

Kernel Module Packages Manual

SUSE Linux Enterprise 12 SP2 or later and SUSE Linux Enterprise 15

SUSE Linux Enterprise Server 12 SP2 and later
SUSE Linux Enterprise Server 15

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SUSE-based distributions use the RPM Package Manager for software management. As such, any external kernel modules (these are kernel modules not included in SUSE kernel packages) should be packaged in RPM packages. These RPMs should be built in accordance with specific guidelines to ensure that the resulting Kernel Module Packages (KMPs) can be installed and updated appropriately, in synchronization with kernel updates.

This document specifies the requirements for RPM packages that contain kernel modules, and describes the processes surrounding those packages including building, signing, installing and upgrading. A complete example is given and explained. This version of the Kernel Module Packages Manual applies to SUSE Linux Enterprise Server 12 (Service Pack 2 and later), and SUSE Linux Enterprise Server 15, and all products based on these versions.

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1 Scope

This version of the Kernel Module Packages Manual applies to:

- SUSE Linux Enterprise Server 12 Service Pack 2 and later or SUSE Linux Enterprise Desktop 12 Service Pack 2 and later, and all products based on these versions
- SUSE Linux Enterprise Server 15 and SUSE Linux Enterprise Desktop 15 (along with service packs)
- All products and extensions based on SUSE Linux Enterprise Server 12 SP2 or later and SUSE Linux Enterprise Server 15

Developers who want to build for SUSE Linux Enterprise Server versions before SUSE Linux Enterprise Server 12 SP2 should use previous versions of this document [SUSE SolidDriver Documentation: Kernel Module Packages Manual for Code 11](https://documentation.suse.com/sbp/all/html/SBP-KMP-Manual/index.html) (<https://documentation.suse.com/sbp/all/html/SBP-KMP-Manual/index.html>) [↗](#).

Appendix B provides a list of changes that have been made to this document to accommodate new features.

2 Background

The Linux kernel supports adding functionality at runtime through kernel-loadable modules. It includes more than 1500 modules, about 75 percent of which are hardware drivers. These modules are shipped as part of the kernel packages. In some cases it is desirable to add additional modules or replace existing ones. For example, a driver for a particular storage controller that was not available at the time of product release might be added later to support new hardware. Kernel modules interact with the kernel by the means of exported symbols, in a way similar to how user space binaries use shared libraries. The `/proc/kallsyms` file lists all symbols currently known to the kernel. To ensure that the kernel and modules refer to the same symbols, a version checksum (`modversion`) is added to each symbol. The checksum is computed from the symbol's type: in the case of function symbols, the checksum is determined by the function's parameters and return type.

When any of a function's parameters or the return type changes, the checksum changes as well. This includes all the data types involved recursively:

If a function takes a **struct task_struct** as parameter and **struct task_struct** includes a field of type **struct dentry**, then a change to **struct dentry** will cause the symbol's version checksum to change as well. Symbol version checksums for different kernel flavors (for example **kernel-default** versus **kernel-xen**) will not match, and symbol versions of the same kernel package on different architectures will not match either. This mechanism ensures that the kernel and kernel modules agree on the types of data structures that they use to communicate.

Unless symbol version checking is disabled, modules will load only if the checksums of the symbols they use match the checksums of the symbols that the kernel exports. The exported symbols and their version checksums comprise the kernel Application Binary Interface (kABI). When an updated kernel includes kABI changes, kernel modules that use any modified symbols must be updated as well.

During their multi-year lifecycle, products like SUSE Linux Enterprise Server undergo continuous changes. Different kinds of updates like service packs (SPs), maintenance/security updates, and customer-specific updates (Program Temporary Fixes) are released. The Application Binary Interface (ABI) between the kernel and kernel modules is volatile. Some kernel updates will change the kernel ABI (kABI) by adding or removing exported symbols, or existing symbol checksums can change in a kernel update because of changes in data structures they reference. SUSE strives to keep the kernel ABI stable in maintenance and security and customer-specific updates, but sometimes changes cannot be avoided. In service packs, SUSE reserves the right to introduce more intrusive changes, which increases the likelihood of ABI changes. SUSE believes that the added flexibility outweighs the disadvantages of breaking older modules. For full discussion of this topic, see the documentation [SUSE SolidDriver Documentation: SUSE Kernel ABI Stability \(https://drivers.suse.com/doc/SolidDriver/SUSE_Kernel_ABI_Stability.html\)](https://drivers.suse.com/doc/SolidDriver/SUSE_Kernel_ABI_Stability.html) and [The Linux Kernel Driver Interface \(http://www.kroah.com/log/linux/stable_api_nonsense.html\)](http://www.kroah.com/log/linux/stable_api_nonsense.html) from Greg Kroah-Hartman (also provided as **stable_api_nonsense.txt** in the upstream kernel source tree). SUSE Linux Enterprise-based operating systems include technology to ensure that kernel modules can be reused or updated in synchronization with kernel updates. To use this technology, kernel modules must be packaged into Kernel Module Packages (KMPs) as defined in this document.

3 Kernel packages

Each product based on SUSE Linux Enterprise 12 SP2 or SUSE Linux Enterprise 15 contains a set of kernel packages that share the same version and release number; they are built from the same kernel sources. These packages are:

kernel-FLAVOR, kernel-FLAVOR-base

The binary kernel packages. Each architecture has its own set of kernel flavors (for example kernel-default, kernel-debug, etc.). These are the packages that the kernel modules will be used with.

The kernel-FLAVOR-base packages are subsets of the kernel-FLAVOR packages, intended for use with minimal installs. They are not installed by default.

kernel-source

The kernel source tree, generated by unpacking the vanilla kernel sources and applying all necessary patches. Although the kernel-FLAVOR packages technically are not built from the kernel-source package, they are built from the same source tree. This tree should be used for module building.

kernel-devel, kernel-macros

Kernel-level headers, makefiles, and RPM macros and templates required for development of external kernel modules.

kernel-syms, kernel-FLAVOR-devel

Kernel symbol version information for compiling external modules. The kernel-FLAVOR-devel package is *required* for building external modules. If this package is not used, the resulting modules will be missing symbol version information, which will cause them to break during kernel updates. The kernel-syms package is a placeholder package which depends on the kernel-FLAVOR-devel packages for all kernel flavors.

For more information, refer to the document “Working With The SUSE 2.6.x and 3.x Kernel Sources” from Andreas Gruenbacher and Michal Marek. This document is provided as README.SUSE in the SUSE `kernel-source` package.

4 Kernel modules

Documentation on general kernel module building can be found in abundance on the Internet. Two good lectures are:

- Peter Jay Salzman, Michael Burian, Ori Pomerantz: The Linux Kernel Module Programming Guide, <http://www.tldp.org/LDP/lkmpg/2.6/html/index.html> ↗
- Jonathan Corbet, Alessandro Rubini, Greg Kroah-Hartman: Linux Device Drivers, Third Edition, February 2005, <http://www.oreilly.com/catalog/linuxdrive3/> ↗ (also available online at <http://lwn.net/Kernel/LDD3/> ↗)

SUSE-specific information is found in the above-mentioned README.SUSE in the `kernel-source` package.

When built, kernel module binaries are installed below `/lib/modules/VERSION-RELEASE-FLAVOR` on the file system (example: `/lib/modules/4.4.73-5-default` for the SUSE Linux Enterprise Server 12 SP3 `kernel-default-4.4.73-5` package). Different kernels have different module directories, and will usually not see each other's modules.

Update modules are modules intended to replace or augment the modules that are provided in the kernel packages. Update modules must be stored below the `/lib/modules/VERSION-RELEASE-FLAVOR/updates/` directory. Modules in the `updates/` directory have precedence over other modules with the same name. Never replace modules from the kernel package by overwriting files: this would lead to inconsistencies between the file system and the RPM database.



Note: Where to store modules

Modules intended to take precedence over in-kernel modules of the same name should be stored below `/lib/modules/VERSION-RELEASE-FLAVOR/updates/`. Other add-on modules can be stored below `/lib/modules/VERSION-RELEASE-FLAVOR/extra/`.

Modules usually remain compatible with a range of `kernel-FLAVOR` packages. To make such modules visible to other `kernel-FLAVOR` packages, symbolic links to compatible modules are put in `/lib/modules/VERSION-RELEASE-FLAVOR/weak-updates/` directories. Modules in the

weak-updates/ directory have lower priority than modules in the updates/ directory, but higher priority than all other modules in /lib/modules/VERSION-RELEASE-FLAVOR. If more than one compatible module is available for a kernel, the module with the highest kernel release is chosen. Kernel Module Packages must never directly install modules into weak-updates/ directories.

Kernel modules must never be installed as individual files on a production system, but always as part of a Kernel Module Package.

5 Kernel Module Packages

SUSE has worked closely with the Linux Foundation Driver Backport Workgroup to establish a standard structure for building Kernel Module Packages for all RPM-based distributions. The information in this document includes the standards as appropriate.

Kernel Module Package spec files define a main package, and a sub-package for each kernel flavor supported. The kernel-flavor-specific sub-packages are defined with the %kernel_module_package RPM macro. The macro automatically determines for which kernel flavors to generate sub-packages. Several options are available to modify the macro's behavior, which are described below:

```
%kernel_module_package [-f filelist] [-p preamble] [-n name] [-v version] [-r release] [-t template] [-x flavor] [-b]
```

The main package of a Kernel Module Package can either contain no **%files** section, in which case **rpm** will not create a binary package with the main package's name, or the files section can also be used for the user space part associated with the kernel modules that end up in the kernel specific sub-packages. The example Kernel Module Package in Appendix A has a main package without a **%files** section.

Kernel Module Packages must adhere to the following rules:

- The package Name should consist of two components: a unique provider prefix, and a driver name. Hyphens are disallowed in the provider prefix, and allowed in the driver name. The provider prefix serves to create a non-overlapping name space for all providers.

The sub-package names are composed of the main package name, followed by a dash, the string “kmp”, followed by another dash and the flavor of the supported kernel. The first component (main package name) can be overridden with a different value by using the `-n` option of the `%kernel_module_package` macro.

- The kernel module package `Version` can have an arbitrary value.
The sub-package versions are composed of the main package version, followed by an underscore, and the version of the kernel source used during the build.
Since sub-packages already include the supported kernel's flavor in their name, the flavor is not again included in the sub-package's version. Dashes in the kernel release are replaced by underscores. The first component (main package version) can be overridden with the `-v` option of the `%kernel_module_package` macro.
- The kernel module package `Release` can be assigned freely as required. It must be incremented at least once for each package release.
The sub-package release numbers equal the main package's release number. It can be overridden with the `-r` option of the `%kernel_module_package` macro.
- The appropriate **Requires** and **Provides** tags are computed automatically by `rpm` as described in the RPM Provides and Requires section below. Requires and Provides tags in the spec file will only be effective for the main package.
- Kernel modules must be installed below `/lib/modules/VERSION-RELEASE-FLAVOR/updates/`.
- Packages must be signed with a public/private key pair, and the public key of the private/public key-pair used for signing must be made known to RPM. See [Section 8.1, “Signing packages”](#) for details.

The `%description` tag will be applied to both the main package and the sub-packages.

The `%kernel_module_package` macro uses a default sub-package template that should work for most KMPs. This template can be overridden using the macro's `-t` option. The default template takes care of the following:

- When a KMP package is installed, `depmod` is called to update module dependency information and various maps. Symbolic links pointing at the new modules are created in other kernels' `weak-modules/` directories for all compatible modules. Initial RAM disks used during booting are re-created automatically if they contain some of the added modules.

Using the macro's `-b` option will force the recreation of the initial RAM disk regardless of whether the existing RAM disk contains modules with the same names as the modules being installed.



Note: RAM disk rebuild

The `-b` option simply forces a RAM disk rebuild using the existing RAM disk configuration. If the existing RAM disk configuration does not include previous versions of the new modules being installed, using the `-b` option will not include the new modules in the new RAM disk. In such cases, the Kernel Module Package spec file also needs to make appropriate RAM disk configuration changes to include the new modules. This can for example be done by creating or updating files in `/etc/dracut.conf.d`.

- When a KMP is removed, `depmod` is called to update module dependency information and various maps. The symbolic links pointing to the modules being removed are removed as well. Initial RAM disks are re-created in case they did contain some of the removed modules.

By default, each kernel-specific sub-package will have the following list of files, which can separately be overridden with the `-f` option:

```
%defattr (-,root,root)
/lib/modules/%2-%1
```

Additional sub-package preamble lines such as **Requires**, **Provides**, and **Obsoletes** tags can be specified with the `-p` option. File name arguments specified in `-f`, `-p` and `-t` should be given as absolute path names (for example `$_sourcedir/file`) and should be listed as sources. The following substitutions are defined in those files:

- `%1` Flavor of the sub-package (for example: default)
- `%2` Kernel release string without flavor (for example: 4.4.73-5)
- `%{-v*}` The sub-package version
- `%{-r*}` The sub-package release

Some Kernel Module Packages may make sense only for some of the kernel flavors a given architecture supports. A list of flavors to exclude from the build should be passed with the `-x` option to the `%kernel_module_package` macro.

Appendix A contains an example Kernel Module Package spec file and the source code referenced by it. When this spec file and its accompanying source is built into an x86_64 RPM as described in section [Section 7, “Building Kernel Module Packages”](#), the **BuildRequires** tag in the spec file will pull the `module-init-tools`, `kernel-source`, `kernel-syms` and `kernel-devel` packages into the build root.



Note: Dependency

The `%kernel_module_package_buildreqs` macro does not need to explicitly list “kernel-source” since the `kernel-syms` package has a dependency on the `kernel-source` package.

Now assume that the required packages are available in SUSE Linux Enterprise Server 12 SP3 (kernel 4.4.73-5), and that the default kernel flavor is available on that platform. Assuming a release number of “0”, `rpm` would then create the following packages:

`suse-hello-kmp-default-1.0_k4.4.73_5-0.x86_64.rpm`

The generated packages would contain the following module, and require and provide the following symbols:

TABLE 1: PACKAGE INFORMATION

Package	Requires	Provides	Modules
suse-hello-kmp-default	ksym(default:_fentry_) = bdfb6dbb ksym(default:module_layout) = 86aec989 ksym(default:param_ops_int) = dbc5e1fa ksym(default:printk) = 27e1a049	ksym(default:exported_function) = e52d5bcf	/lib/modules/4.4.73-5-default/updates/hello.ko

6 RPM Provides and Requires

Kernels export symbols that kernel modules use. Symbols have version checksums attached, and the checksums of the exported kernel symbols must match the checksums of the kernel symbols that the Kernel Module Package uses.

Similarly, at an RPM level, each `kernel-FLAVOR` package (for example `kernel-default`) provides the symbols and checksums that are exported by that flavor of the kernel, and each Kernel Module Package requires the specific kernel symbols and checksums needed by the module(s) that it contains. Installation of a KMP will succeed as long as an installed kernel package provides the symbols and checksums that are required by the KMP.

When modules in Kernel Module Packages export additional symbols, such symbols are mapped to **Provides** of those packages. Modules in other Kernel Module Packages may require those symbols. As an example, assume that a Kernel Module Package provides an exported function as `ksym(default:exported_function) = e52d5bcf`. Any Kernel Module Package that uses this function would require this same symbol and checksum.

7 Building Kernel Module Packages

In addition to the C and kernel programming skills required for writing the kernel module source code, creating proper Kernel Module Packages requires some familiarity with the `rpm` command and with build environments. For more information on kernel module building refer to the above-mentioned [Linux Kernel Module Programming Guide \(http://www.tldp.org/LDP/lkmpg/2.6/html/index.html\)](http://www.tldp.org/LDP/lkmpg/2.6/html/index.html) and the book [Linux Device Drivers \(http://www.oreilly.com/catalog/linuxdrive3/\)](http://www.oreilly.com/catalog/linuxdrive3/). Additional SUSE-specific kernel and kernel module information can be found in the README.SUSE in the kernel-source package. SUSE recommends using the example package found in Appendix A as a template to reduce the complexities related to RPM. A lot of additional information on RPM can be found at <http://www.rpm.org/>, including a reference to the excellent Maximum RPM.

SUSE strongly recommends using the kernel build infrastructure (`kbuild`) for building and installing the kernel modules, as done in the example package. `kbuild` is documented in the file `/usr/src/linux/Documentation/kbuild/` from the `kernel-source` package. Trying to emulate `kbuild` will lead to various problems including mis-compilations and missing or wrong symbol versions, and increased support load because of subtle breakages.

To achieve consistent and reproducible builds in a defined environment independent of the software installed on the system used for building, use the build script from the `build.rpm` package. This script sets up a build environment from the RPM packages the script is pointed at. The packages are then built in this environment using `chroot` (see the `chroot(1)` manual page at <https://linux.die.net/man/1/chroot>). All SUSE packages are built using the same mechanism. When building Kernel Module Packages with `build.rpm`, the following options of the build script are particularly relevant:

`--root directory`

Define the directory in which to set up the build environment. Defaults to the `BUILD_ROOT` environment variable, and to `/var/tmp/build-root` if unset.

`--RPMs path1[:path2:...]`

Define where build will look for packages for constructing the build environment. The directories are searched recursively. Packages found earlier in the path have precedence over packages found later, similar to how the `PATH` environment variable works. Defaults to the `BUILD_RPMS` environment variable, and to `/media/dvd/suse` if unset. The `--rpms` option must only be specified once.

`--clean, --no-init`

Reconstruct the build environment entirely from scratch (`--clean`), or start the build without initializing the build environment (`--no-init`), which skips checking whether all packages in the build environment are up-to-date.

Build stores the created packages below `home/abuild/rpmbuild/` in the build environment.

On dual-architecture machines, packages for the other supported architecture can be built by running the build script inside an architecture selector. On Intel 64/AMD64, the selector is called `linux32`, on IBM POWER this is `ppc32`, and on IBM Z the selector is called `s390x`. The same build environment cannot be reused for different architectures unless it is reinitialized with build's `--clean` option.

See the `build(1)` manual page for further information.



Note: Building external modules

For building external modules, you need to have both the `kernel-source` and `kernel-FLAVOR-devel` packages installed in the build environment. The **BuildRequires** line in spec files takes care of this: the `%kernel_module_package_buildreqs` macro specifies the `kernel-syms` package, which pulls in the `kernel-source` package and the `kernel-FLAVOR-devel` packages because of its dependency on them. Without the `kernel-syms` package the module build can still succeed depending on how you do the build, but the resulting modules will have module symbol versions disabled. Kernel Module Packages without module symbol versions will appear to match any kernel although in fact they do not. This can easily lead to very hard-to-diagnose system malfunctions.

8 Signing

Signing (as applied to a piece of software) is the process of digitally tagging the software to verify the author and guarantee that the software has not been altered since it was signed. SUSE Linux Enterprise Server and SUSE Linux Enterprise Desktop include utilities to sign and validate signatures on packages and repositories. In addition, SUSE Linux Enterprise Server and SUSE Linux Enterprise Desktop 12 and later versions include technology to sign and validate signatures on kernel modules.

The following sections describe how to sign packages and kernel modules. The topic of repository signing is beyond the scope of this document.

8.1 Signing packages

All packages that are provided in SUSE Linux Enterprise Server and SUSE Linux Enterprise Desktop are digitally signed with the SUSE Build key. SolidDriver/PLDP packages that are built on the SolidDriver Build Server by the SUSE SolidDriver team are automatically signed with the SUSE SolidDriver/PLDP key. For more information, visit https://drivers.suse.com/doc/Usage/Package_Signing_Key.html#package-signing-key. Partners who build and/or provide their own packages are encouraged to sign them with their company keys.

For testing purposes, developers can sign packages using their own personal and/or test keys. RPM uses GnuPG (gpg) for signing. To sign packages, a private/public key pair must be installed on the GNU Privacy Guard (GPG) keyring of the signing user (see the `--gen-key` option in the `gpg(1)` manual page at <https://linux.die.net/man/1/gpg>). Then the following command can be used to sign a package:

```
$ rpm --eval "%define _signature gpg" \  
  --eval "%define _gpg_name build@suse.com" \  
  --addsign package.rpm
```

Ensure to replace **build@suse.com** with the identity that identifies your signing key).

A package can only be signed once. Another `--addsign` operation will replace an existing old signature, and will add the new one.

The public key used for signing must then be exported into a file with the command:

```
$ gpg --armor --export build >build-pubkey.txt
```

Next, import the key into the RPM database with the command:

```
$ rpm --import build-pubkey.txt
```

You can verify that both package signing and key import have succeeded with RPM's `--check-sig` option (note the “gpg” in the output):

```
$ rpm --checksig package.rpm  
package.rpm: (sha1) dsa sha1 md5 gpg OK
```

The public key exported to `build-pubkey.txt` must be delivered to customers in a way that they will trust. It must be imported into the RPM database on systems on which the signed packages are to be installed.

8.2 Signing module object files (*UEFI Secure Boot*)

Although using signed packages and other OS security features can secure an installed and running system, they cannot prevent system subversion before the OS has booted. To address pre-OS security concerns, the UEFI Secure Boot specification (see <http://www.uefi.org/specs>) details a protocol to prevent the loading of boot loaders or kernels (including modules) that are not signed with an approved digital key stored in the system firmware.

The UEFI Secure Boot specification allows for variation in implementation. A simple way to implement secure boot is to ensure that the base system (as provided by the system vendor) contains all the keys that will be used by the boot loader, the OS, and any drivers. But having

the system vendor simply place all needed keys into the firmware is not a full solution, as it does not give appropriate control to the system user/owner. SUSE's secure boot implementation addresses this control issue by extending the secure-boot-enabled EFI shim loader to accept keys that have been approved by the system owner. Thus, if there is a need to load a module with an unrecognized key, the key can be added to the “approved key” database (reboot and system-owner approval required).

8.2.1 Creating a key and certificate

Module signing requires having access to a digital key and certificate. Official keys and certificates are generally maintained by an organization's security team or by build services (such as the Open Build Service or the SolidDriver/PLDP Build Service). Developers and packagers can also generate their own keys and certificates for example for testing purposes.

To create a key and certificate using the `openssl req` command, type the following:

```
export USER="your company name"
openssl req -new -x509 -newkey rsa:2048 -sha256 -keyout key.asc -out cert.der \
    -outform der -nodes -days 4745 -addext "extendedKeyUsage=codeSigning" \
    -subj "/CN=$USER/"
```

The above sequence of commands will create a `key.asc` key file and a `cert.der` x509 certificate in the current working directory. The `4745` option generates a certificate which will be valid for 13 years.



Note: Extended Key Usage (EKU) setting

The `-addext "extendedKeyUsage=codeSigning"` openssl option has been added to this document as of October 2021. The EKU `codeSigning` setting is now required for latest kernel releases of SUSE Linux Enterprise 15 SP2 and all kernels of subsequent service packs to accept the certificate for signature verification of kernel modules.

The `-addext` option requires OpenSSL version 1.1.1 or later. For earlier versions of OpenSSL, consult the documentation for setting the EKU.

8.2.2 Signing modules during packaging

Signing modules as part of the packaging process requires making several changes to the KMP spec file. The spec file template in Appendix A.1 includes these changes, which are:

1. List the certificate file as a **%Source** file. The top-level directory of the build structure (where the spec file is located) should include both a private key file and a certificate file. The spec file should list the certificate as a *%Source* file. The spec file should not list the key file (since the private key should not be included in the source KMP).



Note: Naming

To be recognized by the kernel Makefile, the key file must be named “`signing_key.priv`” and the certificate file must be named “`signing_key.x509`”. The example above describes how to use the `openssl req` command to create a `key.asc` key file and a `cert.der` certificate file; to use these files at packaging-time, they should be renamed to “`signing_key.priv`” and “`signing_key.x509`”.

2. Invoke the `%kernel_module_package` macro with the `-c %_sourcedir/signing_key.x509` option to generate a `<name>-ueficert` package which installs the certificate and calls the `mokutil` utility to enroll the public key. The actual module signing is handled in the `%install` section of the spec file.
3. Add `%install` section code to invoke the `kernel-sign-file` file to sign the modules.



Note: Own Keys and Certificates

The Appendix A.1 sample spec file is designed to be used by developers and packagers who provide their own keys and certificates and their own build environments. Developers/packagers who use the Open Build Service should modify their spec file as described in the `pesign-obs-integration` package [README \(https://github.com/openSUSE/pesign-obs-integration/blob/master/README\)](https://github.com/openSUSE/pesign-obs-integration/blob/master/README).

8.2.3 Signing an existing KMP

The `pesign-obs-integration` package in SUSE Linux Enterprise Server provides a `mod-sign-repackage` utility that can be used to sign kernel modules in an existing KMP. `mod-sign-repackage` unpacks the original RPM, signs any included modules and re-creates the

RPM. It also creates a second `<NAME>-ueficert` RPM that installs the certificate and calls the `mokutil` utility to enroll the public key. The re-packaged RPM will have a dependency on the `<NAME>-ueficert` RPM, ensuring that the certificates will be installed at the same time as the module(s).

To repackage the `suse-hello-kmp-default-1.0_k4.4.73_5-0.x86_64.rpm` package with the key and the certificate created above, do the following:

```
modsign-repackage -c ./cert.der -k ./key.asc
                  ./suse-hello-kmp-default-1.0-k4.4.73_5-0.x86_64.rpm
```

The above command creates the following directories and files in the current working directory:

```
./RPMS/
  x86_64/
    suse-hello-kmp-default-1.0-k4.4.73_5-0.x86_64.rpm
    suse-hello-ueficert-1.0-0.x86_64.rpm
```

To see the module signature, unpack the repackaged KMP and use the `modinfo` command to view the module signature info:

```
rpm2cpio suse-hello-kmp-default-1.0-k4.4.73_5-0.x86_64.rpm | cpio -idv
modinfo ./lib/modules/4.4.73-5-default/updates/hello.ko | grep signature
```



Note: rpm-build must be installed

`modsign-repackage` uses the `/usr/bin/rpmbuild` utility which is provided by the SUSE Linux Enterprise Server `rpm-build` package. This means the `rpm-build` package must be installed to use `modsign-repackage`.

8.2.4 Installation of secure-boot-enabled KMPs

As discussed above, secure-boot-enabled KMPs include an additional `<NAME>-ueficert` package to install the certificate and enroll the public key. The `<NAME>-kmp-<flavor>` packages require the `<NAME>-ueficert` package.

After the `<NAME>-ueficert` package is installed, the system must be rebooted and the newly-enrolled key approved by the system owner before the key (and thus the signed modules) can be used.

The `mokutil` utility can also be used on its own to view and manage keys in the key database.

9 Deploying Kernel Module Packages

Kernel Module Packages can be provided as stand-alone RPMs. However, SUSE encourages distributing them via add-on products (for drivers that do not need to be included in the installation kernel), or in driver update disks or full bootable driver kits (for drivers that do need to be included in the installation kernel).

Add-on products can be created using the YaST Add-on Creator module in the SUSE Linux Enterprise Server 12 Software Development Kit (SDK). They can also be created manually using the information available in the section **Creating Add-Ons** from the document [Update Media HOWTO](ftp://ftp.suse.com/pub/people/hvogel/Update-Media-HOWTO) (<ftp://ftp.suse.com/pub/people/hvogel/Update-Media-HOWTO>) ↗.

Driver update disks can be created using the information in the section **SUSE Update Media Howto** from the document [Creating Add-Ons](https://www.novell.com/developer/creating_add-ons.html) (https://www.novell.com/developer/creating_add-ons.html) ↗. To create full custom bootable installation media, use the `mksusecd` utility included in SUSE Linux Enterprise Server. Note that `mksusecd` does not include a man page but provides detailed usage information via `mksusecd --help`.

10 System installation and Kernel Module Packages

Initial system installation is carried out by YaST from some installation media (CDs or DVDs, network locations, etc.). As noted above, support for additional hardware that the installation media do not provide can be added with Driver Update Disks or Bootable Driver Kits/Installation Kits. This is most important to enable hardware needed for booting, such as storage controllers. Update media such as Driver Update Disks and Bootable Driver Kits/Installation Kits provide two kinds of modules: those which the kernel that runs the installation uses, and those which are installed onto the final target system. Both types of modules are provided by including Kernel Module Packages on the update media. In addition, update media can contain scripts which are run at specific times during the installation.

After the initial YaST installation, additional driver packages can be installed using any of the mechanisms for installing RPM packages (YaST Add-on Products, YaST Software Management, YaST Online Update, the `rpm` command, etc.). The add-on product format supports the ability to register the system for an update site.



Note: **initrd**

Any drivers required for getting to and accessing the root file system must be part of the initial RAM disk. YaST will automatically include necessary kernel modules in the **initrd** created during installation. But when Kernel Module Packages are installed by hand or are updated, it can be necessary to explicitly rebuild the **initrd** to include the new modules. As noted in [Section 5, “Kernel Module Packages”](#), a Kernel Module Package will automatically rebuild the **initrd** in its `%postinstall` script if the module being installed is already part of the existing **initrd** or if the `-b` option to the `%kernel_module_package` macro is used. The `-b` option simply forces a RAM disk rebuild using the existing RAM disk configuration: If the existing RAM disk configuration does not include the module being installed, then simply using the `-b` option will not include the new module in the new RAM disk. In such cases, the Kernel Module Package also needs to make appropriate RAM disk configuration changes (for example by creating or updating files in `/etc/dracut.conf.d`) to include the new module.

11 Kernel updates and Kernel Module Packages

After all software repositories that should be checked for updates have been added, the package manager will automatically detect when new kernel packages and new Kernel Module Packages become available. The dependencies between those packages will ensure that the installed kernel packages match the installed Kernel Module Packages.

12 Appendix A: Sample source for `suse-hello` Kernel Module Package

The following sample is described in the section [Section 5, “Kernel Module Packages”](#). For a sample spec file that signs modules during packaging, see [Appendix A.1](#).

suse-hello.spec

```
# norootforbuild

Name:          suse-hello
Version:       1.0
Release:       0
Summary:       Sample Kernel Module Package
```

```

License:          GPL-2.0
Group:            System/Kernel
Source0:          %{name}-%{version}.tar.bz2
BuildRequires:   %kernel_module_package_buildreqs
BuildRoot:        %{_tmppath}/%{name}-%{version}-build

%kernel_module_package

%description
This package contains the hello.ko module.

%prep
%setup
set -- *
mkdir source
mv "$@" source/
mkdir obj

%build
for flavor in %flavors_to_build; do
    rm -rf obj/$flavor
    cp -r source obj/$flavor
    make -C %{kernel_source $flavor} modules M=$PWD/obj/$flavor
done

%install
export INSTALL_MOD_PATH=$RPM_BUILD_ROOT
export INSTALL_MOD_DIR=updates
for flavor in %flavors_to_build; do
    make -C %{kernel_source $flavor} modules_install M=$PWD/obj/$flavor
done

```

The following two files should be compressed to form the suse-hello-1.0.tar.bz2 TAR archive referenced as Source0 in the suse-hello.spec file above.

suse-hello-1.0/Kbuild

```

obj-m      := hello.o
hello-y    += main.o

```

suse-hello-1.0/main.c

```

/*
 * main.c - A demo kernel module.
 *
 * Copyright (C) 2003, 2004, 2005, 2006
 * Andreas Gruenbacher <agruen@suse.de>, SUSE Labs
 *

```

```

* This program is free software; you can redistribute it and/or
* modify it under the terms of the GNU General Public License as
* published by the Free Software Foundation.
*
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* http://www.gnu.org/.
*/

#include <linux/module.h>
#include <linux/init.h>

MODULE_AUTHOR("Andreas Gruenbacher <agruen@suse.de>");
MODULE_DESCRIPTION("Hello world module");
MODULE_LICENSE("GPL");

int param;

module_param(param, int, 0);
MODULE_PARM_DESC(param, "Example parameter");

void exported_function(void)
{
    printk(KERN_INFO "Exported function called.\n");
}
EXPORT_SYMBOL_GPL(exported_function);

int __init init_hello(void)
{
    printk(KERN_INFO "Hello world.\n");
    return 0;
}

void __exit exit_hello(void)
{
    printk(KERN_INFO "Goodbye world.\n");
}

module_init(init_hello);
module_exit(exit_hello);

```

13 Appendix A.1: Sample spec file for signing modules during packaging

The following spec file can be used to sign modules during packaging as described in Section 8.2.2 above.

suse-hello.spec

```
# norootforbuild

Name:          suse-hello
Version:       1.0
Release:       0
Summary:       Sample Kernel Module Package
License:       GPL-2.0
Group:         System/Kernel
Source0:       %{name}-%{version}.tar.bz2
# Required to sign modules: Include certificate named "signing_key.x509"
# Build structure should also include a private key named "signing_key.priv"
# Private key should not be listed as a source file
Source1:       signing_key.x509
BuildRequires: %kernel_module_package_buildreqs
BuildRoot:     %{_tmppath}/%{name}-%{version}-build

# Required to sign modules: The -c option tells the macro to generate a
# suse-hello-ueficert subpackage that enrolls the certificate
%kernel_module_package -c %_sourcedir/signing_key.x509

%description
This package contains the hello.ko module.

%prep
%setup
# Required to sign modules: Copy the signing key to the build area
cp %_sourcedir/signing_key.* .
set -- *
mkdir source
mv "$@" source/
mkdir obj

%build
for flavor in %flavors_to_build; do
    rm -rf obj/$flavor
    cp -r source obj/$flavor
    make -C %{kernel_source $flavor} modules M=$PWD/obj/$flavor
done
```

```
%install
export INSTALL_MOD_PATH=$RPM_BUILD_ROOT
export INSTALL_MOD_DIR=updates
for flavor in %flavors_to_build; do
    make -C %{kernel_source $flavor} modules_install M=$PWD/obj/$flavor
    # Required to sign modules: Invoke kernel-sign-file to sign each module
    for x in $(find $INSTALL_MOD_PATH/lib/modules/*-$flavor/ -name '*.ko'); do
        /usr/lib/rpm/pesign/kernel-sign-file -i pkcs7 sha256 $PWD/obj/$flavor/
        signing_key.priv $PWD/obj/$flavor/signing_key.x509 $x
    done
done
```

14 Appendix B: Changes and references

14.1 Documentation updates: Changes from the previous version of the document

February 12, 2022 - andavis@suse.com

- Added information and sample spec file (Appendix A.1) for signing modules during packaging.

October 12, 2021 - sbahling@suse.com

- Added "codeSigning" Extended Key Usage option to OpenSSL command for creating key/certificate for kernel module signing.

November 19, 2018 - andavis@suse.com

This document is based on the previous version [Kernel Module Packages Manual for Code 11 \(https://documentation.suse.com/sbp/all/html/SBP-KMP-Manual/index.html\)](https://documentation.suse.com/sbp/all/html/SBP-KMP-Manual/index.html) with the following changes:

- Limit scope to SUSE Linux Enterprise Server 12 SP2 and later and SUSE Linux Enterprise Server 15. Previous versions of SUSE Linux Enterprise Server are covered by the previous version of this document.
- Remove instructions for signing during packaging.
- Remove OBS-specific spec file example.

14.2 References

- SUSE SolidDriver Documentation: Kernel Module Packages Manual for Code 11, <https://documentation.suse.com/sbp/all/html/SBP-KMP-Manual/index.html>
- SUSE SolidDriver Documentation: SUSE Kernel ABI Stability, https://drivers.suse.com/doc/SolidDriver/SUSE_Kernel_ABI_Stability.html
- Greg Kroah-Hartman: The Linux Kernel Driver Interface, http://www.kroah.com/log/linux/stable_api_nonsense.html (also provided as stable_api_nonsense.txt in the upstream kernel source tree)

- Andreas Gruenbacher, Michal Marek: Working With The SUSE 2.6.x and 3.x Kernel Sources (provided as README.SUSE in SUSE kernel-source packages)
- Peter Jay Salzman, Michael Burian, Ori Pomerantz: The Linux Kernel Module Programming Guide, <http://www.tldp.org/LDP/lkmpg/2.6/html/index.html> ↗
- Jonathan Corbet, Alessandro Rubini, Greg Kroah-Hartman: Linux Device Drivers, Third Edition, February 2005, <http://www.oreilly.com/catalog/linuxdrive3/> ↗ (also available online at <http://lwn.net/Kernel/LDD3/> ↗)
- UEFI Specification, <http://www.uefi.org/specs> ↗
- Update Media HOWTO, <ftp://ftp.suse.com/pub/people/hvogel/Update-Media-HOWTO> ↗
- Creating Add-Ons, https://www.novell.com/developer/creating_add-ons.html ↗

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