EVALUATION OF THE INTRUSION DETECTION CAPABILITIES AND PERFORMANCE OF A SECURITY OPERATION CENTER

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Abstract: Detecting all kinds of intrusions efficiently requires a global view of the monitored network. We have developed a security operation center which is able to detect coordinated attacks that are not detected by traditional IDS. In this article, we present several methods used to test the accuracy and the performance of our security operation center. A real ISP network have been used as well as experiments in our lab.

1 INTRODUCTION

Ensuring network security requires two modules: protection and supervision. Protection is composed of hardware, software and a security policy that must be followed. Even the best protection is always vulnerable to attacks due to unknown security bugs. Besides, the network configuration is subject to constant changes and possibly adds security holes. That is why the network supervision is an essential part of the security process and is realized by security experts.
In order to help the supervisors, Intrusion Detection Systems (IDS) have been developed (Anderson, 1980), but these systems have several flaws. First of all, IDSs have an insufficient rate of detection: either too many intrusions are detected or missed (Cuppens, 2001). Furthermore, simple IDSs have no sufficient information to detect coordinated attacks. Other types of IDS have been created and tested like distributed one (Neumann and Porras, 1999). Cooperation of IDSs is still ongoing work (Yu et al., 2005).
We have proposed a completely integrated Security Operation Center (SOC), called SOCBox[1], in order to overcome the limitations of IDS. The SOCBox gathers data from a wide range of sources (IDS, firewall, router, workstation, etc.) and therefore has a global view of the network. Its analysis engine can then correlate all messages generated by all the network components and find patterns of intrusion. For more details about the SOCBox please see (Bidou et al., 2003).
To measure the detection capabilities and performance of the SOCBox, an evaluation has been performed with Snort 2.4.3 (Snort, 2005) as a baseline. This evaluation has taken place in two different but complementary environments: a real Internet Service Provider network and our laboratory.

The rest of the paper is structured as follows: Section 2 designs the global architecture of the SOCBox. In Section 3, we focus on the SOCBox evaluation and we provide details about the experimentation. Section 4 presents some work related to intrusion detection system evaluations. Section 5 summarizes the main results and presents our conclusions.

2 THE SOCBOX GLOBAL ARCHITECTURE

The SOCBox implements the different box types defined for network intrusion detection system (Northcutt and Novak, 2002). However, beside the pure technical aspects involved in such implementation, it is necessary to consider the supervision of an IT infrastructure as a full operational project. We will thus follow the functional steps of such a project in order to describe both the purpose and the concepts of selected parts of the architecture described in Figure 1.

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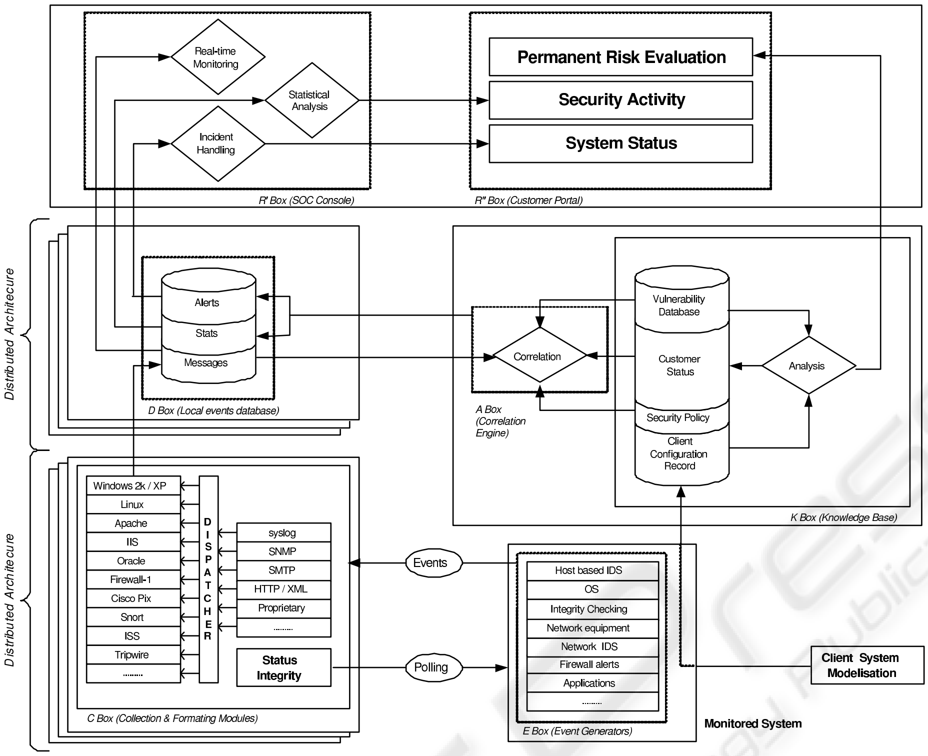


Figure 1: Global architecture of the SOCBox.

2.1 Data Acquisition

Before setting up sensors and designing any correlation or analysis rule, it is necessary to evaluate the overall security level of the IT infrastructure to be supervised. This will make it possible to determine if an intrusion path may effectively lead to an intrusion into the target system and the criticality associated with such an intrusion attempt.

Another point to be defined is the security policy, mostly in terms of access rights, permitted operations, etc.

2.1.1 Vulnerability Database

The vulnerability database holds information about security breaches and insecure behavior that would either impact the overall security level or that could be exploited by an attacker in order to perform an intrusion. The database format must make it possible to include three types of vulnerability: structural vulnerability, functional vulnerability and topology-based vulnerability.

2.1.2 Security Policy

The next step of the supervised system inventory is an organizational one and, more specifically, a review of security policy aspects that would impact either event generation and/or the reaction-reporting processes.

It is clear that the two major aspects of security policy that need to be reviewed are authorization and testing/audit procedures. These two aspects will provide information concerning behavior that sensors would detect. Events generated (administrator login, portscans, etc.) will then be marked as matching security policy criteria. Others will be analyzed as possible part of an intrusion attempt. This information is stored in the Knowledge Base.

2.2 Data Analysis

The main operations performed to generate alerts are the following: correlation, structural analysis, intrusion path analysis and behavior analysis. Correlation is a stand-alone operation leading to the creation of contexts in which further analysis will be made, in order to check if they match the characteristics of an intrusion attempt. Structural analysis may be compared to an advanced pattern matching process, used to determine if events stored within a certain context lead to a known intrusion path or to an attack tree (Schneier, 1999). Intrusion path analysis is the next step whose output provides the intrusion attempt detected with information about the exposure of the target system. Then, the behavior analysis integrates elements from the security policy in order to determine if the intrusion attempt is allowed or not. The purpose of such operations is to generate alerts that do not only match the structural path of intrusion (i.e. scan, fingerprinting, exploiting, backdooring and cleaning), but also take care of the security policy defined, as well as the criticality of target systems.

3 EVALUATION

In this section, we evaluate the intrusion detection capabilities of the SOCBox and its performance. The SOCBox evaluation consists in running it in a real ISP network and to verify its capacity to manage events coming from heterogeneous platforms (routers and access servers, hardware and software firewalls, unix and linux servers, windows workstations, web and mail servers, an AAA server and other ISP applications). This test has taken place for a week. After that, some exploits were executed against the network to check the capacity of the SOCBox to detect various classes of intrusions. Then, the ability of the SOCBox to detect distributed intrusions is evaluated. After that, the clarity and the relevance of the SOCBox reports are studied. Finally, performance evaluation take place in comparison with Snort.

3.1 The Evaluation Network Design

The SOCBox is evaluated in a real ISP network (Figure 2) which manages more than 50000 subscribers. This ISP network is composed by a core sub-net and several regional sub-nets.

3.2 Detection Capabilities

3.2.1 Capabilities to Manage Heterogeneous Platform Events

For the SOCBox be able to manage data coming from sensors, it is necessary to install log redirection towards it on sensors. To verify the SOCBox capabilities to manage heterogeneous platform events, we run it in a real situation on a ISP network for a week. This showed multiple attempts at intrusion into the network servers (including the SOCBox), in particular port scans, authentication attempts, brute force attacks, sql attacks, mail relay attempts, etc. These attacks are carried out on sensors running Solaris, Hp ux, Linux, Windows 2000, Cisco IOS, Pix OS and applications such as Bind, Tacacs+, Apache, etc.

3.2.2 Intrusions Detection Capability

In this part, some classes of attacks are launched against some critical sensors and the SOCBox itself. The goal is to verify the intrusion detection capability of the SOCBox. Some of the tests carried out are presented below :

Flood an pollution attacks	Detection	Comment
Flooding the SOCBox with Harpoon (Sommers, 2005) followed by a brute force attack (with THC-Hydra (THC, 2006)) on a Cisco access server (Victim 3).	YES	The SOCBox detects multiple ”authentication failed” against the access server.
Flooding and polluting the SOCBox with a random MAC address generator (Macof (Song, 2001b)) followed by a brute force attack (with THC-Hydra) on a router (Victim 3).	YES	The SOCBox detects the brute force attack on the access server (multiple ”authentication failed”).

Scan and sniff	Detection	Comment
Scanning the network with nmap.	YES	The SOCBox detects the scan (data were collected by the firewall sensor).
Sniffing the network with Dsniff (Song, 2001a).	NO	the SOCBox is unable to detect the attack because it can not sniff on a network.

Fragmentation, insertion and camouflage attack	Detection	Comment
Fragrouter (Ptacek and Newsham, 1998) attack on the backbone router (Victim 5) from a remote host.	YES	The intrusion is detected by the SOCBox.
nmap with DECOY option (source IP camouflage).	YES	the SOCBox detects the attack.

Web attack	Detection	Comment
A Whisker (Puppy, 2003) attack on a web server running Solaris and Apache 2 on the ISP site.	YES	The SOCBox generates ”target identification” alerts.

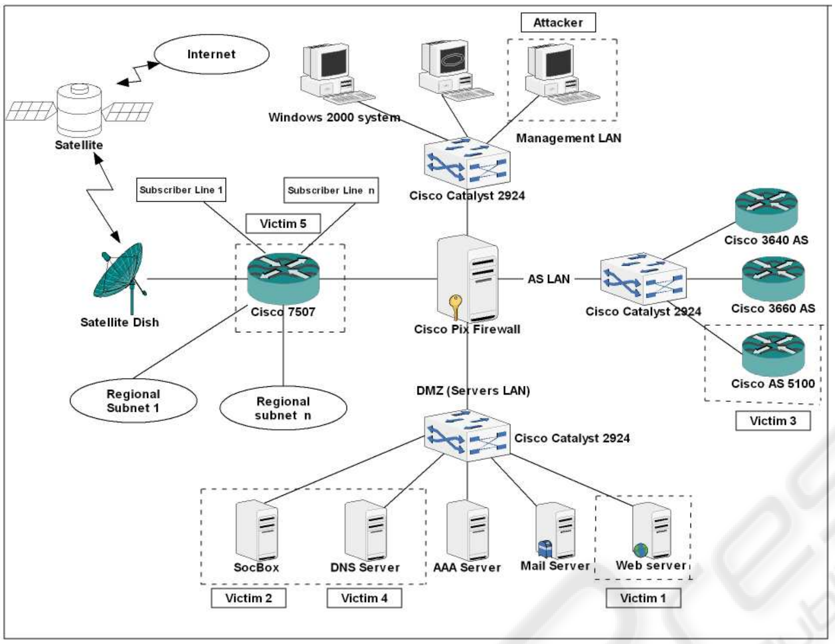


Figure 2: The ISP network used for the SOCBox evaluation.

Attack against filtered ports and services	Detection	Comment
Executing a brute force attack with THC-Hydra on a router (Victim 5) having ssh, telnet, rlogin and rsh filtered.	YES	The intrusion is ignored by the SOCBox because it can never succeed.
Executing a web server attack on the DNS server (Victim 4, which does not run a web server).	YES	The intrusion is ignored by the SOCBox because it can never succeed.

Brute force and password cracking attack	Detection	Comment
Brute force attack against a router with THC-Hydra	YES	The attack is detected.
Attempt to crack password by John the Ripper (Openwall-Project, 2006)	YES	the attack is detected.

Anomaly behavior intrusion detection evaluation	Detection	Comment
Attempt to connection at 9 pm to a windows 2000 server with a username authorized to connect only between 7 am and 8 pm.	YES	The SOCBox generates a "suspicious behavior" alarm.

Multi steps attacks	Detection	Comment
Lpr attack (lpr file1 (big file); rm file1; ln -s /etc/shadow file1)	YES	The intrusion is detected by the SOCBox.

Offline detection capability	Detection	Comment
Replaying in the ISP site the DARPA 2000 (Zissman, 2002) DDOS attack data set with TcpReplay (Aaron and Matt, 2005).	YES	The SOCBox generates alerts about the DDOS attacks.

As we can see, the SOCBox is able to detect various classes of intrusions, suspicious behavior (defined by the security manager) and it can ignore events which generate useless alerts (attacks against non-vulnerable systems). It also appears that the more sensors send their logs to the SOCBox, the better its detection capability is. Online exploits executions and the replay of DARPA 2000 data sets show that the SOCBox can detect online and offline intrusions.
In summary, we can say that the SOCBox has proved its efficiency in detecting intrusions and in presenting the network security status clearly by using graphical representations.

3.2.3 Detection of Distributed Intrusions

The evaluation of the aptitude of the SOCBox for detecting distributed intrusions is described on Figure 3.

The scenario of this attack is the following:
An attacker wants to hack a host (*Victim*) located on the ISP core sub-net and hosting information about subscribers. His idea is to gain access to *Victim* by brute force attack and to steal data about subscribers. *Victim* is secured and can be accessed only from special hosts in the Management LAN and in some regional sub-nets (for maintenance purpose). The attacker tries to compromise *Victim* and unfortunately for him, all his actions are refused. After further thought, he thinks that it would be easier for him to try to hack *Victim* from hosts located on the ISP network. He uses social engineering technique to know the name of the administrators of the ISP core and regional sub-nets; this can help to improve the username database of the brute forte attack tool. After several attempts at intrusion, he compromises three less secured hosts on the ISP network (one in the Management LAN and two in regional sub-nets). From these hosts, he initiates the attack, composed of the following actions:

- From *Attacker 1* located in a regional sub-net, he launches a quick scan (with nmap) to detect opened ports on *Victim*. He sees that ssh and mysql are opened on *Victim*.
- From *Attacker 2* located in the ISP core sub-net, he executes an OS Fingerprinting with Xprobe2. He see that *Victim* runs Solaris 8.
- From *Attacker 3* located in another regional sub-net, he launches a brute force attack (with THC-Hydra) against *Victim* to gain access to the mysql database.

This test shows that the SOCBox can gather events and alerts coming from different sensors (Cisco Pix Firewall sensor detects the quick scan, Snort sensor detects the OS Fingerprinting, and logs of *Victim* permit to detect the brute force attack). Because these events have the same target and they take place approximatively in the same time, the SOCBox matches them with the same context and generates a suspicious behavior alert. An alarm is also sent to the security manager for advanced investigation on *Attacker 1*, *Attacker 2* and *Attacker 3*. Investigation on these hosts shows that Attacker acceded them. Then, the security manager concludes that *Victim* is attacked by Attacker.
Without correlation of alerts, it would be impossible to detect this attack. The SOCBox is thus able to correlate alerts coming from divers sources (firewalls, IDS, hosts, etc.) to generate a single alert.

3.3 Performance Evaluation

At this stage, we check the aptitude of the SOCBox to handle high bandwidth traffic and its ability to detect intrusions when a massive attack occurs. We use D-ITG (Avallone et al., 2004) and IP-Traffic (Zti-Telecom, 2005) to generate traffic in this test. The same tests are apply to Snort for comparison purpose. In spite of the fact that Snort isn't a Soc and the SOCBox isn't an NIDS (the SOCBox is much more than an NIDS because it has a global view of a network security), the comparison between Snort and the SOCBox is justified in this test: Both monitor the security of a unique host and they generate alerts only about attacks on this host.

3.3.1 Evaluation of the SOCBox Maximum Processing Capacity

A victim host (which sends its log to the SOCBox via syslog) is flooded and attacked (Figure 7(a)). Then, we observe the SOCBox behavior. The SOCBox host characteristics are: Pentium III, 450 MHz, 256MB of RAM. The same tests are carried out with Snort installed on a host which have the same characteristics (Figure 7(b)). The tests are summed up in the following tables:

Action	The SOCBox reaction	Snort reaction
Launching a Whisker attack on a victim running Apache.	The SOCBox generates ”Target identification” alerts.	Snort generates ”WEB-MISC whisker” alerts.
Flooding the SOCBox and Snort with 10^6 packets of 10 bytes each second for 15mins followed by a Whisker attack.	The SOCBox runs slowly and it detects the Whisker attack (the SOCBox host uses more than 245 MB of RAM).	Snort detects the Whisker attack and it runs too slowly (around 250 MB of RAM is used).
Flooding the SOCBox and Snort with $1,2 * 10^6$ packets of 10 bytes each second for 15mins followed by a Whisker attack.	The SOCBox detects the Whisker attack (around 250MB of RAM is used by the SOCBox host). It runs slowly.	Snort host has not enough memory to continue (all the memory is used up).
Flooding the SOCBox and Snort with $1,4 * 10^6$ packets of 10 bytes each second for 15mins followed by a Whisker attack.	The SOCBox host has not enough memory.	

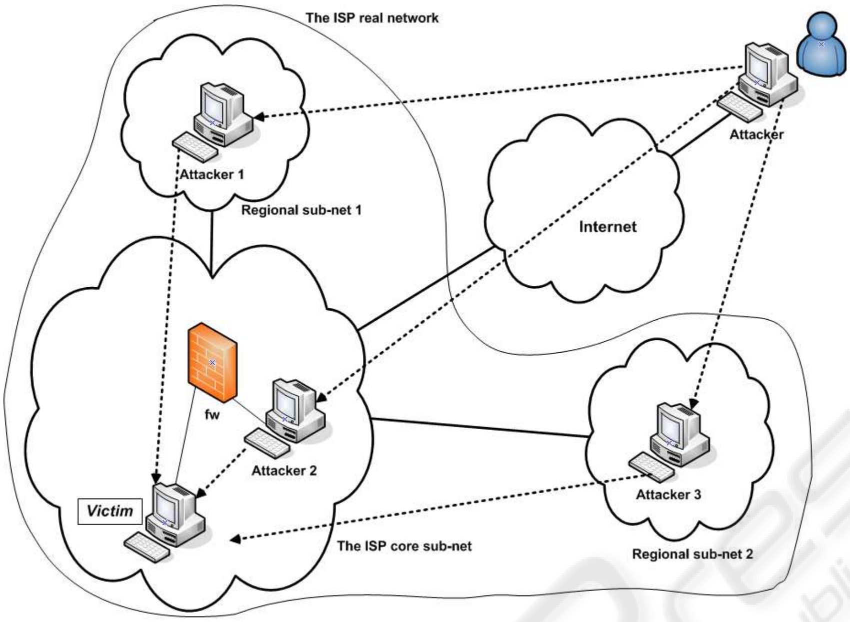


Figure 3: Evaluation of the SOCBox aptitude for detecting distributed intrusions.

After that, ping with large packet flood is carried out against both the SOCBox and Snort, followed by a Whisker attack against the victim host. The goal is to observe the behavior of the SOCBox and Snort under a strong attack. The victim host characteristics are: Pentium III, 450 MHz, 256 MB of RAM.

- *Action*: Sending 20 millions ($2 * 10^7$) Ping with 50000 bytes each one (time between 2 Pings = 0) to the Victim host (via IP-Traffic), followed by a Whisker attack.
- *The SOCBox behavior*: Up to $1,8 * 10^6$ Ping, the SOCBox is able to detect the Whisker attack. At $1,9 * 10^6$ Ping the SOCBox host is broken down and is unable to detect the Whisker attack.
- *Snort behavior*: Snort generates too many alerts about the Ping (10^5 Ping generate 100576 alerts, including 50283 Large ICMP packets detected). At 10^6 Ping, Snort generates 4GB of dumped data and is unable to generate alerts.

3.3.2 Comments

This test shows that the SOCBox is able to detect intrusions under a high traffic or under a massive attack. Under a massive attack the SOCBox uses less resources than Snort and has better performance. It also generates far fewer alerts than Snort and is able to compact similar alerts to generate one only. Moreover, the SOCBox only records events that match security rules defined by the security manager.
The SOCBox and Snort performance, memory usage and hard disk usage during the Ping test are shown on Figures 4, 5 and 6.

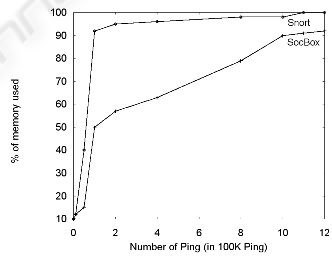


Figure 4: Snort and the SOCBox memory usage during Ping test.

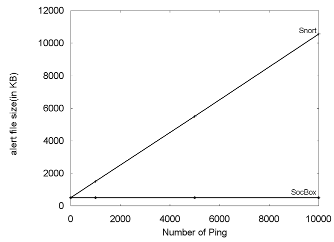
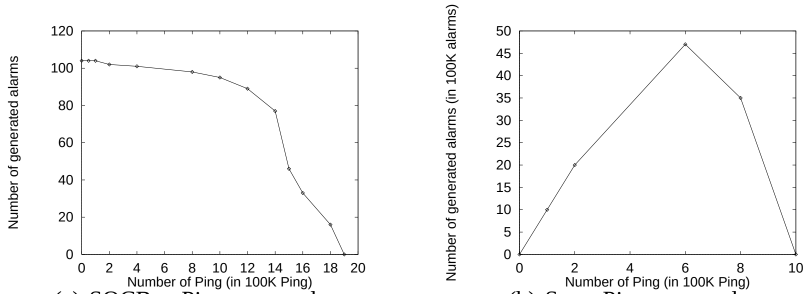
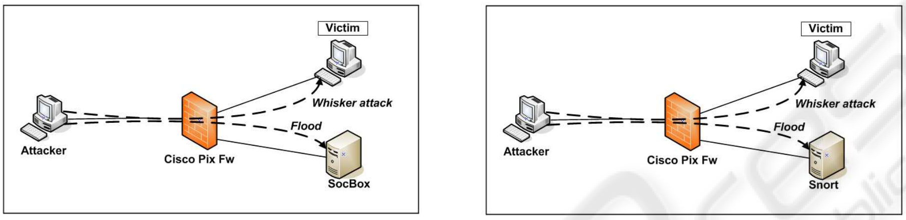


Figure 5: Snort and SOCBox alert file (in KB) during the Ping test.



(a) SOCBox Ping test result (b) Snort Ping test result

Figure 6: The SOCBox and Snort behavior during the Ping test.



(a) The SOCBox performance evaluation (b) Snort performance evaluation

Figure 7: The SOCBox and Snort performance evaluation networks.

4 RELATED WORK

Various papers coming from both academy and industry laboratories and related to intrusion detection system evaluation have been published. Some industrial evaluations are biased because the tests are not always done in an objective way; the behavior of IDSs are adapted to the data sets and some tests are carried out without baseline. In this section, we will present some well-known intrusion detection systems evaluations, coming primarily from academy laboratories.

4.1 Mit Lincoln Labs Evaluation

Sponsored by DARPA in 2000, this evaluation (Lippman et al., 2000) is one of the best-known intrusion detection tests. This evaluation uses a testbed which generates live background traffic containing hundreds of users and thousands of hosts. More than 200 instances of 58 attack types are embedded in 7 weeks' training data and 2 weeks' test data. The goal is to evaluate the efficiency for more than 18 research IDSs to detect unknown attacks without first training on instances of these attacks. Automated attacks are launched against a router and hosts running Unix/Linux and Windows NT. Attacks include Dos, user to root, probe, remote to local attacks. The drawback of this evaluation is the lack of baseline.

4.2 The UCAD Evaluation

In this evaluation (Puketza et al., 1997), automated attacks using TELNET, FTP and RLOGIN sessions were executed to evaluate a NIDS called Network Security Monitor (NSM) (Heberlein et al., 1990). Scripts of normal and intrusion sessions were executed to verify the ability of the NSM to distinguish between suspicious behavior and normal one. Its ability to handle high bandwidth traffic was also evaluated. This evaluation has shown that NSM was unable to detect intrusions under high CPU load. A similar IDS evaluation (Debar et al., 1998) was performed by IBM Zurich in 1998 to improve IDS systems designed to detect intrusions into FTP servers.

4.3 The NSS Group Evaluation

In this evaluation (NSS-Group, 2001), 15 commercial IDS and Snort were compared using 18 or 66 commonly available exploits such as Dos, DDos, ports scan, Trojans, FTP, HTTP or IDS evasion technique attacks. These systems were evaluated according to the following criteria: their ease of installation and configuration, their architecture, the type of reports and analysis provided. Only attacks reported in ”as straightforward and clear a manner as possible” were supposed to be detected. In this evaluation, attack detection rates are difficult to compare with the other IDS evaluations because the simple detection of an intrusion is not sufficient; each generated alert must be clearly labeled to be taken into account.

5 CONCLUSION

Intrusions are clearly taking place and thus there is a need for operational supervision systems today. Experience shows that a pragmatic approach needs to be taken in order to implement a professional SOC that can provide reliable results. The SOCBox is our response to these new threats.

During its evaluation, the SOCBox proved that it is a powerful tool giving the cartography of network security in a graphical and ergonomic way. It generates clear reports including graphs for helping the security managers better and has an interface for security alert consulting. It also has the ability to compact similar alerts to facilitate the legibility of the generated reports; this can be a great advantage during a troubleshooting operation for example. Moreover, the SOCBox does not need a powerful host: its detection performance is closely linked to the capacity of the sensors to send it their logs.

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