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CORE TECHNOLOGY

Dive under the skin of your Linux system to find out what really makes it tick.

PAM: Pluggable Authentication Modules

Take control of your system's security policy by mastering the minutiae of PAM.

Pluggable Authentication Modules (known to its friends as PAM) is one of those technologies that most users are entirely unaware of, like the engine management computer in their Volvo. Basically, PAM provides a framework within which an application can assemble one or more stacks of PAM modules to perform the authentication tasks it needs to perform and to implement the security policy that it (or the system administrator) wants to implement.

From a system administrator's point of view, PAM has two parts. The first is a set of configuration files in **/etc/pam.d** that define how an application's PAM stacks are to be assembled. The config file is usually named after the application, so that (for example) the file for the **ssh** daemon would be **/etc/pam.d/sshd**. The second part is a collection of PAM modules that are implemented as dynamically linked libraries. Red Hat puts them in **/lib64/security**, though different distros choose different directories. The range of tasks that these modules perform is quite diverse, ranging from doing traditional Unix-style authentication (**pam_unix**) to enforcing password strength (**pam_cracklib**) and locking an account after too many failed logins (**pam_tally2**). The PAM modules table on the facing page provides a longer list, but it is by no means complete. The modules listed in the table are relatively mainstream but they may not all be installed by default on your distro.

By the way, PAM is entirely in userspace. There are no PAM kernel modules.

PAM in a paragraph

Here's how it works. A program that wants to use PAM links to a library called **libpam**. This is probably the least visible part of PAM but it's really the heart of the whole thing. Under control of the program's PAM config file (we'll see an example in a moment), **libpam** assembles up to four stacks of modules that the application can use. The four stacks are called **auth**, **account**, **password** and **session**, and they refer to the four classes of activity that PAM helps to manage. Typically, an application won't use all four stacks; it may only need the **auth** and **session** stacks, for example.

> **"The basic concept that underpins PAM is not really that hard. The devil is in the details."**

Let's suppose you're a program that wants to perform authentication. Maybe you're the classic command line **login** program. Through **pamlib**, you call the PAM modules in your **auth** stack, in order. You don't even know what those modules are; this information is held in an external configuration file, which **pamlib** knows about, but you don't. Each PAM module performs its function, and returns a 'success' or 'failure' status. The status values of the modules combine (according to rules in the config file) to provide a success or failure status for the stack as a whole.

So the basic concept is not really that hard. The devil is in the details. Let's take a look at a typical PAM configuration file:

```
auth      required   pam_securetty.so
auth      required   pam_unix.so shadow nullok
auth      required   pam_nologin.so
account   required   pam_unix.so
password  required   pam_cracklib.so retry=3
password  required   pam_unix.so shadow nullok
use_authtok
session   required   pam_unix.so
```

This particular file assembles all four stacks – **auth**, **account**, **password** and

Disable direct root login

Disabling direct root logins (so that you have to log in as a regular user then use **su** to switch to root) is a great way to improve security. You can do this by adding the **pam_securetty** module into the 'auth' stack. No, I haven't mis-spelled it; 'securetty' means 'secure terminal', and it harks back to the days when people logged in on text-based console devices, some of which were secure (behind a locked door).

The **pam_securetty** module consults the file **/etc/securetty** to find out which terminals are deemed secure. It will fail if root tries to log in on a terminal not listed here. In particular, if the file exists (but is empty) root isn't allowed to log in anywhere. Start by creating an empty list of secure terminals:

```
# echo "none" > /etc/securetty
```

Note that a non-existent **securetty** file has an entirely different effect than an empty one. If the file doesn't exist, root can log in anywhere. If the file is empty, root can log in nowhere.

Next, add an entry near the top of the auth stack in **/etc/pam.d/system-auth**, like this:

```
auth  required  pam_securetty.so
```

With this change in place you should find that root can no longer log in on a text console. Note that, to prevent root logging in on the graphical desktop, you will probably need to make similar changes to the PAM stacks for the display manager, such as **gdm**.

Defeat brute-force login attempts

The module **pam_tally2** can be used to count failed login attempts and to lock accounts for a specified length of time if there are too many. Try adding a line like this to the **auth** stack in **system-auth**:

```
auth   required   pam_tally2.so  deny=3   even_deny_root  unlock_time=600
```

This will lock a user out for 600 seconds after three failed login attempts. Pick a user account you know the password for and deliberately enter the wrong password three times in succession. Subsequent login attempts should then fail even if you use the correct password.

From a command prompt you can query the failed login count with the command:

```
# pam_tally2 --user bob
```

where **bob** is the account name, and reset the count back to zero with:

```
# pam_tally2 --user bob --reset
```

A sampling of PAM modules

Module	What it does
pam_unix	Traditional password authentication
pam_cracklib	Checks password strength against dictionary words
pam_passwdqc	Checks password strength based on length and character classes
pam_securetty	Limits root login to secure terminals
pam_tally2	Counts failed logins, denies access if too many attempts fail
pam_deny	Denies access. Used as a 'backstop' at the bottom of a stack
pam_time	Implements time-of-day and day-of-week login restrictions
pam_shells	Restricts access to the shells listed in **/etc/shells**
pam_timestamp	Enables a user to authenticate based on a recent successful authentication
pam_env	Sets environment variables when a user logs in
pam_abl	Maintains a blacklist of hosts making repeated failed logins
pam_limits	Sets limits on resource usage during a login session
pam_rootok	Allows authentication to succeed if the user is root
pam_mkhomedir	Creates a user's home directory if it doesn't exist

session. The **auth** stack has three modules; the **password** stack has two; the **account** and **session** stacks each have just one. So to perform authentication, for example, the program first calls **pam_securetty**. This module can restrict root access to specific 'secure' terminals. Then it calls **pam_unix**. This is an important PAM module; it handles the traditional authentication against a local account database. Finally, **pam_login** is invoked to prevent non-root logins if the file **/etc/nologin** exists. The **nologin** file is usually created during the shutdown sequence; its purpose is to stop regular users logging in during the shutdown period.

The second field in the PAM config file specifies the control flag, and you will notice that all of these modules are marked as **required**. This means that they all have to succeed for the stack as a whole to succeed. The other control flags (**requisite**, **sufficient** and **optional**) are described on page 66 and I'll re-visit them later. You'll also notice that some of these modules have parameters passed to them. For example in the **password** stack, **pam_cracklib** has the parameter **retry=3**. Some of the modules even have their own configuration files.

Factoring out

It's common for the same pieces of the PAM stack to appear in the configuration of several applications. To make this easier, there's an **include** control flag that brings in stack definitions from an external file. On a Red Hat-style system the most widely used example of this is the file **/etc/pam.d/system-auth**. You'll find this file included in the PAM stacks of most applications through a line like this:

```
auth include system-auth
```

Other distros do things slightly differently. On Ubuntu there are four of these "common" files (**common-auth**, **common-account**, **common-session** and **common-password**) and they are included by lines of the form:

```
@include  common-auth
```

"Factoring out" pieces of the PAM stack in this way not only makes the individual PAM config files shorter, it also means that you can change the login policy for most PAM-aware applications just by editing the one common file. As an example, Red Hat has a little tool called **authconfig-tui**, which you can use to enable authorisation against LDAP, Kerberos, or Active Directory accounts. The only PAM file that this tool needs to adjust is **system-auth**. There are even some applications whose PAM configurations do nothing except include the relevant stacks from **system-auth**.

Preventing non-root reboots

By default, my CentOS 6.5 system allows a non-root user to halt or reboot the system, using the **reboot** command. This is probably acceptable for a single-user desktop machine but definitely not a good idea on a server. We can modify this policy by changing the PAM configuration.

Here's the default PAM **auth** stack for the reboot program, from **/etc/pam.d/reboot**:

```
auth      sufficient   pam_rootok.so
auth      required     pam_console.so
```

which says you can go ahead if you're root, or if you're logged in on the console.

Change the **auth** stack in **/etc/pam.d/reboot** as follows:

```
auth      sufficient   pam_rootok.so
auth      required     pam_deny.so
```

Now, if we're root we're fine, but if not, we're doomed. With this change in place, attempts to reboot as a non-root user should fail:

```
$ reboot
need to be root
```

Like several other technologies we now take for granted in Linux, PAM originated with Sun Microsystems. It dates from 1995, and was soon adopted (1996) into Red Hat Linux.

Restrict su to members of the wheel group

By default, anyone can use **su** to switch to root if they know the root password. You can tighten up on this using the **pam_wheel** module, which tests that you're a member of the wheel group (or some other specified group).

As an aside, the use of the "wheel" group for privileged users goes back to the early days of Unix, but I have never found a satisfactory explanation of why it's called "wheel". The default **auth** stack for **su** looks like this:

```
auth        sufficient    pam_rootok.so
auth        include       system-auth
```

which says that if you're root, you're in, otherwise you have to go through the standard system-auth stack. You can adjust this like so:

```
auth        sufficient    pam_rootok.so
auth        required      pam_wheel.so use_uid
auth        include       system-auth
```

which adds the requirement that we belong to the wheel group. To check this out you will need to add at least one account to this group, for example:

```
# usermod -G wheel chris
```

You should now find that the user chris can **su** to root, but a user who is not a member of the wheel group cannot.

To illustrate the importance of the control flags, try changing the **auth** stack of **su** to look like this:

```
auth        sufficient    pam_rootok.so
auth        sufficient    pam_wheel.so trust use_uid
auth        include       system-auth
```

The stack now says that if you're a member of the wheel group you can **su** to root without needing to authenticate at all. Try it!

Wait! There's more!

It turns out there's more to PAM configuration than simply assembling stacks of modules. For a start, many PAM modules can be passed parameters (specified within the PAM config file). Let's look at a couple of examples:

The **pam_cracklib** module (which does password strength checking and is usually found in the **password** stack) accepts a parameter like **minlen=9** that specifies the minimum password length; it also accepts **retry=3**, which says to give the user three attempts to enter an acceptable password. So you might see a line like this:

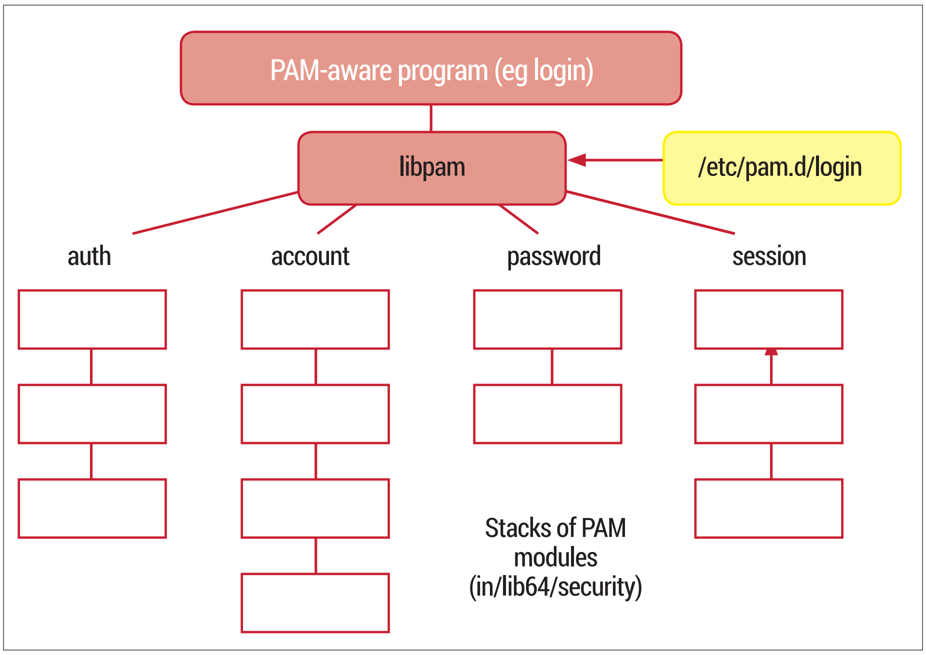
```
password  required  pam_cracklib retry=3 minlength=9
```

Going a step further, some PAM modules have their own configuration files. For example, **pam_time** (which implements time-of-day access control) reads its configuration from **/etc/security/time.conf**, where you might find rules of breathtaking obscurity, such as this:

```
login ; * ; !fred ; MoTuWe0800-2000
```

By the way, although **pam_time** plays its part in determining whether a user is allowed to log in, it is not concerned with authenticating the user, and so it belongs in the **account** stack, not the **auth** stack.

In most cases the PAM modules have man pages that document these parameters. (The command **apropos pam** may help get you a list of these.) Sometimes the individual config files have man pages too. In some cases the documentation is a little thin on the ground, but it's a very great deal better now than it was in the early days of PAM.



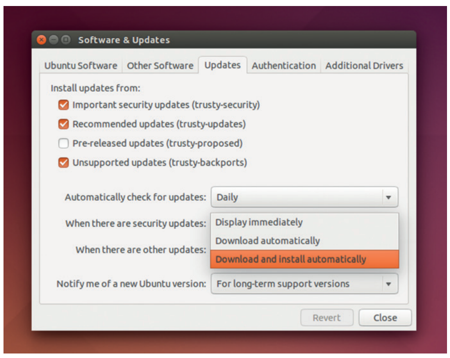
PAM-aware applications assemble stacks of modules to implement their security policy, under control of a configuration file in **/etc/pam.d**.

Why bother?

It's when you get down into the details of PAM – the control flags and the large range of modules with their parameters and config files – that you start to get a feel for its complexity. And since Linux distributions invariably include working PAM configurations out of the box it's reasonable to ask why you should care. Well, I'd wager that many system administrators actually don't care – they leave their default PAM configurations well alone. But there may be times when you need to bring extra PAM modules into play to implement pieces of your security policy, such as "users are only allowed to log in between 10am and 4pm on

PAM control flags

Control flag	What it means
sufficient	If the module succeeds, the stack succeeds and no further modules are called
required	If the module fails, the stack will fail, but remaining modules will be called
requisite	If the module fails, the stack will fail; no more modules are called
optional	Success or failure of the module is ignored
include	Include a piece of stack defined in a separate file



On Ubuntu there are four of the "common" files (**common-auth**, **common-account**, **common-session** and **common-password**).

Mondays and Tuesdays" or "passwords must be a minimum of 10 characters with three character classes". Or you might need to augment your login process to include user accounts stored in a Windows Active Directory (via the *winbind* daemon). Or maybe you're plagued by brute-force login attempts from a specific host and would like to block them. There are PAM modules to do all of these things.

Getting to grips with the control flags

I've been trying hard to avoid a proper discussion of the control flags in PAM because, frankly, they are painful and I don't like to inflict pain. But they have a major impact in the way PAM stacks work and we can't really ignore them. There are two styles of syntax for defining the control flags – a simple one and a more complicated one.

Don't leave home without the key

A word of warning if you're playing around with your PAM set-up. It is extremely easy to create a configuration which won't let you log in at all. To reduce the risk of locking yourself out of your house and ending up doing a rescue boot, I strongly recommend that you keep a root login open (maybe on a text-based console terminal or maybe an ssh login from another machine) until you're confident that your new configuration works. You can test PAM (mostly) by logging in on a console terminal or by doing an ssh login to localhost. Alternatively, test your configuration on a virtual machine with a snapshot you can drop back to.

PAM's four management classes

Stack	What it's for
auth	Verifies the credentials of a user (logging in)
account	Account management (eg account expiry or time-of-day restrictions)
password	Password management (changing your password)
session	Session management (anything else you want to do when a user logs in)

We'll take the simple syntax first – it uses the four keywords **sufficient**, **required**, **requisite** and **optional**. Recall that each PAM module returns a 'success' or 'failure' status. The control flags specify how the status returned by the individual modules in a stack contributes to the success or failure of the stack as a whole. Consider a stack such as the example we showed earlier, in which all modules in the stack are 'required'. Then all modules must succeed for the stack to succeed. This seems to me the most straightforward and obvious way for modules to combine.

The **required** flag is similar, but, if a module fails, the stack is immediately abandoned – later modules are not invoked. The **sufficient** flag does what it says on the tin – if the module succeeds, the stack will succeed and later modules are not called. Finally, the **optional** flag means that the return status of the module is ignored. This flag is often found within the **session** stack, where modules are called for their side effect (such as setting environment variables or creating an initial home directory) rather than for a yes/no decision. There's a more complex syntax that can be used for the control flags, which gives you finer grain control over querying the return status of a PAM module, and more options on deciding what to do in each case. This form of control flag consists of a series of **status=action** pairs, in square brackets. Here's an example:

```
auth [user_unknown=ignore success=ok default=bad]
pam_securetty.so
```

This example is being used to distinguish the case where the username is unknown from the case where the module's 'secure tty' test fails, and to react differently in the two cases. The return status values are not well documented. These extensions, which almost turn PAM configuration into a programming language in its own right, are difficult to get your head round, and (I'm pleased to say) don't seem to be very common in modern PAM configurations.

So there you have it. Next time the conversation in the pub turns to PAM, you can smile enigmatically and say "ah yes, I know PAM well!"

Command of the month: ldd

The **ldd** command answers the question "Which libraries does this application use?". Here's a simple example:

```
# ldd /bin/bash
 linux-vdso.so.1 =>
 libtinfo.so.5 => /lib64/libtinfo.so.5
 libdl.so.2 => /lib64/libdl.so.2
 libc.so.6 => /lib64/libc.so.6
 /lib64/ld-linux-x86-64.so.2
```

It's not at first sight the most exciting of commands, but there are some quirks here that you can uncover, expecially if you wrap a little shell scripting around it to answer the opposite question: "Which programs are linked against this library?"

Here's the script I came up with – it could be spruced up in several ways but it does the basic job:

```
#!/bin/bash
# Script "whatuses"
# Finds which executables are linked against a given library

lib=$1
for x in /usr/bin/*  # Better to traverse entire $PATH
do
 if ldd $x 2> /dev/null | grep $lib > /dev/null 2>&1
 then
  echo $x uses $lib
 fi
done
```

Here are a couple of examples. First, there's an access control mechanism called 'TCP wrappers', which is implemented by the library **libwrap.so**. So we can answer the question "Which apps use TCP wrappers?" like this:

```
 ./whatuses libwrap
/usr/bin/empathy uses libwrap
/usr/bin/gnome-shell uses libwrap
/usr/bin/pulseaudio uses libwrap
/usr/bin/vinagre uses libwrap
```

I've edited most of the output for brevity. Or we can ask "Which apps are PAM-aware?" by looking for linkage against **libpam**:

```
# ./whatuses libpam
/usr/bin/at uses libpam
/usr/bin/login uses libpam
/usr/bin/passwd uses libpam
/usr/bin/su uses libpam
/usr/bin/vncpasswd uses libpam
```

Again, the output is trimmed – Linux dependencies can get complicated, but **ldd** can help make sense of them!