Make It Count: an Analysis of a Brute-forcing Botnet

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This short paper was presented at Botconf 2015, Paris, 2-4 December 2015, www.botconf.eu
It is published in the Journal on Cybercrime & Digital Investigations by CECyF, https://journal.cecyf.fr/ojs

DOI: 10.18464/cybin.v1i1.5

***Abstract*—The smallest element in a botnet is a bot. The behavior of a bot can change dynamically based on the decision of the botmaster. Commonly driven by profit, bots are expected to be profitable. If an infected bot does not fulfill the expectations, the botmaster can instruct the bot to switch it's behavior to serve a better purpose. This paper presents a detailed analysis of a network traffic capture of a machine originally infected by a Gamarue variant. The analysis will uncover the behavior of the bot during the initial infection, inactivity period, delivery of a new payload and the following switch of behavior of the bot. The paper will analyze the infection in detail, including the horizontal brute-forcing activity affecting thousands of WordPress websites. The goal of the paper is to show a concrete example of a bot performing brute-forcing, analyze it, identify the mechanisms used and indicators of compromise that will help detect it.**

I. INTRODUCTION

Botnets are always recruiting new bots to increase their size and be more profitable. It is a common practice that researchers execute malware in sandboxed environments in order to study the botnet's behavior. When the sandboxing time is short, about a few minutes, it is only possible to capture the initial behavior of the bot. This initial behavior is very important as it gives critical information about the botnet that can be immediately used for detecting the threat. However, when the sandboxing time is longer, such as days or months, it is possible to acquire knowledge not only from the particular bot and the botnet actions in that period of time, but it is also possible to have an insight on the underlying strategies behind a botnet's actions.

Gamarue is a complex and modular botnet, also known as Andromeda. It has been studied thoroughly and new reports on its behavior are being published continuously. As a modular botnet, its behavior can dynamically change. The botnet is capable of deploying new modules and behaves in ways that are still unknown. Usually these different behaviors cannot be captured by current sandbox solutions that execute malware for short periods of time. It is only when a malware is run for extended periods of time that their more complex capabilities can be observed.

In 2015, as part of our research of malware behavior through long term sandboxing experiments, we infected several virtual machines (VMs) with a particular Gamarue sample[1]. Every VM was run for a specific amount of time. The shortest sandbox time was 4 hours and the longest sandbox time was 45 days. After each infection stopped, the dynamic behavior of the malware was analyzed.

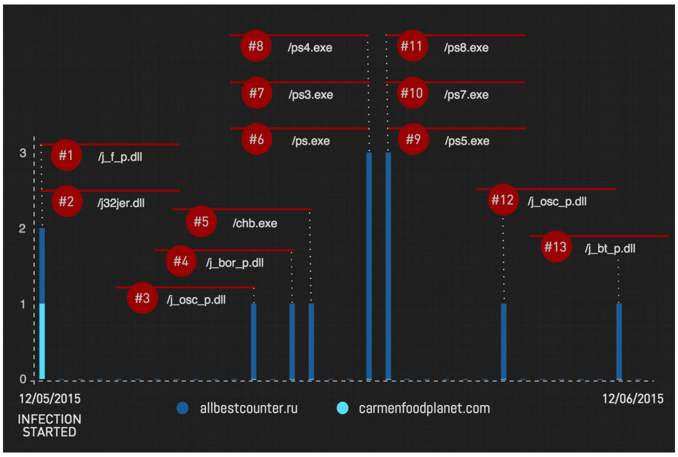


Fig. 1. The timeline shows different binaries the Gamarue bot attempted to download per day since the beginning of the infection. Each download represents a potential behavioral change in the bot.

This paper will present a detailed network capture analysis of a 30 days Gamarue infection, covering the different stages of the infected bot, the observed infrastructure of the botnet and how different command an control (C&C) channels were used for different purposes. Our work also presents an analysis of a previously unknown behavior of the Gamarue botnet: the capability to perform an horizontal brute-forcing of WordPress sites in a highly aggressive and automated fashion.

II. INFECTION TIMELINE

The malware infection experiment lasted thirty days, from May 12, 2015 to June 12, 2015. Two command and control channels were identified in the capture:

1) Gamarue C&C
2) Brute-forcing module C&C

The bot started communicating with the Gamarue C&C immediately after the binary was executed on the VM. The bot was idle the first 10 days of the infection, there was an active communication with the C&C servers but no additional traffic

[1] c13b6e28f889b5597efcfc52564ab28fadd676c572088036da16cb6e90138334

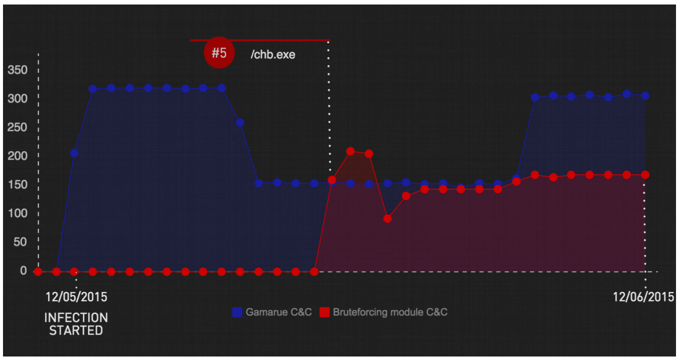


Fig. 2. Comparison of the C&C traffic of the initial Gamarue infection and the second infection associated to the brute-forcing module. The image shows the number of daily HTTP requests per C&C channel in the 30 days experiment.

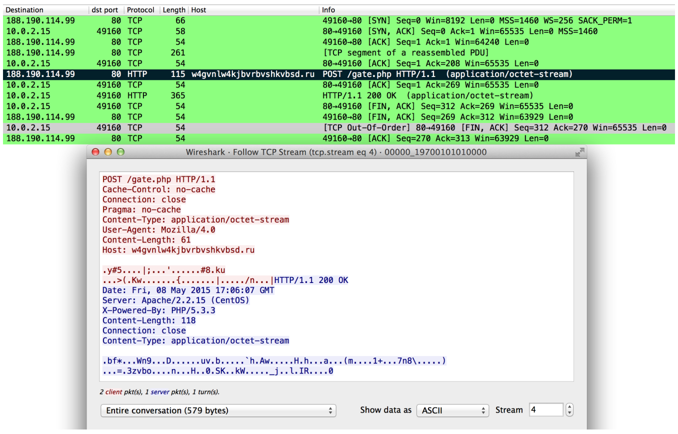
was seen during this period. After this long inactivity time, the bot was instructed to start downloading and deploying new payloads into the infected machine as shown on Figure 1.

The bot attempted to download 13 files from 2 different servers in the 30 days infection experiment. The first 4 downloads didn't produce any change on the behavior of the bot. However, the fifth payload (http://allbestcounter.ru/chb.exe) triggered a second infection on the already infected host. A comparison of the network traffic of each C&C channel is shown in Figure 2, where it is visible how both remained active until the end of the experiment.

Gamarue is the primary infection that controls the activity of the bot and is independent of the second module's C&C seen on the host. During the thirty days the primary C&C remained active, the bot attempted to communicate with three different servers:

- 188.190.114.99 (w4gvnlw4kjbvrbvshkvbsd.ru)
- 93.95.98.50 (okiijlijlili.eu)
- 166.78.144.80 (f34234f234f2sdcsv.info)

The communication to the C&C servers was done through the HTTP protocol, by sending and receiving encrypted data. An example of a successful HTTP connection to the C&C is shown on Figure 3, where it is possible to observe how the bot is sending encrypted data and the C&C server is also responding with encrypted data. There is also additional key information visible on the Figure, such as the specific User-Agent used on the request "Mozilla/4.0" and the small amount of data sent and received in each query. Figure 4 shows an HTTP connection example to an unavailable server, where the bot is sending encrypted data but the server is responding with a standard "404 Not Found" error page.



```
Destination      dst port Protocol Length Host                       Info
188.190.114.99       80 TCP       66                            49160→80 [SYN] Seq=0 Win=8192 Len=0 MSS=1460 WS=256 SACK_PERM=1
10.0.2.15         49160 TCP       58                            80→49160 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 MSS=1460
188.190.114.99       80 TCP       54                            49160→80 [ACK] Seq=1 Ack=1 Win=64240 Len=0
188.190.114.99       80 TCP      261                            [TCP segment of a reassembled PDU]
10.0.2.15         49160 TCP       54                            80→49160 [ACK] Seq=1 Ack=208 Win=65535 Len=0
188.190.114.99       80 HTTP     115 w4gvnlw4kjbvrbvshkvbsd.ru  POST /gate.php HTTP/1.1  (application/octet-stream)
10.0.2.15         49160 TCP       54                            80→49160 [ACK] Seq=1 Ack=269 Win=65535 Len=0
10.0.2.15         49160 HTTP     365                            HTTP/1.1 200 OK  (application/octet-stream)
10.0.2.15         49160 TCP       54                            80→49160 [FIN, ACK] Seq=312 Ack=269 Win=65535 Len=0
188.190.114.99       80 TCP       54                            49160→80 [FIN, ACK] Seq=269 Ack=312 Win=63929 Len=0
10.0.2.15         49160 TCP       54                            [TCP Out-Of-Order] 80→49160 [FIN, ACK] Seq=312 Ack=270 Win=65535 Len=0
188.190.114.99       80 TCP       54                            49160→80 [ACK] Seq=270 Ack=313 Win=63929 Len=0
```

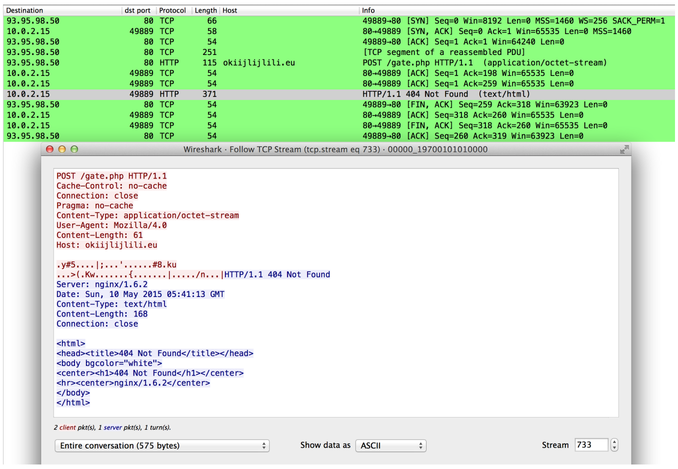
Wireshark · Follow TCP Stream (tcp.stream eq 4) · 00000_19700101010000

```
POST /gate.php HTTP/1.1
Cache-Control: no-cache
Connection: close
Pragma: no-cache
Content-Type: application/octet-stream
User-Agent: Mozilla/4.0
Content-Length: 61
Host: w4gvnlw4kjbvrbvshkvbsd.ru

.y#5....|;...'......#8.ku
...>(.Kw.......{.......|...../n...|HTTP/1.1 200 OK
Date: Fri, 08 May 2015 17:06:07 GMT
Server: Apache/2.2.15 (CentOS)
X-Powered-By: PHP/5.3.3
Content-Length: 118
Connection: close
Content-Type: application/octet-stream

.bf*...Wn9...D......uv.b.....`h.Aw.....H.h...a...(m....1+...7n8\.....)
...=.3zvbo....n...H..0.SK..kW....._j..l.IR....0
```

2 client pkt(s), 1 server pkt(s), 1 turn(s).

Entire conversation (579 bytes) | Show data as: ASCII | Stream: 4

Fig. 3. Example of a successful Gamarue HTTP POST request and response example to an active C&C server. The bot exchanges encrypted data with the C&C server through the HTTP protocol.



```
Destination      dst port Protocol Length Host              Info
93.95.98.50          80 TCP       66                   49889→80 [SYN] Seq=0 Win=8192 Len=0 MSS=1460 WS=256 SACK_PERM=1
10.0.2.15         49889 TCP       58                   80→49889 [SYN, ACK] Seq=0 Ack=1 Win=65535 Len=0 MSS=1460
93.95.98.50          80 TCP       54                   49889→80 [ACK] Seq=1 Ack=1 Win=64240 Len=0
93.95.98.50          80 TCP      251                   [TCP segment of a reassembled PDU]
93.95.98.50          80 HTTP     115 okiijlijlili.eu   POST /gate.php HTTP/1.1  (application/octet-stream)
10.0.2.15         49889 TCP       54                   80→49889 [ACK] Seq=1 Ack=198 Win=65535 Len=0
10.0.2.15         49889 TCP       54                   80→49889 [ACK] Seq=1 Ack=259 Win=65535 Len=0
10.0.2.15         49889 HTTP     371                   HTTP/1.1 404 Not Found  (text/html)
93.95.98.50          80 TCP       54                   49889→80 [FIN, ACK] Seq=259 Ack=318 Win=63923 Len=0
10.0.2.15         49889 TCP       54                   80→49889 [ACK] Seq=318 Ack=260 Win=65535 Len=0
10.0.2.15         49889 TCP       54                   80→49889 [FIN, ACK] Seq=318 Ack=260 Win=65535 Len=0
93.95.98.50          80 TCP       54                   49889→80 [ACK] Seq=260 Ack=319 Win=63923 Len=0
```

Wireshark · Follow TCP Stream (tcp.stream eq 733) · 00000_19700101010000

```
POST /gate.php HTTP/1.1
Cache-Control: no-cache
Connection: close
Pragma: no-cache
Content-Type: application/octet-stream
User-Agent: Mozilla/4.0
Content-Length: 61
Host: okiijlijlili.eu

.y#5....|;...'......#8.ku
...>(.Kw.......{.......|...../n...|HTTP/1.1 404 Not Found
Server: nginx/1.6.2
Date: Sun, 10 May 2015 05:41:13 GMT
Content-Type: text/html
Content-Length: 168
Connection: close

<html>
<head><title>404 Not Found</title></head>
<body bgcolor="white">
<center><h1>404 Not Found</h1></center>
<hr><center>nginx/1.6.2</center>
</body>
</html>
```

2 client pkt(s), 1 server pkt(s), 1 turn(s).

Entire conversation (575 bytes) | Show data as: ASCII | Stream: 733

Fig. 4. Example of a Gamarue HTTP POST request to an unavailable server. The bot sends encrypted data to the server, but the server responds with a "404 Not Found" error page.

The HTTP requests to each of these servers were identical: a POST request sending the same amount of encrypted data to the resource "/gate.php". The C&C server on 188.190.114.99 was the only one that seemed to be active: responding to the bot with encrypted data. The other two were inactive or responded with an HTTP error code. Figure 5 shows the average of uploaded content-bytes (without headers) per each C&C server related to Gamarue. The bot's communication to the servers was highly stable, constantly sending the same amount of data, 61 bytes. The average of downloaded content-bytes (without headers), as seen on Figure 6, shows that the server on 166.78.144.80 was sending zero bytes as response; the server on 93.95.98.50 had a higher daily average of bytes received, which indicates that the server was not available and the response was a typical HTTP not found error.

The behavior of the Gamarue bot during the first 10 days is standard for this botnet. Indicators discussed in this section can be used to identify and detect this type of traffic in the network. The activity associated with the download of new payloads provides new insight on this botnet's long term activity and potential capabilities. The next section will discuss in depth the behavior of the second infection responsible for the horizontal brute-forcing of WordPress sites.

III. HORIZONTAL BRUTE-FORCING C&C

The second infection on the host was triggered by the download of a new payload after 14 days of the original

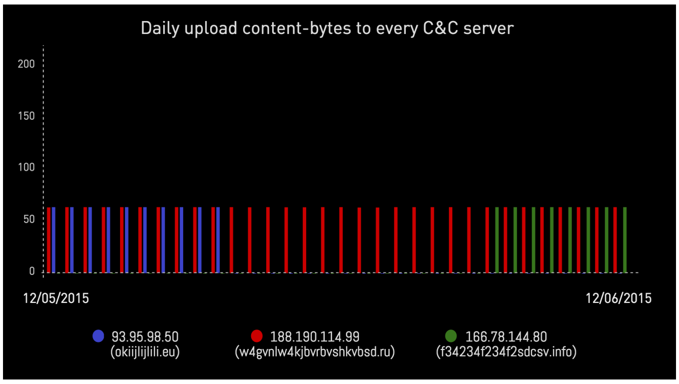


Fig. 5. The Figure shows the average bytes per day sent by the bot to each C&C server. The behavior of the bot was stable during all the experiment.

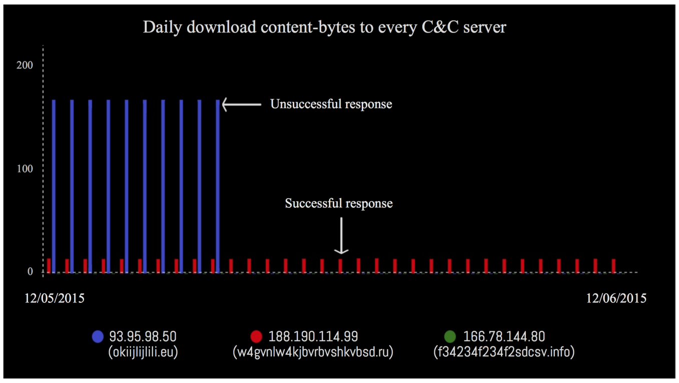


Fig. 6. The Figure shows the average bytes per day received from each contacted C&C server.

infection. The delivered payload[2] doesn't have a concrete detection signature according to Virus Total[3], causing a poor threat categorization.

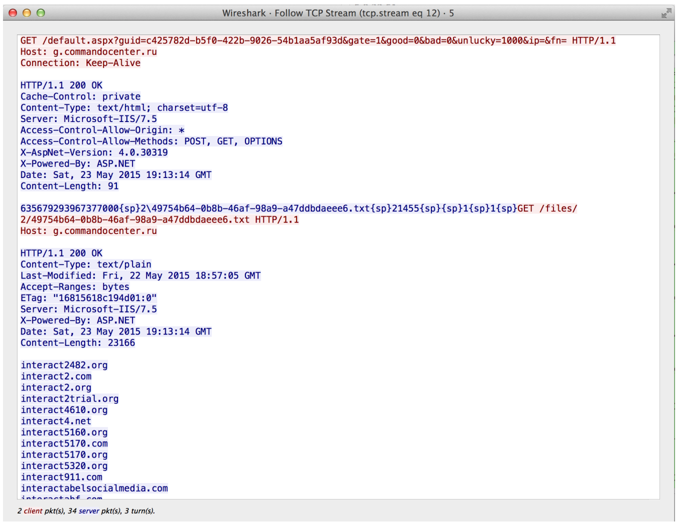
The behavior of this particular module can be summarized as follows:

1) It obtains a list of WordPress targets to attempt to login from the C&C server.
2) It takes the next entry from the list and attempts to login with chosen credentials (explained in section V) in order to gain access.
3) If the login attempt was successful, reports it to the C&C server.
4) If the login attempt was unsuccessful, it will iterate from step 2) until exhausting the retrieved websites.

The C&C communication was not encrypted and sent through HTTP to only one server:

- g.commandocenter.ru (5.8.32.51)

The analysis of the network traffic associated to this C&C corroborates the simplicity of the malware behavior stated above. There are only three different types of HTTP requests made to this server, as exemplified next:



```
GET /default.aspx?guid=c425782d-b5f0-422b-9026-54b1aa5af93d&gate=1&good=0&bad=0&unlucky=1000&ip=&fn= HTTP/1.1
Host: g.commandocenter.ru
Connection: Keep-Alive

HTTP/1.1 200 OK
Cache-Control: private
Content-Type: text/html; charset=utf-8
Server: Microsoft-IIS/7.5
Access-Control-Allow-Origin: *
Access-Control-Allow-Methods: POST, GET, OPTIONS
X-AspNet-Version: 4.0.30319
X-Powered-By: ASP.NET
Date: Sat, 23 May 2015 19:13:14 GMT
Content-Length: 91

635679293967377000{sp}2\49754b64-0b8b-46af-98a9-a47ddbdaeee6.txt{sp}21455{sp}{sp}1{sp}1{sp}GET /files/
2/49754b64-0b8b-46af-98a9-a47ddbdaeee6.txt HTTP/1.1
Host: g.commandocenter.ru

HTTP/1.1 200 OK
Content-Type: text/plain
Last-Modified: Fri, 22 May 2015 18:57:05 GMT
Accept-Ranges: bytes
ETag: "16815618c194d01:0"
Server: Microsoft-IIS/7.5
X-Powered-By: ASP.NET
Date: Sat, 23 May 2015 19:13:14 GMT
Content-Length: 23166

interact2482.org
interact2.com
interact2.org
interact2trial.org
interact4610.org
interact4.net
interact5160.org
interact5170.com
interact5170.org
interact5320.org
interact911.com
interactabelsocialmedia.com
```

2 client pkt(s), 34 server pkt(s), 3 turn(s).

Fig. 7. Example of the HTTP communication between the bot and the brute-forcing C&C. It can be observed how the content of the communication is not encrypted and what type of information is retrieved from the C&C server.

1) http://g.commandocenter.ru/default.aspx ?guid=dca94d1f-f7eb-487f-ad24-923cd1b4f946&**gate=1**&**good=-1**&**bad=0**&**unlucky=1**&ip=&fn= **??**
2) http://g.commandocenter.ru/files/2/9d753bd0-33a5-46ac-841d-f99d9ace3446.txt **??**
3) http://g.commandocenter.ru/col.aspx ?**t=wp_b**&g=1&gid=1 **??**

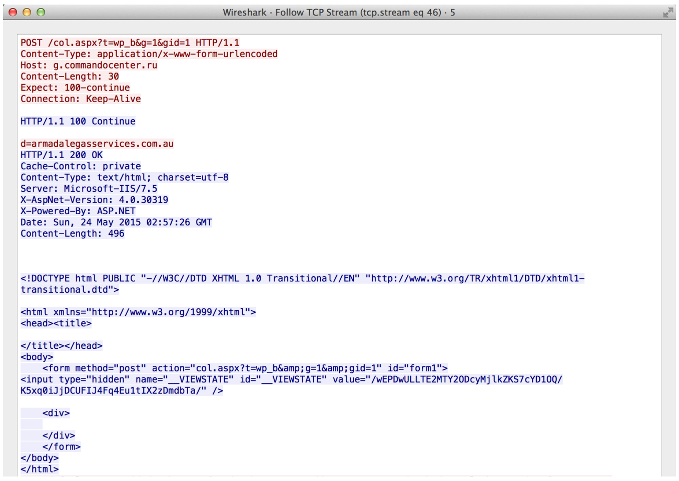
The purpose of the first request is twofold: send a status report to the C&C and retrieve the name of a new file to download. The second request is the one that actually retrieves the file from the server as indicated on the response of the previous request. The file retrieved from the server contains a list of 1,000 WordPress domains, in average, that the bot will attempt to brute-force. The first and second requests are usually in the same TCP session as it can be seen on the example shown in Figure 7.

While the first and second request occur with a high frequency during the brute-forcing activity, the third request is not common. The third request is used to send information to the C&C server about the successful attempts made by the bot. The POST request will send a list of domains that the bot could successfully log into. Figure 8 illustrates an example in which just one website is being reported as a successful attempt. This request will trigger again the first and second requests, sharing the same TCP session: reporting the status of the last brute-forcing attempt and getting a new batch of domains to brute-force as seen in Figure 9.

A breakdown of the amount of traffic associated to each one of these individual behaviors during the whole infection is shown in Figure 10.

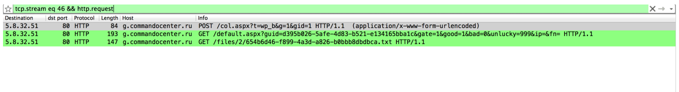
The brute-forcing activity was condensed on the first four days after the deployment of the new payload, as it can be observed in Figure 10. The activity of the bot during this

[2] 29ab1a0ec1e3aa4222e17cb392d0a7c0e30f4a9b8ce3a2eb2f8d1887a9d61f3c
[3] https://www.virustotal.com



```
POST /col.aspx?t=wp_b&g=1&gid=1 HTTP/1.1
Content-Type: application/x-www-form-urlencoded
Host: g.commandocenter.ru
Content-Length: 30
Expect: 100-continue
Connection: Keep-Alive

HTTP/1.1 100 Continue

d=armadalegasservices.com.au
HTTP/1.1 200 OK
Cache-Control: private
Content-Type: text/html; charset=utf-8
Server: Microsoft-IIS/7.5
X-AspNet-Version: 4.0.30319
X-Powered-By: ASP.NET
Date: Sun, 24 May 2015 02:57:26 GMT
Content-Length: 496



<!DOCTYPE html PUBLIC "-//W3C//DTD XHTML 1.0 Transitional//EN" "http://www.w3.org/TR/xhtml1/DTD/xhtml1-
transitional.dtd">

<html xmlns="http://www.w3.org/1999/xhtml">
<head><title>

</title></head>
<body>
    <form method="post" action="col.aspx?t=wp_b&amp;g=1&amp;gid=1" id="form1">
<input type="hidden" name="__VIEWSTATE" id="__VIEWSTATE" value="/wEPDwULLTE2MTY2ODcyMjlkZKS7cYD1OQ/
K5xq0iJjDCUFIJ4Fq4Eu1tIX2zDmdbTa/" />

    <div>

    </div>
    </form>
</body>
</html>
```

Fig. 8. Example of how the bot is reporting a successful attempt to the C&C. The communication initiates with an HTTP POST request but the actual data is sent as a response to the ’100 Continue’ message received from the C&C server.



```
tcp.stream eq 46 && http.request
Destination  dst port Protocol Length Host                 Info
5.8.32.51          80 HTTP         84 g.commandocenter.ru  POST /col.aspx?t=wp_b&g=1&gid=1 HTTP/1.1  (application/x-www-form-urlencoded)
5.8.32.51          80 HTTP        193 g.commandocenter.ru  GET /default.aspx?guid=d395b026-5afe-4d83-b521-e134165bba1c&gate=1&good=1&bad=0&unlucky=999&ip=&fn= HTTP/1.1
5.8.32.51          80 HTTP        147 g.commandocenter.ru  GET /files/2/654b6d46-f899-4a3d-a826-b0bbb8dbdbca.txt HTTP/1.1
```

Fig. 9. Sequence of requests triggered by a successful attempt report

period was highly aggressive. With more than 40,000 sites attempted per day, the bot attempted to login into 167,066 WordPress sites. Figure 11 shows a general overview of the brute-forcing activity where it is possible to observe the burst on the first 3 days, a considerable reduction on day 4 and a stop of the activity on day 5.

As it was mentioned before, the bot downloaded files from the C&C server containing lists of WordPress sites. Every new file retrieved by the bot contained a list of 1,000 WordPress domains or less. In the four days of activity 300 files were downloaded, containing 219,078 WordPress domains. Every list contained sites in alphabetical order, usually one list contained domains starting with ’a’, next one with ’b’ and so on. While it is unknown how these lists of sites were gathered and created, there are clues that seem to indicate they are generated in an automatic fashion. Some of the lists contained what seem to be IP addresses but with only three octets instead of four of them; some lists contained two domain names concatenated, and some lists contained domains starting with ”.”, which may mean a parsing error or some mistake in the retrieval of those domains.

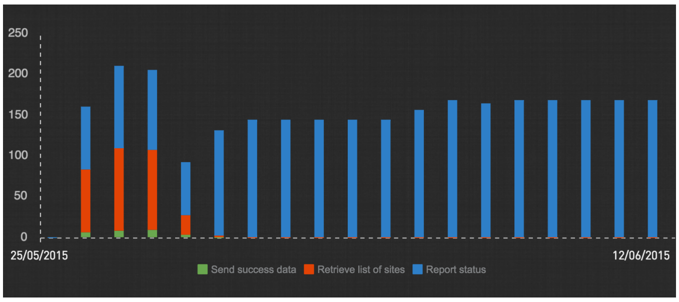


Fig. 10. General overview of the individual behaviors of the brute-forcing botnet during the infection

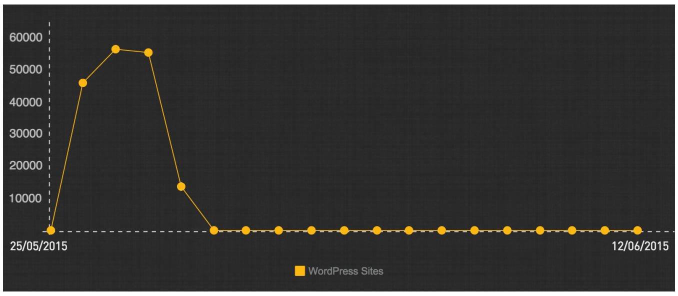


Fig. 11. Amount of WordPress sites the bot attempted to login per day

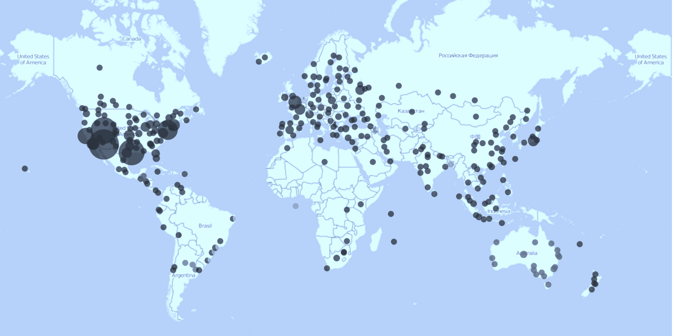


Fig. 12. Global Map of Attacked WordPress Sites

IV. INSIGHT ON TARGETS

An analysis of the domains targeted by the botnet showed that the brute-forcing activity was not focused in a particular geographic region as illustrated on Figure 12. It was a global brute-forcing attack of WordPress sites located all over the world.

The WordPress domains seem to have been chosen automatically in no particular order. An analysis on the TLD distribution shows that there were domains matching 164 different TLDs. A breakdown of common TLDs targeted by the bot is displayed in Figure 13.

Many of the targeted domains seem unattended, giving advantage to the attackers as there are higher chances that passwords on those sites are left by default and there are less chances that the site will be cleaned up immediately.

V. BRUTE-FORCE LIST OF USER NAMES AND PASSWORDS

As mentioned in the previous section, many of the successful login attempts were because of WordPress sites using a weak user name and password combination. Due to the fact that every login attempt was performed through a HTTP POST request, it was possible to analyze the combinations of user names and passwords the bot used in its activity.

The analysis of login credentials showed that there was no variability on user names. The bot only attempted to login as

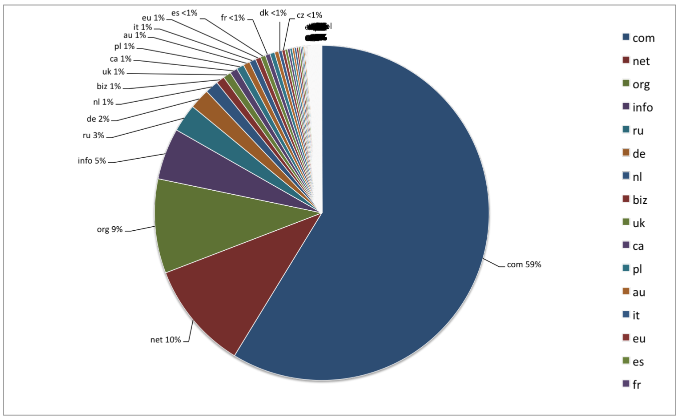
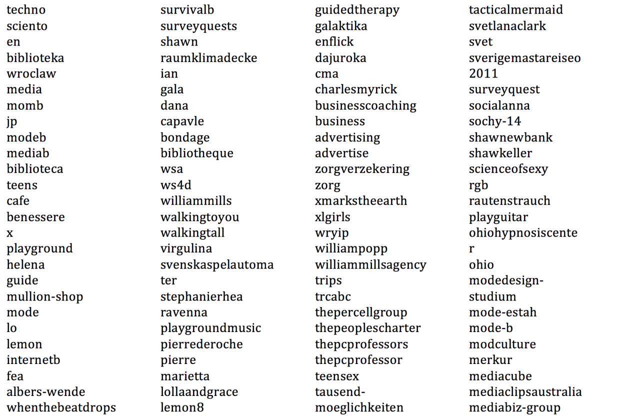


Fig. 13. Distribution of domains by TLD


techno
sciento
en
biblioteka
wroclaw
media
momb
jp
modeb
mediab
biblioteca
teens
cafe
benessere
x
playground
helena
guide
mullion-shop
mode
lo
lemon
internetb
fea
albers-wende
whenthebeatdrops

survivalb
surveyquests
shawn
raumklimadecke
ian
gala
dana
capavle
bondage
bibliotheque
wsa
ws4d
williammills
walkingtoyou
walkingtall
virgulina
svenskaspelautoma
ter
stephanierhea
ravenna
playgroundmusic
pierrederoche
pierre
marietta
lollaandgrace
lemon8

guidedtherapy
galaktika
enflick
dajuroka
cma
charlesmyrick
businesscoaching
business
advertising
advertise
zorgverzekering
zorg
xmarkstheearth
xlgirls
wryip
williampopp
williammillsagency
trips
trcabc
thepercellgroup
thepeoplescharter
thepcprofessors
thepcprofessor
teensex
tausend-
moeglichkeiten

tacticalmermaid
svetlanaclark
svet
sverigemastareiseo
2011
surveyquest
socialanna
sochy-14
shawnewbank
shawkeller
scienceofsexy
rgb
rautenstrauch
playguitar
ohiohypnosiscente
r
ohio
modedesign-
studium
mode-estah
mode-b
modculture
merkur
mediacube
mediaclipsaustralia
mediabiz-group

Fig. 14. Examples of passwords used to attempt login to the targeted sites

'admin' in all the cases. The decision by the attacker was right: WordPress sites have a default 'admin' user and fixing this variable reduces the complexity of the brute-forcing. There is additional information leveraged by the attackers in this aspect, and it is the fact that WordPress is designed to be easy to be used by anyone that increases the success chances as many non-experienced users just use default or easy to guess credentials.

The passwords used by the bot were interestingly distributed in two groups:

- Default credentials (admin,admin): 47,5% of the cases
- Custom passwords: 52,5% of the cases

There is a huge number of unique combinations of user names and passwords used by the bot as alternatives to the default 'admin' password. Figure 14 shows a few examples of these observed unique passwords. The existence of this list of passwords may initially indicate that the bot downloaded such a list from the C&C server. The analysis of the network traffic showed no signs of this request or of any additional download by the bot. Additionally, there is a correspondence between some of the passwords and domain names of targeted WordPress sites. This may indicate that the malware has the ability to generate possible passwords by parsing domain names. In many cases, this simple functionality led to successful login attempts. As an example, the bot made two attempts to login to the site '[REDACTED-VICTIM-DOMAIN].biz'; the first user name and password combination was admin/admin; the second combination was admin/[REDACTED-VICTIM-DOMAIN].

VI. CONCLUSION

In this paper we have discussed technical details and network behavior characteristics of how a bot initially infected with a Gamarue was re-infected with a different malware payload, leading to a drastic change in the bot's behavior. The delivered payload seems to be an independent malware that is distributed by the botnet. The analysis gave an insight to this previously unknown malware, the modus operandi, characteristics of the traffic and speed of the attacks.

The goal of the reinfection was to provide functionality that increased the profitability of an idle infection. The presumable benefit out of this activity is to expand the current botnet C&C infrastructure or resell brute-forced websites to other actors.

The analysis showed the powerful capacity of a single bot for this activity. It also showed us how this new malware, by massively harvesting vulnerable websites, may be supplying other malicious actors with compromised sites to use as part of their moving infrastructure. The main reason of the success of this type of botnet relies on the human factor: people keeping default user names and passwords or choosing passwords that are easy to guess.

The presented work also served as a concrete example of what type of extra information can be extracted from long term sandboxing experiments and how this uncommon long term captures can give an unexpected insight of the often complex behavior of botnets. We hope it will also server as motivation for others to experiment as well with long term sandboxing malware captures.

VII. LIST OF IOCS

The following domains and IPs were observed during this investigation:

```
188.190.114.99
w4gvnlw4kjbvrbvshkvbsd.ru
93.95.98.50
okiijlijlili.eu
166.78.144.80
f34234f234f2sdcsv.info
g.commandocenter.ru
5.8.32.51
```