Comprehensive Anomaly Detection (CAD)

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Title: Comprehensive Anomaly Detection (CAD)  

Note: This paper assumes that the reader has a working knowledge of Linux administration, shell scripting, Perl programming and TCP/IP networking.  

Abstract  
A mid-size city in North Carolina had all of its servers and workstations directly connected to the Internet and was under continual attack (city administration, police department, fire department, water and power, etc.). With loss of service and data exposure as key concerns, the city was considering a set of traditional firewalls to mitigate the risk. An additional concern was that those firewalls could be compromised as well (without the city’s knowledge) and leave them just as exposed as before installing the firewalls. Coupled with the security risks was a practical issue of a limited municipal budget, which steered the solution towards the world of open source.  

When researching possible open source solutions, one utility stood out as an example of what we needed to accomplish: portsentry[1]. Portsentry[16] is a port-monitoring tool that is able to take action when a change occurs in the signature of a machine's ports. Put another way, if an intruder accesses a port that is not in the allowed port list, portsentry[16] can automatically add a packet filtering rule (among other responses) to block the intruder from any further connection efforts. Watching how portsentry[16] reacted led to the idea that we could build a set of firewalls that could monitor their own health once they were connected to the Internet. This monitoring went beyond the usual combination of Tripwire[25] and HID/NID systems and included the ability to take automated action in response to detecting a change in the known and expected state of each firewall. The actions were ranked by the severity of the detected change and could range from simple notification to network disconnect to full system shutdown. Several years after implementation, the firewalls have deflected a steady stream of attacks and in one case, a firewall took itself off the Internet when an ftp service was compromised, proving the value of the monitoring daemons.  

Before Snapshot  

Before beginning the project, the city was running Oracle on a HP9000 (HP/UX), accounting systems on IBM RS6000’s (AIX) and MIPS-based minis (RISCOS), Microsoft Exchange, primary/backup Domain Controllers and file servers on PC-based servers (Windows NT) and various applications on several hundred PC's running different flavors of Windows 95/98. PC's were networked via a mix of Microsoft networking and an aging Novell network. All of these machines were connected directly
to the Internet via an ISP-supplied router with each machine owning a static, external IP address. The city's intranet was a spider web of hubs and switches within buildings, bridges/frame-relay to connect some buildings and a private cable system (city-owned head-end unit) to connect other buildings.

Microsoft Windows-based machines were compromised on a daily basis via direct attacks (NT null-password attacks), email-delivered backdoors (Back Orifice) as well as a continual parade of virii and worms. Although there was no direct evidence that the AIX/HPUX/RISCOS machines were being hacked, anyone with access to the same wire as the city's subnet could have easily lifted a telnet login stream and logged in to those servers. Also at risk was the exposure of the police department's data to the rest of the city. In addition to wanting to isolate itself from the rest of the city, the police department was interested in establishing an independent, direct internet connection to the state's Justice department for access to online driving records and criminal records. With the city's security problems, however, the state would not allow the connection to be set up.

As an initial solution, the city asked their ISP to block external access to the usual Microsoft ports (137/udp, 138/udp, 139/tcp) as well as telnet (23/tcp) and Oracle (1521/tcp). The ISP assured the city that the ports were being blocked, but nmap[13] scans of the city's address space showed that the ports were still visible to the outside world.

At this juncture, the city elected to solve their problems without the ISP's help and a decision was made to install a set of firewalls.

During Snapshot

Building the firewalls consisted of installing GNU/Linux on PC-class hardware, configuring the Linux kernel[10], installing the Comprehensive Anomaly Detection (CAD) utilities and most important of all -- creating a complete signature of each firewall before ever connecting it to the internet.

1. Operating System (GNU/Linux) Installation

Three Dell PC's were purchased, each with 350 MHZ Pentium II CPUs, 64 MB of RAM, 8 GByte disks and two 3Com NICs. The Slackware[18] GNU/Linux distribution (Slackware v3.6, Linux kernel[10] 2.0.35) was installed on each PC. The kernel was configured to disable IP-forwarding and to only include those drivers necessary to support the installed hardware. All services except for ftp were disabled in /etc/inetd.conf and all daemons were disabled in the /etc/rc.d startup scripts except for named (DNS), sendmail[17] (SMTP), ssh and CERN[8] (HTTP proxy server). A TCP wrapper[24] was used for the ftp service. At the time these firewalls were built, named was still in the 4.7 source tree and susceptible to root compromise, so it was installed under /chroot/named and invoked via chroot. The firewalls are currently running the latest 9.X version of the BIND[6] source.
Since the firewalls were configured to be non IP-forwarding, there would be no way for PC's behind the firewall to surf the internet, so the CERN[8] http proxy server (v3.0) was installed. Although CERN[8] did not have the throughput proxy performance of SQUID[23] or Apache[22], it was selected due to its excellent security record. Recent changes to the way modern websites behave (Microsoft ASP-based servers, in particular) dealt a blow to CERN's[8] ability to proxy all pages and it was replaced with an Apache[22] proxy server from the Apache V1.3 source tree.

All routing on the firewalls is based upon static routes created at boot-time. No dynamic routing protocols (RIP, etc.) are installed. And although these firewalls were built some time ago, they have been kept current with the latest versions of the Linux 2.2 kernel[10], zlib[21], openssl[15], openssh[14], BIND[6], Apache[22], sendmail[17], wu-ftpd[20] and related utilities.

2. Network Topology

The city consists of two logical groups: the police department and everyone else. The network and firewalls were laid out as follows:

FW1 = Firewall between City and Internet
FW2 = Firewall between City and Police Department
FW3 = Firewall between Police Department and State Justice Department

Internet <> FW1 <> City <> FW2 <> Police Dept <> FW3 <> State Justice Dept.

3. CAD Installation

The CAD utilities were designed, written and tested over a several month period on an offline (not connected to the Internet) system. When they were complete, installation of the CAD system on the firewalls was accomplished by copying the CAD source tarball from a CD into the /tmp directory of each firewall. The tarball’s contents were extracted, creating the following subdirectories in the firewall's /root directory:

Directory          Functionality

fence/admin       This directory contains routines that are common to all the individual utilities (described below in this section), as well as a template for creating new CAD utilities. Definition of users, interfaces, firewall rules and responses to actions are all set in this directory. The files that require modification are listed below in sections 3.1 through 3.4.

fence/attr        This utility monitors the attributes of every file found in each of the directories found in the $PATH variable. Monitored objects include links, files, pipes, inodes and directories. At run time, discrepancies
are considered to be of SEVERITY_MEDIUM, resulting in the external NIC being taken offline after notifications are sent to users.

**fence/cops**  
This is the veteran COPS[9] utility. It checks directory and file ownership, groups and permissions from the vantage point of correct configuration for system data (/etc/passwd, /etc/groups, uucp setup, mail setup, ftp configuration, world writable files that shouldn't be, etc.). If you can make it through COPS, you're in pretty good shape.

**fence/daemons**  
This keeps track of which daemons are running, as well as the MD5[12] checksum of the in-memory image of each daemon. The /proc filesystem allows you to treat running executables as though they are disk images, allowing the comparison of the MD5 value of a true disk image against the in-memory /proc/PID#/exe image. Daemons that have been altered after being loaded are thus easily identified.

**fence/dev**  
The dev utility keeps track of the entries in the /dev directory structure, notifying the system when new devices appear or existing devices drop off. Changes to the /dev structure after boot time could indicate a serious breach.

**fence/diskspace**  
The diskspace utility keeps track of the amount of free diskspace, free memory and consumed swap space. Getting this utility set up takes some time as it is not trivial to figure out what the 'normal' memory usage is. This is typically a matter of setting limits, letting the diskspace utility trigger an alert, analyzing the alert and adjusting the limits again. It took several months to get this setting right on each firewall.

**fence/dirs**  
The dirs utility tracks the expected directory structure of the firewall, reporting on newly created and missing directories. The presence of a new directory is considered an indication of a breach.

**fence/files**  
The files utility works in the same way as the dirs utility, tracking the expected file contents of directories, reporting on new files and missing files. Unlike the dirs utility, which is pretty easy to set up, it took several months to get the false alerts written into the 'skip' file for this module. Once it was done, though, it became a valuable addition to the tool set.

**fence/fw**  
This directory contains the firewall 'fw.run' kernel packet-filtering setup utility and is described in section 3.1, below.

**fence/ftp**  
This utility keeps track of all files uploaded to the ftp server directories.
fence/kernel  This utility keeps track of the kernel run-level, setting an alert if the level changes.

fence/links Much like the CAD dirs and files utilities, this module keeps track of soft links, notifying when new links appear or existing links are deleted, both of which indicate breaches. In addition, it will notify when the hard object underneath a soft link is deleted (ie., bad soft link), again indicating a breach.

fence/logins The logins module keeps track of all unexpected logins by validating against a set of allowed userids and ttys. Exceptions are treated as malicious logins.

fence/logs This directory contains the 'logs' utility which monitors the size of files in the /var/log directory. Since each firewall is running a log rotation/truncate utility (home-grown, 'trim_all'), excessive logfile size is an indication of unwanted activity, signalling a potential breach.

fence/md5 This utility keeps a Tripwire[25]-like database of MD5[12] values for selected directories and files. The utility is driven by a set of tables that are created once at system generation time. Every 10 minutes, the MD5[12] values of every file in the database are checked against the database and exceptions are taken to be an indication of a breach. A 'replace.value' utility allows one or more files to have their MD5[12] values updated in the database when making approved changes to the firewall.

fence/ports The 'ports' utility watches all open server ports, validates them against a list of known ports and notifies when unexpected ports appear as server ports. There is also a 'skip' mechanism that lets the administrator use the lsof[11] utility to accept some transient server ports as non-malicious. The 4.7 BIND named daemon was notorious in this regard and generated quite a few false alerts when this utility was first installed. Netdate can also generate false alarms with transient server ports.

fence/rcommands This utility scans the entire drive for the presence of any r-prefixed commands. Although this appears to be a redundant utility, overlapping the CAD 'files' utility, this is different in that it scans the entire drive, while the 'files' utility scans a selected list of directories. In general r-prefixed utilities should not be anywhere on the system (rlogin, rdist, etc.).

fence/setuid This utility scans the entire drive for the presence of any new setuid commands. Although this appears to be a redundant utility, overlapping
the CAD 'files' utility, this is different in that it scans the entire drive, while the 'files' utility scans a selected list of directories.

**fence/snort**

This module runs snort[19] on every interface, archives the results every 12 hours and aggregates the activity into attack-report summaries. This utility currently is only used as an administrative reporting utility, but could easily be extended to use the CAD notify function as well.

Four files required customization for each firewall:

3.1 fence/admin/fw.run (kernel packet-filtering rules)

/fence/admin/fw.run is a bash script that employs a table-driven approach to configure the kernel's packet filtering rules. The tables are embedded within the script itself (see Appendix for full source) and are processed at run time by the script reading itself to determine addresses and ports. An example of a data table within the fw.run script is

```bash
_networks_clean() {
    # Field 1: IP Address block for interface
    # Field 2: Comment
    192.168.100.0/24 Intranet
}
```

The fw.run script requires the private IP address block of the clean-side intranet, the address block of the external NIC, as well as a list of the services that will be advertised on the firewall. The script itself contains extensive instructions on configuration.

3.2 fence/admin/nics (determines internal/external NICS)

The fence/admin/nics file is a list of the firewall's network adapters and identifies which adapter is the 'clean-side' NIC and which is the 'dirty-side' NIC. While it might seem that one could determine which is which at run time by using the RFC-1918 private addresses as a clue, that doesn't work when the firewall is a barrier between two private address networks. This is in fact the case for FW2 in the city's infrastructure. The nics file contains clear documentation of the record format for the data.

3.3 fence/admin/services (describes severity levels)

The fence/admin/services file is a list of all the scripts that will use the CAD system's notify function. Each line in the script contains the script name that will call notify, as well as an associated severity, described in full later in this paper. The services file contains embedded instructions on how to add entries. The services files is an important construct because it allows utilities that do not ship with the CAD system to also use the CAD's notify function. Again, this is also explained further on in this paper.
3.4 fence/admin/users (describes whom to notify)

The fence/admin/users file is a list of users that should be notified for the
SEVERITY_LOW and SEVERITY_MEDIUM events. The list also distinguishes
between local and remote users.

4. Firewall Signature Creation and CAD Startup

After all software had been installed (GNU/Linux, CAD, daemon upgrades), each utility
in the CAD system was run to initialize its piece of the firewall signature. This was a
simple matter of cd'ing into each of the /fence directories listed in section 3 (above) and
running "/create". Running the create script would create a flatfile dataset in each
subdirectory. The flatfile contained the signature of that subsystem when the firewall
was clean. To get the CAD system running, entries were added to root's crontab
database for each CAD utility and the system was ready for connection to the internet.

One of the liabilities of monitoring a comprehensive signature for a firewall is the care
you must take when making approved changes to the system. One must always be
thinking about what part of the firewall's signature is being changed before it is changed.
As an example, if you are going to upgrade the sendmail daemon (a too-frequent task),
you know that you'll be changing the MD5 values of the /sbin/sendmail daemon and
probably those of the /etc/mail/*.cf files, too.

There are two ways to deal with that. One way is to make the changes and let the
system trip an alarm and then clear the alarm quickly before the system shuts down.
The other method is to know what the time window is between the MD5 checks and
then get the work done within that window, replacing the MD5 values with the 'md5'
utility's 'replace.value' function. Either way, it requires careful work to keep the
signature intact and the system online.

5. CAD top-level Monitor/Response System

The CAD system operates by running the individual tests (described in section 3,
above) on a frequent schedule via the cron scheduling facility. When a test completes
with no errors, it exits quietly. When a test encounters an error, indicating that the
signature of the firewall has been altered, the test first generates a message file with a
description of the error and then calls the fence/admin/notify script with the following
syntax:

fence/admin/notify name_of_calling_script full_path_to_message_file

After logging the event in an audit trail (fence/admin/audit_trail), the notify script then
looks in the fence/admin/services table to determine what action to take. A few lines
from the services table will serve to show its use:
/root/fence/dev/test  SEVERITY_LOW
/root/fence/md5/test  SEVERITY_HIGH
/root/fence/ports/test  SEVERITY_MEDIUM

Based upon the SEVERITY associated with the script that encountered the error, the notify script will take the following actions:

SEVERITY_LOW  email users in fence/admin/users table
SEVERITY_MEDIUM  email users, shut down internet-side NIC
SEVERITY_HIGH  email users, shut down all NICs
SEVERITY_EXTREME  message to console, halt machine

In the case of SEVERITY_LOW and SEVERITY_MEDIUM events, an administrator can still connect to the firewall through the intranet-side NIC, resolve the condition and keep running. In the case of SEVERITY_HIGH and SEVERITY_EXTREME events, physical access to the machine is necessary to allow restart, forensic analysis and subsequent recovery.

* An interesting note is that any root-privileged process can take advantage of the CAD system's fence/admin/notify process, by simply making sure that fence/admin/services has an entry for the calling script. This means that the CAD system can be easily extended beyond the utilities that come packaged with it.

6. Individual CAD Utilities

The individual CAD utilities share a common format. Each subdirectory typically contains the following files:

Scripts:

list  A ksh or bash script to scan for items of interest.
create  A ksh or bash script that runs the 'list' script to create a flatfile named 'allowed'.
test  A ksh or bash script that first runs the 'list' script to create a flatfile named 'current' and then runs an intelligent comparison of the 'allowed' and 'current' flatfiles.

Datafiles:

allowed  A list of the allowed objects, created by the 'create' script.
skip  A flatfile that contains known exceptions that we don't want to trigger errors.
current  A list of the current objects, created by the 'test' script.

diffs  A list of differences between the 'allowed' and 'current' flatfiles, taking into
account the exceptions found in the 'skip' flatfile. When the 'diffs' file is
greater than zero bytes in length, the individual CAD utility will call the
fence/admin/notify script so that appropriate action can be taken.

The differences between utilities typically are found in the test script, which can vary
from a simple 'ls' output to a complex analysis of 'lsof' and 'netstat' data. Each CAD
script is documented internally. An example of one CAD utility (ports) is included in this
paper's Appendix VI. All of the utilities can be reviewed by downloading the CAD utility
set. (See reference [7], below).

After Snapshot

The firewalls achieved the three goals of isolating the city's machines from the internet,
isolating the police department's machines from the rest of the city and allowing the
police department to set up a direct connection to the state's Justice department. To
date, although the snort[19]-based logging has shown many deflected attacks, there
has been just one intrusion, wherein a ftp server (wu-fptd) on the primary, outward-
facing firewall was compromised by a buffer-overflow attack, granting the attacker a root
shell. Fortunately, the directory scanning daemon detected the directory creation that is
part of the attack and as a response, disconnected the firewall from the internet,
eliminating the root login of the attacker.

There are still outstanding issues that surround the potential compromise of Microsoft
Windows-based machines from behind the firewall. The non-forwarding primary firewall
is helpful when a PC is compromised and turned into a malware-driven server, as the
newly created server port can not be seen from outside the firewall. For the same
reason, compromised PC's can not establish outbound connections other than to the
SMTP server or the HTTP proxy server. And there lies the vulnerability -- a malware
application that wants to send information home via the HTTP proxy or via email can not
be stopped. Also, a malware application can not be prevented from wandering around
the city's intranet, scanning and attempting to break into other machines behind the
firewalls. Thus far the city's effort to deal with this liability has centered around running
virus detection software on all Windows-based machines, but that is only as good as the
current virus definitions.

Alert readers will have noted that the monitoring, detection and response processes are
all running as root, which is a liability in itself. It would take a non-trivial effort to change
the daemons to run as non-root, as some of the system information needed by the
monitoring daemons requires root privileges. Still, every little bit helps when you are
putting layers of protection in place, so whatever could run as non-root would improve
the security of the system.
All in all, the CAD project was successful, eliminating the vulnerabilities identified at the beginning of the task. Subsequent to the completion of the CAD project, the cablemodem-based infrastructure was replaced with a GNU/Linux-based VPN, the police department began selling services to other police departments via GNU/Linux-based VPNs, malicious email attachments were made safe via procmail and a remote ssh/expect-based NOC was constructed for external monitoring and software deployment, but those are topics for other papers.

References

Note: The original PSIONIC website has been absorbed into Cisco and is now only available at the Internet Archive Project (Wayback Machine).


Source Code:


Note: This source is no longer available at CERN. This tarball is what we used for our project.

Note: This source is no longer available at Purdue’s FTP server. This tarball is what we used for our project.

URL: ftp://lsof.itap.purdue.edu/pub/tools/unix/lsof

Note: This is not the latest MD5 source, but reflects what we used for the project.

[13] fyodor@insecure.org. nmap scanner.
URL: http://www.insecure.org/nmap/nmap_download.html

[14] Tatu Ylönen and many others. SSH. OpenSSH.
URL: http://www.openssh.com/portable.html

URL: http://www.openssl.org/source/

[16] Craig Rowland. portsentry.
URL: ftp://ftp.dnsppp.net/pub/nmills/portsentry-1.0.tar.gz
Note: The original PSIONIC website has been absorbed into Cisco and is no longer online. This tarball is the one we used for the project.


URL: http://www.slackware.com/getslack/

URL: http://www.snort.org/dl/


[21] Jean-loup Gailly and many others. zlib compression library.
URL: http://www.gzip.org/zlib/

URL: http://httpd.apache.org/download.cgi

[23] SQUID: http://www.squid-cache.org/Versions/v2/2.5/
Note: not used for project. Only noted as a reference.

Appendices

Appendix I - fence/admin/services

# services
# # Field 1: full path to service
# # Field 2: severity, as defined in notify script
# # Notes:
# # 1. Fields are whitespace-delimited.
# 2. Record order is not important.
# 3. Comments begin with '#' and are ignored.
# 4. Comments begin in column 1 only.
# 5. Empty records are ignored.

/root/fence/dev/test     SEVERITY_LOW
/root/fence/ftp/test     SEVERITY_LOW
/root/fence/logins/test  SEVERITY_LOW
/root/fence/logs/test    SEVERITY_LOW
/root/fence/md5/test     SEVERITY_HIGH
/root/fence/attr/test    SEVERITY_LOW
/root/fence/ports/test   SEVERITY_MEDIUM
/root/fence/dirs/test    SEVERITY_MEDIUM
/root/fence/files/test   SEVERITY_MEDIUM
/root/fence/links/test   SEVERITY_MEDIUM
/root/fence/rcommands/rcommands SEVERITY_LOW
/root/fence/rlogin/test  SEVERITY_LOW
/root/fence/setuid/setuid_chk  SEVERITY_MEDIUM
/root/fence/cops/test    SEVERITY_LOW
/root/fence/snort/test   SEVERITY_LOW

# End services

Appendix II - fence/admin/nics

# nics
#
# Field 1: short hostname, as returned by "hostname --short | tr [A-Z] [a-z]"
# Field 2: device name for nic (as defined by ifconfig)
# Field 3: clean or dirty
#
# Notes:
#
# 1. Fields are whitespace-delimited.
# 2. Record order is not important.
# 3. Comments begin with `#' and are ignored.
# 4. Comments begin in column 1 only.
# 5. Empty records are ignored.

# Remote

fw1      eth0   dirty
fw1      eth1   clean
fw2      eth0   dirty
fw2      eth1   clean
fw2      eth1:0 clean
fw2      eth2   dirty
fw2      eth3   clean
fw3      eth0   clean
fw3      eth1   dirty

# End nics

Appendix III - fence/admin/users

# users
#
# Field 1: short hostname, as returned by "hostname --short | tr [A-Z] [a-z]"
# Field 2: email_address
# Field 3: local or remote
# Field 4: service name or SERVICES_ALL
#
# Notes:
#
# 1. Fields are whitespace-delimited.
# 2. Record order is not important.
# 3. Comments begin with `#' and are ignored.
# 4. Comments can only begin in column 1.
# 5. Empty records are ignored.

# Remote

fw1      msp@XXXXXXXXXX.XXX     remote  SERVICES_ALL
fw1      root@localhost        local   SERVICES_ALL
fw2      msp@XXXXXXXXXX.XXX     remote  SERVICES_ALL
fw2  westj@localhost  local  SERVICES_ALL
fw2  root@localhost  local  SERVICES_ALL
fw3  msp@XXXXXXXXXXX.XXX  remote  SERVICES_ALL
fw3  westj@localhost  local  SERVICES_ALL
fw3  root@localhost  local  SERVICES_ALL

# Local

mojave  msp@localhost  local  SERVICES_ALL
sawtooth  msp@localhost  local  SERVICES_ALL
camelot  msp@localhost  local  SERVICES_ALL
hatcreek  msp@localhost  local  SERVICES_ALL
bigsur  msp@localhost  local  SERVICES_ALL

# End users

Appendix IV - fence/admin/notify

#!/bin/bash

# Usage:
#
# /root/fence/admin/notify full_path_to_current_script full_path_to_message_file
> /dev/null 2>&1 &

alias source=.
source /usr/bin/ksh/common.path

_shutdown_delay=10 # minutes

_fence=/root/fence
_services=$_fence/admin/services
_users=$_fence/admin/users
_nics=$_fence/admin/nics
_audit_trail=$_fence/admin/audit_trail
_errors=$_fence/admin/errors
_911=$_fence/admin/911
_hostname=$(hostname --short | tr [A-Z] [a-z])

_error()
{
   cat >>$_errors <<EOF
$(date): $*
EOF
   cat <<EOF
$(date): "$*
EOF
exit 1
}

#--------------------------------------------------------#
# Get service name and notification type. #
#--------------------------------------------------------#

_argument1=$1
_argument2=$2

if [ x"$_argument1" = x"" ]
then
   _error S001: notify invoked without service-name argument
fi

if [ ! -f $_services ]
then
   _error S002: $_services not found
fi

if [ ! -r $_services ]
then
   _error S003: $_services exists, but is not readable
fi

# (leading/duplicate spaces in records don't matter with "set --")
_service_count=$(egrep -c ^$_argument1 $_services)
case $_service_count in
  0)
    _error S004: unable to locate service in $_services: $_argument1
   ;;
  1)
    set -- $(egrep ^$_argument1 $_services)
    _service_name=$1
    _severity=$2
   ;;
  *)
    _error S005: duplicate records for service in $_services: $_argument1
   ;;
esac

#-------------------#
# Get message file. #
#-------------------#
if [ x"$_argument2" = x""]
then
  _error M001: $_service_name invoked notify without message-file argument
fi

if [ ! -f $_argument2 ]
then
  _error M002: can not locate $_service_name message-file: $_argument2
fi

if [ ! -r $_argument2 ]
then
  _error M003: $_service_name message-file is not readable: $_argument2
fi

_message_file=$_argument2

#-------------------#
# Perform actions based upon severity. #
#-------------------#

_message_to_audit_trail()
{
  echo $(date): $_severity $_service_name $* >> $_audit_trail
}

_message_to_console()
{
  _date=$(date)
  echo -e "$_date: ALERT: $_severity " >/dev/console
  echo -e "$_date: $_service_name "    >/dev/console
  echo -e "$_date: $* "                >/dev/console
  while read _line
    do
      echo -e "$_date: $_line\r" >/dev/console
  done < $_911

  _message_to_audit_trail message sent to console: $*
}

_user_list()
{
# $1 contains 'local' or 'remote'

```bash
/email_list=$(egrep ^$_hostname $_users | fgrep -e SERVICES_ALL -e $_service_name | fgrep $1 | fgrep -v -e '#' | sed -e 's/[[space:]]*/g' -e 's/[[space:]]/ /g' | cut -f2 -d\ | sort | uniq) # two spaces after '-d'
```

```bash
_email_users()
{
    for _user_type in $* # where $* contains 'local' and/or 'remote'
do
        _user_list $_user_type # load _users with list of email addresses
    for _user in $_email_list
do
        _message_to_audit_trail emailing $_user
        _service_dirname=$(dirname $_service_name)
        echo $_extra_message > /tmp/notify.message.$$ echo >> /tmp/notify.message.$$ cat $_message_file >> /tmp/notify.message.$$ mailx -s "$(echo $_severity | sed 's/ERITY_/-/g') $(hostname) $(basename $_service_dirname)" $_user < /tmp/notify.message.$$ done
    done

    rm -f /tmp/notify.message.$$ }
```

```bash
_shutdowndown_nics()
{
    for _nic_type in $* # where $* contains 'dirty' and/or 'clean'
do
        for _nic in $(egrep ^$_hostname $_nics | fgrep $_nic_type | fgrep -v DISALLOW_SHUTDOWN | fgrep -v -e '#' | sed -e 's/[[space:]]*/g' -e 's/[[space:]]/ /g' | cut -f2 -d\ ) # two spaces after backslash
do
            _message_to_audit_trail shutting down ${_nic_type}-side NIC: $_nic
            ifconfig $_nic down # DEBUG ONE ITEM
            _message_to_audit_trail ifconfig $_nic down return code: $?
done
    done
}
```
```bash
_delay()
{
  _message_to_audit_trail delay for $_shutdown_delay minutes

  _shutdown_delay_seconds=$(expr $_shutdown_delay \* 60)

  sleep $_shutdown_delay_seconds # yes, posix sleep takes 'm' as modified, but this is more portable

  _message_to_audit_trail delay completed
}

_shutdown_machine()
{
  _message_to_audit_trail shutting down machine

  shutdown -h now # DEBUG ONE ITEM

  _message_to_audit_trail shutdown -h now return code: $?
}

_message_to_audit_trail alert received

case $_severity in
  SEVERITY_LOW)
    _extra_message=""
    _email_users local remote
    ;;
  SEVERITY_MEDIUM)
    _extra_message="$(hostname): DIRTY-SIDE NICS WILL BE SHUT DOWN IN $_shutdown_delay MINUTES"
    _email_users local remote
    _message_to_console DIRTY-SIDE NICS WILL BE SHUT DOWN IN $_shutdown_delay MINUTES
    _delay
    _message_to_console DIRTY-SIDE NICS HAVE BEEN SHUT DOWN
    _shutdown_nics dirty
    ;;
  SEVERITY_HIGH)
    _extra_message="$(hostname): ALL NICS HAVE BEEN SHUT DOWN"
    _email_users local
    _message_to_console ALL NICS HAVE BEEN SHUT DOWN
    _shutdown_nics dirty clean
```
SEVERITY_EXTREME)
  _extra_message=""
  _message_to_console MACHINE HAS BEEN SHUT DOWN
  _shutdown_machine
  ..
  *
  _error A001: unknown severity: $service_name $severity
  ..
esac
# End

Appendix V - fence/admin/fw.run

#!/bin/bash

_networks_clean()
{
  # Field 1: IP Address block for interface
  # Field 2: Comment

  # Please ensure that NIC addresses are in
  # /usr/local/psionic/portsentry/portsentry.ignore

  192.168.100.0/24 Intranet
}

_networks_dirty()
{
  # Field 1: IP Address block for interface
  # Field 2: Comment

  # Please ensure that NIC addresses are in
  # /usr/local/psionic/portsentry/portsentry.ignore

  XXX.XXX.XXX.0/24 XXXXXX SDSL 512KB
  0.0.0.0/0 Internet
}

_forwards()
{
  # Field 1: IP Address
  # Field 2: interface to be used for forwarding
  # Field 3: Comment (optional)
services_clean()
{
  # Clean-side services.
  # Field 1: Protocol (tcp, udp, icmp or all)
  # Field 2: Port (numeric) or port-range (number:number)
  # Field 3: Service-name (used as comment)
  # Field 4: Clean-side incoming addresses: Internal-host, netblock or "all"
  # Field 5: Access-allowed: intranet, extranet or both
  # Field 6: Comment (optional)
  #
  # Do not enable 8080 proxy, that is driven by /etc/proxy/allowed
  #
  # If "all" is specified, # open up for
  # entire clean-side netblocks.
  #
  # Protocol/port records can be repeated.

tcp 20   ftp-data all    both
 tcp 21   ftp    all    both
 tcp 22   ssh    all    both
 tcp 222  ssh-ITIC all    both
 tcp 23   telnet 192.168.100.32 intranet
 tcp 25   smtp   all    both
 tcp 37   time   all    intranet
 tcp 53   dns    all    both
 tcp 67   bootps all    intranet
 tcp 110  pop3   all    both but will be limited to intranet in _services_dirty
 tcp 119  nntp   all    intranet
 tcp 137  netbios-ns all    both but will be limited to intranet in _services_dirty
 tcp 138  netbios-dgm all    both but will be limited to intranet in _services_dirty
 tcp 139  netbios-ssn all    both but will be limited to intranet in _services_dirty
 tcp 143  imap2 all    intranet
 tcp 220  imap3 all    intranet
# Dirty-side services.

# Field 1: Protocol (tcp, udp, icmp or all)
# Field 2: Port (numeric) or port-range (number:number)
# Field 3: Service-name (used as comment)
# Field 4: External-host, netblock or "all"
# Field 5: Comment

# If "all" is specified, # open up for entire dirty-side netblock # (0.0.0.0/0).
#
# Protocol/port records can be repeated.

tcp 20  ftp-data all
tcp 21  ftp all
tcp 22  ssh all
tcp 222 ssh-ITIC 192.168.100.0/24 intranet
tcp  25   smtp   all
tcp  53   dns   all
tcp  80   www   all
tcp  110  pop3   192.168.100.0/24 intranet
tcp  137  netbios-ns  192.168.100.0/24 intranet
tcp  138  netbios-dgm  192.168.100.0/24 intranet
tcp  139  netbios-ssn  192.168.100.0/24 intranet
tcp  445  msoft-ds   192.168.100.0/24 intranet replaces 137/8/9 for Win2000
tcp  515  printer  192.168.100.0/24 intranet
tcp  6346  gnutella all
tcp  1723  pptp all

tcp  53    dns    all
udp  53   dns   all
udp  137  netbios-ns  192.168.100.0/24 intranet
udp  138  netbios-dgm  192.168.100.0/24 intranet
udp  139  netbios-ssn  192.168.100.0/24 intranet
udp  445  win2k-netbios  192.168.100.0/24 intranet replaces 137/8/9 for Win2000
    udp  500  ipsec all
    icmp    all
}

_proxy_server()
{
    # Field 1: IP Address for proxy server
    # Field 2: Comment

    192.168.100.1 Apache
}

_black_list()
{
    # Field 1: IP Block
    # Field 2: Comment

    210.0.0.0/8 Asia APNIC-CIDR-BLK2, Australia
    211.0.0.0/8 Asia APNIC-CIDR-BLK2
    218.0.0.0/8 Asia APNIC4
}

####################################################
#####                                          #####
##### NO USER-MODIFIABLE CODE BELOW THIS POINT #####
#####                                          #####
####################################################

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#--------------------------------------------------#  
#                  STANDARD SETUP                  #  
#--------------------------------------------------#  

alias source=
source /root/fence/admin/path
source /root/fence/admin/fw

Appendix VI - Example of single CAD utility (ports)

VI (1) create script:

#!/bin/bash
source /root/fence/admin/path
cd /root/fence/ports
./list tcp > tcp.allowed
./list udp > udp.allowed

VI (2) list script

#!/bin/bash
source /root/fence/admin/path

case $1 in
tcp)
  netstat -tan | fgrep LISTEN | sort | sed 's/ */ /g' | cut -f4 -d" " ;;
udp)
  netstat -uan | egrep \^udp | fgrep '0.0.0.0:.*' | sort | sed 's/ */ /g' | cut -f4 -d" " ;;
*) echo invalid or missing argument ;;
esac

VI(3) test script

#!/bin/bash

#----------------------#  
# Pre-Processing Setup #  
#----------------------#  

alias source=. # PRECURSOR_ZERO
source /root/fence/admin/path # PRECURSOR_ONE
cd /root/fence/ports         # PRECURSOR_TWO
__baseline=$(pwd)           # PRECURSOR_THREE

#----------------------#
#  Global Variables   #
#----------------------#

#----------------------#
#   Subroutines       #
#----------------------#

_validate()
{
    # The subroutine is called with "valid" set to "no".
    # If all is well, this routine leave valid unchanged.
    protocol=$1
    port=$2
    service=$3
    interface=""$4"

    # debug
    #
    # echo protocol is $protocol
    # echo port is $port
    # echo service is $service
    # echo interface is $interface

    # -P = no port names (ie., don't check /etc/services)
    # so that the netstat port will match the lsof port

    case $protocol in
        udp)
            lsof -P -iUDP |
            tee ./test.lsof.tmp.$$ |
            grep -e COMMAND -e $port |
            tee ./test.tmp.$$ |
            egrep ^$service |
            grep "$interface" |
            grep -q :$port >/dev/null 2>&1
            retval=$? ;;;
        tcp)
            lsof -P -iTCP |
            tee ./test.lsof.tmp.$$ |
            grep -e COMMAND -e $port |
            tee ./test.tmp.$$ |
            egrep ^$service |
fgrep -q ":$port >/dev/null 2>&1
retval=$? ;;
*)
    protocol_lsof=UNDEFINED
    retval=1 ;;
esac

if [ $retval = 0 ]
then
    # Criteria match approved data.
    valid=yes
else
    if [ ! -s ./test.tmp.$$ ]
then
        # Port was gone before we could check it.
        valid=yes
    fi
fi

_report_diffs_new()
{
    while read symbol data
    do
        port=$(echo $data | cut -f2 -d:)
        valid=no

        while read record_type service_exception interface_exception
        do
            if [ x"$record_type" = x"exception" ]
            then
                _validate $protocol $port $service_exception "$interface_exception"
            fi
        done < exceptions

        if [ $valid = no ]
        then
            echo port in question is port $port for protocol $protocol
            echo
            echo test.tmp.$$:
            echo
            sed 's/^/new port: /g' < ./test.tmp.$$
            echo
            sed "s/^/$protocol.diffs.new: /g" < $protocol.diffs.new
        fi
    done < exceptions

    if [ $valid = no ]
    then
        echo port in question is port $port for protocol $protocol
        echo
echo

case $protocol in
tcp)
    netstat -tan ;;
    *;
    esac ;;

ps xaflw

for protocol in tcp udp
do
    diff $protocol.allowed $protocol.current > $protocol.diffs
    egrep -e '^>' $protocol.diffs > $protocol.diffs.new
    egrep -e '^<' $protocol.diffs > $protocol.diffs.missing
    > $protocol.errors

if [ -s $protocol.diffs.new ]
then
    _report_diffs_new >> $protocol.errors
fi

if [ -s $protocol.diffs.missing ]
then
    echo Missing $protocol ports: >> $protocol.errors
    echo >> $protocol.errors
    cat $protocol.diffs.missing >> $protocol.errors
    echo >> $protocol.errors
fi

if [ -s $protocol.errors ]
then
    echo END >> $protocol.errors

        # Save some debug info - not needed now that we're using lsof.
        #
        # timestamp=$(date '+%Y.%m.%d.%T')
        # cp $protocol.errors $_timestamp.errors.$protocol
        # ps xaf >> $_timestamp.errors.$protocol
        # netstat -tan >> $_timestamp.errors.$protocol
        # netstat -uan >> $_timestamp.errors.$protocol

        /root/fence/admin/notify /root/fence/ports/test
        /root/fence/ports/$protocol.errors >/dev/null 2>&1 &
    fi
done

#----------------------#
#     Housekeeping     #
#----------------------#
# End
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