Porting Android to New Hardware

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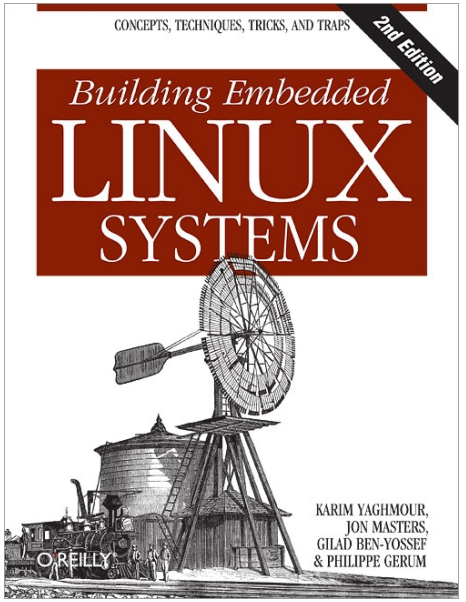
About ...

- Author of:



- Introduced Linux Trace Toolkit in 1999
- Originated Adeos and relayfs (kernel/relay.c)

1. Components to port
2. Cross-development toolchain
3. Porting the bootloader
4. Porting the Linux kernel
5. Developing device drivers
6. Getting the AOSP
7. Implementing Android hardware libs
8. Customizing the user-space
9. Building the AOSP
10. Components to write to flash
11. Useful Embedded Linux tricks

1. Components to port

	CPU Architecture	CPU Model	Target Board
GNU toolchain	X	X	
bootloader	X		X
Kernel	X	X	X
Bionic	X		
OSS packages	X		
Dalvik	X		
Hardware libs	X		X

2. Cross-development toolchain

- Mainly ARM
- Prebuilt toolchains:
  - Codersourcery
  - Linaro
- Auto-generating a toolchain:
  - crosstool-ng
  - Buildroot
  - PTXdist
  - OpenEmbedded

3. Porting the bootloader

- Check aosp/bootable/bootloader/legacy
  - README
  - fastboot_protocol.txt
- CPU support:
  - include/[cpu]/*
  - arch_[cpu]/*
- Board support:
  - Have your pick ...

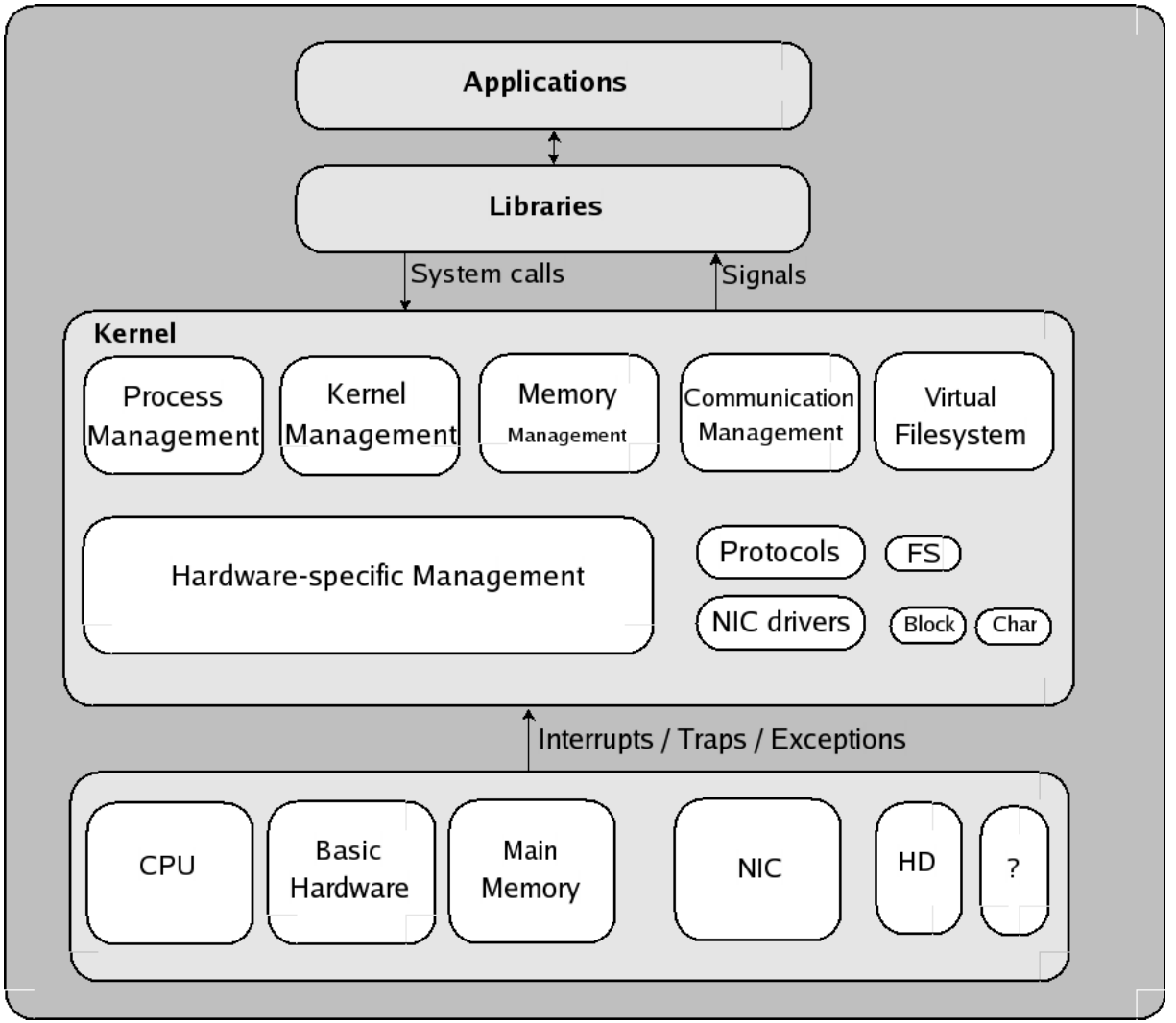
4. Porting the Linux kernel

- Requirements
- Kernel Architecture
- Androidisms
- Which kernel to start from
- An intro to kernel source layout
- Using a JTAG debugger

4.1. Requirements

- Kernel is loaded in RAM and run by bootloader
- Board schematics
- Physical memory map
- Chip timings
- Receiving proper boot parameters from bootloader

4.2. Kernel Architecture



4.3. Androidisms

- Wakelocks
- lowmem handler
- Binder
- RAM console
- Logger
- ...

4.4. Which kernel to start from

- Google:
  - http://android.git.kernel.org/
- Vanilla:
  - http://www.kernel.org
- Either way ... you're screwed:
  - Android kernel is a fork
  - No resolution in sight
  - **Cannot** use vanilla kernel as-is ... wakelocks
  - Learn how to use “git rebase”

4.5. An intro to kernel source layout

arch	112MB =>	architecture-dependent functionality
block	600KB =>	block layer
Documentation	17MB =>	main kernel documentation
drivers	231MB =>	all drivers
fs	31MB =>	virtual filesystem and all fs types
include	20MB =>	complete kernel headers
init	150KB =>	kernel startup code
ipc	224KB =>	System V IPC
kernel	**4.7MB =>**	**core kernel code**
mm	2.2MB =>	memory management
net	20MB =>	networking core and protocols
scripts	1.1MB =>	scripts used to build kernel
tools	2.1MB =>	misc. kernel-related tools

- arch/

```
2.4M  alpha
29M   arm
1.4M  avr32
5.3M  blackfin
4.9M  cris
1.4M  frv
856K  h8300
4.6M  ia64
8.0K  Kconfig
1.4M  m32r
5.7M  m68k
1.1M  m68knommu
1.2M  microblaze
11M   mips
1.7M  mn10300
2.4M  parisc
13M   powerpc
2.4M  s390
636K  score
5.4M  sh
4.7M  sparc
1.9M  tile
1.9M  um
8.5M  x86
1.4M  xtensa
```

- arch/arm:

```
136K    boot
208K    common
676K    configs
1.1M    include
252K    lib
96K     mach-aaec2000
1.2M    mach-at91
808K    mach-bcmring
…
748K    mm
308K    nwfpe
12K     oprofile
60K     plat-iop
788K    plat-mxc
76K     plat-nomadik
...
```

- drivers/

```
accessibility  cpufreq   hwmon        mca        parisc     sbus       uio
acpi           cpuidle   i2c          md         parport    scsi       usb
amba           crypto    ide          media      pci        serial     uwb
ata            dca       idle         memstick   pcmcia     sfi        vhost
atm            dio       ieee802154   message    platform   sh         video
auxdisplay     dma       infiniband   mfd        pnp        sn         virtio
base           edac      input        misc       power      spi        vlynq
block          eisa      isdn         mmc        pps        ssb        w1
bluetooth      firewire  Kconfig      mtd        ps3        staging    watchdog
cdrom          firmware  leds         net        rapidio    tc         xen
char           gpio      lguest       nubus      regulator  telephony  zorro
clocksource    gpu       macintosh    of         rtc        thermal
connector      hid       Makefile     oprofile   s390       tty
```

- include/

```
acpi          config  drm     keys   math-emu  mtd  pcmcia  rxrpc  sound  video
asm-generic   crypto  Kbuild  linux  media     net  rdma    scsi   trace  xen
```

- Looking for something:
  - Try `grep`
  - Have a look at the Linux Cross-Referencing project:
    - URL: http://lxr.linux.no/
    - Code: http://lxr.sourceforge.net/
  - Advanced kernel searching/understanding:
    - CScope: http://cscope.sourceforge.net/
    - KScope front-end: http://kscope.sourceforge.net/
  - ETAGS (emacs)

4.6. Using a JTAG debugger

- Allows debugging of:
  - Bootloader
  - Early kernel code
  - Device drivers
- Need to find one that supports Linux kernel:
  - Abatron
  - Lauterbach
  - GreenHills Software
  - ...

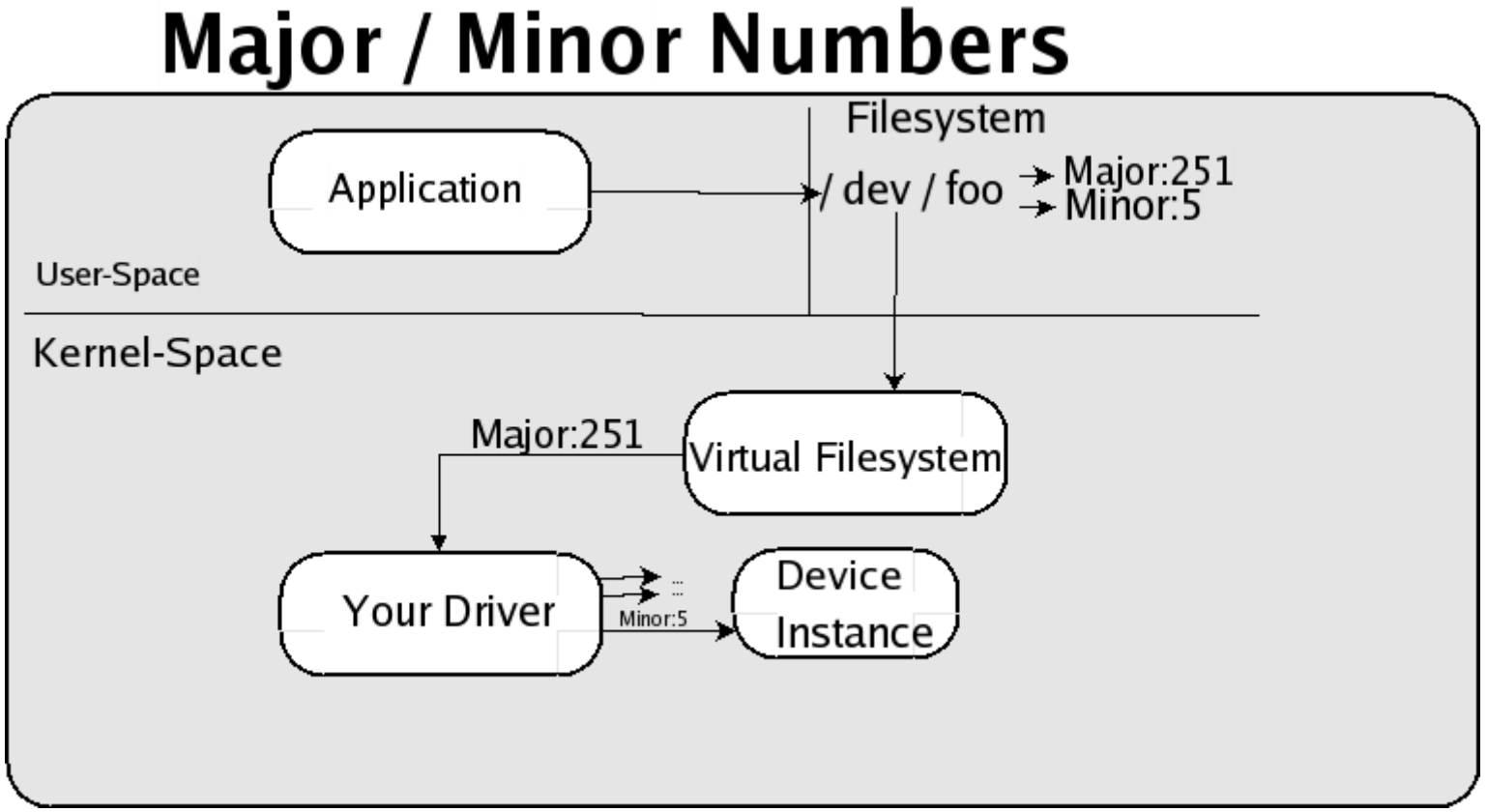
5. Developing device drivers

- Everything in Unix is a file, including devices
- Get a copy of Linux Device Drivers, 3rd ed.
- BTW, emulator kernel doesn't allow modules >:(
- Use standard Linux model API
- Try avoiding wakelocks in drivers
- Use modules for development
- Build drivers in when you ship
- Remember: kernel is GPL, drivers are ... ???
- Try using user-space “drivers” for proprietary parts
- Android actually promotes use of user-space hardware libs

5.1. User space vs. kernel space

- Separate address space:
  - No explicit references to objects from other space
- Memory protection amongst processes:
  - No process can directly access or alter other processes' memory areas.
- Memory protection between processes and kernel:
  - No process can access anything inside the kernel
  - Processes that attempt die (segfault)
- Crossing between user space and kernel space is through specific events

5.2. Connecting user-space and drivers



5.3. Types of drivers

- Char
- Block
- Net
- Subsystem:
  - USB
  - MTD
  - Framebuffer
  - Input

5.4. Kernel primitives

- Timing
- Interrupt handling and deferral
- Memory management
- /sys, hotplug, etc.
- Locking mechanisms
- Hardware access
- ...

6. Getting the AOSP

- Code-drop every ~6 months
- Location:
  - http://android.git.kernel.org/
- Get “repo”:

  $ curl http://android.git.kernel.org/repo > ~/bin/repo

  $ chmod a+x ~/bin/repo
- Fetch the AOSP:
  - Make sure you fetch a tagged release
  - Gingerbread:

    $ repo init -u git://android.git.kernel.org/platform/manifest.git -b gingerbread

    $ repo sync

6.1. AOSP content

bionic	C library replacement
bootable	Reference bootloader
build	Build system
cts	Compatibility Test Suite
dalvik	Dalvik VM
development	Development tools
device	Device-specific files and components
external	Copy of external projects used by AOSP
frameworks	System services, android.*, Android-related cmds, etc.
hardware	Hardware support libs
libcore	Apache Harmony
ndk	The NDK
packages	Stock Android apps, providers, etc.
prebuilt	Prebuilt binaries
sdk	The SDK
system	pieces of the world that are the core of the embedded linux platform at the heart of Android.

6.2. Useful pointers

- See the build system doc at source.android.com
- Check out device/ in AOSP
- Check out Cyanogenmod
- Check out xda-developers

7. Implementing Android hardware libs

Bluetooth	BlueZ through D-BUS IPC (to avoid GPL contamination it seems)
GPS	Manufacturer-provided libgps.so
Wifi	wpa_supplicant
Display	Std framebuffer driver (/dev/fb0)
Keymaps and Keyboards	Std input event (/dev/event0)
Lights	Manufacturer-provided liblights.so
Backlight	
Keyboard	
Buttons	
Battery	
Notifications	
Attention	
Audio	Manufacturer-provided libaudio.so (could use ALSA underneath ... at least as illustrated in their porting guide)
Camera	Manufacturer-provided libcamera.so (could use V4L2 kernel driver underneath ... as illustrated in porting guide)
Power Management	“Wakelocks” kernel patch
Sensors	Manufacturer-provided libsensors.so
Accelerometer	
Magnetic Field	
Orientation	
Gyroscope	
Light	
Pressure	
Temperature	
Proximity	
Radio Layer Interface	Manufacturer-provided libril-<companyname>-<RIL version>.so

8. Customizing the user-space

- Boot screen
- Status bar
- Network
- Preloaded apps
- Browser bookmarks
- Email provider customization
- Themes
- Adding new applications
- Adding new services / new hardware type
- Init

8.1. Boot screen

- Create 320x480 image
- Install imagemagick

  $ sudo apt-get install imagemagick
- Convert image to .r format

  $ sudo apt-get install imagemagick
- Convert image to 565 format

  $ rgb2565 < screen.rgb > screen.565
- Write image to flash

  $ fastboot flash splash1 screen.565

8.2. Status bar

- Location:
  - frameworks/base/packages/SystemUI/src/com/android/systemui/statusbar
- Look for:
  - mService.setIcon(...)
- Disable icons with:
  - mService.setIconVisibility(“[ICON_NAME]", false);

8.3. Network

- Locations:
  - Global static:
    - frameworks/base/core/res/res/xml/apns.xml
  - Device static:
    - PRODUCT_COPY_FILES := vendor/acme/etc/apns-conf-us.xml:system/etc/apns-conf.xml
  - Dynamic:
    - system/etc/apns-conf.xml
- Format:

```
<apn carrier="T-Mobile US"
        mcc="310"
        mnc="260"
        apn=" wap.voicestream.com"
        user="none"
        server="*"
        password="none"
        proxy=" 216.155.165.50"
        port="8080"
        mmsc="http://216.155.174.84/servlets/mms"
/>
```

8.4. Preloaded apps

- See build/target/products

```
PRODUCT_PACKAGES := \
    bouncycastle \
    com.android.location.provider \
    com.android.location.provider.xml \
    core \
    core-junit \
    create_test_dmtrace \
    dalvikvm \
    dexdeps \
...
```

8.5. Browser bookmarks

- See packages/apps/Browser/res/values/strings.xml

```
<!-- Bookmarks -->
<string-array name="bookmarks">
    <item>Google</item>
    <item>http://www.google.com/</item>
    <item>Yahoo!</item>
    <item>http://www.yahoo.com/</item>
    <item>MSN</item>
    <item>http://www.msn.com/</item>
    <item>MySpace</item>
    <item>http://www.myspace.com/</item>
...
```

8.6. Email provider customization

- See packages/apps/Email/res/xml/providers.xml

```
<!-- Gmail variants -->
    <provider id="gmail" label="Gmail" domain="gmail.com">
        <incoming uri="imap+ssl+://imap.gmail.com" username="$email"/>
        <outgoing uri="smtp+ssl+://smtp.gmail.com" username="$email"/>
    </provider>
    <provider id="googlemail" label="Google Mail" domain="googlemail.com">
        <incoming uri="imap+ssl+://imap.googlemail.com" username="$email"/>
        <outgoing uri="smtp+ssl+://smtp.googlemail.com" username="$email"/>
    </provider>
...
    <!-- Common US providers -->

    <provider id="aim" label="AIM" domain="aim.com">
        <incoming uri="imap://imap.aim.com" label="IMAP" username="$email"/>
        <outgoing uri="smtp://smtp.aim.com:587" username="$email"/>
    </provider>
    <provider id="aol" label="AOL" domain="aol.com">
        <incoming uri="imap://imap.aol.com" label="IMAP" username="$email"/>
        <outgoing uri="smtp://smtp.aol.com:587" username="$email"/>
    </provider>
...
```

8.7. Themes

- See framework/base/core/res/res/values/styles.xml

8.8. Adding new applications

- Add application in packages/apps
- Can use Eclipse to create initial version
- Copy Eclipse project to packages/apps
- Add an appropriate Android.mk file to project
- Add project to PRODUCT_PACKAGES

8.9. Adding new services / new hardware type

- Add your code to: frameworks/base/services/java/com/android/server/
- Have the SystemServer.java init+reg. your service
- Define hardware API for apps
- Expose through:
  - frameworks/base/core/java/android/os/[server].aidl
- Call on native “driver” code through JNI
- Implement or connect to appropriate driver
- Create an app that calls on service
- May need to create new SDK ...

8.10. Init

- Android init semantics are different from:
  - System V init
  - Busybox init
- See “Android Init Language” doc in porting guide
- See init.rc examples:
  - Emulator's init.rc
  - device/[manufacturer]/[device]/init.rc
- Global “properties” that can be set and read
- Can be used to tweak low-memory conditions

9. Building the AOSP

- Requires 64-bit Ubuntu 10.04
- Packages required:

```
$ sudo apt-get install ia32-libs  bison flex gperf \
> g++ libia32 libc6-dev-i386 libz-dev libstdc++ \
>  libstdc++6 libstdc++6-32 ia32-libstdc++6 \
> ia32-libstdc++ ia32-libstdc++5 ia32-libs \
> libncurses-dev lib32ncurses-dev \
> ia32-libncurses-dev ia32-libncurses lib32ncurses \
> lib32ncurses5-dev
```

- Patch build/core/droiddoc.mk
  - https://groups.google.com/group/android-building/browse_thread/thread/833a8159a0e5c56c

- Fix a few symbolic links:

  $ sudo ln -s /usr/lib32/libstdc++.so.6 /usr/lib32/libstdc++.so

  $ sudo ln -s /usr/lib32/libz.so.1 /usr/lib32/libz.so
- Set up build environment:

  $. build/envsetup.sh

  $ lunch
- Launch build and go watch tonight's hockey game:

  $ make -j2
- ... though you should check your screen at breaks ...
- Just launch emulator when it's done:

  $ emulator &

- Some nice tricks:
  - See build/envsetup.sh for commands
  - Use “lunch” from AOSP root to set env vars
    - You'll need that if you come back later and want to relaunch emulator from AOSP root.

10. Components to write to flash

- See out/target/product/[product]/*.img
- Typically:
  - Bootloader
  - boot (kernel and ramdisk)
  - system (/system)
  - userdata (/data)

11. Useful Embedded Linux tricks

- crosstool-ng
- Busybox
- uClibc

11.1. crosstool-ng

- Cross-development toolchain generator
- Successor to crosstool
- Available at:

  http://ymorin.is-a-geek.org/projects/crosstool
- Downloads, patches, builds, installs, etc.
- Comprises **23** steps
- Menuconfig-based
- Supports uClibc, glibc and eglibc
- Supports ARM, Blackfin, MIPS, PowerPC, SH, …
- Fairly well maintained

11.2. Busybox

- Replicate Linux CLI experience

[, [[, acpid, add-shell, addgroup, adduser, adjtimex, arp, arping, ash, awk, base64, basename, beep, blkid, blockdev, bootchartd, brctl, bunzip2, bzcat, bzip2, cal, cat, catv, chat, chattr, chgrp, chmod, chown, chpasswd, chpst, chroot, chrt, chvt, cksum, clear, cmp, comm, cp, cpio, crond, crontab, cryptpw, cttyhack, cut, date, dc, dd, deallocvt, delgroup, deluser, depmod, devmem, df, dhcprelay, diff, dirname, dmesg, dnsd, dnsdomainname, dos2unix, du, dumpkmap, dumpleases, echo, ed, egrep, eject, env, envdir, envuidgid, ether-wake, expand, expr, fakeidentd, false, fbset, fbsplash, fdflush, fdformat, fdisk, fgconsole, fgrep, find, findfs, flock, fold, free, freeramdisk, fsck, fsck.minix, fsync, ftpd, ftpget, ftpput, fuser, getopt, getty, grep, gunzip, gzip, halt, hd, hdparm, head, hexdump, hostid, hostname, httpd, hush, hwclock, id, ifconfig, ifdown, ifenslave, ifplugd, ifup, inetd, init, insmod, install, ionice, iostat, ip, ipaddr, ipcalc, ipcrm, ipcs, iplink, iproute, iprule, iptunnel, kbd_mode, kill, killall, killall5, klogd, last, length, less, linux32, linux64, linuxrc, ln, loadfont, loadkmap, logger, login, logname, logread, losetup, lpd, lpq, lpr, ls, lsattr, lsmod, lspci, lsusb, lzcat, lzma, lzop, lzopcat, makedevs, makemime, man, md5sum, mdev, mesg, microcom, mkdir, mkdosfs, mke2fs, mkfifo, mkfs.ext2, mkfs.minix, mkfs.vfat, mknod, mkpasswd, mkswap, mktemp, modinfo, modprobe, more, mount, mountpoint, mpstat, mt, mv, nameif, nbd-client, nc, netstat, nice, nmeter, nohup, nslookup, ntpd, od, openvt, passwd, patch, pgrep, pidof, ping, ping6, pipe_progress, pivot_root, pkill, pmap, popmaildir, poweroff, powertop, printenv, printf, ps, pscan, pwd, raidautorun, rdate, rdev, readahead, readlink, readprofile, realpath, reboot, reformime, remove-shell, renice, reset, resize, rev, rm, rmdir, rmmod, route, rpm, rpm2cpio, rtcwake, run-parts, runlevel, runsv, runsvdir, rx, script, scriptreplay, sed, sendmail, seq, setarch, setconsole, setfont, setkeycodes, setlogcons, setsid, setuidgid, sh, sha1sum, sha256sum, sha512sum, showkey, slattach, sleep, smemcap, softlimit, sort, split, start-stop-daemon, stat, strings, stty, su, sulogin, sum, sv, svlogd, swapoff, swapon, switch_root, sync, sysctl, syslogd, tac, tail, tar, tcpsvd, tee, telnet, telnetd, test, tftp, tftpd, time, timeout, top, touch, tr, traceroute, traceroute6, true, tty, ttysize, tunctl, udhcpc, udhcpd, udpsvd, umount, uname, unexpand, uniq, unix2dos, unlzma, unlzop, unxz, unzip, uptime, usleep, uudecode, uuencode, vconfig, vi, vlock, volname, wall, watch, watchdog, wc, wget, which, who, whoami, xargs, xz, xzcat, yes, zcat, zcip

- Some features of interest:
  - color-coded file lists
  - tab completion
  - "home", "end"
  - grep, sed, wc, more, less
  - vi
  - ifconfig
  - httpd
  - sendmail
  - tftp
  - top
  - ...

- Download BusyBox (1.18.3)
- Move to the directory for the rest of the setup:

```
$ cd busybox-1.18.3
```

- Configuration of BusyBox's options:

```
$ make menuconfig
```

- Options that must be set:
  - “Build Options” -> “Do you want to build BusyBox with a Cross Compiler?”
  - Cross-compiler prefix: `arm-unknown-linux-gnueabi-`
  - `“Installation Options” ->` “Don't use /usr”
  - Installation prefix: `${PRJROOT}/rootfs`
- Build:

```
$ make
```

- Install:

```
$ make install
```

- Cheat sheet:

  Commands to get the new Busybox onto the rootfs:

```
$ adb shell mount -o remount,rw rootfs /
$ adb shell mkdir /bin
$ adb push busybox /bin/
$ adb shell /bin/busybox --install /bin
$ adb shell
```

  To do after going into the shell:

```
# /bin/ash
# export PATH=/bin:$PATH
```

11.3. uClibc

- Originates from uClinux effort
- Support both CPUs that have and those that lack an MMU and/or an FPU.
- Allows both static and dynamic linking
- Most applications that build with glibc will build and work the same with uClibc.
- Available from: http://uclibc.org/

Thank you ...

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