Workshop: Encrypting hard disks with DM-Crypt and LUKS

THE WHOLE DISK

Encrypting a home directory is easy. Encrypting your whole hard disk – including the root filesystem – takes a little more effort.

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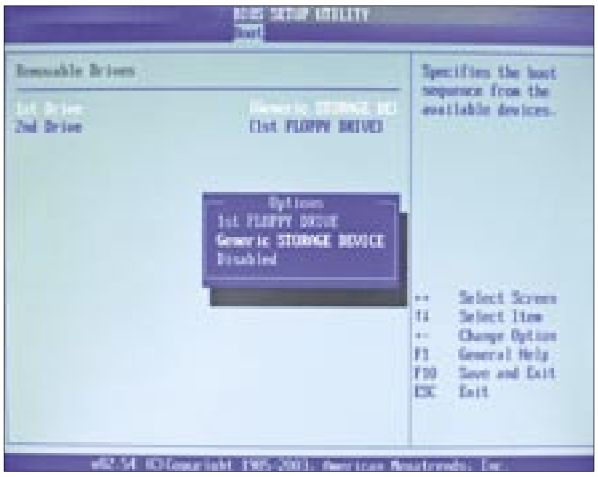
Encrypting individual filesystems is no big deal; in fact, some distributions allow you to encrypt directories as part of the installation routine. But encrypting the home directory on your laptop is a job half done. Dishonest finders can still draw conclusions from log and configuration files. If you're serious about providing security through encryption, you need to protect the whole hard disk against spying – something that no distribution can do out of the box.

Things start to become more complex if you need to protect the root filesystem. Neither Suse nor Debian Linux give users a tool to help encrypt the root filesystem during the install (or later). That means you'll need to roll up your shirt sleeves for some hands-on configuration.

In this workshop, we will start by installing a standard Linux system and then progress to encrypting the existing filesystems one at a time. We will finish off by deleting the unprotected partition and using the space for other tasks, such as swapping out the */home* directory to an encrypted partition of its own.

Our goal is to encrypt the entire hard disk (with the exception of the partition table in the Master Boot Record). Because it isn't possible to encrypt the boot partition, we will move */boot* to an external medium – a USB stick, in this case. To boot from the stick, we will need to modify the BIOS and GRUB bootloader settings. The USB stick then creates an additional layer of security by serving as a kind of "key" that the thief will need to possess in order to gain access to the laptop. If this approach seems impractical for your purposes, you can keep the boot partition on your hard disk. However, */boot* must be on an unencrypted partition of its own.

In this article, we'll use DM-Crypt [1] for our filesystem encryption. DM-Crypt has been the tool of choice for encrypting filesystems since kernel



```
                    BIOS SETUP UTILITY
                          Boot
Removable Drives                              Specifies the boot
                                              sequence from the
1st Drive               [Generic STORAGE DE]  available devices.
2nd Drive               [1st FLOPPY DRIVE]

                      Options
                 1st FLOPPY DRIVE
                 Generic STORAGE DEVICE
                 Disabled

                                              ←→   Select Screen
                                              ↑↓   Select Item
                                              +-   Change Option
                                              F1   General Help
                                              F10  Save and Exit
                                              ESC  Exit

       v02.54 (C)Copyright 1985-2003, American Megatrends, Inc.
```

Figure 1: Booting from a USB stick – every BIOS does its own thing. Our sample BIOS refers to removable drives and a generic storage device.

2.6.4. It uses the device mapper infrastructure [2], and it encrypts block devices transparently, relying on the kernel's Crypto API to do so. Linux Unified Key Setup (LUKS) adds some enhancements, which were discussed in a previous issue of Linux Magazine [3]. The LUKS design is implemented as the *cryptsetup-luks* [4] configuration tool.

As an alternative to a fresh installation, you can modify an existing system, assuming you have enough free space on the disk to create a new partition for the data you are encrypting.

Don't worry! After you finish encrypting, the disk patches and kernel updates should not cause any problems, and your backup and recovery tools should work like they always did.

Preparation

The equipment you need for this lab is a suitable laptop, a USB stick with a capacity of about 64 Mbytes, and your favorite Linux distribution (kernel 2.6.11 or newer) – we tested Suse Linux 9.3 / 10.0 and Debian Sarge. Check the laptop BIOS to see if it supports booting from USB (Figure 1). Use a Live CD to ensure that Linux supports your laptop; you might like to take this opportunity to erase the laptop disk (see the "Secure data erasure" box).

For the initial install, divide the hard disk into four partitions, as shown in column 1 of Table 1. This configuration puts an unencrypted version of the Linux system on */dev/hda4*. (If you prefer not to boot from a USB stick, use the alternative partitioning suggestion shown in column 2 of the table.)

Set up the size and number of partitions to match your laptop's hard disk and intended use – dual or multiple boot configurations are possible. Do not create a user at this phase of the installation; you can do so later on the encrypted system.

After completing the installation, you should have a working Linux system on */dev/hda4*. If you have a kernel version older than 2.6.11 (with Debian Sarge, for example), you will need to update the kernel now. For the following steps, you also need the *cryptsetup-luks* configuration tool.

The "Updates for Debian Sarge" box describes how to update a Sarge system; for Suse Linux, you just need to add *cryptsetup-luks*. The LUKS homepage at [4] has a prebuilt, statically linked version that you can copy to */sbin/cryptsetup-luks*.

Booting from a USB-Stick

Linux typically detects USB sticks as SCSI devices and addresses them as the SCSI hard disk */dev/sda* (unless you have some other SCSI devices). Use *fdisk* to create a partition table with at least one partition and format the partition (*mkfs.ext2 /dev/sda1*). Then do:

```
mount /dev/sda1 /mnt
cp -ax /boot/* /mnt
```

This copies the */boot* directory to the USB stick. If it does not already exist, give the *ln -s . boot* command to create a symbolic link in the */mnt* directory, to avoid a hitch with *grub-install* later on.

Now modify the GRUB bootloader configuration on the USB stick: */mnt/grub/device.map* states how GRUB maps BIOS and Linux device names; you need an entry of *(hd0) /dev/sda*.

Change the entries for the BIOS device names from *(hd0,3)* to *(hd0,0)* (this corresponds to */dev/sda1*) in the */mnt/grub/menu.lst* configuration file:

```
title Suse Linux 9.3 (USB-Boot)
   kernel (hd0,0)/vmlinuz root=⮐
   /dev/hda4
   initrd (hd0,0)/initrd
```

Finally, run *grub-install --root-directory=/mnt /dev/sda* to install GRUB on the Master Boot Record of your memory stick. If everything works, you can boot the laptop from the USB stick – to do so, set the BIOS boot order to boot the computer from external boot media first.

Encrypting Partitions

For security reasons, either change to single user mode, or close any unneces-

Secure Data Erasure

Whenever files are deleted by running *rm* against the filenames, Linux simply removes the inodes for the files from the directory. The data stays on the disk and can be reconstructed with a little effort. Reformatting with *mkfs* will not overwrite the partition.

To permanently remove the data, you need to actively modify the magnetization of the sectors (in an appropriate way). The simplest way of doing this is with a command such as *dd if=/dev/zero of=/dev/hda*. But just as a regular fall of snow will not cover the outlines of the landscape, some residual magnetization will remain after overwriting a file with null bytes. An attacker with the right kind of equipment might be able to reconstruct the original data.

A more time consuming approach, but one that is ultimately far more secure, uses */dev/urandom* instead of */dev/zero*. Depending on how paranoid you are, you can do this between three and 35 times [5] to be "fairly certain" that you have removed the data. The *shred* and *wipe* [7] tools will help you do so. But you should be aware that these tools assume a few basic conditions that may not apply to RAID systems, journaling filesystems (such as ReiserFS or Ext3), or certain hard disk drivers and firmware components that buffer data and perform multiple write operations at a single pass.

To be absolutely safe, you would need to destroy the hard disk and dispose of it somewhere where it will never be found. But you can save yourself all that trouble by implementing the mechanisms described in this article, and then just forgetting the passwords.

Table 1: Partitioning

Boot from USB Stick	Alternative: Boot from hard disk	Content
–	*/dev/hda1*	Boot partition */boot*
–	*/dev/hda2*	Extended partition
/dev/hda1	*/dev/hda5*	Encrypted swap partition
/dev/hda2	*/dev/hda6*	Encrypted filesystem */tmp*
/dev/hda3	*/dev/hda7*	Encrypted root filesystem
/dev/hda4	*/dev/hda8*	Unencrypted root filesystem (to be deleted later)

sary applications, stop all unnecessary services, and shutdown any user sessions.

We will be using the Linux system we just installed to encrypt the partitions on the laptop step by step; the partitions in question are */dev/hda1* through */dev/hda3*. Partition */dev/hda4*, which holds the root filesystem right now, will not be needed later. You can recycle it and create a partition for the */home* directory if you like.

The basic steps (see the "Device Mapper, DM-Crypt, and Cryptsetup" box) are always the same: use *cryptsetup-luks* to create a virtual block device with integrated AES encryption, and map it to an appropriate block device (on the laptop hard disk). While doing so, you need to enter a passphrase, which the program will use to create a symmetric key. The key is then used for data encryption. Finally, format the virtual block device with a filesystem, and mount the filesystem.

Warming Up

The swap partition and the */tmp* directory are useful candidates for our first experiments with *cryptsetup-luks*: these filesystems contain temporary data and are no big loss if something goes awry.

Listing 1 shows the command sequences for manually enabling and disabling encryption for swap and */tmp*. For swap, you need to set up a virtual block device, */dev/mapper/swap*, using *cryptsetup-luks*, then initialize the device by running *mkswap* and enable the device by running *swapon*. In the same way, create another virtual block device, */dev/mapper/tmp*, format it with the Ext2 by running *mkfs.ext2*, and then mount the device as */tmp*. For Debian, replace the *cryptsetup-luks* commands with *cryptsetup* or create a suitable link.

In both cases, *cryptsetup-luks* uses random passphrases from */dev/urandom*; the passphrases reside in the laptop's main memory and disappear when you power down the laptop. As nobody knows the passphrases, the data stored on swap and */tmp* is irretrievably lost, but this is intended. Swap contains memory dumps and is reinitialized whenever you boot your computer. There are no benefits from keeping swap readable, and there are a number of security risks. Every distribution has its own approach to handling temporary files. As a rule, programs should not rely on data in */tmp* surviving a reboot.

Genuinely Temporary

It makes sense to recreate these filesystems every time you boot. Debian makes this simple: just set the *CRYPTDISKS_ENABLE = Yes* parameter in */etc/defaults/cryptdisks* (if it is not already set), and add the following to */etc/crypttab*:

```
#<target dev> <source dev>⮐
<key> <options>
swap /dev/hda1 /dev/urandom swap
tmp  /dev/hda2 /dev/urandom tmp
```

You also need to modify */etc/fstab*; remove the existing entry for swap, or modify the entry:

```
/dev/mapper/swap  none  ⮐
swap  sw,pri=1  0 0
/dev/mapper/tmp  ⮐
/tmp  ext2  defaults  0 0
```

Suse Linux also has an */etc/cryptotab* file – but it uses loop devices. For Suse, it makes sense to use an *init.d* script to enable */tmp* and swap. A shell script that

Updates for Debian Sarge

To prepare Debian Sarge for encrypting the root partition, complete the standard installation, and then do this: add the following Apt source (and comment out all other sources in */etc/apt/sources.list*):

```
deb http:⮐
//http.us.debian.org/debian ⮐
unstable contrib main
```

Then run *apt-get update* and *apt-get install -f* to update the package database, and do the following:

```
apt-get install ⮐
yaird linux-image-2.6.17-2-686
apt-get install cryptsetup
```

This installs a current kernel version, *cryptsetup*, and *yaird*, a tool for creating initial RAM disks (like *mkinitrd*). (Note that the kernel image version number may have changed since this issue went to press – version 2.6.17-1 was available on the servers when we started initial testing.) Now boot your computer with the new kernel.

Device-Mapper, DM-Crypt, and Cryptsetup

Just like loop devices, the device mapper infrastructure [2] unhitches physical block devices from virtual block devices (Figure 2). This virtualization creates an abstraction layer that is leveraged by various applications, DM-Crypt [1] being just one of them. DM-Crypt transparently encrypts data passed in by the virtual block device and stores the data on the physical block device – and vice-versa. The physical block device appears to contain garbage – you need to supply the correct passphrase to mount a filesystem via the virtual block device to be able to use the data in a meaningful way.

The *cryptsetup* userspace tool is required to configure DM-Crypt; the virtual block devices are set up in the */dev/mapper/* directory.

cryptsetup-luks is an extension of *cryptsetup*, and offers enhancements, which we discussed in greater detail in [3] – but to summarize:

- A random key is used for data encryption; the key is stored in the LUKS header of the partition – encrypted with the key generated from the passphrase. This gives administrators the ability to change the passphrase without needing to re-encrypt the whole partition.
- Use of salting and stretching makes dictionary attacks on users' passphrases more difficult.
- ESSIV (Encrypted Salt Sector IV) makes watermarking attacks in Cipher Block Chaining mode more difficult; this feature was introduced with kernel 2.6.11.

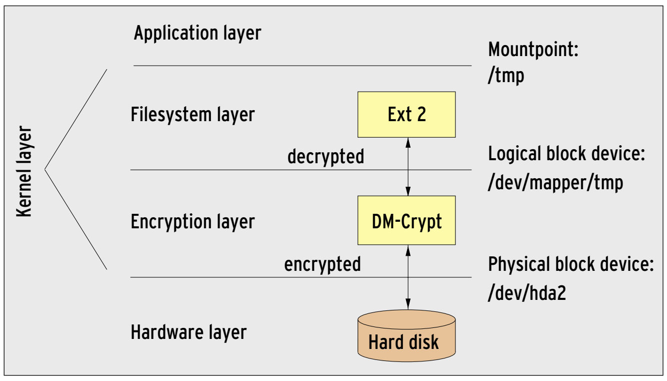


Figure 2: Multiple layered file access – LUKS encryption adds another layer, which resides between the logical filesystem and the hardware (hard disk access).

does this for you (*cryptfs*), and which is based on [8], is available from the Linux Magazine website [9]. After downloading the script (to */etc/init.d/*) create symbolic links in */etc/rcX.d* to call the script in the required runlevels. Finally, delete the line for the previous, unencrypted swap partition from */etc/fstab*.

Root Management

Let's reboot, just to make sure that Linux creates and enables the filesystems. If everything works out, we can move on to our major task, encrypting the root filesystem.

In contrast to */tmp* and swap, the root filesystem is permament: that is, it is not recreated whenever you reboot. Root is created once and mounted at boot time. We need some extended LUKS functionality (from *cryptsetup-luks*) at this point, and the procedure is slightly different:

The following parameters create a LUKS header on */dev/hda3*; LUKS uses the AES encryption algorithm with a key length of 256 bits and sets a passphrase:

```
cryptseup-luks -c ➘
aes-cbc-essiv:sha256 -y -s ➘
256 luksFormat /dev/hda3
```

Now create a virtual block device, */dev/mapper/dm-root*, which will map to the */dev/hda3* partition. *cryptsetup* will prompt you for the passphrase you just specified. Then go on to format the virtual block device (Ext3 format in our example) and mount the device:

```
cryptsetup-luks luksOpen ➘
/dev/hda3 dm-root
mkfs.ext3 /dev/mapper/dm-root
mount /dev/mapper/dm-root /mnt
```

The newly encrypted root filesystem is now mounted below */mnt*, and it is still empty. You will need to insert your bootable memory stick for the following steps. Copy the complete installation from the */dev/hda4* partition to */mnt* – this process encrypts and stores the data on */dev/hda3*. Do not copy the */boot*, */lost+found*, */proc*, */sys*, */tmp*, and */mnt* directories. The copy command looks like this:

```
cd /; cp -ax bin dev etc ➘
home lib media opt root ➘
sbin usr var /mnt/
```

The copy can take awhile, as two to three Gbytes need to be run through the encryption layer. This leaves you with an image of the root filesystem from */dev/hda4* on */dev/hda3*. You can manually umount (*umount /mnt; cryptsetup-luks luksClose dm-root*), and remount (*cryptsetup-luks luksOpen /dev/hda3 dm-root; mount /dev/mapper/dm-root /mnt*) now.

Now use *chroot* to work with the encrypted system. Start by setting up the missing mountpoints, and mount the memory stick as */boot*.

```
chroot /mnt
mkdir -p /boot /proc ➘
/sys /tmp /mnt
mount -t proc proc /proc
mount -t sysfs sysfs /sys
mount /dev/sda1 /boot
```

If you attempted to boot from the memory stick with the root filesystem on */dev/hda3*, or */dev/mapper/dm-root*, would fail right now, as the *init* program (which is part of *initrd*) would not be able to handle the root filesystem in either case: partition */dev/hda3* would seem to contain garbage, and the virtual device, */dev/mapper/dm-root*, does not exist at this point.

The Whole Enchilada

To let Linux boot from the encrypted root filesystem, we need to modify *initrd* as follows:

The *cryptsetup-luks* program, and the required kernel modules, must be referenced in *initrd*.

init has to load the kernel modules, and mount the virtual block device, */dev/mapper/dm-root*, as the root filesystem.

Listing 1: Creating Swap and /tmp

```
# swapoff -a
# cryptsetup-luks -s 256 -d /dev/urandom create swap /dev/hda1
# ls -l /dev/mapper/
total 124
crw-------  1 root root  10, 63 Apr  3  2006 control
brw-r-----  1 root root 253, 0 Apr  2 23:53 swap
# mkswap /dev/mapper/swap
Setting up swapspace version 1, size = 1019895 kB
# swapon /dev/mapper/swap
# cat /proc/swaps
Filename            Type      Size    Used   Priority
/dev/mapper/swap    partition 995988  0      -3
# swapoff /dev/mapper/swap
# cryptsetup-luks remove swap
# cat /proc/swaps
#
# cryptsetup-luks -s 256 -d /dev/urandom create tmp /dev/hda2
# mkfs.ext2 /dev/mapper/tmp
mke2fs 1.36 (05-Feb-2005)
[...]
# mount /dev/mapper/tmp /tmp
# ls -l /tmp/
total 17
drwx------   2 root root 12288 Apr  2 23:55 lost+found
# umount /tmp
# cryptsetup-luks remove tmp
# ls -l /dev/mapper/
total 124
crw-------  1 root root 10, 63 Apr  3  2006 control
```

Depending on the integration status of *cryptsetup* for your distribution, there are different approaches to doing this.

Debian Ramdisk

Debian Sarge has some fairly useful support here. Add the *aes-i586* and *sha256* modules to */etc/mkinitd/modules* (each in a separate line); add the following line to the existing */etc/crypttab* file:

```
dm-root /dev/hda3 none ↩
luks,cipher=aes-cbc-essiv:sha256
```

In a similar way, change the root filesystem in */etc/fstab* to point to */dev/mapper/dm-root*:

```
/dev/mapper/dm-root / ↩
ext3 defaults  0 1
```

Then run *yaird -o /boot/initrd* to create a working *initrd* on the memory stick. *yaird* (yet another initrd) replaces the standard *mkinitrd* tool, which can't handle encrypted root filesystems in the Debian version.

Suse Ramdisk

For Suse Linux, you'll need to add the required kernel modules *dm-mod*, *dm-crypt*, *aes-i586*, *sha256*, and *ext3*, using the *INITRD_MODULES* parameter to the */etc/sysconfig/kernel* file. (The module names must be separated by blanks.)

More changes are required to the */sbin/mkinitrd* program: you might like to create a backup copy before you continue. In the *mkinitrd_kernel* function, look for the lines that copy */sbin/insmod* to the ramdisk; depending on your Suse version, they may look slightly different. For Suse Linux 10.1 the lines look like:

```
if ! cp_bin $initrd_insmod ↩
$tmp_mnt/sbin/insmod 2>↩
/dev/null ; then
    error 5 "no static insmod"
fi
```

Add the following two lines immediately below this:

```
cp_bin /sbin/cryptsetup-luks ↩
$tmp_mnt/sbin/ 2>↩
/dev/null \  || error 5 ↩
"no static cryptsetup-luks"
```

In the *udev_discover_root* function, add the following as the first command:

```
| echo "Setting up LUKS ↩
device $rootdev. ↩
Provide pass phrase now."
| /sbin/cryptsetup-luks ↩
luksOpen /dev/hda3 dm-root
```

Then you just need to change the entry for the root filesystem to */dev/mapper/dm-root* (for the *ext3* filesystem) in */etc/fstab*. Finally, give the */sbin/mkinitrd -o /boot/initrd* command to create a new initial RAM disk on the memory stick.

The Tension Mounts

Before rebooting, modify the */boot/grub/menu.lst* file on your memory stick. Change the *root* kernel parameter in the menu entry that launches the Linux system to point to the virtual block device, */dev/mapper/dm-root*. You also need to modify the *initrd* entry (*/boot/initrd*). A typical entry will look like this:

```
title Suse Linux 10.0 ↩
(USB-Boot, Encrypted Root)
    kernel (hd0,0)/vmlinuz ↩
root=/dev/mapper/dm-root
    initrd (hd0,0)/initrd
```

Reboot the laptop. Make sure you have set USB as the default boot device in the BIOS boot order. *cryptsetup-luks* will now prompt you for the passphrase for the root filesystem, and assuming that you provide the correct password, boot to the login screen. Calling *mount* removes any trace of doubt (Figure 3). If this does not work, try booting without the memory stick: you still have the unencrypted Linux system on the hard

Security 101

Encrypting your laptop hard disk is just one layer in an all-encompassing security policy – and it is no replacement for a security policy, as it only protects the data while the computer is switched off. If you lose your laptop after entering the correct pass phrases and with a user session running on the Linux system, an attacker would have the same access as to a completely unprotected machine. This warning also applies to threats from the Internet, assuming the laptop has an Internet connection. Malware has unrestricted access to your data once it gains access to the system.

In other words, this workshop cannot give you absolute security; but following these rules will keep your laptop as secure as possible:

- Store the laptop and memory stick separately.
- Configure a power-on password and a supervisor password in your laptop's BIOS; only allow a USB stick as the boot medium.
- Use robust passwords, and change them at regular intervals.
- Do not work with root privileges if you can avoid doing so.
- Use a restrictive (personal) firewall configuration.
- Use at least one virus scanner with current virus signatures.
- Set up a password-protected screensaver, and let the screensaver enable automatically.
- Check your logfiles for suspicious entries at regular intervals.
- Check for and install security patches and updates for any software you use.
- Back up your data at regular intervals; keep the backups in a safe place.

INFO

[1] DM-Crypt: *http://www.saout.de/misc/dm-crypt*

[2] Device Mapper Resource Page: *http://sources.redhat.com/dm/*

[3] "Secret Messages: Hard disk encryption with DDM-Crypt, LUKS, and cryptsetup," by Clemens Fruhwirth and Markus Schuster, Linux Magazine 12/05, pg. 65.

[4] Linux Unified Key Setup (LUKS): *http://luks.endorphin.org/dm-crypt*

[5] Peter Gutmann, "Secure Deletion of Data from Magnetic and Solid-State Memory": *http://www.cs.auckland.ac.nz/~pgut001/pubs/secure_del.html*

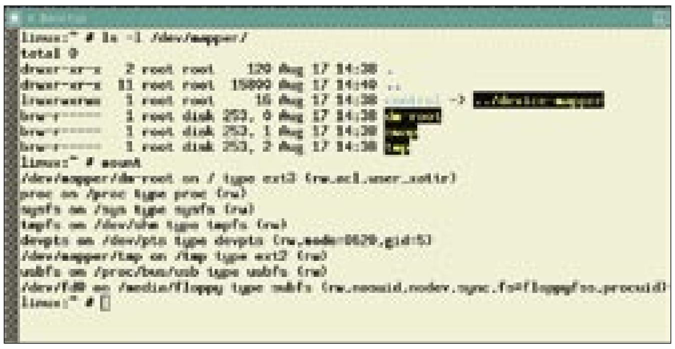
[6] Suspend 2: *http://www.suspend2.net*

[7] Wipe – Secure File Deletion: *http://wipe.sourceforge.net*

[8] Luksopen script on the DM-Crypt Wiki: *http://www.saout.de/tikiwiki/tiki-index.php?page=luksopen*

[9] Shell script *cryptfs*: *http://www.linux-magazine.com/Magazine/Downloads/72/DM-Crypt*

[10] Clemens Fruhwirth: "New Methods in Hard Disk Encryption," *http://clemens.endorphin.org/nmihde/nmihde-A4-ds.pdf*



```
linux:~ # ls -l /dev/mapper/
total 0
drwxr-xr-x   2 root root     120 Aug 17 14:38 .
drwxr-xr-x  11 root root   15080 Aug 17 14:40 ..
lrwxrwxrwx   1 root root      16 Aug 17 14:38 control -> ../device-mapper
brw-r-----   1 root disk 253, 0 Aug 17 14:38 dm-root
brw-r-----   1 root disk 253, 1 Aug 17 14:38 swap
brw-r-----   1 root disk 253, 2 Aug 17 14:38 tmp
linux:~ # mount
/dev/mapper/dm-root on / type ext3 (rw,acl,user_xattr)
proc on /proc type proc (rw)
sysfs on /sys type sysfs (rw)
tmpfs on /dev/shm type tmpfs (rw)
devpts on /dev/pts type devpts (rw,mode=0620,gid=5)
/dev/mapper/tmp on /tmp type ext2 (rw)
usbfs on /proc/bus/usb type usbfs (rw)
/dev/fd0 on /media/floppy type subfs (rw,nosuid,nodev,sync,fs=floppyfss,procuid)
linux:~ #
```

Figure 3: After completing the operations, you should see three encrypted filesystems below /dev/mapper and in the mount table. To remove the remaining cleartext information from your disk, create an encrypted /home on hda4.

disk, and you can start troubleshooting from there.

Fine Tuning

If all of this works out, you no longer need the unencrypted root filesystem on */dev/hda4*. Delete the data on the partition and use *cryptsetup-luks* to set up another encrypted filesystem called */dev/mapper/dm-home*. Format the partition, and mount it as */home*. Then create any users you need; their home directories are automatically encrypted on */dev/hda4*.

One downside to this is that encrypted swap and suspend to disk are mutually exclusive – make sure to disable the latter for this reason (if it exists, remove the kernel parameter *resume=/dev/hda1* from */grub/menu.lst*.) Suspend2 [6] is an alternative that supports suspend to disk with an encrypted swap partition; however, this means patching and compling the vanilla kernel.

You will not need the memory stick while the laptop is running, however, it is essential to plug in the stick for kernel updates, as *mkinitrd* or *yaird* will want to install the new *initrd* on the stick. To be on the safe side, backup the memory stick before you update the kernel, or add an entry to the previous, working system to your GRUB configuration. Kernel 2.6.13 saw a few modifications to *udev*, and they may prevent the *initrd* you created from performing as desired. *yaird* does not share this problem. To be really safe, create a live CD with LUKS support. You can use the CD to manually mount and back up encrypted partions.

Suse users need to be careful if YaST updates the *mkinitrd* package. Back up the LUKS changes to the */sbin/mkinitrd* script and compare them with the new version after updating *mkinitrd*.

Conclusions

During this workshop, we have encrypted the whole laptop hard disk except for the Master Boot Record. You need the memory stick to boot. This gives road warriors a high degree of passive security. But you should still be aware of common protective and security measures (see the "Security 101" box). ■

advertisement