

May 15th, 10:00 AM

Kelihos Botnet: A Never-Ending Saga

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Arora, Arsh; Gannon, Max; and Warner, Gary, "Kelihos Botnet: A Never-Ending Saga" (2017). *Annual ADFSL Conference on Digital Forensics, Security and Law*. 4.

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KELIHOS BOTNET: A NEVER-ENDING SAGA

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ABSTRACT

This paper investigates the recent behavior of the Kelihos botnet, a spam-sending botnet that accounts for many millions of emails sent each day. The paper demonstrates how a team of students are able to perform a longitudinal malware study, making significant observations and contributions to the understanding of a major botnet using tools and techniques taught in the classroom. From this perspective, the paper has two objectives: encouragement and observation. First, by providing insight into the methodology and tools used by student researchers to document and understand a botnet, the paper strives to embolden other academic programs to follow a similar path and to encourage such discovery. Second, the paper shares observations and insights gathered about the botnet’s recent spam activity showing evidence of the “spam as a service” model and demonstrating a variety of unique and dangerous spam campaigns conducted via the Kelihos botnet, including banking trojans, credential phishing, and ransomware attacks.

Keywords: Kelihos, Botnet, Malware, Spam, Ransomware, Banking Trojan, Pharma, Pump and Dump, Geo-Targeting

1. INTRODUCTION

While the Kelihos botnet first debuted in 2009, the current botnet is a functional derivative of two other famous botnets, Waledac, and the Storm Worm [Adair, 2012, Bureau, 2011]. The Kelihos botnet is known by a number of aliases in the community including Hlux and Slenfbot [Singh et al., 2014]. Kelihos evolved and became sophisticated over time, but no interruption could stop the working of Kelihos. Two widely celebrated takedowns of Kelihos have been performed by security companies. The first was Operation b79, conducted by Microsoft in September of 2009 [Nadji et al., 2013]. In March of 2012,

CrowdStrike, Dell Secureworks, Kaspersky, and others sinkholed 100,000 nodes of the Kelihos.B malware [Kerkers et al., 2014]. At RSA Conference 2013, CrowdStrike demonstrated a repeat performance, targeted Kelihos.C [Rossow et al., 2013, Werner, 2013]. Despite these admirable attempts, Kelihos continues to send significant volumes of spam on a daily basis [Stringhini et al., 2014]. Even after all of the takedown attempts, Kelihos was still ranked as the top spam-sending botnet in 2015 and continues to yield a significant spam volume today [McAfee, 2016, Tech, 2016].

The Kelihos botnet utilizes a peer to peer

network infrastructure that hides the location of the true command and control server [Dietrich et al., 2013]. Kelihos-infected computers communicate with one another and are used in two primary ways, depending on whether they have a publicly reachable IP address or not. Nodes which cannot be addressed from the Internet just send spam. Internet addressable nodes help to anonymize the location of the C&C server by acting as a multi-tiered proxy, receiving requests for spam details from spamming nodes, and requesting those same details from other nodes, eventually leading to a job server which is leased infrastructure and communicates with the C&C server, as documented by Fortinet’s Kyle Yang at BlackHat [Yang, 2012].

The most unique aspect of Kelihos is the diversity in its spam and its delivery mechanism. The spam diversity is primarily because Kelihos provides “spam as a service” offering the use of its spamming infrastructure for hire to deliver any messages for a sender who is willing to pay their fees. The spam messages are dominated by pharmaceutical spam, but are not limited to it. Pharma spam seems to be the fall-back position, when other higher paying customers have not hired the botnet to deliver something else. Kelihos has been observed sending spam for pump and dump manipulation of different stock symbols, money mule job applications, and credential phishing for Polish and French financial institutions. In the summer of 2016, Kelihos began geo-targeting for email delivery sending different messages and payloads based on the country-code Top Level Domain (ccTLD) of the email recipient (’.pl’,’.uk’). Malware, including ransomware and Zeus banking trojans, were delivered only to certain geographies using this technique. Kelihos has been seen spamming ransomware, sending WildFire [Arora & Warner, 2016b], CryptFile2 [Arora & Warner, 2016a] and Troldesh [Arora & Warner, 2016f] encryption ransomware fam-

ilies.

Another addition to the spam campaign is sending links to a Word document that will drop a variant of Zeus, specifically, geo-targeting for German and United Kingdom banks. In the current iteration, it uses stolen SMTP credentials to login as a legitimate user to a large number of mail servers and sends spam.

2. NETWORK

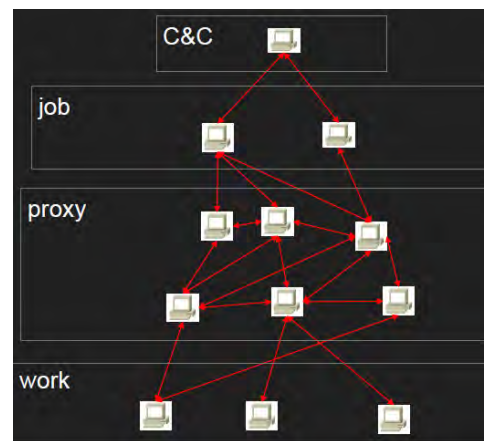


Figure 1. Courtesy: Kyle Yang outlining Kelihos distribution network [Yang, 2012]

Although the division of the botnet’s operation appears to be clear in Figure 1, the path is actually complex. Starting from the bottom, the chart displays the worker or client nodes, which sends spam to the end user and only communicate to the servers at the proxy level. The proxy level is the most interesting one as it connects with other proxies, clients, and job servers. This 3-way communication makes it the most attractive and the one that contains maximum information. The proxy level receives templates from other proxies and also communicates with the job servers. While Kelihos-infected Windows computers serve as the proxy and worker nodes, job servers are leased hardware controlled by the criminals. Job servers are the ones that serve as the main operators to the command and control center. Job servers are often in disguise and try to be invisible under the shadow

of different proxies; thus, making detection extremely complex and difficult. Lastly, the command and control center is handled by the bot herder and provides the information, spam templates, and updates needed to be distributed across the botnet.

3. INITIALIZATION

In this section, researchers will describe the pattern that is followed by the Kelihos binary to initiate, then communicate to its command and control center and eventually send spam. The process will be illustrated with screen captures from OllyDbg and Wireshark. The details are shared so that they can be easily replicated by any individual who has expertise with OllyDbg. The following analysis was performed in a virtual environment (VMWare) operating in NAT network mode.

3.1 Processes

In the subsequent section, researchers will describe the process of how a Kelihos binary performs when we try to self-infect. The preliminary observations can be viewed with the help of programs such as Wireshark, Process Hacker, and OllyDbg 2.0 version. Next, we will explain the process of self-infecting with a complete description of the process as depicted in Figure 2. As soon as we launch the binary, it initiates and starts a child process. Once the child process gets fully activated, it terminates the parent process and starts the communication process. Initially, it tries to make a TCP connection with several Internet Protocol (IP) addresses which are hard-coded in the binary. There is a unique identifier in the message that helps to authenticate the communication coming from the Kelihos binary. Once a connection is established, it makes a request for configuration (config) files. The config files contain the information about the spam template and the email addresses to be used for sending spam messages.

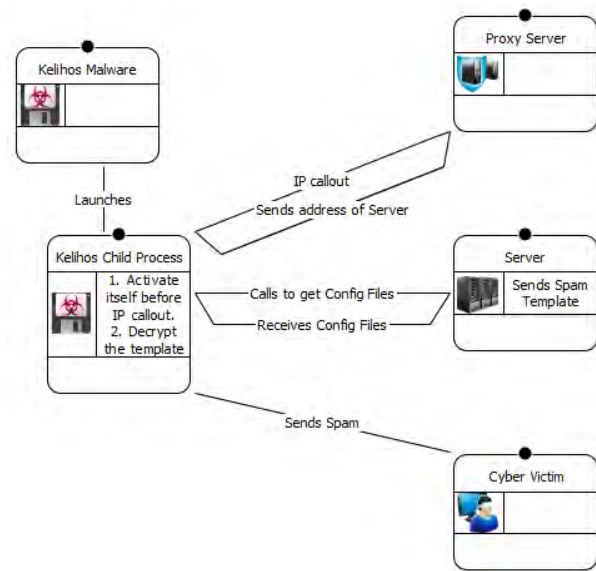


Figure 2. Architecture of Kelihos Malware

3.1.1 Parent Process

In the following sub-section, researchers will demonstrate some breakpoints in OllyDbg that are helpful in performing the analysis. To attain optimum results, the following steps should be followed in the order mentioned.

After introducing a Kelihos binary into the virtual environment, start Process Hacker and OllyDbg as an administrator. Next, open the Kelihos binary in OllyDbg. Now, one can see a process being activated in Process Hacker. The following breakpoints should be enabled under the Executables (E) tab of OllyDbg:

1. Ntdll.dll
 - (a) RtlReportSilentProcessExit
 - (b) NtTerminateProcess
 - (c) NtResumeThread
2. kernel32.dll
 - (a) Resume Thread

Address	Module	Status	Disassembly	Comment
75C80F1C	kernel32	Active	MOV EDI,EDI	UINT kernel32.ResumeThread(Thread)
77836A08	ntdll	Active	MOV EAX,130	ntdll.NtResumeThread(guessed Arg1,Arg2)
778368C8	ntdll	Active	MOV EAX,172	ntdll.NtTerminateProcess(guessed Arg1,Arg2)
77840FDC	ntdll	Active	MOV EDI,EDI	ntdll.RtlReportSilentProcessExit(guessed Arg1,Arg2)

Figure 3. Breakpoints for Parent Process

The researchers provide the specific breakpoints in Figure 3, so that the results may be

easily replicated. Once we start debugging the program, it will stop at the breakpoints in the following manner:

1. RtlReportSilentProcessExit
2. NtTerminateProcess
3. RtlReportSilentProcessExit
4. NtTerminateProcess
5. ResumeThread
6. NtResumeThread

The process is complicated, but this method seems to obtain the maximum information from the parent process before moving to the child process. This child process can be observed in Process Hacker. The timing of when to attach to the child process is crucial, if one does it before or after the following steps mentioned above, the desired result may not be obtained. Next, we attach the child process in a new OllyDbg window with administrative rights.

3.1.2 Child Process

Once the child process is attached successfully, we check the Executables (E) box and set a breakpoint in the child process at the following location displayed in figure 4.

1. kernel32.dll

(a) Virtual Protect



Figure 4. Breakpoints for Child Process

By setting a breakpoint on kernel32.VirtualProtect, we can pause the malware execution only after the code has been unpacked. One way to understand this unpacking is to observe the DLLs listed in the Executables window in OllyDBG. Before running to the next breakpoint, there are only four DLLs under the Executable section, as shown in Figure 5.

After the execution pauses at the Virtual Protect breakpoint, we can see in figure 6, that the number is significantly greater than what was observed previously.

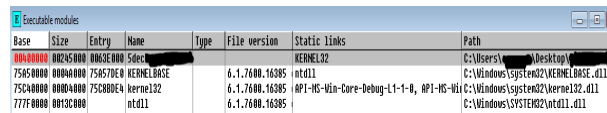


Figure 5. Pre-loaded DLLs at Virtual Protect

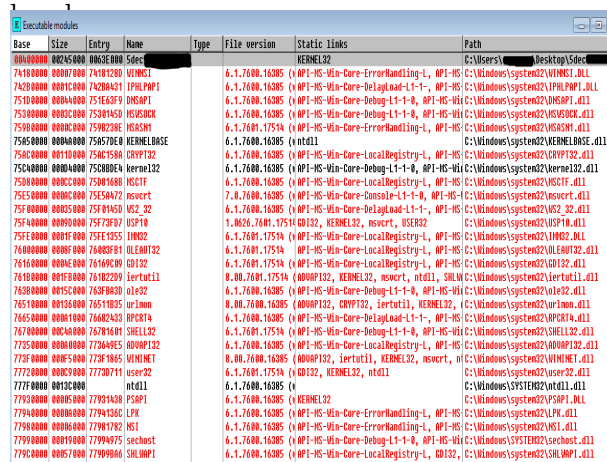


Figure 6. New DLLs loaded shown in Red

Next, the binary will decrypt itself and then proceed towards its communication channel.

3.2 Preparing for Take-Off

This section demonstrates a decoding loop that is run across the code within the binary. Figure 7 displays a certain memory address with non-human readable content.

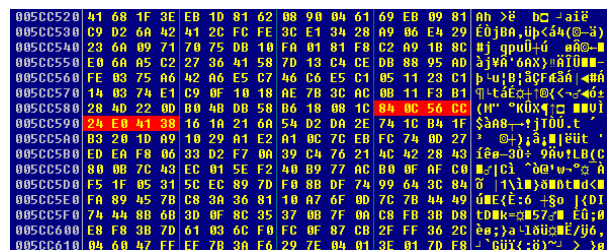


Figure 7. Encrypted Text

After applying this decoding function at the same memory location, displayed in Figure 8, now the same memory location contains readable ASCII code that will be used to request a configuration file from a peer node, displayed in Figure 9. The request is accompanied by NET_SERVER_WORKER ID and an IP address.

After decrypting and activating itself, the binary again stops at Virtual Protect to take

you set the breakpoint at the following address, debug the program. The program will stop at the place with the function call:

```
MOV EBX, EAX
```

This is the location where the IP address gets stored before making a Transmission Control Protocol (TCP) connection. The value is stored in hex in the EAX registry and can be confirmed with Wireshark. As soon as the call is made, Wireshark displays a TCP connection request to the IP in the EAX registry. This can be viewed in Figure 13.

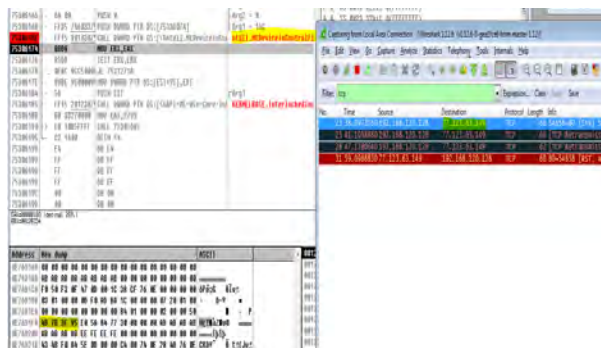


Figure 13. Proof of Hard-coded IP address

Since we knew the IP address from the Wireshark connection (77.123.63.149) it can be safely assumed that the IP is hardcoded in the binary. When we visited the hex address in the EAX Registry and checked for the value in '0E76D1F8' location it contained:

Hex 4D 7B 3F 95 to IP 77.123.63.149

This is the first check done by Kelihos binary to the following IP address, based on the hard-coded IPs in the binary. The binary attempts to establish the connection with the IP addresses one by one in the hope of securing a connection with one of them. In almost all cases, the binary is able to establish connection with one of the 145 IP addresses. If it is not able to establish the connection, it falls back to a list of hard coded domains to try and establish a connection. A list of these domains are shown in the figure 14.

The dominant ones are 'gorodkoff.com' and 'goloduha.info.' During the past year, Pas-

- 2014br.biz
- abrorra.biz
- avroran.biz
- bayermun.biz
- bypomsa.info
- chemp14.biz
- demyator.biz
- ecuad69.biz
- ekidjop.info
- fahhtaz.biz
- fucmethve.info
- goloduha.info
- gorodkoff.com
- gorotza.biz
- hockelen.info
- ibayermun.biz
- jagesxij.info
- jiqnipun.ru
- meuvbayt.info
- mydear.name
- newcounter.biz
- niggawhat.net
- niwrebsa.info
- pasbuyr.info
- pookagyx.info
- segbuktem.info
- usdivqo.info
- omyxiglet.info
- onabgitry.info
- ggabwav.info
- zadofadsun.info

Figure 14. List of the Fast Flux domain names sive DNS systems at Internet Identity (IID) recorded 3,261 distinct IP addresses used by goloduha.info. The researchers' monitoring station was observed by IID resolving gorodkoff.com, goloduha.info, and zavodchikshop.com at least once during each month from July 2016 through December 2016, proving that our "proxy node" was being used as part of the Fast Flux hosting.

3.3.2 Second Communication

Once the initial TCP connection is established with one of the IP addresses, the binary tries to initiate a 164 bytes encrypted conversation with the IP address. The consistent thing in the communication is the presence of string 'IUUE..H@' at the starting of the message in the first 12 bytes, as depicted in Figure 15. This is the unique identifier that is used to confirm that Kelihos binary indeed sends the communication. Before this communication gets sent, it makes the following call:

```
Nt Device IO Control File 753044EE
```

The location can be found by the same manner as you found the previous location. In this case, you add '44EE' to the MSWsock.dll location and put a breakpoint at the following address. One may notice that the function call is the same, but it is the address which is the key here. Therefore, one has to be careful about the address because the function call is mentioned in ten

other places in the binary when searched in OllyDbg. Once the call is made, it uses 'WSA Send' to send the initial communication.

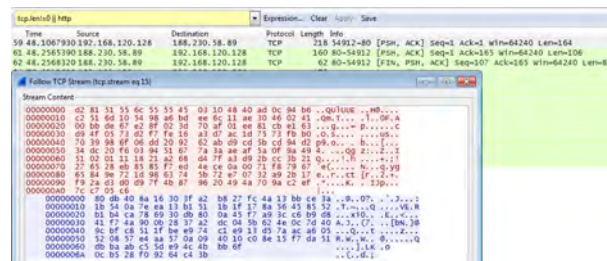


Figure 15. Initial communication with unique identifier 'IUUE..H@'

Next, it waits for a reply from the connected IP; in case it does not receive a response, it moves on to the next IP and performs the same process over and over again. Finally, it uses 'WSA Receive' when the binary can establish a connection and then it receives a consistent string of 227 bytes.

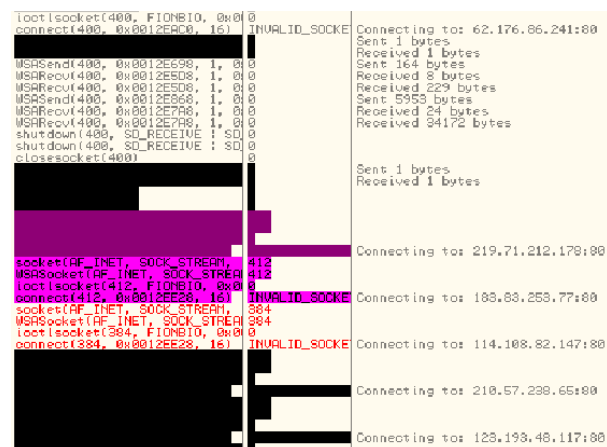


Figure 16. Olly Socket Trace displaying the back and forth communication

Next step, the binary sends a reply and communicates back and forth exchanging pertinent information with the established IP connection about how to obtain the config files. The information is encrypted, but the network communication can be viewed in Wireshark and can be confirmed with a special plugin named 'Olly Socket Trace,' being displayed in Figure 16.

3.3.3 Third Communication

This is the most important section of the communication cycle. The section includes the process of receiving the encrypted config files and then displaying the decryption of the config files into the various fields of 'To,' 'From,' 'Subject' and 'Email Body' for the spam template.

After the above communication is established, the binary requests to receive config files. For the following, we would need to continuously monitor Wireshark and for better results of the experiment use the filter 'http.request.method == GET.' The binary uses HTTP protocol, as shown in Figure 17, to request for config files with the usage of the 'GET' command.

GET /file.htm HTTP/1.1

Info	Protocol
GET /start.htm	HTTP/1.1
GET /start.htm	HTTP/1.1
GET /home.htm	HTTP/1.1
GET /home.htm	HTTP/1.1
GET /main.htm	HTTP/1.1
GET /main.htm	HTTP/1.1
GET /main.htm	HTTP/1.1
GET /main.htm	HTTP/1.1
GET /search.htm	HTTP/1.1
GET /login.htm	HTTP/1.1
GET /login.htm	HTTP/1.1
GET /search.htm	HTTP/1.1
GET /file.htm	HTTP/1.1
GET /default.htm	HTTP/1.1
GET /default.htm	HTTP/1.1
GET /file.htm	HTTP/1.1

Figure 17. Some examples of GET config file request

Figure 18 displays a list of different '.html' file names that are used to obtain various GET config files:

- default
- file
- home
- index
- install
- login
- main
- online
- search
- setup
- start
- welcome

Figure 18. GET config files

After the files are received, the process of decrypting the data starts. Multiple levels of decoding, involving six to seven permutations, are used to convert the encrypted text into readable text. Figures 19 and 20 will give a more picturesque view of the commands use to decrypt the files and the decoded text.

- FZRO FlashZero Corp.
- CWTC Clearwave Telecommunication Inc.
- UPOT Indie Growers Association, Inc.
- SNXG Sunx Energy

Most of the stock symbols were spammed for a couple of weeks, but a few of them came back after taking a break. For example, APTY was first seen on January 22, 2016 and then seen frequently in January, February, and March. It was the most consistent symbol that was being spammed by Kelihos botnet for a long period.

4.3 Money Mule Spam

The Kelihos botnet also often sends spam for money mule or work at home position vacancies. The targets are mostly based on language and location. In this particular spam, the operators seek for unemployed workers or people looking for a job. They urge the reader to reply back to an email address with his/her personal information, promising to pay handsomely with flexible work hours. One of the biggest factors for this spam campaign was that the employee would have the option to work from home, which allowed readers to reply back with their information promptly. Different languages such as English, French, Italian, Spanish, Portuguese, and Dutch have been noted in this particular spam campaign. Notable organizations like Apple and Walmart were also used in some spam campaigns to attract readers.

4.4 Credential Phish Spam

Frequently, we encounter multi-language credential phish. In recent months, the Kelihos botnet targets mostly Polish and French banks, and attempts to steal user credentials by asking the victim to verify their information via clicking a link. The link leads to a phishing website and tries to steal the victims username and password. An example of such

an email was documented in April 2016 and can be seen in the figure 26:



Figure 26. Polish Bank Phish Email

4.5 Kronos Banking Trojan

An interesting thing that was observed on November 9, 2016 was that, in addition to spamming the world, the Kelihos binary behaved covertly and dropped Microsoft Word document on the infected machines desktop [Arora & Warner, 2016e]. The document name can be viewed in Figure 27.



Figure 27. Pictorial view of the document link on the infected user's desktop

The intention was to surprise the user and hope that the document will be viewed out of curiosity. As expected, the 'oldversion.doc' was a malicious document and after clicking 'Enable Content,' it downloaded Kronos banking trojan malware. This was confirmed with Figure 28 that contains a string found in Ollydbg

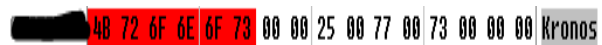


Figure 28. Confirmation of Kronos malware with the help of OllyDbg

5. RANSOMWARE

5.1 WildFire Ransomware

The latest addition to the Kelihos botnet was WildFire Ransomware. On July 8, 2016, a Kelihos sample was encountered that was

sending a Dutch-language spam with a link to a Microsoft Word document [Arora & Warner, 2016b]. The behavior has never been seen before and it was the first time that Kelihos botnet was distributing links to ransomware. Ransomware has evolved drastically and seems to be the most profitable form of malware distributed by malware authors. Through a single click on a malicious link or enabling a macro script, the malware has the ability to encrypt all the files on a victim’s machine and requests a payment in return for decrypted files. Figures 29 and 30 display the original email in the Dutch language and its translation to English.



Figure 29. Word document link being distributed in the email

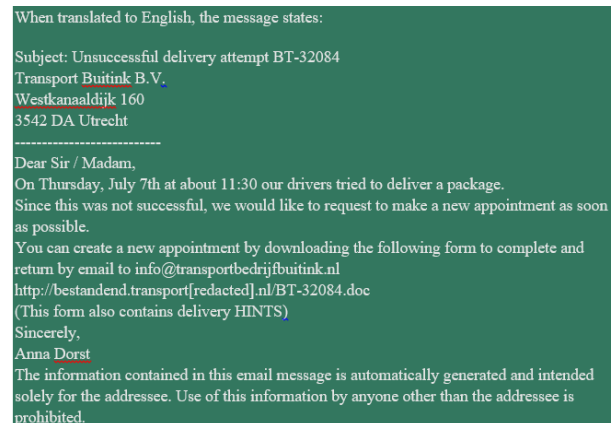


Figure 30. Word document email translated in English

In this particular case, the message informs the user of an unsuccessful package delivery. The user is required to fill a form in order to reschedule the delivery and is requested to click the embedded link to download a Microsoft Word document. Once the Word document opens, the document is presented in “Protected View” and requires “Enable Editing”.



Figure 31. Word document in protected view

Once enabled, it followed a similar process required by most hostile macro scripts “Enable Content”. After fulfilling all requirements by the Word document, the macro leverages a connection with its command and control center in order to encrypt the files on the machine. The process can be better understood with help of Figures 31, 32 and 33



Figure 32. Word document asking to enable content



Figure 33. Wildfire Encryption Ransomware ransom note

Different payment sites are listed where the user can pay the ransom amount in Bitcoin and receive the decryption key. This was a significant change for the Kelihos botnet given that it normally targets victims with

less aggressive methods. The introduction of ransomware made the long lasting Kelihos botnet extremely treacherous.

5.2 CryptFile2 Ransomware

On August 4, 2016, another interesting addition to the long-lasting Kelihos spam was that American Airlines themed spam messages delivered Microsoft Word documents, which eventually delivered CryptFile2 ransomware [Arora & Warner, 2016a]. The ransom note is mentioned in Figure 34



Figure 34. CryptFile2 Encryption Ransomware ransom note

5.3 No_More_Ransom Ransomware

On November 30, 2016, Kelihos spammed a wide variety of payloads, including a banking trojan, credential phishing, and a new ransomware variant. The criminals altered their malware to change the extension of encrypted files to “.nomoreransom” poking fun at the “No More Ransomware” campaign [No More Ransom, 2016] started by National High Tech Crime Unit of the Netherlands police, Europol’s European Cybercrime Centre, Kaspersky Lab, and Intel Security. Rather than being cowed by the new public service campaign, the criminals challenged them. This particular spam campaign was geo-targeting Australian email addresses ending in ‘.au’ with a lure impersonating Bank of America to trick the users to believe that the spam is legitimate and coming from a well-established corporation.

5.3.1 Inauguration of JavaScript

In this campaign, the infection vector changed from a Microsoft Word document to a JavaScript file. Clicking the link in the email downloaded a zip file which contained a small JavaScript program [Arora & Warner, 2016f]. The necessary details of the zip file are visible in Figure 35



Figure 35. Downloaded zip file containing JavaScript

After the JavaScript is executed, the malware contacts the command and control center and encrypts the file system. Afterwards, it displays the following ransom note, noted in Figure 36, in Russian as well as in English.

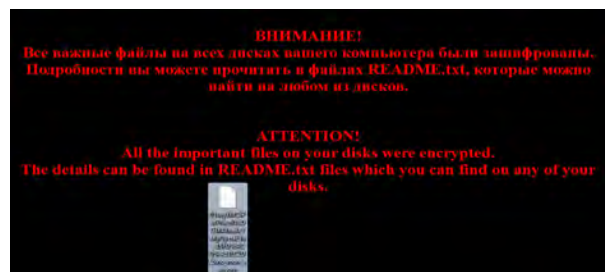


Figure 36. Ransom note of Troldesh ransomware in Russian and English

As can be seen in the ransom note, the extension of the file is changed to ‘no_more_ransom’. On further analysis, it was found that it was ‘Troldesh’ ransomware.

5.3.2 Pony Info Stealer Malware

After encrypting the files on the victim’s machine with the Troldesh ransomware, the malware also downloaded the Pony information stealer malware. This behavior is unique and has never been associated with Kelihos malware. Even though the files are encrypted, the malware still wants to acquire additional information from the victim’s computer. Figure 37 depicts the admin page of Pony malware.

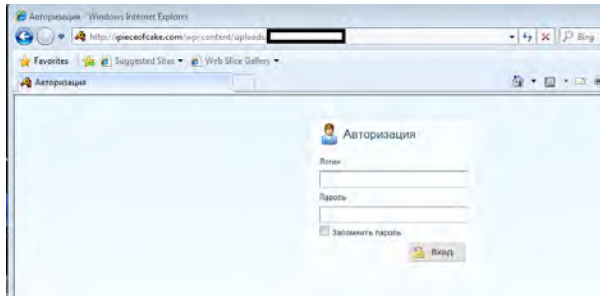


Figure 37. Pony Info Stealer Malware Admin Panel

6. GEO-TARGETED SPAM

6.1 Europe Geo-Targeted with Panda Zeus

Perhaps the clearest example of geo-targeting comes from a set of spam campaigns conducted on August 12, 2016 by Kelihos. The botnet was geo-targeting based on the top level domain of the recipient’s email addresses [Arora & Warner, 2016d]. Some examples of the specific targeted spam campaigns were:

- *If you are a “.de” you get “German banking” spam that drops a Word doc that leads to a Panda Zeus infection*
- *If you are a “.co.uk” you get “British banking” spam that drops a Word doc that leads to a Panda Zeus infection*
- *If you are a “.it” you get invited to start a romance with lyudmilafedoji@gmail[.]com*
- *If you are anyone else, you get pill spam.*

The Zeus banking trojan is well-known among the information security community. Zeus is a form of malware that targets various operating systems and tries to steal financial data; especially, banking information, credit card, social security, and so on [Kaspersky, 2010]. While this seemed a dramatic change in the Kelihos botnet spamming techniques,

it is merely a sign of the “Spam as a Service” model used by Kelihos. Any malware actor can hire the Kelihos spammers to deliver their message or payload. The same mechanism, as previously mentioned, was used to spread several different malware campaigns and target the geographies desired by the customer.

6.2 Canada Geo-Targeted with Desjardins Phish

On August 16, 2016, another example of geo-targeting was observed. Email addresses ending with “.ca” were targeted with a French language spam message for one of many Desjardins phishing websites [Arora & Warner, 2016c]. The link advertised in the spam went was of a credential phishing form, intended to steal the username and password of users of Desjardins Bank. The spam message in French and English is shown in Figure 38.

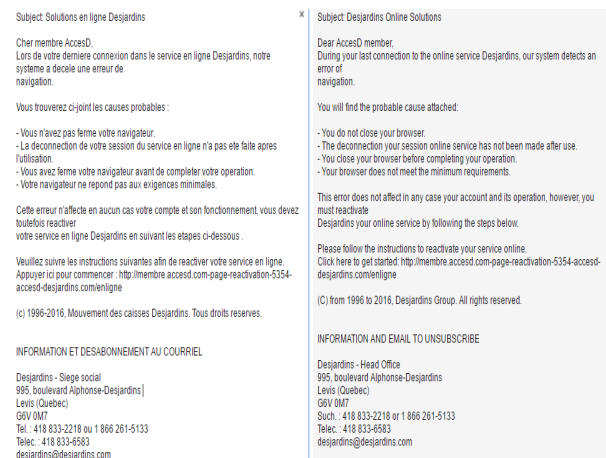


Figure 38. French Desjardins Phishing Email; Google Translate

6.3 United States of America Geo-Targeted with Nymaim

On August 30, 2016, Kelihos began geo-targeted US based emails ending with the top level domain .us by spamming the online shopping site Amazon. The Kelihos botnet

was delivering Nymaim banking trojan with an Amazon Gift Card theme [Arora et al., 2016]. In this case, the link in the spam body downloaded a Word document, which downloaded a Nullsoft Installer, and eventually executed the Nymaim banking trojan.

7. BEHAVIOR

It is well known that the Kelihos botnet behaves differently based on the network connection type [Yang, 2012]. The behavior changes in accordance to the network communication and ability to send spam. The network connections that will be referred in the following section are:

1. Network Address Translation (NAT) - Private IP and internal facing
2. Bridged Mode - Public IP and external facing

7.1 Network Address Translation

When the Virtual Machine or the infected computer is in NAT mode, with an IP address that is not directly reachable from the Internet, the Kelihos botnet behaves like a client or work server. It connects to a single node and receives the information. This means that it receives a single spam template and sends out the same spam message to everyone with an identical subject and message content. A single URL and similar text is used in the spam message that is distributed in a single run.

7.2 Bridged

When the Virtual Machine or infected computer is in bridged mode, meaning that it requests or is assigned a publicly addressable IP number, the Kelihos botnet drastically changes its behavior. Kelihos acts as a proxy server, where it receives not one but many spam templates and send them in different directions. Other Kelihos nodes approach

the server to obtain various spam messages for them to send. In bridged mode, it acts as a proxy as well as a client; thus, receiving spam templates and forwarding them to various other clients or servers.

7.2.1 Credential Exchange

Each Kelihos-infected computer has the capacity to steal userids and passwords from the user logged in at that station, particularly focusing on email and FTP credentials. Stolen credentials are passed upstream to the C&C server. When a node is in bridge mode, Kelihos receives some of these stolen credentials to test and logs into various targets using the FTP addresses and checking for the ability to write files. The SMTP credentials are tested and, if they work, are used to send spam disguising itself as the user whose credentials were used. Kelihos receives a list that includes ‘Username’, ‘Password’, ‘From’, and ‘To’ to be used for the spam message. After a successful establishment of connection and logging into the machine as the user, the spam is sent out using the same email address within one or two seconds. Another interesting observation is that the same server IP address is used for different username and password logins. Once the email is sent, the malware logs in with a different account and keeps on repeating the process. On average, for a 30 minute run it exchanges approximately 700-800 FTP and SMTP credentials combined. With the given quantity, one can imagine how many credentials are being circulated across the globe. This is one of the main reasons why Kelihos is considered to be the most poisonous and resilient spam botnet in the entire world.

8. FUTURE WORK

While the Kelihos botnet has successfully endured through multiple take-down attempts, the researchers share everything they learn about the botnet with law enforcement and the greater anti-virus community. We will

continue to document the Kelihos botnet's regular spam campaigns and seek a greater understanding of its infection and communication methodologies as we train additional team members and begin to pursue other botnets in a similar fashion. We would welcome contact with other researchers who would like to see similar programs adopted in their research or teaching curriculum.

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