Yocto Project® Kernel Lab, Hands-On

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Ignoring TheYocto Project (briefly)

Kernel Workflow - first pass

- obtain kernel
- obtain cross-toolchain
- setup cross-toolchain/environment
- configure kernel/tweak DT
- build kernel/modules/dtb
- install kernel/modules/dtb
- test

Kernel Workflow - later

- edit kernel
- write kernel module
- do -rt stuff
- build, install, test

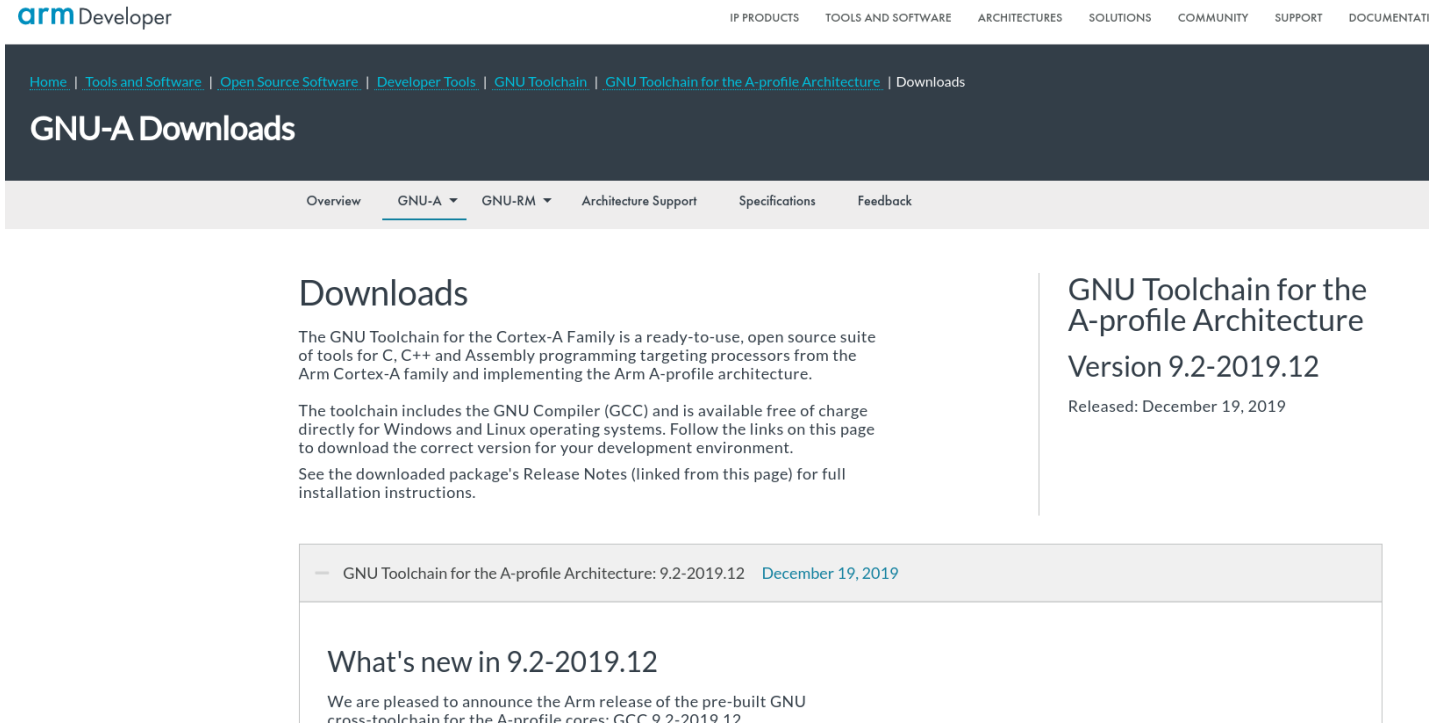
Obtain Kernel

- upstream Linus
- upstream linux-stable
- vendor kernel (tries to be good)
- evil vendor kernel (franken-kernel)

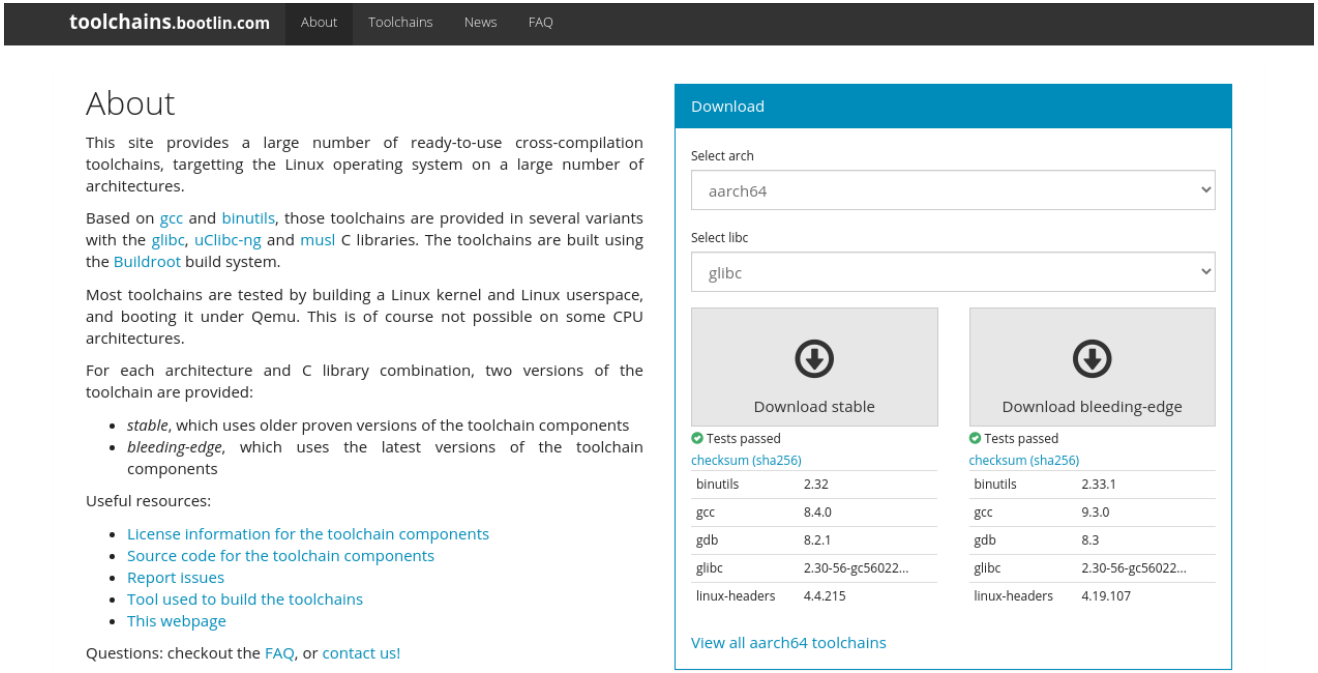
Obtain Cross-Toolchain

- cross-compiler from your distro
- gnu.gcc.org (compile your own, good luck)
- crosstool-NG (compile your own, with help)
- ARM/Linaro
- Bootlin
- kernel.org (NOTE: kernel only)
- vendor

Obtain Cross-Toolchain ARM/Linaro



Obtain Cross-Toolchain
Bootlin - https://toolchains.bootlin.com



Obtain Cross-Toolchain
kernel.org - https://www.kernel.org/pub/tools/crosstool

Compilers

Target Architecture		Host Architecture		
Kernel Arch	Compiler Arch	Intel 64-bit	ARM 64-bit	PowerPC 64-bit
Fully supported architectures				
arm64	aarch64-linux	10.1.0	10.1.0	10.1.0
alpha	alpha-linux	10.1.0	10.1.0	10.1.0
arm	arm-linux-gnueabi	10.1.0	10.1.0	10.1.0
arc	arc-linux	10.1.0	10.1.0	10.1.0
c6x	c6x-elf	10.1.0	10.1.0	10.1.0
csky	csky-linux	10.1.0	10.1.0	10.1.0
h8300	h8300-linux	10.1.0	10.1.0	10.1.0
parisc64	hppa64-linux	10.1.0	10.1.0	10.1.0
parisc	hppa-linux	10.1.0	10.1.0	10.1.0

Setup Toolchain/Environment

- (compile +) install toolchain
- setup $PATH

either:

- tweak environment

```
$ export ARCH=arm
$ export CROSS_COMPILE=<toolchain-prefix>
```

- specify on cmdline

```
$ ARCH=arm CROSS_COMPILE=<toolchain-prefix> make
```

Build Kernel, Modules, DTB

```
$ ARCH=arm CROSS_COMPILE=<toolchain-prefix> make
```

Install Kernel, Modules, DTB

- by default:
  - kernel: $INSTALL_PATH (default: /boot)
  - modules: $INSTALL_MOD_PATH/lib/modules/$VER
  - dtb: $INSTALL_PATH/dtbs/$VER
- this doesn't work for embedded
  - each board is… "unique"

Install Kernel, Modules, DTB

- how and where these various parts are installed is highly board-specific:
  - extlinux.conf
  - uEnv.txt
  - separate partitions
  - APPENDED_DTB (i.e. "bundled")
  - U-Boot FIT image

Install Kernel, Modules, DTB

- how and where these various parts are installed is highly board-specific:
  - "magic" offsets on storage device
  - multi-partition UBI (raw flash)
  - initial FAT/VFAT partition

Install Kernel, Modules, DTB

- there is a very tight coupling between
  - bootloader
  - kernel cmdline
  - kernel + modules + dtb
  - final image assembly (e.g. wic)

Edit Kernel

- not too difficult, locate and edit kernel sources
- just make sure you're editing the correct sources (multiple boards, multiple projects, multiple configurations) and using the correct toolchain (correctly)

Write Kernel Module

- need to copy+paste an example Makefile to get the out-of-kernel-tree build plumbing correct
- otherwise the mechanics aren't too complicated

Do -rt Stuff

- I hope the kernel version you're using is one for which there is an -rt patch available, otherwise forget it
- if the above is true, manually applying the -rt patch against an *unmodified* base isn't too difficult

Kernel Workflow Without Yocto

- it's not too hard if you've done it once or twice before
- but can be tricky to get it right the first time
- the amount of work compounds with the number of boards you need to support
  - multiple toolchains
  - multiple configurations
  - multiple install layouts

Can TheYocto Project Help?

Kernel Workflow - multiple users

- tweaking a kernel/config or writing a kernel module using an existing BSP
- board bring-up (creating a BSP) for a new board

Kernel Workflow - existing BSP

- obtain kernel
- obtain cross-toolchain
- setup cross-toolchain/environment
- configure kernel/tweak DT
- build kernel/modules/dtb
- install kernel/modules/dtb

Kernel Workflow TODO - existing BSP

- change kernel
- obtain cross-toolchain
- setup cross-toolchain/environment
- configure kernel/tweak DT
- build kernel/modules/dtb
- install kernel/modules/dtb
- edit kernel sources
- write a kernel module

Kernel Workflow TODO - existing BSP change kernel

- many kernels from which to choose (upstream, vendor, stable)
- The Yocto Project provides its own (linux-yocto) plus tooling for use with linux-yocto, or your own
- linux-yocto comes in a couple variants:
  - (base)
  - -dev
  - -tiny
  - -rt

Kernel Workflow TODO - existing BSP tweak config

- use your own defconfig
- use an in-kernel *_defconfig*
- generate one or more config "fragments" which are applied on top of the base configuration

Kernel Workflow TODO - existing BSP
edit kernel code

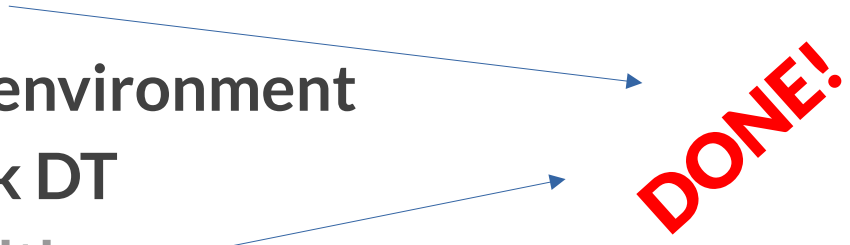
- good for *pr_notice()* debugging
- edit/add device IDs (PCI, USB) for new hardware

Kernel Workflow TODO - existing BSP
write a module

- a frequent activity with embedded devices
- autoload on boot with KERNEL_MODULE_AUTOLOAD
- be sure to include your modules into your image (MACHINE_EXTRA_RRECOMMENDS)

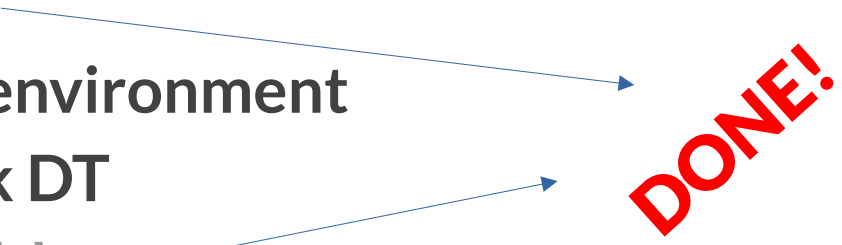
Kernel Workflow - new BSP

- obtain kernel
- obtain cross-toolchain
- setup cross-toolchain/environment
- configure kernel/tweak DT
- build kernel/modules/dtb
- install kernel/modules/dtb



Kernel Workflow - new BSP

- obtain kernel
- obtain cross-toolchain
- setup cross-toolchain/environment
- configure kernel/tweak DT
- build kernel/modules/dtb
- install kernel/modules/dtb
- *… but with a lot of help!*



Kernel Workflow - new BSP

- obtain kernel
  - implicit understanding of how to fetch code
- setup cross-toolchain/environment
  - set the processor "TUNE" in $MACHINE
- configure kernel/tweak DT
  - lots of linux-yocto tooling
- install kernel/modules/dtb
  - lots of kernel-handling classes

Hands On: Existing BSP

Hands-On: Prep

```
ilab01:~$ cd scratch
ilab01:~/scratch$ git clone -b dunfell git://git.yoctoproject.org/poky.git
Cloning into 'poky'...
remote: Enumerating objects: 479650, done.
remote: Counting objects: 100% (479650/479650), done.
remote: Compressing objects: 100% (113534/113534), done.
remote: Total 479650 (delta 359015), reused 478925 (delta 358472)
Receiving objects: 100% (479650/479650), 164.40 MiB | 28.37 MiB/s, done.
Resolving deltas: 100% (359015/359015), done.
```

Hands-On: Prep

```
ilab01:~/scratch$ . poky/oe-init-build-env
...
### Shell environment set up for builds. ###
...
ilab01:~/scratch/build$
```

- I like to remind myself this is now a modified-environment shell for builds:

```
ilab01:~/scratch/build$ export $PS1="${PS1}lab> "
ilab01:~/scratch/build$ lab>
```

Hands-On: Prep

```
ilab01:~/scratch/build$ lab> $EDITOR conf/local
```

- here's what you need to change:

```
MACHINE = "qemux86-64"
DL_DIR = "/scratch/downloads"
SSTATE_DIR = "/scratch/sstate-cache"
SDKMACHINE = "x86_64"
OE_TERMINAL = "screen"
```

Hands-On: Prep

- baseline build:

```
ilab01:~/scratch/build$ lab> bitbake core-image-minimal
Build Configuration:
BB_VERSION           = "1.46.0"
BUILD_SYS            = "x86_64-linux"
NATIVELSBSTRING      = "universal"
TARGET_SYS           = "x86_64-poky-linux"
MACHINE              = "qemux86-64"
DISTRO               = "poky"
DISTRO_VERSION       = "3.1.1"
TUNE_FEATURES        = "m64 core2"
TARGET_FPU           = ""
meta
meta-poky
meta-yocto-bsp       = "dunfell:93ef4736915090ac9a2402916df8924ac4439490"
```

Hands-On: Prep

- verify it runs

```
ilab01:~/scratch/build$ lab> runqemu slirp nographic serial
...
hwclock: settimeofday: Invalid argument
chmod: /var/log/wtmp: No such file or directory
Failed to set mode -0664- for -/var/log/wtmp-.
INIT: Entering runlevel: 5
Configuring network interfaces... ip: RTNETLINK answers: File exists
hwclock: settimeofday: Invalid argument
Starting syslogd/klogd: done

Poky (Yocto Project Reference Distro) 3.1.1 qemux86-64 /dev/ttyS0

qemux86-64 login:
```

Hands-On: Prep

- shutdown

```
Poky (Yocto Project Reference Distro) 3.1.1 qemux86-64 /dev/ttyS0

qemux86-64 login: root
root@qemux86-64:~# uname -a
Linux qemux86-64 5.4.43-yocto-standard #1 SMP PREEMPT Thu May 28 15:33:30 UTC
2020
root@qemux86:~# shutdown -h now
...
[  130.239174] ACPI: Preparing to enter system sleep state S5
[  130.242375] reboot: Power down
runqemu - INFO - Cleaning up
ilab01:~/scratch/build$ lab>
```

Hands-On: Prep

- create/add a layer for your changes

```
ilab01:~/scratch/build$ lab> bitbake-layers create-layer meta-mytweaks
NOTE: Starting bitbake server...
Add your new layer with 'bitbake-layers add-layer meta-mytweaks'
ilab01:~/scratch/build$ lab> bitbake-layers add-layer meta-mytweaks
NOTE: Starting bitbake server...
ilab01:~/scratch/build$ lab>
```

Hands-On: Edit the Kernel

Hands-On: Edit the Kernel

- use *devtool*

```
ilab01:~/scratch/build$ lab> devtool modify virtual/kernel
...
Currently  1 running tasks (431 of 437)  98% | ############################## |
0: linux-yocto-5.4.43+gitAUTOINC+aafb8f095e_9e1b13d7f9-r0 do_kernel_checkout
- 1m49s (pid 1615575)
INFO: Copying kernel config to srctree
INFO: Source tree extracted to /scratch/build/workspace/sources/linux-yocto
INFO: Recipe linux-yocto now set up to build from
/scratch/build/workspace/sources/linux-yocto
```

Hands-On: Edit the Kernel

- edit init/main.c

```
ilab01:~/scratch/build$ lab> $EDITOR workspace/sources/linux-yocto/init/main.c
1137         /*
1138          * We try each of these until one succeeds.
1139          *
1140          * The Bourne shell can be used instead of init if we are
1141          * trying to recover a really broken machine.
1142          */
1143         pr_notice("*** --- >>> edit <<< --- ***\n");
1144         if (execute_command) {
1145                 ret = run_init_process(execute_command);
1146                 if (!ret)
1147                         return 0;
1148                 panic("Requested init %s failed (error %d).",
1149                       execute_command, ret);
```

Hands-On: Edit the Kernel

- build

```
ilab01:~/scratch/build$ lab> bitbake core-image-minimal
...
NOTE: linux-yocto: compiling from external source tree
/scratch/build/workspace/sources/linux-yocto
...
```

Hands-On: Edit the Kernel

- test (you might have to scroll up)

```
ilab01:~/scratch/build$ lab> runqemu slirp nographic serial
...
[    5.209719] VFS: Mounted root (ext4 filesystem) on device 253:0.
[    5.211596] devtmpfs: mounted
[    5.312611] Freeing unused kernel image memory: 1580K
[    5.313286] Write protecting kernel text and read-only data: 20480k
[    5.313744] *** --- >>> edit <<< --- ***
[    5.313980] Run /sbin/init as init process
INIT: version  booting
Starting udev
[    6.096177] udevd[138]: starting version 3.2.9
[    6.162295] udevd[139]: starting eudev-3.2.9
...
```

Hands-On: Edit the Kernel

- commit your changes *(don't forget upstream-status)*

```
ilab01:~/scratch/build$ lab> pushd workspace/sources/linux-yocto
~/scratch/build/workspace/sources/linux-yocto ~/scratch/build
ilab01:~/scratch/build$ lab> git commit -avs -m "init/main.c: add my tweaks"
ilab01:~/scratch/build$ lab> popd
~/scratch/build
```

Hands-On: Edit the Kernel

- update your metadata *(emphasis mine)*

```
ilab01:~/scratch/build$ lab> devtool finish linux-yocto meta-mytweaks
...
NOTE: Writing append file
/scratch/build/meta-mytweaks/recipes-kernel/linux/linux-yocto_%.bbappend
NOTE: Copying 0001-init-main.c-add-my-tweaks.patch to /scratch/build/meta-
mytweaks/recipes-kernel/linux/linux-yocto/0001-init-main.c-add-my-
tweaks.patch
INFO: Cleaning sysroot for recipe linux-yocto...
INFO: Leaving source tree /scratch/build/workspace/sources/linux-yocto as-is;
if you no longer need it then please delete it manually
ilab01:~/scratch/build$ lab> rm -fr workspace/sources/linux-yocto
```

Hands-On: Edit the Kernel

- check

```
ilab01:~/scratch/build$ lab> tree meta-mytweaks
meta-mytweaks/
├── COPYING.MIT
├── README
├── conf
│   └── layer.conf
└── recipes-kernel
    └── linux
        ├── linux-yocto
        │   └── 0001-init-main.c-add-my-tweaks.patch
        └── linux-yocto_%.bbappend
```

Hands-On: Tweak the Kernel Configuration

Hands-On: Tweak the Kernel Configuration

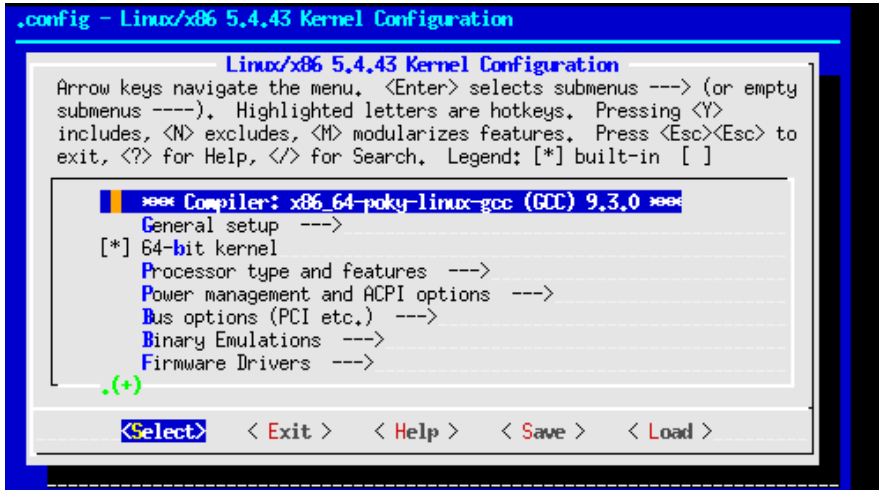
- use devtool, setup

```
ilab01:~/scratch/build$ lab> devtool modify virtual/kernel
...
NOTE: Tasks Summary: Attempted 437 tasks of which 426 didn't need to be rerun
and all succeeded.
INFO: Copying kernel config to srctree
INFO: Source tree extracted to
/z/3.1-build-dunfell/kernellab/x86-64/build/workspace/sources/linux-yocto
INFO: Recipe linux-yocto now set up to build from
/z/3.1-build-dunfell/kernellab/x86-64/build/workspace/sources/linux-yocto
```

Hands-On: Tweak the Kernel Configuration

- use devtool

```
ilab01:~/scratch/build$ lab> devtool menuconfig linux-yocto
```



Hands-On: Tweak the Kernel Configuration

- navigate to:
  - General Setup
    - Preemption Model
- select:
  - No Forced Preemption (Server)
- hit double-esc or <Exit> and save your changes

```
INFO: Updating config fragment
/z/3.1-build-dunfell/kernellab/x86-64/build/workspace/sources/linux-yocto/oe-
local-files/devtool-fragment.cfg
```

Hands-On: Tweak the Kernel Configuration

- test

```
ilab01:~/scratch/build$ lab> bitbake core-image-minimal
NOTE: linux-yocto: compiling from external source tree
/scratch/build/workspace/sources/linux-yocto
ilab01:~/scratch/build$ lab> runqemu slirp nographic serial
...
[    0.223909] rcu: Hierarchical RCU implementation.
...
qemux86-64 login: root
root@qemux86-64:~# uname -a
Linux qemux86-64 5.4.43-yocto-standard #1 SMP Wed Jul 1 20:06:32 UTC 2020
x86_64 GNU/Linux
```

- NOTE: missing "Preemptible hierarchical RCU" and "PREEMPT" in "uname -a"

Hands-On: Tweak the Kernel Configuration

- update metadata

```
ilab01:~/scratch/build$ lab> devtool finish linux-yocto meta-mytweaks
...
NOTE: Writing append file
/scratch/build/meta-mytweaks/recipes-kernel/linux/linux-yocto_%.bbappend
NOTE: Copying devtool-fragment.cfg to /scratch/build/meta-mytweaks/recipes-
kernel/linux/linux-yocto/devtool-fragment.cfg
INFO: Cleaning sysroot for recipe linux-yocto...
INFO: Leaving source tree /scratch/build/workspace/sources/linux-yocto as-is;
if you no longer need it then please delete it manually
ilab01:~/scratch/build$ lab> rm -fr workspace/sources/linux-yocto
```

Hands-On: Tweak the Kernel Configuration

- check

```
ilab01:~/scratch/build$ lab> tree meta-mytweaks
meta-mytweaks/
├── COPYING.MIT
├── README
├── conf
│   └── layer.conf
└── recipes-kernel
    └── linux
        ├── linux-yocto
        │   ├── 0001-init-main.c-add-my-tweaks.patch
        │   └── devtool-fragment.cfg
        └── linux-yocto_%.bbappend
```

Hands-On: Tweak the Kernel Configuration

- check

```
ilab01:~/scratch/build$ lab> cat meta-mytweaks/recipes-kernel/linux/linux-yocto/devtool-fragment.cfg
CONFIG_PREEMPT_NONE=y
# CONFIG_PREEMPT is not set
CONFIG_TREE_RCU=y
CONFIG_INLINE_SPIN_UNLOCK_IRQ=y
CONFIG_INLINE_READ_UNLOCK=y
CONFIG_INLINE_READ_UNLOCK_IRQ=y
CONFIG_INLINE_WRITE_UNLOCK=y
CONFIG_INLINE_WRITE_UNLOCK_IRQ=y
```

Hands-On: Tweak the Kernel Configuration

- NOTE: subsequent menuconfig changes clobber previous changes, so you'll need to move/rename them if you're generating more than one

Hands-On: *alt*

- if you're not "sold" on the *devtool* workflow, you could generate an SDK and use that instead

```
ilab01:~/scratch/build$ lab> bitbake core-image-minimal -c populate_sdk
```

- it is then very much like using any other SDK, but this one is tailored to your image
- it comes with an *environment* file that you source which includes (among other things) settings for ARCH and CROSS_COMPILE

The Yocto Project Kernel Metadata

Kernel Metadata

- in the hands-on portion you saw an example of a kernel configuration fragment and a patch
- the Linux kernel configuration system has always had the ability to handle config fragments, but few have made use of it
- patches and configs can be grouped into features
- we have tooling to help organize and apply fragments and patches in various conditions

Kernel Metadata

- 3 types of kernel metadata:
  - scc files
  - patches
  - config fragments

Kernel Metadata - config fragments

- we saw this in the hands-on
- use *devtool* or *-c menuconfig/-c diffconfig* to generate
- filename has a **.cfg* extension

Kernel Metadata - patches

- we also saw this in the hands-on
- use *devtool+git* or *patch* or manually use *git --format-patch* to generate
- filename has a **.patch* extension

Kernel Metadata - scc

- "scc" = Series Configuration Control
- ties together config fragments and/or patches with extra metadata that is useful to the build
- filename has an *.*scc* extension

Kernel Metadata - e.g. 1

- you have a set of 6 boards:
  - 2 have graphics capabilities
  - 3 can make sounds
  - 1 uses raw flash
  - 4 have DVD devices
- you could create sets of *.cfg/*.patch for each feature, described in *scc files, then apply them as required

Kernel Metadata - e.g. 2

- you have "development" and "production" builds
- for development builds you might want to enable more kernel debugging and/or verbosity or NFS or lax security
- for production builds you might want to enable more kernel hardening and disable potential security things (i.e. disable modules)

Kernel Metadata - e.g. 3

- you're creating a BSP layer and some of your boards use one GPU while others use a second GPU and the rest use yet another GPU
- you can create metadata for each GPU and include them in your builds as required

Kernel Metadata - storage

- there are 2 places you can store the kernel metadata:
  - in-tree
  - in a separate repository
- regardless, add the location of the metadata to your *SRC_URI* variable and be sure to specify "*type=kmeta*"

Kernel Metadata - enabling

- reference the *.scc file with *KERNEL_FEATURES*

Kernel Metadata - down the rabbit hole

- it's much more sophisticated
- you can define kernel types (i.e. KTYPE) and have features enabled based on the kernel type (e.g. -tiny, -dev, -rt)
- *.scc files can include other *.scc files but there are ways to say "include this *.scc file but not anything it wants to include"

Kernel Metadata

- examples of in-tree kmeta include:
  - https://github.com/akuster/meta-odroid
  - git.yoctoproject.org/meta-arm
  - git.yoctoproject.org/meta-xilinx
- git.yoctoproject.org/meta-raspberrypi is an example of just using *.cfg files without *.scc

Kernel Metadata

- an example of out-of-tree kmeta is:
  - git.yoctoproject.org/yocto-kernel-cache

Recommendations

Recommendations

- use linux-yocto if at all possible
  - your users will appreciate being able to take advantage of the tooling and features that come with The Yocto Project (i.e. they can tweak the config)
- otherwise base your kernel recipe on poky/meta-skeleton/recipes-kernel/linux/linux-yocto-custom.bb

```
inherit kernel
require recipes-kernel/linux/linux-yocto.inc
```

Thank You!



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