

Maximum segment size - Wikipedia
https://en.wikipedia.org › wiki › Maximum_segment_size

About Featured Snippets Feedback

People also ask

What is TCP adjust MSS?

Maximum segment size

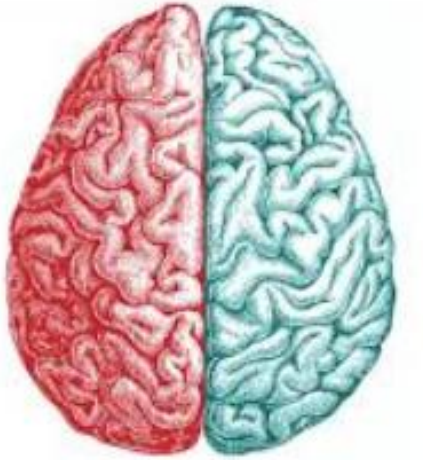
The maximum segment size is a parameter of the options field of the TCP header that specifies the largest amount of data, specified in bytes, that a computer or communications device can receive in a single TCP segment. It does not count the TCP header or the IP header. Wikipedia

Feedback

1st Leg Completed

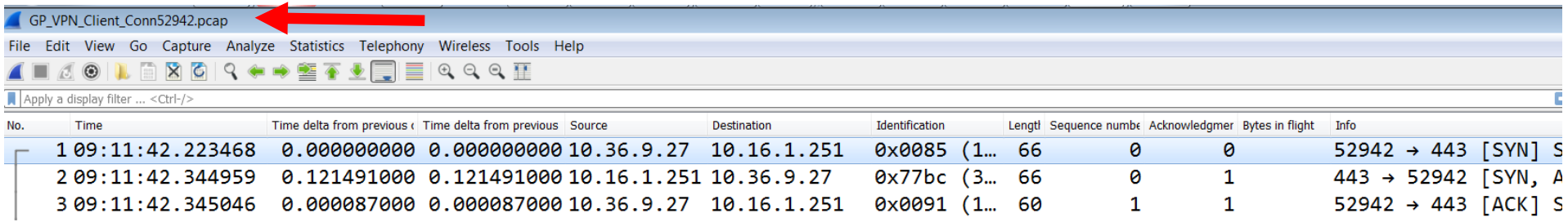
Split Brain Comparisons

- Latency Checks

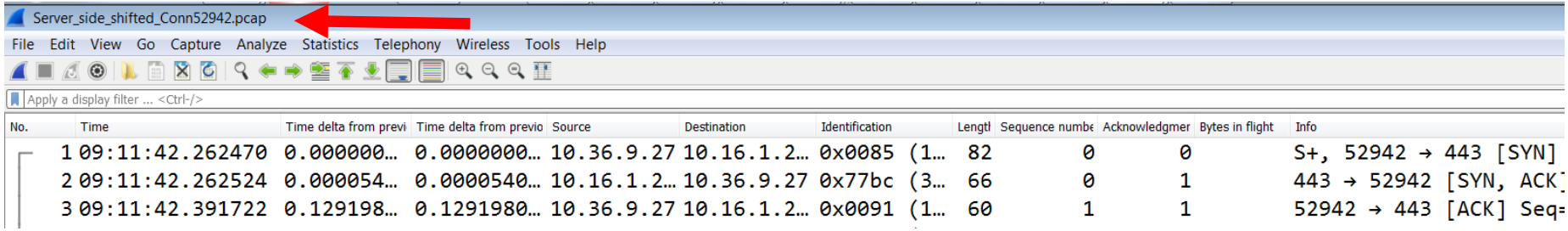


Latency Check

- Client Capture – 121ms



- Server Capture – 129ms



Latency Check

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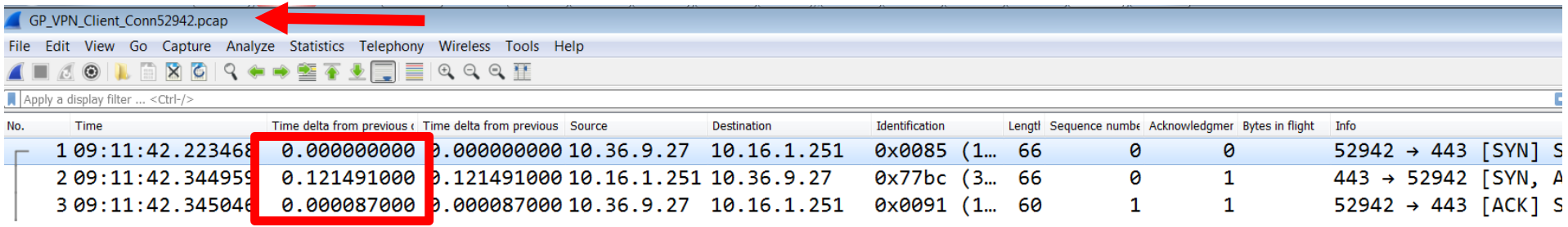
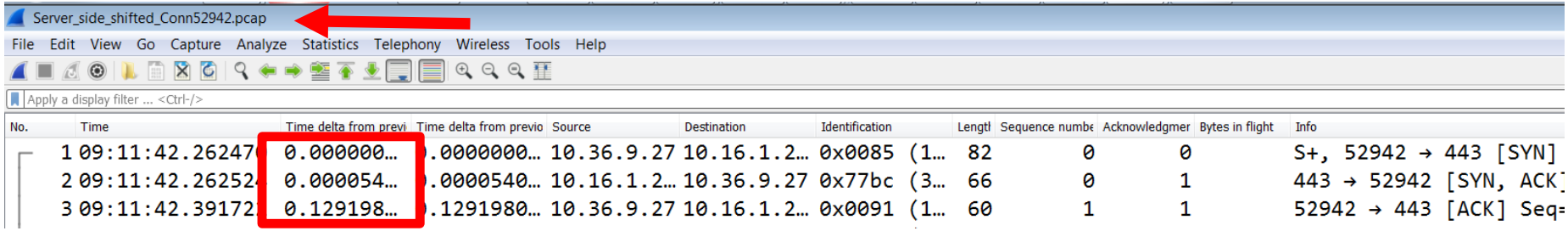


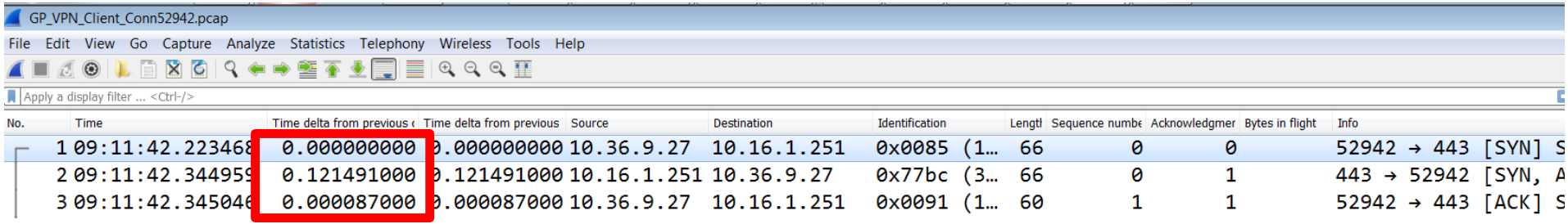
- Server Capture – 129ms

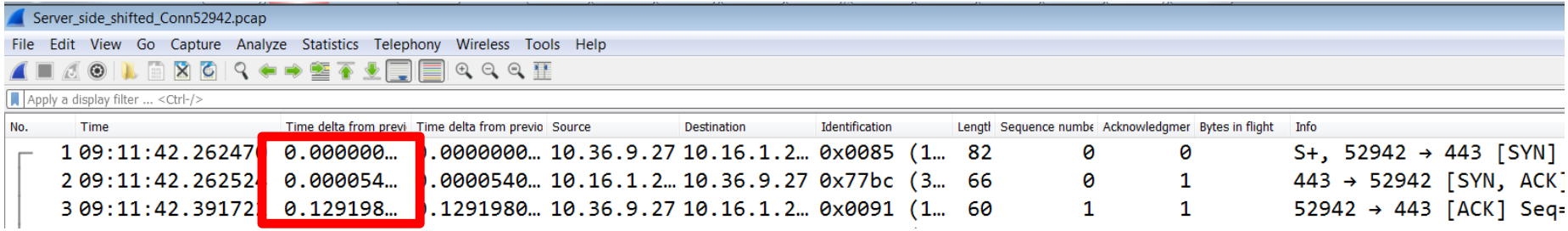


Pop Quiz

- If you've been given a packet capture, and you don't know if it's the server or the client, how can tell?

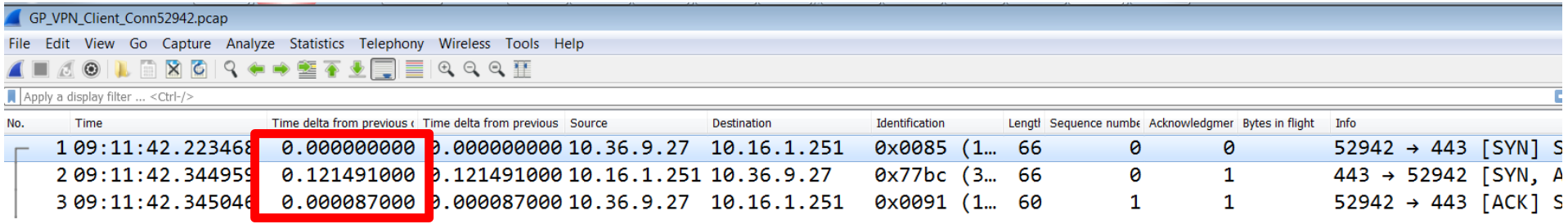
Identify Role from SYN



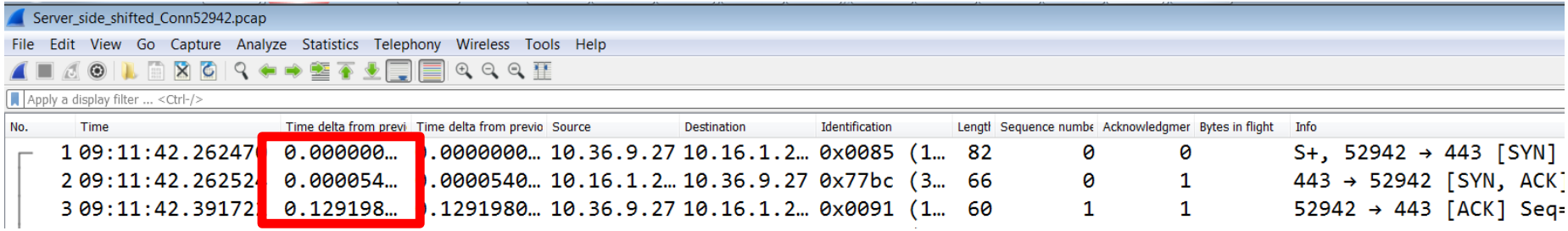


Identify Role from SYN

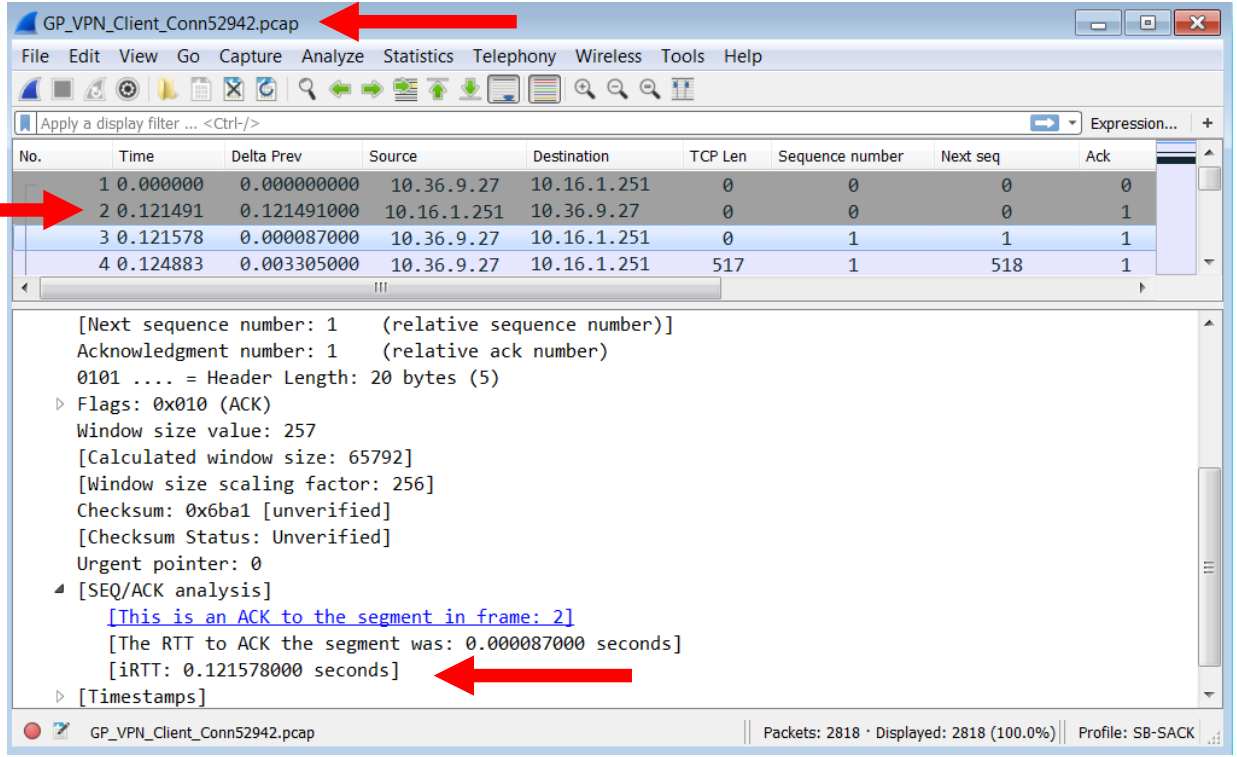
If SYN+ACK has high time delta, then capture came from client



If ACK has high time delta, then capture came from client



Wireshark i(nitial)RTT



0:15

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2	Latency	Can be different in each direction	Client iRTT == 121ms	Server iRTT == 129ms

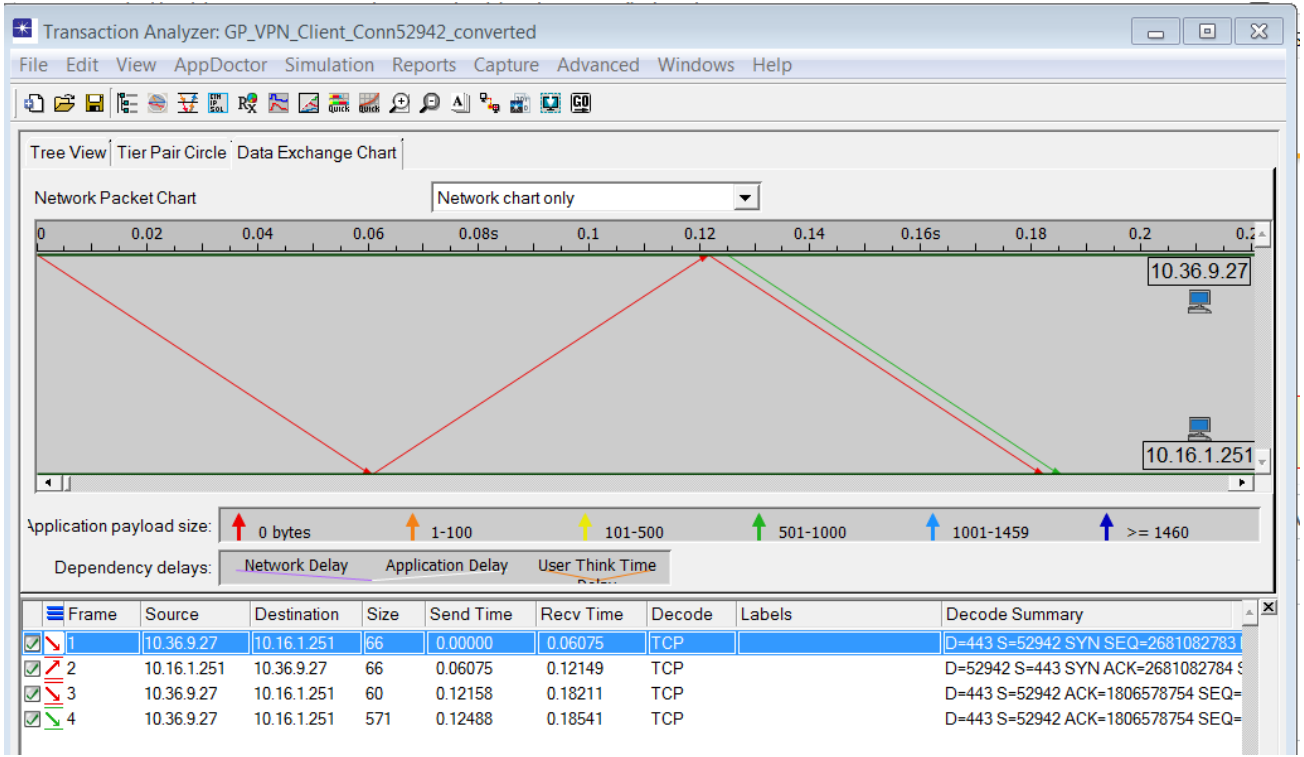
2nd Leg Completed

What if we could visualize the traffic exchanges?

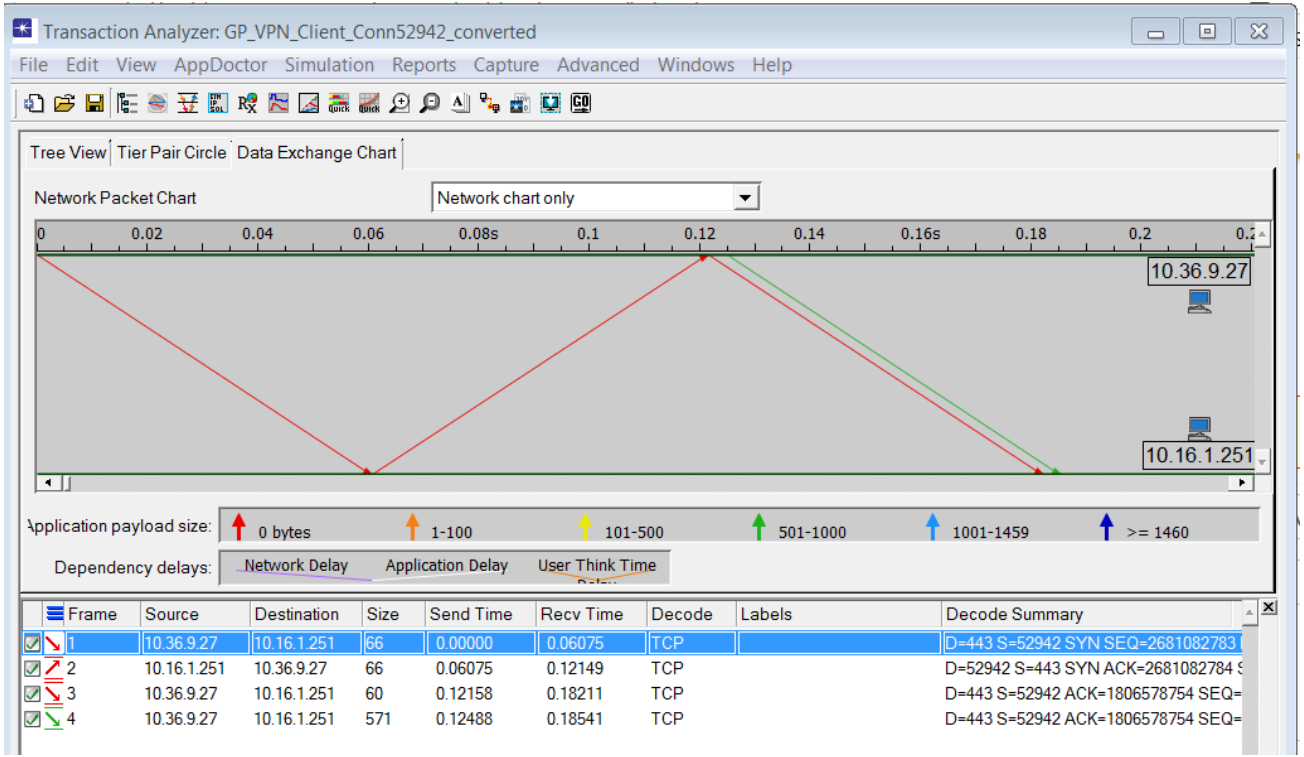
- Traffic bouncing between hosts
- Frequency, density, duration over time
- Transfer time
- Expert analytics overlaid with the visualized traffic

- If only there were such a capability…

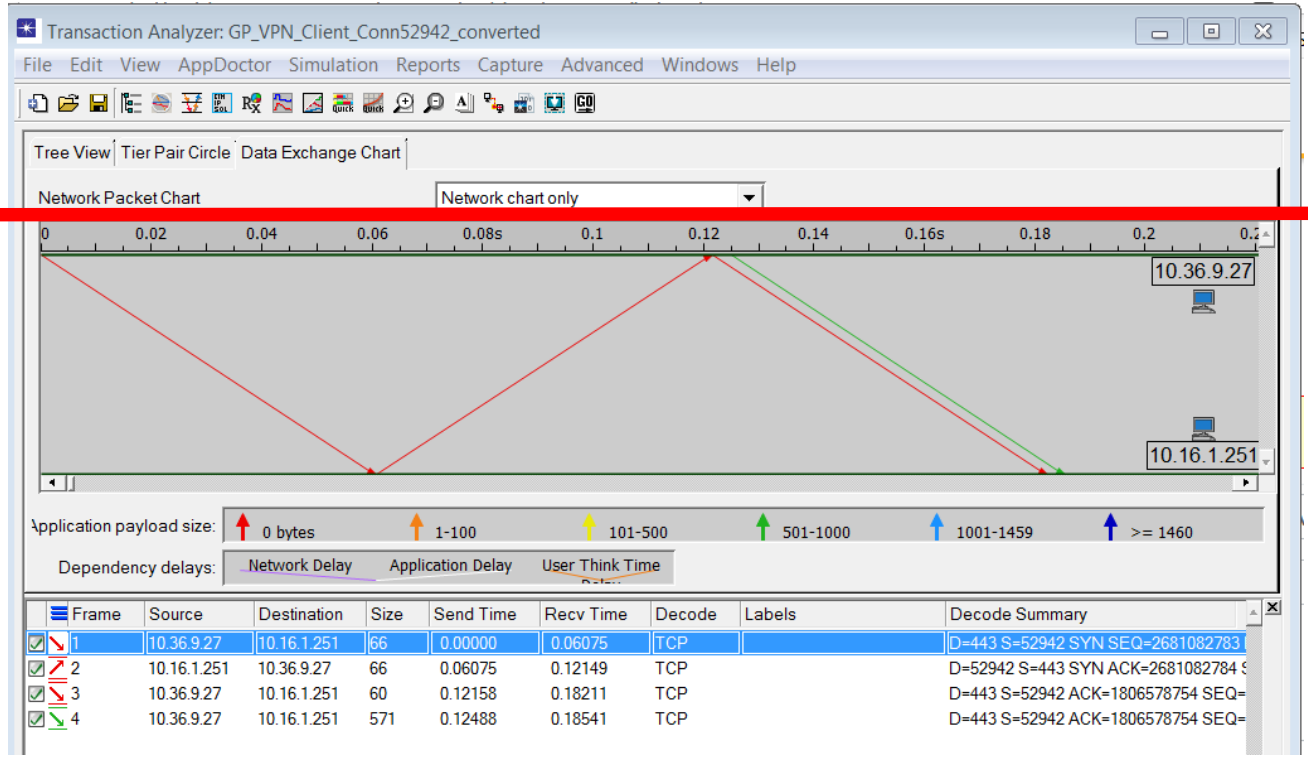
Visualize Traffic over Time



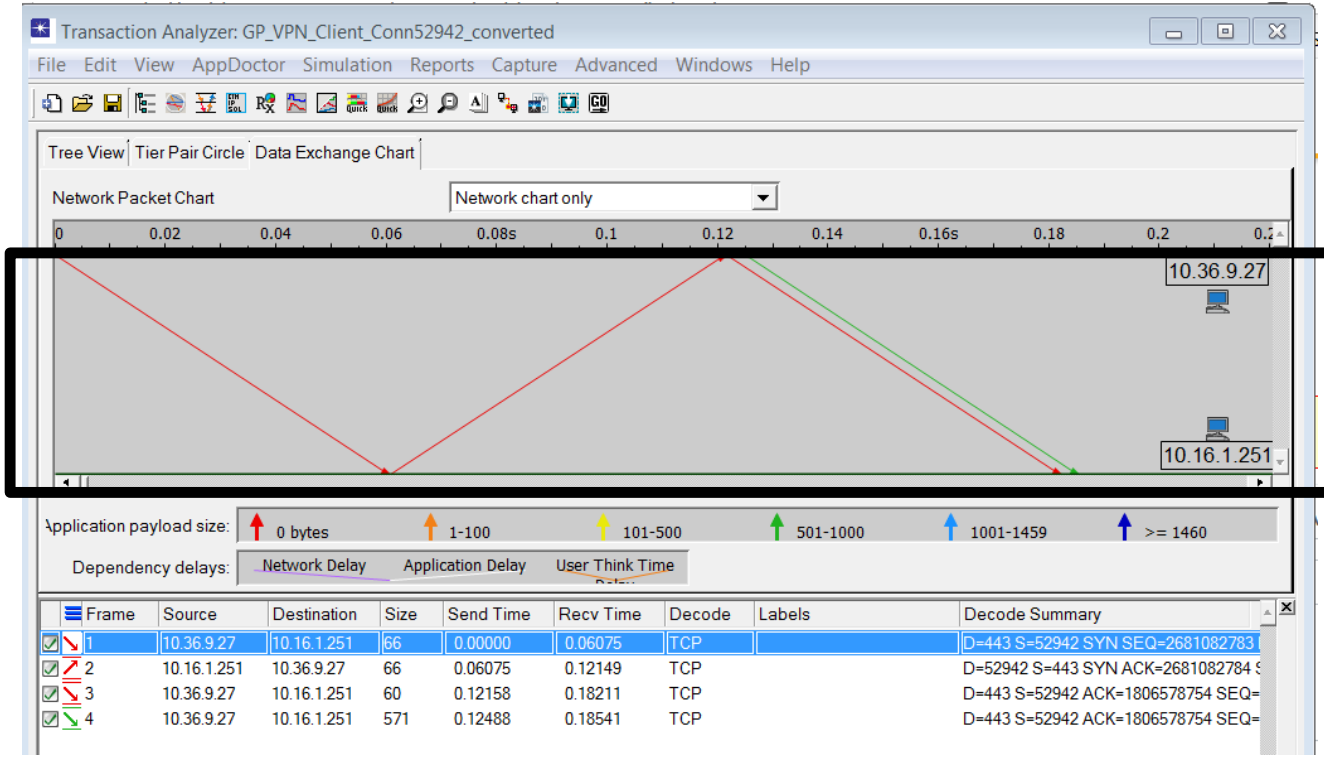
Quick Orientation



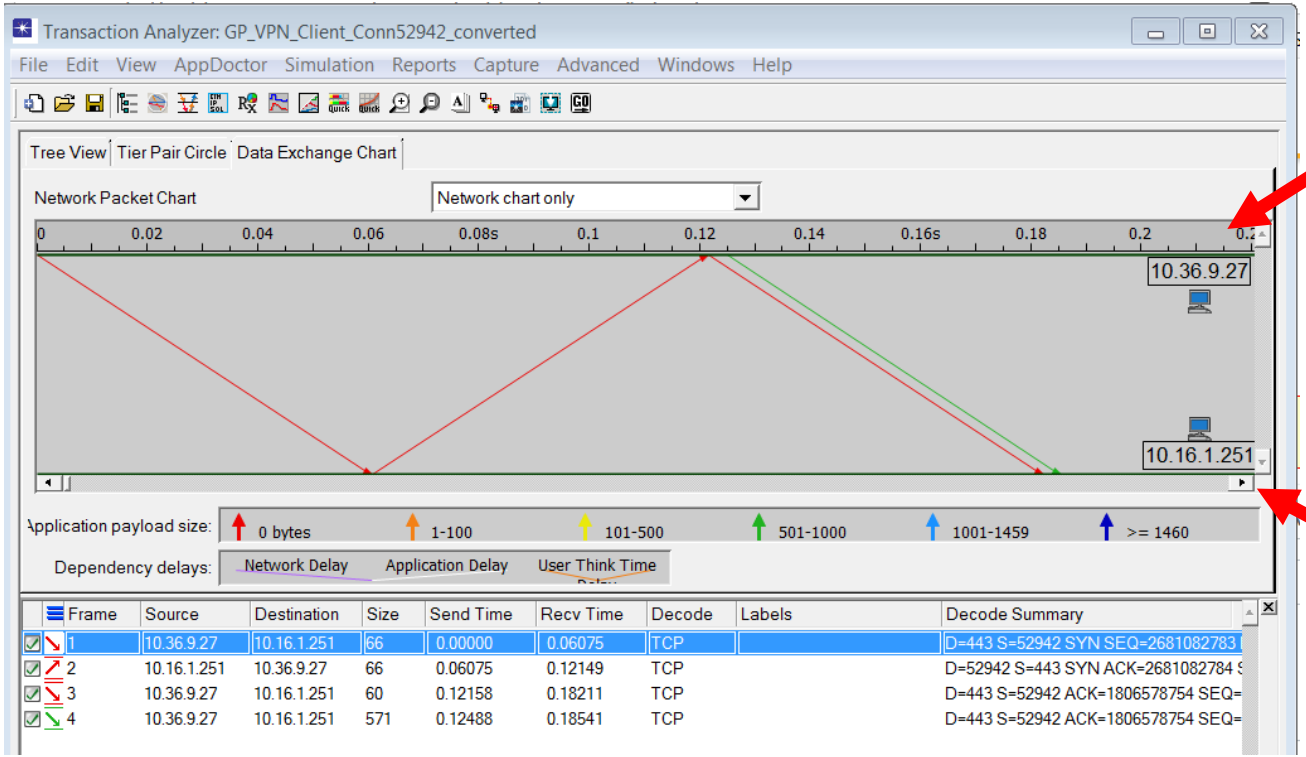
Time Moves Left to Right



Swimlane


Transaction Analyzer: GP_VPN_Client_Conn52942_converted
File Edit View AppDoctor Simulation Reports Capture Advanced Windows Help
Tree View Tier Pair Circle Data Exchange Chart
Network Packet Chart
Network chart only
0 0.02 0.04 0.06 0.08s 0.1 0.12 0.14 0.16s 0.18 0.2
10.36.9.27
10.16.1.251
Application payload size:
0 bytes 1-100 101-500 501-1000 1001-1459 >= 1460
Dependency delays:
Network Delay Application Delay User Think Time
Frame Source Destination Size Send Time Recv Time Decode Labels Decode Summary
1 10.36.9.27 10.16.1.251 66 0.00000 0.06075 TCP D=443 S=52942 SYN SEQ=2681082783
2 10.16.1.251 10.36.9.27 66 0.06075 0.12149 TCP D=52942 S=443 SYN ACK=2681082784
3 10.36.9.27 10.16.1.251 60 0.12158 0.18211 TCP D=443 S=52942 ACK=1806578754 SEQ=
4 10.36.9.27 10.16.1.251 571 0.12488 0.18541 TCP D=443 S=52942 ACK=1806578754 SEQ=

Top and Bottom of Swimlane

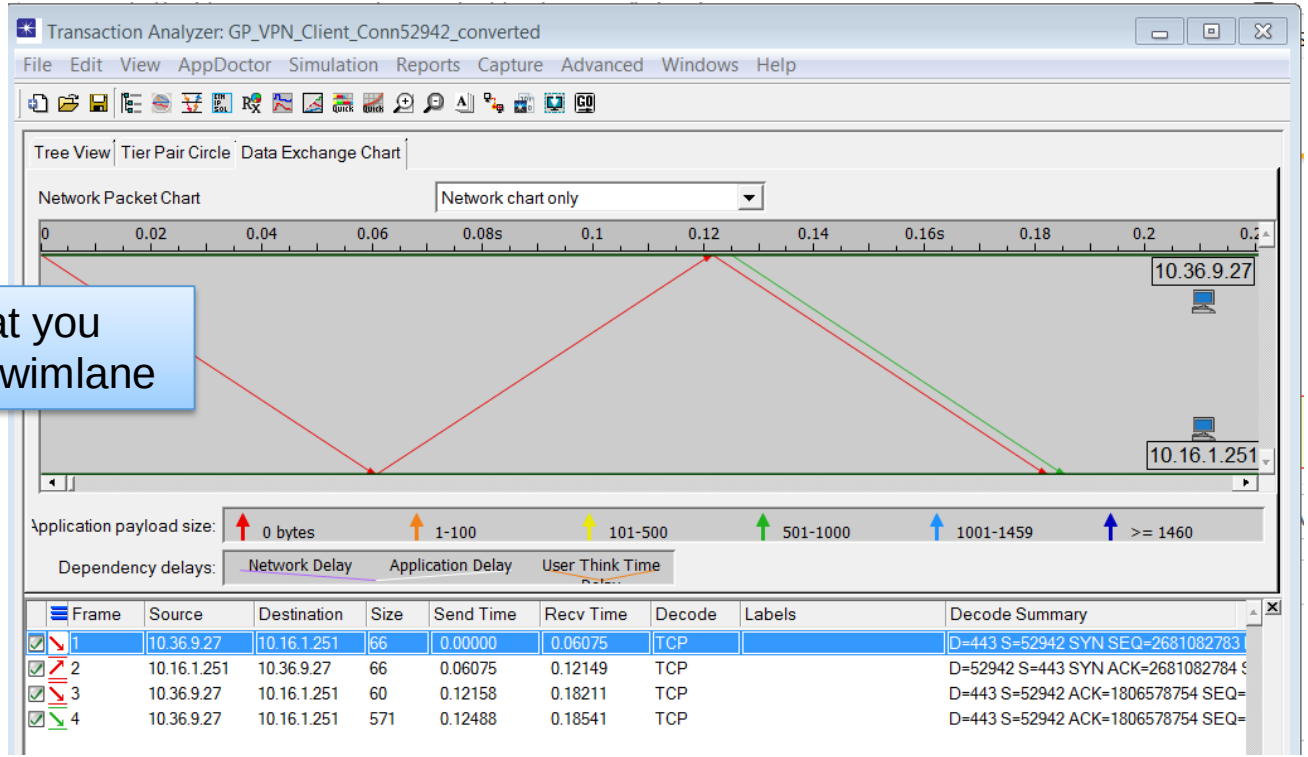


Client

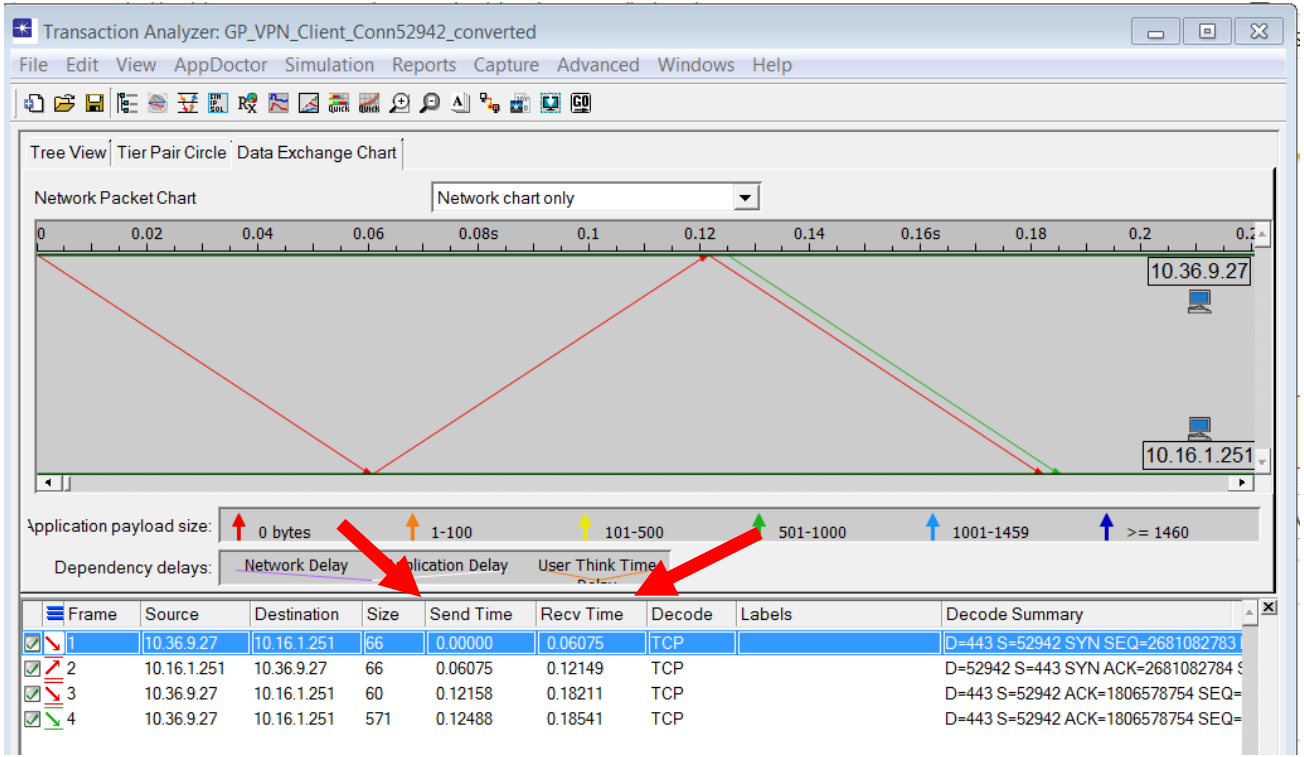
Server

Optional Summary Decodes

Based on what you select in the swimlane



Send Time / Recv Time



Estimated vs. Actual Times

- Essential aspect of TCP Split Brain
- Each capture has the actual times a packet is sent or received from / to the host running the capture
- Using what we do know, we can estimate what we don’t know

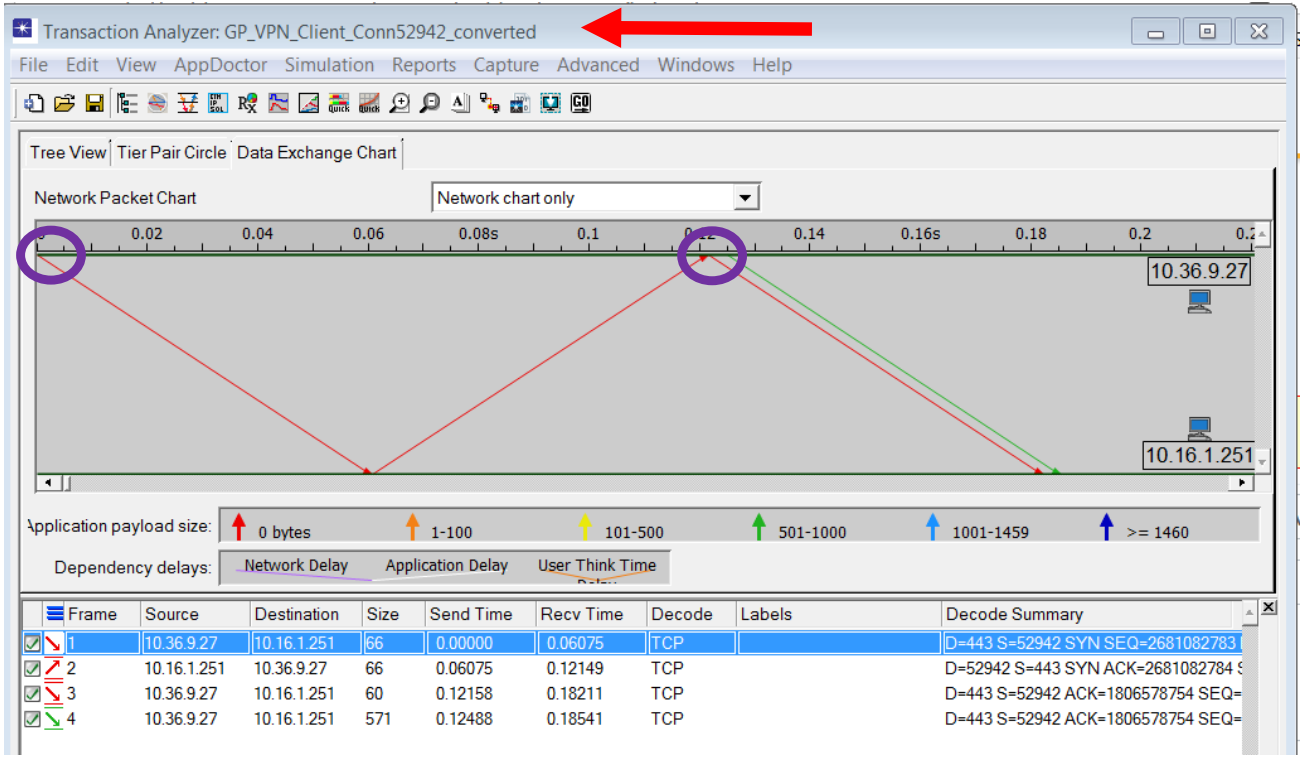
Estimated vs. Actual Times

- If we know when we received a packet…
- … and we have an idea of latency…
- …we can make a reasonable estimate about the time it was transmitted from the other host

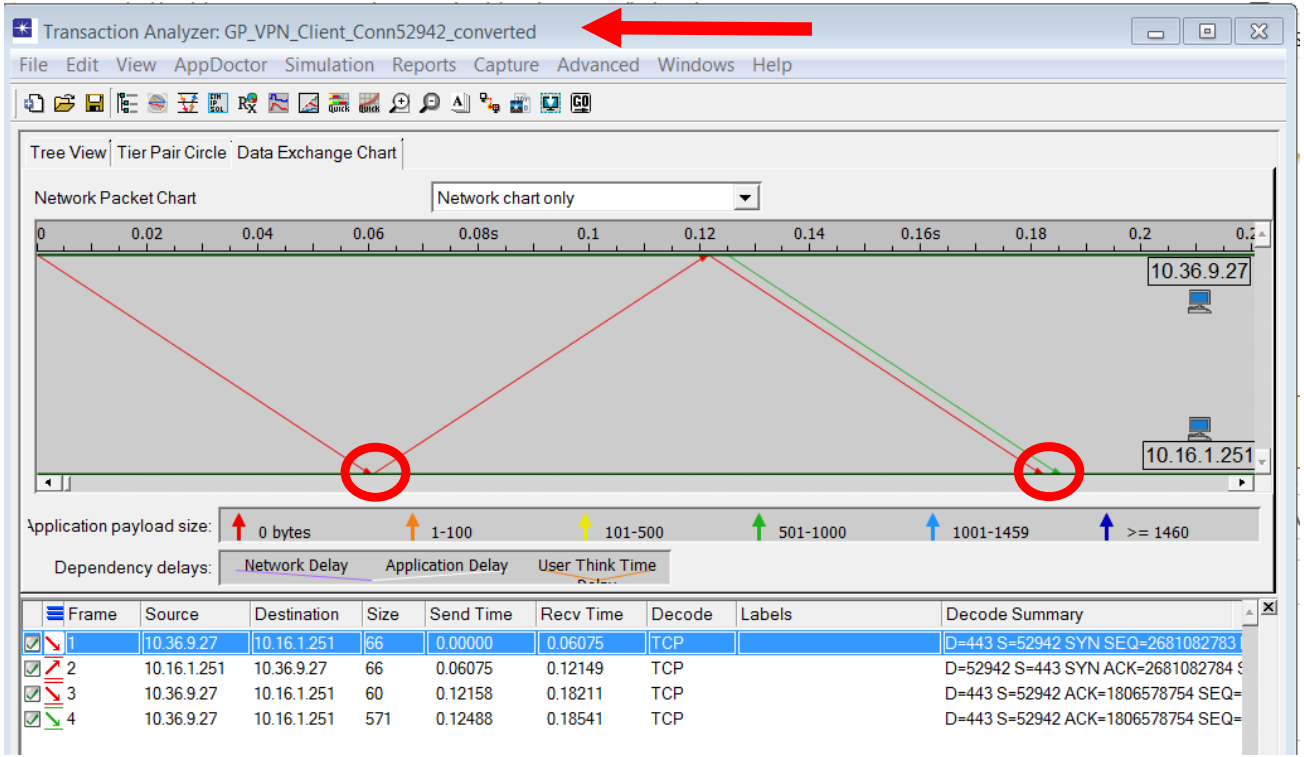
Estimated vs. Actual Times

- If we know when a packet was transmitted…
- …and we have an idea of latency…
- …we can make a reasonable estimate about the time it was received at other host

Example: What we know



Here's what we can estimate



Affairs of State

- Now let’s look at how we can use the visualization to understand the TCP state of each end point at a given point in time

RFC 793: TCP State Overview

```
    TCP A                                                TCP B

1.  CLOSED                                               LISTEN

2.  SYN-SENT    --> <SEQ=100><CTL=SYN>               --> SYN-RECEIVED

3.  ESTABLISHED <-- <SEQ=300><ACK=101><CTL=SYN,ACK>  <-- SYN-RECEIVED

4.  ESTABLISHED --> <SEQ=101><ACK=301><CTL=ACK>       --> ESTABLISHED

5.  ESTABLISHED --> <SEQ=101><ACK=301><CTL=ACK><DATA> --> ESTABLISHED

        Basic 3-Way Handshake for Connection Synchronization
```

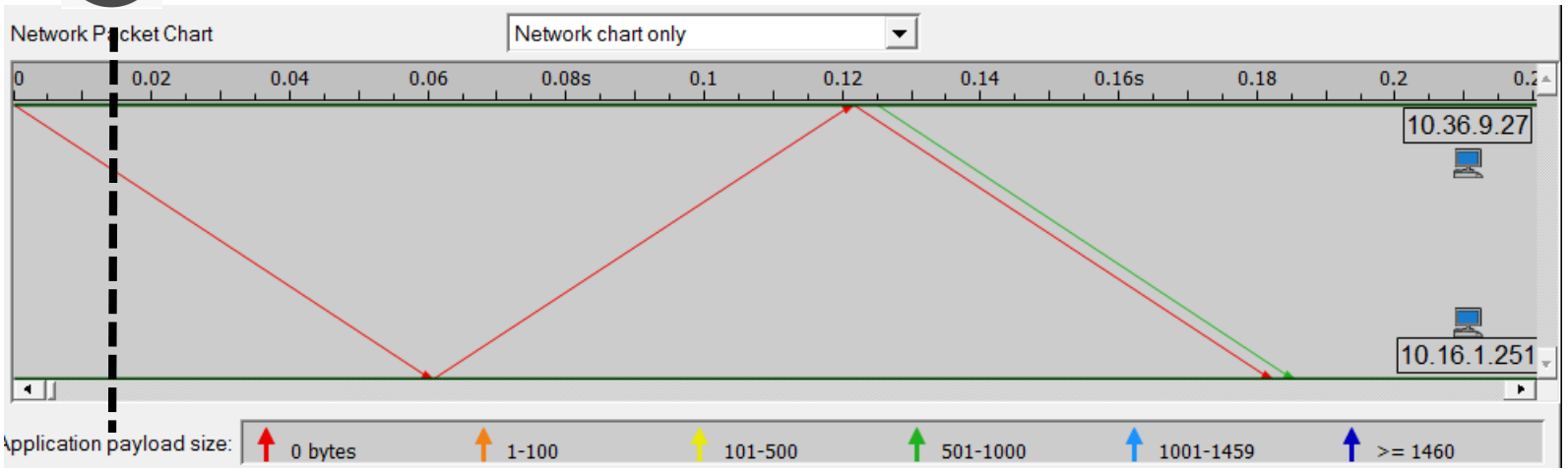
Stopwatch to Freeze Time

Split Brain – State Discussion

What is the TCP State of each host at this timepoint?

Client

Server



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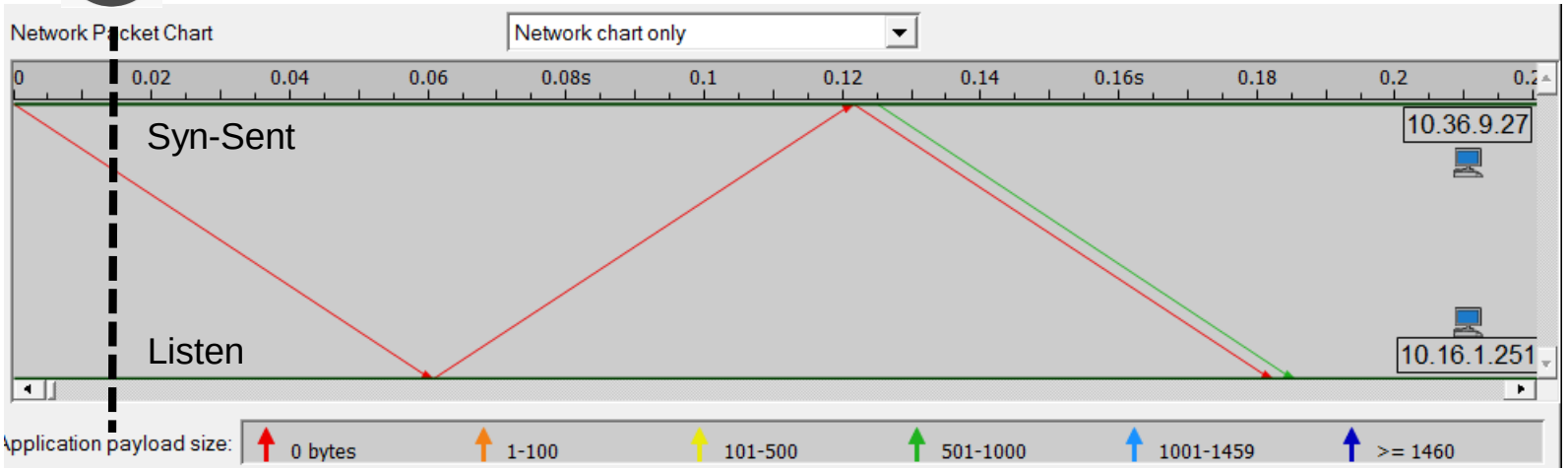
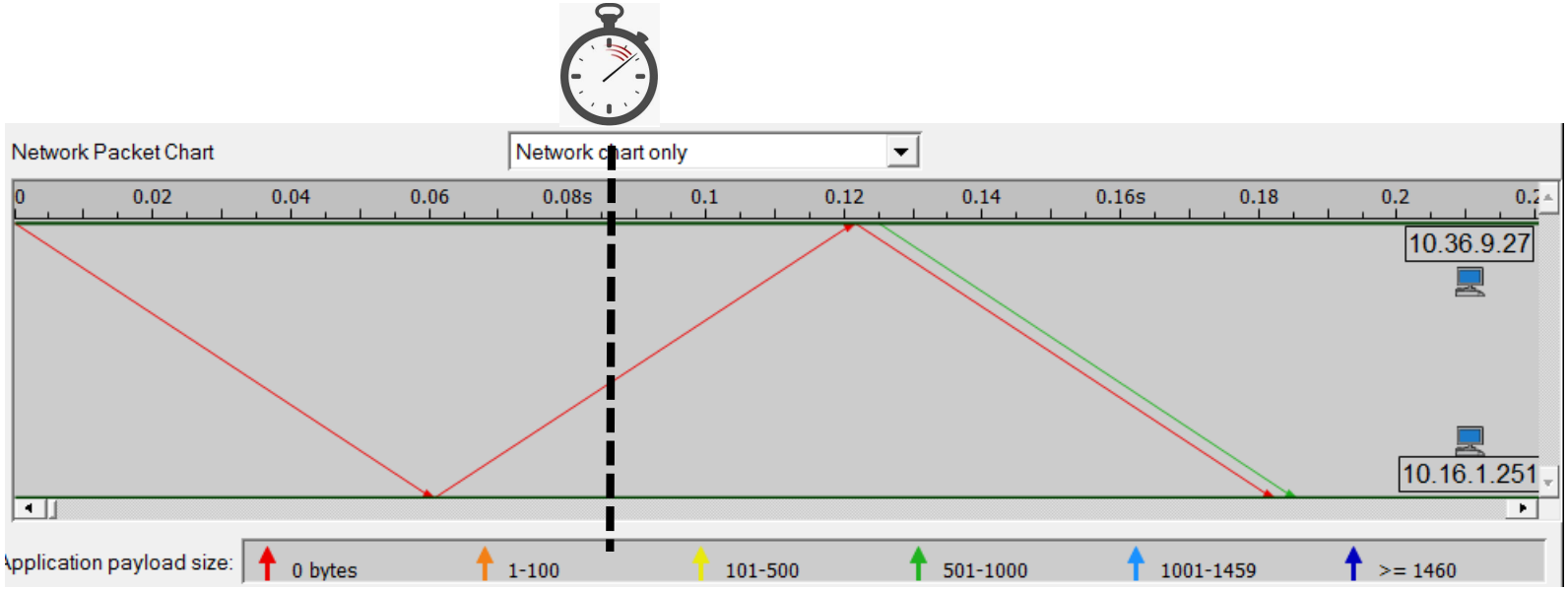
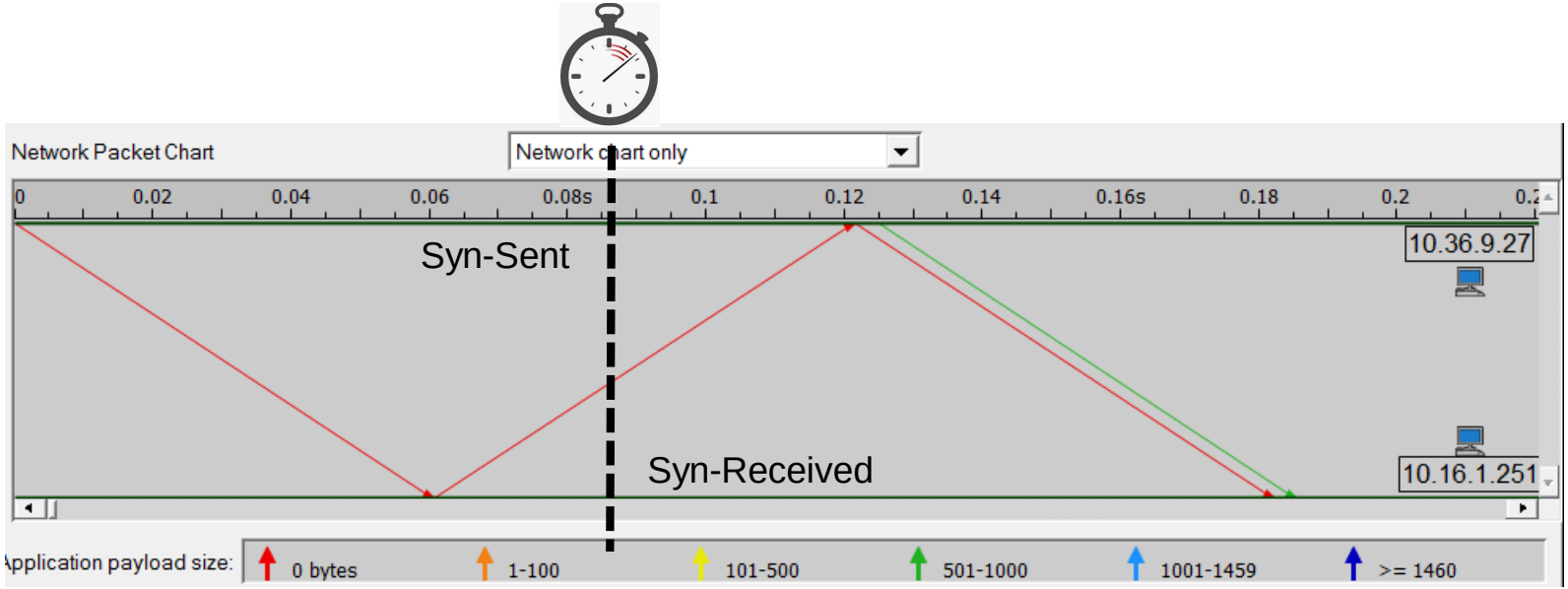


Split Brain – State Discussion



Split Brain – State Discussion



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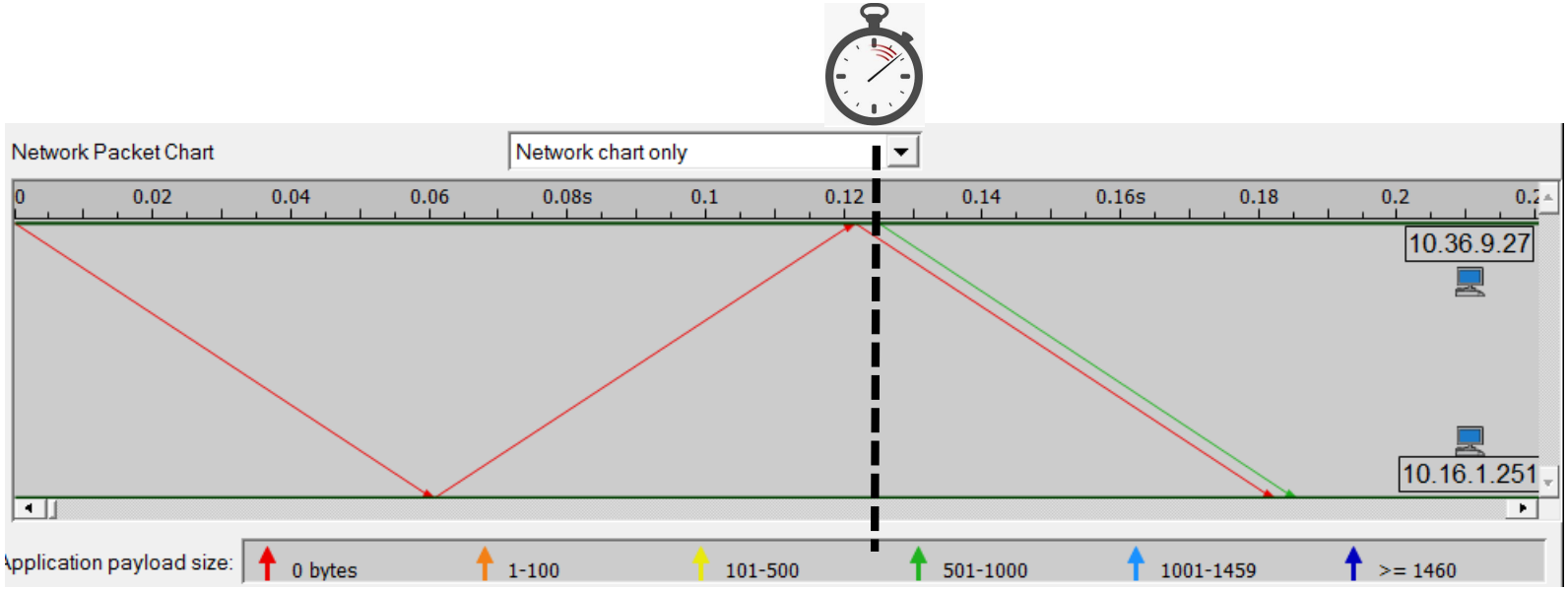

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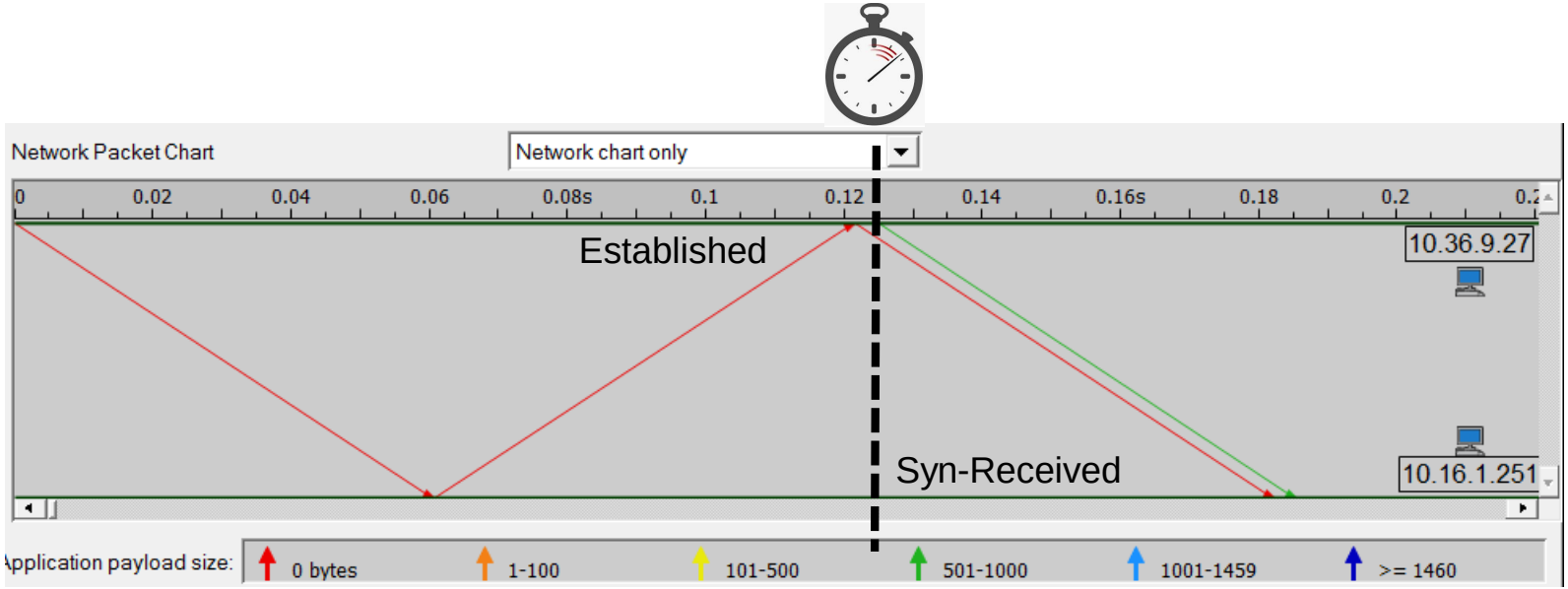

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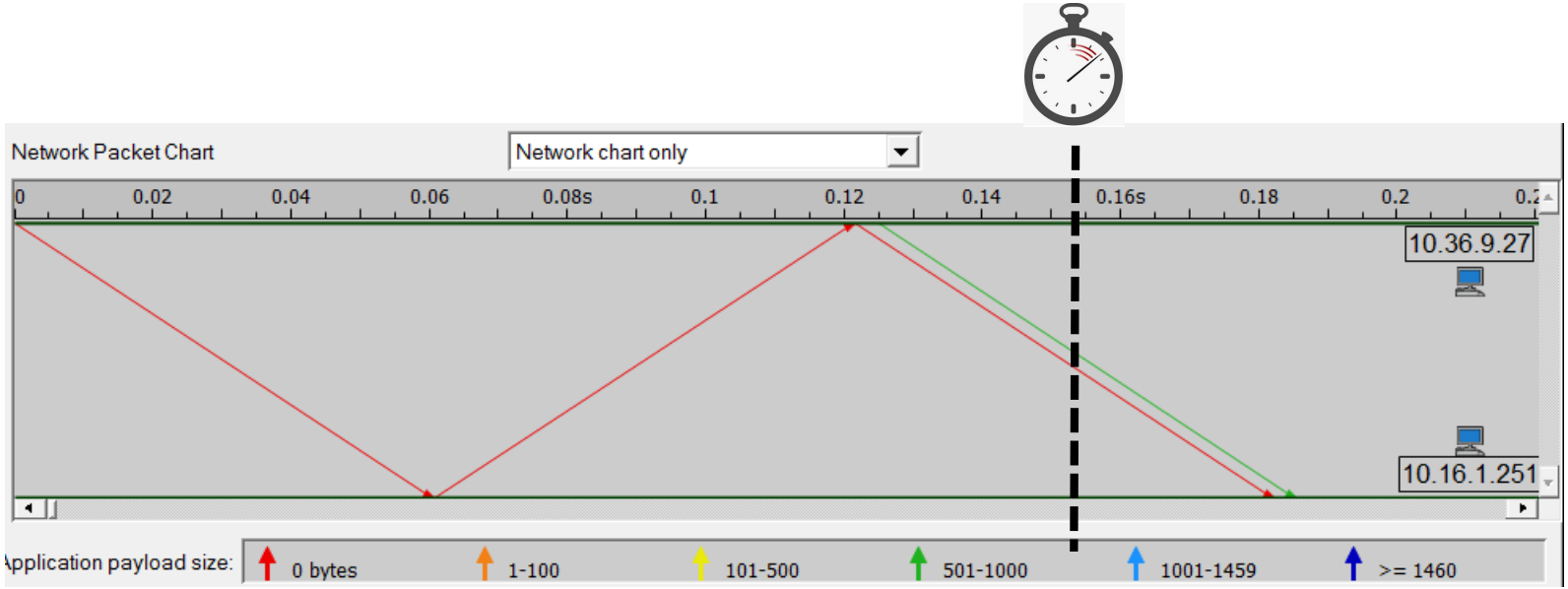
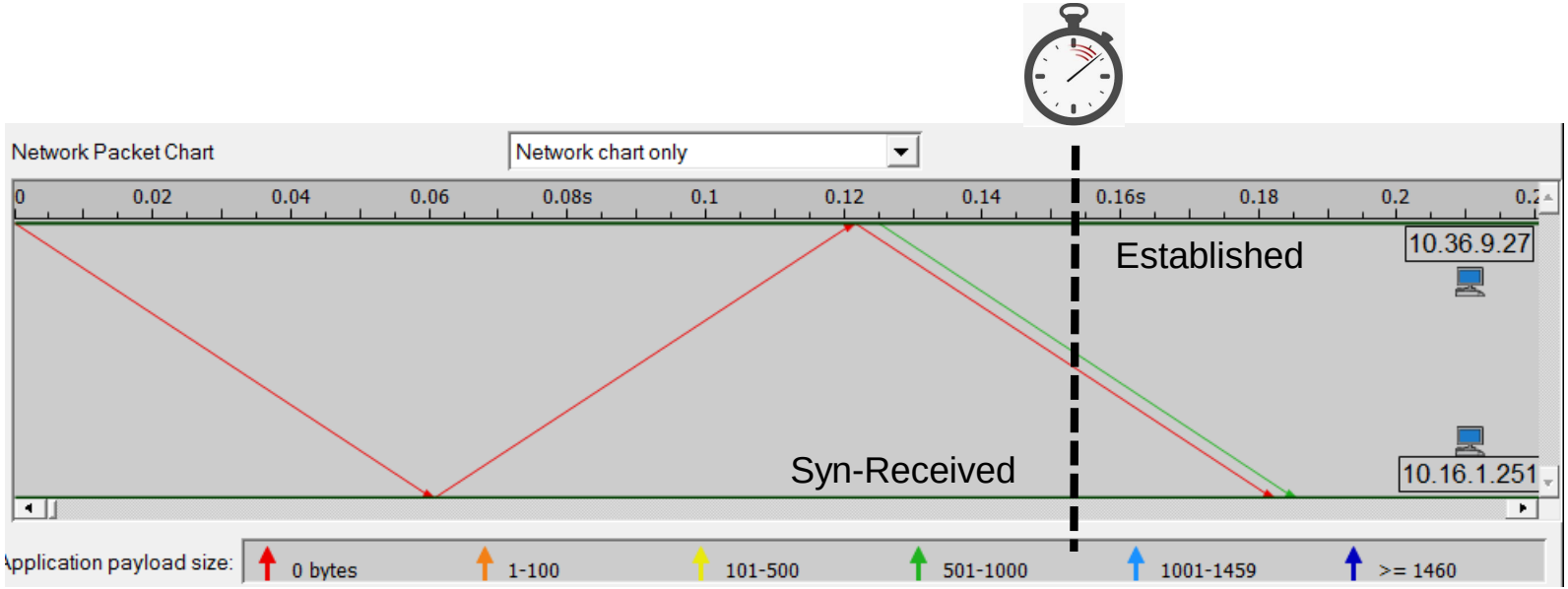
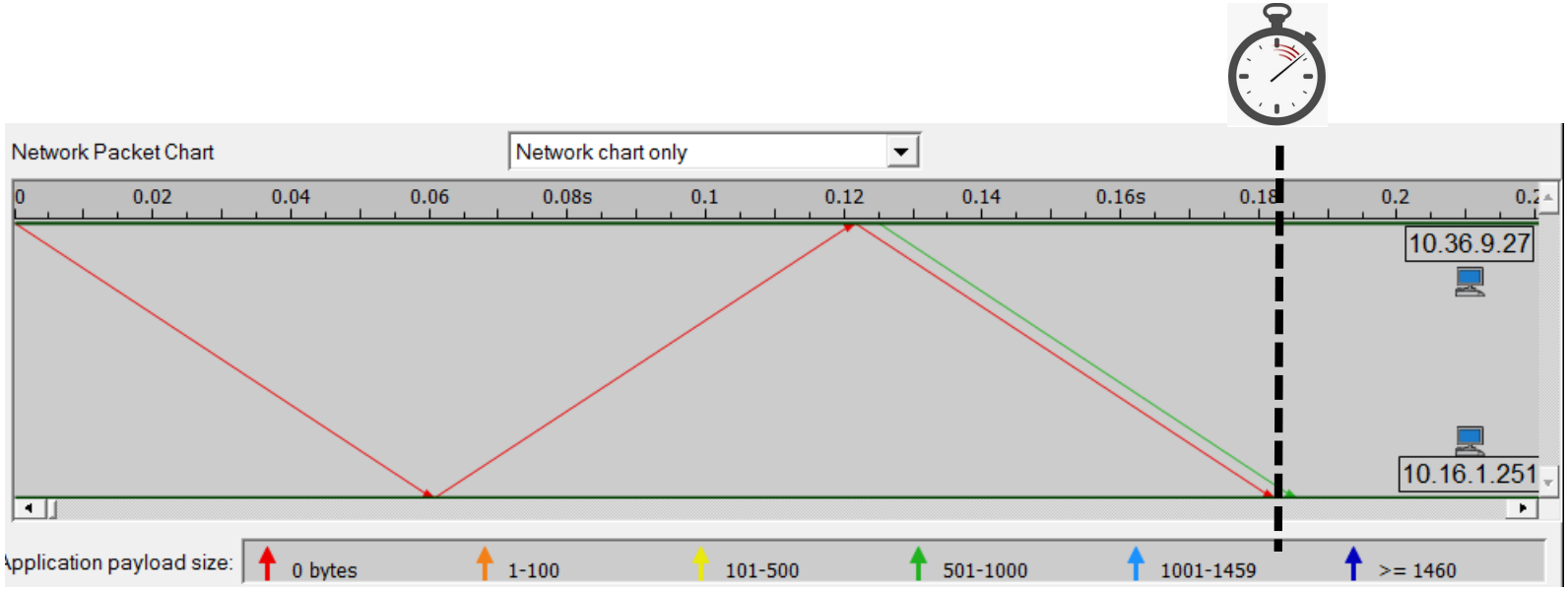


Split Brain – State Discussion



Split Brain – State Discussion



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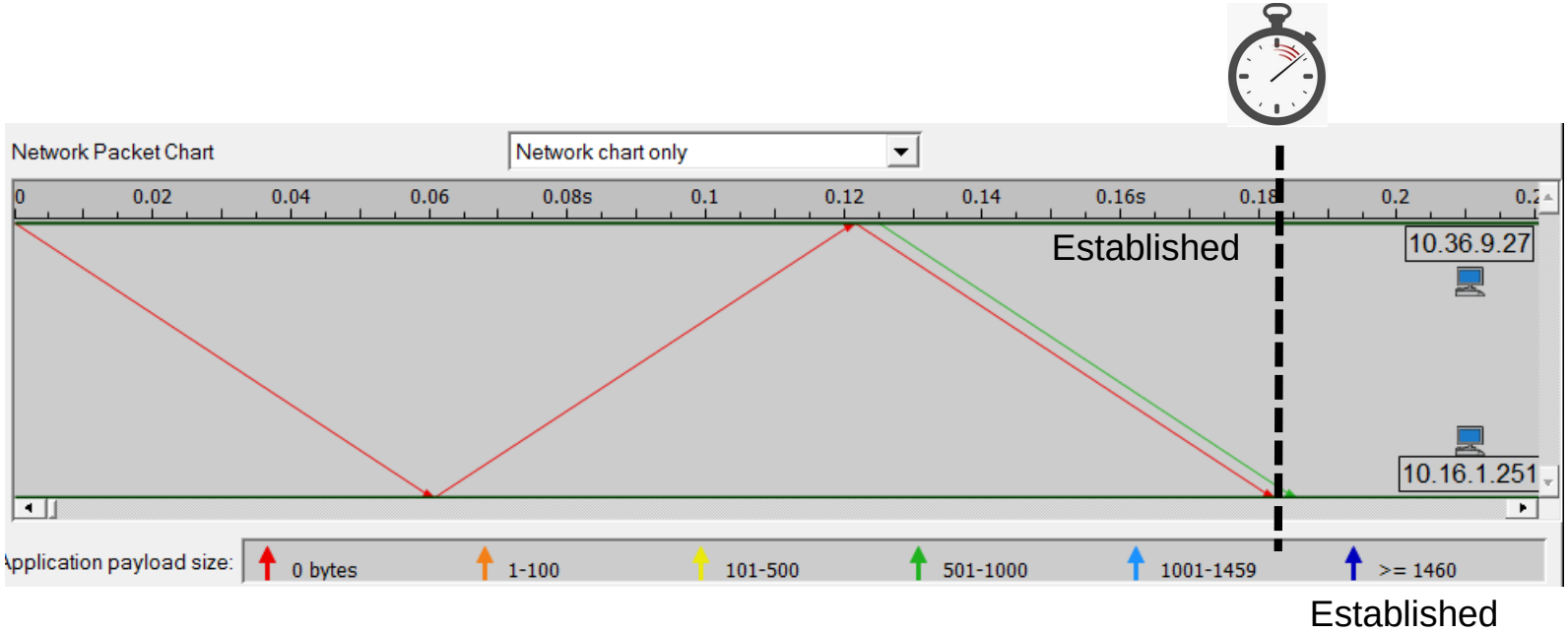

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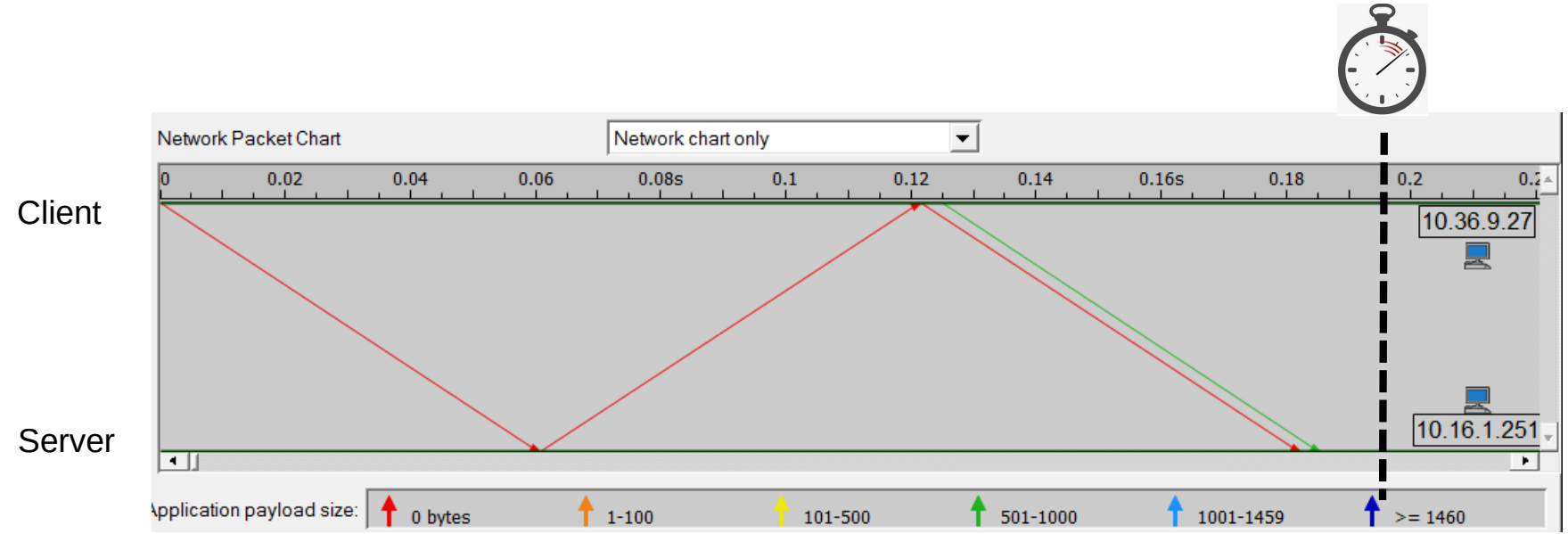

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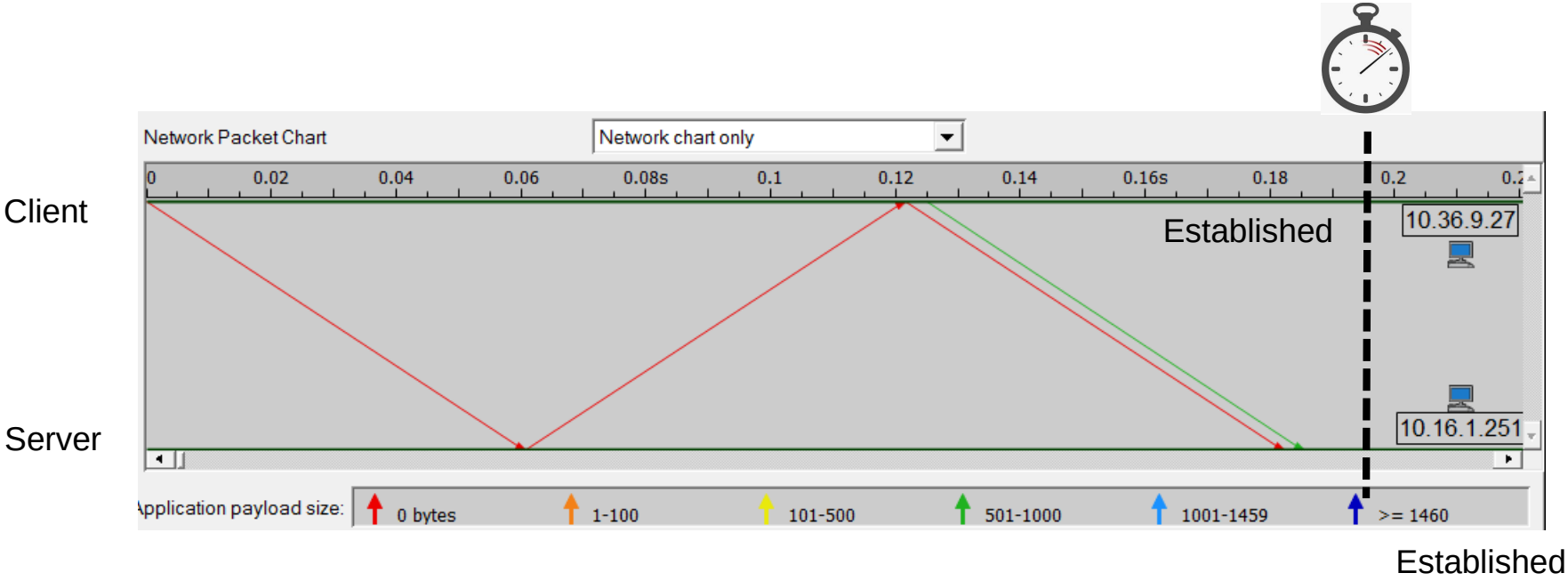


Discussion

- Do you currently consider the send/receive time of the “other end point” when you do analysis?
- Do you think about each side’s TCP state?
- We’re just getting started on our journey…

Comparison Summary

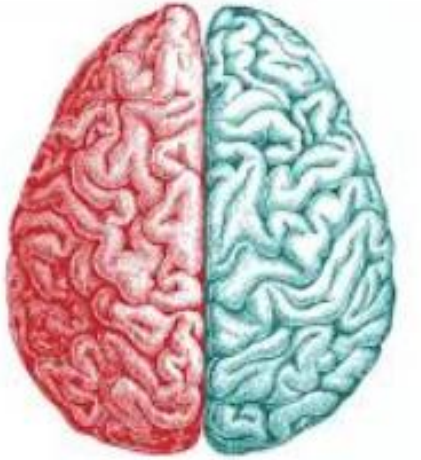
TCP Split Brain Comparison Summary (Sender vs. Receiver)

Item	Topic	Summary	Sender	Receiver
1	SYN Options	MSS, Scaling, TimeStamps, SACK	Negotiation & Adapt, MSS=1460, WS=8, SACK	Negotiation & Adapt, MSS=1360, WS=8, SACK
2	Latency	Can be different in each direction	Client iRTT == 121ms	Server iRTT == 129ms
3	TCP State	Different States at startup and shutdown; state change only occurs when packet sent / received	Closed, SYN-Sent, Established	Listen, SYN-Received, Established

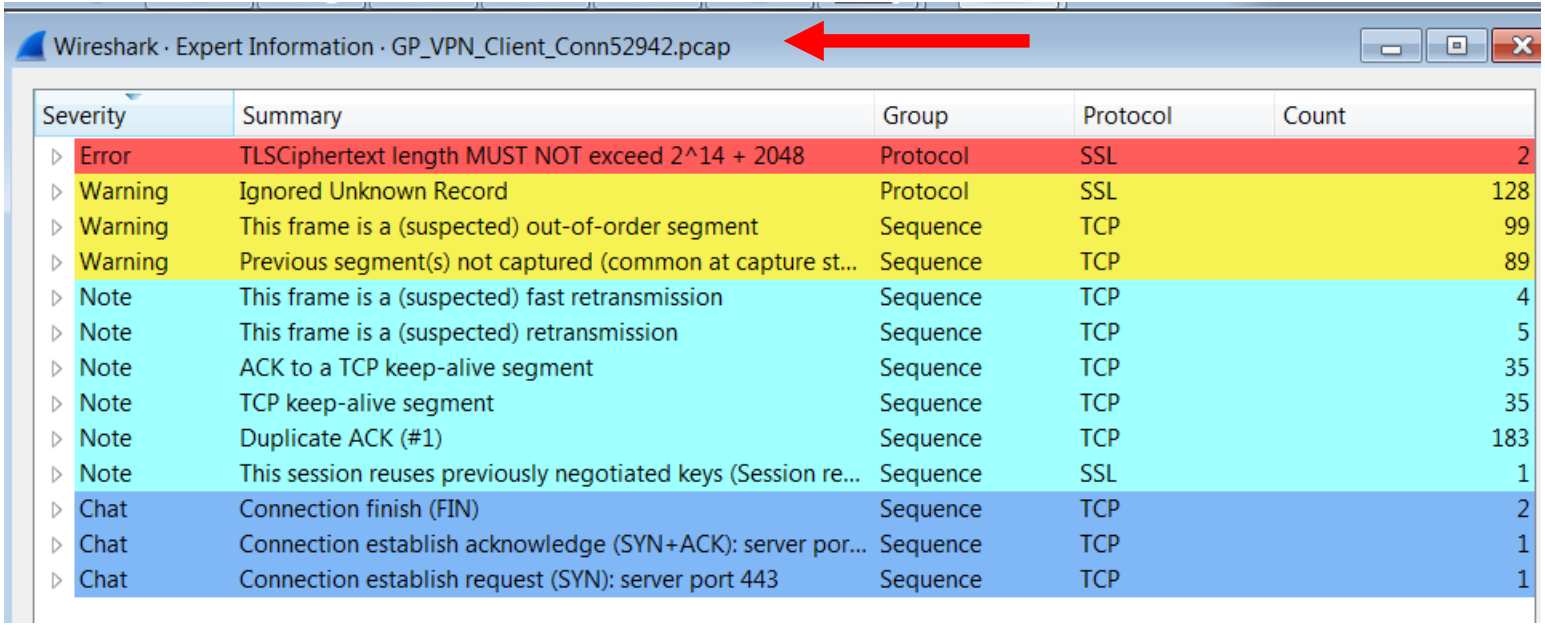
3rd Leg Completed

Split Brain Comparisons

- Next we'll compare Wireshark Expert Info for Client vs. Server capture for a single connection



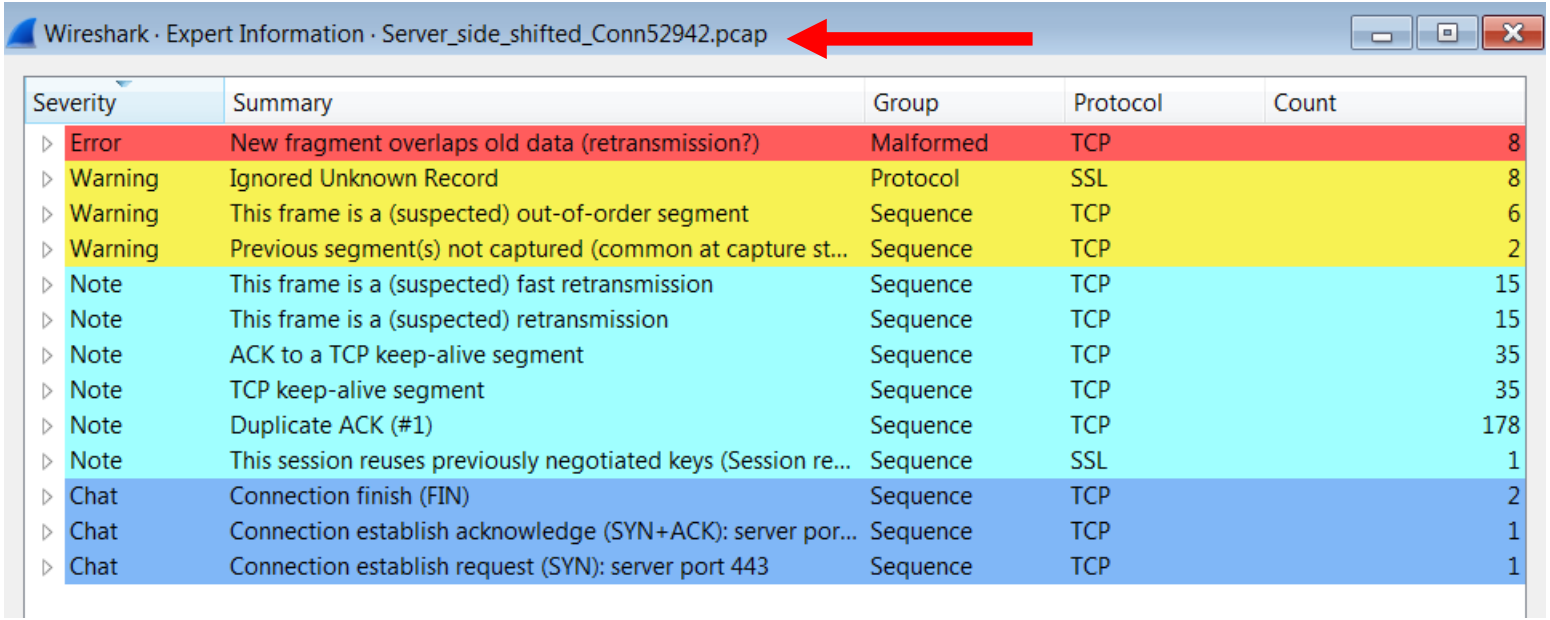
Client Conn52942



Severity	Summary	Group	Protocol	Count
Error	TLSCiphertext length MUST NOT exceed 2^14 + 2048	Protocol	SSL	2
Warning	Ignored Unknown Record	Protocol	SSL	128
Warning	This frame is a (suspected) out-of-order segment	Sequence	TCP	99
Warning	Previous segment(s) not captured (common at capture st...	Sequence	TCP	89
Note	This frame is a (suspected) fast retransmission	Sequence	TCP	4
Note	This frame is a (suspected) retransmission	Sequence	TCP	5
Note	ACK to a TCP keep-alive segment	Sequence	TCP	35
Note	TCP keep-alive segment	Sequence	TCP	35
Note	Duplicate ACK (#1)	Sequence	TCP	183
Note	This session reuses previously negotiated keys (Session re...	Sequence	SSL	1
Chat	Connection finish (FIN)	Sequence	TCP	2
Chat	Connection establish acknowledge (SYN+ACK): server por...	Sequence	TCP	1
Chat	Connection establish request (SYN): server port 443	Sequence	TCP	1

* Same results in Wireshark 3.0.5

Server Conn52942

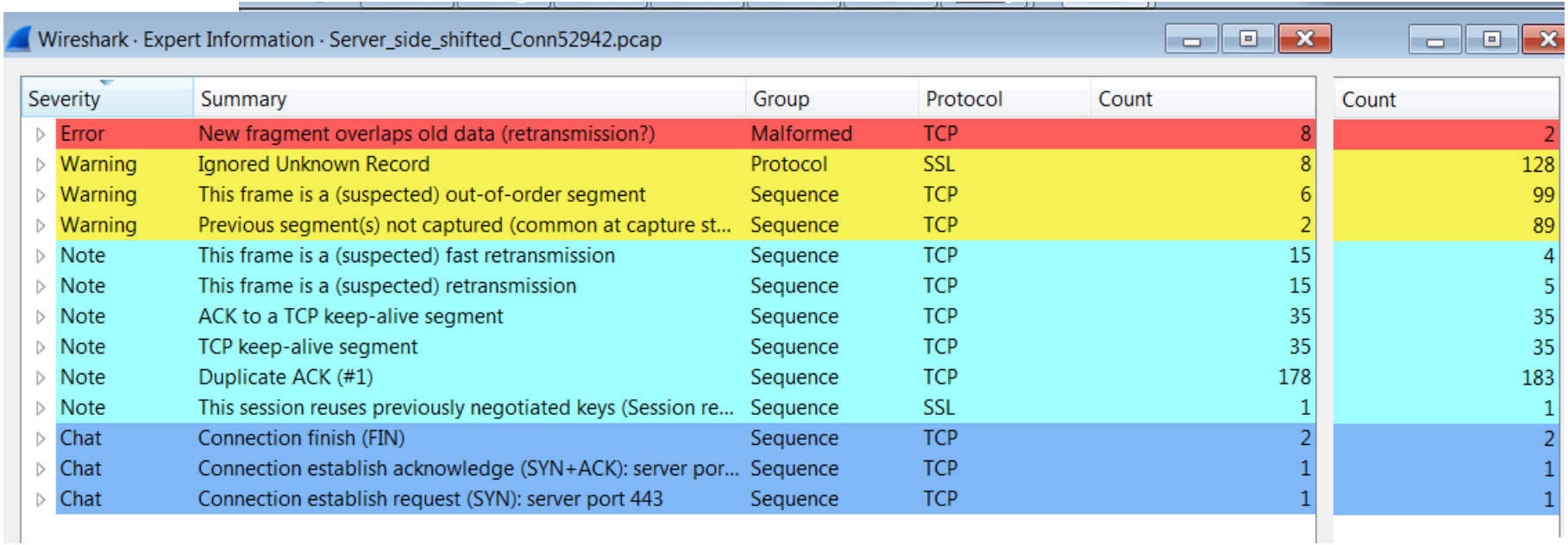


Severity	Summary	Group	Protocol	Count
Error	New fragment overlaps old data (retransmission?)	Malformed	TCP	8
Warning	Ignored Unknown Record	Protocol	SSL	8
Warning	This frame is a (suspected) out-of-order segment	Sequence	TCP	6
Warning	Previous segment(s) not captured (common at capture st...	Sequence	TCP	2
Note	This frame is a (suspected) fast retransmission	Sequence	TCP	15
Note	This frame is a (suspected) retransmission	Sequence	TCP	15
Note	ACK to a TCP keep-alive segment	Sequence	TCP	35
Note	TCP keep-alive segment	Sequence	TCP	35
Note	Duplicate ACK (#1)	Sequence	TCP	178
Note	This session reuses previously negotiated keys (Session re...	Sequence	SSL	1
Chat	Connection finish (FIN)	Sequence	TCP	2
Chat	Connection establish acknowledge (SYN+ACK): server por...	Sequence	TCP	1
Chat	Connection establish request (SYN): server port 443	Sequence	TCP	1

* Same results in Wireshark 3.0.5

Server Left – Client Right

Server Client



Severity	Summary	Group	Protocol	Count	Count
Error	New fragment overlaps old data (retransmission?)	Malformed	TCP	8	2
Warning	Ignored Unknown Record	Protocol	SSL	8	128
Warning	This frame is a (suspected) out-of-order segment	Sequence	TCP	6	99
Warning	Previous segment(s) not captured (common at capture st...	Sequence	TCP	2	89
Note	This frame is a (suspected) fast retransmission	Sequence	TCP	15	4
Note	This frame is a (suspected) retransmission	Sequence	TCP	15	5
Note	ACK to a TCP keep-alive segment	Sequence	TCP	35	35
Note	TCP keep-alive segment	Sequence	TCP	35	35
Note	Duplicate ACK (#1)	Sequence	TCP	178	183
Note	This session reuses previously negotiated keys (Session re...	Sequence	SSL	1	1
Chat	Connection finish (FIN)	Sequence	TCP	2	2
Chat	Connection establish acknowledge (SYN+ACK): server por...	Sequence	TCP	1	1
Chat	Connection establish request (SYN): server port 443	Sequence	TCP	1	1

Discussion - Retransmissions

					Server	Client
Note	This frame is a (suspected) fast retransmission	Sequence	TCP		15	4
Note	This frame is a (suspected) retransmission	Sequence	TCP		15	5

- Why does server report more retransmissions than client?
- How does Wireshark define a “fast retransmission”?

Wireshark Help

TCP Fast Retransmission

Set when all of the following are true:

- This is not a keepalive packet.
- In the forward direction, the segment size is greater than zero or the SYN or FIN is set.
- The next expected sequence number is greater than the current sequence number.
- We have more than two duplicate ACKs in the reverse direction.
- The current sequence number equals the next expected acknowledgement number.
- We saw the last acknowledgement less than 20ms ago.

Supersedes “Out-Of-Order”, “Spurious Retransmission”, and “Retransmission”.

Discussion – OOS & Drops

				Server	Client
Warning	This frame is a (suspected) out-of-order segment	Sequence	TCP	6	99
Warning	Previous segment(s) not captured (common at capture st...	Sequence	TCP	2	89

- Why does client report more OOS and "previous segment(s) not captured" than server?
- Why does server report *any* OOS?

Wireshark Help

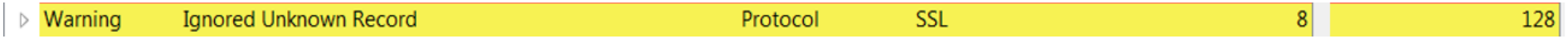
TCP Out-Of-Order

Set when all of the following are true:

- This is not a keepalive packet.
- In the forward direction, the segment length is greater than zero or the SYN or FIN is set.
- The next expected sequence number is greater than the current sequence number.
- The next expected sequence number and the next sequence number differ.
- The last segment arrived within the calculated RTT (3ms by default).

Supersedes “Spurious Retransmission” and “Retransmission”.

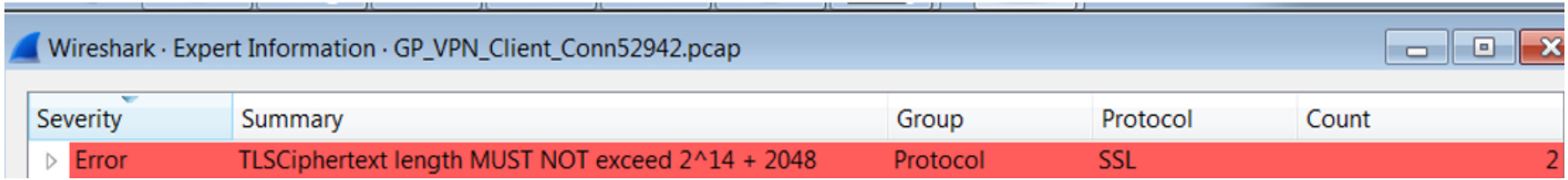
Discussion – Unknown Records



				Server	Client
Warning	Ignored Unknown Record	Protocol	SSL	8	128

- Why does client report more SSL unknown records than server?

Discussion – Length Error



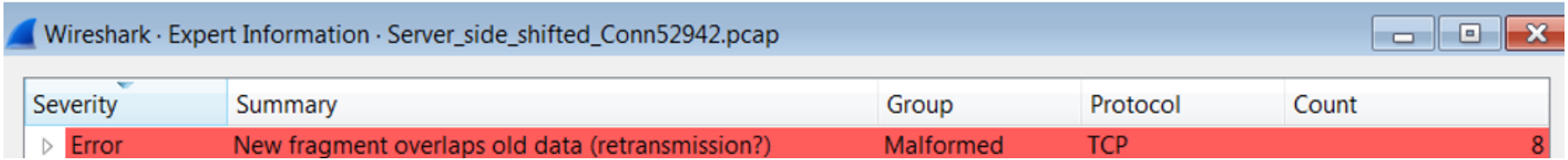
- Why does client report Ciphertext length error and Server does not?

* Protocol shows as TLS in Wireshark 3.0.5

Wireshark Updates

- Wireshark 2.6.3 was used for this course
- Found same Expert Info in 3.0.5
- Future versions may handle OOS & SSL reassembly with more tolerance

Discussion: Fragment Overlap



- Why does Server report Fragment Overlap error and Client does not?
- Should this really be Severity == Error?

Discussion

- Do these differences make sense?
- Additional thoughts?
- Comments?

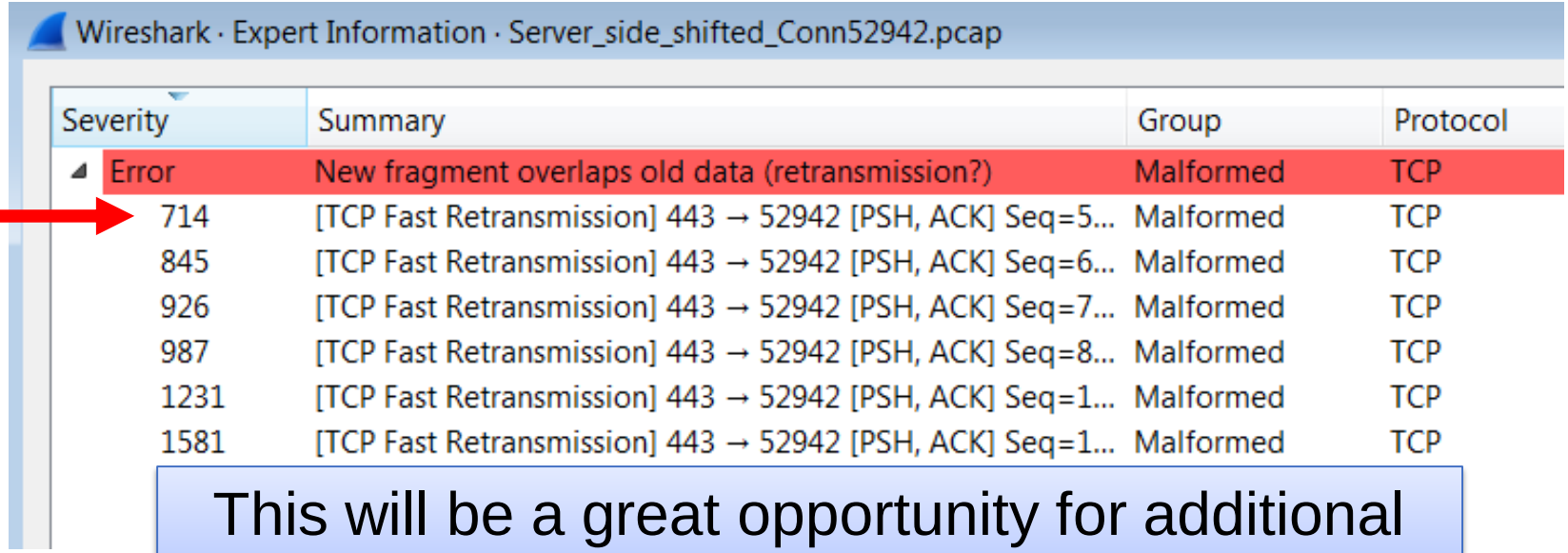
Comparison Summary

TCP Split Brain Comparison Summary (Sender vs. Receiver)				
Item	Topic	Summary	Sender	Receiver
4	Expert Info			
4.1	Duplicate ACK	Should be close to the same on both captures		
4.2	OOS		Not expected on sender; but retrans could be interpretted as OOS	Will be higher than sender
4.3	Retransmissions		Will be higher than receiver; could also be flagged as OOS	Might be flagged as OOS
4.4	Previous Segement Not Captured	Can be different	Not expected on sender unless there's a capture integrity issue	Expected on receiver when there's packet loss or OOS
4.5	SSL Errors	Could be side effect of reassembly in presence of OOS	Not expected	Likely to be reassembly issue

4th Leg Completed

Let's drill into one of these...

In the neighborhood of packet #714



This will be a great opportunity for additional Split Brain comparisons

Split Brain Comparisons

- Drill down into Fragment Overlap Details – Part I

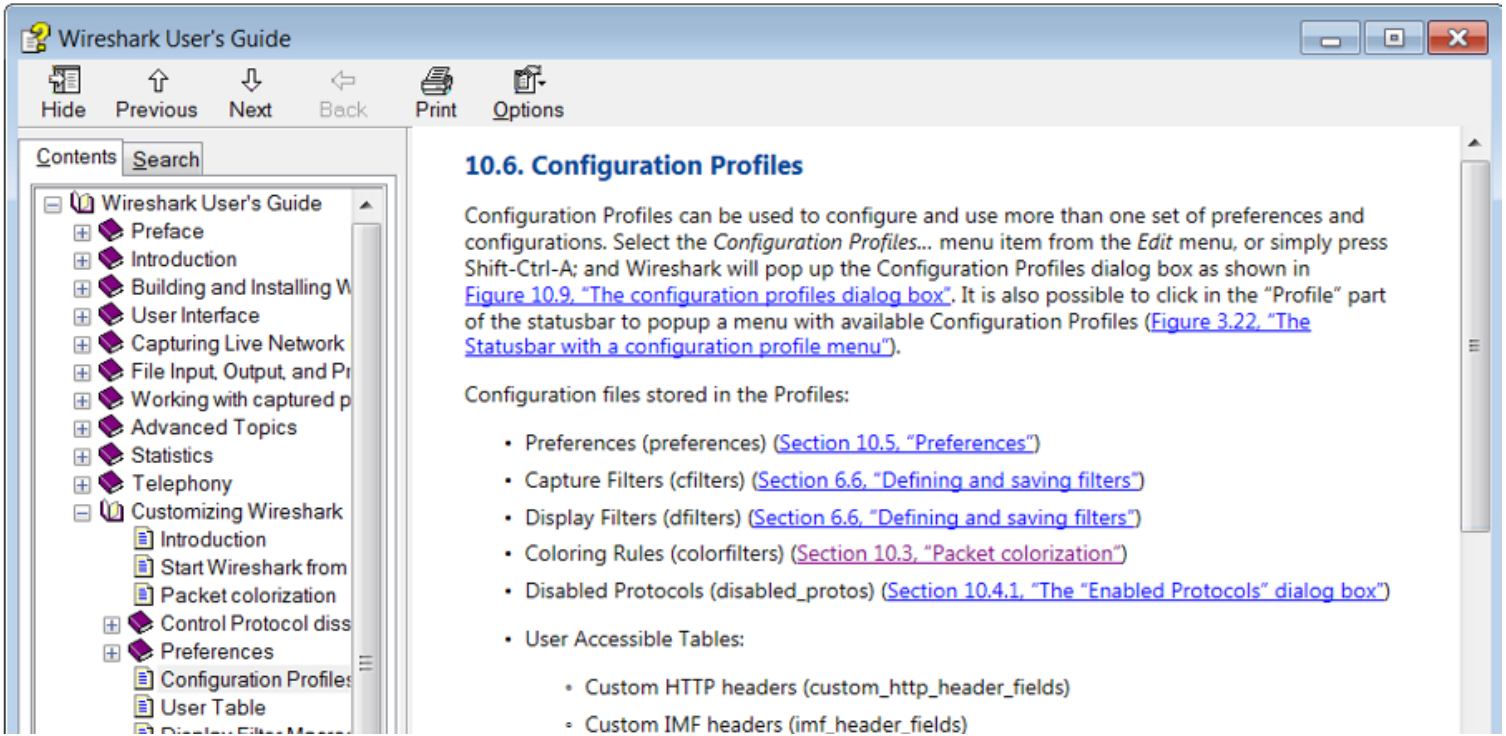
Pop Quiz

- What's one of the best things about Wireshark?

Pop Quiz

- OK…, besides the Developers?
- Totally flexible columns, views, and profiles!!

Configuration Profile Help

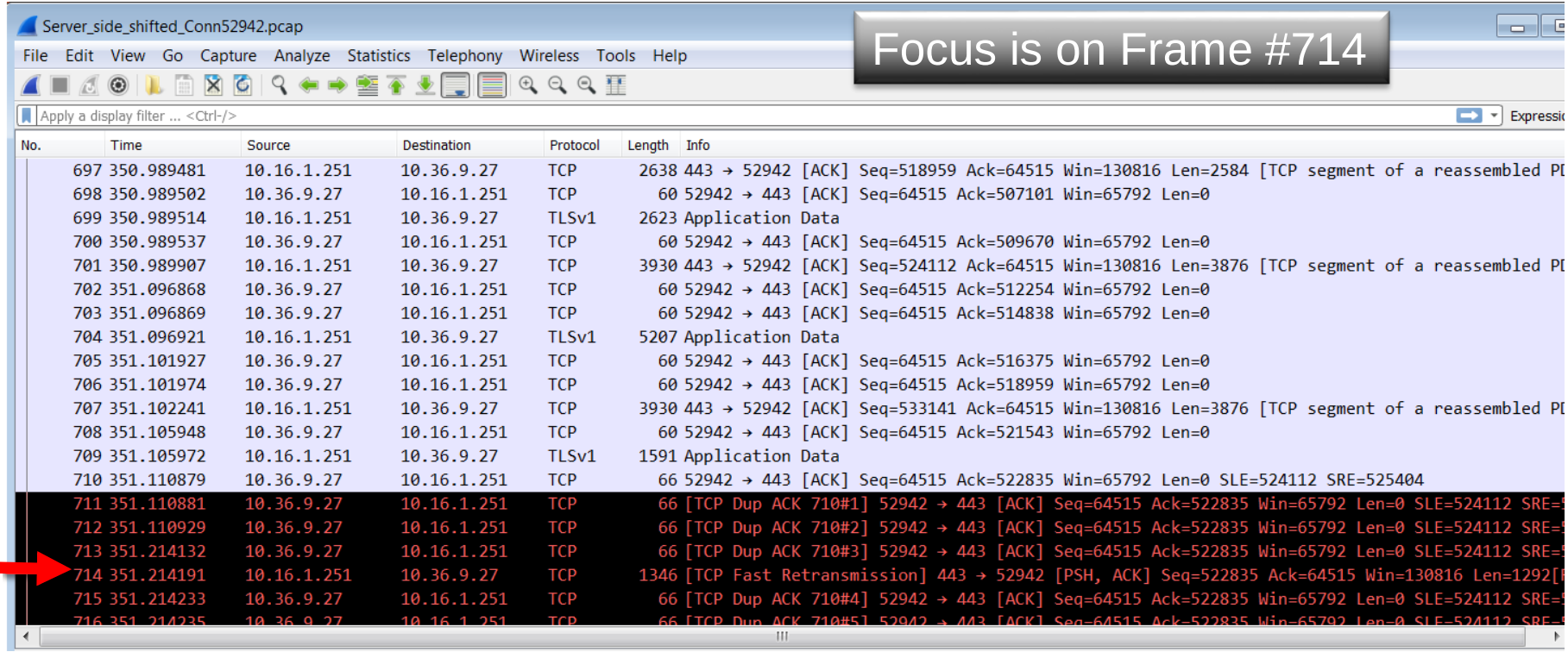


Wireshark Profile Resources

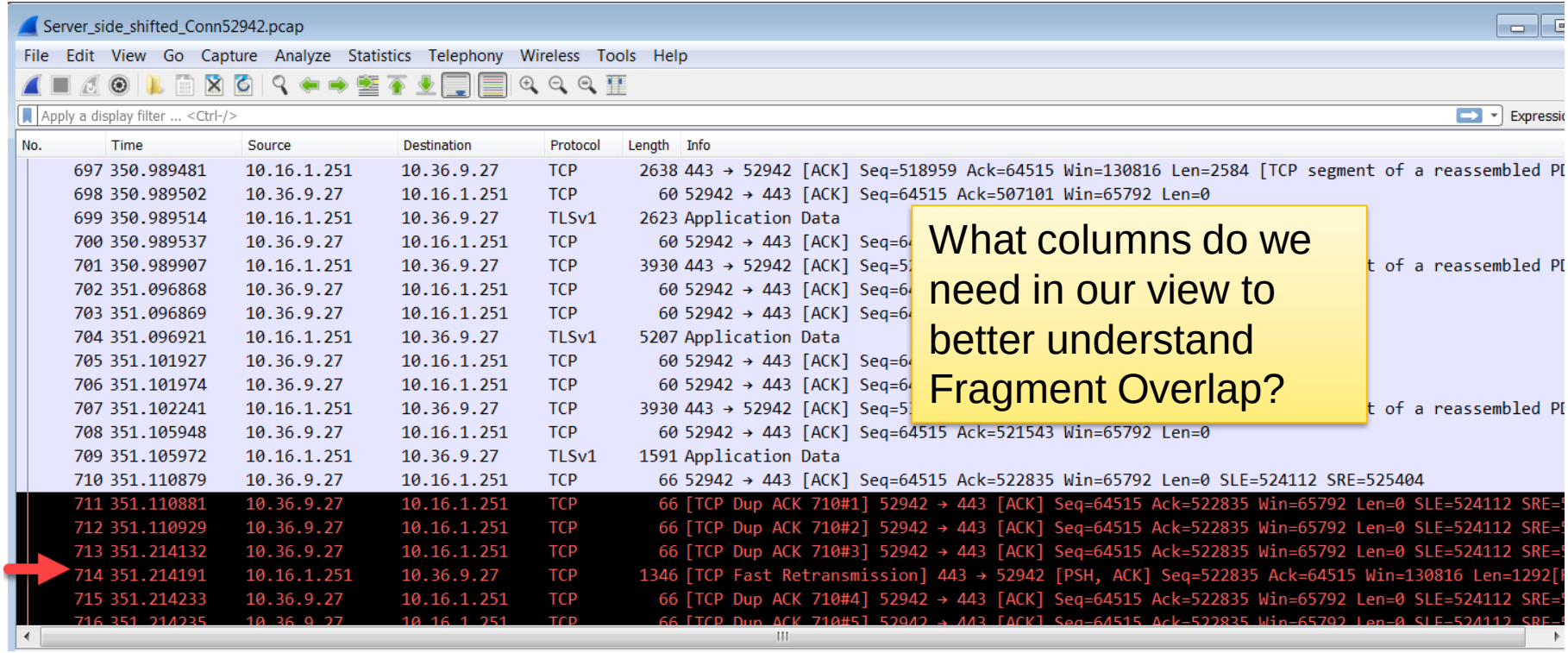
- SB-SACK
- SB-IP ID
- SB-Seq Analysis

- (will be posted on the Sharkfest retrospective page with the capture files)

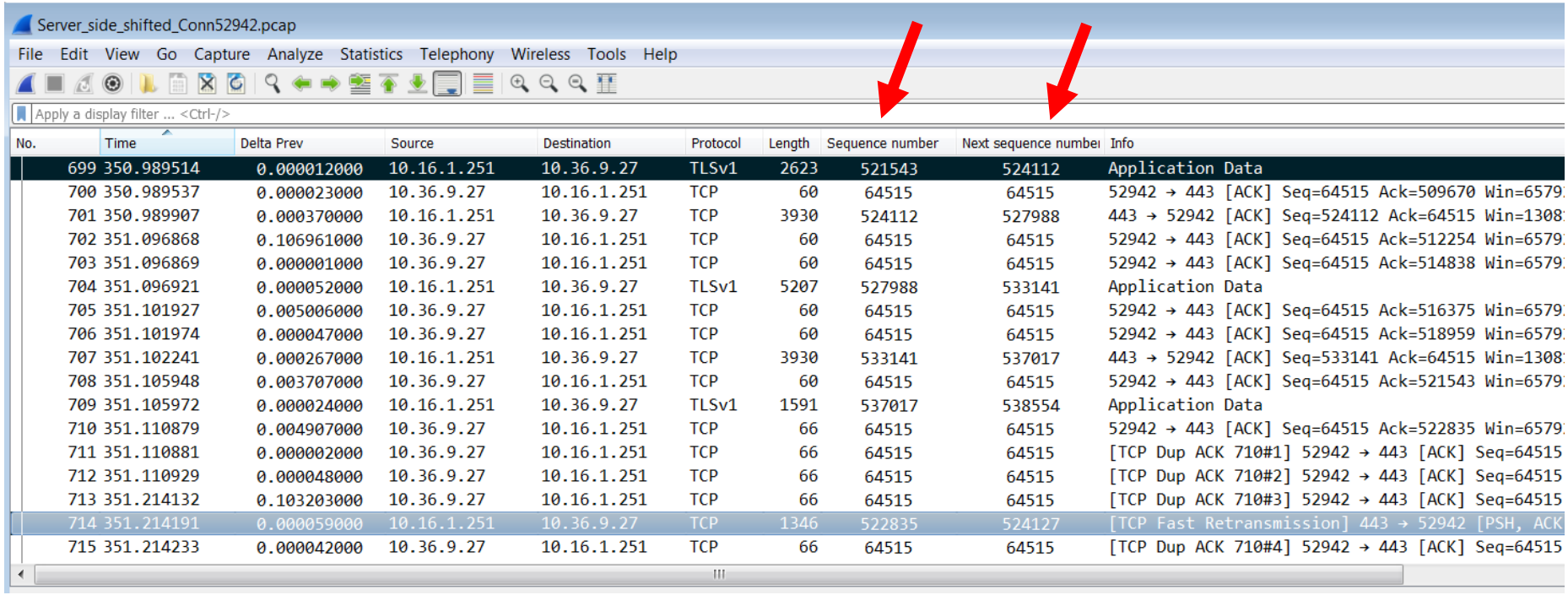
View with Classic Profile



View with Classic Profile



Profile SB-Seq Analysis



Pop Quiz

- What are Jumbo frames?

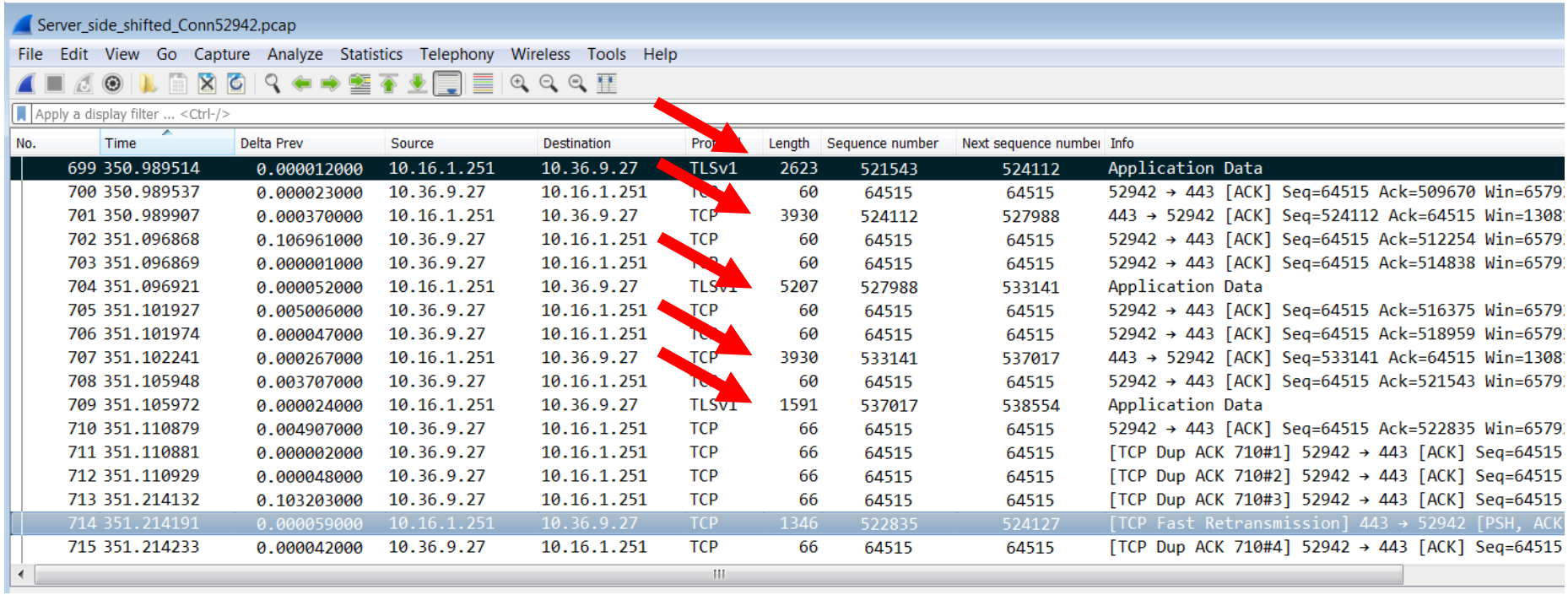
Pop Quiz

- What are Jumbo frames?
- What are Super Jumbo Frames?

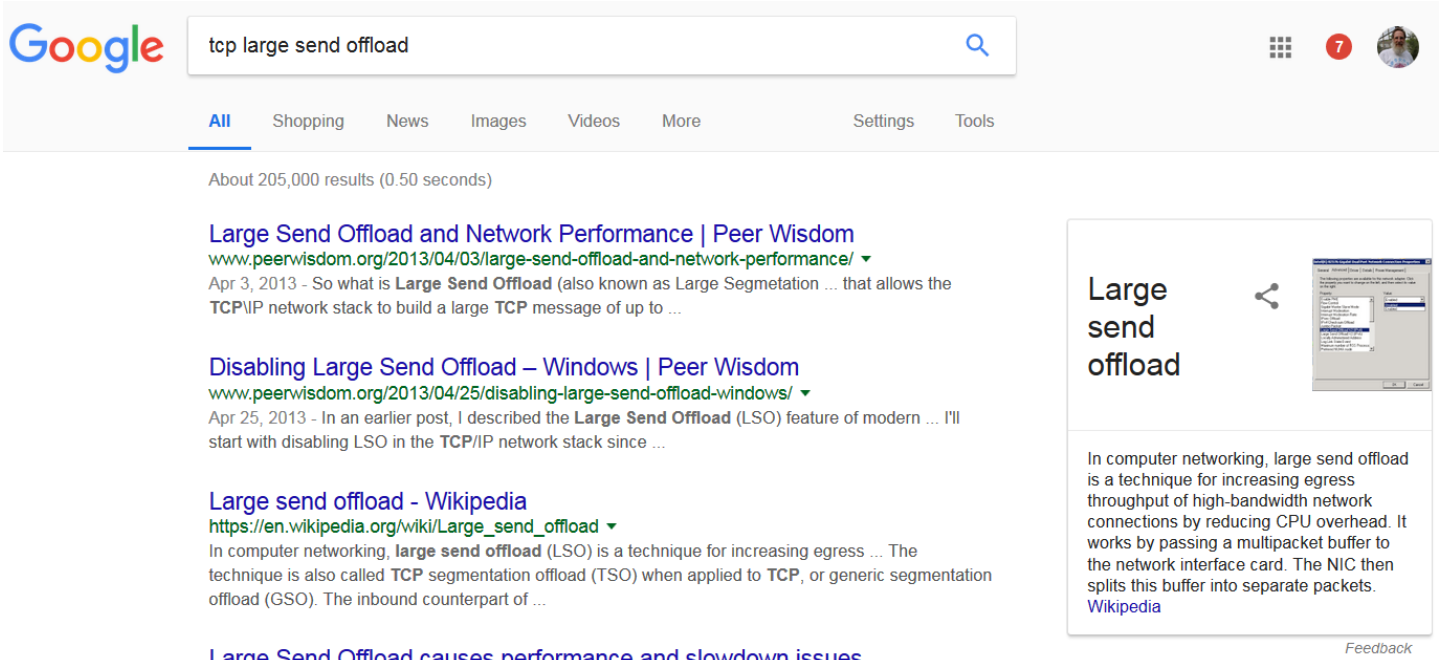
Pop Quiz

- When is a Jumbo frame not a Jumbo Frame?

Are these “Jumbo” frames?



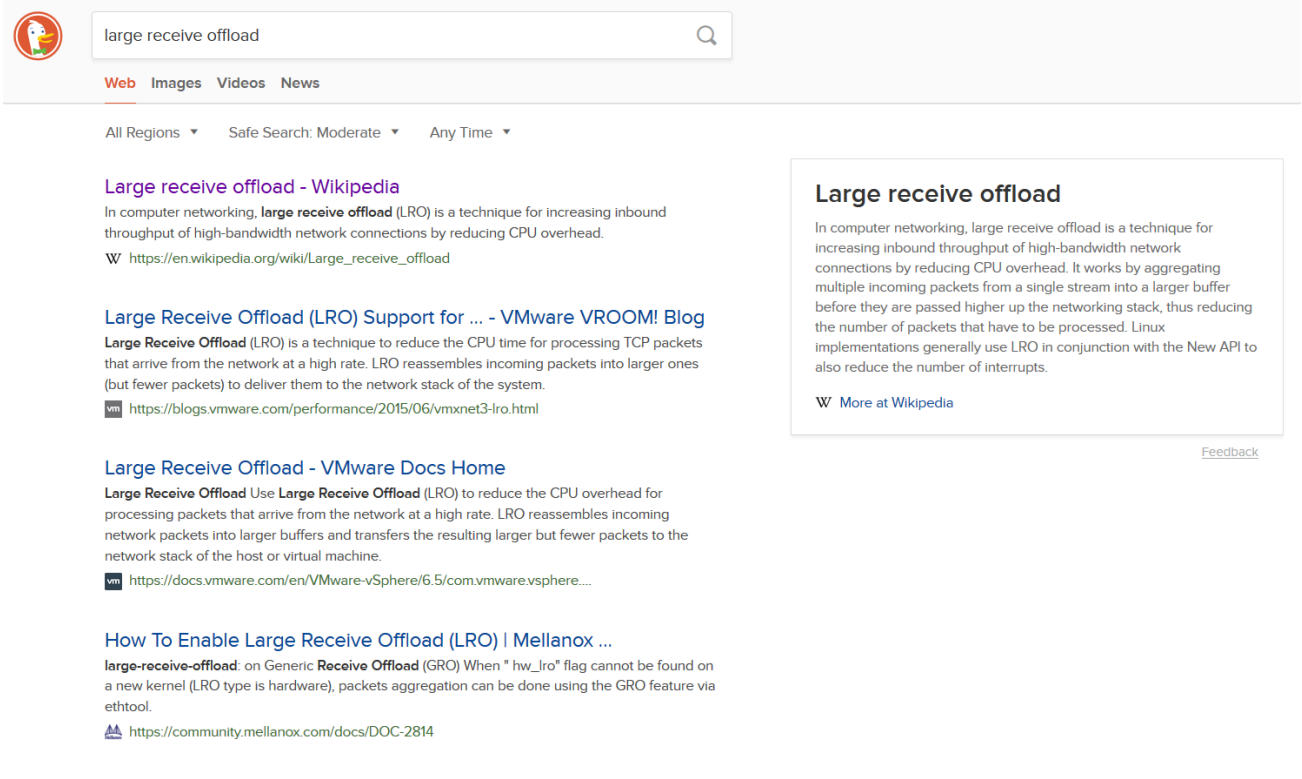
TCP Large Send Offload



Discussion

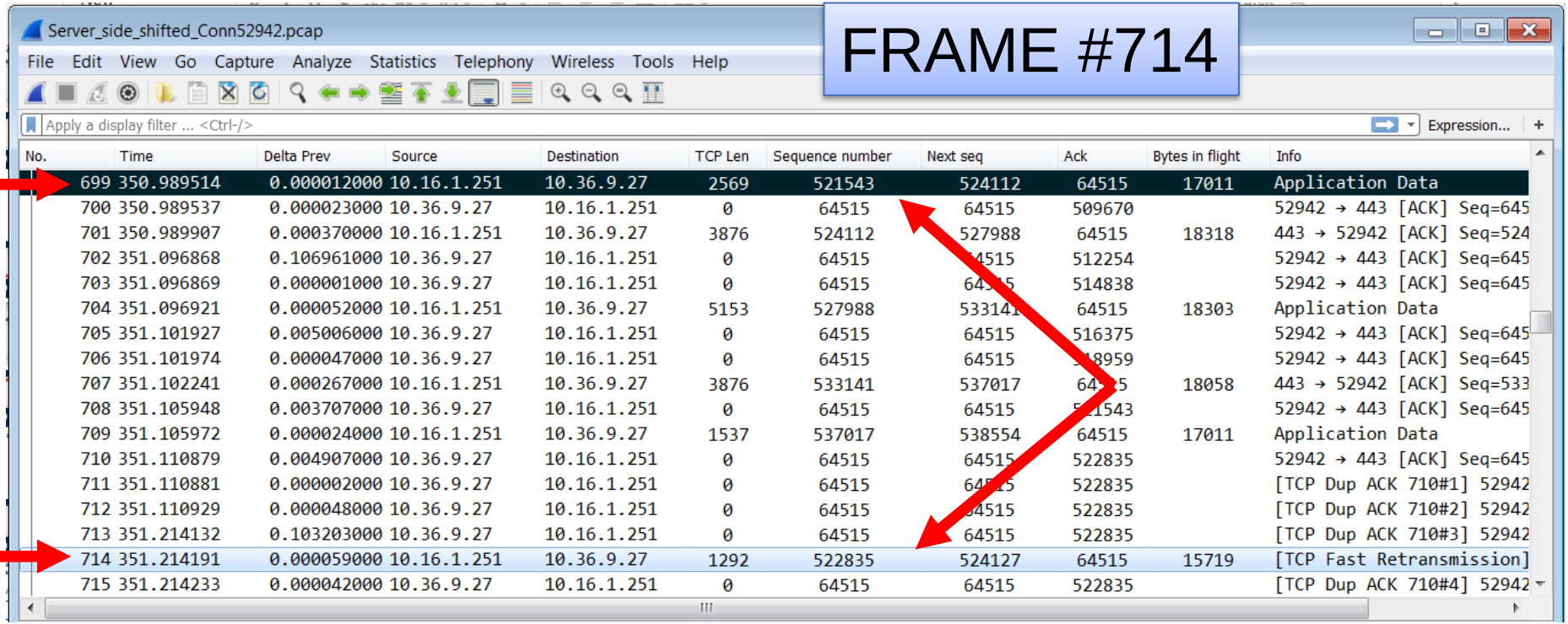
- Where does pcap intercept packets?
- What is the packet's journey after pcap capture?
- How is this different on a VM?
- How about a host running on a blade chassis technology (aka Blade Server)?

TCP Large Receive Offload



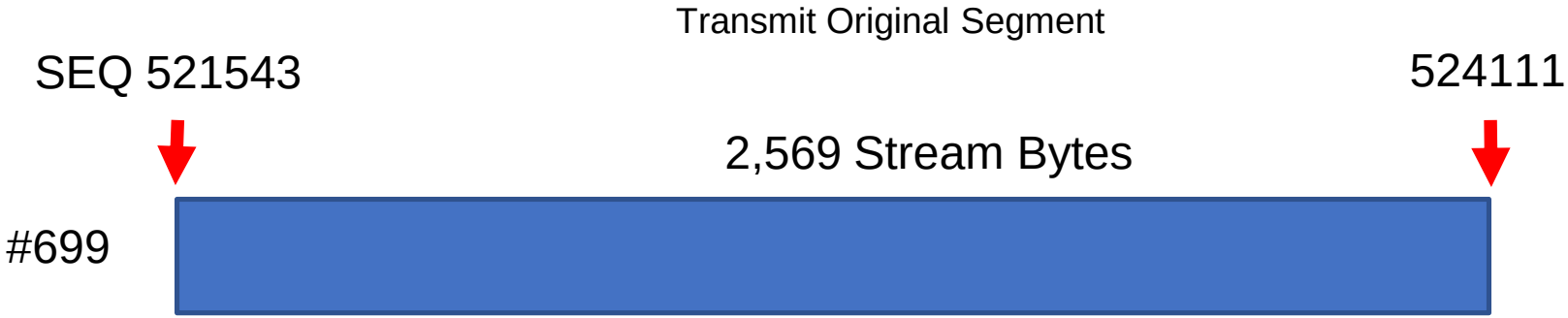
Back to Fragment Overlap

Here is the overlap

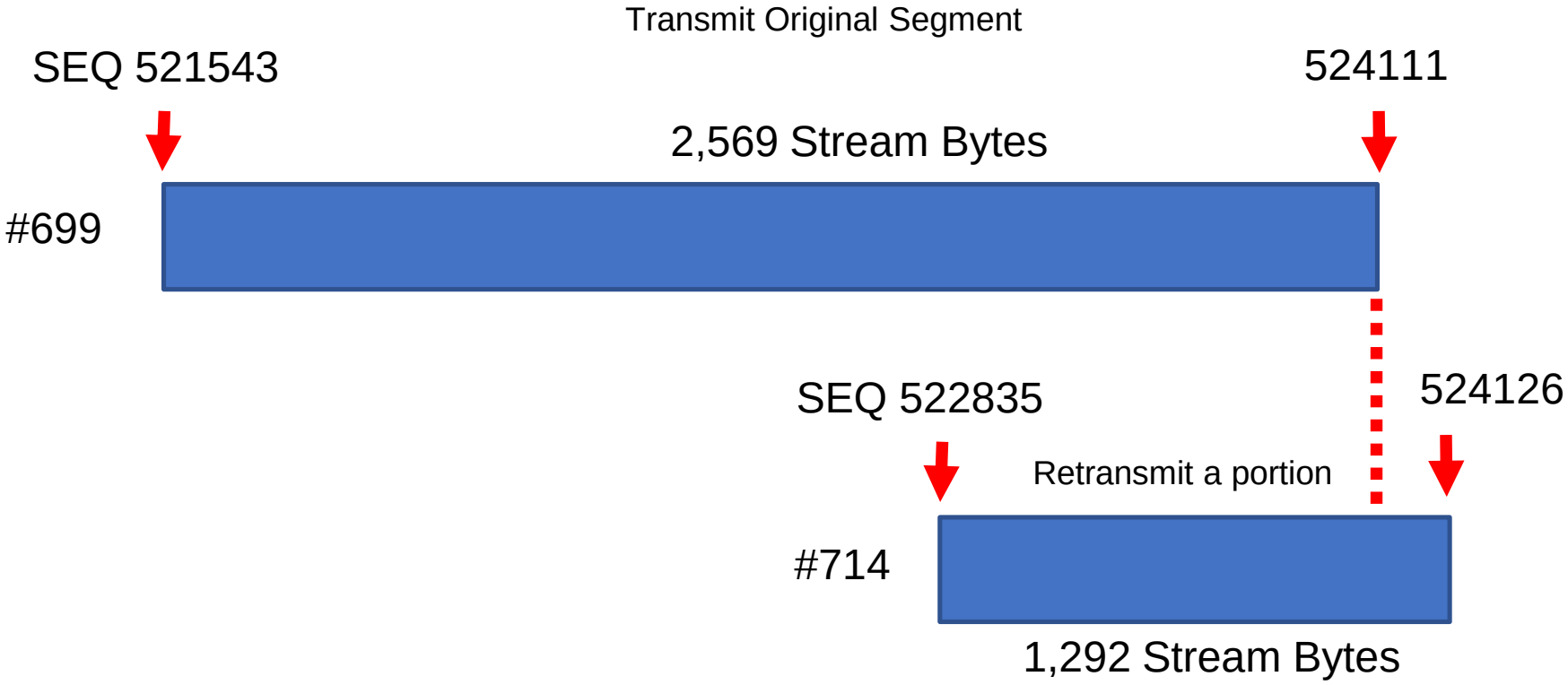


No.	Time	Delta Prev	Source	Destination	TCP Len	Sequence number	Next seq	Ack	Bytes in flight	Info
699	350.989514	0.000012000	10.16.1.251	10.36.9.27	2569	521543	524112	64515	17011	Application Data
700	350.989537	0.000023000	10.36.9.27	10.16.1.251	0	64515	64515	509670		52942 → 443 [ACK] Seq=645
701	350.989907	0.000370000	10.16.1.251	10.36.9.27	3876	524112	527988	64515	18318	443 → 52942 [ACK] Seq=524
702	351.096868	0.106961000	10.36.9.27	10.16.1.251	0	64515	64515	512254		52942 → 443 [ACK] Seq=645
703	351.096869	0.000001000	10.36.9.27	10.16.1.251	0	64515	64515	514838		52942 → 443 [ACK] Seq=645
704	351.096921	0.000052000	10.16.1.251	10.36.9.27	5153	527988	533141	64515	18303	Application Data
705	351.101927	0.005006000	10.36.9.27	10.16.1.251	0	64515	64515	516375		52942 → 443 [ACK] Seq=645
706	351.101974	0.000047000	10.36.9.27	10.16.1.251	0	64515	64515	518959		52942 → 443 [ACK] Seq=645
707	351.102241	0.000267000	10.16.1.251	10.36.9.27	3876	533141	537017	64515	18058	443 → 52942 [ACK] Seq=533
708	351.105948	0.003707000	10.36.9.27	10.16.1.251	0	64515	64515	521543		52942 → 443 [ACK] Seq=645
709	351.105972	0.000024000	10.16.1.251	10.36.9.27	1537	537017	538554	64515	17011	Application Data
710	351.110879	0.004907000	10.36.9.27	10.16.1.251	0	64515	64515	522835		52942 → 443 [ACK] Seq=645
711	351.110881	0.000002000	10.36.9.27	10.16.1.251	0	64515	64515	522835		[TCP Dup ACK 710#1] 52942
712	351.110929	0.000048000	10.36.9.27	10.16.1.251	0	64515	64515	522835		[TCP Dup ACK 710#2] 52942
713	351.214132	0.103203000	10.36.9.27	10.16.1.251	0	64515	64515	522835		[TCP Dup ACK 710#3] 52942
714	351.214191	0.000059000	10.16.1.251	10.36.9.27	1292	522835	524127	64515	15719	[TCP Fast Retransmission]
715	351.214233	0.000042000	10.36.9.27	10.16.1.251	0	64515	64515	522835		[TCP Dup ACK 710#4] 52942

Server Side Stream Visual



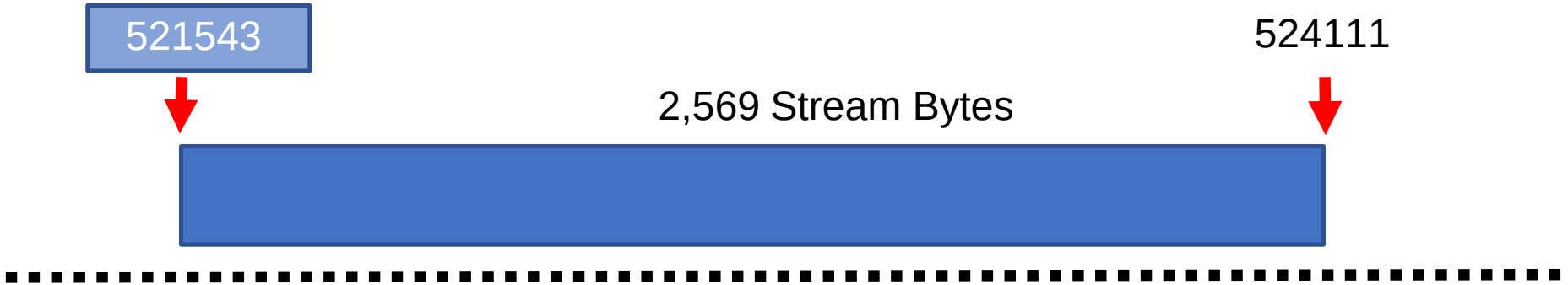
Server Side Stream Visual



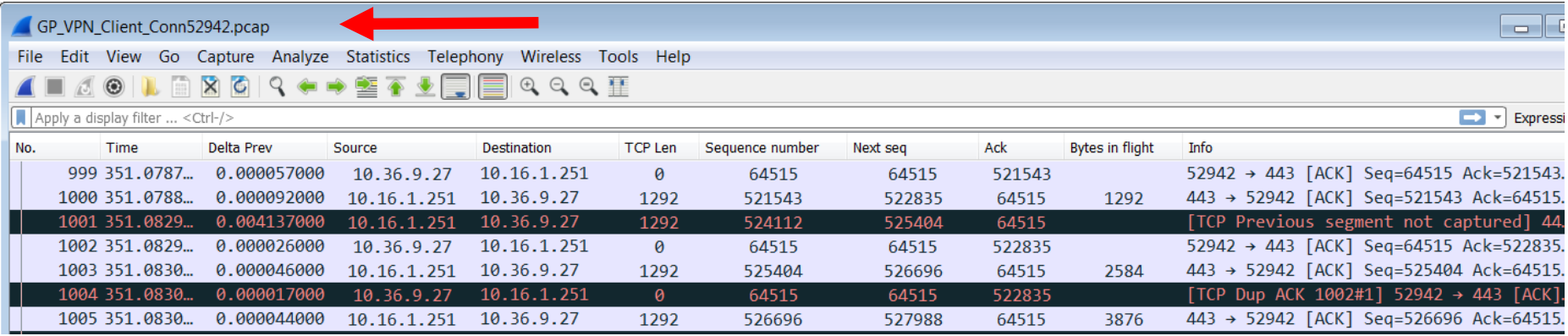
Discussion

- At first, it might seem odd that the retransmitted segment does not “line up” with original segment
- We can be reasonably confident this is result of Large Send Offload
- Let’s jump to client capture to confirm…

Anchor on SEQ==521543



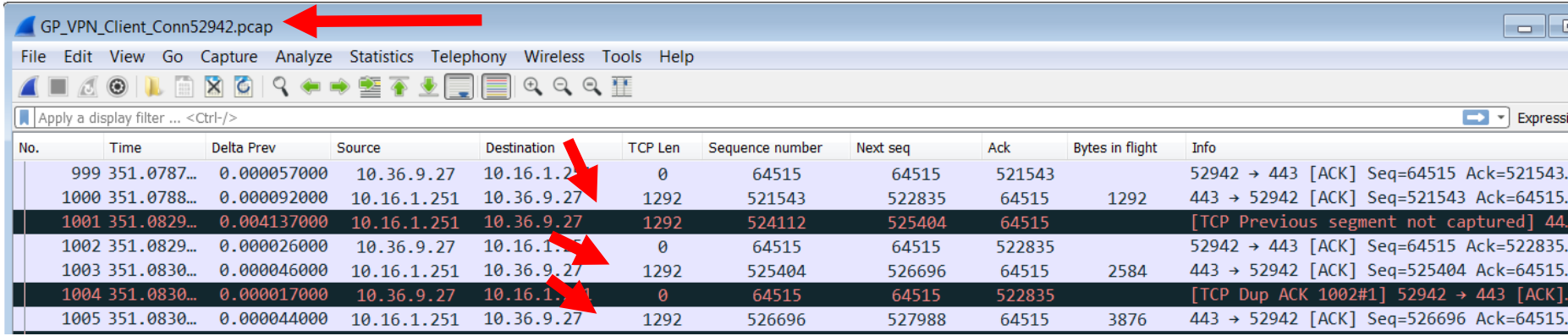
Several Observations



No.	Time	Delta Prev	Source	Destination	TCP Len	Sequence number	Next seq	Ack	Bytes in flight	Info
999	351.0787…	0.000057000	10.36.9.27	10.16.1.251	0	64515	64515	521543		52942 → 443 [ACK] Seq=64515 Ack=521543.
1000	351.0788…	0.000092000	10.16.1.251	10.36.9.27	1292	521543	522835	64515	1292	443 → 52942 [ACK] Seq=521543 Ack=64515.
1001	351.0829…	0.004137000	10.16.1.251	10.36.9.27	1292	524112	525404	64515		[TCP Previous segment not captured] 44.
1002	351.0829…	0.000026000	10.36.9.27	10.16.1.251	0	64515	64515	522835		52942 → 443 [ACK] Seq=64515 Ack=522835.
1003	351.0830…	0.000046000	10.16.1.251	10.36.9.27	1292	525404	526696	64515	2584	443 → 52942 [ACK] Seq=525404 Ack=64515.
1004	351.0830…	0.000017000	10.36.9.27	10.16.1.251	0	64515	64515	522835		[TCP Dup ACK 1002#1] 52942 → 443 [ACK].
1005	351.0830…	0.000044000	10.16.1.251	10.36.9.27	1292	526696	527988	64515	3876	443 → 52942 [ACK] Seq=526696 Ack=64515.

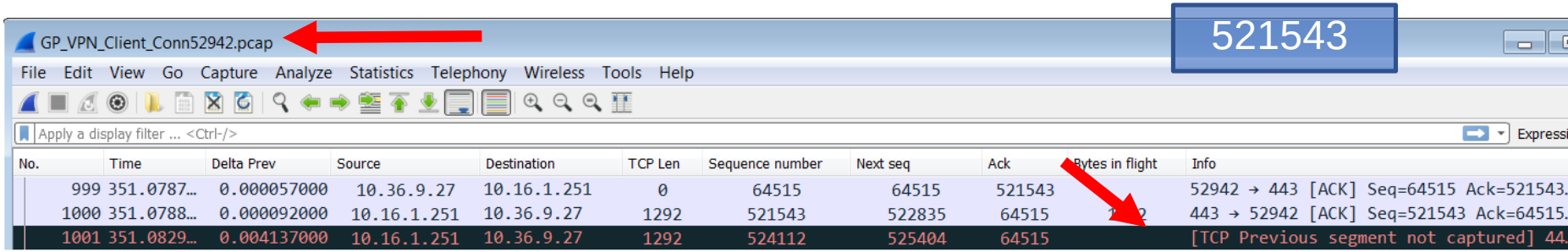
- Note file name in the title bar

Segment Size Differences



- Confirmed: Large Send Offload configured on Server
- Looks like the server NIC is handling segmentation

Dropped or OOS?



- If we ***freeze time*** right here, we can't be sure if it's just OOS or really a dropped packet
- We have to examine what comes next…

Break Time

- 15 Minute Break
- When we return we'll switch to Session #14
- TCP Split Brain Part II Deck

Summary & Wrap-Up

- Interpreting TCP behavior can be confusing and complicated, especially when there is “high” latency in the path
- Captures from both end points can be beneficial
- You need to split your brain into “sender perspective” and “receiver perspective” to fully interpret complex situations

Summary Results

TCP Split Brain Comparison Summary (Sender vs. Receiver)

Item	Topic	Summary	Sender	Receiver
1	SYN Options	MSS, Scaling, TimeStamps, SACK	Negotiation & Adapt, MSS=1460, WS=8, SACK	Negotiation & Adapt, MSS=1360, WS=8, SACK
2	Latency	Can be different in each direction	Client iRTT == 121ms	Server iRTT == 129ms
3	TCP State	Different States at startup and shutdown; state change only occurs when packet sent / received	Closed, SYN-Sent, Established	Listen, SYN-Received, Established
4	Expert Info			
4.1	Duplicate ACK	Should be close to the same on both captures		
4.2	OOS		Not expected on sender; but retrans could be interpretted as OOS	Will be higher than sender
4.3	Retransmissions		Will be higher than receiver; could also be flagged as OOS	Might be flagged as OOS
4.4	Previous Segement Not Captured	Can be different	Not expected on sender unless there's a capture integrity issue	Expected on receiver when there's packet loss or OOS
4.5	SSL Errors	Could be side effect of reassembly in presence of OOS	Not expected	Likely to be reassembly issue
4.6	Fragment Overlap	Most likely caused by Segmentation Offoad	Most likely to show up on Sender's capture	Receiver could flag overlap using SACK field
5	Frame Sizes	Can be different	Effects of LSO / IP Fragmentation	Effects of LRO
6	Display Time Delta	Very unique to each endpoint	ACKs will usually apply to segments sent much earlier in time	Interpretation can seem confusing, especially when lots of packets are in flight
7	Bytes In-Flight	OOS and retransmissions may impact calculation	Should be pretty accurate	Generally not very interesting from receiver's capture
8	RTT2ACK		Can include receiver's Delayed ACK Timer; never less than 1 RTT	Generally Super Fast! When less than Delayed ACK Timer, could reflect degraded condition for TCP stack
9	Congestion	Requires advanced analytics		
10	Service Response Time		Client: May include latency + protocol delay + congestion	Server: should be most accurate

Final Wrap-Up

- Wireshark features are extremely helpful, but can only take you so far
- Visualization can help you understand behavior and quickly interpret root cause
- Advanced analytics are icing on the cake…
- Please join us for Part II after the break

Thank You!

- For your participation!
- Hope you found this session informative and insightful
- Hope you'll join us for Part II – after the break
- We'll continue our Split Brain deep dive into compare Bytes in Flight, RTT2ACK, followed by Congestion

End of Session