



### **APPLICATION NOTE**

How to do basic Concurrent Connection and Connection Per Second testing on a firewall



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Firewalls are stateful inline network devices. Unlike a switch/router, a firewall caches TCP session state information in a session table and tracks the session until the session ends.

Different firewalls have different capacities for concurrent TCP connections (TCP CC) due to the finite space in the memory, so this is an important test criterion. Establishing a TCP connection is usually costlier than tearing it down because the firewall must register a new entry into the session table. Thus, how fast a firewall can establish TCP connections (TCP CPS) is another important performance index to test. Firewalls are inline devices - they inspect and forward incoming packets to their intended destinations. If a firewall can't process all the traffic it receives, it will be a performance bottleneck or point of failure on the network. Verifying throughput is therefore also critical when it comes to firewall performance testing.

This Application Note describes how to test these three critical performance parameters for a firewall: TCP CC, TCP CPS, and throughput against different packet sizes.



### **Basic Concepts**

This section describes the basic concepts that are used in a test configuration.

### **TCP** Connection

A TCP connection is defined by 4 parameters: {source IP address, source port number, destination IP address and destination port number}, e.g. 192.168.1.111:49152  $\leftarrow \rightarrow$  21.2.3.40:8080.

Source IP address typically describe the IP address of a client, e.g. 192.168.1.111. Source port number describes the application running on the client, e.g. 49152. Destination IP address is the IP address of the server 21.2.3.40, which the client is establishes TCP connections to. Destination port number, 8080, describes the service on the server that listen from incoming TCP connections. Thus, the number of TCP connections is determined by:

$$N_{TCP} = N_{src_{ip}} \times N_{src_{port}} \times N_{dst_{ip}} \times N_{dst_{port}}$$

### Load Profile

A *load profile* describes the "shape" of your traffic load. As shown in the figure below, a basic load profile is defined by 4 parameters:

#### Number of concurrent TCP connections

The number of concurrent TCP connections defines how many TCP connections you want your DUT to maintain at any time during the steady phase. Connections may close and open during the test but the total number of concurrent TCP connections is maintained. This parameter is typically related to the TCP CC testing.

#### • Ramp-up duration

Ramp-up duration defines the time duration for all TCP connections to be established. Increasing or decreasing the ramp-up duration results in a lower or higher connection establish rate. This parameter is typically related to the TCP CPS testing.

#### • Steady duration

Steady duration defines how long you want the converged traffic status to run on your DUT. Throughput is supposed to reach to the highest since all the TCP connections are established and the concurrent number of connections is maintained. This parameter is usually related to soak testing, where stability of the DUT is tested.

#### • Ramp-down duration

Ramp-up duration defines the time duration for all TCP connections to be closed. Increasing or decreasing the ramp-down duration results in a lower or higher connection close rate.





Figure 1. Concept of Load Profile

### **Connection Update**

During the steady phase, connections can open and close at a fixed rate. In order to stabilize the number of concurrent TCP connections, the connection establish rate must equal to connection closure rate, as shown in the figure below.



Figure 2. Concept of Connection Update

### TCP CC and CPS Testing

The scenario to build is shown as in Figure 3. Maximum concurrent TCP connections is 1M. Connections establishment rate is 200K connections/s. Ramp-up duration is 5 seconds. After the ramp-up phase, connections will be created and closed at 200K connections/s, so that the number of concurrent connections does not change during the steady phase. Traffic direction is from servers to clients. In the ramp-down phase, no more connections are created, and all are closed at 200K connections/s. Packet size is 800 bytes.



### 1. Create Test Scenario

Create a *RAW* test scenario. Select *No TLS*, *TCP*, and *IPv4* as shown below.

ENA Edit	in Test Reporting			0
Chassis Test Add Add Testcase Scenario	No Active Scenario     Subnets: Missing Select Scenario		×	
Explorers Test setup	Load Library Application Library			
Explorers Test setup  Test Explorer  Comparison  Test case 0  Test case 0  Test case 0  Test case 0	Load Library Application Library  Collapse Name  Sector Library  Raw Establish  Raw Raw Raw Raw Raw Raw Replay  Http Trans Http GET	connections with pattern or custom payload	l up, down or bidirectional.	Client - Server 0 0
실 Chassis Explorer 🔄 Test Exp	Secure Tra ® No TL D TLS	isport Protocol: Transport Protocol: Internet Pr S TCP IPv4 UDP IPv6	otocot OK Cancel	Ine Rat Clien III Subnets - Ports III Load Profile III Line Rate Utilization

Figure 4. Create RAW Test Scenario

#### 2. Configure Load Profile

Expand the test tree in Test Explorer, and click Connection Establishment.

As shown in Figure 4, change *Number of Source Ports* to 10, and you will see *Total Users: 100,000*, and *Total Connections: 1,000,000*.

Change Steady duration to 300 seconds.



<b>XENA</b>	Edit Ru	in Test	Reporting							0
Chassis Test	Add Add Testcase Scenario	<ul> <li>Scenario</li> <li>Network</li> <li>Ports assign</li> </ul>	nments missing							
Test Explore	ar	a	() Econoria O							Connection Establishment
D Collapse			V Scenario U							Connection Establishment
Name		Use	Subnet Selection		Subnet size:	Us	sed IP addresses: Use	ed IP Range:		
RHT Dem     Device	10 under test		Client Subnet:	Client IPv	4 • 16,777	,213	100,000 1	0.0.0.2 - 10.1.134.161		
sha Subnet:	S		Server Subnet:	Server IP	16,777	,213	1	11.0.0.2		
▲ ☐ Test c	ase 0		User Connections Se	tup						
⊿ Raw	Scenario 0		Number of Source Pe	rts:	10		Number of Destinat	ion IP Addresses:	1	
<> Ci	onnection Establishme	nt	Use Ephemeral Source	e Port Range:			Number of Destinat	ion Ports:	1	
<> La	ayer 4 - TCP		Causes Dest Minimus				Destination Dest Mir			
⇔ La	ayer 3 - IPv4		Source Port Minimur	43			Destination Port Mir	himum:	80	
€ D	ownstream		Connections per Use	n	10					
			<b>Connection Establis</b>	ment Profile			Connection Update	s		
		- (	Total Users:	100	,000		Connection Rebirth:	No rebirth	•	
			Total Connections:	1,000	,000		Repetitions:		1	
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							5 500 6			
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							0	2 Time	4 e [Minutes]	6 S
때 Chassis Exp	lorer 🔚 Test Explo	rer								Ŧ

Figure 5. Configure Load Profile

### 3. Configure Connection Update

In *Connection Updates* section, change *Connection Rebirth* from *No rebirth* to *With same Src IP*. Delete the value in *Repetitions* or set it to 0 so that the connection opening and closing will continue until the ramp-down phase.

The reason for choosing *With same Src IP* is to avoid IP address depletion during the test. You can also choose *With new Src IP*. If you do so, as soon as a TCP connection is closed, a new connection with a new source IP address will be created. The new source IP address is from the client subnet.



ENA Edit Run Te	est	Reporting					0
Chassis Test Explorers Add Add Test Scenario Test setup	Scenario Network Ports assign Test Confi	ments missing					
Test Explorer	ą.	Scenario 0					Connection Establishment
ම් Collapse		Subnet Selection					A
Name	Use	Subict Selection		Subnet size:	Used IP addresses:	Used IP Range:	
<ul> <li>RHT Demo</li> </ul>		Client Subnet:	Client IPv4 *	16,777,213	100,000	10.0.0.2 - 10.1.134.161	
Jevice under test ► A Subnets I Test cases		Server Subnet:	Server IPv4 *	16,777,213	1	11.0.0.2	
<ul> <li>Test case 0</li> </ul>		User Connections Setup					
<ul> <li>Raw Scenario 0</li> </ul>		Number of Source Ports:	10		Number of De	stination IP Addresses:	1
Connection Establishment		Use Ephemeral Source Po	ert Range: 🔳		Number of De	stination Ports:	1
Layer 3 - ICP		Source Port Minimum:	49152		Destination Po	ort Minimum:	80
← Downstream		Connections per User:	10		-		-
		Connection Establishme	nt Profile		Connection U	pdates	
		Total Users: Total Connections:	100,000 1,000,000		Connection Re Repetitions:	birth: With same Src IP	
					Concurrent Us	sers	
		Users Offset 100,000 0	Up Steady Down 5 300 5	Time Scale Segments Seconds + Add X Remon	ve <u>8</u> 50.0 k	2	6 8
🛍 Chassis Explorer 🖃 Test Explorer					°	Time [M	inutes]

Figure 6. Configure Connection Updates

#### 4. Set TCP Segment Size

In *Test Explorer*, click *Layer 4 – TCP*. In *Maximum TCP Segment Size (Client)*, change value to 746 bytes. By doing this, the clients will advertise this value in their TCP SYN packets and the server will adjust the outgoing TCP segment size accordingly.

To generate traffic of 800-byte frame size, the TCP segment size should be 746 bytes, i.e. 800 bytes (frame size) - 14 bytes (Ethernet header) - 20 bytes (IP header) - 20 bytes of (TCP header).



Chassis Test	Add Add Testcase Scenario	<ul> <li>Scenario</li> <li>Network</li> <li>Ports</li> </ul>						
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ur Collapse			TCP (Client)			TCP (Server)		
		Use	TCP Congestion Mode:	New Reno *		TCP Congestion Mode:	New Reno *	
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۰ 🖧 Subnet	ts		Enable Window Scaling:			Enable Window Scaling:		
<ul> <li>Test ca</li> </ul>	ses		Window Scaling Factor:	3	2^factor	Window Scaling Factor:	3	2^factor
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00	Connection Establishme	nt	Modifier Type:	Fixed *		Modifier Type:	Fixed *	
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<> L	ayer 3 - IPv4		Minimum Value:	70	hutar	Minimum Value:	70	butar
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			waxinum value.	1400		Maximum value.	1400	bytes
			Retransmission (Cliant)			Retransmission (Server)	2	
			Duplicate ACK Threshold:	3		Duplicate ACK Threshold:	3	
			Retries:	32		Retries:	32	
			Back Off:	3		Back Off:	3	
			Timeout Type:	Dynamic *		Timeout Type:	Dynamic *	
			Timeout:		milliseconds	Timeout		milliseconds
			Timeout Minimum:	200	milliseconds	Timeout Minimum:	200	milliseconds
			Timeout Maximum:	120000	milliseconds	Timeout Maximum:	120000	milliseconds
			SYN Retransmission (Clie	ent)		SYN Retransmission (Clie	ent)	
			Timeout:	200	milliseconds	Timeout:	200	milliseconds
			Retries:	32		Retries:	32	
			Back Off:	3		Back Off:	3	

Figure 7. Set TCP Segment Size

### HTTP CC and CPS Testing

The scenario to build is shown as in Figure 8. Maximum concurrent HTTP connections is 1M. Connections establishment rate is 200K connections/s. Ramp-up duration is 5 seconds. After the ramp-up phase, connections will be created and closed at 200K connections/s, so that the number of concurrent connections does not change during the steady phase. In the ramp-down phase, no more connections are created, and all are closed at 200K connections/s. Packet size is 800 bytes.



Figure 8. Target Test Scenario



### 1. Create Test Scenario

Create a HTTP GET test scenario. Select No TLS, TCP, and IPv4 as shown below.

Elit Run T	Test Reporting		
💌 🚛 🔚 🗋	No Active Scenario		
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Explorers Test setup	Load Library Application Library		
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P Collapse	Name	Hup GE I	
Name	🖌 🔳 Stateful Loading	Establish connections with a Http GET request, response payload pattern.	
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Device under test	Raw Raw		0
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<ul> <li>Test cases</li> </ul>	Replay Replay		
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	nus map our		
			u Column Groupe
			Subnets - Ports
			Load Profile
			Line Rate Utilization
		Secure Transport Protocol: Internet Protocol:	
	(	No TLS     IPv4	
		⊖ TLS O IPv6	
		OK Cancel	
🛍 Chassis Explorer 📃 Test Explorer	f		•

Figure 9. Create HTTP GET Test Scenario

#### 2. Configure Load Profile

Expand the test tree in Test Explorer, and click Connection Establishment.

As shown in Figure 10, change *Number of Source Ports* to 10, and you will see *Total Users: 100,000*, and *Total Connections: 1,000,000*.

Change Steady duration to 300 seconds.



ENA Edit	Run Test	Reporting						
Chassis Test Add Add Testcase Scenario	<ul> <li>Scenario</li> <li>Network</li> <li>Ports assign</li> </ul>	nments missing						
Explorers Test setup	Test Con	figuration State						
Test Explorer	¢.	Scenario 0						Connection Establishmen
Collapse		Subnet Selection						
Name	Use			Subnet size:	Used IP addresses:	Used IP Range:		
<ul> <li>Basic Stateful Load Testing</li> </ul>		Client Subnet:	Client IPv4 *	16,777,213	100,000	10.0.0.2 - 10.1.134.161		
Device under test		Course Subaat						
Subnets		Server Subnet:	Server IPv4 *	16,777,213	1	11.0.0.2		
<ul> <li>I lest cases</li> <li>D Test cases</li> </ul>		User Connections Set	un 🥏					
Trans Scenario 0	_	oser connections set						
<> Connection Establishr	ment	Number of Source Por	10	)	Number of Destin	nation IP Addresses:	-	
<> Layer 4 - TCP		Use Ephemeral Source	Port Range: 🔳		Number of Desti	nation Ports:	1	
<> Layer 3 - IPv4		Source Port Minimum:	49152		Destination Port	Minimum:	80	
→ Request		Connections per User:	10					
← Response		Connection scaplish	nent Profile		Connection Upd	ates		
		Total Users:	100.000		Connection Rebi	rth: No rebirth	•	
	C	Total Connections:	1.000.000	)	Repetitions:		1	
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🛍 Chassis Explorer 🔳 Test Exp	olorer						ne [minadea]	

Figure 10. Configure Load Profile

### 3. Configure Connection Update

In *Connection Updates* section, change *Connection Rebirth* from *No rebirth* to *With same Src IP*. Delete the value in *Repetitions* or set it to 0 so that the connection opening and closing will continue until the ramp-down phase.

The reason for choosing *With same Src IP* is to avoid IP address depletion during the test. You can also choose *With new Src IP*. If you do so, as soon as a TCP connection is closed, a new connection with a new source IP address will be created. The new source IP address is from the client subnet.



EIII Edit	Run Test	Reporting					
Chassis Test Add Add Add Testcase Scenario	<ul> <li>Scenario</li> <li>Network</li> <li>Ports assign</li> </ul>	nments missing					
Explorers Test setup	Test Cont	figuration State					
Test Explorer	4	Scenario 0					Connection Establ
		Subnet Selection					
Aame     Basic Stateful Load Testing     Device under test	Use	Client Subnet:	Client IPv4 🔹	Subnet size: 16,777,213	Used IP addresses: 100,000	Used IP Range: 10.0.0.2 - 10.1.134.161	
<ul> <li>A Subnets</li> <li>▲ Test cases</li> </ul>		Server Subnet:	Server IPv4 🔹	16,777,213	1	11.0.0.2	
<ul> <li>Test case 0</li> </ul>		User Connections Setup	2				
<ul> <li>Trans Scenario 0</li> </ul>		Number of Source Ports:	10		Number of Dest	ination IP Addresses:	1
Connection Establishing	nent	Use Ephemeral Source P	ort Range: 🔳		Number of Dest	tination Ports:	1
Layer 4 - ICP Layer 3 - IPv4		Source Port Minimum:	49152		Destination Port	Minimum:	80
→ Request		Connections per User:	10				
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					50.0 k		
					0	2	4 6 8
🛍 Chassis Explorer 🔳 Test Exp	lorer					Time	[Minutes]

Figure 11. Configure Connection Updates

#### 4. Set TCP Segment Size

In *Test Explorer*, click *Layer 4 – TCP*. In *Maximum TCP Segment Size (Client)*, change value to 746 bytes. By doing this, the clients will advertise this value in their TCP SYN packets and the server will adjust the outgoing TCP segment size accordingly.

To generate traffic of 800-byte frame size, the TCP segment size should be 746 bytes, i.e. 800 bytes (frame size) - 14 bytes (Ethernet header) - 20 bytes (IP header) - 20 bytes of (TCP header).



<b>XENA</b>	Edit R	un Test	Reporting							(
Chassis Test	Add Testcase	<ul> <li>Scenario</li> <li>Network</li> <li>Ports assign</li> </ul>	iments missing							
Explorers	Test setup	Test Conf	iguration State							
Test Explore	r	Ą	Scenario 0						Layer	4 - TC
Collapse			TCD (CII			TCD //				
Name		Use	TCP (Client)			TCP (Server)				
<ul> <li>Basic Stat</li> </ul>	eful Load Testing		TCP Congestion Mode:	New Reno *		TCP Congestion Mode:	New Reno *			
Device	under test		Window Size:	65535	bytes	Window Size:	65535	bytes		
Garage Subnets			Enable Window Scaling:			Enable Window Scaling:				
<ul> <li>Intest cas</li> <li>Intest cas</li> </ul>	es ase 0		Window Scaling Factor:	3	2^factor	Window Scaling Factor:	3	2^factor		
▲ Trans	Scenario 0		Maximum TCP Segment	Size (Client)		Maximum TCP Segment	Size (Server)			
<> Co	onnection Establishm	ent	Modifier Type:	Fixed •		Modifier Type:	Fixed •			
<> La	iyer 4 - TCP		Value:	746	byte	Value:	746	bytes		
<> La	iyer 3 - IPv4		Minimum Value:	70	ivtes	Minimum Value:		bytes		
→ Ke	equest		Maximum Value:	1460	bytes	Maximum Value:	1460	hytes		
			Determinelar (Client)		5,05	Deterrorization (Convert		0)(0)		
			Retransmission (Client)	2		Retransmission (Server)	2			
			Duplicate ACK Threshold:	3		Duplicate ACK Infeshold:	3			
			Retries:	32		Retries:	32			
			Back Off:	3		Back Off:	3			
			Timeout Type:	Dynamic *		Timeout Type:	Dynamic *			
			Timeout:	200	milliseconds	Timeout:	200	milliseconds		
			Timeout Minimum:	200	milliseconds	Timeout Minimum:	200	milliseconds		
			Timeout Maximum:	120000	milliseconds	Timeout Maximum:	120000	milliseconds		
			SYN Retransmission (Clie	ent)		SYN Retransmission (Clie	ent)			
			Timeout:	200	milliseconds	Timeout:	200	milliseconds		
			Retries:	32		Retries:	32			
			Back Off:	3		Back Off:	3			
1. Chassis Even	larar 🖂 Tast Evol									

Figure 12. Set TCP Segment Size

### 5. Set HTTP Request and Response

In *Test Explorer*, click *Request* or *Response* to view/modify the HTTP Request or Response. To modify the payload, click Import on the right side to import any file. The total length of the payload should be less than 256 KB.



<b>XENA</b>	Edit	Run	Test	Reporting							
Chassis Test	Add Ar Testcase Scen	dd nario	Scenario Network Ports assign	ments missing							
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= Test Explore	r		ġ.	→ Request							Requ
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lame			Use	Payload Configuration	1			Transmit Setup			
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<> Co	nnection Estab	olishment						Enable Bursty Traffic:			
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► 🖧 Subnet	ts					Transmit During Ramp Down			
🖌 🔳 Test ca	ses					T	1		
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Trans	Scenario 0					Traffic Burst			
0	Connection Establish	iment				Enable Bursty Traffic:			
O L	ayer 4 - TCP					Traffic Busy Period:	ms		
O L	ayer 3 - IPv4					Traffic Inactive Deried			
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€ R	Response		Payload Editor						
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1								-	

Figure 13. Set HTTP Request and Response