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Effects of Ransomware: Analysis, Challenges and Future Perspective

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Abstract:

This review paper highlights the challenges and best practices in malware analysis, specifically focusing on the age of ransomware. It provides an overview of malware and its impact on computer systems and user privacy by lists various types of malware, including viruses, Trojans, spyware, adware, worms and highlights major malware attacks including the methods used and the resulting damages. Further, the article explores the challenges faced in ransomware analysis, including advanced encryption and evasion techniques, anti-analysis mechanisms, zero-day exploits and vulnerabilities, polymorphic and dynamic behavior, lack of resources, complexity of ransomware, collaboration difficulties, and cost implications. These challenges make it necessary for security researchers to constantly update their knowledge and techniques to effectively analyze ransomware. This study concludes best practices for ransomware analysis including isolating and segmenting ransomware samples in controlled environments, emphasizing behavior analysis and threat hunting, investing in advanced reverse engineering and automated analysis techniques, promoting collaborative intelligence and information sharing, and implementing security measures to protect against ransomware attacks. Additionally, the article briefly mentions static analysis techniques which explains that static analysis involves examining malware files and code without executing them. It can be used to identify ransomware characteristics, such as encryption algorithms, ransom demands, remote command execution, and obfuscation techniques. Moreover, file and code analysis methods, signature-based detection, code deobfuscation and unpacking techniques, and malicious document analysis and exploit detection are also suggested as part of static analysis.

Keywords: Malware Analysis, Dynamic Analysis, Ransomware, Static Analysis, Virus

1. Introduction

Malicious software or malware are designed to harm or cause trouble with the purpose of gaining unauthorized access to computer systems and networks, disrupt computer operations, and collect personal information without the owner's permission. This poses a threat to Internet use, the integrity

of computer systems, and the privacy of users [1].

2 Types Of Malwares

There are many types of malware such as viruses, worms, Trojan horses, rootkits, backdoors, botnets, spyware, and adware. It's important to note that a single malware can exhibit characteristics of multiple types simultaneously [1].

2.1 Virus

A virus is a harmful program that enters a computer and causes damage by changing

data or information. It needs people to open up. It can access the system via links, images, acquisition or internet download [2]. There are many types of viruses:

a) **Boot sector virus: Infects the boot of the computer.** disk (floppy, CD, or hard disk) by changing its contents with its own harmful code. However, recent advancements in threat detection have helped mitigate this virus [3].

b) **File Virus:** This virus infects executable files and stays in the computer's memory. It tries to infect all programs that load into Bad memory by adding viruses to executable files [3].

c) **Internal virus:** This virus is stored in the computer's memory and is opened when the operating system starts or something is done.

d) **Virus not here:** This virus is not in memory, it has spread to the target and transfers control to the infected application. It has a search module to find new targets and patterns to disseminate new knowledge.

e) **Macro Virus:** This virus, written in macro language, spreads through phishing e-mails containing malicious information. It can also spread by sharing infected files.

f) **Polymorphic virus:** This virus changes its behavior every time it infects new information so that it can detect malware scanners. Its changing nature or hiding process makes it difficult to detect [4].

g) **Virus metamorphosis:** This virus changes its properties and rules with each virus, making search and analysis very difficult.

h) **Stealth virus:** This virus uses various methods to hide in memory, files and boot to avoid detection. It affects boot sectors and tries to hide changes in data or boot sectors. Antivirus software should be able to identify hidden viruses by looking at memory evidence.

2.2 Trojan

This is a malicious program designed to steal sensitive information from the victim's computer. It disguises itself as a non-malicious program and does not copy or forward other files. It survived undetected by antivirus software. Trojans can create backdoors, spy, send messages, access remote computers, and create bot networks for DDoS attacks [3].

1) **Spyware:** This malware is installed on the victim's computer without the victim's knowledge and is used to track and gather information about the user. Anti-spyware tools can be used to prevent spyware [5].

2) **Adware:** Software that displays ads to users and collects information about users' marketing preferences. It analyzes users' behavior on the Internet to display ads. Adware enters the computer through freeware, shareware, and infected websites [5].

3) **Viruses:** Viruses are self-replicating malware that infects other computers without human intervention. Their main goal is to damage the network by using the bandwidth and increasing the load. There are different viruses such as email worms, Internet browsing worms and mobile worms that are transmitted via Bluetooth or mobile communication applications [5].

Table 1 Major Malware attacks and their impact

Year	Event	Description
1999	Melissa	The Melissa malware attack, although it may seem outdated now due to improved malware detection and prevention techniques, demonstrated the destructive power of a major cyberattack. It took the form of a Word file that claimed to contain passwords to popular adult websites, which grabbed the attention of victims. When the file is opened, it triggers a macro that sends the virus to the first 50 contacts in the user's email address book. The email phenomenon has impacted not only the US government but also business, including large companies like Microsoft and Intel. In total, the Melissa attacks caused $1.2 billion in damage. The malware was created and distributed by a man named David L. Smith [5].
2000	I LOVE YOU	The Love Bug or Love Letter worm was another notorious malware that infected millions of computers. It spread through emails with a subject line saying "ILOVEYOU," which tempted victims to open it. The email contained an attachment called "Love Letter" with the extension VBS (Visual Basic Script) which was not recognized as a problem by Windows at the time. Like the Melissa virus, the Love Bug virus infects everyone in the address book. The total damage caused by the virus is estimated at $20 billion [5].
2003	SQL Slammer	SQL Slammer is a virus that spreads rapidly and causes serious damage. It exploits vulnerabilities in Microsoft's SQL Server and database products to cause denial of service (DDoS) attacks that severely disrupt the Internet. The term "Warhol's worm" became famous for this attack, referring to a virus that can spread rapidly. Losses from SQL Slammer attacks are estimated to be worth billions of dollars. Bank of America ATMs unavailable due to strike, Continental Airlines forced to cancel several reservations due to storm [5].

2004	Mydoom	In 2004, the fastest spreading malware in the history of cyber attacks occurred. It uses deceptive email phrases like "mail delivery system" and "error" to trick users into opening the email. The malware spread rapidly on the internet, infecting 25% of all emails. Affected users are compromised by leaving and opening the network, allowing unauthorized access to their computers. This resulted in a distributed denial-of-service (DDoS) attack that impacted companies such as Google, Microsoft, and Lycos. The attack,estimated at $38.5 billion, is the most costly cyberattack ever recorded.[5].
2007	Zeus	In 2007, a Trojan horse was discovered that targeted the US transportation department and caused data wiping. This malicious software compromised approximately 74,000 FTP (File Transfer Protocol) accounts, including those belonging to banks and corporations such as Cisco and Amazon. The Trojan uses the Zeus botnet designed to steal credentials for social media, banking and email accounts. The total damage from the attack is estimated at $70 million. [5].
2010	Stuxnet	Stuxnet is a key element in the development of cyberwarfare and makes headlines as the first futuristic cyberwarfare tactic. It was sent using a USB flash drive and targeting software that controls Iran's nuclear power plant. The impact of Stuxnet was far-reaching, causing chaos globally as it successfully stole nuclear codes. This unprecedented digital weapon brought forth concerns about the potential power of cyber attacks. The events surrounding Stuxnet were so remarkable that they were captured in a documentary titled "Zero Days," shedding light on this alarming affair [5].
2014	Sony Pictures Hack	Three years prior to the Stuxnet attack, a major cyber breach occurred where the data of 77 million users was stolen, resulting in the service being offline for 10 days. Returning to a later date, the infamous hacker group known as the Guardians of Peace (GOP) targeted Sony. They managed to hack into Sony's systems and stole approximately 100 terabytes of data, which included emails, movie scripts, and the phone numbers of 100 celebrities. The attack involved the use of malware that infected Sony's computers, rendering them inoperable. This cyber attack on Sony was a significant event in the history of cyber security [5].
2017	Wanna Cry	WannaCry, considered by cybersecurity experts as one of the largest malware attacks, successfully infected computers in approximately 150 countries. It exploited security vulnerabilities found in older versions of the Windows operating system. WannaCry is a type of ransomware that encrypts data on infected computers and requires a ransom to unlock and regain access to encrypted data.This attack caused widespread disruption and financial losses for individuals and organizations affected by it [5].

3 Challenges In The Age Of Ransomware Analysis

Ransomware has emerged as a formidable cybersecurity threat, constantly evolving in complexity and sophistication. Malware analysts face unique challenges in the age of ransomware analysis, necessitating innovative approaches to combat this growing menace.

3.1 Encryption and Obfuscation Techniques

Ransomware strains employ advanced encryption and obfuscation techniques to evade detection and analysis. These techniques make it difficult for analysts to analyze the underlying code, hampering efforts to understand the ransomware's behavior and develop effective countermeasures [6].

3.2 Rapidly Evolving Variants

Ransomware variants evolve at a rapid pace, with new strains and families constantly emerging. This rapid evolution challenges analysts to keep up with the latest techniques and develop timely detection and analysis methods [7]

3.3 Anti-Analysis Mechanisms

Ransomware incorporates anti-analysis mech anisms that actively detect and evade virtual environments, sandboxes, and debugging tools. These mechanisms hinder analysts' ability to observe the ransomware's behavior in controlled environments [8].

3.4 Stealthy Delivery and Execution

Ransomware employs various stealthy delivery and execution techniques, such as fileless attacks and exploit kits. These techniques allow the malware to infiltrate systems undetected and hinder traditional analysis methods [9].

3.5 Data Integrity Risks

Ransomware poses risks to data integrity, as decrypting files without the proper decryption key may result in permanent loss or corruption of data. Analysts must carefully handle ransomware samples to prevent unintended damage [10].

4 Best Practices For Ransomware Analysis

To address the challenges posed by ransomware analysis, analysts can adopt best practices that enhance their effectiveness in detecting, analyzing, and mitigating ransomware threats.

4.1 Dynamic Analysis

Employ dynamic analysis techniques to observe the ransomware's behavior in a controlled environment, allowing for better understanding of its execution flow and potential impact [11].

4.2 Automated Analysis Frameworks

Develop automated analysis frameworks that combine behavior-based analysis, static analysis, and machine learning techniques to expedite detection and classification of ransomware strains [12].

4.3 Collaboration and Information Sharing

Foster collaboration among analysts and organizations to share insights, indicators of compromise (IOCs), and mitigation strategies. Collective knowledge can strengthen defenses against ransomware attacks [13].

4.4 Threat Intelligence Feeds

Leverage threat intelligence feeds to stay

updated on the latest ransomware variants, their associated indicators, and attack patterns. This information can enhance the accuracy and efficacy of analysis efforts [14].

4.5 Network and Endpoint Monitoring

Implement robust network and endpoint monitoring solutions to detect and respond to ransomware activities promptly. Early detection can mitigate the impact of an attack and aid in subsequent analysis [15].

4.6 Regular Backup and Recovery

Establish a good backup strategy to regularly recover important data, enabling rapid recovery in the event of a ransomware attack. This practice minimizes the potential impact of ransomware on data integrity[16].

4.7 Security Awareness and Training

Provide security awareness and regular training to educate employees about ransomware threats, phishing techniques, and security practices. This will help create a safe environment [17].

4.8 Incident Response Planning

Have an incident response plan that outlines the steps to take in the event of a ransomware incident. This allows for quick coordination to resolve the issue and facilitates follow-up. [18].

4.9 Reverse Engineering and Code Analysis

Utilize reverse engineering and code analysis techniques to dissect ransomware samples, understand their underlying functionalities, and identify vulnerabilities that can be exploited for analysis and mitigation [19].

4.10 *Continuous Learning and Research*

Stay abreast of the latest advancements in ransomware analysis techniques and actively participate in ongoing research and knowledge sharing forums. Continuous learning ensures analysts remain equipped to tackle emerging ransomware challenges [20].

5 Static Analysis Techniques For Ransomware Analysis

Over the last few years, malware has continued to evolve in terms of the complexity of malware cloaking and the variety of attack vectors [21]. Ransomware is one of the biggest and fastest growing threats facing the digital world [22]. Ransomware usually works by locking a desktop computer or accessing, overwriting, or deleting the user's data to prevent the user from accessing the computer [23]. To counter changing cyber threats, security researchers and analysts are turning to static analysis techniques as a powerful tool for ransomware detection and analysis. Static testing is the process of analysing program code without running the code. We analysed the ransomware samples using the PEView program and the PE parser. PEFile analysis is an essential part of static analysis [24]. This can be done by disassembling the malware code, examining the file header, and searching for strings and other indicators of malicious activity. Static analysis is the analysis of code that is not executed at write time. [25]. Static analysis can be used to identify ransomware characteristics, such as:

a) The use of encryption algorithms to encrypt victim files.

b) The presence of ransom demands.

c) The use of remote command execution to communicate with the attacker.

d) The use of obfuscation techniques to make the malware more difficult to analyze.

We will explore static analysis techniques for ransomware analysis: file and code analysis methods, signature-based detection, code deobfuscation and unpacking techniques, and malicious document analysis and exploit detection.

6 File And Code Analysis Methods To Identify Ransomware Characteristics

Static analysis involves the examination of files and code without executing them. This technique allows analysts to uncover vital insights about ransomware and its underlying characteristics. By scrutinizing file headers, metadata, and code structure, researchers can identify suspicious activities such as file encryption routines, command and control communication, or attempts to modify system settings. Analyzing ransomware behavior patterns is crucial for building detection mechanisms and developing effective mitigation strategies. This can be done using a tool **file**, which will display the file type and other characteristics of the file. For example, the following output from the **file** command shows that the file **ransomware.exe** is a Windows executable file:

$ file ransomware.exeransomware.exe: PE32 executable for MS Windows (GUI) Intel 80386, for MS Windows

Once the file type has been identified, the next step is to disassemble the malware code. This can be done using a tool like IDA Pro, which will display the assembly code for the malware. The assembly code can be used to identify ransomware characteristics, such as the use of encryption algorithms, the presence of ransom demands, and the use of remote command execution.

7 Signature-based Detection And Pattern Matching

Ransomware can also be detected using signature-based detection and pattern matching. Signature-based detection relies on predefined patterns or signatures to identify known ransomware variants. Analysts create signatures based on unique characteristics or behaviors exhibited by specific ransomware families. These signatures are then matched against files or code samples to detect potential infections. Commercial antivirus scanners often look for signatures, which are sequences of bytes in the malware code, declaring that the scanned program is malicious. There are three types of malware: simple malware, polymorphic malware, and metamorphic malware. In simple malware, the program's entry points are changed to transfer control to the malicious payload. Diagnosis is relative if the signature of the virus code is visible[26]. While signature-based detection is effective against known ransomware strains, it may struggle with new or modified variants. Continuous updates and expansion of signature databases are necessary to combat emerging threats effectively. Pattern matching techniques analyze the structure, behavior, and code of ransomware samples to identify common patterns or characteristics associated with specific ransomware families. YARA is

an efficient and optimized tool for pattern matching . Signature-based detection and pattern matching are both effective methods for detecting ransomware. However, they canbe defeated by ransomware authors who use obfuscation techniques to make their malware more difficult to analyze [26].

8 Unpacking Techniques

Ransomware authors often employ obfuscation and packing techniques to evade detection and analysis. Obfuscation hides information so others cannot find the true meaning. Software vendors use obfuscation techniques to make software harder to reverse. Malware is better to write this down and uses many modifications to confuse malicious programs, making it difficult to reverse engineer the malware so that it cannot recognize its malicious intent [27].

Unpacking, on the other hand, refers to the process of extracting and reconstructing the original code from its packed form. Code deobfuscation is a technique for reversing the effects of obfuscation. This can be done using a variety of tools and techniques, including manual deobfuscation, automated deobfuscation tools, and dynamic analysis. Static analysis techniques include identifying and deobfuscating these code transformations, allowing researchers to gain insight into the ransomware's inner workings, encryption algorithms, and communication protocols. Deobfuscation improves when static and dynamic analyses are combined [28].

9 Malicious Document Analysis And Exploit Detection

Portable Document Format (PDF) is one of the most popular file formats for data exchange. The origin of the PDF format has made PDF files the primary vector for malware distribution, as the targets of attackers have recently changed from server-side attacks to client-side attacks [29]. Basically, the corrupt PDF file can be thought of as the reincarnation of the macro virus that infected Microsoft Office and other products from the mid-1990s to the early 2000s [30]. Static analysis techniques play a vital role in analyzing these documents to detect potential exploits or malicious macros. By dissecting the document's structure, examining embedded objects, and analyzing script or macro code, analysts can uncover the ransomware's delivery mechanisms, payloads, and potential vulnerabilities that attackers exploit. After reading the input data, MDScan analyzes its structure and removes all recognized objects placed in hierarchies. The complexity and ambiguity of the PDF specification makes this process a daunting task. Also, most PDF viewers (like Adobe Reader) even try to render the document incorrectly and often do not conform to the PDF specification. This gives attackers more room to compromise data analysis, and they can use this complexity to uncover patterns of malicious PDF files. Exploit detection is a technique for identifying malicious documents that contain embedded macros or scripts that can be executed when the document is opened. Exploit detection can be done using a variety of tools and techniques, including signature-based detection, pattern matching, and dynamic analysis [31].

10 Dynamic Analysis Techniques For Ransomware Analysis

Ransomware analysis is essential for investigating ransomware attacks and understanding the actions and behavior of malicious campaigns. It includes three main categories: static analysis, dynamic analysis, and hybrid analysis. The analysis seems to focus on analyzing the ransomware's code and features without success. Dynamic analysis involves running the ransomware in a controlled environment to monitor its behavior in a timely manner. Hybrid analysis combines static and dynamic analysis techniques. Dynamic analysis is a great way to achieve success by writing bad code. Malicious code written in a controlled environment and exposed to features captured by the controlled environment [32,33].

A system called EldeRan uses dynamic analysis to monitor what the application is doing. It captures API calls and strings at runtime to monitor the malicious behavior of ransomware applications. Applications are monitored during installation to identify ransomware signatures [34].

11 Research On Dynamic Analysis Of Ransomware Using Machine Learning

The system aims to perform an in-depth analysis by recording system calls. Introduce optimization techniques to minimize API calls and train machine learning classes on data to optimize system calls [35].

A multi-layered ransomware detection system based on machine learning works in three phases: identification, learning, and discovery. Perform behavioral analysis to identify unknown ransomware variants [36].

Build a real-time ransomware detection system integrated with the Integrated Clinical Environment (ICE) to protect a hospital network. The system detected and isolated victim devices to prevent the spread of the attack [37].

12 Conclusion

It is concluded that ransomware analysis faces different challenges due to its tactics and challenging nature employed by cyber criminals. The key challenges are evasion techniques, advanced encryption, dynamic behavior, zero-day exploits, anti-analysis mechanism and most importantly lack of resources to follow up the latest track. Security researchers have been continuously finding out AI solutions, relating with software vendors and produce effective measures against ransomware attacks. Sometimes it is difficult for individuals and organizations to stay vigilant and use robust measures and update their defense to reduce the risk of falling victim to ransomware.

In addition to this, the constantly updation of nature of ransomware requires security researchers to stay updated and work on adaption of latest techniques to fight against new strains strongly. Thus, these new changes require collaboration, continuous research, huge investments and proper planning to stay one step ahead of cyber criminals. Effective Ransomware Analysis is about behavior analysis, combination of segmentation and isolation

skills, reverse engineering and high intelligence. By analyzing these ransomware samples in controlled environments such as sandboxes, virtual machines can prevent malwaring from infecting the systems. Behavior analysis can detect malicious pursuit and alleviate ransomware campaigns.

Furthermore, to apply security measures in organizations prevent them from ransomware attacks. Regular upgradation, backup plan and strong passwords can help the organizations on how to analyze ransomware and reduce its impact. Static analysis techniques serve as a fundamental pillar in the fight against ransomware attacks. By employing file and code analysis methods, signature-based detection, code deobfuscation and unpacking techniques, and malicious document analysis, security analysts can effectively identify ransomware characteristics, detect infections, and understand the underlying mechanisms used by attackers. As ransomware continues to evolve, it is imperative to stay abreast of the latest static analysis techniques and continuously enhance detection mechanisms to mitigate the impact of these malicious threats.

Dynamic analysis techniques are essential for analyzing and understanding the behavior of ransomware. Through sandboxing, behavior monitoring, traffic analysis, memory analysis, dynamic code analysis, and runtime environment analysis, analysts can gain valuable insights into a ransomware's capabilities, evasion techniques, communication patterns, and potential impact on a system. These techniques allow for a comprehensive understanding of the ransomware's functionalities and aid in the development of effective countermeasures and mitigation strategies.

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