

# Study on Advanced Botnet based on Public-available Resources

**Abstract.** In order to prevent the emerging botnet activities and ensure the cyberspace security, this paper designs an advanced botnet based on public-available resources, and implements its prototype system, which is named as PR-Bot. Simultaneously, the targeted defense measures are provided. First of all, in terms of system design, PR-Bot is completely constructed based on the third-party public-available resources and supports the bidirectional communication between the control end and the controlled end. At the same time, the system's command and control (C&C) channel consists of three sub-channels: command control channel (CC channel), command addressing (CA channel) and result feedback (RF channel), which can improve the robustness and concealment of the botnet. Secondly, in terms of defense technology, aiming at the intrinsic weakness of PR-Bot, this paper proposes the targeted defense strategies in the perspective of detection, measurement and tracking, so as to achieve the goal of actively defending and combating against such botnets. In short, the ultimate purpose of this paper is not to design a high-harmful botnet, but to accurately predict the techniques that the botnet may adopt in the future and judge its new threats from the point of attack and defense.

**Keywords:** Public-available Resource, Command and Control, Bidirectional Communication, Defense Technology.

## 1 Introduction

### 1.1 Background

A botnet refers to a group of compromised computers that are remotely controlled by botmaster via C&C channel [1]. Based on botnets, multiple types of Internet attack can be initiated, such as: DDoS, Email Spam, Bitcoin or Monero Mining, etc. At present, the studies on botnets can be summarized into two aspects: attack technology and defense technology. The purpose of studying on attack technology is predicting the attack trends and techniques of future botnet, so as to prevent the possible emerging botnet activities; and the purpose of studying on defense technology is improving the detection efficiency of botnets and discovering the botnets that are already in the cyberspace but not yet exposed in a timely manner, so as to reduce the actual harm caused by them.

In the early days, attackers usually controlled the bot based on IRC [2, 3] or HTTP [4, 5] protocol. This centralized architecture is simple, efficient and has good interactive. However, its main disadvantage is: once the C&C server is discovered, the defender can close it through technical or coordinated means, making it exist a serious problem of single point of failure. Although a modified architecture based on the Domain-Flux [6] or Fast-Flux [7] protocol appeared later, which can eliminate the problem of single point of failure certainly, it may be attacked by Sinkhole [8]. Once the DGA (Domain Generation Algorithm) adopted by botnet is reversed (which is unavoidable),

the defender can register the domain name in advance, making the bot access the forged C&C server built by the defender.

In order to make up for the deficiency of centralized botnets, the botnet with P2P protocol as C&C channel have also evolved. In P2P botnet, each infected host can act as both a client and a server. Based on the distributed features of P2P protocol, the botmaster can issue commands at any node, so it can hide the real address of the C&C server and effectively solve the single point of failure. However, P2P botnets are not perfect, which still have inherent weakness. For example, the structured P2P botnets, such as Strom [9, 10], are vulnerable to Index Pollution attack and Sybil attack, and its scale is easy to be measured by Crawler and Sybil nodes; the unstructured P2P botnets usually communicate by the way of random scanning or peer-list, so that the former has the inherent weaknesses of flow anomaly, and the latter is vulnerable to Peer-list Pollution attack.

In recent years, the new generation of botnets based on social network have been proposed, such as: Koobface [11], Stegobot [12], etc. Among the social botnet, each social account is a control node, which is equivalent to a C&C server in the traditional botnet, and is used to transfer the commands between botmaster and bot. Although the social botnet can hide the malicious traffic into the normal legitimate traffic with good concealment, the social platforms are generally only applicable for botmaster issuing commands and do not apply for bot feeding back result information, especially file information. Moreover, for the botnet based solely on the social platform, its C&C channel is relatively single, and it is easily detected and destroyed by the defender. Therefore, in order to make up for the inadequacies of social botnet, this paper proposes an advanced botnet based on multiple public-available resources, which includes three sub-channels. And each sub-channel can be extended in the form of plug-in, with good reconstitution and destroy-resistant capabilities.

## 1.2 Contribution

The goal of this paper is to study the development trends of future botnet, increase the defenders' understanding of the advanced botnet, and promote more effective cyber defense to deal with the possible similar cases.

The contributions of this paper mainly include three aspects:

- 1) Based on the idea of "severless botnet", an advanced botnet based on public-available resources is designed. The system adopts three-channel scheme, and each sub-channel can be supported by multiple public-available resources and extended in the form of plug-in.
- 2) 5 categories and 37 websites are actually tested, and the application scenarios of each website when constructing C&C channel are discussed. Meanwhile, the operation flow between the botmaster and bot is analyzed and described in detail to verify the feasibility of the proposed model.
- 3) The attributes of PR-Bot are analyzed, and its weakness that are difficult (or impossible) to bypass are extracted. So the targeted defense solutions in terms of detection, measurement and tracing are proposed, which can provide basis for the defender to carry out practical defense work.

## 2 The Design of PR-Bot

### 2.1 System Overview

**Definition 1 (Public-available Resource Botnet).** In this paper, we believe that all botnets that construct C&C channel based on the public-available resources (including but not limited to: social network, URL shortener, image hosting, online clipboard or cloud disk, etc.) could be called the Public-available Resource Botnet.

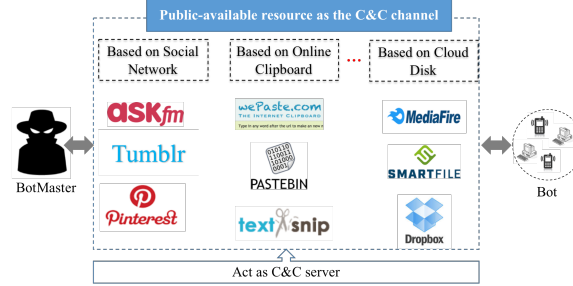


Fig. 1. Basic characteristics of Public-available Resource Botnet

The basic characteristics of this type of botnets are: the botmaster no longer relies on the self-built C&C server to control the bots, but uses the open and free website on the Internet to act as the C&C server. All communication flows are transferred through the Internet public-available resources.

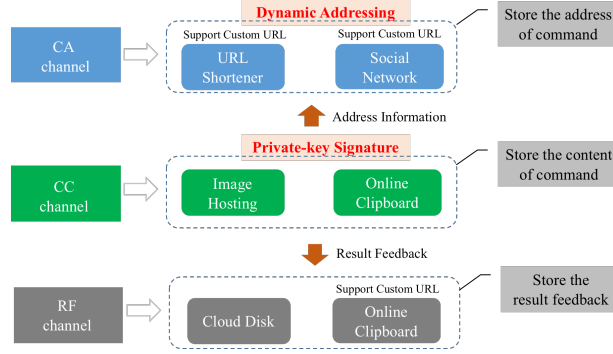
### 2.2 System Design

In botnets, no matter how complex the control model of botnet is or how powerful the bot program is, the interaction between the control end and the controlled end usually involves only the transfer of text information (that is: string content) or file information (that is: binary content), as shown in Table 1.

Table 1. Interactive information between the control end and the controlled end

	Text information	File information
Control end	command or others	malicious program
Controlled end	callhome or others	stolen files

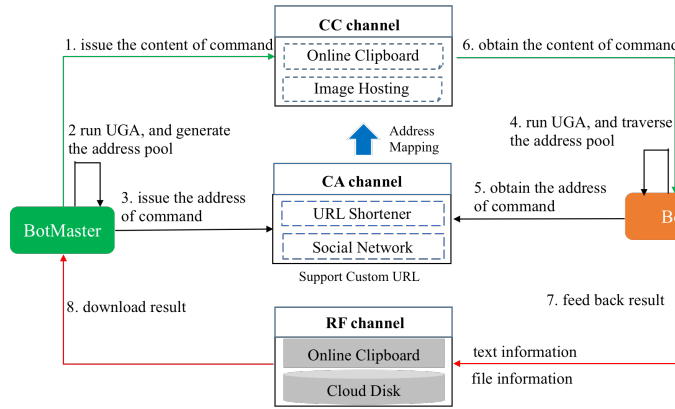
Although there are many kinds of public-available resources on the Internet, as long as the information can be released, there is a possibility that an attacker can abuse it to act as C&C server. However, due to the limitations of the nature of the public-available resources, not all public-available resources are suitable for issuing both text information and file information. For example, the social platforms used by social botnet are generally only applicable to store the commands issued by botmaster, but not applicable to store the result information fed back from bot, the communication of which is one-way.



**Fig. 2.** The control model of PR-Bot

The PR-Bot, an advanced botnet designed in this paper, takes into account the limitations of a purely social platform as C&C channel, so it combines multiple public-available resources and uses their respective advantages to construct C&C channel. And PR-Bot is suitable for transmitting both text information and file information, as well as supporting two-way communication between botmaster and bot. All in all, the PR-Bot adopts the three-channel scheme, and the interaction information in each channel is distributed in different locations of cyberspace, as shown in Figure 2.

### 2.3 System Architecture



**Fig. 3.** The system architecture of PR-Bot

The architecture of PR-Bot is shown in Figure 3, which communication between botmaster and bot includes the following six stages:

**1) Botmaster issues the content of command:** The botmaster issues the content of command to the public-available resources, such as an online clipboard or image hosting website, and records the URL of the website (abbreviated as PR\_Address\_A) where the command is located. Among them, for the online clipboard, the command is issued in the form of string; for the image hosting, the command is first converted into a picture and then issued in the form of picture.

**2) Botmaster issues the address of command:** First, the botmaster selects a URL shortener or social network that supports custom URL, designs and runs the UGA algorithm, followed by selecting several candidate addresses (abbreviated as PR\_Address\_B) from the URL address pool. And then, the botmaster issues the address PR\_Address\_A recorded in Stage 1 as content to the website corresponding to the address PR\_Address\_B.

**3) Bot obtains the address of command:** After the bot infects the controlled end, to establish the communication with the control end, it will first run the UGA algorithm consistent with the botmaster, and then traverse the URL address pool one by one. When an address (take PR\_Address\_B as an example here) is found to be accessible, it is considered that address of command is stored at this place, and then the address PR\_Address\_A will be extracted.

**4) Bot obtains the content of command:** After the bot has obtained the address PR\_Address\_A in Stage 3, the content of command is then obtained from this address. After obtaining the content of command, the bot first verifies its validity and availability, and only the command passed by the verification can be executed. Otherwise, the control logic of the bot program will jump to Stage 3 and run again. Among them, “validity” refers to whether the command is within the validity period specified by the botmaster; “availability” refers to whether the command is signed by the private key of the botmaster.

**5) Bot feeds back the result information:** For the command that needs to feed back the result information, the botmaster is required to specify the receiving address as a parameter in the issued command. The bot will feed back the relevant information based on this parameter in the command and the custom protocol with the control end. Among them, for the “callhome” command, the bot needs to feed back the basic information of the infected device, such as: system type, internal and external network IP, and host name, etc; for the “file stealing” command, the bot needs to feed back the files of the infected device.

**6) Botmaster downloads the result information:** After a certain period of time, for the command that will feed back the result information, the corresponding result acquisition module will be run. During the operation of the module, it will download the text information (such as callhome information) or file information (such as stolen files) returned by the bot for further analysis, which is based on the address parameter in the issued command and the custom protocol with the controlled end.

What needs to be explained here is, during the acquisition of the command, the bot does not first locate the address (that is PR\_Address\_A) where the content of command is located, but the address (that is PR\_Address\_B) where the address of command is located. Based on this address PR\_Address\_B, the bot will know the address PR\_Address\_A and further obtains the actual content of the command. In other words, the bot will obtain the content of command through the “Secondary Addressing Mechanism”, which will be described in detail in 3.2. To a certain extent, this mechanism can effectively improve the robustness and flexibility of the C&C channel.

## 2.4 The standard for selecting public-available resources

As shown in Table 2, this paper tests five major types of public-available resources and analyzes the specific application scenarios of each when constructing C&C channel. Among them, PR-Bot stores the content of command based on online clipboard or image hosting website; stores the address of command based on a URL shortener or social network that can custom URL address, stores the stolen files based on public cloud disk website, stores the callhome information based on online clipboard that can custom URL address, so as to provide support for the requirements of CC channel, CA channel, and RF channel.

**Table 2.** Application scenarios of public-available resources

Type	Is it suitable for issuing text?	Is it suitable for issuing file?	Is it suitable for issuing picture?	Application scenarios
Online Clipboard	Y	N	N	store the content of command store the callhome information
Image Hosting	N	N	Y	store the content of command
URL Shortener	Y	N	N	store the address of command
Social Network	Y	N	Y	store the address of command
Cloud Disk	N	Y	Y	store the stolen files from bot

### 1) public-available resource for storing the content of command

**Table 3.** Online clipboard and its selection standard

Name	Site	Custom URL	Storage Space	Storage Time
dpaste	<a href="http://dpaste.com/">http://dpaste.com/</a>	N	unknown	1 year
pasted	<a href="http://pasted.co/">http://pasted.co/</a>	N	unknown	unknown
pastebin	<a href="http://pastebin.com/">http://pastebin.com/</a>	N	512KB	unlimited
wepaste	<a href="http://www.wepaste.com">http://www.wepaste.com</a>	Y	unknown	unlimited
cllp	<a href="https://www.cllp.net/">https://www.cllp.net/</a>	Y	unknown	1 time
textsnip	<a href="http://www.textsnip.com">http://www.textsnip.com</a>	Y	70000 characters	unknown
showtxt	<a href="http://showtxt.cn/">http://showtxt.cn/</a>	Y	unknown	unknown

**Table 4.** Image hosting and its selection standard

Name	Site	Registration	File Size Limit	Is it compressed?
baidu-pic	<a href="http://image.baidu.com">http://image.baidu.com</a>	N	5MB	N
360-pic	<a href="https://st.so.com/">https://st.so.com/</a>	N	2MB	Y
Imgbb	<a href="https://imgbb.com/">https://imgbb.com/</a>	N	16M	N
sm.ms	<a href="https://sm.ms/">https://sm.ms/</a>	N	5MB	N
upload.cc	<a href="https://upload.cc/">https://upload.cc/</a>	N	5MB	N
Imgur	<a href="https://imgur.com/">https://imgur.com/</a>	N	1MB	N
sina	<a href="http://photo.weibo.com/">http://photo.weibo.com/</a>	Y	20MB	Y
qiniu	<a href="https://www.qiniu.com/">https://www.qiniu.com/</a>	Y	unlimited	N

In CC channel, when selecting an online clipboard, PR-Bot only considers two factors: one is the size of the space for storing information, and the other is the length of time for storing information. And at this stage, it does not consider whether the website supports custom URL. As long as the storage space can reach 200KB and the storage time can reach 1 month, it means that the requirements is met. In addition, for the image hosting website, PR-Bot only selects the websites that have no registration required and do not compress the pictures. And the size of signal picture allowed to upload should meet the requirements of 1MB. Moreover, because the storage time supported by the image hosting website is usually unlimited, so this factor was not taken into account here.

## 2) public-available resource for storing the address of command

**Table 5.** URL Shortener and its selection standard

Name	Site	Custom URL	Storage Time
tinyurl	<a href="https://tinyurl.com/">https://tinyurl.com/</a>	Y	unlimited
is.gd	<a href="https://is.gd/">https://is.gd/</a>	Y	unlimited
yep.it	<a href="http://yep.it/">http://yep.it/</a>	Y	unlimited
shorturl	<a href="https://shorturl.com/">https://shorturl.com/</a>	N	unlimited
shorl	<a href="http://shorl.com/">http://shorl.com/</a>	N	unlimited
bit.ly	<a href="https://bitly.com/">https://bitly.com/</a>	N	unlimited

**Table 6.** Social network and its selection standard

Name	Site	Custom URL	Temporary Mailbox
tumblr	<a href="https://www.tumblr.com">https://www.tumblr.com</a>	Y (Revisable)	Y
pinterest	<a href="https://www.pinterest.com">https://www.pinterest.com</a>	Y (Revisable)	Y
ask.fm	<a href="https://ask.fm">https://ask.fm</a>	Y	Y
twitter	<a href="https://twitter.com">https://twitter.com</a>	Y (Revisable)	N
facebook	<a href="https://www.facebook.com">https://www.facebook.com</a>	N	N
weibo	<a href="https://weibo.com">https://weibo.com</a>	N	N
qzone	<a href="https://qzone.qq.com/">https://qzone.qq.com/</a>	N	N
renren	<a href="http://sns.renren.com/">http://sns.renren.com/</a>	N	N

In CA channel, for the URL shortener website, because it itself stores the mapping relationship between the long URL and the short URL, and the storage time is usually unlimited, PR-Bot does not have too many restrictions when selecting such public-available resources, as long as it supports custom URL for dynamic addressing. Similarly, for social network website, in order to achieve the dynamic addressing, PR-Bot only selects the social platform that can custom homepage URL based on the user name. In addition, priority is given to websites that support temporary mailbox registration in order to avoid exposing too much real information about the botmaster.

## 3) public-available resource for storing the feedback result information

**Table 7.** Public cloud disk and its selection standard

Name	Site	File Size Limit	Storage Time
sendspace	<a href="https://www.sendspace.com">https://www.sendspace.com</a>	300M	30
fileden	<a href="http://fileden.net/">http://fileden.net/</a>	100M	60
senduit	<a href="http://www.senduit.com/">http://www.senduit.com/</a>	100M	7
zippyshare	<a href="https://www.zippyshare.com/">https://www.zippyshare.com/</a>	500M	30
rapidshare	<a href="http://www.rapidshare.com.cn/">http://www.rapidshare.com.cn/</a>	100M	30

In RF channel, for the online clipboard website, except for the storage space of up to 200 KB and the storage time up to 1 month, the website that supports custom URL is required, for making that the botmaster can find the result information fed back from bot by a certain rule (URL+ numeric string). For the public cloud disk, PR-Bot mainly considers two factors: one is the file size limit, and the other is the storage time, which is similar to the image hosting. If the website allows 10M-sized files to be uploaded and storage time can be up to 1 month, it is enough. In addition, the public cloud disk is available without registration.

### 3 The Implementation of PR-Bot

#### 3.1 CC channel

PR-Bot mainly supports two types of commands, the “callhome” and “file stealing”, which parameters are shown in Tables 8.

**Table 8.** The parameters of commands

Command	Key	Value	Remark
callhome	cmd_type	callhome	command type
	paste_name	wepaste	website name
	address	<a href="http://www.wepaste.com/abcde">http://www.wepaste.com/abcde</a>	url address
file stealing	cmd_type	upload_file	command type
	cloud_name	sendspace	website name
	paste_name	wepaste	website name
	file_type	doc	file type
	address	<a href="http://www.wepaste.com/abcde">http://www.wepaste.com/abcde</a>	url address

In order to prevent C&C hijacking and replay attacks, before issuing the command, the botmaster will specify the validity period of the command and sign the command based on the private key. The format of the command to be issued is as follows:

*Base64 (Base64 (private key signature (**original command** ^ **validity period**)))#original command ^ validity period)*

Take the “callhome” as an example, its original content is a string in JSON format, which is as follows:

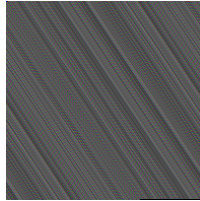


```
{
  "cmd_type":"callhome",
  "paste_name":"wepaste",
  "address":"http://www.wepaste.com/abcde"
}
```

First, after specifying validity period, private key signature, base64 encoding and string splicing, the corresponding content is as follows:

```
bqi+YmecF62Li+INvT4xRdO8d6Z7GXY74E8qVKYwHNrCYUY7wGEuLHrm5bdfyeuQ4S7BH5fx
zIQmsQn9xY/+iPjzXv9ap/mZefCY5JCpzQ6X/uLsQPYulvihTJZ52deiQZvPRwWZtPwSCBu3si1Pga
N/mxs8eWSg17PGuWD1L37/TT7BvG+IrdozFqBQF5klLIX3hahElqsh7DRJpDpwyfCH5Nz2K5zm7
X3apA34Sz1OL1vNxfHML2TZtNBR2LTCgtaXWa9JNiszHulPEF7pgHdTxWLuqQ/IG5Tc9/5LN04y
7evFnJETMPK+WLV4mRaFwkjlx3c6kHkZJ64eyI5qiQ==#{ "cmd_type":"callhome", "paste_name":"w
epaste", "address":"http://www.wepaste.com/abcde"}^2018_05_12-2018_06_12
```

Next, if selecting the online clipboard website to store the command, it only need to issue the above content in the form of text to the online clipboard website, which corresponding address looks like <http://dpaste.com/0SV8NS5>. But if selecting the image hosting website to store the command, the above content shall be converted into picture firstly and then issued, which corresponding address looks like <http://h.hiphotos.baidu.com/image/pic/item/c8177f3e6709c93db7a0d055933df8dcd00054c6.jpg>. In the process of storing data based on picture, PR-Bot does not embed the command into an existing picture, but directly converts it into pixels, and stores the original content in the form of pixels. The converted image style is shown in Figure 4.



**Fig. 4.** Image style generated from text

Normally, each pixel in a colored image is composed of three color information of RGB. Each color information occupies 8 bits, and the three colors are 24 bits, which means that each pixel can store 3 bytes of data. For a 500\*500 RGB picture, it can store 75000 bytes of data, about 730KB, which is enough to meet the space required for storing command. Take the string “callhome” as an example: its hexadecimal representation is “0x63, 0x61, 0x6c, 0x6c, 0x68, 0x6f, 0x6d, 0x65”. First, it is divided into groups and each group consists of three units, if there are less than three, add 0 at the end. In this way, the original hexadecimal string is divided into three groups of {0x63, 0x61, 0x6c}, {0x6c, 0x68, 0x6f} and {0x6d, 0x65, 0x00}, and the corresponding RGB can produce three pixels. That is, the string “callhome” is converted into three pixel values. In addition, in the process of generating a picture, in addition to recording the content of the original data, the size of the original data also needs to be recorded to

restore it normally. For PR-Bot, it uses two pixel units at the beginning of the picture, which is the six-byte space, for recording the data size. Finally, the pixel information in the picture consists of “*data size (2 fixed pixels) + data content + 0 (may exist)*”.

### 3.2 CA channel

When issuing the address of command, the botmaster designs a UGA algorithm, which seed is based on the current date and hottest topics. The method is to prevent the address list generated by the bot from being predicted prematurely by the defender. For the hottest topics, it may change every day and has no fixed pattern. Even if defender have mastered the UGA algorithm, they can know the address list only waiting until that day, making it impossible to predict prematurely. Although unavoidable, it increases the working costs of defender to some extent. The generated address list is as follows:

URL Shortener:

<https://tinyurl.com/shehuim>

<https://tinyurl.com/ixniimli>

<https://tinyurl.com/vyowinfo>

...

Social Network:

<https://www.tumblr.com/yfvqwvvi>

<https://www.tumblr.com/nshynnuu>

<https://www.tumblr.com/ldtctknm>

...

Fig. 5. How to use the URL Shortener

For the URL Shortener, when storing the address of comand, only the URL address to be converted and the suffix of the alternative URL is needed, as shown in Figure 5. And for the social network website, the user’s personal homepage address needs to be configured based on the alternative URL suffix, and then the address of command can be issued as a new message. Of course, all operations are automated by the program.

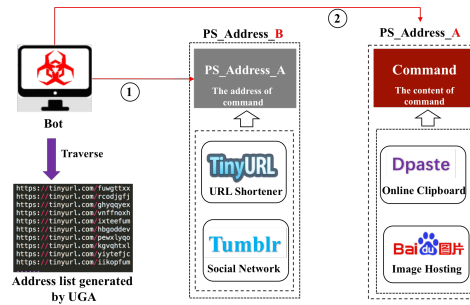
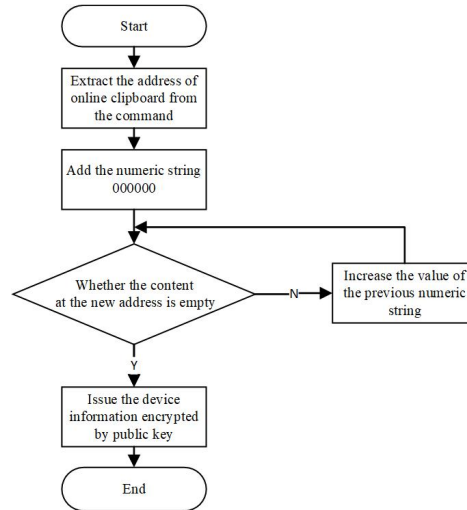


Fig. 6. Secondary Addressing Mechanism

As shown in Figure 6, for the bot, it undergoes two steps when obtaining the content of command, that is the “Secondary Addressing Mechanism” described above. First, the bot will traverse the generated address list based on the hard-coded UGA algorithm. When finding the address PS\_Address\_B, it will obtain the address PS\_Address\_A and further extract the content of command. The reason for adopting the “Secondary Addressing Mechanism” is to improve the flexibility and scalability of the PR-Bot. For some public-available resources that are suitable for storing command but not support custom URL, the jump relationship provided by the “Secondary Addressing Mechanism” can make it become “a public-available resource that supports custom URL”. In addition, this mechanism can also improve the robustness and concealment of the C&C channel to some extent.

### 3.3 RF channel

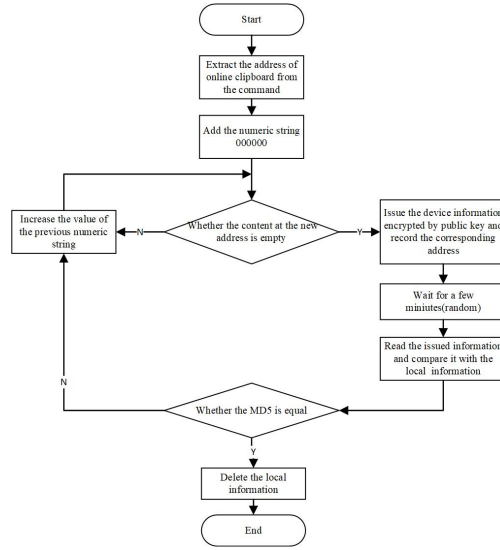
**Callhome Module.** Obviously, if all bots upload the information of controlled end to the unique URL specified in the command, there is a problem of information loss due to the limited storage space of the online clipboard website. In order to avoid this problem, this paper adopts the strategy of “URL + numeric string”.



**Fig. 7.** The brief solution for result feedback

As shown in Figure 7, after the bot extracts the address parameter from the command, it does not upload the device information to the address directly. Instead, the bot will add a numeric string of the specified digits (according to the law from small to large) behind the address, and then it sends the device information to the new address. Take the address <http://www.wepaste.com/abcde> as an example: After the bot obtains the address parameter, it will add a numeric string from 000000 to 999999 behind it and then traverse the URLs from <http://www.wepaste.com/abcde000000> to <http://www.wepaste.com/abcde999999>. The device information is not fed back until an address with empty content is found.

However, if only the above brief solution is adopted, although the problem of the limited storage space can be solved, there is a problem of information coverage due to concurrent operation of bots. That is, if an address with blank content is found by two bots at the same time, they will upload device information to the address, no matter who comes first, there must be a case where one bot overwrites information uploaded by another bot. It is because the content on the online clipboard website is readable and writable.



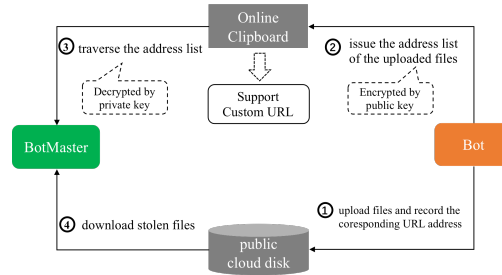
**Fig. 8.** The enhancement solution for result feedback

In order to solve this new problem, this paper uses the enhancement solution, as is shown in Figure 8. Specifically, after several minutes of uploading device information, the bot reads the uploaded information again and compares it with the locally stored information to verify whether the information is uploaded by itself. If the MD5 of the two are the same, it is considered that the device information is successfully uploaded. Otherwise, the new address is traversed sequentially and the device information is re-uploaded. In this way, even if multiple bots find an address with empty content at the same time, it will be no problem of information coverage.

For the botmaster, when downloading the device information, it is also in accordance with the law of "URL+ numeric string", sequentially traversing the address from "URL + 000000" to "URL + 999999". Theoretically, as long as the background program traverses to the first address with blank content, it means that all the device information uploaded by the bots has been downloaded. However, in the specific implementation process of PR-Bot, in order to improve reliability, the background program only terminates when it traverses ten consecutive addresses with empty content.

**File Stealing Module.** Cloud disk website, also known as cloud storage website, is mainly classified into two categories: the public cloud disk and the private cloud disk. Among them, the public cloud disk can be used without registering, and the information

on it is public ; and the private cloud disk needs to be registered before they can be used, and the information on it is private and cannot be seen by other users unless the owner actively shares them. In addition, most private cloud disks provide the API interfaces for users to operate data in it.



**Fig. 9.** File feedback process based on public cloud disk

In the process of feeding back files, PR-Bot selects a public cloud disk to store the stolen files, which is shown in Figure 9. First, the bot traverses the specific types of files in the controlled end and uploads them to public cloud disks one by one, and records the corresponding URL address at the same time. Then, all URL addresses are issued to the online clipboard website in the form of string. When issuing the address, it is basically the same as the flow of issuing callhome information, including the strategy of “URL + numeric string” and the mechanism of secondary verification.

**Table 9.** Parameters of API interface of private cloud disk

Name	Site
Mediafire	{email}, {password}, {app_id}, {folder_key}
Mega	{email}, {password}
Smartfile	{key}, {password}

Here, we will discuss the reason why PR-bot does not choose private cloud storage to store stolen files. If PR-Bot selects the private cloud disk to store stolen files, it is necessary to specify the parameters required by the private cloud disk API interface in the command, which is used for authentication and as shown in Table 9. It will cause two problems:

1) Once the defender has mastered the identification information, it is equivalent to obtaining the control authority of the account corresponding to the private cloud disk, so that the files in the cloud disk can be viewed and deleted, and even let the bot upload spam data deliberately;

2) Because only one or a few account parameters are specified in the command, with the increase in the number of bots, the behavior of sharing the same account can easily cause abnormalities on the website, and may expose the entire botnet's activities.

For the public cloud disk, the above two problems are inexistent. First, even if the defender obtains the command and masters the law of “URL address+ numeric string” adopted by bot, it cannot locate the network location where the stolen file is located. It is because the uploaded address list is encrypted by the public key, and it can only be

decrypted by the private key of botmaster. Second, when a file is uploaded through a public cloud disk, each bot is equivalent to an independent user and has no necessary correlation, so there is no problem that multiple bots share the same account. Therefore, PR-Bot selects the public cloud disk to store stolen files, which purpose is to ensure the security of the C&C channel.

## 4 The Defense Measures

Accurately finding botnets similar to PR-Bot and taking targeted measures to contain them is the ultimate goal of this paper. For the PR-Bot botnet proposed in this paper, this section describes the contents of PR-Bot defense from the aspects of detection, measurement and tracking, in order to take over the control of the botnet or reduce its availability.

### 4.1 Detection

In CA channel, PR-Bot uses the UGA algorithm to generate an address pool, and the bot obtains commands by connecting the pseudo-random addresses. This process is similar to DGA. Therefore, some methods for detecting DGA also apply to UGA detection: (1) Character feature detection based on domain name [13]. There are still differences between the addresses generated by UGA and the normal addresses, such as: the use of a large number of URL Shortening services, the use of unusual user names, the use of fixed social network and etc. Therefore, the rules of distribution of domain name strings can be found by constructing the semantic rules and feature vectors, and they can be identified by the methods such as data mining and machine learning. (2) Detection based on domain name activity. In order to obtain commands, the bot will constantly address, and the addressing time will show some regularity, such as addressing once every 1 hour, or addressing at a fixed point of time and even early in the morning. These features all show the non-human characteristics, so the domain name activity and spatio-temporal features can be used to detect the malicious addresses. In addition, for the service provider, the content of the account on the platform can be monitored in real time, and the release of the suspicious character string shall be further traced or handled by the security personnel.

In CC channel, the PR-Bot mainly uses the online clipboard website and image hosting website. Therefore, the detection method based on communication content and network layer anomalies can be used. (1) For the commands issued on an online clipboard website, the bot will obtain the commands in the form of text, which are encoded and have the specificity, as well as identifiability. Among them, for the transmission content of the HTTP protocol, a feature matching rule may be configured in advance, such as Snort and other intrusion detection systems, to quickly and accurately discover such botnet. (2) For the commands issued on the map bed website, the bots will obtain commands from the downloaded pictures, and it can also detect through the abnormality of the transmitted information. However, the detection method based on the communication content is only applicable to botnets with specific characteristics. The disadvantage is that the unknown botnets cannot be detected, and the signature of bot program needs to be continuously maintained and updated. The network layer anomaly detection

method assumes that the communication mode between the bot and the botmaster is quite different from the normal user communication, so that the trail of the botnet can be found through the flow analysis. In RF channel, PR-Bot uploads the text information according to the address specified by the botmaster, which is similar to the CC channel, so the detection method based on the communication content and the network layer anomaly may also be used.

#### 4.2 Measurement

By measuring the PR-Bot botnet, it can portray its topological structure and corresponding scale, so that the defender can understand more about the outline and characteristics of the PR-Bot. However, due to the mechanism characteristics of PR-Bot itself, it is difficult to measure the PR-Bot, and the traditional measurement methods based on Crawler and Sybil cannot be applied. However, in RF channel, the bot adopts the strategy of “URL + numeric string” to upload the callhome information or the address list of stolen files. The defender can find out the law adopted by PR-Bot through reverse analysis or flow monitoring, so that the entire scale of the botnet can be measured through the method of address traversal. Although the PR-Bot measurements are affected by various factors, such as time zone, startup/shutdown, so it is difficult to accurately estimate the scale of the entire botnet, but it can estimate the number of bots as much as possible.

#### 4.3 Tracking

If the defenders have mastered the botnet C&C channel, they can run the bot in a controlled environment or join the botnet in an infiltrated form to understand the internal activity of the botnet. However, because the existing bots usually check the operating environment more strictly, the former method can be easily detected by the attackers, and this is true for the PR-Bot introduced in this paper. In this section, we focus on how to track botnet by means of infiltration, and the infiltrating agent is called “Infiltrator”. Infiltrator can disguise as an infected controlled device to join the botnet and simulate the real communication protocol of PR-Bot to communicate with the botmaster to observe the internal activities of PR-Bot. Among them, in RF channel, infiltrator can intentionally submit a honeybee file with tracking watermark or other payloads, so as to track the botmaster. For example: infiltrator embeds a hidden remote picture URL in a Word document, once the botmaster downloads and opens the file, it will actively request the URL and load the remote picture, and then the defender can trace the position of the botmaster based on the source of the request.

### 5 Conclusions

This paper introduces an advanced botnet based on public-available resources, which is named PR-Bot. The PR-Bot is constructed by three-channel scheme, which includes three sub-channel: CC channel, CA channel and RF channel. Each sub-channel can be supported by multiple public-available resources and can be extended in the form of plug-in. Meanwhile, PR-Bot also uses the technologies, such as information hiding, content encryption and digital signature, to improve the robustness and concealment of

C&C channel. In addition, in the face of new challenges, this paper proposes the defense strategies for PR-Bot in terms of detection, measurement and tracking to deal with possible similar cyberspace threats. We believe that it is of great practical significance to study how to construct a highly antagonistic botnet from the perspective of the attackers and propose the effective defense strategies before the attackers. In the next step, we will conduct an in-depth study on this type of botnets, and design a rapid and effective detection system.

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