kmod-Linux内核模块工具

1. 项目背景分析

kmod 是为了能够操作 Linux 内核模块而推出的一系列工具集，这些操作包括 插入（insert），删除（remove），列出（list），检查属性（check properties）和解决依赖关系（dependencies）。

这些工具在底层都需要用到 libkmod 这个库，相关的源码也会跟着 kmod 项目一同发布。这个项目的目标是能够实现与在此之前 module-init-tools 项目所提供的工具兼容。

项目建立时间

从 git.kernel.org 上的 commit log 分析，该项目的建立时间是 2011-11-21。最初的项目是通过继承了 libabc 的框架开始逐步演变而来。2011-12-15 发布了 kmod 1 版本。

参考项目主页
http://git.kernel.org/cgit/utils/kernel/kmod/kmod.git

项目创建者和维护者

创建者是 Lucas De Marchi。这个人就职于巴西 Brazil Campinas 的一家公司ProFUSION Embedded Systems（该公司的主页http://profusion.mobi/），从他在 github 个人项目的帐号创建时间看是 2008年10月30号，应该是属于比较早期的 github 用户。

参考个人主页
https://github.com/lucasdemarchi

项目更新记录

项目最近一次提交 commit log 表明，该项目近期处于一个比较活跃的状态。从 2013-4-9 发布了最新的 kmod 13 版本之后，该项目几乎每隔1，2天有一次或多次提交。最近的一次提交是 2013-4-17，主要的贡献者仍然是 Lucas De Marchi。

参考提交记录
http://git.kernel.org/cgit/utils/kernel/kmod/kmod.git/log/

项目版本情况

第一个可以下载的软件包 kmod-1.tar.gz 是2012-2-24 上传的，最新的软件包 kmod-13.tar.gz 是 2013-4-9 上传的。

目前 kmod 已经发布到了第13个版本，从项目 NEWS 中可以看到，项目从版本 1 就开始支持原来的 insmod/rmmod/lsmod/modprobe 这几个常用命令，发展至今libkmod 库已经提供了100多个函数接口用于方便用户管理内核模块。

项目资源汇总

- 代码下载
  https://www.kernel.org/pub/linux/utils/kernel/kmod
- 邮件列表

linux-modules@vger.kernel.org

- Git项目仓库
  git://git.kernel.org/pub/scm/utils/kernel/kmod/kmod.git
  https://git.kernel.org/pub/scm/utils/kernel/kmod/kmod.git
- Gitweb页面
  http://git.kernel.org/?p=utils/kernel/kmod/kmod.git

2. 项目技术分析

开发环境准备

- 首先需要安装如下的软件工具
  - GCC compiler 编译工具
  - GNU C library 标准C库
  - autoconf 自动化配置工具，可以生成项目所需的 makefile
  - shtool 一个兼容之前类似 mkdir.sh/install.sh 的shell脚本工具
  - libtool 制作可生成依赖关系的共享库，生成文件后缀名为 .la, lo
  - xsltproc 快速XSLT引擎，可以通过XSL层叠样式表把XML转换为其他格式，例如 html/pdf
- 可选的依赖关系:
  - ZLIB library
  - LZMA library

编译和安装

```
$ sudo apt-get install autoconf
$ sudo apt-get install shtool
$ sudo apt-get install libtool
$ sudo apt-get install xsltproc

$ aclocal
$ autoconf
$ ./configure CFLAGS="-g -O2" --prefix=/usr --sysconfdir=/etc --libdir
$ make && make install
```

错误及解决

代码编译过程会出现不少问题，但都可以通过安装和配置逐一解决。现对编译过程中的问题做一总结：

1）autoconf 缺少环境变量文件

```
$ autoconf
configure.ac:10: error: possibly undefined macro: AM_INIT_AUTOMAKE
      If this token and others are legitimate, please use m4_pattern_a
      See the Autoconf documentation.
configure.ac:28: error: possibly undefined macro: AM_PROG_CC_C_O
configure.ac:89: error: possibly undefined macro: AM_CONDITIONAL
$ aclocal
```

通过 aclocal 命令生成，获取当前系统的环境变量，生成一个 aclocal.m4 文件。

2）configure 脚本执行时缺少 libtool 工具

```
$ ./configure CFLAGS="-g -O2" --prefix=/usr --sysconfdir=/etc --libdir
configure: error: cannot find install-sh, install.sh, or shtool in bui
$ autoreconf -f -i -Wall,no-obsolete
Can't exec "libtoolize": No such file or directory at /usr/bin/autorec
Use of uninitialized value in pattern match (m//) at /usr/bin/autoreco
$ sudo apt-get install libtool
```

通过 sudo apt-get 安装解决。

3）configuire 脚本执行缺少 xsltproc 命令

```
$ ./configure CFLAGS="-g -O2" --prefix=/usr --sysconfdir=/etc --libdir
configure: error: xsltproc command not found, try ./configure --disabl
$ sudo apt-get install xsltproc
```

通过 sudo apt-get 安装解决，成功之后，会在当前目录下生成 Makefile 文件。

编译过程

编译过程总体比较顺利，执行 make 和 make install 命令即可完成。

```
$ make
make --no-print-directory all-recursive
Making all in .
  CC     libkmod/libkmod.lo
  CC     libkmod/libkmod-list.lo
  CC     libkmod/libkmod-config.lo
  CC     libkmod/libkmod-index.lo
  CC     libkmod/libkmod-module.lo
  CC     libkmod/libkmod-file.lo
  CC     libkmod/libkmod-elf.lo
  CC     libkmod/libkmod-signature.lo
  CC     libkmod/libkmod-hash.lo
  CC     libkmod/libkmod-array.lo
  CC     libkmod/libkmod-util.lo
  CCLD   libkmod/libkmod-util.la
  CCLD   libkmod/libkmod.la
  CCLD   libkmod/libkmod-private.la
  CC     tools/kmod.o
  CC     tools/lsmod.o
  CC     tools/rmmod.o
  CC     tools/insmod.o
  CC     tools/modinfo.o
  CC     tools/modprobe.o
  CC     tools/depmod.o
  CC     tools/log.o
  CC     tools/static-nodes.o
  CCLD   tools/kmod
  CCLD   tools/kmod-nolib
```

```
  GEN    tools/insmod
  GEN    tools/rmmod
  GEN    tools/lsmod
  GEN    tools/modprobe
  GEN    tools/modinfo
  GEN    tools/depmod
  GEN    libkmod/libkmod.pc
Making all in libkmod/docs
make[2]: Nothing to be done for `all'.
Making all in man
  GEN    depmod.d.5
  GEN    modprobe.d.5
  GEN    modules.dep.5
  GEN    depmod.8
  GEN    insmod.8
  GEN    lsmod.8
  GEN    rmmod.8
  GEN    modprobe.8
  GEN    modinfo.8
```

由以上编译过程可知，项目主要架构分为2层，上层为 tools 目录下提供的各种工具（兼容之前的命令集，例如 insmod/rmmod），下层为 libkmod 目录下生成的 libkmod.la，为上层工具提供所需要的库函数。

生成文件

```
$ ls tools/ -l | grep x
lrwxrwxrwx 1 akaedu akaedu     10 Apr 17 04:43 depmod -> kmod-nolib
lrwxrwxrwx 1 akaedu akaedu     10 Apr 17 04:43 insmod -> kmod-nolib
-rwxrwxr-x 1 akaedu akaedu   8385 Apr 17 04:43 kmod
-rwxrwxr-x 1 akaedu akaedu 488644 Apr 17 04:43 kmod-nolib
lrwxrwxrwx 1 akaedu akaedu     10 Apr 17 04:43 lsmod -> kmod-nolib
lrwxrwxrwx 1 akaedu akaedu     10 Apr 17 04:43 modinfo -> kmod-nolib
lrwxrwxrwx 1 akaedu akaedu     10 Apr 17 04:43 modprobe -> kmod-nolib
lrwxrwxrwx 1 akaedu akaedu     10 Apr 17 04:43 rmmod -> kmod-nolib
```

可以看出以上所有工具，均是 kmod-nolib 的软链接。实现了一个 kmod-nolib 程序，也就实现了之前的各种工具。 这种实现思路，类似于嵌入式开发中的 busybox 项目，也是实现了一堆工具，但只有一个真正的可执行文件。

```
$ ls libkmod/ -l | grep lo
-rw-rw-r-- 1 akaedu akaedu   308 Apr 17 04:43 libkmod-array.lo
-rw-rw-r-- 1 akaedu akaedu   310 Apr 17 04:43 libkmod-config.lo
-rw-rw-r-- 1 akaedu akaedu   304 Apr 17 04:43 libkmod-elf.lo
-rw-rw-r-- 1 akaedu akaedu   306 Apr 17 04:43 libkmod-file.lo
-rw-rw-r-- 1 akaedu akaedu   306 Apr 17 04:43 libkmod-hash.lo
-rw-rw-r-- 1 akaedu akaedu   308 Apr 17 04:43 libkmod-index.lo
-rw-rw-r-- 1 akaedu akaedu   306 Apr 17 04:43 libkmod-list.lo
-rw-rw-r-- 1 akaedu akaedu   296 Apr 17 04:43 libkmod.lo
-rw-rw-r-- 1 akaedu akaedu   310 Apr 17 04:43 libkmod-module.lo
-rw-rw-r-- 1 akaedu akaedu   316 Apr 17 04:43 libkmod-signature.lo
-rw-rw-r-- 1 akaedu akaedu   306 Apr 17 04:43 libkmod-util.lo
```

上面所列的 lo 文件中，libkmod-module.lo 中包含了在整个库中，最靠近上层调用所需要用的接口函数。其他的 lo 文件基本上都是为 libkmod-module.lo 所服务的，比较重要的例如 libkmod-elf, libkmod-file, libkmod-list 等。

```
$ ls libkmod/ -l | grep la
-rw-rw-r-- 1 akaedu akaedu   923 Apr 17 04:43 libkmod.la
-rw-rw-r-- 1 akaedu akaedu   893 Apr 17 04:43 libkmod-private.la
-rw-rw-r-- 1 akaedu akaedu   884 Apr 17 04:43 libkmod-util.la
```

最终提供的库文件是以 libkmod.la 的形式存在。

```
$ ls libkmod/ -l | grep pc
-rw-rw-r-- 1 akaedu akaedu   210 Apr 17 04:43 libkmod.pc
-rw-rw-r-- 1 akaedu akaedu   255 Apr 17 00:53 libkmod.pc.in
```

此文件暂时没看出有什么特殊的作用，只包含了一些对当前库的说明信息，是一个纯文本文件。

安装过程

```
$ make && make install
make --no-print-directory all-recursive
Making all in .
Making all in libkmod/docs
make[2]: Nothing to be done for `all'.
Making all in man
make[2]: Nothing to be done for `all'.
Making install in .
test -z "/usr/lib" || /bin/mkdir -p "/usr/lib"
 /bin/bash ./libtool   --mode=install /usr/bin/install -c   libkmod/li
libtool: install: /usr/bin/install -c libkmod/.libs/libkmod.so.2.2.3 /
/usr/bin/install: cannot create regular file `/usr/lib/libkmod.so.2.2.
make[2]: *** [install-libLTLIBRARIES] Error 1
make[1]: *** [install-am] Error 2
make: *** [install-recursive] Error 1
```

编译过程中，因为需要用到对 /usr/bin 目录的读写权限，因此需要用 sudo 来执行。

```
$ sudo make install
Making install in .
test -z "/usr/lib" || /bin/mkdir -p "/usr/lib"
 /bin/bash ./libtool   --mode=install /usr/bin/install -c   libkmod/li
libtool: install: /usr/bin/install -c libkmod/.libs/libkmod.so.2.2.3 /
libtool: install: (cd /usr/lib && { ln -s -f libkmod.so.2.2.3 libkmod.
libtool: install: (cd /usr/lib && { ln -s -f libkmod.so.2.2.3 libkmod.
libtool: install: /usr/bin/install -c libkmod/.libs/libkmod.lai /usr/l
libtool: finish: PATH="/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/b
----------------------------------------------------------------------
Libraries have been installed in:
   /usr/lib

If you ever happen to want to link against installed libraries
```

```
in a given directory, LIBDIR, you must either use libtool, and
specify the full pathname of the library, or use the `-LLIBDIR'
flag during linking and do at least one of the following:
   - add LIBDIR to the `LD_LIBRARY_PATH' environment variable
     during execution
   - add LIBDIR to the `LD_RUN_PATH' environment variable
     during linking
   - use the `-Wl,-rpath -Wl,LIBDIR' linker flag
   - have your system administrator add LIBDIR to `/etc/ld.so.conf'

See any operating system documentation about shared libraries for
more information, such as the ld(1) and ld.so(8) manual pages.
----------------------------------------------------------------------
test -z "/usr/bin" || /bin/mkdir -p "/usr/bin"
  /bin/bash ./libtool   --mode=install /usr/bin/install -c tools/kmod
libtool: install: /usr/bin/install -c tools/.libs/kmod /usr/bin/kmod
make --no-print-directory install-exec-hook
if test "/usr/lib" != "/usr/lib"; then \
        /bin/mkdir -p /usr/lib && \
        so_img_name=$(readlink /usr/lib/libkmod.so) && \
        so_img_rel_target_prefix=$(echo /usr/lib | sed 's,\(^/\|\)[^/]
        ln -sf $so_img_rel_target_prefix/usr/lib/$so_img_name /usr/lib
        mv /usr/lib/libkmod.so.* /usr/lib; \
    fi
test -z "/usr/include" || /bin/mkdir -p "/usr/include"
 /usr/bin/install -c -m 644 libkmod/libkmod.h '/usr/include'
test -z "/usr/lib/pkgconfig" || /bin/mkdir -p "/usr/lib/pkgconfig"
 /usr/bin/install -c -m 644 libkmod/libkmod.pc '/usr/lib/pkgconfig'
Making install in libkmod/docs
make[2]: Nothing to be done for `install-exec-am'.
make[2]: Nothing to be done for `install-data-am'.
Making install in man
make[2]: Nothing to be done for `install-exec-am'.
test -z "/usr/share/man/man5" || /bin/mkdir -p "/usr/share/man/man5"
 /usr/bin/install -c -m 644 depmod.d.5 modprobe.d.5 modules.dep.5 modu
test -z "/usr/share/man/man8" || /bin/mkdir -p "/usr/share/man/man8"
 /usr/bin/install -c -m 644 depmod.8 insmod.8 lsmod.8 rmmod.8 modprobe
$ sudo make install
```

这个 make 和 make install 的过程，帮助我们理清了哪些文件参与最后的编译生成过程。特别是对于最后 make install 的执行分析，也让我们了解了项目最终要实现的目标和生成的重要文件。以下将对这一过程展开详细分析。

安装文件

```
$ ls /usr/lib/libkmod.so
libkmod.so        libkmod.so.2      libkmod.so.2.2.3
$ ls /usr/lib/libkmod.so* -l
lrwxrwxrwx 1 root root     16 Apr 17 04:55 /usr/lib/libkmod.so -> libk
lrwxrwxrwx 1 root root     16 Apr 17 04:55 /usr/lib/libkmod.so.2 -> li
-rwxr-xr-x 1 root root 313349 Apr 17 04:55 /usr/lib/libkmod.so.2.2.3
```

libkmod.so 是一个软链接，安装在系统的 /usr/lib 目录下，链接的时候只需要指定 -lkmod 就可以。

```
$ ls /usr/lib/libkmod.l* -l
-rwxr-xr-x 1 root root 924 Apr 17 04:55 /usr/lib/libkmod.la

$ ls /usr/lib/libkmod.* -l
-rwxr-xr-x 1 root root    924 Apr 17 04:55 /usr/lib/libkmod.la
lrwxrwxrwx 1 root root     16 Apr 17 04:55 /usr/lib/libkmod.so -> libk
lrwxrwxrwx 1 root root     16 Apr 17 04:55 /usr/lib/libkmod.so.2 -> li
-rwxr-xr-x 1 root root 313349 Apr 17 04:55 /usr/lib/libkmod.so.2.2.3
```

真正起作用的 so 文件，也就是 libkmod 共享库的 real name 是 libkmod.so.2.2.3。

```
$ ls /usr/bin/kmod  -l
-rwxr-xr-x 1 root root 233584 Apr 17 04:55 /usr/bin/kmod
$ file /usr/bin/kmod
/usr/bin/kmod: ELF 32-bit LSB executable, Intel 80386, version 1 (SYSV
$ kmod
missing command
kmod - Manage kernel modules: list, load, unload, etc
Usage:
    kmod [options] command [command_options]

Options:
    -V, --version     show version
    -h, --help        show this help

Commands:
  help         Show help message
  list         list currently loaded modules
  static-nodes outputs the static-node information installed with the

kmod also handles gracefully if called from following symlinks:
  lsmod        compat lsmod command
  rmmod        compat rmmod command
  insmod       compat insmod command
  modinfo      compat modinfo command
  modprobe     compat modprobe command
  depmod       compat depmod command
```

kmod 是一个工具，可以实现内核模块的 list 和 打印输出已经被加载的内核模块的详细信息。

```
$ ls /usr/include/libkmod.h -l
-rw-r--r-- 1 root root 9429 Apr 17 04:55 /usr/include/libkmod.h
$ 文件内容见下面小节
```

头文件是最重要的生成文件，会被之后所有调用 libkmod 库的上层应用所包含。一个文件就包含了所有需要用的函数接口声明，使用起来也非常方便。只不过这个文件中包含了较多的函数，互相之间不是平行的，内部是有上下层次关系的。

```
$ ls /usr/lib/pkgconfig/libkmod.pc -l
-rw-r--r-- 1 root root 210 Apr 17 04:55 /usr/lib/pkgconfig/libkmod.pc
$ cat /usr/lib/pkgconfig/libkmod.pc
prefix=/usr
```

```
exec_prefix=/usr
libdir=/usr/lib
includedir=/usr/include

Name: libkmod
Description: Library to deal with kernel modules
Version: 13
Libs: -L${libdir} -lkmod
Libs.private:
Cflags: -I${includedir}
$
```

这个文件只是一个纯文本文件，里面包含了如上所列出的信息。

```
$ ls /usr/share/man/man5/ -l | grep "Apr 17"
-rw-r--r-- 1 root root  3969 Apr 17 04:55 depmod.d.5
-rw-r--r-- 1 root root  9306 Apr 17  2012 fonts-conf.5.gz
-rw-r--r-- 1 root root  1599 Apr 17  2012 initramfs.conf.5.gz
-rw-r--r-- 1 root root  8059 Apr 17 04:55 modprobe.d.5
-rw-r--r-- 1 root root  2494 Apr 17 04:55 modules.dep.5
-rw-r--r-- 1 root root    18 Apr 17 04:55 modules.dep.bin.5
-rw-r--r-- 1 root root   585 Apr 17  2012 update-initramfs.conf.5.gz
$ ls /usr/share/man/man8/ -l | grep "Apr 17"
-rw-r--r-- 1 root root  6398 Apr 17 04:55 depmod.8
-rw-r--r-- 1 root root  5170 Apr 17  2012 initramfs-tools.8.gz
-rw-r--r-- 1 root root  2151 Apr 17 04:55 insmod.8
-rw-r--r-- 1 root root   526 Apr 17  2012 lsinitramfs.8.gz
-rw-r--r-- 1 root root  1839 Apr 17 04:55 lsmod.8
-rw-r--r-- 1 root root  1570 Apr 17  2012 mkinitramfs.8.gz
-rw-r--r-- 1 root root  4009 Apr 17 04:55 modinfo.8
-rw-r--r-- 1 root root 10618 Apr 17 04:55 modprobe.8
-rw-r--r-- 1 root root  3058 Apr 17 04:55 rmmod.8
-rw-r--r-- 1 root root  1016 Apr 17  2012 update-initramfs.8.gz
```

以上所有文件，均为 man 手册所准备的，通过 make install 将安装到系统路径 /usr/share/man/man8 下。

功能简介

- libkmod.so
  - kmod 库的共享库文件，用于动态链接。
- libkmod.la
  - 用 libtool 工具生成的库文件，其实就是一个文本文件，记录同名共享库的相关信息
  - libtool 工具的作用，是在编译大型软件的过程中解决了库的依赖问题。
  - 特别是在交叉编译的条件下，解决动态链接器如何去寻找共享库的问题。
- kmod
  - 一个管理内核模块的工具，提供列表list，加载load，卸载unload等功能。
  - 目前的版本似乎只支持 help, list, static_nodes 三条命令
  - help 列出帮助信息

    - list 列出当前加载模块
    - static-nodes 输出当前内核加载的 static-node 信息，包括设备节点文件名，类型，主设备号和次设备号。

- libkmod.h
    - 使用 libkmod 库所需要包含的头文件，详细接口定义见下节--项目代码分析。

- libkmod.pc
    - 文本文件，包含了使用 libkmod 库所需要了解的一些信息，例如 安装目录，头文件所在目录，库名称，描述等。

- man5 & man8
    - 提供通过类似 man 8 insmod 命令来查看帮助的源文件 inssmod.8
    - 提供通过类似 man 5 depmod.d 命令来查看帮助的源文件 depmod.d.5

3. 项目代码分析

源码目录结构

- tools
    - insmod.c
    - rmmod.c
    - lsmod.c
    - depmod.c
    - modinfo.c
    - modprobe.c
    - kmod.c
    - kmod.h
    - log.c
    - log.h
    - static-nodes.c
- libkmod
    - COPYING
    - docs
    - libkmod-array.c
    - libkmod-array.h
    - libkmod.c
    - libkmod-config.c
    - libkmod-elf.c
    - libkmod-file.c
    - libkmod.h
    - libkmod-hash.c
    - libkmod-hash.h
    - libkmod-index.c
    - libkmod-index.h
    - libkmod-list.c
    - libkmod-module.c
    - libkmod.pc.in
    - libkmod-private.h
    - libkmod-signature.c
    - libkmod.sym
    - libkmod-util.c

    - libkmod-util.h
    - macro.h
    - missing.h
    - README
- testsuite
    - COPYING
    - delete_module.c
    - init_module.c
    - mkdir.c
    - mkdir.h
    - path.c
    - README
    - rootfs-pristine
    - stripped-module.h
    - test-alias.c
    - test-blacklist.c
    - test-dependencies.c
    - test-depmod.c
    - test-init.c
    - test-loaded.c
    - test-modinfo.c
    - test-modprobe.c
    - test-new-module.c
    - testsuite.c
    - testsuite.h
    - test-testsuite.c
    - uname.c
- m4
    - attributes.m4
- man
    - depmod.d.xml
    - depmod.xml
    - insmod.xml
    - lsmod.xml
    - Makefile.am
    - modinfo.xml
    - modprobe.d.xml
    - modprobe.xml
    - modules.dep.xml
    - rmmod.xml

头文件分析

```
$ cat /usr/include/libkmod.h

/*
 * libkmod - interface to kernel module operations
 *
 * Copyright (C) 2011-2013  ProFUSION embedded systems
 *
 * This library is free software; you can redistribute it and/or
 * modify it under the terms of the GNU Lesser General Public
 * License as published by the Free Software Foundation; either
 * version 2.1 of the License, or (at your option) any later version.
 *
```

```
 * This library is distributed in the hope that it will be useful,
 * but WITHOUT ANY WARRANTY; without even the implied warranty of
 * MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.  See the GNU
 * Lesser General Public License for more details.
 *
 * You should have received a copy of the GNU Lesser General Public
 * License along with this library; if not, write to the Free Software
 * Foundation, Inc., 51 Franklin St, Fifth Floor, Boston, MA  02110-13
 */

#pragma once
#ifndef _LIBKMOD_H_
#define _LIBKMOD_H_

#include <fcntl.h>
#include <stdarg.h>
#include <stdbool.h>
#include <inttypes.h>

#ifdef __cplusplus
extern "C" {
#endif

/*
 * kmod_ctx
 *
 * library user context - reads the config and system
 * environment, user variables, allows custom logging
 */
struct kmod_ctx;
struct kmod_ctx *kmod_new(const char *dirname, const char * const *con
struct kmod_ctx *kmod_ref(struct kmod_ctx *ctx);
struct kmod_ctx *kmod_unref(struct kmod_ctx *ctx);
void kmod_set_log_fn(struct kmod_ctx *ctx,
            void (*log_fn)(void *log_data,
                    int priority, const char *file, int line,
                    const char *fn, const char *format,
                    va_list args),
            const void *data);
int kmod_get_log_priority(const struct kmod_ctx *ctx);
void kmod_set_log_priority(struct kmod_ctx *ctx, int priority);
void *kmod_get_userdata(const struct kmod_ctx *ctx);
void kmod_set_userdata(struct kmod_ctx *ctx, const void *userdata);

/*
 * Management of libkmod's resources
 */
int kmod_load_resources(struct kmod_ctx *ctx);
void kmod_unload_resources(struct kmod_ctx *ctx);

enum kmod_resources {
    KMOD_RESOURCES_OK = 0,
    KMOD_RESOURCES_MUST_RELOAD = 1,
    KMOD_RESOURCES_MUST_RECREATE = 2,
};
int kmod_validate_resources(struct kmod_ctx *ctx);
```

```
enum kmod_index {
    KMOD_INDEX_MODULES_DEP = 0,
    KMOD_INDEX_MODULES_ALIAS,
    KMOD_INDEX_MODULES_SYMBOL,
    KMOD_INDEX_MODULES_BUILTIN,
    /* Padding to make sure enum is not mapped to char */
    _KMOD_INDEX_PAD = (1 << 31),
};
int kmod_dump_index(struct kmod_ctx *ctx, enum kmod_index type, int fd

/*
 * kmod_list
 *
 * access to kmod generated lists
 */
struct kmod_list;
struct kmod_list *kmod_list_next(const struct kmod_list *list,
                        const struct kmod_list *curr);
struct kmod_list *kmod_list_prev(const struct kmod_list *list,
                        const struct kmod_list *curr);
struct kmod_list *kmod_list_last(const struct kmod_list *list);

#define kmod_list_foreach(list_entry, first_entry) \
    for (list_entry = first_entry; \
         list_entry != NULL; \
         list_entry = kmod_list_next(first_entry, list_entry))

#define kmod_list_foreach_reverse(list_entry, first_entry) \
    for (list_entry = kmod_list_last(first_entry); \
         list_entry != NULL; \
         list_entry = kmod_list_prev(first_entry, list_entry))

/*
 * kmod_config_iter
 *
 * access to configuration lists - it allows to get each configuration
 * key/value stored by kmod
 */
struct kmod_config_iter;
struct kmod_config_iter *kmod_config_get_blacklists(const struct kmod_
struct kmod_config_iter *kmod_config_get_install_commands(const struct
struct kmod_config_iter *kmod_config_get_remove_commands(const struct
struct kmod_config_iter *kmod_config_get_aliases(const struct kmod_ctx
struct kmod_config_iter *kmod_config_get_options(const struct kmod_ctx
struct kmod_config_iter *kmod_config_get_softdeps(const struct kmod_ct
const char *kmod_config_iter_get_key(const struct kmod_config_iter *it
const char *kmod_config_iter_get_value(const struct kmod_config_iter *
bool kmod_config_iter_next(struct kmod_config_iter *iter);
void kmod_config_iter_free_iter(struct kmod_config_iter *iter);

/*
 * kmod_module
 *
 * Operate on kernel modules
 */
```

```
struct kmod_module;
int kmod_module_new_from_name(struct kmod_ctx *ctx, const char *name,
                        struct kmod_module **mod);
int kmod_module_new_from_path(struct kmod_ctx *ctx, const char *path,
                        struct kmod_module **mod);
int kmod_module_new_from_lookup(struct kmod_ctx *ctx, const char *give
                        struct kmod_list **list);
int kmod_module_new_from_loaded(struct kmod_ctx *ctx,
                        struct kmod_list **list);

struct kmod_module *kmod_module_ref(struct kmod_module *mod);
struct kmod_module *kmod_module_unref(struct kmod_module *mod);
int kmod_module_unref_list(struct kmod_list *list);
struct kmod_module *kmod_module_get_module(const struct kmod_list *ent

/* Removal flags */
enum kmod_remove {
    KMOD_REMOVE_FORCE = O_TRUNC,
    KMOD_REMOVE_NOWAIT = O_NONBLOCK,
};

/* Insertion flags */
enum kmod_insert {
    KMOD_INSERT_FORCE_VERMAGIC = 0x1,
    KMOD_INSERT_FORCE_MODVERSION = 0x2,
};

/* Flags to kmod_module_probe_insert_module() */
enum kmod_probe {
    KMOD_PROBE_FORCE_VERMAGIC =     0x00001,
    KMOD_PROBE_FORCE_MODVERSION =       0x00002,
    KMOD_PROBE_IGNORE_COMMAND =     0x00004,
    KMOD_PROBE_IGNORE_LOADED =      0x00008,
    KMOD_PROBE_DRY_RUN =            0x00010,
    KMOD_PROBE_FAIL_ON_LOADED =     0x00020,

    /* codes below can be used in return value, too */
    KMOD_PROBE_APPLY_BLACKLIST_ALL =    0x10000,
    KMOD_PROBE_APPLY_BLACKLIST =        0x20000,
    KMOD_PROBE_APPLY_BLACKLIST_ALIAS_ONLY = 0x40000,
};

/* Flags to kmod_module_apply_filter() */
enum kmod_filter {
    KMOD_FILTER_BLACKLIST = 0x00001,
    KMOD_FILTER_BUILTIN = 0x00002,
};

int kmod_module_remove_module(struct kmod_module *mod, unsigned int fl
int kmod_module_insert_module(struct kmod_module *mod, unsigned int fl
                            const char *options);
int kmod_module_probe_insert_module(struct kmod_module *mod,
            unsigned int flags, const char *extra_options,
            int (*run_install)(struct kmod_module *m,
                        const char *cmdline, void *data),
            const void *data,
```

```
            void (*print_action)(struct kmod_module *m, bool install,
                        const char *options));

const char *kmod_module_get_name(const struct kmod_module *mod);
const char *kmod_module_get_path(const struct kmod_module *mod);
const char *kmod_module_get_options(const struct kmod_module *mod);
const char *kmod_module_get_install_commands(const struct kmod_module
const char *kmod_module_get_remove_commands(const struct kmod_module *
struct kmod_list *kmod_module_get_dependencies(const struct kmod_modul
int kmod_module_get_softdeps(const struct kmod_module *mod,
                struct kmod_list **pre, struct kmod_list **post);
int kmod_module_get_filtered_blacklist(const struct kmod_ctx *ctx,
                    const struct kmod_list *input,
                    struct kmod_list **output) __attribute__ ((depreca
int kmod_module_apply_filter(const struct kmod_ctx *ctx,
                    enum kmod_filter filter_type,
                    const struct kmod_list *input,
                    struct kmod_list **output);

/*
 * Information regarding "live information" from module's state, as re
 * by kernel
 */

enum kmod_module_initstate {
    KMOD_MODULE_BUILTIN = 0,
    KMOD_MODULE_LIVE,
    KMOD_MODULE_COMING,
    KMOD_MODULE_GOING,
    /* Padding to make sure enum is not mapped to char */
    _KMOD_MODULE_PAD = (1 << 31),
};
const char *kmod_module_initstate_str(enum kmod_module_initstate state
int kmod_module_get_initstate(const struct kmod_module *mod);
int kmod_module_get_refcnt(const struct kmod_module *mod);
struct kmod_list *kmod_module_get_holders(const struct kmod_module *mo
struct kmod_list *kmod_module_get_sections(const struct kmod_module *m
const char *kmod_module_section_get_name(const struct kmod_list *entry
unsigned long kmod_module_section_get_address(const struct kmod_list *
void kmod_module_section_free_list(struct kmod_list *list);
long kmod_module_get_size(const struct kmod_module *mod);

/*
 * Information retrieved from ELF headers and sections
 */

int kmod_module_get_info(const struct kmod_module *mod, struct kmod_li
const char *kmod_module_info_get_key(const struct kmod_list *entry);
const char *kmod_module_info_get_value(const struct kmod_list *entry);
void kmod_module_info_free_list(struct kmod_list *list);

int kmod_module_get_versions(const struct kmod_module *mod, struct kmo
const char *kmod_module_version_get_symbol(const struct kmod_list *ent
uint64_t kmod_module_version_get_crc(const struct kmod_list *entry);
void kmod_module_versions_free_list(struct kmod_list *list);
```

```
int kmod_module_get_symbols(const struct kmod_module *mod, struct kmod
const char *kmod_module_symbol_get_symbol(const struct kmod_list *entr
uint64_t kmod_module_symbol_get_crc(const struct kmod_list *entry);
void kmod_module_symbols_free_list(struct kmod_list *list);

enum kmod_symbol_bind {
    KMOD_SYMBOL_NONE = '\0',
    KMOD_SYMBOL_LOCAL = 'L',
    KMOD_SYMBOL_GLOBAL = 'G',
    KMOD_SYMBOL_WEAK = 'W',
    KMOD_SYMBOL_UNDEF = 'U'
};

int kmod_module_get_dependency_symbols(const struct kmod_module *mod,
const char *kmod_module_dependency_symbol_get_symbol(const struct kmod
int kmod_module_dependency_symbol_get_bind(const struct kmod_list *ent
uint64_t kmod_module_dependency_symbol_get_crc(const struct kmod_list
void kmod_module_dependency_symbols_free_list(struct kmod_list *list);

#ifdef __cplusplus
} /* extern "C" */
#endif
#endif
$
```

- 头文件是 libkmod 项目所提供的用于包含的函数调用接口，上层编程者一般都需要 include 这个文件。
- 以 insmod 命令实现为例，以下函数接口将会用于这个命令实现过程中，典型的调用用法如下：
    - kmod_new()
    - kmod_module_new_from_path()
    - kmod_module_insert_module()
    - kmod_module_unref()

数据结构设计

- struct kmod_ctx
    - 该结构体出现在 libkmod/libkmod.c 文件中
    - 用于读取配置和系统环境参数，用户参数等

结构体定义

```
/**
 * kmod_ctx:
 *
 * Opaque object representing the library context.
 */
struct kmod_ctx {
    int refcount;
    int log_priority;
    void (*log_fn)(void *data,
                   int priority, const char *file, int line,
                   const char *fn, const char *format, va_list args);
```

```
    void *log_data;
    const void *userdata;
    char *dirname;
    struct kmod_config *config;
    struct hash *modules_by_name;
    struct index_mm *indexes[_KMOD_INDEX_MODULES_SIZE];
    unsigned long long indexes_stamp[_KMOD_INDEX_MODULES_SIZE];
};
```

- struct kmod_list
  - 该结构体出现在 libkmod/libkmod-private.h 文件中
  - 用于访问 kmod 产生的模块节点链表

结构体定义

```
struct list_node {
    struct list_node *next, *prev;
};

struct kmod_list {
    struct list_node node;
    void *data;
};
```

- struct kmod_config_iter
  - 该结构体出现在 libkmod/libkmod-config.c 文件中

结构体定义

```
struct kmod_config_iter {
    enum config_type type;
    bool intermediate;
    const struct kmod_list *list;
    const struct kmod_list *curr;
    void *data;
    const char *(*get_key)(const struct kmod_list *l);
    const char *(*get_value)(const struct kmod_list *l);
};
```

- struct kmod_module
  - 该结构体出现在 libkmod/libkmod-module.c 文件中

结构体定义

```
/**
 * SECTION:libkmod-module
 * @short_description: operate on kernel modules
 */

/**
 * kmod_module:
 *
```

```
 * Opaque object representing a module.
 */
struct kmod_module {
    struct kmod_ctx *ctx;
    char *hashkey;
    char *name;
    char *path;
    struct kmod_list *dep;
    char *options;
    const char *install_commands;   /* owned by kmod_config */
    const char *remove_commands;    /* owned by kmod_config */
    char *alias; /* only set if this module was created from an alias
    struct kmod_file *file;
    int n_dep;
    int refcount;
    struct {
        bool dep : 1;
        bool options : 1;
        bool install_commands : 1;
        bool remove_commands : 1;
    } init;

    /*
     * private field used by kmod_module_get_probe_list() to detect
     * dependency loops
     */
    bool visited : 1;

    /*
     * set by kmod_module_get_probe_list: indicates for probe_insert()
     * whether the module's command and softdep should be ignored
     */
    bool ignorecmd : 1;

    /*
     * if module was created by searching the modules.builtin file, th
     * is set. There's nothing much useful one can do with such a
     * "module", except knowing it's builtin.
     */
    bool builtin : 1;
};
```

重要接口实现

- kmod_module_insert_module() in libkmod/libkmod-module.c
    - kmod_module_get_path()
    - file = kmod_file_open()
    - kmod_file_get_direct()
    - size = kmod_file_get_size(file)
    - mem = kmod_file_get_contents(file)
    - kmod_elf_new()
    - kmod_elf_strip_section()
    - kmod_elf_get_memory()
    - init_module(mem, size, args)

    - kmod_elf_unref()
    - kmod_file_unref()

- 对比 module-init-tools 的实现，可以发现代码的层次逻辑复杂不少

    - realloc()
    - grab_file()
        - open()
        - malloc()
        - read()
        - close()
    - init_module(file, len, options)
    - free()

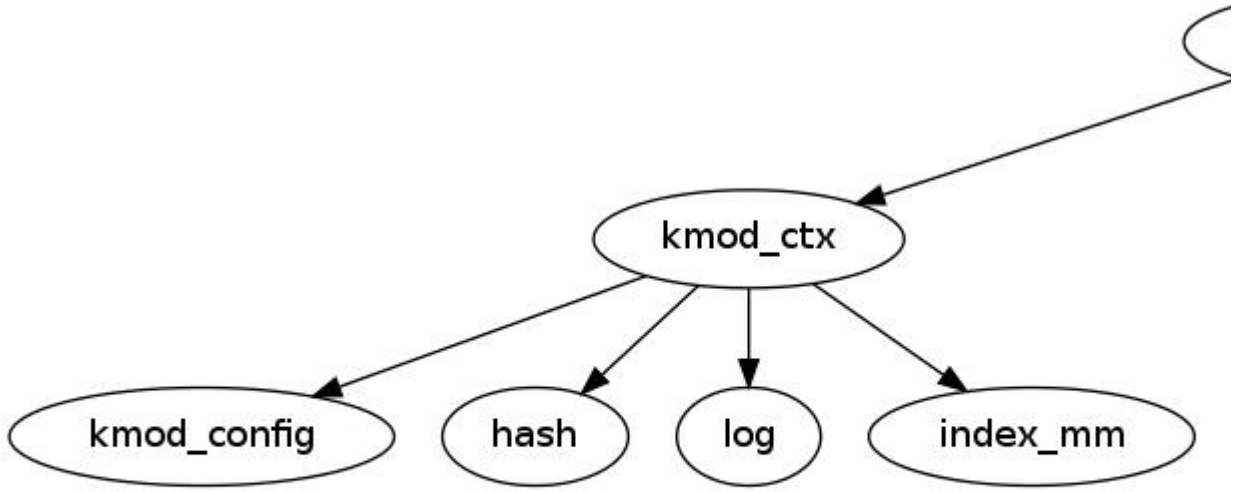
- kmod_module_remove_module in libkmod/libkmod-module.c

    - delete_module()

kmod-11 详细分析报告

1. 架构分析

kmod 项目的整个架构分为 3 层。最底层是 testsuite, 中间是 libkmod, 上层是 tools



应用层

insmod 命令

kmod_ctx 模块

kmod_module 模块

中间层

kmod_config 模块

hash 模块

kmod_elf 模块

kmod_file 模块

抽象层

init_module 系统调用模拟

2. 模块分析

kmod_ctx

kmod_module

kmod_elf

kmod_file

kmod_config

hash

kmod_list

index_mm

elf

list

array

log

3. 运行时调试图

insmod 命令运行时调试图

编写测试用内核模块源码 hello.c

```
$ cat hello.c

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

MODULE_AUTHOR("AKAEDU");
MODULE_DESCRIPTION("module example ");
MODULE_LICENSE("GPL");
```

```
int global = 100;

int __init
akae_init (void)
{
    int local = 200;
    printk ("Hello, akaedu\n");

    printk(".text = %p\n", akae_init);
    printk(".data = %p\n", &global);
    printk(".stack = %p\n", &local);
    return 0;
}

void __exit
akae_exit (void)
{
    int local = 300;
    printk ("module exit\n");

    printk(".text = %p\n", akae_exit);
    printk(".data = %p\n", &global);
    printk(".stack = %p\n", &local);
    return ;
}

module_init(akae_init);
module_exit(akae_exit);
$
```

编写测试用内核模块的 Makefile 文件 Makefile

```
$ cat Makefile

obj-m := hello.o

KDIR := /usr/src/linux-headers-3.2.0-29-generic-pae/

all:
    make -C $(KDIR) SUBDIRS=$(PWD)  modules

clean:
    rm -rf *.o *.ko *.mod.* *.cmd
    rm -rf .*

$
```

编译内核模块 hello.ko

```
$ cd hello-module/
$ make
make -C /usr/src/linux-headers-3.2.0-29-generic-pae/    SUBDIRS=/home/
make[1]: Entering directory `/usr/src/linux-headers-3.2.0-29-generic-p
  CC [M]  /home/akaedu/Github/comment-subs/hello-module/hello.o
```

```
  Building modules, stage 2.
  MODPOST 1 modules
  CC      /home/akaedu/Github/comment-subs/hello-module/hello.mod.o
  LD [M]  /home/akaedu/Github/comment-subs/hello-module/hello.ko
make[1]: Leaving directory `/usr/src/linux-headers-3.2.0-29-generic-pa
$
```

编译生成测试用工具 **insmod**

```
$ cd kmod-11/
$ make
make --no-print-directory all-recursive
Making all in .
  CC       libkmod/libkmod.lo
  CC       libkmod/libkmod-list.lo
  CC       libkmod/libkmod-config.lo
  CC       libkmod/libkmod-index.lo
  CC       libkmod/libkmod-module.lo
  CC       libkmod/libkmod-file.lo
  CC       libkmod/libkmod-elf.lo
  CC       libkmod/libkmod-hash.lo
  CC       libkmod/libkmod-array.lo
  CC       libkmod/libkmod-util.lo
  CCLD     libkmod/libkmod-util.la
  CCLD     libkmod/libkmod.la
  CCLD     libkmod/libkmod-private.la
  CC       tools/kmod.o
  CC       tools/lsmod.o
  CC       tools/rmmod.o
  CC       tools/insmod.o
  CC       tools/modinfo.o
  CC       tools/modprobe.o
  CC       tools/depmod.o
  CC       tools/log.o
  CCLD     tools/kmod
  CCLD     tools/kmod-nolib
  GEN      libkmod/libkmod.pc
Making all in libkmod/docs
make[2]: Nothing to be done for `all'.
Making all in man
  GEN      depmod.d.5
  GEN      modprobe.d.5
  GEN      modules.dep.5
  GEN      depmod.8
  GEN      insmod.8
  GEN      lsmod.8
  GEN      rmmod.8
  GEN      modprobe.8
  GEN      modinfo.8
$
```

使用测试用工具 **insmod** 插入内核模块

```
$ sudo ./kmod-11/tools/insmod hello-module/hello.ko
```

查看插入内核模块后的打印结果

```
$ lsmod | grep hello
hello                  12415  0
$ dmesg | tail
[350775.859640] usb 2-2.1: USB disconnect, device number 14
[350777.611134] Bluetooth: hci0 urb c7304180 submission failed
[350778.217886] usb 2-2.1: new full-speed USB device number 15 using u
[352048.604051] usb 2-2.1: USB disconnect, device number 15
[352048.630829] Bluetooth: hci0 urb dd3d3000 submission failed
[352049.254135] usb 2-2.1: new full-speed USB device number 16 using u
[352111.505217] Hello, akaedu
[352111.505223] .text = e0844000
[352111.505225] .data = e0c03000
[352111.505227] .stack = df6e3f54
$
```

重复插入同样的内核模块系统会报错

```
$ sudo ./kmod-11/tools/insmod hello-module/hello.ko
insmod: ERROR: could not insert module hello-module/hello.ko: File exi
$ lsmod | grep hello
hello                  12415  0
```

rmmod 命令运行时调试图

使用测试用工具 rmmod 卸载内核模块

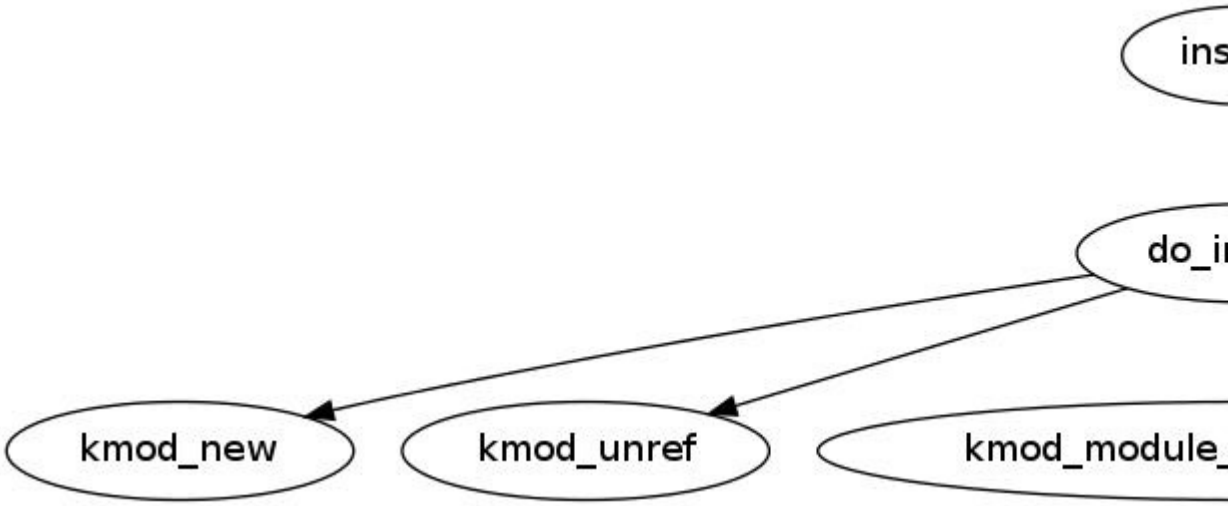
```
$ sudo ./kmod-11/tools/rmmod hello-module/hello.ko
$ （rmmod 命令的执行，运行在 hello 的后面加上 .ko 的后缀，这个和以前的命令有所不
```

查看卸载内核模块后的打印结果

```
$ lsmod | grep hello
$ （可以看到上面命令的执行结果没有任何输出信息）
$ dmesg | tail
[352048.630829] Bluetooth: hci0 urb dd3d3000 submission failed
[352049.254135] usb 2-2.1: new full-speed USB device number 16 using u
[352111.505217] Hello, akaedu
[352111.505223] .text = e0844000
[352111.505225] .data = e0c03000
[352111.505227] .stack = df6e3f54
[352365.795618] module exit
[352365.795624] .text = e0c01000
[352365.795626] .data = e0c03000
[352365.795628] .stack = dd197f40
$
```

4. 运行流程分析

insmod 命令实现流程



do_insmod 核心代码分析

```
do_insmod()
{
    opts = argv[x]; // name=value
    ctx = kmod_new(NULL, &null_config);
    err = kmod_module_new_from_path(ctx, filename, &mod);
    err = kmod_module_insert_module(mod, 0, opts);
    kmod_module_unref(mod);
    kmod_unref(ctx);
}
```

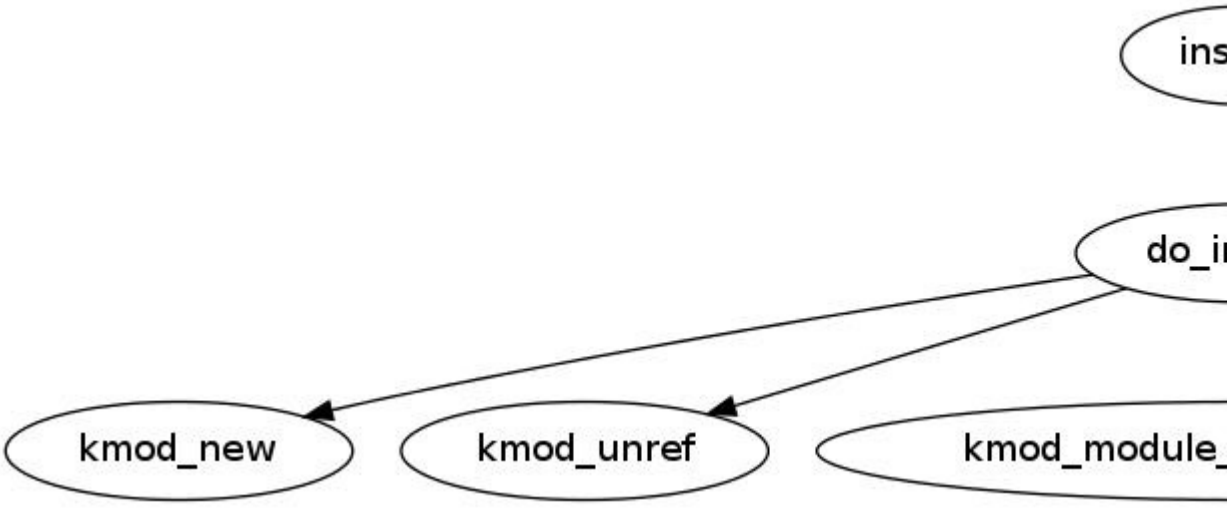
do_insmod() 的实现可以分为5个步骤

- 创建模块的上下文 struct kmod_ctx ctx
- 通过 filename 和 ctx 获得模块 struct kmod_module mod
- 将 mod 插入到当前模块列表中, 完成真正的插入内核功能
- 释放 mod
- 释放 ctx

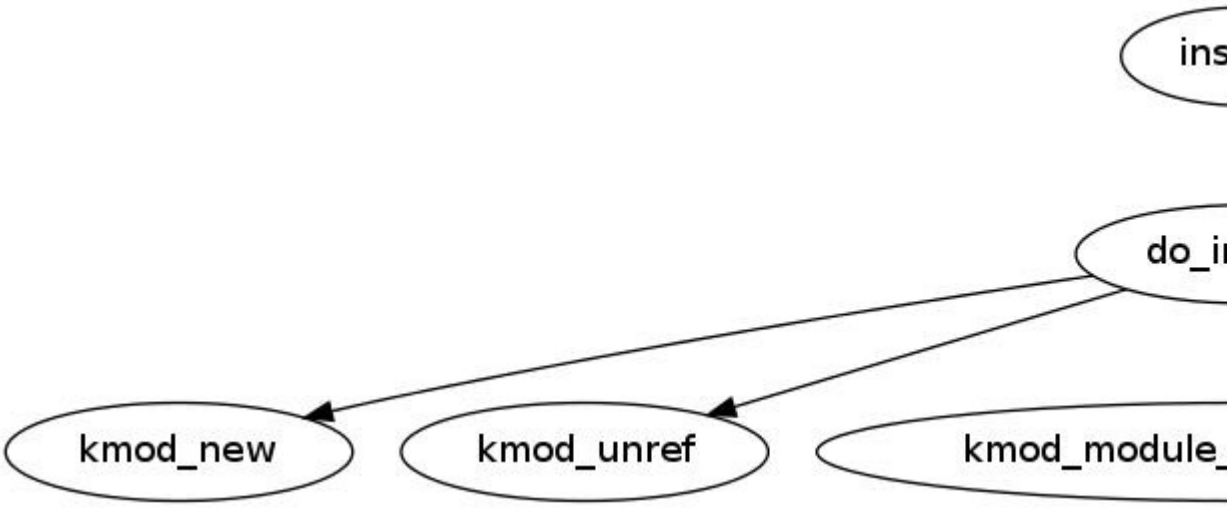
涉及到两个模块的5个接口，两个模块是

- libkmod/libkmod.c
  - kmod_new()
  - kmod_unref()
- libkmod/libkmod-module.c
  - kmod_module_new_from_path()
  - kmod_module_insert_module()
  - kmod_module_unref()

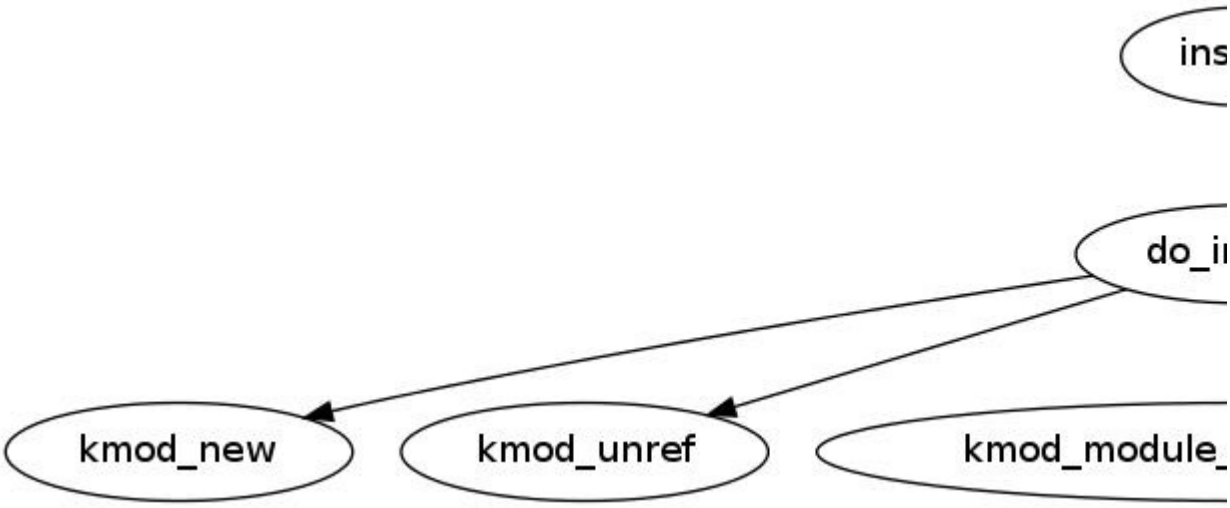
rmsmod 命令实现流程



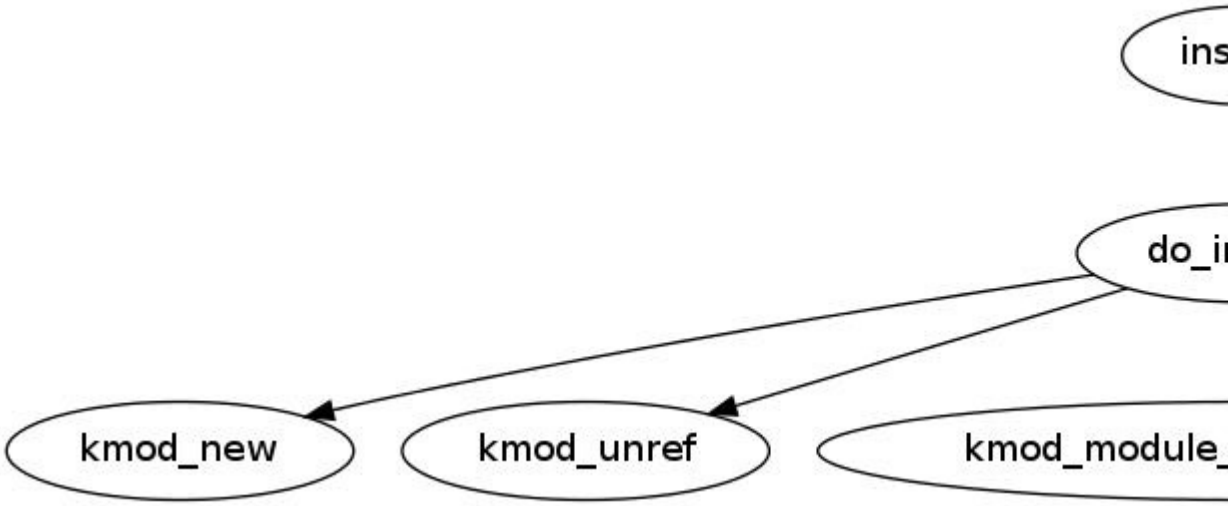
lsmod 命令实现流程



modinfo 命令实现流程



depmod 命令实现流程



do_depmod() 核心代码分析

```
do_depmod(int argc, char *argv[])
{
    ctx = kmod_new(cfg.dirname, &null_kmod_config);

    err = depmod_init(&depmod, &cfg, ctx);
    err = depmod_load_symvers(&depmod, module_symvers);
    err = depmod_load_system_map(&depmod, system_map);
    err = cfg_load(&cfg, config_paths);
    err = depmod_modules_search(&depmod);
    err = kmod_module_new_from_path(depmod.ctx, path, &mod);
    err = depmod_module_add(&depmod, mod);
    err = depmod_modules_build_array(&depmod);
    depmod_modules_sort(&depmod);
    err = depmod_load(&depmod);
    err = depmod_output(&depmod, out);

    depmod_shutdown(&depmod);
    cfg_free(&cfg);
    kmod_unref(ctx);
}
```

modprobe 命令实现流程

do_modprobe() 核心代码分析

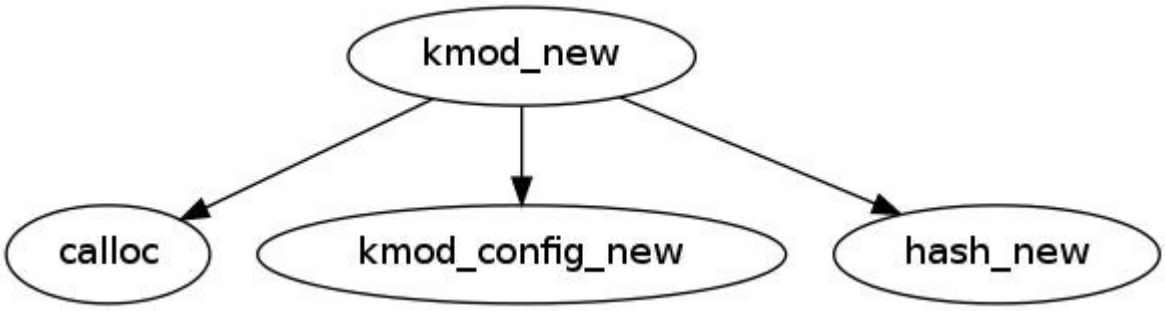
```
do_modprobe(int argc, char *argv[])
{
    log_open(use_syslog);

    snprintf(dirname_buf, sizeof(dirname_buf), "%s/lib/modules/%s", ro
    dirname = dirname_buf;

    ctx = kmod_new(dirname, config_paths);

    log_setup_kmod_log(ctx, verbose);
    kmod_load_resources(ctx);
```

```
    if (do_xxx)
        err = show_config(ctx);
        err = show_modversions(ctx, args[0]);
        err = insmod_all(ctx, args, nargs);
        err = rmmod_all(ctx, args, nargs);

    err = options_from_array(args, nargs, &opts);
    err = insmod(ctx, args[0], opts);

    kmod_unref(ctx);

    log_close();
}
```

5. 函数接口分析

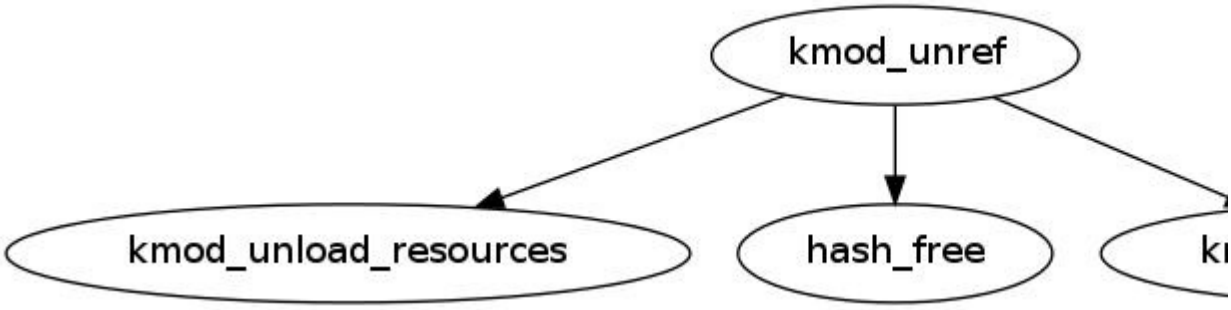
kmod_new() 核心代码分析

```
kmod_ctx *kmod_new(char *dirname, char *config_paths)
{
    ctx = calloc(1, sizeof(struct kmod_ctx));
    ctx->dirname = get_kernel_release(dirname);
    err = kmod_config_new(ctx, &ctx->config, config_paths);
    ctx->modules_by_name = hash_new(KMOD_HASH_SIZE, NULL);

    return ctx;
}
```



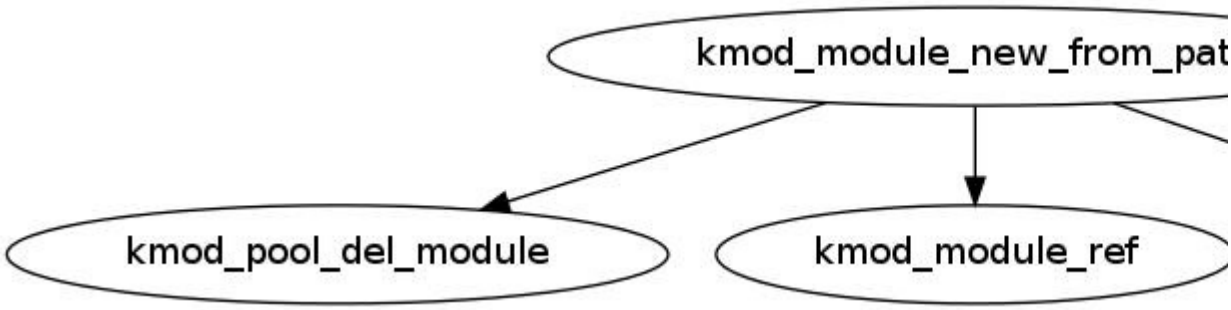
kmod_unref() 核心代码分析

```
kmod_ctx *kmod_unref(kmod_ctx *ctx)
{
    kmod_unload_resources(ctx);
    hash_free(ctx->modules_by_name);
    kmod_config_free(ctx->config);
    free(ctx);

    return NULL;
}
```



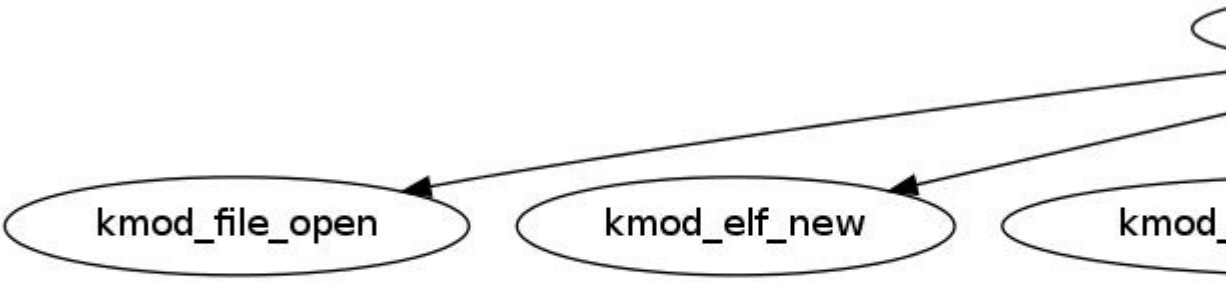
kmod_module_new_from_path() 核心代码分析

```
int kmod_module_new_from_path(kmod_ctx *ctx, char *path, kmod_module *
{
    path_to_modname(path, name, &namelen);
    m = kmod_pool_get_module(ctx, name);
    kmod_module_ref(m);
    err = kmod_module_new(ctx, name, name, namelen, NULL, 0, &m); *
    *mod = m;
    return 0;
}
```



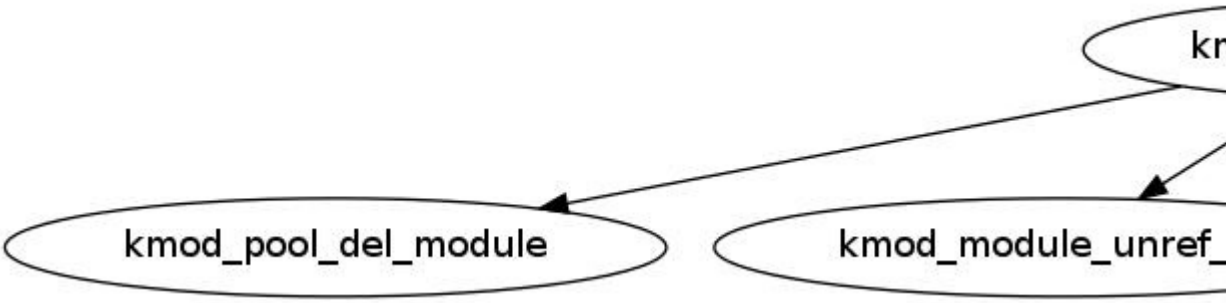
kmod_module_insert_module() 核心代码分析

```
int kmod_module_insert_module(kmod_module *mod, int flags, char *optio
{
    path = kmod_module_get_path(mod);
    file = kmod_file_open();
    size = kmod_file_get_size(file);
    mem = kmod_file_get_contents(file);
    elf = kmod_elf_new(mem, size);
    kmod_elf_strip_section(elf);
    mem = kmod_elf_get_memory(elf);
    init_module(mem, size, args);
    kmod_elf_unref(elf);
    kmod_file_unref(file);
}
```



kmod_module_unref() 核心代码分析

```
kmod_module *kmod_module_unref(kmod_module *mod)
{
    --mod->refcount;

    kmod_pool_del_module(mod->ctx, mod, mod->hashkey);
    kmod_module_unref_list(mod->dep);
    kmod_file_unref(mod->file);
    kmod_unref(mod->ctx);

    return NULL;
}
```



init_module() 核心代码分析

```
long init_module(void *mem, unsigned long len, const char *args)
{
    kmod_elf *elf = kmod_elf_new(mem, len);

    err = kmod_elf_get_section(elf, ".gnu.linkonce.this_module", &buf,
    kmod_elf_unref(elf);
    mod = find_module(modules, modname);
    if(mod != NULL)
    {
    } else if (module_is_inkernel(modname))
    {
    } else
```

```
        create_sysfs_files(modname);

    return err;
}
```

do_rmmod() 核心代码分析

```
do_rmmod(int argc, char *argv[])
{
    flags = argv[x];    // -f, -w,
    ctx = kmod_new(NULL, &null_config);
    err = kmod_module_new_from_path(ctx, filename, &mod);
    err = kmod_module_remove_module(mod, flags);
    kmod_module_unref(mod);
    kmod_unref(ctx);
}
```

kmod_module_remove_module() 核心代码分析

```
int kmod_module_remove_module(kmod_module *mod, int flags)
{
    err = delete_module(mod->name, flags);

    return err;
}
```

delete_module() 核心代码分析

```
long init_module(void *mem, int flags)
{
    struct mod *mod;

    mod = find_module(modules, modname);

    return mod->ret;
}
```

insmod_all

```
static int insmod_all(struct kmod_ctx *ctx, char **args, int nargs)
{
        for (i = 0; i < nargs; i++)
        err = insmod(ctx, args[i], NULL);

    return err;
}
```

insmod

```
-> kmod_module_probe_insert_module()
```

kmod_module_probe_insert_module

```
int kmod_module_probe_insert_module(mod, flags, extra_options, run_ins
{
    err = kmod_module_get_probe_list(mod, !!(flags & KMOD_PROBE_IGNORE

    kmod_list_foreach(l, list)
    {
        struct kmod_module *m = l->data;
        err = kmod_module_insert_module(m, flags, options);
    }
}

-> kmod_module_get_probe_list
    -> __kmod_module_get_probe_list
        -> __kmod_module_get_probe_list
            -> kmod_module_get_dependencies
                ->  module_get_dependencies_noref
                    -> kmod_module_parse_depline
```

kmod_module_get_dependencies

```
kmod_list *kmod_module_get_dependencies(struct kmod_module *mod)
{
    module_get_dependencies_noref(mod);

    kmod_list_foreach(l, mod->dep)
    {
        l_new = kmod_list_append(list_new, kmod_module_ref(l->data));
        list_new = l_new;
    }

    return list_new;
}
```

module_get_dependencies_noref

```
kmod_list *module_get_dependencies_noref(struct kmod_module *mod)
{
    char *line = kmod_search_moddep(mod->ctx, mod->name);

    kmod_module_parse_depline(mod, line);

    return mod->dep;
}
```

kmod_search_moddep

```
char *kmod_search_moddep(struct kmod_ctx *ctx, const char *name)
{
    // name = nfs;      // modprobe nfs
    return index_mm_search(ctx->indexes[KMOD_INDEX_MODULES_DEP], name)

    DBG(ctx, "file=%s modname=%s\n", fn, name);
```

```
    idx = index_file_open(fn);
    line = index_search(idx, name);
    index_file_close(idx);

    return line;
}
```

kmod_module_parse_depline

```
int kmod_module_parse_depline(struct kmod_module *mod, char *line)
{
    for (p = strtok_r(p, " \t", &saveptr); p != NULL;
         p = strtok_r(NULL, " \t", &saveptr))
    {
        err = kmod_module_new_from_path(ctx, path, &depmod);
        list = kmod_list_prepend(list, depmod);
        n++;
    }

    mod->dep = list;
    mod->n_dep = n;

    return n;
}
```