Current Challenges in Intrusion Detection Systems

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INTRODUCTION

Along with its numerous benefits, the Internet also created numerous ways to compromise the security and stability of the systems connected to it. In 1995, 171 vulnerabilities were reported to CERT/CC © while in 2003, there were 3,784 reported vulnerabilities, increasing to 8,064 in 2006 (CERT/CC©, 2006). Operations, which are primarily designed to protect the availability, confidentiality, and integrity of critical network information systems are considered to be within the scope of security management. Security management operations protect computer networks against denial-of-service attacks, unauthorized disclosure of information, and the modification or destruction of data. Moreover, the automated detection and immediate reporting of these events are required in order to provide the basis for a timely response to attacks (Bass, 2000). Security management plays an important, albeit often neglected, role in network management tasks.

Defensive operations can be categorized in two groups: static and dynamic. Static defense mechanisms are analogous to the fences around the premises of a building. In other words, static defensive operations are intended to provide barriers to attacks. Keeping operating systems and other software up-to-date and deploying firewalls at entry points are examples of static defense solutions. Frequent software updates can remove the software vulnerabilities, which are susceptible to exploits. Firewalls provide access control at the entry point; they therefore function in much the same way as a physical gate on a house. In other words, the objective of a firewall is to keep intruders out rather than catching them. Static defense mechanisms are the first line of defense, they are relatively easy to deploy and provide significant defense improvement compared to the initial unguarded state of the computer network. Moreover, they act as the foundation for more sophisticated defense mechanisms.

No system is totally foolproof. It is safe to assume that intruders are always one step ahead in finding security holes in current systems. This calls attention to the need for dynamic defenses. Dynamic defense mechanisms are analogous to burglar alarms, which monitor the premises to find evidence of break-ins. Built upon static defense mechanisms, dynamic defense operations aim to catch the attacks and log information about the incidents such as source and nature of the attack. Therefore, dynamic defense operations accompany the static defense operations to provide comprehensive information about the state of the computer networks and connected systems.

Intrusion detection systems are examples of dynamic defense mechanisms. An intrusion detection system (IDS) is a combination of software and hardware, which collects and analyzes data collected from networks and the connected systems to determine if there is an attack (Allen, Christie, Fithen, McHugh, Pickel, & Stoner, 1999). Intrusion detection systems complement static defense mechanisms by double-checking firewalls for configuration errors, and then catching the attacks that firewalls let in or never perceive (such as insider attacks). IDSs are generally analyzed from two aspects:

- **IDS deployment:** Whether to monitor incoming traffic or host information.
- **Detection methodologies:** Whether to employ the signatures of known attacks or to employ the models of normal behavior.

Regardless of the aspects above, intrusion detection systems correspond to today's dynamic defense mechanisms. Although they are not flawless, current intrusion detection systems are an essential part of the formulation of an entire defense policy.

DETECTION METHODOLOGIES

Different detection methodologies can be employed to search for the evidence of attacks. Two major categories exist as detection methodologies: misuse and anomaly detection. Misuse detection systems rely on the definitions of misuse patterns, which are the descriptions of attacks or unauthorized actions (Kemmerer & Vigna, 2002). A misuse pattern should summarize the distinctive features of an attack and is often called the signature of the attack in question. In the case of signature based IDS, when a signature appears on the resource monitored, the IDS records the relevant information about the incident in a log file. Signature-based systems are the most common examples of misuse detection systems. In terms of advantages, signature-based systems, by definition, are very accurate at detecting known attacks, which are included in their signature database. Moreover, since signatures are associated with specific misuse behavior, it is easy to determine the attack type. On the other hand, their detection capabilities are limited to those within signature database. As the new attacks are discovered, a signature database requires continuous updating to include the new attack signatures, resulting in potential scalability problems. Furthermore, attackers are known to alter their exploits to evade signatures. Work by Vigna, Robertson, Balzarotti (2004) described a methodology to generate variations of an exploit to test the quality of detection signatures. Stochastic modification of code was employed to generate variants of exploits to render the attack undetectable. Techniques such as packet splitting, evasion, and polymorphic shellcode were discussed.

As opposed to misuse IDSs, anomaly detection systems utilize models of the acceptable behavior of the users. These models are also referred to as normal behavior models. Anomaly-based IDSs search for the deviations from the normal behavior. Deviations from the normal behavior are considered as anomalies or attacks. As an advantage over signature-based systems, anomaly-based systems can detect known and unknown (i.e., new) attacks as long as the attack behavior deviates sufficiently from the normal behavior. However, if the attack is similar to the normal behavior, it may not be detected. Moreover, it is difficult to associate deviations with specific attacks since the anomaly-based IDSs only utilize models of normal behavior. As the users change their behavior as a result of additional service or hardware, even the normal activities of a user may start raising alarms. In that case, models of normal behavior should be redefined to maintain the effectiveness of the anomaly-based IDS. Similar to the case of misuse IDSs, attackers are known to alter their exploits to be recognized as normal behavior by the detector, hence evading detection. The general approach employed for evading anomaly detectors is based on the generation of mimicry attacks to perform evasion. A mimicry attack is an exploit that exhibits legitimate normal behavior while performing malicious actions. Methodologies exist to create mimicry attack automatically (Giffin, Jha, & Miller, 2006; Kayacik, Zincir-Heywood, & Heywood, 2007) or manually (Kruegel, Kirda, Mutz, 2005; Tan, Killourhy, & Maxion, 2002; Wagner & Soto, 2002).

In today's intrusion detection systems, human input is essential to maintain the accuracy of the system. In the case of signature-based systems, as new attacks are discovered, security experts examine the attacks to create corresponding detection signatures. In the case of anomaly systems, experts are needed to define the normal behavior. Therefore, regardless of the detection methodology, frequent maintenance is essential to uphold the performance of the IDS.

Given the importance of IDSs, it is imperative to test them to determine their performance and eliminate their weaknesses. For this purpose, researchers conduct tests on standard benchmarks (Kayacik & Zincir-Heywood, 2003; Pickering, 2002). When measuring the performance of intrusion detection systems, the detection and false positive rates are used to summarize different characteristics of classification accuracy. In simple terms, false positives (or false alarms) are the alarms generated by a nonexistent attack. For instance, if an IDS raises alarms for the legitimate activity of a user, these log entries are false alarms. On the other hand, detection rate is the number of correctly identified attacks over all attack instances, where correct identification implies the attack is detected by its distinctive features. An intrusion detection system becomes more accurate as it detects more attacks and raises fewer false alarms.

IDS DEPLOYMENT STRATEGIES

In addition to the detection methodologies, data is collected from two main sources: traffic passing through