Linux kernel

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Linux kernel key features

- Portability and hardware support
- Scalability
- Compliance to standards and interoperability
- Exhaustive networking support
- Stability and reliability
- Modularity
- Easy to program.

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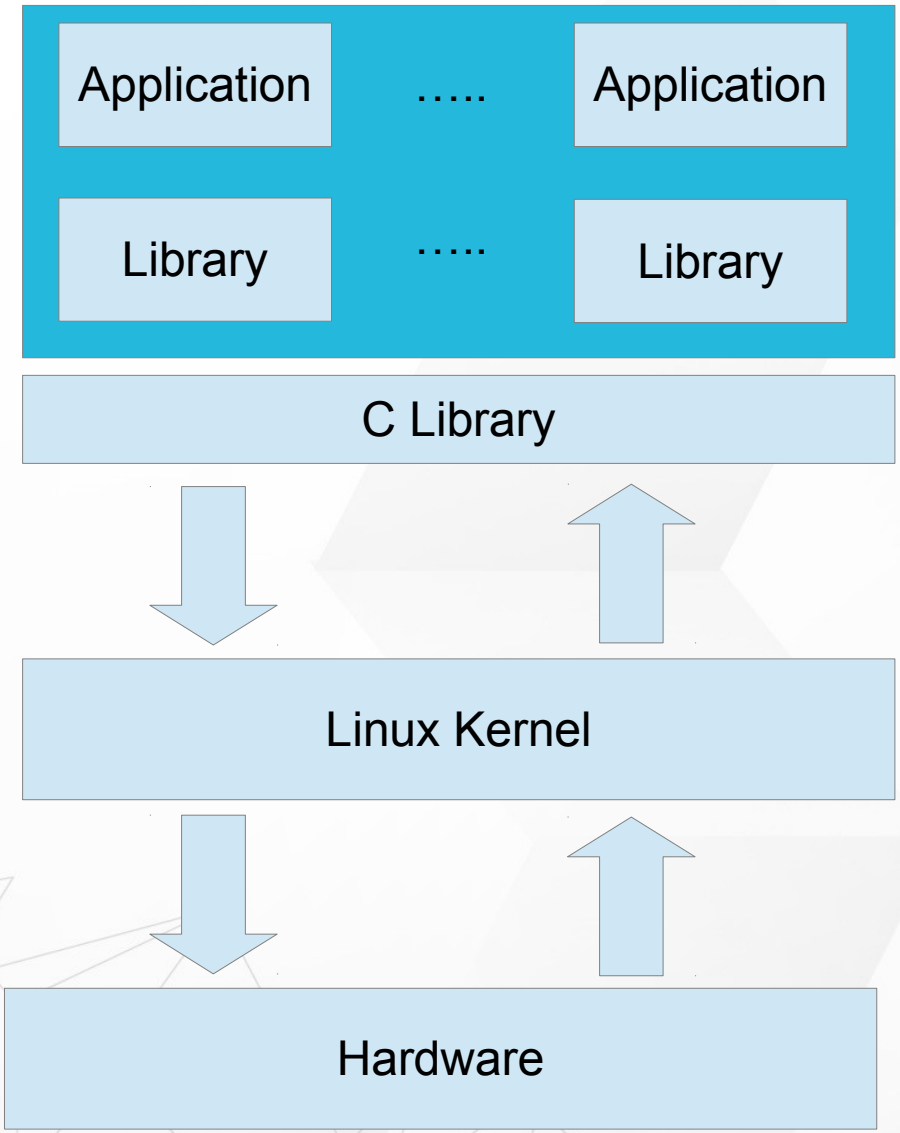
Linux kernel in the system



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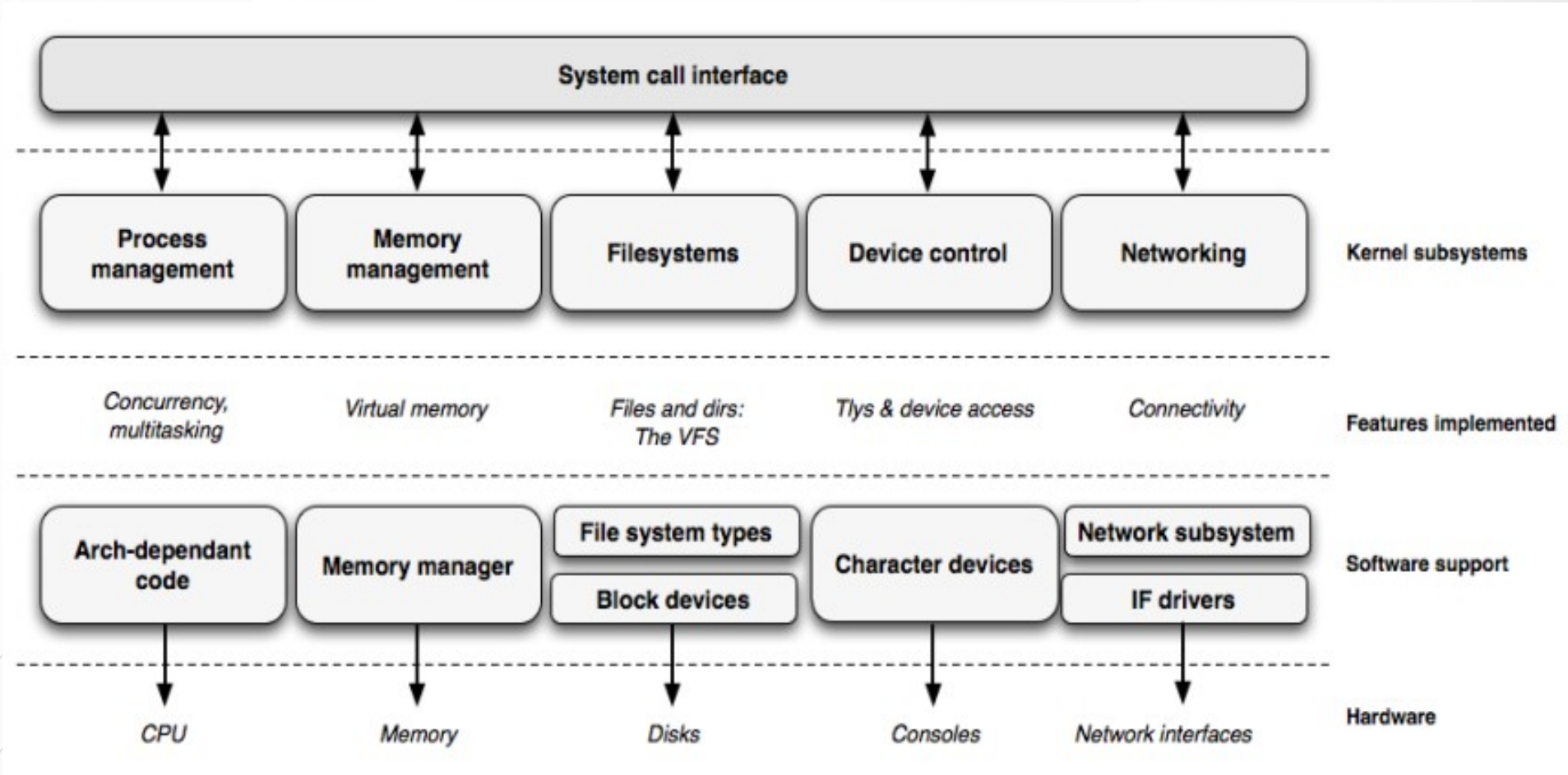
Linux kernel



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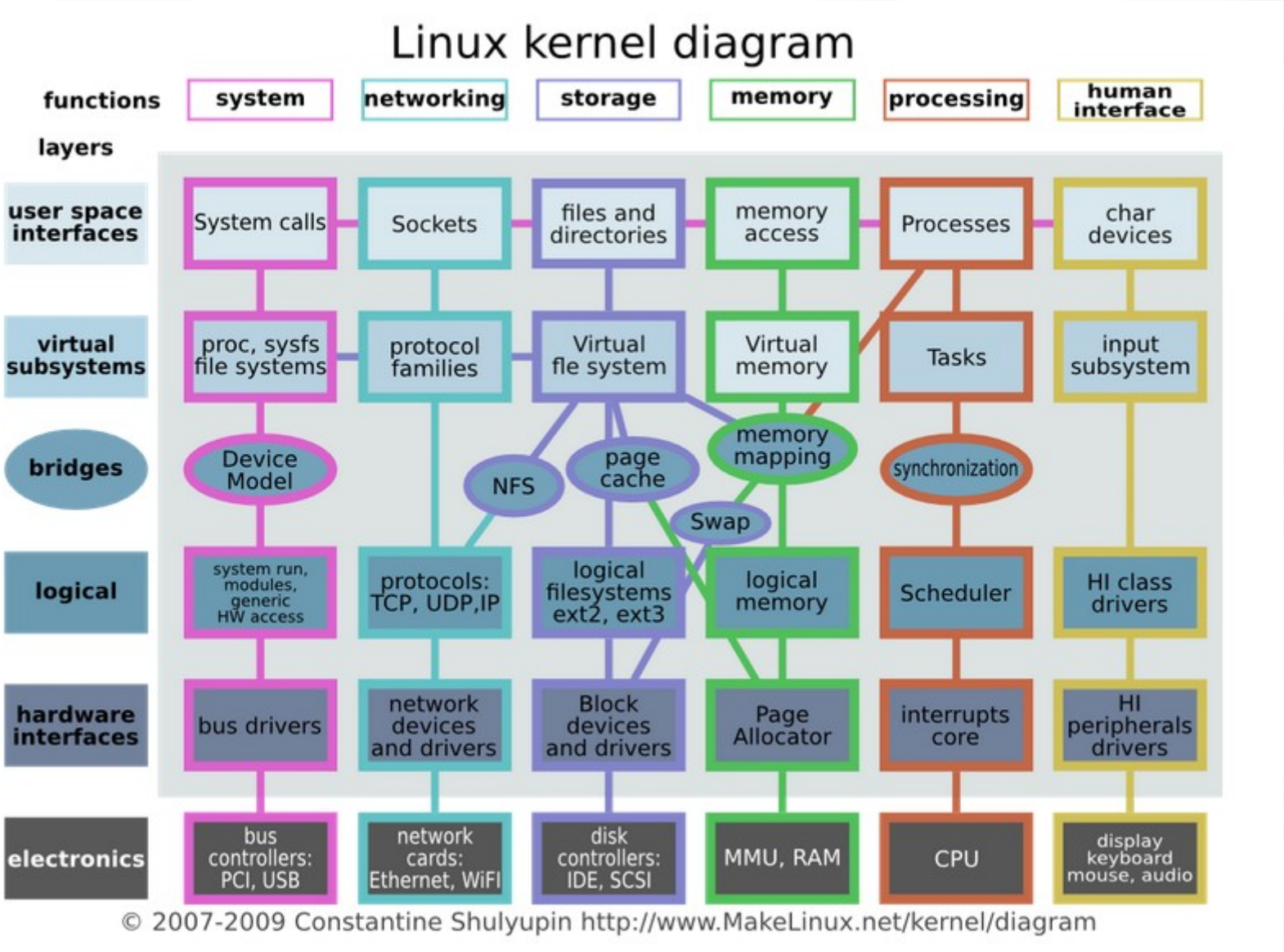
Linux kernel



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Kernel Source

- https://www.kernel.org/
- Many chip vendors
- kernel sub-communities
  - Architecture communities
    - ARM, MIPS, PowerPC ...
  - device drivers communities
    - I2C, SPI, USB, PCI, network ...

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Programming language

- Implemented in C like all Unix systems
- A little Assembly is used too
- **No C++ used**
- **No C library**
- **No floating point** computation
- Kernel code has to supply its own library implementations
  - X : printf(), memset(), malloc(),...
  - O: printk(), memset(), kmalloc()

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Linux sources structure

- arch/<ARCH>
- Architecture specific code
  - arch/<ARCH>/mach-<machine>
  - arch/<ARCH>/include/asm
  - arch/<ARCH>/boot/
- driver/
- Documentation/

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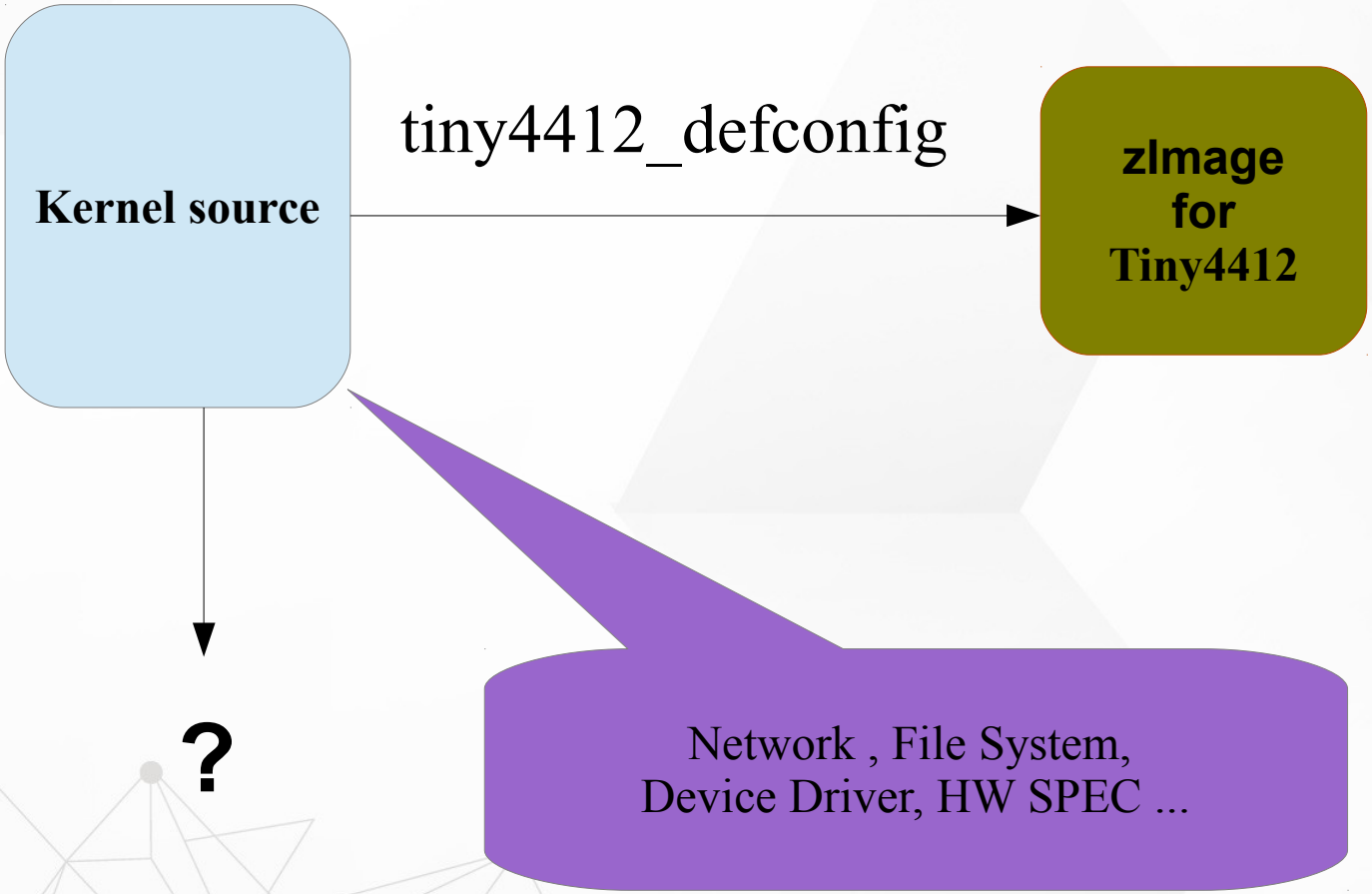
Kernel configuration



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Kernel configuration

- The kernel configuration and build system is based on multiple Makefiles
- The configuration is stored in the .config file at the root of kernel sources
- As options have dependencies, typically never edited by hand, but through graphical or text interfaces
  - make menuconfig → Text
  - make xconfig → graphical

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Kernel configuration

```
slash@slash-huang:linux_3.5.0_tiny4412$ ls -la
total 574796
drwxr-xr-x  24 slash slash      4096 Sep  9 14:14 .
drwxrwxr-x   4 slash slash      4096 Sep  8 11:44 ..
drwxr-xr-x  29 slash slash      4096 Apr 22  2014 arch
drwxr-xr-x   3 slash slash      4096 Sep  9 14:06 block
-rwxrwxr-x   1 slash slash        37 Mar  4  2015 change_lib.sh
-rw-rw-r--   1 slash slash     83180 Sep  9 14:04 .config
-rw-r--r--   1 slash slash     18693 Apr 22  2014 COPYING
-rw-r--r--   1 slash slash     94956 Apr 22  2014 CREDITS
drwxr-xr-x   3 slash slash      4096 Sep  9 14:12 crypto
```

.config

$KERNEL_PATH/arch/arm/configs/

tiny4412_defconfig

```
slash@slash-huang:linux_3.5.0_tiny4412$ ls arch/arm/configs/
acs5k_defconfig             cm_x2xx_defconfig          g3evm_defconfig          lpd270_defconfig        pcm027_defconfig          spear13xx_defconfig
acs5k_tiny_defconfig        cm_x300_defconfig          g4evm_defconfig          lubbock_defconfig       pleb_defconfig            spear3xx_defconfig
afeb9260_defconfig          cns3420vb_defconfig        h3600_defconfig          mackerel_defconfig      pnx4008_defconfig         spear6xx_defconfig
ag5evm_defconfig            colibri_pxa270_defconfig   h5000_defconfig          magician_defconfig      prima2_defconfig          spitz_defconfig
am200epdkit_defconfig       colibri_pxa300_defconfig   h7201_defconfig          mainstone_defconfig     pxa168_defconfig          stamp9g20_defconfig
ap4evb_defconfig            collie_defconfig           h7202_defconfig          marzen_defconfig        pxa255-idp_defconfig      tct_hammer_defconfig
armadillo800eva_defconfig   corgi_defconfig            hackkit_defconfig        mini2440_defconfig      pxa3xx_defconfig          tegra_defconfig
assabet_defconfig           cpu9260_defconfig          imote2_defconfig         mmp2_defconfig          pxa910_defconfig          tiny4412_android_defconfig
at91_dt_defconfig           cpu9g20_defconfig          imx_v4_v5_defconfig      msm_defconfig           qil-a9260_defconfig       tiny4412_linux_defconfig
at91rm9200_defconfig        da8xx_omapl_defconfig      imx_v6_v7_defconfig      mv78xx0_defconfig       raumfeld_defconfig        tiny4412_ubuntu_defconfig
at91sam9260_defconfig       davinci_all_defconfig      integrator_defconfig     mxs_defconfig           realview_defconfig        trizeps4_defconfig
at91sam9261_defconfig       dove_defconfig             iop13xx_defconfig        neponset_defconfig      realview-smp_defconfig    u300_defconfig
at91sam9263_defconfig       ebsa110_defconfig          iop32x_defconfig         netwinder_defconfig     rpc_defconfig             u8500_defconfig
at91sam9g20_defconfig       edb7211_defconfig          iop33x_defconfig         netx_defconfig          s3c2410_defconfig         usb-a9260_defconfig
at91sam9g45_defconfig       em_x270_defconfig          ixp4xx_defconfig         nhk8815_defconfig       s3c6400_defconfig         versatile_defconfig
at91sam9rl_defconfig        ep93xx_defconfig           jornada720_defconfig     nuc910_defconfig        s5p64x0_defconfig         vexpress_defconfig
at91x40_defconfig           eseries_pxa_defconfig      kirkwood_defconfig       nuc950_defconfig        s5pc100_defconfig         viper_defconfig
badge4_defconfig            exynos4_android_defconfig  kota2_defconfig          nuc960_defconfig        s5pv210_defconfig         xcep_defconfig
bcmring_defconfig           exynos4_defconfig          ks8695_defconfig         omap1_defconfig         sam9_l9260_defconfig      zeus_defconfig
bonito_defconfig            ezx_defconfig              kzm9g_defconfig          omap2plus_defconfig     shannon_defconfig
cam60_defconfig             footbridge_defconfig       lart_defconfig           orion5x_defconfig       shark_defconfig
cerfcube_defconfig          fortunet_defconfig         lpc32xx_defconfig        palmz72_defconfig       simpad_defconfig
slash@slash-huang:linux_3.5.0_tiny4412$
```


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Kernel or module?

- The kernel image is a single file, resulting from the linking of all object files that correspond to features enabled in the configuration
- Some features (device drivers, filesystems, etc.) can however be compiled as modules

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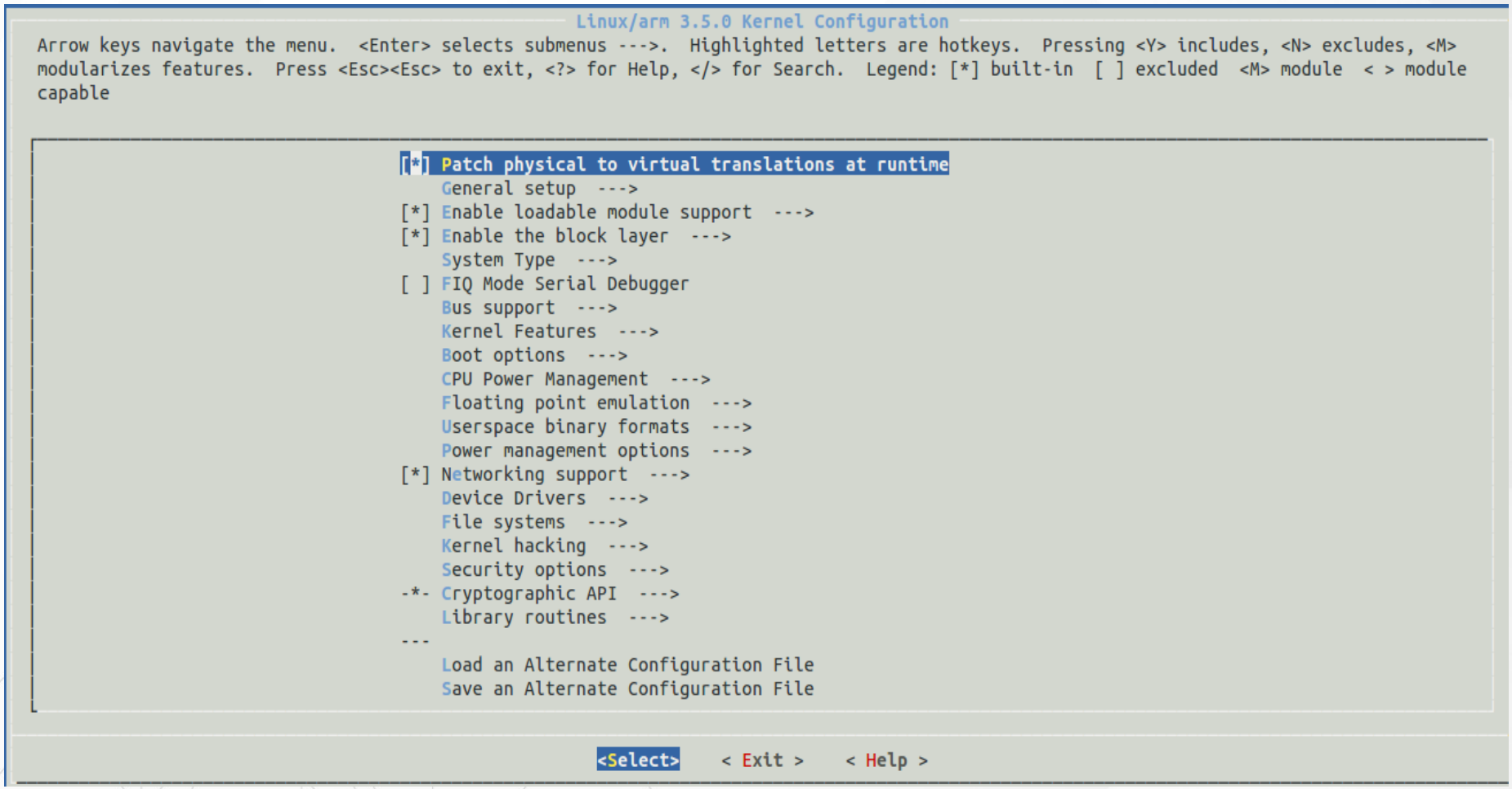
menuconfig



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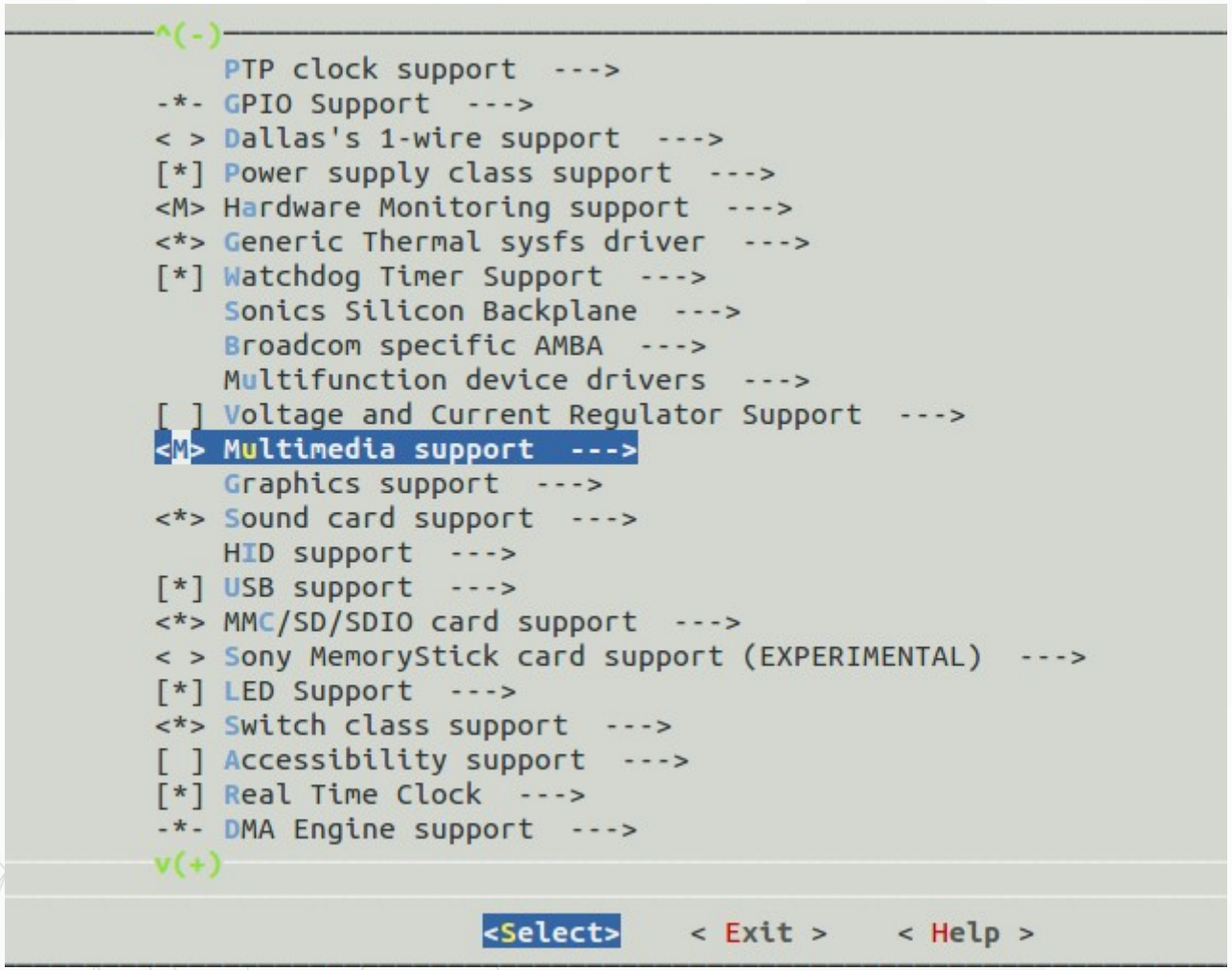
Kernel configuration options



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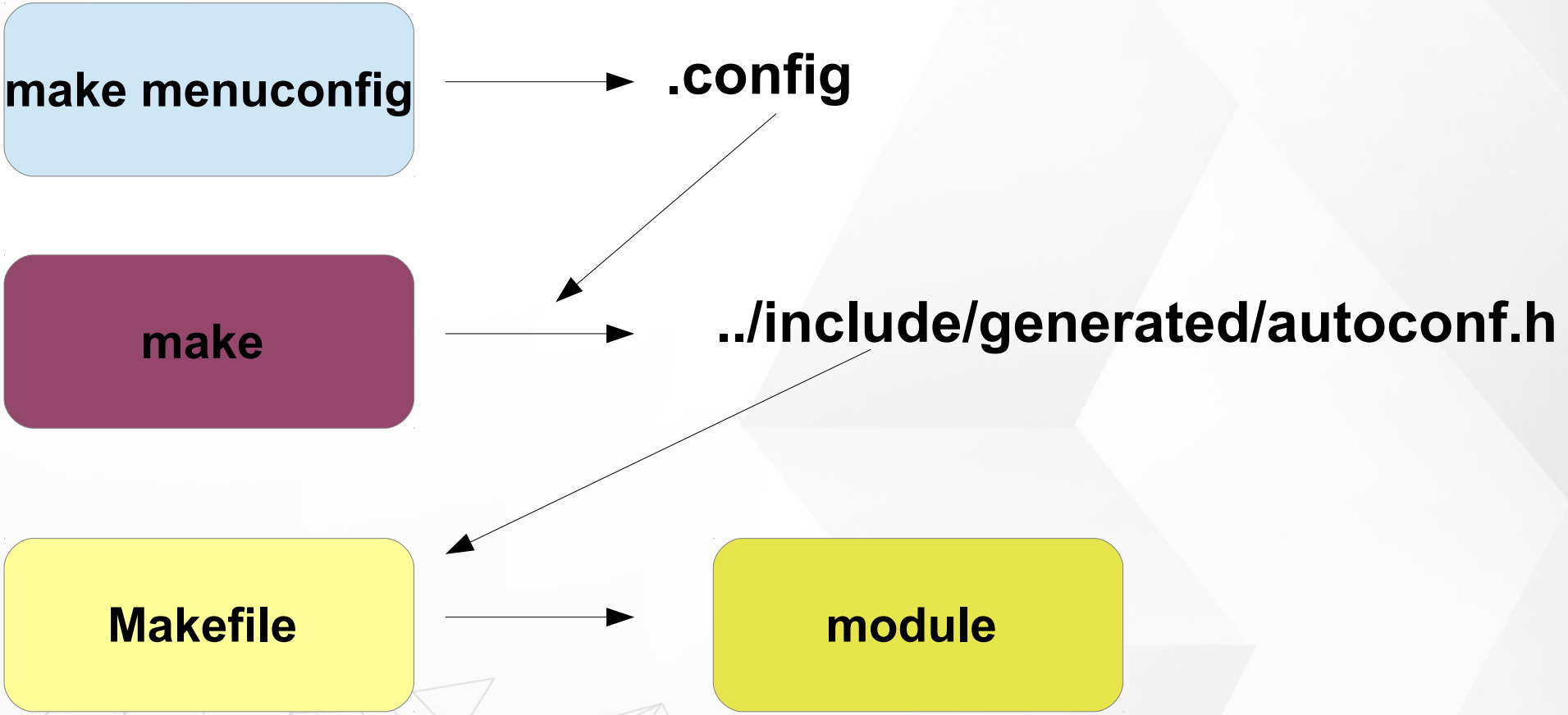
Configuration



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Corresponding .config file excerpt

```
ONFIG_BLK_DEV_SD=y
 CONFIG_CHR_DEV_ST is not set
 CONFIG_CHR_DEV_OSST is not set
 CONFIG_BLK_DEV_SR is not set
ONFIG_CHR_DEV_SG=y
 CONFIG_CHR_DEV_SCH is not set
ONFIG_SCSI_MULTI_LUN=y
 CONFIG_SCSI_CONSTANTS is not set
 CONFIG_SCSI_LOGGING is not set
 CONFIG_SCSI_SCAN_ASYNC is not set
ONFIG_SCSI_WAIT_SCAN=m

 SCSI Transports

 CONFIG_SCSI_SPI_ATTRS is not set
 CONFIG_SCSI_FC_ATTRS is not set
 CONFIG_SCSI_ISCSI_ATTRS is not set
 CONFIG_SCSI_SAS_ATTRS is not set
 CONFIG_SCSI_SAS_LIBSAS is not set
 CONFIG_SCSI_SRP_ATTRS is not set
ONFIG_SCSI_LOWLEVEL=y
 CONFIG_ISCSI_TCP is not set
 CONFIG_ISCSI_BOOT_SYSFS is not set
```

```
# --- NOTE ORDERING HERE ---
# For kernel non-modular link, transport attributes need to
# be initialised before drivers
# ---------------------------
obj-$(CONFIG_SCSI_SPI_ATTRS)    += scsi_transport_spi.o
obj-$(CONFIG_SCSI_FC_ATTRS)     += scsi_transport_fc.o
obj-$(CONFIG_SCSI_ISCSI_ATTRS)  += scsi_transport_iscsi.o
obj-$(CONFIG_SCSI_SAS_ATTRS)    += scsi_transport_sas.o
obj-$(CONFIG_SCSI_SAS_LIBSAS)   += libsas/
obj-$(CONFIG_SCSI_SRP_ATTRS)    += scsi_transport_srp.o
obj-$(CONFIG_SCSI_DH)       += device_handler/
```

$(KERNEL_PATH)/drivers/scsi/Makefile

.config

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Kernel cleanup targets

- **make clean**
  - Kernel cleanup targets
- **make mrproper**
  - Remove all generated files (.config)
- **make distclean**
  - Remove editor backup and patch reject files

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Specifying cross-compilation

- make **ARCH=arm CROSS_COMPILE=arm-linux-** …
- export ARCH=arm

  export CROSS_COMPILE=arm-linux
- Add above setting to script
  - source set_arm_toolchain.sh

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Predefined configuration files

- Default configuration files available, per board or per-CPU family
  - They are stored in arch/<arch>/configs/, and are just minimal .config files
- **make tiny4412_linux_defconfig**
- To create your own default configuration file
  - make savedefconfig, to create a minimal configuration file
  - mv defconfig arch/<arch>/configs/myown_defconfig

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Kernel compilation

- make
  - To run multiple jobs in parallel if you have multiple CPU cores
    - **make -j4**
- Generates
  - arch/<arch>/boot/*Image
    - zImage for ARM,

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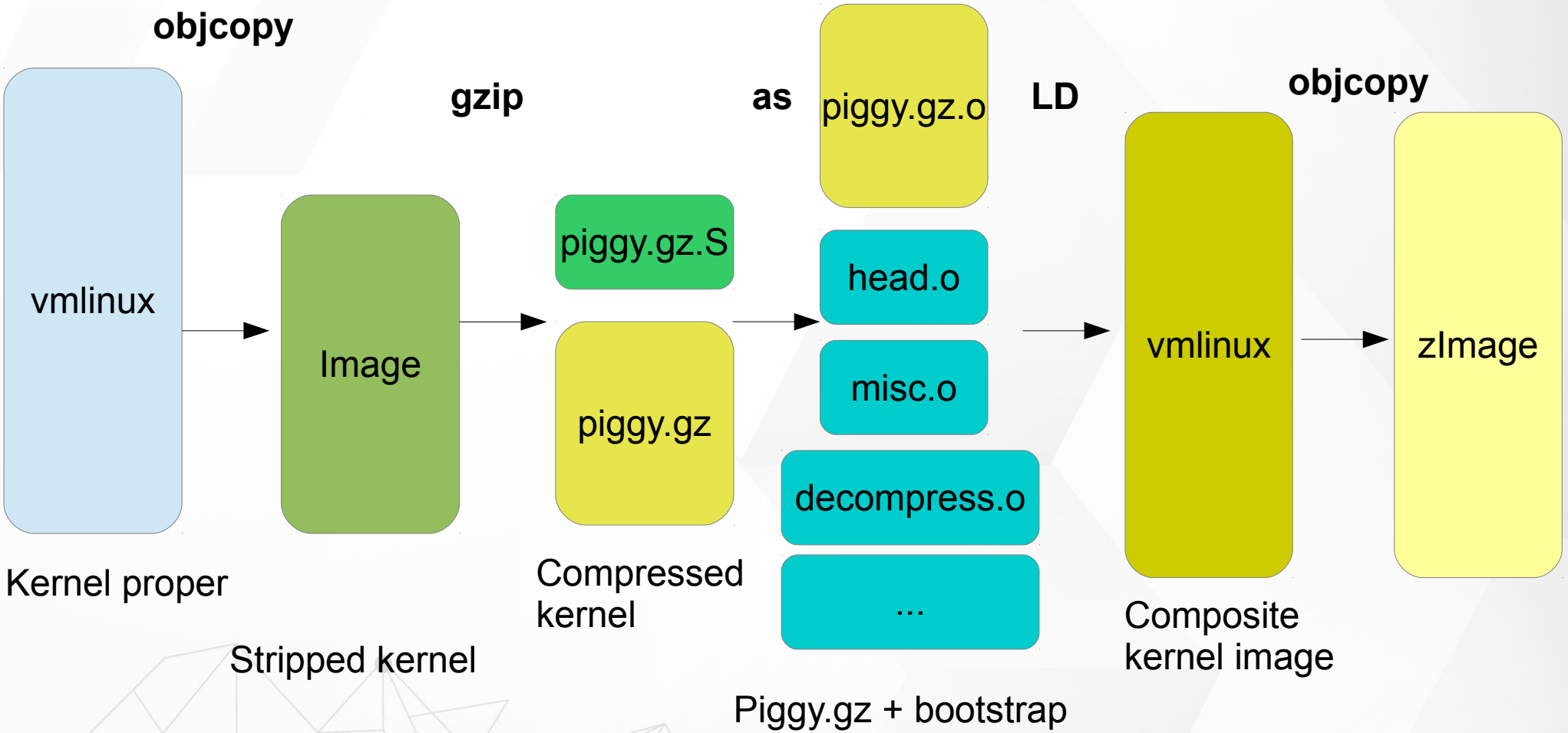
Make help

```
acs5k_defconfig            - Build for acs5k
acs5k_tiny_defconfig       - Build for acs5k_tiny
afeb9260_defconfig         - Build for afeb9260
ag5evm_defconfig           - Build for ag5evm
am200epdkit_defconfig      - Build for am200epdkit
ap4evb_defconfig           - Build for ap4evb
armadillo800eva_defconfig - Build for armadillo800eva
assabet_defconfig          - Build for assabet
at91_dt_defconfig          - Build for at91_dt
at91rm9200_defconfig       - Build for at91rm9200
at91sam9260_defconfig      - Build for at91sam9260
at91sam9261_defconfig      -
at91sam9263_defconfig      -
at91sam9g20_defconfig      -
at91sam9g45_defconfig      -
at91sam9rl_defconfig       -
at91x40_defconfig          -
badge4_defconfig           -
bcmring_defconfig          -
bonito_defconfig           -
cam60_defconfig            -
cerfcube_defconfig         -
cm_x2xx_defconfig          -
cm_x300_defconfig          -
cns3420vb_defconfig        -
colibri_pxa270_defconfig   -
colibri_pxa300_defconfig   -
collie_defconfig           -
corgi_defconfig            -
cpu9260_defconfig          - Build for cpu9260
cpu9g20_defconfig          - Build for cpu9g20
```

```
Other generic targets:
  all              - Build all targets marked with [*]
* vmlinux          - Build the bare kernel
* modules          - Build all modules
  modules_install  - Install all modules to INSTALL_MOD_PATH (default: /)
  firmware_install- Install all firmware to INSTALL_FW_PATH
                    (default: $(INSTALL_MOD_PATH)/lib/firmware)
  dir/             - Build all files in dir and below
  dir/file.[oisS]  - Build specified target only
  dir/file.lst     - Build specified mixed source/assembly target only
                    (requires a recent binutils and recent build (System.map))
  dir/file.ko      - Build module including final link
  modules_prepare  - Set up for building external modules
  tags/TAGS        - Generate tags file for editors
  cscope           - Generate cscope index
  gtags            - Generate GNU GLOBAL index
  kernelrelease    - Output the release version string
  kernelversion    - Output the version stored in Makefile
  headers_install  - Install sanitised kernel headers to INSTALL_HDR_PATH
                    (default: /home/xlloss/work/tiny-4412/build/linux_3.5.0_tiny4412/usr)
```

How to zImage



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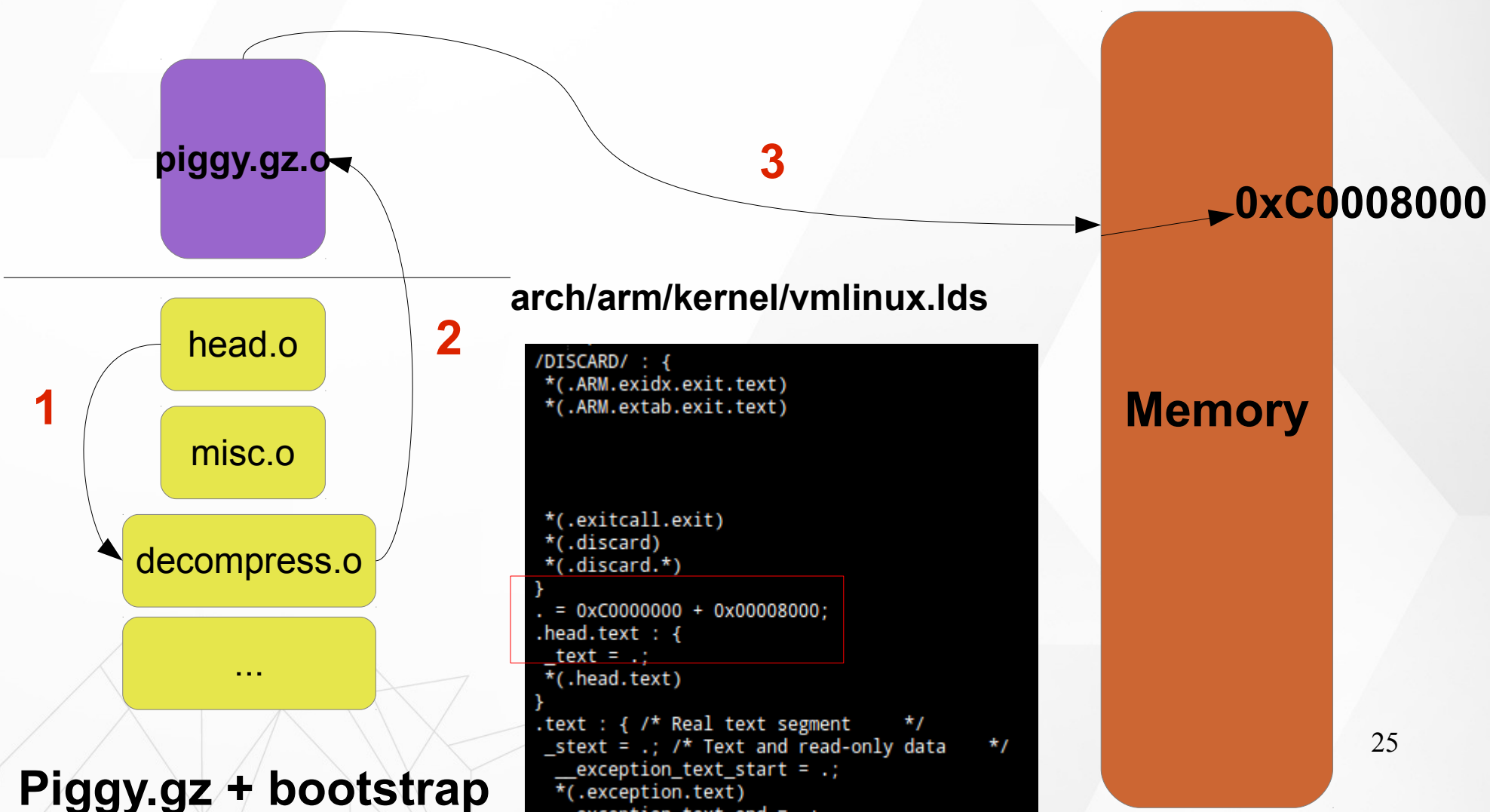
Kernel boot



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Linux boot

$(linux)/arch/arm/boot/compressed/head.S

entering

```
/*
 * sort out different calling conventions
 */
        .align
        .arm                    @ Always enter in ARM state
start:
        .type   start,#function
        .rept   7
        mov r0, r0
        .endr
   ARM(     mov r0, r0      )
   ARM(     b   1f      )
 THUMB(     adr r12, BSYM(1f)   )
 THUMB(     bx  r12     )

        .word   0x016f2818      @ Magic numbers to help the loader
        .word   start           @ absolute load/run zImage address
        .word   _edata          @ zImage end address
 THUMB(     .thumb          )
1:      mov r7, r1          @ save architecture ID
        mov r8, r2          @ save atags pointer

#ifndef __ARM_ARCH_2__
        /*
         * Booting from Angel - need to enter SVC mode and disable
         * FIQs/IRQs (numeric definitions from angel arm.h source).
         * We only do this if we were in user mode on entry.
         */
```


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Check overwrite

```
/*
 * Check to see if we will overwrite ourselves.
 *   r4  = final kernel address
 *   r9  = size of decompressed image
 *   r10 = end of this image, including  bss/stack/malloc space if non XIP
 * We basically want:
 *   r4 - 16k page directory >= r10 -> OK
 *   r4 + image length <= address of wont_overwrite -> OK
 */
        add r10, r10, #16384
        cmp r4, r10
        bhs wont_overwrite
        add r10, r4, r9
        adr r9, wont_overwrite
        cmp r10, r9
        bls wont_overwrite

/*
```


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Relocate

```
/*
 * Relocate ourselves past the end of the decompressed kernel.
 *   r6  = _edata
 *   r10 = end of the decompressed kernel
 * Because we always copy ahead, we need to do it from the end and go
 * backward in case the source and destination overlap.
 */
        /*
         * Bump to the next 256-byte boundary with the size of
         * the relocation code added. This avoids overwriting
         * ourself when the offset is small.
         */
        add r10, r10, #((reloc_code_end - restart + 256) & ~255)
        bic r10, r10, #255

        /* Get start of code we want to copy and align it down. */
        adr r5, restart
        bic r5, r5, #31

        sub r9, r6, r5      @ size to copy
        add r9, r9, #31     @ rounded up to a multiple
        bic r9, r9, #31     @ ... of 32 bytes
        add r6, r9, r5
        add r9, r9, r10

1:      ldmdb   r6!, {r0 - r3, r10 - r12, lr}
        cmp r6, r5
```


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Decompress kernel

```
/*
 * The C runtime environment should now be setup sufficiently.
 * Set up some pointers, and start decompressing.
 *   r4  = kernel execution address
 *   r7  = architecture ID
 *   r8  = atags pointer
 */
        mov r0, r4
        mov r1, sp              @ malloc space above stack
        add r2, sp, #0x10000    @ 64k max
        mov r3, r7
        bl  decompress_kernel
        bl  cache_clean_flush
        bl  cache_off
        mov r0, #0              @ must be zero
        mov r1, r7              @ restore architecture number
        mov r2, r8              @ restore atags pointer
 ARM(       mov pc, r4  )       @ call kernel
 THUMB(     bx  r4  )       @ entry point is always ARM

        .align  2
        .type   LC0, #object
LC0:        .word   LC0         @ r1
        .word   __bss_start     @ r2
        .word   _end            @ r3
        .word   _edata          @ r6
        .word   input_data_end - 4  @ r10 (inflated size location)
        .word    got_start      @ r11
```


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Kernel startup entry point

- MMU = off, D-cache = off, I-cache = dont care
- R0 = 0, R1 = machine ID, R2 = atags or dtb pointer
- Machine ID
  - linux/arch/arm/tools/mach-types
- kernel at 0xc0008000

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Kernel Startup Entry Point

```
/*
 * Kernel startup entry point.
 * ---------------------------
 *
 * This is normally called from the decompressor code.  The requirements
 * are: MMU = off, D-cache = off, I-cache = dont care, r0 = 0,
 * r1 = machine nr, r2 = atags or dtb pointer.
 *
 * This code is mostly position independent, so if you link the kernel at
 * 0xc0008000, you call this at __pa(0xc0008000).
 *
 * See linux/arch/arm/tools/mach-types for the complete list of machine
 * numbers for r1.
 *
 * We're trying to keep crap to a minimum; DO NOT add any machine specific
 * crap here - that's what the boot loader (or in extreme, well justified
 * circumstances, zImage) is for.
 */
   .arm

   __HEAD
ENTRY(stext)

 THUMB( adr r9, BSYM(1f)    )   @ Kernel is always entered in ARM.
 THUMB( bx  r9      )   @ If this is a Thumb-2 kernel,
 THUMB( .thumb          )   @ switch to Thumb now.
 THUMB(1:           )

   setmode PSR_F_BIT | PSR_I_BIT | SVC_MODE, r9 @ ensure svc mode
                        @ and irqs disabled
   mrc p15, 0, r9, c0, c0      @ get processor id
   bl  __lookup_processor_type     @ r5=procinfo r9=cpuid
   movs    r10, r5             @ invalid processor (r5=0)?
 THUMB( it  eq )        @ force fixup-able long branch encoding
```


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Machine Init

$linux/arch/arm/mach-exynos/mach-tiny4412.c

```
        else
            initialize_non_prime_clocks();
    }
#ifdef CONFIG_BUSFREQ_OPP
    dev_add(&busfreq, &exynos4_busfreq.dev);
    ppmu_init(&exynos_ppmu[PPMU_DMC0], &exynos4_busfreq.dev);
    ppmu_init(&exynos_ppmu[PPMU_DMC1], &exynos4_busfreq.dev);
    ppmu_init(&exynos_ppmu[PPMU_CPU], &exynos4_busfreq.dev);
#endif
    set_tmu_platdata();
}

MACHINE_START(TINY4412, "TINY4412")
    /* Maintainer: FriendlyARM (www.arm9.net) */
    /* Maintainer: Kukjin Kim <kgene.kim@samsung.com> */
    /* Maintainer: Changhwan Youn <chaos.youn@samsung.com> */
    .atag_offset    = 0x100,
    .init_irq   = exynos4_init_irq,
    .map_io     = smdk4x12_map_io,
    .handle_irq = gic_handle_irq,
    .init_machine   = smdk4x12_machine_init,
    .init_late  = exynos_init_late,
    .timer      = &exynos4_timer,
    .restart    = exynos4_restart,
    .reserve    = &smdk4x12_reserve,
MACHINE_END
```


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Mach Type

$linux/arch/arm/tools/mach-types

```
vybrid_vf4xx        MACH_VYBRID_VF4XX   VYBRID_VF4XX        4148
aria_g25        MACH_ARIA_G25       ARIA_G25        4149
bcm21553        MACH_BCM21553       BCM21553        4150
smdk5410        MACH_SMDK5410       SMDK5410        4151
lpc18xx         MACH_LPC18XX        LPC18XX         4152
oratisparty     MACH_ORATISPARTY    ORATISPARTY     4153
qseven          MACH_QSEVEN     QSEVEN          4154
gmv_generic     MACH_GMV_GENERIC    GMV_GENERIC     4155
th_link_eth     MACH_TH_LINK_ETH    TH_LINK_ETH     4156
tn_muninn       MACH_TN_MUNINN      TN_MUNINN       4157
rampage         MACH_RAMPAGE        RAMPAGE         4158
visstrim_mv10       MACH_VISSTRIM_MV10  VISSTRIM_MV10       4159
mx28_wilma      MACH_MX28_WILMA     MX28_WILMA      4164
msm8625_ffa     MACH_MSM8625_FFA    MSM8625_FFA     4166
vpu101          MACH_VPU101     VPU101          4167
baileys         MACH_BAILEYS        BAILEYS         4169
familybox       MACH_FAMILYBOX      FAMILYBOX       4170
ensemble_mx35       MACH_ENSEMBLE_MX35  ENSEMBLE_MX35       4171
sc_sps_1        MACH_SC_SPS_1       SC_SPS_1        4172
tiny4412        MACH_TINY4412       TINY4412        4608
```


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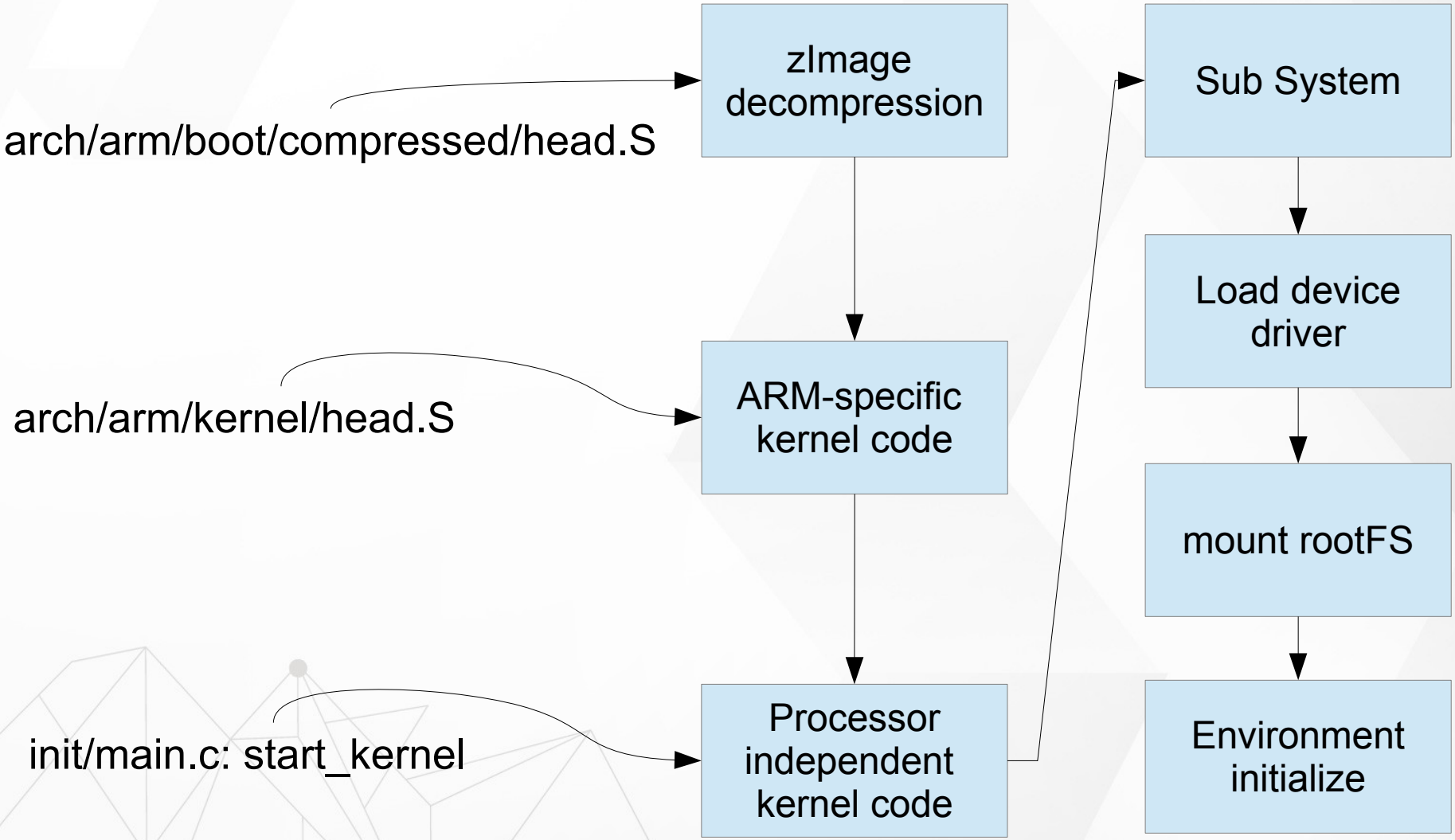
Linux Kernel Booting



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Write rootFS to eMMC

Step 1 – Creation of the actual EXT4.img

dd if=/dev/zero of=rootfs_ext4.img bs=512k count=60

Translation of the terms,

bs =blocksize,

count=60, the number of block`s, in our case will result an image of 30 Mb.

To get the exact size of the image that you create use simple maths.

60 * 512K = 31457280 byte = 30M bytes

Step 2 Formating the rootfs_ext4.img with EXT4

mkfs.ext4 rootfs_ext4.img

It will be a question where you will select yes (Y)

Step 3 mount the directories that we previous created.

mkdir rootfs_ext4 && mount -o loop rootfs_ext4.img rootfs_ext4/

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Write rootFS to eMMC

Step 4 copy the content from the old system.img in the system_new.img

cp -v -r -p /home/cadtc/tiny4412/experiment/root_mkfs/* ./rootfs_ext4

Step 5 sync the files

sync

Step 6 Unmounting the partitons.

umount rootfs_ext4/

Step 7 reboot EVB and into Linux console with NFS

Step 8 dd rootfs_ext4.img to /dev/mmcblk0p2

dd if=/tmp/rootfs_ext4.img of=/dev/mmcblk0p2

Step 9 Modify u-boot args then reboot

setenv bootargs 'noinitrd init=/linuxrc root=/dev/mmcblk0p2 rw noinitrd rootfstype=ext4 console=ttySAC0 lcd=S70'

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