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Diplomarbeit

Honey-DVD

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Hiermit versichere ich, daß ich die Arbeit selbständig verfaßt und keine anderen als die angegebenen Quellen und Hilfsmittel benutzt, sowie Zitate kenntlich gemacht habe.

Aachen, den 22. Dezember 2005

(Nils Gedicke)

Abstract

This work describes the development and implementation of an easy to use, bootable solution on DVD for deploying Honeynets. To achieve this different existing bootable Linux systems on CD and virtualisation techniques are reviewed and analysed for their usability in this work and finally combined to a working solution for the problem. The whole software is assembled on a single DVD which is used as booting and data source for the complete system since nothing will be installed on the harddrives.

The standard method for deploying a Honeynet is to setup the Honeypots and the Honeywall on different real systems. The approach of this work is to virtualise all systems and put them together in a virtual network and thus giving a high flexibility for the Honeynet layout.

The whole Honeynet is configured and maintained via a centralised controller on the DVD's base system which allows for an easy configuration of the single components and automates all necessary procedures in the virtual network.

Zusammenfassung

Der in dieser Arbeit verfolgte Ansatz beschäftigt sich mit der Entwicklung und Implementierung einer einfachen Möglichkeit um Honeynets mit hilfe einer bootbaren DVD ein zu richten. Um dieses Ziel zu erreichen werden verschiedene existierende, von einer CD bootbare, Linux Systeme und Virtualisierungstechniken untersucht und auf ihre Tauglichkeit in dieser Arbeit geprüft bevor sie letztendlich zu einem lauffähigen System zusammengesetzt werden. Die gesamte Software wird auf einer einzigen DVD untergebracht, die sowohl zum Starten des Systems als auch als einzige Datenquelle verwendet wird, da kein Teil des Systems auf einer Festplatte installiert werden wird.

Normalerweise werden Honeynets auf verschiedene Rechner für die Honeywall und die Honeypots verteilt. Die Herangehensweise in dieser Arbeit ist es jedoch alle Systeme zu virtualisieren und zu einem virtuellen Netzwerk zu verbinden, wodurch eine Hohe Flexibilität der möglichen Honeynet layouts erreicht wird.

Das so aufgebaute Honeynet wird durch ein zentrales Programm auf der DVD configuriert und gewartet, das eine einfache Konfiguration des Honeynets erlaubt und sämtliche nötigen Prozeduren zum betrieb des Honeynets automatisiert.

If you know the enemy and know yourself, you need not fear the result of a hundred battles.

– Taken from “On the art of war”

Sun Tzu

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1. Introduction

The introduction of computer networks and especially the internet has brought great new possibilities. Distributed computing, worldwide communication networks and global information exchange are only three among hundreds. But as allways, with new possibilities new risks are included.
Like in the rea lworld there always will be the hackers, cracker or whatever you might call those who seek to cause trouble in the cyberspace. Since the modern society heavily relies on computers and network communication, those are the modern targets for attacks on almost any resource in the world. The spectrum reaches from relatively simple denial of service attacks on single targets via the distribution of malicious software like trojans or viruses to the attempts of gaining complete control over target systems and using them as bases for causing further harm.

1.1. Know your enemy - The Honeynet Project

Through the centuries the words of Sun Tzu were a widely used strategy and a well known advise in many conflicts. But today to *know your enemy* is no longer only a strategy in ordinary warfare; also in the efforts taken against the computer criminals it is of big interest to know why and how someone is doing something.
The Honeynet Project [10] was founded in 1999 with the goal to learn as much as possible about the adversaries and their actions.

1.1.1. History of Honeynets

The idea was to develop a network, dedicated for the only purpose to be attacked and compromised while the administrator could stealthily monitor the actions of the attacker. The base concept was to deploy a subnetwork of so called *Honeypots*, computers designed for being hacked and equipped with additional monitoring software, in systems with some importance and thus rather high probability of being attacked. But in deploying such networks great risks are included.
For example, an adversary might gain controll of a Honeypot, use it as base for further attacks and cause harm to other non Honeypot systems. To prevent this, some standards [16] for Honeynets were defined:

Definition 1 (Data Controll)
Once a Honeypot within the Honeynet is compromised, we have to contain the activity and ensure the Honeypots are not used to harm non Honeynet systems. There must be some means of controlling how traffic can flow in and out of the Honeynet, without beeing detected by the attacker. Data Control always takes priority over Data Capture.

Definition 2 (Data Capture)
Capture all activity within the Honeynet and the information that enters and leaves the Honeynet without attackers knowing they are being watched.

Definition 3 (Data Collection)
If the Honeynet is part of a distributed environment, then that Honeynet must meet the third requirement of Data Collection. Once data is captured, it is securely forwarded to a centralised data collection point. This allows data captured from numerous Honeynet sensors to be centrally collected for analysis and archiving.

GenII Honeynets

After some Honeynets, the so called GenI networks, where deployed the shortcomings of the implementation where obvious. The second generation, so called GenII, of Honeynets was designed to solve these issues.

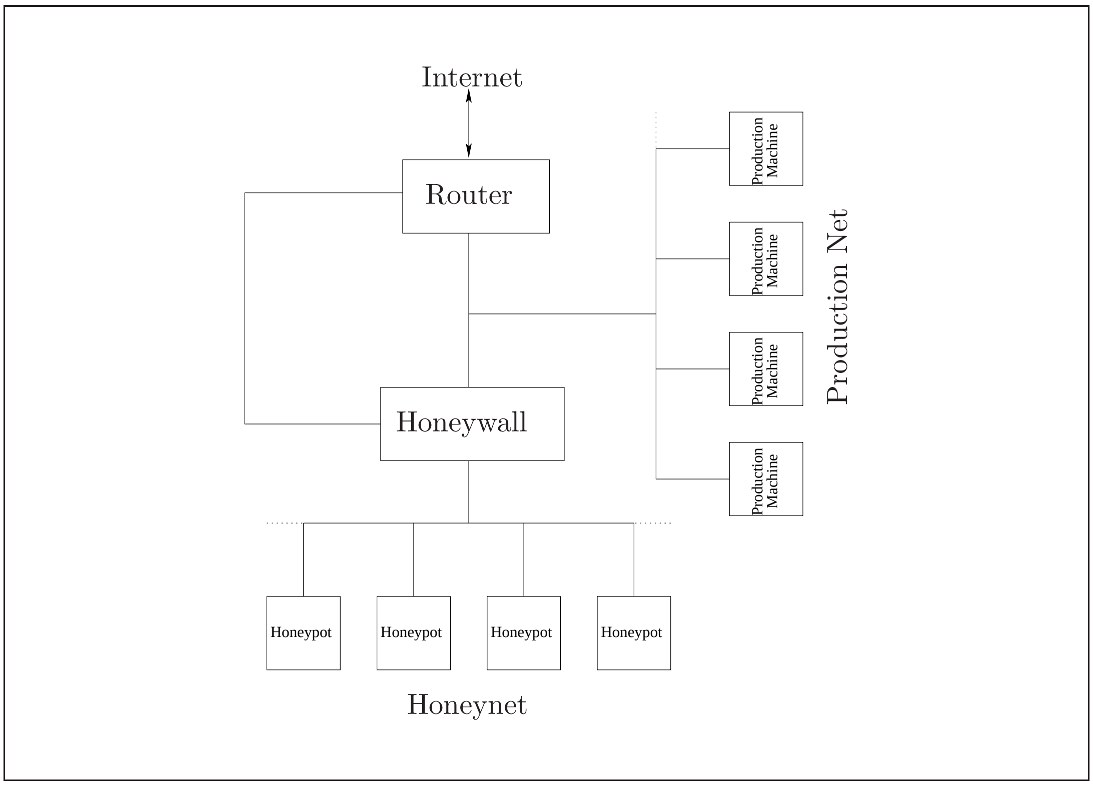
The biggest change in the layout from the GenI to the GenII Honeynets is the introduction of the *Honeywall*. Figure 1.1 shows how this component divides the network into the production network and the Honeynet. The Honeywall is equipped with three network interfaces. No IP-address is assigned to the two network interfaces connected to the production network and the Honeypots and the traffic is directly forwarded between these two interfaces without increasing the TTL. Thus the Honeywall should be completely invisible to an adversary attacking the Honeynet. The third interface, connected to the main network router is for management purpose and doesn't interfere in any way with the Honeynet traffic. Data Controll and Data Capture are both implemented on the Honeywall and also Data Collection can be done there.
Every Honeypot is equipped with tools to capture data which is not accessible in the connections data flows and stealthily export this data to the Data Colletion server.

1.1.2. Deploying a Honeynet

Deploying a Honeynet is a rather complex task. The most critical point of the setup are:

- The Honeypots must be configured and different operating systems installed and patched for Honeypot usage.

Figure 1.1.: Generic GenII Honeynet layout



- Setting up the Honeywall and configuring it in a way that provides security for the normal network on the one hand and allows the attacker a certain freedom on the other hand is critical for the whole setup and must be done with great care.

- The data capture and controll mechanisms must be configured and maintained to grant a continuous secure and productive setup.

A more detailed introduction into Honeynets, their deployment and maintenance can be found in [17], [19] and [18].

1.2. About this work

The Honeynet Project took a first step to create a simple solution for the problem of Honeynet deployment by creating the Honeywall CDROM. The Honywall CDROM is a bootable CD which allowes the user to setup and maintain a Honeywall in a quite intuitive and easy to use fashion. Furthor development of this CD finally led to the current release called *Roo* [20], which can be used to easily install a Honeywall on any PC system.

1.2.1. The Honey-DVD

The idea behind the Honey-DVD is to take the next step and implement a solution for not only deploying a functional Honeywall but a complete Honeynet setup with not much more effort than booting the DVD.

For this goal, different techniques from different fields must be analysed for their usability in this work:

- **Live Linux distributions**
  Live Linux Distributions are distributions of the Linux system capable of booting from a CD or DVD and able to run completely in the memory without interacting with harddiscs.
- **Virtualisation techniques**
  The complete Honeynet setup must be implemented as a virtual network of independent systems. The different Virtualisation techniques available have huge differences in their performance and usability with different operating systems.
- **Remote configuration**
  Since the Honey-DVD should be controlled with a centralised tool which should allow the user to configure every component of the Honeynet, the Honeypots operating systems must allow for remote configuration.

Finally the chosen components and methods must be combined to an implementation which fulfils the following requirements:

- The Honey-DVD should be bootable on every system able to boot from a DVD.
- The Honey-DVD should provide a complete GenII Honeynet setup including different Honeypots and the Honeywall.

- The Honeynet setup should be easy, but the Honey-DVD should allow to configure all important values.
- The maintenance of a running Honeynet, including at least basic capabilities for the analysis of the Captured data, should be possible and the provided tools easy to use.
- The Honey-DVD should not interfere with the data stored on the harddrives of the machine its running on.

2. Base concepts

The first step of this work is to decide about what components to use for the infrastructure of the DVD. In this chapter the general concepts of live Linux distributions and virtualisation software will be discussed and some basic decisions concerning the general direction of this work will be made.

2.1. Live Linux distributions

A live Linux distribution is a distribution of the operating system Linux which is capable of starting and running from a CD or DVD without the need of beeing installed to a harddisc. Many live Linux distributions go even further and are able to run comletely without using any harddisc space, which is also an integral part of the Honey-DVDs concept.

2.1.1. Requirements to a live Linux distribution

The live Linux system will be the base of the whole Honey-DVD. Hence it is of great interest that this system provides some specific fundamentals to be used in this project. The following two primary requirements can be defined:

Requirement 4 (Stability)
To be considered stable, the system core of the linux distribution and all software installed on the system must be fairly tested versions without any major issues that would cause software or system crashes.

Requirement 5 (Security)
For a system to be secure, all available security patches for the system core and the software must be correctly installed.

If these two requirements are fulfilled by a live Linux distribution it can be used for this project. Nevertheless some secondary issues must be considered to make the final decision.

Requirement 6 (Minimal software)
The more software is running on the system the more resources are bound. Since diskspace, memory and performance will be critical issues, a system which lacks unnecessary software is to be prefered to a system which comes with a complete software package. Another simple reason for minimal software is that the more software is running the more failures and potential security issues may occur.

Requirement 7 (Easy maintenance)
To preserve the requirements 4 and 5 beyond the first versions it should be easy to update and patch main system components and software.

Requirement 8 (Compatibility)
The system must be compatible to the most hardware. That means it must not only have the supported modules installed to the kernel but also autodetect all available and necessary resources during startup.

Requirement 9 (Supports customisation)
To build a virtual Honeynet upon the live Linux, it may be necessary to modify some of the components already provided by the distribution. One example would be the startup sequence and automatic login behaviour of the most distributions.

A system fulfilling all of these requirements would be an optimal system to build on. Nevertheless, there are many different ways to build such a system and hence one has to look closer to the pros and cons of each single one to decide.

2.1.2. Distribution similarities

When analysing different live Linux distributions, it turns out that the first steps and the main layout of nearly every distribution are very similar. The common implementation of the boot sequence of a live system is like this:

1. Boot the Linux kernel with an initial ramdrive image
2. Execute a startup script contained in this image
3. Detect CD- or DVD-Drive and allocate space for the ramdrive
4. Mount compressed read-only image from the CD or DVD into the ramdrive
5. Copy and link all files to the needed locations to boot the main system from the read-only image

6. Start Linux boot sequence from the ramdrive

From this point onward the behaviour of the system depends on the Linux distribution which was taken as the base of the live system. Every distribution has its own ways of organising its' startup scripts and its own runtime behaviour. Some live systems are based on major distributions like Debian, Fedora or Slackware while others go their own way and assemble the necessary parts completely independently. A Linux system built especially to run as a live system can be designed to be extremely small with respect to its purpose but most times customisation is quite complex since nearly every additional software must be recompiled and reconfigured to run on these systems. On the other hand, a system based on another distribution can access the base distributions package repositories to customise and update the system. But since the base structure is given by a distribution originally built for harddisk installation, it will never be as small as a special build might be and it will inherit the advantages and disadvantages of its base distribution.

2.2. Virtualisation

The second integral part of the Honey-DVD is the Virtualisation. Virtualisation allows to imlpement multiple computer systems on the hardware of only one really existing machine. Those additional so-called, *virtual machines* will act independant of each other with their own operating system and virtual resources. In this work virtualisation will be used to implement a complete virtual Honeynet as described in chapter 1.1.1.

2.2.1. Methods of Virtualisation

One of the main questions during the design phase was, which software would be the best for the virtualisation. Since there are not only many different providers of implementations but also different ways of doing the virtualisation, the problem of choosing the right virtualisation software is not an easy one.
The first thing to consider is how the virtualisation can be done. The only thing common to all kinds of virtualisation is the need of a software layer that provides the illusion of real machines to multiple instances of guest operating systems. This layer is called the *Virtual Machine Monitor* (VMM) and is necessary since every single operating system will try to directly access the hardware as described in [23]. But the different implementations of this softwarelayer use different strategies to achieve their goal.
[22] provides a good basis for categorising the different approaches. The first differences are in the fundamental behaviour of the VMM. The two strategies available here are:

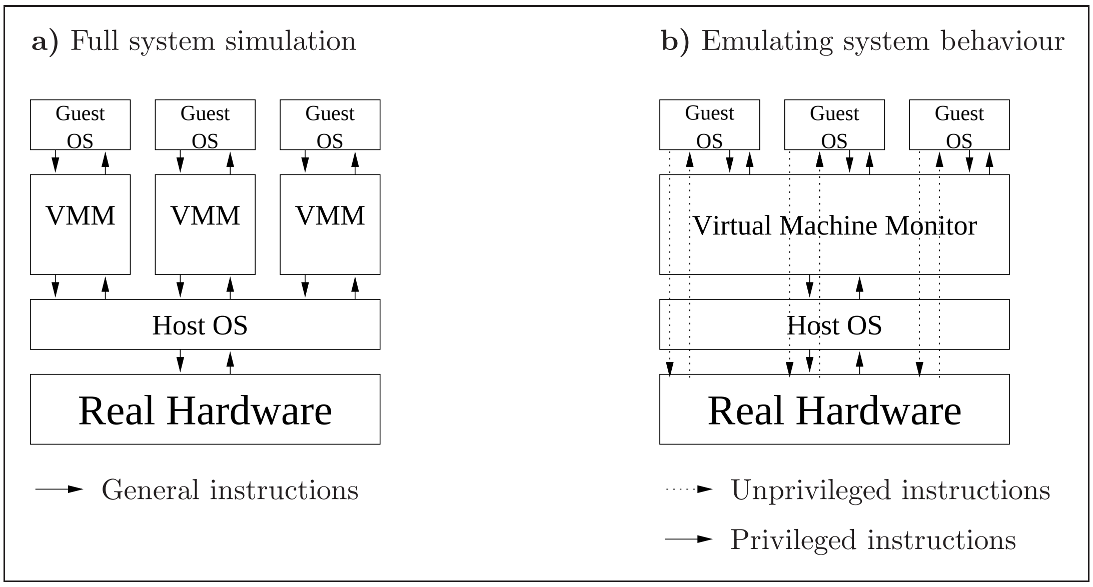
- **Full system simulation**
  Simulating a complete system means to provide software implementations for everything. Not only the CPU and its instruction set, but also all hardware registers, harddisks and other peripherals must be implemented. Full system simulators like Simics [8] are mainly used to develop and test complex electronic systems that are not PCs. They are lacking some features for long time operation in production environments. Another disadvantage inherent to this kind of virtualisation is the great overhead due to redundancy occurring if more than one virtual system is being hosted. Since only comlete systems are simulated and no components shared amoung different virtual machines, every single virtual machine will have its own virtual hardware. As shown in figure 2.1 a), all instructions will be executed by the VMMs which implement the virtual machines and use the real hardware only for their own calculations. The advantage of this strategy is that by simulating a complete system, side effects like unexpected register values, wich will be discussed in chapter 2.2.2, will not occure since the virtual machine will be an exact duplicate of the real machine.

- **Emulation of system behaviour**
  Instead of simulating a complete system with all its components, one can restrict himself to emulating only the behaviour of a machine. This means, that by using time and resource sharing algorithms and, if necessary, converting the instruction set of the virtual machine to instructions for the real machine, the VMMs will pass the commands issued by the guest operating system to the real hardware for execution. This solution is shown in figure 2.1 b). In this case, the overhead of running multiple virtual machines is significantly smaller since the virtual machines are sharing the real hardware for all calculations.

As stated above, the complete simulation of a system provides a virtual machine that is indistinguishable from a real machine. But the complete simulation of a system, not to mention multiple systems, is quite costly and hence the second method is the method of choice for the virtualisation of the Honey-DVD's Honeynet.
But also after deciding about this general question there are again two different possibilities of implementing the emulation:

- **User mode emulation**
  The first possibility is to emulate multiple instances of the real systems hardware by executing other operating systems like ordinary user space programms. This is possible if the VMM is integrated into the host operating system and provides the means for the guest systems to run in the unprivileged mode. The consequence of this is, that all unprivileged instructions of the guest operating systems can be executed directly on the real hardware, while only the privileged ones must

Figure 2.1.: Virtualisation in two different ways



be controlled by the VMM.
The advantage of this kind of virtualisation is that there is only a very small overhead and thus the performance of the virtual machines is nearly the same as of real machines. The drawback on the other hand is that the guest operating systems must be modified to be able to run in user space and under the controll of a certain VMM and thus available patches for operating systems are currently restricted to Linux and a few BSD versions.

- **Emulation of complete systems**
  The second way of implementing the VMM is to try and emulate the behaviour of a complete computer system, independent of the real hardware. In contrast to the full system simulation, the emulator will not be a software implementation of a real system, but just reproduce the behaviour of a real system. To do this the virtualisation software must provide virtual counterparts for the complete hardware of the machine it is virtualising and be able to transpose commands given to the virtual computer into commands for the real hardware.
  Since, in contrast to the user mode emulation, all instructions will be processed by the VMM, this strategy causes more overhead than the user mode emulation.

But the overhead of the emulation is is still smaller than the overhead of the full system simulation, because just some preliminary filtering to convert between the host and guest instruction sets is done before instructions of the hosted system can be directly passed to the real hardware.
The advantage of this strategy on the other hand is, that it allowes the guest operating system to be any unmodified system which would run on the emulated machine.

2.2.2. Detecting Virtualisation

Another point of interest is the question if and how any user of an operating system running on a virtual machine can find out about the virtualisation. This is interesting within the context of this work from two points of view:
On the one hand a virtual machine may be considered an unworthy target for hacking attempts. It is very easy to reset a virtual system to its original state and thus undo all efforts of any hacker. Thus people who are up to deploying some tools for later use won't choose a virtual system for their attack and some Trojans and worms won't install but rather automatically delete themselves and any traces of their former presence when a virtualisation is detected. A second reason is that the knowledge about the true nature of the system might be a hint for any attacker that he is within the borders of a Honeynet and thus monitored. With this knowledge the attacker may just choose to leave without doing anything but maybe also to do some weired things and fill up the logs with useless junk. And in this case the usefulness of the Honeynet is no longer given.
On the other hand, virtual machines are widely used in datacenters and by hacking the virtual system and break out of the virtual environmant, any adversary would gain immediate controll over all virtual systems running on a single host and cause great damage to its owner.
Of course it would be of some interest to gain knowledge about the actions taken by a hacker to break the virtualisation. But in this case there would be a problem: The idea behind the Honey-DVD is to run a complete Honeynet on one real system. If any adversary would break the virtualisation he would be in controll of the Honeynet and all the captured data. Hence the deployed Honeynet would no longer be a trustworthy source of information.
Thus it would be best if the virtual nature of a Honeypot would not be detectable.

- **Detecting full system simulation**
  It has been shown that in the context of performance the simulation of a complete system is a great drawback. In the case of detectability of virtualisation it is a great advantage. Since every single component of a real machine is remodelled in

software there is no way for a program to decide whether it is running on a real or a virtual machine. The only feasible way to detect this kind of virtualisation is by fingerprinting the virtual systems.
This can be done by gathering the complete system data available and run checks on the hardware components of the machine. If the virtual machine is in a default configuration of a well known simulator one can derive a rather high probability of a virtualisation. But if the configuration is changed or the virtualisation software is rather unknown the probability of detecting the virtualisation rapidly drops. Another method of fingerprinting is to derive the systems nature from timing analysis of the target system.

- **Detecting emulated systems**
  Nearly the same argument as in the case of full system simulation applies to the emulated systems. But sadly the other way round. By passing unprivileged instructions directly to the real hardware the virtual system gets comparatively fast but also easy to detect. The system operator can change every bit of the emulated hardware to avoid fingerprinting but the virtualisation will most assuredly be detected.
  [12] states that seventeen instructions of the Intel Pentium Processor are unpreviliged but still sensitive, which basically means these instructions won't cause traps that must be caught by the VMM but the behaviour of these instructions depends upon the processor mode of the system.
  An unprivileged instruction with access to the systems *interrupt descriptor table register* (IDTR) is the *store interrupt descriptor table register* (SIDT) command which stores the contents of the IDTR to a given memory location. Since there is a minimum of two operating systems, the host system and the hosted, running at the same time and only one IDTR on the real hardware, the VMM must relocate the register for the hosted operating system to not conflict with the hosts one.
  One very simple tool for virtualisation detection which uses the SIDT instruction is redpill [21]. As shown in listing 2.1, the tool just stores the IDTR to a predefined location and then compares the value of its sixth byte to the default 0xd0. If the register points to a higher address, then the redpill was executed on a virtual machine and the return value will be one.
  This programm is only one way of detecting virtualisation and its reliability depends on the hosted operating system, i.e. Redpill will most ashuredly detect the virtualisation on a Linux system while it might fail on FreeBSD. Nevertheless, since this kind of behaviour is inherent in the design of the most emulation softwares available it is nearly impossible to avoid being detectable for any system emulator.

Listing 2.1: Redpill.c [21]

```
int swallow_redpill () {
  unsigned char m[2+4],
                rpill[] "\x0f\x01\x0d\x00\x00\x00\x00\xc3";
  *((unsigned*)&rpill[3]) = (unsigned)m;
  ((void(*)())&rpill)();
  return (m[5]>0xd0) ? 1 : 0;
}
```

2.3. Summary

In this chapter the general concepts of live Linux distributions and Virtualisation was discussed.
In the case of virtualisation the differences between *full system simulation* and *emulation of system behaviour* were analysed and the decision to use the latter in this work was made.
Finally, the possibilities of detecting a virtual machine were discussed with the result that it is currently quite impossible to avoid detection because of some issues inherent in current processor and operating system design.

3. Components of the Honey-DVD

After discussing the general concepts of live Linux distributions and virtual systems it is now time to analyse and decide about the exact components used for the implementation of the Honey-DVD. The first part of this chapter will discuss which live Linux implementation and which virtualiser would be suited best for this work. The second part then will look at the components necessary to implement a Honeynet.

3.1. Base system components

To implement the Honey-DVD one has to recall what was discussed in chapter 2. Bearing in mind the requirements of this project one can take a closer look at the different possible software solutions for the problems to solve.

3.1.1. The live Linux distribution

As described in chapter 2.1.2 some considerations where necessary to decide which live Linux distribution would be best suited to be the basement of the Honey-DVD. The first thing to decide was if an independent, or even self made, live Linux or a system based on a major distribution would be the best choice.
Given the requirements 4 and 5 it would be good to have a system specially build for the purpose of serving as Honey-DVD base system, but this would for sure go beyond the scope of this work. A slim independent distribution would most likely lead to some problems, since some of the necessary components to build the Honey-DVD will most likely be missing, and the update capabilities to maintain security are not give. To be sure to have access to all necessary tools and updates for this project, i.e. kernel patches, security features and additional software, the choice is to use a system based on a major distribution.
The differences among the single distributions are again quite small and hence it is the liking of the one or the other which is decisive here. Today nearly all major distributions provide update and installation mechanisms, packet management utilities and quite big software repositories in the web. One of the distributions with the largest repositories is the Debian distribution. This distribution is easy to maintain without the need of a running x-server and the frequency of security updates is quite high and

allways up to date. Hence this distribution will be used for the Honey-DVD.

From all Debian-based systems available, the KNOPPIX [13] live Linux is probably one of the best and most common ones. Advantages of using this distribution would be:

- **Detailed documentation**
  The documentation of KNOPPIX is really detailed and many additional sources of information are available.
- **System compatibility**
  The hardware detection and compatibilities of KNOPPIX are amongst the best and often mentioned to be equal or even better than the ones of commercial Linux distributions.
- **On-the-fly decompression**
  All data is stored on the CD/DVD and only decompressed into RAM when it is used. Unused and unmodified data is deleted from the RAM-drive while virtually the directory structure is unchanged.

But on the other side it also has a big disadvantage:

- **Distribution size**
  KNOPPIX is one of the largest live Linux distributions available. Its enormous selection of software is big enough to allow its use as a full-blown Linux distribution for every-day tasks what is absolutely contrary to the *minimal software* requirement (Requirement 6).

Another quite promissing live Linux distribution is GRML [2]. Based on the KNOPPIX distribution it comes with equal hardware compatibility, and the differences to KNOPPIX in the base components were only minor, so that the KNOPPIX documentation is accurate to work with GRML. Some additional advantages of this distribution are:

- **Designed for recovery and administrator use**
  This distribution was originally build as a rescue system to allow system administrators an easy way of recovering data from defect systems. Hence it is equipped with all necessary tools and modules to use the most common and even some of the uncommon hardware and also tools for system monitoring and testing are included.

- **Good customizability**
  The over all structure of the system, i.e. the startup scripts, configuration, etc., is easy to understand and the customisation can be done quite easy by using the standard Debian tools for installing or removing software.

- **Minimalistic system**
  When started, the standard GRML system boots into a Linux zsh-prompt and allows access to three root and three user consoles. Additionally it starts an IPTables monitor as well as a system monitor and a syslog viewer. One *teletypewriter* (tty) gives a normal login prompt while two ttys are left for x-server usage, but the capabilities included in GRML are reduced to the x-server and a simple window manager *wmi* which is not started after system boot by default.

Since GRML is basically a KNOPPIX striped of all unnecessary software and equipped with easy to use admin tools it seems to be the optimal answer to the question what live Linux to use on the Honey-DVD.

The only disadvantage that may occure is that since GRML is based on Debian, its native packet format is deb-packet format and hence software that is only available in *Redhat Paket Manager* (RPM)-packages will most likely cause problems during the installation. But this is a minor drawback, since the Debian repositories provide acces to a vast amount of packages and hence even if the original program is only available as RPM the chances are high that a Debian portation or at least substitution will be available.

3.1.2. The Virtualisation software

The virtualisation software used on the Honey-DVD will probably be one of the most performance consuming programs running on the system. To avoid performance loss it would be good to avoid every unnecessary program or program instance and use software with preferably high performance. As shown in chapter 2.2.1, using a system emulator would be the best way to achieve this, and, to be more precise, the usermode emulation would seem to be the best solution regarding the performance.
To evaluate which software would be the best for the Honey-DVD some testing with different emulators was done. To measure the overall performance of a virtual machine compared to a real machine a benchmark test was applied. The used benchmark is the *nbench-byte 2.2.2* benchmark [3], a linux port of the BYTE Magazine's BYTEmark benchmark program [1]. It was chosen because it uses several real live algorithms for benchmarking a system. In this way it is possible to predict the systems overall performance in different tasks and compare the results. Amongst others these four algorithms are applied:

- **Numeric sort**
  An algorithm that sorts an array of 32-bit integers.
- **String sort**
  Sorts an array of strings with arbitrary length.
- **Fourier coefficients**
  A numerical analysis routine for calculating series approximations of waveforms.
- **IDEA encryption**
  A cryptographic block cipher algorithm.

After the application of these tests, three indexes relative to a predefined base benchmark taken on an AMD K6/233 processor are generated which measure the overall capabilities of the system. The higher the index, the faster the system compared to the baseline. Another interesting thing is the virtual network. To test this a simple series of ping request was send from a remote system in the network and the average responsetime of 400 pings was taken. The results of these tests can be found in table 3.1.

Table 3.1.: Performance of different virtualisers compared to real systems running on a live Linux distribution

	UML	**Xen**	**Real system**	**VMWare**	**QEMU**
Numeric sort	740,3	736,2	770,4	84,31	76,74
String sort	103,37	98,28	114,48	6,227	4,257
Fourier coefficients	15694	15630	15731	1386	1319,9
IDEA encryption	2496,3	2431,7	2563,8	481,4	253,61
Memory index	10,078	9,315	11,033	1,681	0.650
Integer index	7,862	7,379	8,914	1,182	0.758
Floating-point index	12,538	12,073	13,058	1,351	0.681
Average ping timings	0,24ms	0,28ms	0,19ms	55ms	60ms

These first experiments with Xen [11], whose VMM is directly integrated into the kernel, and UML [7], which mainly just allows a Linux kernel to run as a user space program, showed two things:

- The maximum performance of the guest operating systems was nearly the same as on real machines.

- The timings of the virtual network were only slightly slower then of the real machine.

The network test with Xen had an additional result:

- The connection was quite unstable. Some packet losses and even complete link failure occured.

Given these observations UML would be probably the best choice, but as mentioned in chapter 2.2.1, only modified Linux kernels will run on this VMM. But the same problem would also apply to Xen, even if the network problems would be solved. Some modified BSD versions to run in the Xen environment are available. Even a patch for Microsoft Windows XP was created, but due to some leagal issues never officially released. Also these modifications and patches only apply to newer system kernels what additionally diminishes the amount of usable operating systems. Hence the user mode emulation is not the right choice to virtualise the Honeypots.

In its book [17] the Honeynet-Project gives advice to use VMWare-Workstation [9], a commercial full system emulator, to virtualise the Honeypots. Hence this was the first choice for testing full system emulation. VMWare emulates multiple x86 based machines in one consistent framework and allows to customise the virtual systems, i.e. adding and removing resources or changing the network infrastructure, as needed in a very comfortable manner.
Another interesting candidate was the software QEMU [4], released under the GNU Lesser General Public License. QEMU allows to emulate x86/x86-64 PCs as well as PowerMac, PowerPC and SPARC Sun4m systems. It is not as comfortable as VMWare, since all configration is done via the commandline at startup and a text based monitor interface during runtime. It not only accepts disc immages in its own *qcow* format, but also UMLs *cow* and some versions of VMWares *vmdk* format are supported. Other additional image formats are the easily exportable *raw*-, linux compressed *cloop*- and the simple *dd*-image. QEMU also comes with an accelerator module which is optional and allows QEMU to run most of the target application code directly on the host processor without the additional filtering for instruction sets if a PC is emulated on a PC. Sadly this accelerator is a closed source proprietary product and redistribution is prohibited.
To be comparable the same tests as to the user mode emulators were applied to the system emulators. The results can also be seen in table 3.1.

Since QEMU is only slightly slower than VMWare and given the open source nature of the project, which would allow the redistribution on the Honey-DVD, it seems to be a good choice for the virtualisation in this work. The only drawback, compared to VMWare, is, that the code hasn't been reviewed for security issues and hence it is yet unknown if and how an adversary could break out of the virtual environment.

3.2. Honeynet components

As described in chapter 1.1.1 the structure of a Honeynet is composed out of several components. The Honeypots on the one side and the gateway/Honeywall on the other. As discussed the different elements have their different functions in the Honeynet. To build the Honey-DVD one has to decide which software to use for the implementation of these funktions.

3.2.1. Data control

The data control mechanisms of the Honey-DVD will be implemented in two layers, according to [16]:

- **Connection rate limitation**
  Connection rate limitation is used to restrict the number of connections a Honeypot can initiate. In this way it is, for example, possible to prevent the further distribution of malware from a Honeypot.
  The connection rate limitation can quite easily be done with IPTables[1], a very powerful tool, that is used for implementation of firewall rules under linux. It provides the capabilities to define rules to accept all incoming connections while outbond traffic will be restricted to a predefined amount of possible connections per time period. This restriction can be applied separately for each of the TCP, UDP, ICMP, or other protocols and even some exceptions for special connections may be implemented. (i.e. DNS, NTP or similar standard queries.)

- **Extrusion prevention**
  In the case of data control intrusion detection is not meant as preventing intrusion into our honeynet but rather intrusion into other systems with the honeynet as a source. For this cause a modified version of the Snort intrusion detection system called snort_inline is used. It allows to analyse outbound packets for known attacks and gives the possibility of either dropping or modifying those packets. The second way is interesting because the attacker will be able to verify that his packets are delivered but won't know why his attacks fail.

[1]Detailed information of IPTables functionality can be found at http://netfilter.org/projects/iptables/index.html

3.2.2. Data capture

The data capture functionality will be implemented in three layers.

1. **Firewall logging**
   Since the Honeypots normally won't have any traffic any activity is of interest. By logging every connection or connection attempt from or to a Honeypot the Honeywall provides some basic information even if no actual data was transfered. For example port scans or single ping requests will be captured in this way.

2. **Intrusion detection**
   The maintainer of a Honeynet will most likely want to be informed if a known attack on the system was tried. This information is not critical, but allows for example some statistical evaluations off what attacks are the most common and which backdoors the most known ones. Another reason for an *intrusion detection system* (IDS) is, that an IDS allows to log all network traffic for later use to do some offline analysis of the collected traffic with a vast number of tools.

3. **Data capture on the Honeypots**
   The last layer of data capture is completely based on the Honeypots. While the Honeywall has total control about the in- and outbound traffic, some of the intruders actions are only clearly visible on the attacked system itself. Either because the network connection is encrypted or because the activity of the tools used by the intruder are only local. The Honeynet Project uses Sebek [15], a keystroke logger, developed specifically to meet Honeynet needs. Sebek collects process tree, socket and file opening data and is available for Linux 2.4, Linux 2.6 and Win32 while the BSD versions are considered as testing versions. Roo [20], the Honeywall CDROM distributed by the Honeynet Project, implements a sebek server and [16] defines Sebek as a standard for data capture in Honeynets. Hence sebek will be used as the third layer of data capture in the Honey-DVD.

3.2.3. Honeypot images

Finally the decision must be made, what kind of Honeypots to include in the Honey-DVD. Althoug the later Implementation described in chapter 4.3.1 will use a double-layer-DVD with a capacity of 8.5 GB, the initial concept was to use a single-layer-DVD as medium. Since the space on a single-layer-DVD is restricted to 4.7 GB and about 700 MB are allready used by the base GRML-System, the space left for the Honeypot images is about 4 GB. The requirements of the honeypots can be measured as follows:

- **Not the newest version**
  To be used as a Honeypot the system should in some way be attractive for

hackers. One way to achieve this is to install older versions of widely used operating systems instead of the newest and best patched ones. But of course a system which is too old would also be a bad choice, because no new security threads will be monitored on those systems. A system which is about one year old seems to be the best trade-of between up-to-dateness of the system and the known security issues.

- **Compatibility to sebek**
  Another requirement of the operating system is that it must be supported by sebek. The documentation of the current version of the linux-client (i.e. v 3.0.3) states that it has been successfully tested on Redhat systems with kernel 2.4. The BSD-Versions are available for FreeBSD 5.3, NetBSD 2.0 and OpenBSD 3.7. The recently released win32 version runs on Windows 2000, XP and 2003.

- **Free distribution**
  To be able to include the Honeypots image in the Honey-DVD, the used operating system must be free distributable.

- **Availability of services**
  Some services like a web- or FTP-server should be available on the Honeypots. Hence free implementations of this services must exist for the operating system in use.

Putting all these things together, the possible solutions are reduced to the BSD and Linux distributions. And due to the available space on the DVD and the space requirements of the operating systems, including the possibility of compiling additional software on the Honeypots, only two base-images, each with 1.5 GB image size, will be included in the Honey-DVD. I.e. a BSD and a Linux image. Which specific ditributions will be included into the Honey-DVD will be decided in chapter 4.1.2.

3.3. Summary

The analysis of the different implementations of live Linux distributions and virtualisation software was the first part of this chapter. It resulted in the decision to use the GRML live Linux distribution and the system emulator QEMU to implement the Honey-DVD.
In the second part the different components that will be used to build the Honeynet were discussed and different possibilities for theri implementation were analysed. Finally decisions were made to to include a Linux and a BSD Honeypot in the Honey-DVD and to follow the standards, defined by the Honeynet Project, for the implementation of data control and data capture.

4. Building the Honey-DVD

The next step after deciding with which base components the infrastructure of the Honey-DVD will be implemented is to assemble a first version. This chapter will be divided into three parts. First the description of the system layout and implementation of the First version, then the problems that occurred during the implementation and finally some solutions and the changes done to implement the current version of the Honey-DVD.

4.1. Layout of the prototype

The prototype of the Honey-DVD was designed to follow the standards [16] of the Honeynet Project as close as possible. But since the complete Honeynet should run on only one real machine and without the necessity of installing anything to a harddrive some modifications where inevitable.

4.1.1. The virtual Honeynet

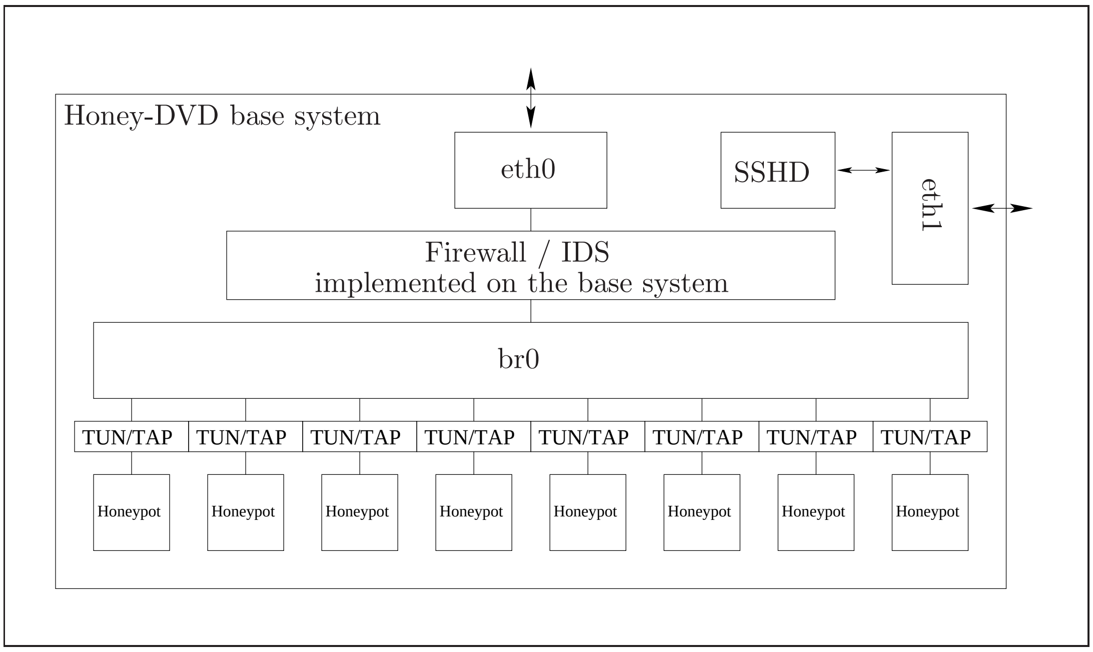
Chapter 1 gives a good overview about how a Honeynet should be build. This section will describe how this implementation is realised on the Honey-DVD.

Network layout

In chapter 1.1.1 the standard layout of a GenII Honeynet has been described. To adopt this layout one has to look at the differences and equalities of the both deployment methods. In a real network, you would have several machines with single network interfaces connected to the gateway over a switch or hub. The network feature of QEMU on the other hand assigns a virtual network interface on the host system to every virtual network interface on the guest systems by using the TUN/TAP virtual point-to-point device driver [6]. The resulting network structure is shown in figure 4.1.

In this layout, the internal device is the network bridge *br0* while the network interface *eth0* is used as the connection to the external network. The network interface *eth1* is used as a command interface which will not be connected to the Honeynet, but

Figure 4.1.: Network layout of the Honey-DVD



will provide the means to export logs, send alarm signals to the administrator or to configure the Honeynet from the outside via an SSH connection. All virtual *tunX* devices are connected to the network bridge and form the network of Honeypots while the base system is used as the gateway to connect the internal bridge *br0* with the external interface *eth0*.
This design is quite similar to the *Self-Contained Virtual Honeynets* discussed in [17]. The main difference here is that, in the original design all Honeypots were running in the VMWare framework, which internally uses a network bridge to implement the virtual network and furthor provides a single network inteface on the real machine as a connection to this network. QEUM doesn't provide this framework and hence every single virtual machine has its' own network interfaces TUN/TAP counterpart on the real system that must be connected to the Honeynet via an aditional network bridge. A consequence of this is, that, since it is not possible to directly connect two network bridges, the Honeynet implementation on the Honey-DVD will use IPTables NAT capabilities to connect the virtual and the external network.

The Honeywall

The main functionality of the Honeywall will be implemented on the base system. For the data controll implementation of the first version it will suffice to use the scripts and tools included in [17]. Since this book dates back to 2004 more recent versions of the used scripts are available which will be discussed and used in this work.
The key part of the Honeywall is a script called *rc.firewall*. It provides multiple functionalities:

- **Network setup**
  Setup the bridging and NAT to connect the external and internal networks and activate the local controll interface.
- **Configure rate limitation**
  Configure IPTables for connection rate limitation and to pass outbound packets to snort_inline as described in chapter 3.2.1.
- **Filtering Sebek packets**
  Configure IPTables to keep Sebek packets from leaving the virtual network. This may be necessary to prevent Sebek packets from leaving the Honeynet if send to a broadcast address, since every system outside the Honeynet will be able to see this packets and hence this would give away the presence of the Honeynet.

Some parts of the data capture mechanisms, i.e. Snort and the Sebek-server, are also installed and configured on the base system. In the case of Snort the program and its rulebase was already included in to the original GRML distribution, while Sebek is available on the web[1].

4.1.2. The Honeypots

In chapter 3 the general possibilities for which kinds of Honeypots can be included into the Honey-DVD was discussed. Now the next point of interest is the detailed implementation of the different Honeypots.

Honeypot operating systems

As discussed in chapter 3.2.3 a Linux and a BSD distribution should be included into the Honey-DVD. The Debian Linux distribution, as mentioned before, has a really

[1] Current versions of the Sebek client and server can be found at `http://www.honeynet.org/tools/sebek/`

big web repository which allows access to all kinds of programs and services and thus would be a good candidate for a Honeypots system. But a very importand thing is that the Sebek client must be supported by the system.
There are two ways of installing Sebek on a Linux system:

- **Installing a precompiled version**
  Precompiled versions of the Sebek client are available for the linux kernel versions 2.4.19-2.4.30.
- **Compile the module**
  A second possibility is to just compile the Sebek module against the kernel-sources of the Honneypots Linux kernel.

Since no precompiled version of the Sebek client is available to match against the Debian kernel and, according to the Sebek documentation, Debian is not amongst the supported Linux distributions, another distribution must be used.

The documentation of the Sebek sourcecode explicitely mentions the Redhat 8 distribution as supported distribution, and after compiling the client against the kernel sources of the Redhat 8 system the first tests confirmed this. Redhat, as a widely used Linux distrubution, has equal big packet repository in the web as Debian, and its' RPM packet format is one of the most commonly used formates. Hence a Redhat 8 Honeypot will be used as the first image included in the Honey-DVD.

As mentioned in chapter 3.2.3 the BSD version of the Sebek client is available for explicitly three BSD versions. Of those systems FreeBSD 5.3 seems to be the best choice, since, compared to the other two, many programs are available for this system either as a port or directly from the provider. Hence the second image included in the Honey-DVD will be a FreeBSD 5.3 Honeypot image.

Honeypot configuration

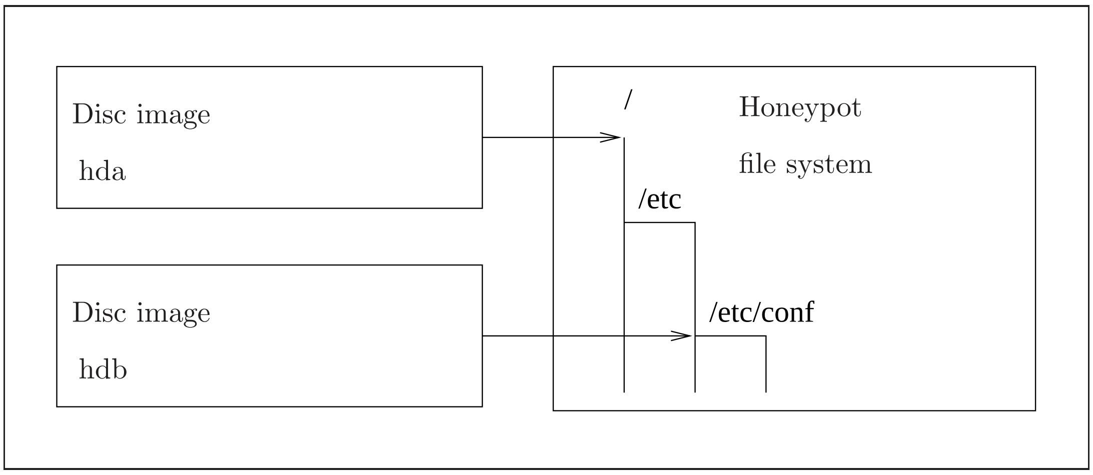
The configuration possibilities of the Honeypots should be as complete but also as easy to use as possible. The following points were the basis for the decision of how to realise configurations:

- **Reusability of images**
  It should be possible to reuse the base images and run several Honeypots with different configurations from them.

- **Configuration before Honeypot startup**
  It should be possible to do the necessary configuration changes before the Honeypot is started.

To be able to change the configuration of the Honeypots before starting the system one must edit the according config files in the image. But to be able to run several Honeypots from the same image one would have to make copies of the image for every single Honeypot and store them on the DVD. To avoid this a second image for the configuration files of the Honeypot base images will be used. Figure 4.2 shows the general idea:

Figure 4.2.: Mountpoints for the disc images of a Honeypot.



The virtual machine running the Honeypot will have two virtual harddrives. The first harddrive *(hda)* will contain the complete system image of the Honeypot, but every configuration file will be “exported” to the second harddrive *(hdb)*. These files will then be linked to their original locations to not break the standard boot procedure of the operating system.
Since the size of the second harddrive image is extremely small (i.e. 10MB) it will be no problem to make copies of this image at runtime of the Honey-DVD and start different Honeypots from the base images with their own copy of the configuration image. The exported configuration files of the Redhat image are shown in table 4.1.

During the boot sequence of the Redhat system, the harddisks are mounted and all symlinks functional at the time when the configuration files are accessed during the boot process. In this way every configuration change done to the files in the configuration harddrive will be active during bootup and all configurations can be done quite

Table 4.1.: Exported configuration files of the Redhat 8 system

Original file	**New location** (Relative to hdb root)	**Contained configuration information**
/etc/sysconfig/network	/network/network	Networking activation and hostname configuration
/etc/sysconfig/ network-scripts/ifcfg-eth0	/network/ifcfg-eth0	Ethernet device configuration
/etc/resolv.conf	/resolv.conf	IP-addresses of DNS-servers to use
/etc/hosts	/hosts	List of hosts and hostnames

easy.

Table 4.2.: Exported configuration files of the FreeBSD 5.3 system

Original file	**New location** (Relative to hdb root)	**Contained configuration information**
/etc/rc.config	/rc.config	Complete basesystem configuration

Since the FreeBSD system uses a more centralised way to store the base configuration, only the file shown in table 4.2 needs to be exported. Nevertheless there are two problems:

- **File system incompatibility**
  The FreeBSD standard file system is ufs, which is readable under Linux but no writing is possible. Hence no changes to configuration files on a ufs-image would be possible.

- **The FreeBSD boot sequence**
  The boot sequence of FreeBSD accesses the main configuration files in a system state, when only the root file system is mounted, and then also just with read access. The mounting of all file systems for runtime usage is done at a later point of time.

The solution for the first problem is to use a file system which is supportet by both, Linux and FreeBSD:

- FreeBSD has integrated support for the ext2 file system and would be able to use this as a source for the configuration. Sadly the ext2 support ends at the filechecking utility which is doing file system checks on all devices listed in */etc/fstab* during the boot sequence. The problem would be solvable by editing the fsck bootscript to exclude the ext2 file system from checks, but when editing the files contained in the ext2 image on the Linux system, some inconsistencies occur which prevent the ext2 image from being remountable in the FreeBSD environment.
- Another possibility of solving this issue was to search the "least common denominator". The FAT file system is supported by both systems and although it is not the native system of either one it seems to have none of the above mentioned problems.

In case of the second problem changes to the FreeBSD boot procedure where inevitable:

- In case of the network and similar configurations there seems to be no objection to just write a script to reconfigure everything needed at the end of the booting sequence while using default values for the initial startup. The hostname on the other side is the real issue, since it will be difficult to change the name of an allready running BSD-host.
  The solution here was to edit and change the standard bootup procedure of FreeBSD. By just mounting the configuration filesystem before the contained values are needed and unmounting it again after they have been read it is possible to bring the configuration file to the attention of the bootup process in time without interfearing with the standard mounting process.

The available services

For the base version of the Honey-DVD only a few services besides the SSH and telnet services were chosen to be available on the Honeypots for testing purpose.

- **Services of the Redhat system**
  On the Redhat system these services were an Apache2 webserver and an FTP-server called proftpd. Both services can be started as daemons with external configuration files which can easily be included in the configuration images for the Honeypot.
- **Services of the FreeBSD system**
  Included in FreeBSD are a great number of services which can be controlled via

the initd daemon. Like on the Redhat system the basic configuration contains the Apache2 webserver as well as an FTP-Server. Additionally the FreeBSD system comes with a TFTP-Server and some minor services like *chargen*, *echo*, *time* etc.

4.1.3. The Honeynet controller

The structure of the Honeynet controll program developed for the Honey-DVD is devided into several stages of execution with different options for the user:

Stage 1: Configuration

When started, the first thing the controller does is to ask for the configuration method that should be applied:

- **Default configuration**
  This option is the simplest configuration method. Every single value of the Honey-DVD is set to default. A list of these values is shown in table 4.3.
- **Customise configuration**
  When choosing to customise the Honeynet setup, the controller will continue to ask what specific components shall be customised. Possible choices are:

  -Configure the Honeywall

  -Configure the number and kind of Honeypots

  -Configure the Honeypots

The second possibility, to customise the configuration, is more complex. It provides access to the single components and then gives the choice to either do a complete reconfiguration or to maintain some or all of the default values. Nevertheless, some of the choices will have consequences to following ones.

- **Configuration dependencies**
  Some of the configuration options will depend on each other. For example, when choosing to change the number and kind of the Honeypots to another value, say two Redhat systems, the controller will ask to configure the Honeypots. If not at least one of the Honeypots is reconfigured both would use the default values and end up in a conflict situation.

Table 4.3.: Default Honeynet configuration

Component	**Identifier**	**Default value**
General	Honeypot number	2
	IP-range	192.168.0.0
	DNS-server	217.237.150.97
	Gateway	192.168.0.11
Honeywall	Management IP	192.168.0.100
	Management network	192.168.0.0/24
	Gateway	192.168.0.11
	DNS-Server	217.237.150.97
Redhat Honeypot	Hostname	Starbug
	IP	192.168.0.101
	Macaddress	52:54:00:12:34:59
FreeBSD Honeypot	Hostname	Apollo
	IP	192.168.0.102
	Macaddress	52:54:00:12:34:5a

- **Value dependencies**
  Some values, i.e. IP-addresses and hostnames, will be usable only once. The controller will check for these values to be unique in the Honeynet and, on finding an equality, ask the user to change one or more of the values.

After the configuration is done the controller enters the second stage.

Stage 2: Startup

In this stage no user interaction is possible. The controller will now write out the previously defined configuration values to the appropriate files and then start the Honeynet. Listing 4.1 shows an excerpt from the sourcecode with the specific steps to start the honenet.

Listing 4.1: Excerpt from HoneyController.c

```
void start_Honeynet(Honeynet *net){
        int i;
        char commandstring[maxcommandlen];
        FILE *pidfile;

        printf ("Starting the Honeynet. It might take some time to \
        load the systems.........\n");

        [...]

        printf ("Creating configuration images.....\n");
        writeout_Honeywall_conf(net);
        writeout_Honeypot_conf(net);

        printf ("Starting the network......\n");
        start_network();

        printf ("Starting Honeywall.....\n");
        if (start_Honeywall())
                net->Honeywall.started = 1;

        printf ("Starting Honeypots.....\n");
        if (start_Honeypots()
                net->Honeypots.started = 1;
        [...]
}
```

In this case all components have been reconfigured and thus all configuration values must be written to new configuration images before starting. In general the startup procedure of the Honeynet is as follows:

1. Create the necessary copies of the configuration images and write out the configuration values if necessary.
2. Bring up all real network devices and network bridges
3. Start the data capture and data controll mechanisms of the Honey-DVD
4. Start the Honeypots

After these steps are completed the Honeynet is running and ready to work.

Stage 3: Runtime

After the Honeynet is started the controllers job is to provide some basic controll mechanisms to maintain the Honeynet. The provided funktions are:

- Reconfigure a Honeypot (only additional services, no ip reconfiguration)
- Configure and start an additional Honeypot (includes restart of the Honeywall and hence short brake in the external connection of the Honeynet)
- Restart the complete Honeynet with current configuration
- Stop the Honeynet for complete reconfiguration
- Stop the Honeynet and shutdown the Honey-DVD

Additional functionalities like data analysis are only available outside of the controller and very limited due to the fact that the whole Honey-DVD system is running in the real machines' memory and hence the possibilities of storing great amounts of data are restricted. The Honey-DVD Controller provides possibilities to export captured data like IPTables-logs to a remote location on the net while Sebek and Snort are both capable of exporting their data to SQL-Servers themselves. Nevertheless, some capabilities are available on the Honey-DVD as well:

- **Iptables monitor**
  As described in chapter 3.1.1 the GRML live Linux CD provides an IPTables monitor which shows all currently active inbound and outbond connections.
- **Honeypot snapshots**
  As can be seen in listing 4.1 QEMU is started with the option *-snapshot* which causes it to use temporal files for storing changes and never write anything to the original image files. Nevertheless QEMU allows to save the current status of the guest system to any specified media.
- **Mail information**
  By using swatch [5] it is possible to send an e-mail notification to the system operator if any suspicious activity on the Honeynet is logged to the Honey-DVDs log base.

4.2. Implementation analysis

Although the first layout was working quite well there are some problems and drawbags inherent to this design that are not acceptable for the Honey-DVD.

4.2.1. Problems of the implementation

To analyse the quality of the first implementation it is necessary to classify the occurring problems into at least two categories.

Main problems

This category contains all those problems which are restricting the possible applications of the Honey-DVD and thus are importand to be solved. Gladly there are only two issues which are of such an importance:

1. As described in chapter 4.1.1 the Honeynet is operating in NAT-mode. Thus the IP-range of the Honeynet must be a different network from the external network. In bridging-mode it would be possible to choose the IP-range of the Honeynet completely without such restrictions.
2. The Honeynet Project [10] uses and propagates the Roo Honeywall CD-ROM [20] as the standard Honeywall setup for their networks. In future versions it is planed to use Roo as a means of distributed data collection by having one Roo-system gather data from multiple Honeynets. Thus being compatible to this efforts will, from now on, be an additional requirenment to the Honey-DVD.

Secondary problems (Fingerprinting)

In chapter 4.1.2 the Honey-DVDs method for configuring the Honeypots was described. Due to these layout it is possible to easily configure the Honeypots before starting them, but the necessary interference with the standard configuration methods of the Honeypots operating systems causes the issue of fingerprinting.

Fingerprinting means, that an adversary, who knows about the structure and key elements of the Honey-DVD, can look for these things to identify the Honeynet. One great problem in terms of fingerprinting is, that the Honey-DVD is absolutely static. All Honeypots in a Honeynet setup based on the Honey-DVD will use the same base images. Hence there allways will be things one can look for:

- **Configuration files**
  The configuration files and additional harddisks will be easy targets for fingerprinting. One can either look for the particular symlinks, the centralised stored configuration files, or just the harddisk device.

- **Available services**
  Since the Honey-DVD should allow to configure and deploy multiple Honeypots from the same image all services must be available for activation on the base Honeypot image. On an active Honeypot only some of this services will be running, but all other services are still available for activation. An adversary will only have to look for a list of installed services to fingerprint the collection of services available on a Honeypot.

- **Network timing**
  Since the network structure of a Honeynet based on the Honey-DVD will allways be the same and the performance of the single Honeypots is not independent of the other Honeypots it may be possible to find some unique reactions, for example in the network timing, to specific commands given to a Honeypot. By identifying these reactions it would be possible to fingerprint the Honeynet and the Honey-DVD.

4.2.2. Possible solutions

Solving the main problems is a task of some complexity because the solutions to the single problems are interfering with each other:

Solving the main problems

The following solutions for the first problem were possible:

- One way to solve the problem is to find a way of treating the Honeynet bridge as if it was a standard network interface and thus being able to use the Roo Honeywall scripts[2], and thus solving the second problem, nearly without any modifications. But the only way to connect two bridges would be by using a third program which provides two virtual network interfaces to create a tunnel between the bridges.

- Another possibility is to reimplement the firewallwall script to be able to manage several internal interfaces. But the necessary changes to the firewall script would be quite complex and the compatibility to Roo could not be guaranteed.

With regard to the issue of adding Roo compatibility to the Honey-DVD, the best solution would be to directly use the Roo packages provided by the Honeynet Project.

[2]The single components of Roo are available as RPM-packets at `http://www.honeynet.org/tools/cdrom/roo/repo/`

But there is another problem:

The GRML system is based on Debian and thus the native packet formate is DEB. Although it is possible to convert one formate to another by using tools like *alien* the innstallation scripts of the packages would still be designed for a Fedora system. This issue is also shortly discussed in [20], but postponed to future work.
To change to a Redhat or Fedora based live Linux distribution for adding the Roo support to the Honey-DVD would solve this issue, but, since the support for NAT-routing has been removed from the Roo Honeywall and is no longer supported by the Honeynet Project, the bridging problem must still be solved first.

A way of solving both problems is to add another virtual machine to the network on which Roo will be installed. By virtualising the Honeywall also some more flexibility due to modularisation will be added to the Honey-DVD, but possible consequences, like the performance loss due to virtualisation, will have to be analysed.

How to prevent Fingerprinting

The problem of fingerprinting can not be solved due to the allready mentioned static nature of the Honey-DVD. Nevertheless one can try to make the fingerprinting as hard as possible. In the case of the modified configuration procedures and the additional images a possibility to achive this is, to add a script to the Honeypots boot procedure that executes the following steps:

1. Replace the symlinks with the real files
2. Delete the files on the configuration harddisk (i.e. override with zero)
3. Unmount the configuration harddisk
4. Remove the mount entry from */etc/fstab*
5. Delete the configuration folder
6. Selfdelete the cleanup script

This procedure can not prevent the scanning of the existing devices, but it helps masking the changes and reduces their obviousness.

In the case of the installed services different measures could be taken:

1. **Remove the inactive services after booting the system**
   This would be quite complex, since it would mean to remove the binaries as well as all documentation files, log files and other components installed with the service.

2. **Restrict the services**
   Another solution would be to restrict the set of available services to mainly the services available in the base distributions of the Honeypots operating systems. I.e. Services available in Redhat 8 and FreeBSD 5.3. But this would restrict also the possible number of different kinds of honeypots that can be deployed.

4.3. The current version

Based on this analysis the current version of the Honey-DVD was implemented.

4.3.1. The revised virtual Honeynet

The Honeynet layout implemented in this version of the Honey-DVD follows the previously discussed idea to solve both of the main problems at once. By using the standard Roo distribution as an additional virtual machine, not only the compatibility but also the bridging problem can be solved.

New network layout

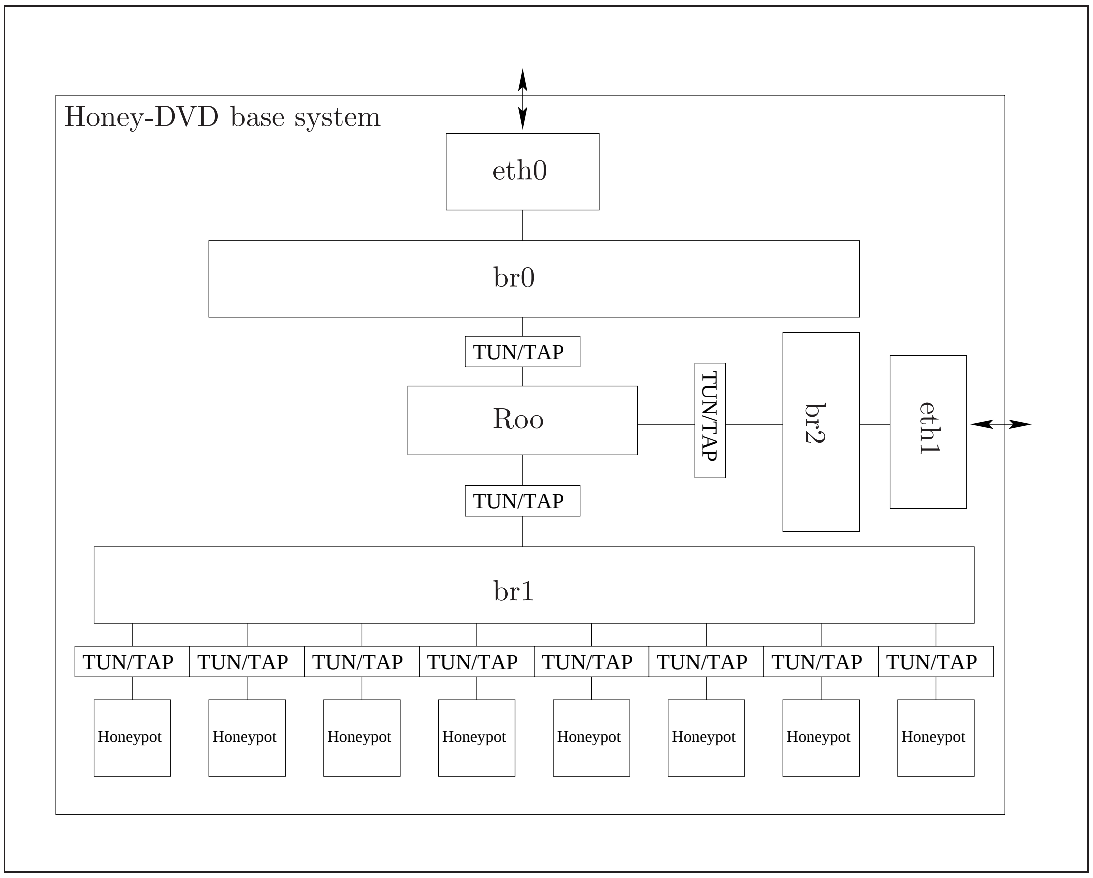
The addition of the Honeywall machine results in some grave changes in the network layout of the Honey-DVD which is shown in figure 4.3.

Again the interfaces *eth0*, *eth1* and *eth2* are used for external, internal and management connections. The additional network bridges *br1* and *br2* are used to connect the external and management interfaces of Roo to the external interfaces of the real machine, while the old bridge *br0* will be used to connect the Honeypots to Roo's internal interface.

The Roo Honeywall

The Roo Honeywall CDROM [20] was designed to be an easy to install solution for Honeynet controll. Unlike the Honey-DVD it is installed to a harddisc and after some basic configurations will be a complete system implementing a Honeywalls capabilities of data controll, data capture and some features for furthor analysis.
Once running it can be monitored and controlled via a web interface called Walleye

Figure 4.3.: Network layout of the Honey-DVD (current version)



and thus is a quite optimal solution for an easy to maintain Honeynet. One drawback of Roo in respect of usability in the Honey-DVD is, that the manual [14] states the minimal requirement of disc space to be 5GB for testing purpose and 10GB for productive usage. As a result to this it was necessary to change the medium for the Honey-DVD to be a Double-Layer-DVD with a capacity of 8.5GB. But also on this larger medium it was only possible to use a 4GB image for the Honeywall due to available disc space. The consequences of this intrinsically to small image will be discussed in chapter 6.

4.3.2. Changes to the Honeypots

In the current layout the Honeypots are quite unchanged. The single change worth mentioning is the export of the FTP and Apache HTTP directories to the configuration image, which opens up the possibility to easy change the contents of the Honeypots websites and downloadable files before the honeypot is started and gives a meaning to the additional harddrive with respect to fingerprinting.

4.3.3. The Honeynet controller (second version)

For an exact description of the new controller please refere to the documentation chapter 5. At this point it should suffice to describe the main changes between the first and second implementation of the Honeynet controller.

- From a developers point of view the change from C to C++ in the used programming language is one of the biggest changes. By handling the single Honeypots as objects instead of simple C structures without any encapsulation it was not only possible to drastically reduce the code complexity, but also to increase the possibilities for further development without having to rewrite most parts of the code.
- Another big change is to revise the single steps an possible configuration changes the user can make to guarantee the best user friendliness without getting to complex.
- A minor change is the addition of some features like the possibility of stopping and reconfiguring single Honeypots without influencing the other systems, or the possibility of using an external Honeywall instead of the Roo Honeywall contained in the Honey-DVD.

4.4. Summary

The implementation of a prototype of the Honey-DVD was successful.
After analysing the drawbags of this implementation the necessary changes for the next version were decided. Issues that had to be solved were the inability of the Honey-DVD to use a network bridge for the connection between the internal and external network, and consequential tie to use NAT-routing in the firewall.
The compatibility to the Honeynet Projects new Honeywall CDROM, called Roo, was also not given and since this would be quite important it was declared as an additional

requirenment to the Honey-DVD.
Both problems were solved by virtualising the Honeywall wich also provided a greater modularity for the complete system.
Also the minor problem of fingerprinting was discussed and, due to the inevitability of this problem, countermeasures were found.
Finally the current version of the Honey-DVD was implemented, incorporating the results of the analysis.

5. Honey-DVD documentation

Now it is time to take a look at the Honey-DVD as a whole and discuss its behaviour and usability from the system bootup to the running Honeynet and finally the shutdown. This chapter will not be a users manual in the usual sense, but will closely follow the sequence of different steps a user can or must take to maintain a Honeynet based on this work.

5.1. Honey-DVD bootup

When booting from the Honey-DVD the fist thing that will happen is the appearance of the welcome screen. If the user does nothing the process will continue after a short time and the system will be booted. Nevertheless the user may choose from some options, most of them inherited from the original GRML-CD. Among many others the main features here are:

- Start memtest86
- Check integrity of the Honey-DVD files
- Set the framebuffer mode to be used for text console
- Set the keyboard layout for the Honey-DVD base system

If no special option is chosen the system will start the GRML-kernel with its normal boot sequence. It will first detect the Honey-DVD sourcedrive and continue with the hardware autodetection while installing the base system into a ramdrive.
After the basic boot routines are completed and runlevel two has been reached the following base setup of the ttys will be available:

- **tty1 to 3:**
  Root console running zsh.
- **tty4:**
  From this console the x-window system will be started with the user *honeydvd*.

- **tty5 and 6:**
  These ttys will provide a console for the user *honeydvd*.
- **tty7 and 8:**
  Tty 7 and 8 are reserved for the x-server output. The Honey-DVD will use tty 8 for the graphical x-server output.
- **tty9:**
  A normal login prompt.
- **tty10:**
  This tty shows the current IPTables state.
- **tty11:**
  Table of running processes.
- **tty12:**
  Current syslog messages.

The x-server at tty4 (output on tty8) will start with Windowmaker, a very slim window manager which is absolutely sufficient for the Honey-DVD. The autorun functionality of Windowmaker is configured to start the Honey-DVD Controller program which will be used for the further configuration process of the Honeynet.

5.2. Using the Honey-DVD Controller

The Honey-DVD Controller is a program designed for configuring and maintaining the Honeynet. When started, it first brings up the three network bridges described in chapter 4.3.1, connects the external interfaces *eth0* and *eth1* to the respective bridges and then prompts the user for the next steps:

- **Start the Honeynet in default mode**
  If this option is chosen the Honeynet is started in a predefined configuration. The basics of this configuration were already described in table 4.3. More details can be found in chapter 5.2.1.
- **Customise the Honeynet configuration**
  This option allows the user to customise the most important aspects of the Honeynet like Honeypot number, IPs and services to start.
- **Shutdown the Honey-DVD**
  This opition will end the Controller and shutdown the system.

5.2.1. The default mode

If the system is started in its default configuration the Honey-DVD Controller will call the following default script:

```
#!/bin/sh

#start honeywall
echo "Starting Honeywall Roo....."
/usr/local/bin/qemu -snapshot -macaddr 52:54:00:12:34:56 \
-n /cdrom/Images/qemu-ifup-br-wall -nics 3 \
-hda /cdrom/Images/RooBase.img \
-hdb /cdrom/Images/Roo.img &
sleep 5

#start honeypots
echo "Starting Redhat Honeypot....."
/usr/local/bin/qemu -snapshot -macaddr 52:54:00:12:34:59 \
-n /cdrom/Images/qemu-ifup-br-pot -hda /cdrom/Images/Redhat.img \
-hdb /cdrom/Images/Redhat.conf.img &
sleep 5

echo "Starting FreeBSD Honeypot....."
/usr/local/bin/qemu -snapshot -macaddr 52:54:00:12:34:5a \
-n /cdrom/Images/qemu-ifup-br-pot -hda /cdrom/Images/FreeBSD.img \
-hdb /cdrom/Images/FreeBSD.conf.img &
sleep 5
```

This script starts the Honeywall and two Honeypots with the images contained on the DVD. It is also a good example of how the virtual machines will be started in general:

- The option `-snapshot` is used to tell QEMU that all images are read only and it should use a temporary file for saving all changes of the file systems.
- `-macaddr` is used to define the macaddress of each Honeypots network interfaces. By default QEMU uses the macaddress defined here as the address of the first interface and increases it by one for every additional network interface. Since the Honeywall will have three network interfaces the first macaddress for a Honeypot will be three more than the Honeywalls base macaddress.

- The `-n` option defines the configuration script for the TUN/TAP interfaces. This script configures what shall be done with the virtual network interfaces after they are available. In the case of the Honeypots they will be started and added to the networkbridge *br1* while the script for the Honeywall just brings the interfaces up.
- The next command for the Honeywall is the `-nics` option which just defines the number of virtual network interfaces.
- The last arguments `-hdX` are defining which image file should be used as which harddrive in the virtual system. The default boot device is *hda*.

The sleep timers after each qemu command are introduced not only to allow the user to see the output of the starting virtual machines, but also to prevent certain race conditions which could possibly occur with the result, that the numbering of the virtual network interfaces is broken. This would cause problems because the Honey-DVD Controller expects the Honeywall to use the interfaces *tun0*, *tun1* and *tun2* and will add those interfaces to the according network bridges automatically. *tun0* is expected to be the external interface, *tun1* the internal and *tun2* the management interface.

After the execution of the default start script is completed the Honey-DVD Controller will proceed to the runtime menu described in chapter 5.2.3.

5.2.2. Customising the Honeynet

The Honey-DVD Controller gives the possibility to customise the Honeynet before starting. It allows to change the configuration of the Honeywall and Honeypots.

Changing the Honeywall configuration

The Roo Honeywall has a vast amount of configuration options. The Honey-DVD Controller allows to customise some of the more basic features while leaving the more complex ones at default[1] state. This is acceptable since the Walleye interface, described in chapter 5.3.1, allows a complete reconfiguration of all values if needed. Nevertheless for future development the Honey-DVD Controller was built in a way that allows adding or removing configuration options without any problem.
The values which can be customised in the Honey-DVD Controller are:

- The IP address of the Honeywalls management interface.

[1]The detailed default Honeywall configuration can be found in the appendix A.1

- The Netmask of the Honeywalls management network.
- The gateway the Honeywalls management interface will use for outbound communication.
- The DNS-server the Honeywall will use.
- The IP-address or IP-range of the clients allowed to connect to the Honeywall from the outside.
- Should the Honeywall alert the administrator via e-mail if suspicious activities are detected?
- In case the answer was yes: Which e-mail address should be informed?
- Should the SSH-daemon be started?
- Again if the answer was yes: Should a remote connection of the user *root* be allowed?
- The public IP-addresses of the Honeypots.
- The DNS-server the Honeypots are allowed to contact without any connection rate limit.
- The IP-range of the Honeynet.
- The broadcast address of the Honeynet.

An alternative to reconfiguring the Honeywall is to set the Honeywall to be external. In this case the virtual Roo system will not be started and the external network interface *eth0* of the base system will be added to the Honeynets network bridge directly. This alternative should be chosen if a Honeywall is already running on another system in the network an the Honey-DVD is used to add Honeypots to the already existing Honeynet.

Changing the Honeypot configuration

This feature allows the user to reconfigure the Honeypots. The first thing he could do is to set the number of honeypots to a different value. The minimum is one, while the maximum possible number of honeypots is set to five in this Version of the Honey-DVD Controller. If the user chooses to increase the number of Honeypots he will be prompted to configure the additional Honeypots.
Another option the user might choose is to reconfigure a single Honeypot of those

already existing in the Honeynet.
Independent of his choice, if he gets to the Honeypot configuration these are the values he will have to configure:

- The Honeypots hostname.
- The domainname of the domain the Honeypot will be in.
- The IP-Address of the Honeypot.
- The IP-Address of the Honeypots network.
- The according netmask.
- The standard gateway used by the Honeypot.
- The DNS-server the Honeypot will use.
- The services which should be started on the Honeypot.

In this version of the Honey-DVD the available services are still restricted to an FTP- and HTTP-server for testing purpose of the different possibilities to start these services on the Honeypots. But for a production release of the Honey-DVD more services can be added to the Honeypots easily, while the necessary changes to the Controller are minimal.

5.2.3. Starting and maintaining the Honeynet

After the configuration is done the Honeynet is started. The single steps taken during the start process are strongly dependent on how the network was configured.

- If the configuration wasn't changed the system is started with the default script described in chapter 5.2.1.
- With a customised configuration, the Honey-DVD Controller will first start the Honeywall and connect its interfaces to the appropriate network bridges before starting the Honeypots one by one.
- If the Honeywall was deactivated due to an existing external Honeywall, its start is skipped and the external interface added to the Honeynet bridge before the Honeypots are started.

Virtual machine start sequence

The start sequence for every virtual machine, independent of its functionality in the Honeynet (i.e. Honeywall or Honeypot), is divided into four parts:

1. Copy the default configuration image of the according system to `/home/honeydvd`.
2. Write out the new configuration values to the image.
3. Start the virtual machine.
4. Retrieve the virtual machines *process identifier* (PID) form a pid-file[2].

There might be some minor differences in the exact execution of these steps dependent on the started system. For example, to write out the configuration file for the FreeBSD system, at first the file must be created outside of the image and then moved to it by a `sudo` command due to write restrictions on the `msdos` filesystem.

Controller functionality at runtime

After the Honeynet is started the Honey-DVD Controller will proceed with the runtime mode. In this mode the user will have the following possibilities:

- Restart a single Honeypot.
- Stop a single Honeypot.
- Stop, reconfigure and restart a single Honeypot.
- Add a Honeypot to the network.
- Restart the Honeynet with the current configuration.
- Stop the Honeynet and return to Configuration menu.

The first four options will only be available if a customised Honeynet setup is started. In the defaultmode only the last two options can be chosen. This is due to the steps that are taken according to single honeypots.
Since all virtual machines are running from read only images it is safe to just kill the QEMU process supporting the machine to stop it without the risk of corrupting the file systems. That's why the PID was retrieved in the startup sequence. If started

[2]QEMU is able to generate a pidfile containing its PID if told so via the commandline arguments

from the default script no PID for single Honeypots is available and hence only the complete Honeynet may be restarted. Of course it would have been possible to retrieve the PIDs of the virtual machines from the default script, but one of the main reasons for using this script instead of letting the Honey-DVD Controller start the Honeynet is to be independent of it if default mode was chosen. The advantages of this design will be discussed in chapter 5.3.3.

5.2.4. Honey-DVD shutdown

In some of the Controller's menus there will be the possibility to choose to shutdown the Honey-DVD. If this option is chosen the Honey-DVD Controller will at first stop all Honeynet components, then give the `halt` command to the system and terminate itself. After this the GRML shutdown sequence will start, do all necessary steps and finally prompt the user to remove the Honey-DVD from the DVD-drive before stopping the system.

5.3. Possibilities besides the Controller

The Honey-DVD Controller is not the only means to maintain the Honeynet. It can be seen as the basis for setting up the system, while more detailed operations are done with other tools.

5.3.1. The Honeywall interface Walleye

Walleye is a Webinterface designed by the Honeynet Project [10] to maintain the Roo Honeywall. It is an easy usable tool not only for the administration but also for data analysis. On the one hand it allows the user to reconfigure the complete Honeywall way beyond the basics configured in the Honey-DVD Controller. On the other hand it also allows the user to monitor the Honeynets activities and evaluate the collected data. A more detailed description of the possibilities of Walleye can be found in the Online User's Manual [14] of Roo.

5.3.2. The QEMU console

QEMU allows the user to switch to a console by pressing *strg-alt-2*. In this console the user has different possibilities. The most useful commands are:

- `commit`
  This command is used to write all changes back to the images. In case of the

Honey-DVD write errors will occur on the images contained in the DVD, but it is possible to write changes back to the configuration image and thus use it to export logged data.

- `savevm`
  Using this command allows the user to save the current state of the virtual machine to a file.
- `loadvm`
  `loadvm` restores the state of a virtual machine from a file.

The complete list of commands can be found at the QEMU website [4].

5.3.3. The Honey-DVD base system

The base system of the Honey-DVD also provides some additional functionalities through the scripts available in the `/home/honeydvd/scripts/` directory.

One quite important issue is the case in which the Honey-DVD is started on hardware with only one network interface. Following the design of the Roo Honeywall the Honey-DVD expects a system with an additional interface to manage the Honeywall. If this interface is missing the script `CombineManagement.sh` will change the layout of the virtual network and add the Honeywall's management interface to the external network bridge of the Honey-DVD.

Another possibility is to change the default configuration of the Honeynet. Additional Honeypot images from other sources may be added to the script `honeynet.sh` without any interference to the Honey-DVD Controller.

5.4. Important notes

Although the Honey-DVD is able to start a complete Honeynet setup without more user interference than selecting the default start method it is quite important that the user is aware of some things and takes some steps directly after the Honeynet is started:

5.4.1. Passwords

All passwords in the Honeynet are set to default values. It is strongly suggested to change these passwords after starting the Honeynet.

- The root password for the Honeypots as well as the Honeywall is *honey*.
- On the Honeywall an additional user named *roo* is available whose password is also *honey*. This user and password are also used in the Walleye interface.
- Every Honeypot has the user called *user* with the password *honey0815*.

5.4.2. Testing release

The current version of the Honey-DVD is still a testing release than a version for productive usage. Hence the Honeynet is not to be put in place as is. For example the Sebek sources are still visible on the Honeypots and must be removed or hidden before the system can be deployed.

6. Performance of the Honey-DVD

The next step after building the current version of the Honey-DVD is to test and analyse its behaviour on different systems. Based on the results it should be possible to measure the usability of the implementation in real life scenarios and gather knowledge about the necessary enhancements to make the Honey-DVD a feasible solution for the task of creating an easy to use application for setting up and maintaining Honeynets.

6.1. Performance tests

A series of tests was done to measure the performance of the Honey-DVD. These tests were applied to different systems to get an overview which components are critical for the usability of the implementation.

6.1.1. Test setup

It was of great importance, that the only variables in the applied tests would be the components of the system running the Honey-DVD. Testing in completely different network setups would have caosed too man interferences and thus the test results would not be comparable and quite useless for this purpose. Hence the following test setup was used:

- The test was always done with two machines.

  -The test machine running the Honey-DVD.

  -The testing machine performing the tests and gathering the results.

- The Honeywall management interface was added to the external network bridge as described in chapter 5.3.3

- Both machines were connected to a minimal network with a category 5 patch cable.

6.1.2. Applied tests

The tests applied to this setup should give an overview of the usability and behaviour of the Honey-DVD, and hence the local behaviour (i.e. times needed for single setup steps) must be included as well as the behaviour observed from a remote machine. To fulfil this, the following tests where performed:

1. Taking the booting time of the base system from Honey-DVD start till the Honey-DVD Controller is available.
2. Taking the time needed to start the Honeywall alone on the test system.
3. Taking the time needed to start the default configuration.
4. Taking the response time (ping) of a single Honeypot without the Honeywall or other active Honeypots.
5. Taking the response time (ping) of a single Honeypot in the default configuration.
6. Taking the response time of the Walleye interface of the Honeywall when no Honeypot is running.
7. Taking the response time of the Walleye interface of the Honeywall in the default configuration.

For testing purpose the Honeywall was configured to do an automatic reconfiguration after the boot sequence to gain additional information on this process. This was important to measure the performance loss mentioned in chapter 4.3.1.

6.1.3. Test results

As mentioned in chapter 6.1.1 the testmachine was the only thing changed for different test rounds. During the tests it became obvious that the tested systems can be categorised into three classes. Hence only the results for the reference systems will be presented here with further information, while a complete but compact list of the results can be found in table 6.1.

Test machine class 1

This class contains the memory restricted machines with average processor capabilities. The reference system was a one year old laptop.

System specifications

- **CPU:** Intel Pentium M
- **CPU-Speed:** 1,6GHz
- **RAM:** 512MB
- **FSB:** 400MHz
- **DVD-Drive speed:** 8x

Test results:

- **Test 1:** 3min Timer was started when bootsequence was activated and stopped as soon as the Honey-DVD Controller was available.
- **Test 2:** 19min This total time contains the startup time of the Honeywall's base system which was 13 minutes and 6 minutes needed for a the reconfiguration of the Honeywall.
- **Test 3:** 21min The time for the complete system startup was higher then for the startup of the Honeywall alone. The Honeypots finished their startup sequence after 4 minutes.
- **Test 4:** 70ms This is an average value of 400 ping requests. At the first ping request, and then in periods of 50 ping requests, the time was over 200ms due to the need of DVD access.
- **Test 5:** 80ms The timings were nearly the same as in the stand alone test but the amount of lag due to DVD access was slightly increased.
- **Test 6:** 2min The time was taken from sending a query until the following webpage was completely loaded. Since the data transfer of the webpages alone was very quick mostly the whole time seemed to be used for calculation.
- **Test 7:** 2,5min This time was taken while the Honeypots were activated but not doing anything. Even the presence of the Honeypots seems to influence the Honeywall's performance.

Test machine class 2

The reference system for this class is a desktop PC system. It represents a class of average home PC systems with a relatively big amount of memory.

System specifications

- **CPU:** Athlon-XP 1900+
- **CPU-Speed:** 1,6GHz
- **RAM:** 1,0GB
- **FSB:** 266MHz
- **DVD-Drive speed:** 16x

Test results:

- **Test 1:** 3min
  Timer was started when bootsequence was activated and stopped as soon as the Honey-DVD Controller was available. No change to previous test series.
- **Test 2:** 14min
  The startup of the Honeywall's base system took 11 minutes while the reconfiguration of the Honeywall itself took 3 minutes.
- **Test 3:** 14min
  The startup time of the Honeynet was equal to the startup time of the Honeywall alone, both Honeypots had finished their starting sequence after 2 minutes.
- **Test 4:** 60ms
  This is the average timing of 400 ping requests. The first ping had a value of over 200 milli seconds due to DVD access.
- **Test 5:** 60ms
  Although some timings seemed slightly increased the average value was still 60ms.
- **Test 6:** 1min
  The time was taken from sending a query until the following webpage was completely loaded.

- **Test 7:** 1min
  This time the measured timings for the standalone Honeywall and the default setup were the same.

Test machine class 3

The third class is the class of modern high end PCs. The representative of this class is a new desktop PC.

System specifications

- **CPU:** Athlon 64 3200+
- **CPU-Speed:** 2GHz
- **RAM:** 2GB
- **FSB:** 1GHz
- **DVD-Drive speed:** 16x

Test results:

- **Test 1:** 1min
  Again no change to previous test series.
- **Test 2:** 6min
  The startup of the Honeywall base system took 4 minutes, the reconfiguration 2 minutes.
- **Test 3:** 6min
  The starting sequence of the Honeypots took 1 minute.
- **Test 4:** 60ms
  The ping results were not different from the previous test series. Again the first ping was high due to DVD access.
- **Test 5:** 60ms
  No change to the standalone behaviour.

- **Test 6:** 30sec
  The time was taken from sending a query until the following webpage was completely loaded. In case of the login page the time was a bit shorter then the time needed for database accesses later.
- **Test 7:** 30sec
  No change to standalone test.

6.2. Analysis of the test results

Table 6.1 shortly summarises the results of the tests above.

Table 6.1.: Testresults

	Type 1					**Type 2**			**Type 3**	
Test 1 (time in min)	3	3	3	3	3	3	2.5	3.5	1	1.5
Test 2 (time in min)	19	20	17	23	21	14	13	15	6	7
Test 3 (time in min)	21	24	18	27	23	14	14	15	6	7
Test 4 (time in ms)	70	70	70	70	70	60	60	65	60	60
Test 5 (time in ms)	80	80	75	80	80	60	60	60	60	60
Test 6 (time in min)	2	2.5	2	3	2	1	1	1	0,5	0,5
Test 7 (time in min)	2.5	2.5	2.5	3	2	1	1	1	0,5	0,5

One thing, that is equal in all systems is, that the Honeywall is the all-dominant part of the Honey-DVD setup. It is the virtual system which takes the longest period of time to start and perform any activity and thus determines the overall performance of the Honey-DVD nearly independent of the running Honeypots. Thus another test was applied to measure the performance loss due to the decision to virtualise the Honeywall:

The Roo Honeywall was installed to the reference system of class one and the needed time for reconfiguration after the boot sequence was taken like in the tests applied to

the Honey-DVD. The result was a time of approximately two minutes.
Comparing this time to the six minutes, measured on the Honey-DVD, the performance of the Honey-DVDs Honeywall is about three times slower than on a real system. But given the fact that an implementation on the base system of the Honey-DVD would also suffer from the unavailability of harddisk space and hence would again have a reduced performance, this loss is acceptable in this implementation.

Another importand result is that the available memory in the real system running the Honey-DVD seems to be a bottleneck. Although the Honey-DVD is able to run on systems with 512MB RAM (testing class 1) it is quite obvious that the performance and usability of the Honey-DVD on this system is not really acceptable. Even the systems in testing class two with 1GB RAM needed a lot of time to start the default network and had a one minute delay in the Walleye interface.
The tests on the high end machines may be interpreted as a continuation of this pattern. The following calculation also supports the conclusion that memory must be the critical component:

6.2.1. Worst case scenario

The worst case scenario of the Honey-DVD would be a scenario in which nearly all virtual systems were modified in a way that almost the complete data of there harddrives must be stored in the memory[1].

- In the default configuration two Honeypots with an image size of 1,5GB are running. This results in a memory usage of 3GB.
- The Honeywall has an image size of 4GB.

These images would use a total of 7GB RAM in the worst case. Another GB would probably be needed for the base system and calculation purpose and thus, to guarantee the full functionality of the Honey-DVD with the highest possible performance in the worst case scenario, at least 8GB of RAM would be needed.

According to these thoughts it is quite sure that, although the CPUs of the class three systems were nearly twice as fast as the CPUs form testing class one and two, the biggest part of the better performance came from the, again doubled, RAM size.

[1]Unmodified data would be removed from memory if possible and reloaded from the DVD if needed

6.3. Summary

The performance of the revised implementation of the Honey-DVD was measured in this chapter with the result, that the usability of the Honey-DVD is strongly dependent on the available amount of memory. The analysis of the worst case scenario emphasised that the Honeywall is the most critical component and thus the reduction of its memory usage would be a main goal for future development.

7. Conclusion and outlook

Within this work a system was developed which fulfils the requirements defined in chapter 1.2.1. The Honey-DVD is an easy to use method of deploying Honeynets without the necessity of installing anything to a harddrive. To achieve this, different components where analysed and tested regarding the requirements of this work.

The available live Linux distributions where analysed regarding the necessary base requirements of stability and security as well as additional features like the lightweightness of the system or the possibilities to install additional software and maintain an up to date status of the system. Finally the decision was made that a slim live Linux system based on the Debian distribution should be used for this work.

The next step was to decide about the virtualisation software which should be used to run the Honeypot systems. The different advantages and disadvantages of full system simulation and emulation of system behaviour were discussed and finally different possibilities of the latter were tested for usability. The final choice was in favour of QEMU, a small open source system emulator which is comparable to the commercial VMWare, which is used in the most Honeynet setups of the Honeynet Project.

After choosing two operating systems for the Honeypots the prototype of the Honey-DVD was successfully implemented on a 4.7GB DVD. This version was proof of the general possibility of a successful implementation but had some major drawbags in the deployment possibilities as well as in the compatibility to the standardised Roo Honeywall, distributed by the Honeynet Project.

The current version of the Honey-DVD solved those problems and stands as the result of this work. It was implemented on a 8.5GB Double Layer DVD and allows to deploy a fully functional Honeynet on nearly every PC capable of booting from a DVD. The deployed network is easy to maintain and, due to the modular design of the network it is possible to use it either as a stand alone system or as an additional part of an already existing honeynet.

Nevertheless the performance analysis showed that the usability of this implementation is strongly dependant on the memory of the used hardware. Further development could explore possibilities to reduce the necessary amount of memory. Interesting ways of realising this would be:

- Using the upcoming remote logging capabilities of Roo. In this way it should be possible to reduce the size of the Honeywall image to a minimum while exporting the captured data to a remote location.
- Implement a Roo compatible Honeywall on the base system. Doing this, one would avoid the problem of fixed disc image sizes due to the dynamic nature of the live Linux memory management.

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A. Abbreviations

DVD	Digital Versatile Disc
IDS	Intrusion detection system
IDTR	Interrupt descriptor table register
PID	Process identifier
RPM	Redhat Packet Manager
RWTH	Rhein-Westfälische Technische Hochschule
SIDT	Store interrupt descriptor table register
SSH	Secure Shell
tty	Teletypewriter
VMM	Virtual Machine Monito

A. Default Honeynet configuration

A.1. Default Honeywall configuration (File excerpt)

```
############################
# Site variables that are  #
# global to all honeywalls #
# at a site.               #
############################

# Specify the IP address(es) and/or networks that are allowed
# to connect  to the management interface.  Specify any to
# allow unrestricted access.
# [Valid argument: IP address(es) | IP network(s) in CIDR notation | any]
HwMANAGER=192.168.0.0/24

# Specify the port on which SSHD will listen
# [Valid argument: TCP (port 0 - 65535)]
HwSSHD_PORT=22

# Specify whether or not to start SSHD at startup.
# [Valid argument: yes | no]
HwSSHD_STARTUP=yes

# Specify whether or not root can login remotely over SSH
# [Valid argument: yes | no]
HwSSHD_REMOTE_ROOT_LOGIN=yes

# NTP Time server(s)
# [Valid argument: IP address]
HwTIME_SVR=


############################
# Local variables that are #
# specific to each         #
# honeywall at a site.     #
############################

# Specify the system hostname
# [Valid argument: string ]
HwHOSTNAME=roo-honeywall

# Specify the system DNS domain
# [Valid argument: string ]
HwDOMAIN=localdomain

#Start the Honeywall on boot
# [Valid argument: yes | no]
HwHONEYWALL_RUN=yes

# To use a headless system.
# [Valid argument: yes | no]
HwHEADLESS=yes

# This Honeywall's public IP address(es)
# [Valid argument: IP address | space delimited IP addresses]
HwHPOT_PUBLIC_IP=192.168.0.101 192.168.0.102

# DNS servers honeypots are allowed to communicate with
# [Valid argument: IP address | space delimited IP addresses]
HwDNS_SVRS=217.237.150.97

# To restrict DNS access to a specific honeypot or group of
# honeypots, list them here, otherwise leave this variable blank
# [Valid argument: IP address | space delimited IP addresses | blank]
HwDNS_HOST=

# The name of the externally facing network interface
# [Valid argument: eth* | br* | ppp*]
HwINET_IFACE=eth0

# The name of the internally facing network interface
# [Valid argument: eth* | br* | ppp*]
HwLAN_IFACE=eth1
```

```
# The IP internal connected to the internally facing interface
# [Valid argument: IP network in CIDR notation]
HwLAN_IP_RANGE=192.168.0.0/24

# The IP broadcast address for internal network
# [Valid argument: IP broadcast address]
HwLAN_BCAST_ADDRESS=192.168.0.255

# Enable QUEUE support to integrate with Snort-Inline filtering
# [Valid argument: yes | no]
HwQUEUE=yes

# The unit of measure for setting oubtbound connection limits
# [Valid argument: second, minute, hour, day, week, month, year]
HwSCALE=hour

# The number of TCP connections per unit of measure (HwScale)
# [Valid argument: integer]
HwTCPRATE=20

# The number of UDP connections per unit of measure (HwSCALE)
# [Valid argument: integer]
HwUDPRATE=20

# The number of ICMP connections per unit of measure (HwSCALE)
# [Valid argument: integer]
HwICMPRATE=50

# The number of other IP connections per unit of measure
# (HwSCALE)
# [Valid argument: integer]
HwOTHERRATE=10

# Enable the SEBEK collector which delivers keystroke and
# files to a remote system even if an attacker replaces
# daemons such as sshd
# [Valid argument: yes | no]
HwSEBEK=yes

# Enable the Walleye Web interface.
#[Valid argument: yes | no]
```

```
HwWALLEYE=yes

# Specify whether whether to drop SEBEK packets or allow them
# to be sent outside of the Honeynet.
# [Valid argument: ACCEPT | DROP]
HwSEBEK_FATE=DROP

# Specify the SEBEK destination host IP address
# [Valid argument: IP address]
HwSEBEK_DST_IP=10.0.0.1

# Specify the SEBEK destination port
# [Valid argument: port]
HwSEBEK_DST_PORT=12345

# Enable SEBEK logging in the Honeywall firewall logs
# [Valid argument: yes | no]
HwSEBEK_LOG=no


# Specify whether the dialog menu is to be started on login to
# TTY1
# [Valid argument: yes | no ]
HwMANAGE_DIALOG=yes

# Specify whether management port is to be activated on start
# or not.
# [Valid argument: yes | no ]
HwMANAGE_STARTUP=yes

# Specy the network interface for remote management.  If set
# to br0, it will assign MANAGE_IP to the logical bridge
# interface and allow its use as a
# management interface.  Set to none to disable the management
# interface.
# [Valid argument: eth* | br* | ppp* | none]
HwMANAGE_IFACE=eth2

# IP of management Interface
# [Valid argument: IP address]
HwMANAGE_IP=192.168.0.100
```

```
# Netmask of management Interface
# [Valid argument: IP netmask]
HwMANAGE_NETMASK=255.255.255.0

# Default Gateway of management Interface
# [Valid argument: IP address]
HwMANAGE_GATEWAY=192.168.0.11

# DNS Servers of management Interface
# [Valid argument: space delimited IP addresses]
HwMANAGE_DNS=217.237.150.97

# TCP ports allowed into the management interface.  If SSH is
# used this list must include the port SSHD is listening on.
# [Valid argument: space delimited list of TCP ports]
HwALLOWED_TCP_IN=22 443

# Specify whether or not the Honeywall will restrict outbound
# network connections to specific destination ports.  When
# bridge mode is utilized, a management interface is required
# to restrict outbound network connections.
# [Valid argument: yes | no]
HwRESTRICT=yes

# Specity the TCP destination ports Honeypots can send network
# traffic to.
# [Valid argument: space delimited list of UDP ports]
HwALLOWED_TCP_OUT=22 25 43 80 443

# Specity the UDP destination ports Honeypots can send network
# traffic to.
# [Valid argument: space delimited list of UDP ports]
HwALLOWED_UDP_OUT=53 123

# Specify whether or not to start swatch and email alerting.
# [Valid argument: yes | no]
HwALERT=no

# Specify email address to use for email alerting.
# [Valid argument: any email address]
```

```
HwALERT_EMAIL=root@localhost.localdomain

# NIC Module List - Set this to the number and order you wish
# to load NIC drivers, such that you get the order you want
# for eth0, eth1, eth2, etc.
# [Valid argument: list of strings]
#
# Example: eepro100 8139too
HwNICMODLIST=

# Blacklist, Whitelist, and Fencelist features.
# [Valid argument: string ]
HwFWBLACK=/etc/blacklist.txt

# [Valid argument: string ]
HwFWWHITE=/etc/whitelist.txt

# [Valid argument: string ]
HwFWFENCE=/etc/fencelist.txt

# [Valid argument: yes | no]
HwBWLIST_ENABLE=no

# [Valid argument: yes | no]
HwFENCELIST_ENABLE=no

# The following feature allows the roo to allow attackers into
# the honeypots but they can't send packets out...
# [Valid argument: yes | no]
HwROACHMOTEL_ENABLE=no

# Should we swap capslock and control keys?
HwSWAP_CAPSLOCK_CONTROL=no
```

A.2. Honepot configuration

A.2.1. FreeBSD 5.3 configuration

Table A.1.: FreeBSD 5.3 default system configuration

Varable	**Value**
defaultrouter	192.168.0.11
hostname	Apollo.localdomain
ifconfig_ed0	inet 192.168.0.102 netmask 255.255.255.0
inetd_enable	YES
keymap	german.cp850
linux_enable	YES
moused_enable	YES
scrnmap	NO
sshd_enable	YES

Table A.2.: FreeBSD5.3 default services started via initd

Service	**File**
ftp	/usr/libexec/ftpd
telnet	/usr/libexec/telnetd
tftp	/usr/libexec/tftpd
daytime	internal
time	internal
echo	internal
discard	internal
chargen	internal

A.2.2. Redhat 8 configuration

A.3. Sourcecode

The complete sourcecodes of this work are available on the CD included in this document.

Table A.3.: FreeBSD 5.3 additional default services

Service	**File**
HTTP	/usr/local/apache/bin/apachectl

Table A.4.: Redhat 8 default system configuration

service	**file**
Hostname	Starbug
Domainname	localdomain
IP	192.168.0.101
Default gateway	192.168.0.11
Broadcast address	192.168.0.255
Netmask	255.255.255.0
Network	192.168.0.0

Table A.5.: Redhat 8 default services

Service	**File**
HTTP	/usr/local/apache/bin/apachectl
FTP	/usr/local/sbin/proftpd