A MOBILE BOTNET DETECTION AND RESPONSE MODEL

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AUTHOR DECLARATION

بسم الله الرحمن الرحيم

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A MOBILE BOTNET DETECTION AND RESPONSE MODEL

ABSTRACT

Mobile botnet exploitation in smartphone could implicate to the leakage of sensitive and private information, loss of financial and degradation of smartphone's performance thus affecting organisations or users that rely on smartphones for business and personal activities. Detecting mobile botnet is a challenge for the existing antimalware software which depends on signature-based detection. Nonetheless, existing works on mobile botnet that are mostly focused on the development of detection model have issues on feature selection, detection accuracy rate and its detection model. In addition the existing works also lack on the mobile botnet threat response. Hence, based on the mobile botnet implication and existing gaps in the extant research, the objectives of this research are to construct a new mobile botnet classification using features based on mobile botnet architecture and feature's risk impact, to develop a mobile botnet detection and response model based on the mobile botnet classification, risk level and by applying apoptosis concept and to evaluate the proposed mobile botnet detection and response model based on accuracy rate. The new mobile botnet classification is used for mobile botnet detection whereas, for the response model, apoptosis is triggered to respond to mobile botnet detection and on risk level of mobile application. The experiment was conducted in a controlled lab environment, using static and dynamic analyses and by applying knowledge discovery procedure (KDD). 1500 mobile botnet samples from University of New Brunswick (UNB) dataset and 1000 benign samples from Google Play Store are used for training whereas 600 mobile botnet samples from Drebin dataset and another 400 benign samples from Google Play Store are used for testing. From the experiment, the proposed model has produced 98.8% detection accuracy rate and 2% false alarm rate. This result outperformed the existing work of ABIS by 6% and 5% improvement in true positive rate and detection accuracy rate respectively. Furthermore, the proposed model is also able to countermeasure the mobile botnet threat using apoptosis mechanism that triggered by application's risk level. Based on the evaluation, the result indicated significant improvement compared to other research findings, thus, fulfilling the abovementioned research gaps. As a conclusion, this research has produced a new model, which can detect and respond to mobile botnet threat effectively. For future work, this research can be used as a reference for the other researchers with the same interest.

Keywords: Mobile Botnet, Classification, Detection, Response, Apoptosis, Risk Level

ABSTRAK

Exploitasi botnet mudah alih dalam telefon pintar menyebabkan kebocoran maklumat sensitif dan peribadi, kehilangan kewangan dan kemerosotan sistem telefon pintar dan memberi kesan kepada organisasi atau pengguna yang bergantung pada telefon pintar untuk urusan perniagaan dan peribadi. Pengesanan botnet mudah alih merupakan satu cabaran untuk perisian antimalware sedia ada yang bergantung kepada pengesanan berasaskan 'signature'. Tambahan pula penyelidikan sedia ada terhadap botnet mudah alih yang kebanyakannya tertumpu kepada pembangunan model pengesanan dan mempunyai isu-isu terhadap pemilihan ciri, kadar ketepatan pengesanan dan model pengesanannya. Di samping itu, penyelidikan sedia ada juga tidak mempunyai tindakbalas terhadap ancaman botnet mudah alih. Oleh itu, berdasarkan implikasi botnet mudah alih dan jurang dalam penyelidikan yang sedia ada, objektif kajian ini adalah: (i) untuk membina klasifikasi botnet mudah alih baru menggunakan ciri-ciri berdasarkan senibina botnet mudah alih dan kesan risiko ciri, (ii) untuk membangunkan pengesan botnet mudah alih dan model tindak balas berdasarkan klasifikasi botnet mudah alih, tahap risiko dan dengan menggunakan konsep apoptosis dan (iii) untuk menilai model pengesanan dan tindak balas botnet mudah alih yang dicadangkan berdasarkan kadar ketepatan. Klasifikasi botnet mudah alih yang baharu digunakan untuk pengesanan botnet mudah alih manakala untuk model respons, apoptosis dipicu untuk bertindak balas terhadap pengesanan botnet mudah alih dan pada tahap risiko aplikasi mudah alih. Eksperimen ini dijalankan di persekitaran makmal terkawal, menggunakan analisis statik dan dinamik dan dengan menggunakan prosedur penemuan pengetahuan (KDD). 1500 sampel botnet mudah alih dari dataset University of New Brunswick (UNB) dan 1000 sampel aplikasi dari Google Play Store digunakan untuk latihan manakala 600 sampel botnet mudah alih dari dataset Drebin dan 400 sampel aplikasi dari Google Play Store digunakan untuk pengujian. Berdasarkan ekperimen yang dijalankan, model yang dicadangkan telah menghasilkan 98.8% kadar ketepatan pengesanan dan 2% kadar penggera palsu. Keputusan ini mengatasi prestasi kerja ABIS sebanyak 6% dan peningkatan 5% dalam kadar positif sebenar dan kadar ketepatan pengesanan. Selain itu, model yang dicadangkan juga dapat memberi respons terhadap ancaman botnet mudah alih, yang dicetuskan oleh tahap risiko dan bertindak balas melalui mekanisme apoptosis. Berdasarkan penilaian, kajian yang dilakukan ini menunjukkan peningkatan yang ketara berbanding dengan penemuan penyelidikan lain, dan memenuhi jurang penyelidikan yang dinyatakan di atas. Sebagai kesimpulan, kajian ini telah menghasilkan model baharu, yang dapat mengesan dan bertindak balas terhadap ancaman botnet mudah alih dengan berkesan. Untuk kerja masa depan, penyelidikan ini boleh digunakan sebagai rujukan kepada penyelidik lain dalam minat yang sama.

Kata Kunci: Botnet, Klasifikasi, Pengesanan, Tindakbalas, Apoptosis, Tahap Risiko

الملخص

ان تسخير شبكة الروبوت (بوتنت) المتنقلة في الهواتف الذكية له تأثير على تسرب المعلومات الحساسة والخاصة, وفقدان وإنحطاط أداء الهواتف الذكية وبالتالي يؤثر على أداء المؤسسات أوالمستخدمين للأجهزة الذكية في الأنشطة التجارية والأنشطة الشخصية. أكتشاف شبكة البوتنت المتنقلة يعتبر تحدي بالنسبة لبرامج الحماية التي تستخدم طريقة قاعدة التوقيع للكشف عنها. ومع ذالك, فإن الأبحاث الحالية على البوتنت المتنقل والتي في الغالب تركز على تطوير نموذج إكتشاف تعتمد على مبادء الإكتشاف المستقبلي وإكتشاف معدل الدقة. بالإضافة إلى ذلك, الأبحاث الحالية أيضا ينقصها دراسة ردة الفعل عند حدوث خطر من شبكة البوتنت المتنقلة. بالتالي, بناءا على تأثيرات شبكة البوتنت المتنقلة والفجوة في البحوث الحالية, هذا البحث سيدرس الأهداف التالية. إنشاء تصنيف جديد لشبكات البوتنت المتنقلة بإستخدام قاعدة المستقبل على بناء شبكة البوتنت المتنقلة وخاصية تأثير المخاطر. تطوير نموذج يشمل إكتشاف وردة الفعل لشبكة البوتنت المتنقلة بناءا على تصنيف شبكة البوتنت, مستوى الخطر, وايضا استخدام مفهوم أبوبتوسيس. وأخيرا تقييم النموذج المقترح بمقارنته بنموذج معدل الدقة. التصنيف المقترح لشبكة البوتنت المتنقلة تم إستخدامه لإكتشاف البوتنت المتنقلة, في حين لنموذج ردة الفعل تم استخدام أبوبتوسيس لشن ردة الفعل على شبكة البوتنت المتنقلة المكتشفه وعلى مستوى الخطر للتطبيق. التجربة العملية أجريت في بيئة مختبر بإستخدام نماذج تحليل ثابتة ومتغيرة و ايضا بتطبيق إجراء كشف المعرفة. لإجراء التجربة تم استخدام 1500 عينة من شبكة البوتنت المتنقلة من جامعة نيو برونسك و 1000 عينة من جوجل بلاي ستور استخدمت للتدريب وايضا 600 عينة من دربين و 400 عينة من جوجل بلاي ستور استخدمت للفحص.من التجربة، أنتج النموذج المقترح 98.8٪ معدل دقة الكشف و 2٪ معدل إنذار كاذب. تفوقت هذه النتيجة على عمل الحالي بنسبة 6 ٪ و 5 ٪ أفضلية على طريقة المعدل إالإيجابي وكذلك طريقة دقة المعدل. علاوة على ذلك, النموذج المقترح قادر على قياس خطر شبكة البوتنت المتنقلة باستخدام آلية أبوبتوسيس التي تشن بإستخدام برنامج مستوى المخاطر. بناءً على التقييم ، أشارت النتيجة إلى تحسن كبير مقارنةً بنتائج البحوث الأخرى ، وبالتالي ، سد ثغرات البحث المذكورة أعلاه.كإستنتاج ، أنتج هذا البحث نموذجًا جديدًا ، يمكنه اكتشاف تهديد شبكة البوتنت المتنقلة بشكل فعال. بالنسبة للعمل في المستقبل ، يمكن استخدام هذا البحث كمرجع للباحثين الآخرين بنفس الاهتمام.

الكلمات المفتاحية: شبكة البوتنت المتنقل، التصنيف، الكشف، ردة الفعل، أبوبتوسيس، مستوى الخطر.

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ABBREVIATION

ABDA	Android Botnet Detection and Response Application
API	Application Programming Interface
C&C	Command and Control
DDoS	Distributed Denial of Service
DVM	Dalvik Virtual Machine
FAR	False Alarm Rate
FNR	False Negative Rate
FPR	False Positive Rate
GPS	Global Positioning System
HIS	Human Immune System
IDS	Intrusion Detection System
KDD	Knowledge Discovery in Databases
NIST	National Institute of Standards and Technology
PAMPs	Pathogen Associated Molecular Patterns
PRRs	Pattern Recognition Receptors
SMS	Short Message System
TNR	True Negative Rate
TPR	True Positive Rate
UID	Unique User Identification
UNB	University of New Brunswick

CHAPTER 1: INTRODUCTION

This chapter highlights the background of the research, current research problems, motivation, research questions, research objectives, scope, contributions, thesis structure and summary of this chapter.

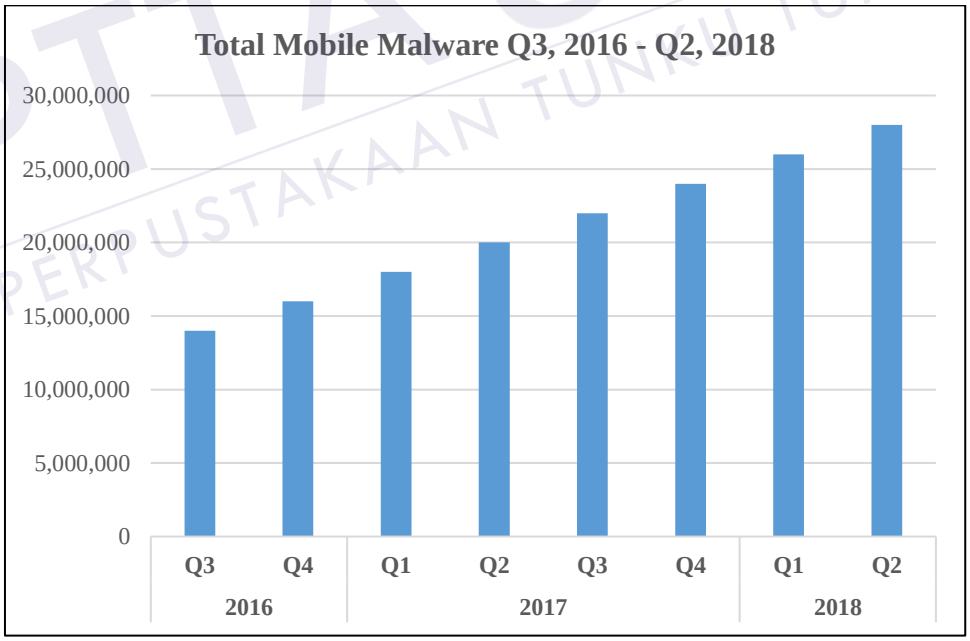
1.1 Background

The number of smartphone users has risen significantly across the globe, due to its multi-functionality capabilities (Li & Clark, 2013; Tong & Yan, 2017; Shezan et al., 2017). Apart from the usual functions of a mobile phone such as making calls or sending text messages, the smartphones also are being used for web browsing, social networking, gaming, business operation and online banking transaction. Smartphone users are also keep confidential information such as bank account number, username and password for online banking, credit card number and private memorabilia in their smartphone. Due to these circumstances, smartphones are recently targeted by the attackers with different way of exploitation such as masquerading as legitimate mobile application (app) and but had embed malwares in it.

Recent report by McAfee Labs, (2018), indicated that mobile malware attacks on smartphone have exponentially growth as presented in Figure 1.1. The attacks came

from different type of malwares such as trojan, ransomware, spyware, virus and mobile botnet (Eslahi et al., 2012; Mylonas et al., 2013; Anwar et al., 2016). Among of these malware, mobile botnet is the most dangerous as it poses serious threat to the smartphone users and the smartphone's system (Zhou & Jiang, 2012; Feizollah et al., 2015; Anwar et al., 2016; Tansettanakorn et al., 2016). A main difference between mobile botnet and other mobile malware is the utilization of Command and Control (C&C) infrastructure. The C&C allows mobile botnet to receive commands from botmaster; an attacker who operates and controls the mobile botnet remotely. Once a smartphone is installed and infected with mobile botnet application, the attacker will have superior access and control over the compromised smartphone.

Figure 1.1: Total Mobile Malware from Q3, 2016 to Q2, 2018 (McAfee Labs, 2018)



For this research, mobile botnet is defined as a malicious application that infected smartphone without user consent or knowledge. Once infected by mobile botnet, the smartphone can be controlled by an attacker called a botmaster via exploitation of

application features that are permission, API call and system call. The botmaster will then be able to manipulate the compromised smartphones to commit cyber-crimes or -attacks, which includes spam messages, premium text messaging services subscription, identity theft scams, degrade smartphone and phishing scams which implying to invasion of privacy (Wang et al., 2016; Chen et al., 2017), financial loss (Etaher et al., 2015; Shezan et al., 2017) and degradation of smartphone system performance (Hsieh et al., 2015; Rodriguez-Mota et al., 2016). These implications could lead to a breach of confidentiality, integrity and availability which are critical principles in information security. Table 1.1 presents the implication, malicious activity, threat and security breach of the mobile botnet on a smartphone.

Table 1.1: Implication, Malicious Activity, Threat and Security Breach of Mobile Botnet Attack on Smartphone.

Implication	Malicious Activity	Threat	Security Breach
Privacy	Expose user location Read phone detail & specification Read contact list Read message	Privacy exposed Leakage of sensitive information	Confidentiality
Financial	Subscribing to premium number Pay-per-phone service Sending unauthorized message via Short Message System (SMS)	Loss of financial Overbilling	Integrity
System	Battery Drainage Wi-Fi Scanning GPS Excessive Scanning Abusive Advertising	Smartphone system malfunction Smartphone system slowdown	Availability

These critical security implications possess by mobile botnet have promoted a strong research interest among security researchers in developing mobile botnet detection models that are able to detect mobile botnet in smartphone. However, most of the models have certain shortcomings, which includes model complexity to be implemented into smartphones and low detection accuracy rate. This research, on the other hand, looked into developing detection model with better detection accuracy rate to rectify the abovementioned shortcomings. Furthermore, the existing mobile botnet detection models also lack the response mechanism to mobile botnet threat once it has been detected. Therefore, an apoptosis concept was also applied in this research as a solution to the response mechanism.

Apoptosis is one of the specialisms in Human Immune System (HIS) and is known as cell- programmed death (Sridevi & Jagajothi, 2014). For this research, the concept of apoptosis which is the ability of human body to eliminate intruder's threat such as virus in human body is being adapted and applied for mobile botnet detection and response model. . However, there are two challenges which need to be addressed. Firstly, how to differentiate between benign and mobile botnet for detection and response? Secondly, how to trigger detection and response mechanism against mobile botnet? This research had successfully solved this challenges by constructing new mobile botnet classification for mobile botnet detection and assessment of risk level based on security metrics to trigger the apoptosis response mechanism. Indeed, mobile botnet detection and apoptosis response algorithms have been developed to solve the challenges.

The discussed issues above and challenges have been the main motivation of this research with the aim to improve mobile botnet detection accuracy rate and response by proposing a new mobile botnet detection in smartphone with applicable response model.

1.2 Problem Statement

Numerous methods have been proposed to counteract a mobile botnet threat due to their devastating consequences on smartphone users and smartphone system. One of the methods is signature-based detection in which implemented by most antimalware vendors (Feizollah et al., 2015; Sharma & Sahay, 2016; Sun, 2016). Signature-based detection is a method where a unique identifier for a known mobile botnet is established so that the botnet can be identified in the future. The signature can be a unique pattern of code that attached to smartphone application or can be the hash algorithms of a known bad application. If that specific pattern or signature is discovered in mobile application, the application can be flagged as being malicious. However, the drawback of this method is, the signature needs to be updated regularly. Falling to update the signature will expose smartphone users from new or unknown mobile botnet attacks. Unfortunately, it has been proven that the speed at which mobile botnets are created is substantially greater than the rate at which signature updates can be carried out (Chang & Wang, 2016). Furthermore, the mobile botnet signature is unique for a single mobile botnet, thus, simple modification in a mobile botnet code leads to a new variant and could bypass the signature-based detection.

On the hand, other existing works, have integrated machine learning with mobile botnet detection method. This method is capable of detecting anomalies with few challenges for implementation. The first challenge is related to smartphone resource constraint, while the second challenge is on feature selection. According to Mostafa et al., (2015); Sun et al., (2017) and Ali et al., (2017), the use of machine learning algorithm in mobile botnet detection models is ineffective as smartphone has limited computational power, storage and battery life. In addition, Khune & Thangakumar, (2012) and J. Milosevic et al., (2017) have indicated that the machine learning algorithms integrated detection models are highly complex and resource consuming when executed on smartphone. As a result, they could not be deployed on smartphone. Hence, these existing models are only executable in smartphone-simulation environment or computer server for the mobile botnet detection. Therefore, a solution for mobile botnet detection is required for implementation in a smartphone.

Basically, feature is an attribute extracted from mobile application and used in machine learning to classify and detect an application whether it is a mobile botnet or benign application. The features consist of numerous elements such as requested permissions, application programming interface (API) calls, strings, operation codes, system calls and network traffics (Feizollah et al., 2015; Baskaran & Ralescu, 2016; da Costa et al., 2017; Chen et al., 2018). However, not all the features are relevant for mobile botnet classification and detection. The used of irrelevant features might present problems such as increasing machine learning model complexity and reduce detection accuracy rate (Vajdi et al., 2016; Fereidooni et al., 2016; Arora & Peddoju, 2017). Karim et al., (2015) and da Costa et al., (2017) have stressed out that selecting significant features which characterized mobile botnet is very important in mobile botnet detection model. This

helps to reduce the selection of irrelevant features. Therefore, in this research, a new feature selection for mobile botnet classification is proposed. The selection of features is based on mobile botnet architecture and feature's risk impact to reduce selection of irrelevant features and for optimal mobile botnet detection's accuracy.

Finally, most existing mobile botnet detection models that have being proposed are not accompanied with applicable have response mechanism towards mobile botnet threat. This is because the existing research mainly focused on feature selection for mobile botnet classification and detection. Undoubtedly, joining in a response mechanism with mobile botnet detection is essential in order to quickly terminate the mobile botnet threat and restore a smartphone back to its safe operational mode.

Therefore, based on the implications of mobile botnet threat and gaps in existing research, it is utmost importance to develop a new mobile botnet detection and response model. Mobile botnet detection and response are crucial in protecting a smartphone user and functionality of the smartphone against privacy, financial and system invasions by mobile botnet. These include the reducing of irrelevant features for mobile botnet classification and the development of high accuracy mobile botnet detection and applicable response model for smartphone.

1.3 Research Questions

This research attempts to answer the following research questions in order to challenge the previously mentioned problems:

1) What are the features that should be selected to construct new mobile botnet classification?
2) How a new mobile botnet classification can differentiate benign application and mobile botnet application?
3) How to trigger detection and response mechanism against mobile botnet threat?

1.4 Research Objectives

The main objectives for this research are as follow:

1) To construct a new mobile botnet classification using features based on mobile botnet architecture and feature's risk impact.
2) To develop mobile botnet detection and response model based on the mobile botnet classification, risk level and by applying apoptosis concept.
3) To evaluate the proposed mobile botnet detection and response model based on accuracy rate.

The objectives of this research have been mapped with research outcome as presented in Figure 1.2.

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