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MASTER THESIS

Bonet Detection Through Passive DNS analysis

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*A thesis submitted in fulfilment of the requirements
for the degree of Masters in Cyber Security*



Declaration of Authorship

I, Gérard TIO NOGUERAS, declare that this thesis titled, “Bonet Detection Through Passive DNS analysis” and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

Signed: Gérard Tio Nogueras

Date: 01/01/2019

“The Domain Name Server is the Achilles heel of the Web. The important thing is that it’s managed responsibly.”

Tim Berners-Lee

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Abstract

Faculty of Science
Cyber Security

Masters in Cyber Security

Bonet Detection Through Passive DNS analysis

by Gérard TIO NOGUERAS

The Thesis Abstract is written here (and usually kept to just this page). The page is kept centered vertically so can expand into the blank space above the title too. . .

keywords:botnet detection; botnet detection model; machine learning-based botnet detection; domain generation algorithm botnet detection; fast flux botnet detection

Acknowledgements

The acknowledgements and the people to thank go here, don't forget to include your project advisor...

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List of Abbreviations

LAH List Abbreviations **Here**
WSF What (it) Stands For

For/Dedicated to/To my...

Chapter 1

Introduction

1.1 Research context

Vulnerabilities keep growing → making botnets even easier to spread, which means cheaper and more powerful.

TODO: Put some context on why it is still a relevant subject today [source]

This is a compilation of Botnet news by Trend Micro: Compilation of Botnets variants:

1.2 Research question

My research question is : "**Can we improve current botnet detection?**" TODO: define proper sub-questions that build the paper. With the following sub-questions:

- What are the current trends of Evasion and detection?
- Can we create a solution that detects effectively all botnets ?
- What effective model can help organisations detect botnets faster and more reliably?

1.3 Thesis objective

The objective of this master thesis in Cyber Security is to improve the all-in solutions for botnet detection through DNS traffic analysis with a machine learning approach. Different papers haven't always provided a deep study of the choice of features or provided a model adapted to certain environments which we will try to do and see if this can improve the existing models.

[source]

The objective of this thesis is to answer the research questions above. This will be done by reviewing the current (scientific) literature on botnets, in particular with relation to DNS, Honeypots, Law and future threats. The authors technical experience will also be used to answer the research questions. It is hoped that others can benefit from the knowledge that this thesis provides to implement better security measures within their own organisations. The information provided in this thesis will provide the reader with in depth knowledge on the subject of botnets, and how they the threat of them within an organisation can be migrated.

TODO: Description of the thesis (chapter by chapter)

Chapter 2

State of the art

2.1 Botnets

As stated in the introduction botnets are an important problem for anyone involved somehow with the internet. Botnets can result in great economic damage.

Botnets continuous improvement to become more resilient and powerful makes them an important threat to information security.

Botnets can become very lucrative and can infect very large amounts of devices resulting in scary entities. Here are some of these enormous entities: **Flashback** with 600k compromised targets, **Grum** with 840k compromised devices and sending 40 Billion spam emails per month, **TDL-4** with 4.5 Million victims in first the 3 months and **Gameover Zeus** with 1 Million infections, because of its resilience mechanisms this botnet was one of the hardest to take down.

The reason botnets are still an ongoing research topic is that there isn't a complete solution for their detection and mitigation. Researchers and organisations have to keep working to keep updated with all the new flavours criminals bring to the market.

2.1.1 Botnet definition

A botnet is a network of infected machines called bots, owned and controlled by a remote attacker called the botmaster. These bots usually infect these machines without their owners' knowledge or consent **Botnet1**. The control of such bots is done through the Command and Control (C2) server. Through the C2 server, the master issues commands to and receives responses from individual bots. These exchanges are done to update the software of the malware, execute attacks, exfiltrate data, etc.

The current trend of botnets is to hide their identities (i.e., the command and control server) using the DNS services to hinder their identification process. In fact, botnets have specific characteristics as compared to other types of malware. For instance, the botmaster can control the infected machines and send commands without directly communicating with them. There are also a lot of bots working in a coordinated way and taking instructions from the botmaster to instantiate coordinated attacks such as the distributed denial-of-service (DDoS) attacks, spam distribution and click fraud. Also, the botnet provide these frauds as a service form botnet operator which are consider part of the botnet economy

A clear distinction between a bot agent and a common piece of malware lies within a bot's ability to communicate with a Command-and-Control (CnC) infrastructure. CnC allows a bot agent to receive new instructions and malicious capabilities, as dictated by a remote criminal entity. This compromised host then can be

used as an unwilling participant in Internet crime as soon as it is linked into a botnet via that same CnC.

Command and Control (CnC) CnC servers is what differentiates Botnets from other malware.

2.1.2 Botnet purpose and actions/attacks

Note: mix attacks and purpose together

The goals of an attacker in terms of bot recruitment can be categorized into two broad categories. In the first case, the target of the attack is the computer that is being recruited. In the second case, the recruited bot is used to attack another target. Computers in a botnet are either the target of the attack, the perpetrator of the attack, or both. When bots are the perpetrator of the attack, the effectiveness of the attack is usually dependent upon the collective power of the botnet. Stated differently, the attacker is either after the valuable information on the computer or the storage, processing, and communication capabilities of the computer, or both.

The value of information on a personal computer is often overlooked. There are many applications for home use, like tax preparation software, that store volumes of key personal and financial information. Browsers can cache website and account information. Email clients store contact information. Many home computers have sensitive work information on them, exposing a company's intellectual property to potential disclosure. These are just a few examples of the type of information that can be exfiltrated and abused by an attacker or sold to cyber criminals.

A common botnet usage is the sending of spam emails. The spam emails can be used to carry malicious payloads in an attempt to infect the recipients of the spam emails. Spam can also be used to influence or manipulate user behavior such as the purchasing of advertised products, visiting of infected websites, or downloading of music or videos with malicious content. Most cryptographic controls just buy the user time, in hopes that by the time the control is no longer good, the protected asset no longer has value. That is the theory behind password expirations. Password lifetime is set to be less than the time it takes to discover the password by brute force or other methods. The processing capabilities of a bot can be used for cryptanalysis purposes. Password cracking, brute force key discovery, and rainbow table creation are but a few examples. The collective power of a botnet greatly reduces the time a control is effective. Data storage is another bot resource an attacker can use without permission. Anonymity is important to the attacker, so storing ill-gotten gain across the botnet keeps incriminating evidence away from the attackers' machines. Additionally, there are efficiency, redundancy, and availability benefits from having a distributed data store. Ill-gotten gains can include personal information seized, pornography, intellectual property and malware.

Botnet rental has become a lucrative business. Botnets are rented and sold, usually for malicious purposes. Decentralized botnet architectures allow massive botnets to be partitioned into groups of smaller children botnets that can be parceled out for use and then reintegrated into the parent botnet after usage. This paper will discuss botnet detection tools and techniques. This paper gives a brief introduction, a brief background on botnet characteristics, a summary of detection techniques, an overview of the BotMiner tool, reviews of two case studies where botnets were used to characterize behavior, and a conclusion.

Because botnets are a large network of infected machines, they are able to carry out large scale attacks.

A victim host could be infected by targeting known vulnerability or by infected programs. When the victim is infected, the botnet will try to stay stealthy and with the exploit kit installed, it can do an extensive amount of damage. Here are some of the methods to control the infected hosts.

1. secure the system
2. spy or steal identity
3. send SPAM emails
4. host illegal sites
5. redirect traffic for the botnet
6. kill unwanted process running on the system
7. test for virtual machines and/or debugger software
8. add or delete auto-start applications
9. run or terminate programs
10. download and execute files
11. perform address and port scan
12. rename files
13. simulate key presses
14. run DDoS attacks

Botnets are the primary means for cybercriminals to carry out their malicious tasks

- sending spam mails
- launching denial-of-service attacks
- stealing personal data such as mail accounts, intellectual property, military secrets, embarrassing information or bank credentials
- A bot is a servant process on a compromised system (unknownst by owner) usually installed by a Trojan or Worm.
- Communicates with a handler or controller via public servers or other compromised systems.
- A botmaster commands bots to perform any of an number of different functions.
- System of bots and controller(s) is referred to as a botnet or zombie network.

2.1.3 Bot

Bot - a small program to remotely control a computer characterized by remote control and communication (CnC) channels to command a victim. For ex., perform denial-of service attack, send spam, ... The remote commands can be use for many different purposes. For ex., update bot binary to a new version, turn on your audio, video, keystroke log.

The spreading mechanisms to propagate it further. For ex., port scanning, email, privilege escalation

After infection these are the uses cases for bots: Secure the system(close NetBIOS shares, RPCDCOM) spy or steal data send spam emails host illegal sites redirect traffic (FF chain) kill unwanted processes (AV, proc mngr) test for vm and dbg software add or remove autostart applications run or terminate programs download and execute files perform scan (IP and port) rename files simulate key presses DDos attacks

2.1.4 Type of attacks

2.1.5 Botnets Lifecycle

Botnet Lifecycle exploitation phase: source 25,26,16 This is where the infection happens by exploiting a vulnerability on the victim's host. Then the Bot's binary is downloaded onto the host. To find this binary a DNS lookup has to be done. Which can't be avoided but can be hidden. rallying source 18,27 attack execution source 17 update and maintenance source 6

Infection behavior 4 phases: 1) Infection: vulnerability scanning

2) Injection: exploited + download of bot's binary code

3) connection to the cnc and start to control the host

4) action on behalf of botmaster + maintain and upgrade periodically

For P2P 1 and 2 are similar but in searches until finds an alive peer 4) phase 1: update of peer list + download any available updates phase 2: starts malicious activities based on STORM but similar for all P2P botnets pp. 18-27, Dec. 2007.

2.1.6 Botnets CnC Channel

TODO: after presenting the botnet structure we focus on the part where botmasters have turned their focus in evading detection and becoming more resilient. In this section we want to discuss how the CnC channel works. Means of receiving and sending commands and information between the botmaster and the zombies. Typical protocols: IRC, HTTP – HTTPS, DNS, etc

Protocols imply (to an extent) a botnet's communication topology. The topology provides trades-off in terms of bandwidth, affectivity, stealth, and so forth.

2.1.7 Botnet architecture

[sources]

Based on CnC channels, there are two typical botnet topologies: Centralized Decentralized (P2P) Traditional botnet metrics: Resiliency A botnet ability to cope with a loss of members (zombies) or servers Latency Reliability in message transmission Enumeration An ability to accurately estimate a botnet size Difficulty for security analysis Re-sale A possibility to carve off sections of the botnet for lease or resale to other operators.

Botnets come in all kinds of shapes and sizes. As a result, they employ a range of CnC topologies in response to commercial defenses, legal shutdowns and hijacking attempts. This evolution means that a criminal botnet operator has a number of wellstudied CnC topology options to base a new botnet upon – each of which have relative strengths and weaknesses

Botnet CnC topologies have been optimized to minimize network chatter and system failures, just like commercial-grade technology tasked with remotely managing tens of thousands of hosts. The precise CnC topology selected by a botnet operator often reflects that individual's perceived risk to continued command access and the financial business model of that botnet

CnC topologies encountered in the wild typically match one of the following types: • Star • Multi-server • Hierarchical • Random

TODO: centralized vs decentralized botnets TODO: metrics analyzed to choose best option: cf slide(11)(<http://www.ijcttjournal.org/Volume4/issue-1/IJCTT-V4I1P104.pdf>)
 TODO: present with visuals the different topologies and their purpose.

Modeling Botnets architectures: diurnal propagation model propagation using time zones," in Proceedings of the 13 th Network and Distributed System Security Symposium NDSS, 2006 Super botnet model Proceedings of Network and Distributed System Security Symposium (NDSS'07), pp. 111– 123, Reston, VA, USA, Feb. 2007 Stochastic P2P model botnets," in Fifth International Conference on Quantitative Evaluation of Systems, pp. 307– 316, Sep. 2008 advanced P2P hybrid model peer-to-peer botnet," in Proceedings of the first Conference on First Workshop on Hot Topics in Understanding Botnets, pp. 2, Berkeley, CA, USA, 2007.

Star

[source] The Star topology relies upon a single centralized CnC resource to communicate with all bot agents. Each bot agent is issued new instructions directly from the central CnC point. When a bot agent successfully breaches a victim computer, it is normally preconfigured to "phone home" to this central CnC, whereupon it registers itself as a botnet member and awaits new instructions.

Pros Speed of Control The direct communication between the CnC and the bot agent means that instructions (and stolen data) can be transferred rapidly Cons Single point of failure If the central CnC is blocked or otherwise disabled, the botnet is effectively neutered.

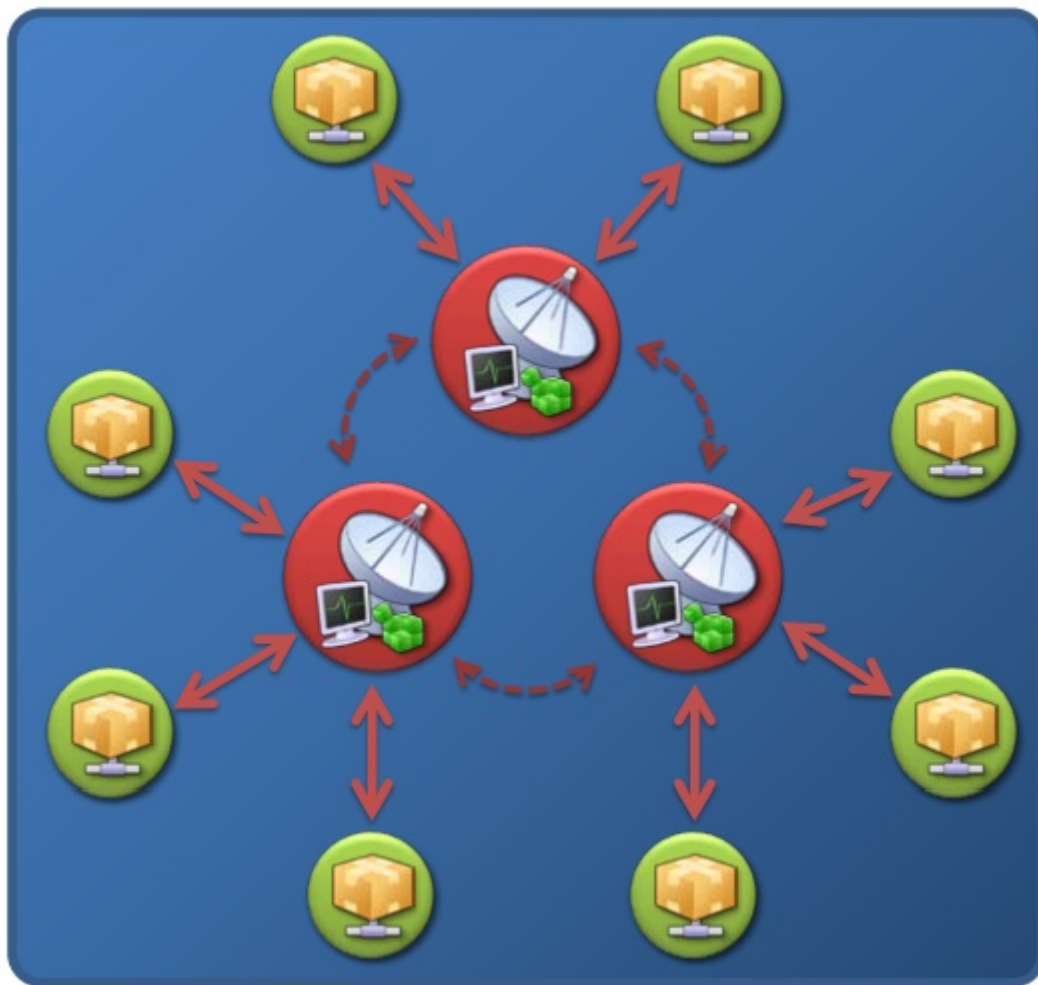


Pros	Pros	Cons
Botnet awareness Interception or hijacking of bot agents will not enumerate all members of the botnet and is unlikely to reveal the C&C server.	Highly resilient Lack of a centralized C&C infrastructure and the many-to-many communication links between bot agents make it very resilient to shutdown.	Command latency The ad hoc nature of links between agents make C&C communication unpredictable, which can result in levels of latency for some clusters of bot agents.
Ease of re-sale A botnet operator can easily carve off sections of their botnet for lease or resale to other operators.		Botnet enumeration Passive monitoring of communication from a single bot-compromised host can enumerate other members of the botnet.

Multi-server

Pros No single point of failure Should any single CnC server be disabled, the botnet operator can still maintain control over all bot agents. Geographical optimization Multiple geographically distributed CnC servers can speed up communications between botnet elements.

Cons Requires advance planning Additional preparation effort is required to construct a multi-server CnC infrastructure.



Hierarchical

Pros Botnet awareness interception or hijacking of bot agents will not enumerate all members of the botnet and is unlikely to reveal the CnC server. Ease of re-sale A botnet operator can easily carve off sections of their botnet for lease or resale to other operators. **Cons** Command latency Because commands must traverse multiple communication branches within the botnet, there can be a high degree of latency with updated instructions being received by bot agents. This delay makes some forms of botnet attack and malicious operation difficult.

Random(dynamic/P2P)

Pros Highly resilient Lack of a centralized CnC infrastructure and the many-to-many communication links between bot agents make it very resilient to shutdown. **Cons** Command latency The ad hoc nature of links between bot agents make CnC communication unpredictable, which can result in high levels of latency for some clusters of bot agents. Botnet enumeration Passive monitoring of communications from a single bot-compromised host can enumerate other members of the botnet

TODO: what was the first structure of botnets and how has it evolved?

2.1.8 Rallying mechanism

TODO: explain the different techniques used to rally bots to an IP or a Domain (how do they regroup with master?)

2.4.2 Command and Control Rallying Mechanisms

According to Choi et al. [20], botmasters want their bots to be invisible but portable, therefore they use different methods for bots rallying. They stated that not all bots can have mobility and invisibility at the same time. They described three rallying methods, namely; hard-coded IP address, dynamic DNS, and distributed DNS. In hard-coded IP address method; the bot binary has a hard-coded IP address of its CnC server, the server can be detected through reverse engineering, and the botmaster can be quarantined or the botnet can be suspended. As hard-coded IP address cannot be changed, this method cannot provide mobility and does not make the botnet invisible as well. On the other hand, in dynamic DNS botnets migrate their CnC server frequently, upon the instruction of botmaster. Using a list of servers provided in the bot binary, a botmaster uses several CnC servers. It uses dynamic DNS in order not to be detected or suspended, and to keep the botnet portable. When connection to the CnC server fails or shutdown, the bots will perform DNS queries and will be redirected to a new CnC server [2]. This redirection behavior of botnets is known as "herding". This method provides mobility and some invisibility to the botnets. Finally, with distributed DNS, botnets run their own distributed DNS service at locations that are out of the reach of law enforcement. Bots include the addresses of these DNS servers and contact these servers to resolve the IP address of CnC servers [2]. This method provides both mobility and invisibility to their botnets. In summary, while the hard-coded IP botnet makes very easy for the newly infected nodes to join the botnet, it also makes easy for law enforcement to track and shutdown the botnet. On the other hand, using DNS to migrate CnC servers make it harder for the newly infected nodes to join the botnet. Some infected nodes might never be able to join the botnet -in case they stay offline long enough for all the addresses in the initial communication list to be obsolete, however, it gives the botnet the flexibility to hide its CnC servers.

Rallying mechanism monitoring group activities in dns traffic," in The 7th IEEE International Conference on Computer and Information Technology, pp. 715-720, Oct. 2007. Objective for bots: invisible but portable -> different methods for bot rallying: - ip hardcoded: the bot binary has a hard-coded IP address of its CnC server, the server can be detected through reverse engineering, and the botmaster can be quarantined or the botnet can be suspended. As hard-coded IP address cannot be changed, this method cannot provide mobility and does not make the botnet invisible as well. dynamic DNS botnets migrate their CnC server frequently, upon the instruction of botmaster. Using a list of servers provided in the bot binary, a botmaster uses several CnC servers. It uses dynamic DNS in order not to be detected or suspended, and to keep the botnet portable. When connection to the CnC server fails or shutdown, the bots will perform DNS queries and will be redirected to a new CnC server. This redirection behavior of botnets is known as "herding". This method provides mobility and some invisibility to the botnets. distributed DNS botnets run their own distributed DNS service at locations that are out of the reach of law enforcement. Bots include the addresses of these DNS servers and contact these servers to resolve the IP address of CnC servers. This method provides both mobility and invisibility to their botnets.

2.1.9 DNS

To understand these methods of evasion we must first explain how DNS works, its normal use and how the botnets abuse it.

Description

TODO: what is DNS, its purpose in general and different parts of the DNS

Protocol

TODO: Common protocol steps

Special capabilities of the protocol

TODO: Explain with the growing services of the internet "new"(research if they were part of the original protocol) capabilities arisen to allow this growth.(find an article supporting that). Explain Fast flux, domain flux and tunnelling used for legitimate purposes. (find an article explaining how these are used by normal services or the standard of the protocol)

DNS is an Internet service which translates names of sites into their numeric IP addresses. For every host, DNS has a list of A records each with a given Time-to-Live (TTL) value (normally from 1 to 5 days). DNS returns these A records in round-robin way. CDN use a lower TTL to provide their content more efficiently Fast-Flux Service Network (FFSN) is a distributed proxy network -built on compromised machines (flux-agents)- that direct incoming DNS requests to the botnet's desired address on the fly.

This is done to allow the botnet's domain name to have multiple IP addresses. In the meantime, involved DNS records are constantly changing every few minutes using a combination of round robin IP addresses and a very short TTL from any given particular DNS resource record. In FFSN, the victim client first sends an address query to DNS. Then, the DNS returns the IPs of a subset of active flux-agents. After that, the flux-agent relays the client's request to the mothership³. The key factor in FFSN is the combination of a very short TTL and the round-robin answer from a large pool of active agents Proceedings of the first Conference on First Workshop on Hot Topics in Understanding Botnets, pp. 2, Berkeley, CA, USA, 2007. Some features for FF detection: nb of A records returned: 1-3 normal, 5 or more ff nb of NS: normal -> small, ff -> several NS + several A records for the NS AS: small nb of A from 1 AS -> normal, located in different AS -> ff Hardware and IP: range of IP is diverged -> ff No physical agent -> ff no guarantee uptime. FIGURE NORMAL FF AND BAD FF (single and double)

Unfortunately, botnets use the DNS traffic as any other legitimate host, which makes differentiating the legitimate DNS traffic from the illegitimate one a very challenging problem [16]. Moreover, botnet owners attempt to hide their communication with the bots to obstruct any deployed botnet detection processes [17]. The attackers or botmasters use the DNS services to hide their command and control (CnC) IP address ;to make the botnet reliable and easy to migrate from server to another without being noticed

Issues with the channel

TODO: exploitable bits of the channel researchers have exploited: Rallying, hard to keep secret

Channel security/lookup resilience

ME The channel resilience of a botnet is critical to ensure good communication with the CnC server. It is a critical component of botnets, its failure is usually the end of the botnet's life.

ME

[source]

The ability for a bot agent to locate CnC infrastructure is a critical requirement for maintaining control of the entire botnet for botnets that rely upon centralized CnC. If the CnC cannot be found, a bot agent will not be able to receive new instructions. While some bot agents may opt to function in an alternative autonomous "zombie" mode – reverting to embedded instructions for propagation and infection – most bot agents will continue to harvest local host information and poll the missing CnC at regularly scheduled times. Botnet Communication Topologies Page 6 Botnet operators use a number of technologies to increase the probability that bot agents will be able to locate the central CnC infrastructure. These tools and techniques also make botnets more resilient to shut-down and hijacking maneuvers. One key technology that enables CnC location resolution and failover resilience is referred to as "fluxing". Fluxing comes in two major flavors: • IP Flux • Domain Flux Both technologies are used extensively by professional botnet operators

TODO: ways of securing their communication channel: encryption, rootkit and a number of DNS evasion techniques

2.1.10 Botnets use and abuse of DNS protocol

TODO: Present the different abuses of the DNS protocol to evade detection (use previous descriptions but revisit writing and add more visualization and explanations on how exactly it works. (it is important for future arguments regarding the evasion methods. We need to inform our reader to be able to convince him later of our arguments)

Domain fast flux

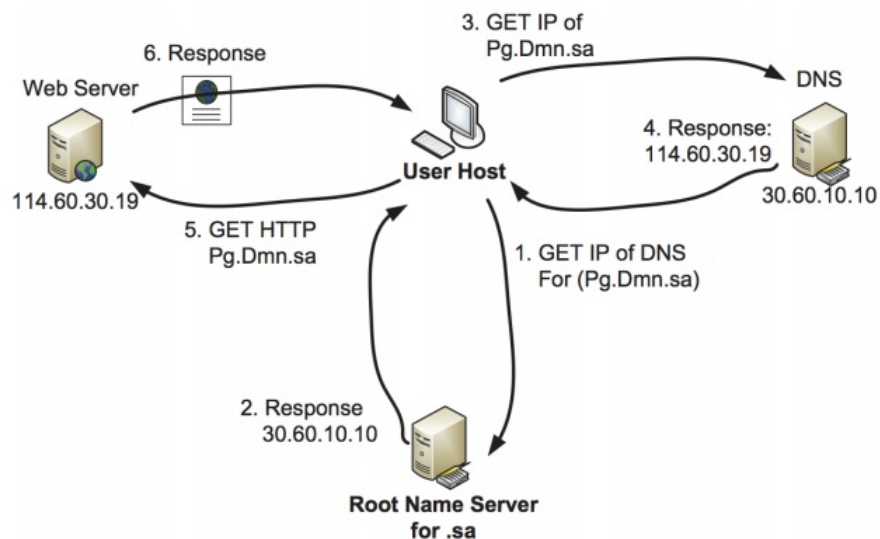
TODO: present DF [source]

Domain Wildcarding abuses native DNS functionality to wildcard (e.g., *) a higher domain such that all FQDN's point to the same IP address. For example, *.damballa.com could encapsulate both mypc.atl.damballa.com and myserver.damballa.com. This technique is most commonly associated with botnets that deliver spam and phishing content – whereby the wildcarded information that appears random (e.g. "asdkjlkw" of asdkjlkw.atl.damballa) is Botnet Communication Topologies Page 7 used by the botnet operator to uniquely identify a victim, track success using various delivery techniques, and bypass anti-spam technologies. • Domain Generation Algorithms are a more recent addition to bot agents. They create a dynamic list of multiple FQDN's each day, which are then polled by the bot agent as it tries to locate the CnC infrastructure. Since the created domain names are dynamically generated in volume and typically have a life of only a single day, the rapid turnover makes it very difficult to investigate or block every possible domain name.

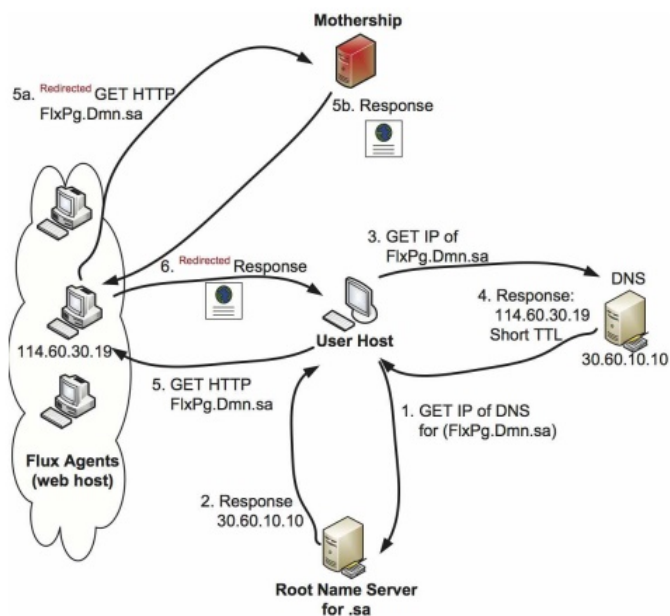
Location Resilience Most botnets today rely upon DNS as the service for location of CnC infrastructure. Fluxing DNS records provides varying degrees of resilience to shutdown and hijacking that can be best summed up as: Brittle: Single domain
Less brittle: Single flux Resilient: Double flux Very resilient: Domain flux

Fast-flux

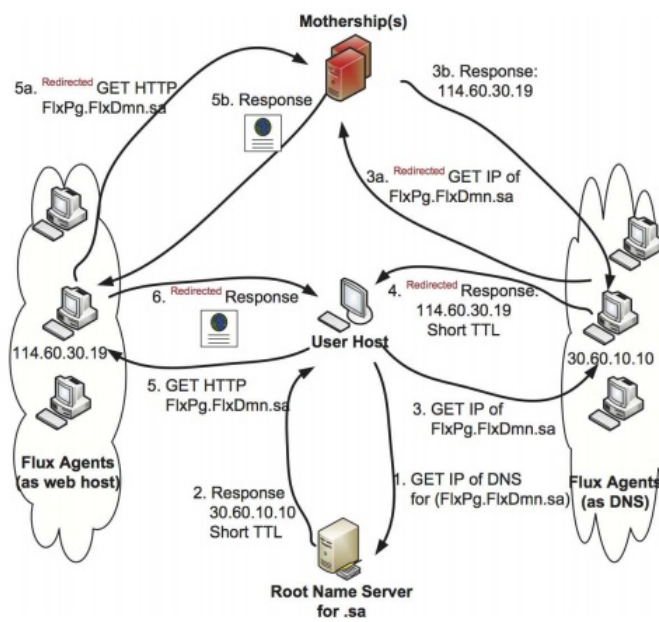
[source] Normal FF



single flux



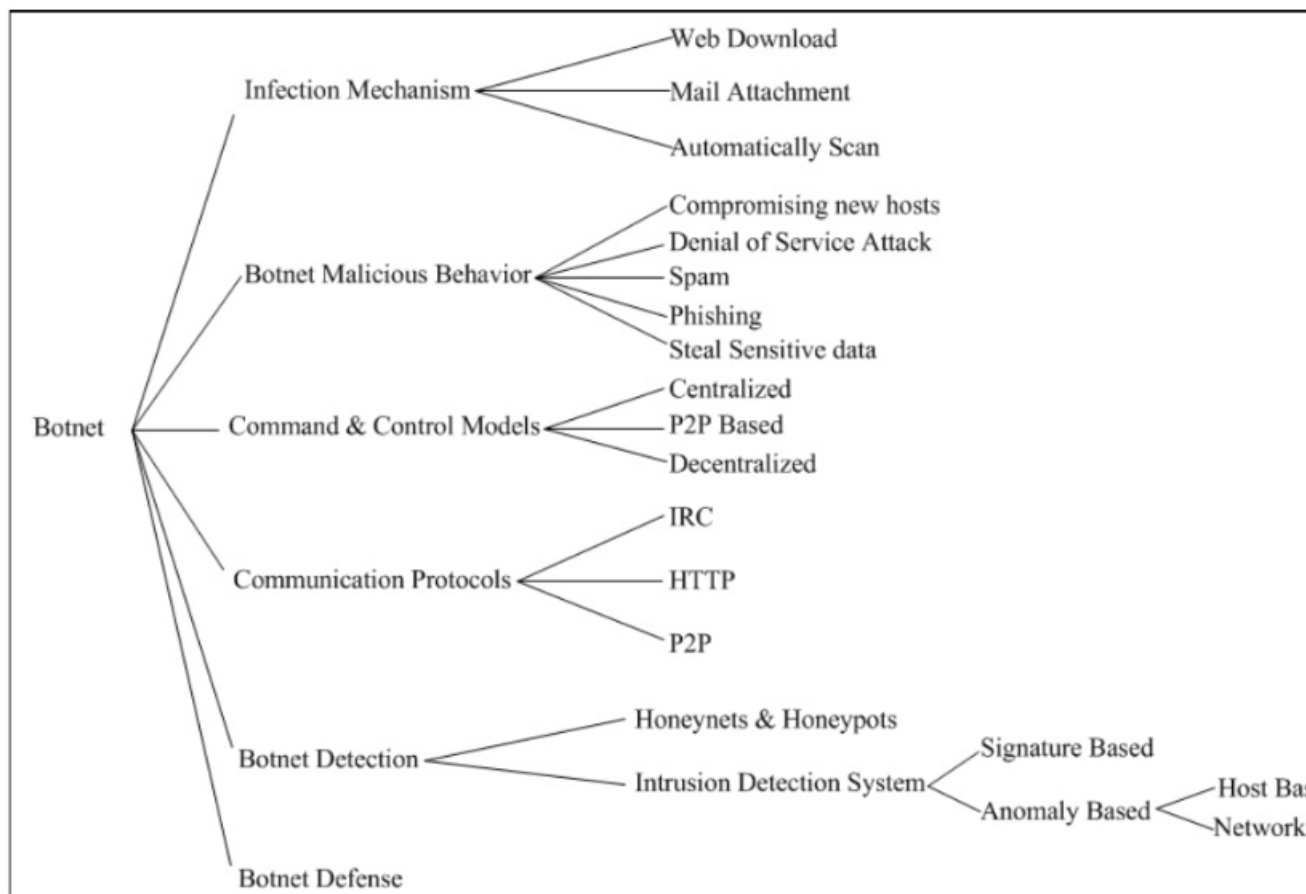
double flux



DNS tunnelling

TODO: General presentation

Maybe Domain shadowing (need more research)



2.2 Botnet detection related papers

In this section related to papers focused on Botnet detection, we are going to present the classifications of botnets and what part of the research we have decided to focus on.

A number of botnet, detection measures, such as honeynet-based and Intrusion Detection System (IDS)-based, have been proposed. However, IDS-based solutions that use signatures seem to be ineffective because recent botnets are equipped with sophisticated code update and evasion techniques

Botnet detection and defence Early bots detected through signature -> vulnerable to any new botnet, but useful for old ones

classification: passive and active 3 types of behavior: - network based behavior: observable network traffic between botmaster and bots, can be used to detect individual bots and their CnC server. - host based behavior: observable calls on the systems infected by botnets. - global correlated behavior: global behavior characteristics, structure will be similar to current structures; same for all mechanisms

"4.1.3 DNS Traffic Botmaster use DNS rallying to make their botnets invisible and portable. Choi et al. [20] proposed botnet detection mechanism by monitoring their DNS traffic. According to the authors, bots use DNS queries either to connect or to migrate to another CnC server. The DNS traffic has a unique feature that they define as group activity. Bots can be detected by using the group activity property of botnet DNS traffic while bots are connecting to their server or migrating to another server. There are three factors that help in distinguishing botnet DNS queries from legitimate DNS queries [20]; (1) queries to CnC servers come only from botnet members (fixed IP address space size), (2) botnet members migrate and act at the same time, which leads to temporary and synchronized DNS queries, (3) botnets usually use DDNS for CnC servers. For a botmaster to keep its bot hidden and portable, it relies on DNS to rally infected hosts. In botnets, DNS queries can appear for many reasons. They appear during rallying process after infection, during malicious activities like spam or DoS attacks, during CnC server migration, during CnC server IP address change, or after CnC server or network link failure. Based on the aforementioned five situations of DNS query used in botnets, the authors have developed a Botnet DNS Q Detection algorithms, which distinguishes the botnet. This algorithm starts by building a database for DNS queries comprised of the source IP address, domain name and timestamp. Then, they group DNS query data using the domain name and timestamp field. After that, they remove redundant DNS queries. Finally, botnet DNS queries are detected using a numerically computed some similarity factor [20] This algorithm cannot detect botnets migrating to another CnC server. Therefore, they developed a Migrating Botnet Detection algorithm by modifying the botnet DNS query detection algorithm. Similarly, this algorithm starts by building a database for DNS queries comprised of the source IP address, domain name and timestamp. Then, it groups DNS query data using the domain name and timestamp field. After that, it removes redundant DNS queries. The next step will be to compare IP lists of different domain name with same size of IP list, because bots use two different domain names for the CnC server during migration [20]. These algorithms are protocol and structure independent and are capable of detecting unknown and encrypted botnets. However, these are not for real-time detections and have low accuracy for small networks. Furthermore, they are very sensitive to threshold values which need to be chosen very carefully to balance false positives and false negative rates.

Honeynet: capture and analyze Pros: Easy to build, low resources requirements
 Cons: Hard to scale, limited interactions + can be reverted by hackers to learn new evasion techniques. IDS: monitor and look for signs 2 types: signature or anomaly based through DNS analysis(most promising) Anomaly detection approaches that work: - DNS Blacklist (for malware, botnets and spambots) - detect botnets when they try to communicate with their CnC: NXDomains - recursive DNS queries detecting botnet related services - DGA 1) Main DGA 2) Decision tree + Bayes for DGA classification - Kopsis = high level DNS query analysis (upper hierarchy) - Exposure graph analysis - reputation system

ME TODO: In the beginning we explain the detection classification proposed by the large survey. Then we explain what we have researched and how we'll use it in our work. Keep in mind that it isn't a list of papers, it is a list of information that will be used or not later in the paper, that has to cover that topics current research state and that we need to argue on reasons we want to keep articles or not and what information we'll use.

After this presentation on the techniques used by Botmaster to set their botnets into certain topologies and evading the best they can current detection systems. We are now presenting the research papers that have tried to detect botnets using this different evasion techniques. Since the end goal is to find the best features for an all-in solution, we have structured the current state of research as follows: First we will present the current all-in solutions that exist, the features they extract and what model they have created. Secondly, to achieve our goal towards improving these solutions, the objective is to find better features and better models. We will present studies focused on single detection models that cover the field of detection through passive DNS analysis. For each study we will list the features proposed, understand their purpose and do a first selection if a thorough comparison has been made with the features presented. Otherwise they will be saved for further analysis.

In a recent survey of the state of the art regarding Botnet detection based on DNS traffic analysis **survey**, they present a classification of botnet techniques (A survey of botnet detection based on DNS). They divide the classification into 2 categories, the honeynets and IDS(Snort). The later having evolved the most and where we want to focus. Most IDS were for a long time using signature-based techniques(check the IDS section for more details, p6). These are effective but only work with known botnets. Because they are signature-based there is a need to keep a blacklist updated very often, because a simple change creates a new signature and would be undetected if the database isn't updated with the latest signatures.

Newer techniques, described as "anomaly based" have emerged for 2 reasons: to detect unknown botnets and to respond to the new type of evasions that followed. Botnets have become a lot more resilient and stealthy. It has pushed the research to focus on features that would allow to distinguish between benign and malicious traffic. These new researches capable of detecting new bots are divided into 2 sections: host-based and network-based. This means anomalies focusing on a single host or the traffic of a network. The host-based research focused on detecting bots in single hosts by monitoring local processes and kernel level routines.(BotSwat) The big problem of these propositions were the inability to scale them, we would need large monitoring system on each host with complex capabilities to communicate with each other and do correlation(EFFORT framework, the only one apparently. Do a bit more research on this framework and correct any mistakes in its previous description). This is what the second section aims to solve by monitoring networks.

This activity can be done passively by simply collecting the traffic and analysing it (passive monitoring) or actively by injecting packets into the network forged to make the bots react, and then analyse the network response. Active monitoring: explain in more detail the rest of the approaches. The part that our study focus on because "explain a valid reason for this part having more weight then the other ones, explain that our study could be a model combining different steps of the classification." Finally explain the different passive approaches:

Explain that these passive detection can also be divided into specific counters for certain evasion systems such as DF, FF, tunnelling. Or be put together in an all-in solution to detect botnets independently of the evasion technique used.

The first step in the research was to find the models that would be the current baseline for all-in solutions: Here we can start with 2 already gathered ones, and used the survey papers to find all-in solutions (if there are more than EXPOSURE), present them completely (features, dataset, model, purpose). IDEA: use the survey study chart to show strengths and weaknesses of papers.

- Step needed before presentation of these papers: classify them into the folders, create a summary for each one with the following information: Model (data processing, dataset used, classification process, features) finally for each relevant paper either do a summary with the 4 components or simple summary if redundant information.

After this part we are supposed to be done with the research, we have a last discussion of how the following step is planned and what information from this chapter will be translated into the rest of the thesis. ASK: should we introduce the research on datasets in the SOTA or the model presentation? ME

Exposure

[source] ME

EXPOSURE, a system that employs large-scale, passive DNS analysis techniques to detect domains that are involved in malicious activity. They use 15 features extracted from DNS traffic.

Time-based

When we analyse many requests to a particular domain over time, patterns indicative of malicious behaviour may emerge.

These were supposed to be the features with the most weight, unfortunately due to lack of the same caliber of capture available to the authors of Exposure, we could not test out the 4 features related to time. Either because the datasets are compositions of smaller datasets, or because the timestamps are too short.

DNS answer based

Here are some domain-flux features: A domain name can map to multiple IP addresses. In such cases, the DNS server cycles through the different IP addresses in a round robin fashion and returns a different IP mapping each time.

Malicious domains typically resolve to compromised computers that reside in different locations. The attackers typically use domains that map

to multiple IP addresses, and IPs might be shared across different domains.

- the number of different IP addresses that are resolved for a given domain during the experiment window
- the number of different countries that these IP addresses are located in
- the reverse DNS query results of the returned IP addresses
- the number of distinct domains that share the IP addresses that resolve to the given domain (false positive can be reduced with google reverse DNS which will have hosting providers in top answers)

TTL value based

Low TTL and Round-Robin DNS:

- high availability (Content Delivery Networks (CDNs))
- botnets using this, makes them resistant to DNS Blacklists(DNSBL) and take downs. Often using Fast-Flux Service Networks (FFSN).

Because FFSN are usually detectable because of low TTL and growing list of distinct IP addresses for a domain, it explains the purpose of the TTL features.

Domain name based

Finally 2 simple features to expect detection of DGA: there is a big difference between legit domain names and domains generated by DGAs(Domain Generation Algorithms(DGAs)).

This can be noticed with 2 simple features:

- ratio numerical chars to length of domain name
- length of the longest meaningful substring to length of domain name

Feature Set	#	Feature Name	# of Atomic Features
Time-Based Features	1	Short life	2
	2	Daily similarity	1
	3	Repeating patterns	2
	4	Access ratio	2
DNS Answer-Based Features	5	Number of distinct IP addresses	1
	6	Number of distinct countries	1
	7	Reverse DNS query results	5
	8	Number of domains share the IP with	1
	9	Average TTL	1
TTL Value-Based Features	10	Standard Deviation of TTL	1
	11	Number of distinct TTL values	1
	12	Number of TTL change	1
	13	Percentage usage of specific TTL ranges	5
Domain Name-Based Features	14	% of numerical characters	1
	15	% of the length of the LMS	1

ME

2.2.1 Recognizing Time-efficiently Local Botnet Infections (Heuer et Al.)

2.2.2 More to come

2.3 Possible approaches to provide better features

2.3.1 Domain-flux

TODO: domain-flux can is mostly about analyzing domain names, here is a list of papers that attempt to do that with different metrics and features:
Detecting domain-flux botnet based on DNS traffic features in managed network Dinh-Tu Truong and Guang Cheng. https://de.wikipedia.org/wiki/Domain_Flux,
<https://www.sciencedirect.com/science/article/pii/S1742287614001182>,
<https://blog.malwarebytes.com/security-world/2016/12/explained-domain-generating-algorithm/>

DGA specific

Detecting Algorithmically Generated Malicious Domain Names, <http://dimva2014.isg.rhul.ac.uk/sli-talk.pdf>

2.3.2 Fast-flux

2.3.3 DNS tunnelling

2.3.4 Behavioral

2.4 Discussion of the features selection

Chapter 3

Model creation

Experiment Dataset Pre-Processing = feature extraction (I LIKE HOW HE EXPLAIN BI-TRI GRAMS)

3.1 Pipeline of the research

3.1.1 Environment

3.1.2 Datasets

Information regarding the datasets

Sources
Content
Labelling

balance of the datasets

3.2 Assessment model (for features and models)

3.2.1 Machine algorithms

Supervised

List of algorithms (to be decided)

Unsupervised

List of algorithms (to be decided)

3.2.2 Training model

3.2.3 Testing model

3.2.4 Results metrics

List of metrics used to analyse the models

Chapter 4

All-in solution process

4.1 Features extraction and features analysis

4.1.1 Domain-flux Features

4.1.2 Fast-flux features

4.1.3 DNS tunnelling features

4.1.4 Features analysis

Distribution of the features for the different datasets, Correlation between features

4.1.5 Features discussion

4.2 Features selection for All-in solution

4.2.1 Feature optimization cycle (adding/removing features, changing or modifying thresholds)

4.3 Comparison of the results

Chapter 5

Sets run and result discussion

5.0.1 Results analysis

5.1 Current All-in solution assessment

5.1.1 Exposure

5.1.2 Recognizing Time-efficiently Local Botnet Infections (Heuer et Al.)

5.1.3 More to come

Chapter 6

Conclusion

6.1 This will depend on results

6.2 Advantages of solution

6.3 Shortcomings

6.4 Improvements propositions

6.5 Welcome and Thank You

Appendix A

Frequently Asked Questions

A.1 How do I change the colors of links?

The color of links can be changed to your liking using:

`\hypersetup{urlcolor=red}`, or

`\hypersetup{citecolor=green}`, or

`\hypersetup{allcolor=blue}`.

If you want to completely hide the links, you can use:

`\hypersetup{allcolors=.}`, or even better:

`\hypersetup{hidelinks}`.

If you want to have obvious links in the PDF but not the printed text, use:

`\hypersetup{colorlinks=false}`.