

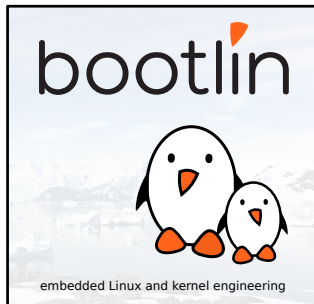


## Yocto Project and OpenEmbedded Training

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Latest update: January 5, 2021.

Document updates and sources:  
<https://bootlin.com/doc/training/yocto>

Corrections, suggestions, contributions and translations are welcome!  
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**Document sources:** <https://github.com/bootlin/training-materials/>



# Hyperlinks in the document

There are many hyperlinks in the document

- ▶ Regular hyperlinks:

<https://kernel.org/>

- ▶ Kernel documentation links:

[dev-tools/kasan](#)

- ▶ Links to kernel source files and directories:

[drivers/input/](#)

[include/linux/fb.h](#)

- ▶ Links to the declarations, definitions and instances of kernel symbols (functions, types, data, structures):

[platform\\_get\\_irq\(\)](#)

[GFP\\_KERNEL](#)

[struct file\\_operations](#)



# bootlin

- ▶ Engineering company created in 2004, named "Free Electrons" until Feb. 2018.
- ▶ Locations: Orange, Toulouse, Lyon (France)
- ▶ Serving customers all around the world
- ▶ Head count: 12 - Only Free Software enthusiasts!
- ▶ Focus: Embedded Linux, Linux kernel, build systems and low level Free and Open Source Software for embedded and real-time systems.
- ▶ Bootlin is often in the top 20 companies contributing to the Linux kernel.
- ▶ Activities: development, training, consulting, technical support.
- ▶ Added value: get the best of the user and development community and the resources it offers.



- ▶ All our training materials and technical presentations:  
<https://bootlin.com/docs/>
- ▶ Technical blog:  
<https://bootlin.com/>
- ▶ Quick news (Mastodon):  
<https://fosstodon.org/@bootlin>
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<https://twitter.com/bootlincom>
- ▶ Quick news (LinkedIn):  
<https://www.linkedin.com/company/bootlin>
- ▶ Elixir - browse Linux kernel sources on-line:  
<https://elixir.bootlin.com>



Mastodon is a free and decentralized social network created in the best interests of its users.

Image credits: Jin Nguyen - <https://frama.link/bQwcWHTP>

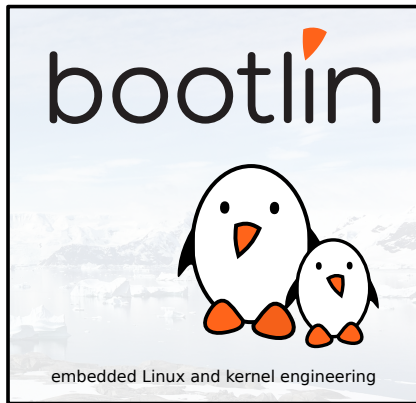


## Generic course information

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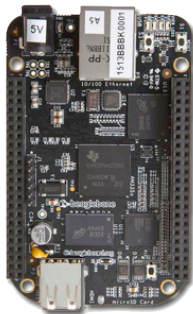
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## Two supported hardware platforms

There are two variants of the practical labs for this course, one supporting the Beaglebone Black board, the other supporting the STMicroelectronics STM32MP157A-DK1 Discovery board.



Beaglebone Black

<https://bootlin.com/doc/training/yocto/>



STM32MP157A-DK1 Discovery

<https://bootlin.com/doc/training/yocto-stm32/>



# Shopping list: hardware for this course

- ▶ Main board, choice 1:
  - ▶ STMicroelectronics STM32MP157A-DK1 Discovery kit (Mouser: 65 EUR + VAT)
  - ▶ USB-C cable (power supply)
  - ▶ USB-A to micro B cable (serial console)
- ▶ Main board, choice 2:
  - ▶ Beaglebone Black or Beaglebone Black Wireless (Mouser: 73 EUR + VAT), USB-A to micro B power cable included
  - ▶ USB Serial Cable - 3.3 V - female ends:  
Olimex: <https://frama.link/zWJDToXP>
- ▶ Nintendo Nunchuk with UEXT connector:  
Olimex: <https://j.mp/1dTYLfs>
- ▶ Breadboard jumper wires - Male ends:  
Olimex: <https://bit.ly/2pSiIPs>
- ▶ SD card with 8 GB capacity



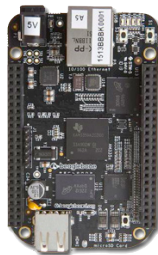




# Supported hardware

BeagleBone Black or BeagleBone Black Wireless, from [BeagleBoard.org](http://BeagleBoard.org)

- ▶ Texas Instruments AM335x (ARM Cortex-A8 CPU)
- ▶ SoC with 3D acceleration, additional processors (PRUs) and lots of peripherals.
- ▶ 512 MB of RAM
- ▶ 4 GB of on-board eMMC storage
- ▶ USB host and USB device, microSD, micro HDMI
- ▶ WiFi and Bluetooth (wireless version), otherwise Ethernet
- ▶ 2 x 46 pins headers, with access to many expansion buses (I2C, SPI, UART and more)
- ▶ A huge number of expansion boards, called *capes*. See [https://elinux.org/Beagleboard:BeagleBone\\_Capes](https://elinux.org/Beagleboard:BeagleBone_Capes).



open source  
hardware



# Supported hardware

## STMicroelectronics STM32MP157A-DK1 Discovery board

- ▶ STM32MP157A (Dual Cortex-A7 + Cortex-M4) CPU from STMicroelectronics
- ▶ 512 MB DDR3L RAM
- ▶ Gigabit Ethernet port
- ▶ 4 USB 2.0 host ports
- ▶ 1 USB-C OTG port
- ▶ 1 Micro SD slot
- ▶ On-board ST-LINK/V2-1 debugger
- ▶ Misc: buttons, LEDs, Audio codec
- ▶ Currently sold at 65 EUR + VAT at Mouser



Board and CPU documentation, design files, software:

<https://www.st.com/en/evaluation-tools/stm32mp157a-dk1.html>



# Course outline - Day 1

First dive into the Yocto Project. Introduction to recipes.

- ▶ Overview of an embedded Linux system architecture.
- ▶ Organization of the Yocto Project source tree.
- ▶ Building an image.
- ▶ Adding packages to the generated image.
- ▶ Recipes syntax. Writing a recipe.

Labs: first Yocto Project build, advanced Yocto configuration, add a custom application.



## Course outline - Day 2

Recipes and layers details: write, use, customize. Machine configuration.

- ▶ Advanced recipes concepts.
- ▶ Extending existing recipes.
- ▶ The Yocto Project layers. Adding a new layer.
- ▶ Writing your own machine configuration.

Labs: create a Yocto layer, create a custom machine configuration.



Images and packagegroups details, advanced concepts, SDK and runtime package management.

- ▶ Adding a custom image.
- ▶ Further recipes concepts.
- ▶ Rootfs generation.
- ▶ Using the Yocto Project SDK.
- ▶ Runtime package management.

Labs: create a custom image, develop your application in the Poky SDK.



# Participate!

During the lectures...

- ▶ Don't hesitate to ask questions. Other people in the audience may have similar questions too.
- ▶ This helps the trainer to detect any explanation that wasn't clear or detailed enough.
- ▶ Don't hesitate to share your experience, for example to compare Linux with other operating systems used in your company.
- ▶ Your point of view is most valuable, because it can be similar to your colleagues' and different from the trainer's.
- ▶ Your participation can make our session more interactive and make the topics easier to learn.



# Practical lab guidelines

During practical labs...

- ▶ We cannot support more than 8 workstations at once (each with its board and equipment). Having more would make the whole class progress slower, compromising the coverage of the whole training agenda (exception for public sessions: up to 10 people).
- ▶ So, if you are more than 8 participants, please form up to 8 working groups.
- ▶ Open the electronic copy of your lecture materials, and use it throughout the practical labs to find the slides you need again.
- ▶ Don't hesitate to copy and paste commands from the PDF slides and labs.



# Advise: write down your commands!

During practical labs, write down all your commands in a text file.

- ▶ You can save a lot of time re-using commands in later labs.
- ▶ This helps to replay your work if you make significant mistakes.
- ▶ You build a reference to remember commands in the long run.
- ▶ That's particular useful to keep kernel command line settings that you used earlier.
- ▶ Also useful to get help from the instructor, showing the commands that you run.

```
gedit ~/lab-history.txt
```

## Lab commands

### Cross-compiling kernel:

```
export ARCH=arm
export CROSS_COMPILE=arm-linux-
make sama5_defconfig
```

### Booting kernel through tftp:

```
setenv bootargs console=ttyS0 root=/dev/nfs
setenv bootcmd tftp 0x21000000 zimage; tftp
0x22000000 dtb; bootz 0x21000000 - 0x2200...
```

### Making ubifs images:

```
mkfs.ubifs -d rootfs -o root.ubifs -e 124KiB
-m 2048 -c 1024
```

### Encountered issues:

Restart NFS server after editing /etc/exports!





# Cooperate!

As in the Free Software and Open Source community, cooperation during practical labs is valuable in this training session:

- ▶ If you complete your labs before other people, don't hesitate to help other people and investigate the issues they face. The faster we progress as a group, the more time we have to explore extra topics.
- ▶ Explain what you understood to other participants when needed. It also helps to consolidate your knowledge.
- ▶ Don't hesitate to report potential bugs to your instructor.
- ▶ Don't hesitate to look for solutions on the Internet as well.



# Command memento sheet

- ▶ This memento sheet gives command examples for the most typical needs (looking for files, extracting a tar archive...)
- ▶ It saves us 1 day of UNIX / Linux command line training.
- ▶ Our best tip: in the command line shell, always hit the **Tab** key to complete command names and file paths. This avoids 95% of typing mistakes.
- ▶ Get an electronic copy on [https://bootlin.com/doc/legacy/command-line/command\\_memento.pdf](https://bootlin.com/doc/legacy/command-line/command_memento.pdf)





# vi basic commands

- ▶ The `vi` editor is very useful to make quick changes to files in an embedded target.
- ▶ Though not very user friendly at first, `vi` is very powerful and its main 15 commands are easy to learn and are sufficient for 99% of everyone's needs!
- ▶ Get an electronic copy on [https://bootlin.com/doc/legacy/command-line/vi\\_memento.pdf](https://bootlin.com/doc/legacy/command-line/vi_memento.pdf)
- ▶ You can also take the quick tutorial by running `vimtutor`. This is a worthy investment!





Prepare your lab environment

- ▶ Download and extract the lab archive

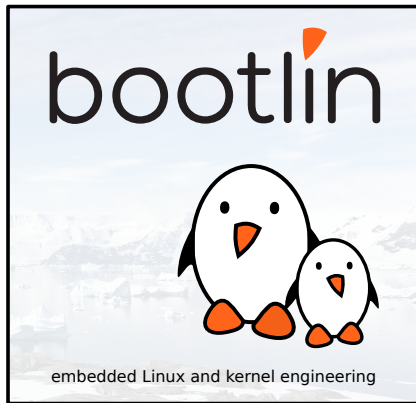


## Introduction to Embedded Linux

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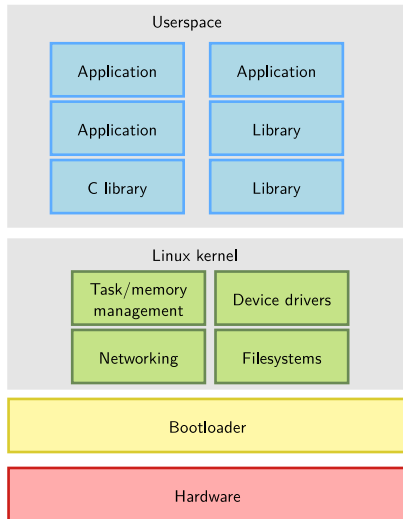
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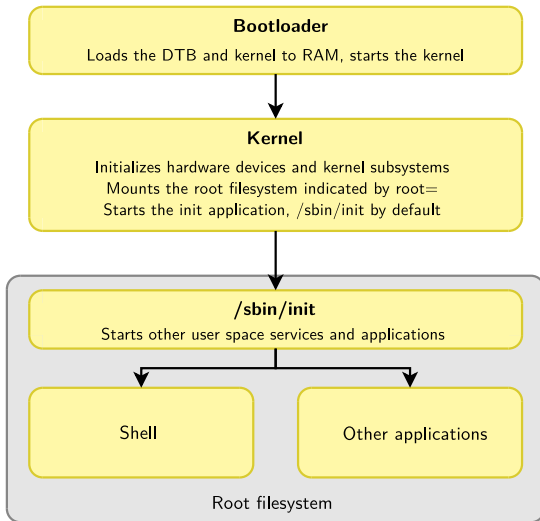


# Simplified Linux system architecture





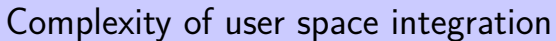
# Overall Linux boot sequence





- ▶ **BSP work:** porting the bootloader and Linux kernel, developing Linux device drivers.
- ▶ **system integration work:** assembling all the user space components needed for the system, configure them, develop the upgrade and recovery mechanisms, etc.
- ▶ **application development:** write the company-specific applications and libraries.





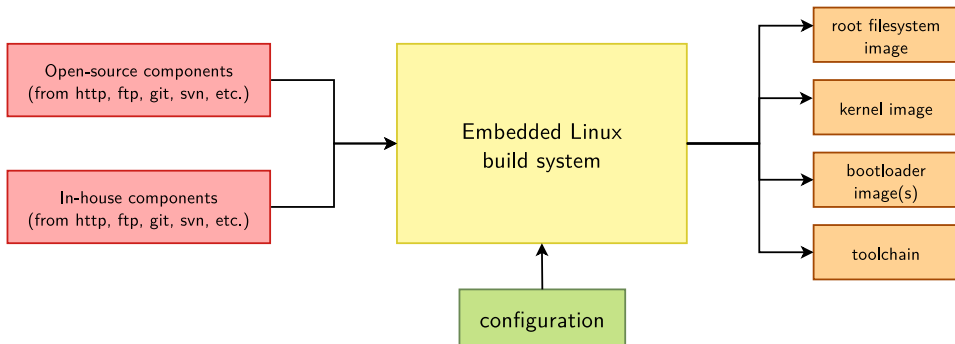


# System integration: several possibilities

	Pros	Cons
<b>Building everything manually</b>	Full flexibility Learning experience	Dependency hell Need to understand a lot of details Version compatibility Lack of reproducibility
<b>Binary distribution</b> Debian, Ubuntu, Fedora, etc.	Easy to create and extend	Hard to customize Hard to optimize (boot time, size) Hard to rebuild the full system from source Large system Uses native compilation (slow) No well-defined mechanism to generate an image Lots of mandatory dependencies Not available for all architectures
<b>Build systems</b> Buildroot, Yocto, PTXdist, etc.	Nearly full flexibility Built from source: customization and optimization are easy Fully reproducible Uses cross-compilation Have embedded specific packages not necessarily in desktop distros Make more features optional	Not as easy as a binary distribution Build time



# Embedded Linux build system: principle



- ▶ Building from source → lot of flexibility
- ▶ Cross-compilation → leveraging fast build machines
- ▶ Recipes for building components → easy



# Embedded Linux build system: tools

- ▶ A wide range of solutions: Yocto/OpenEmbedded, PTXdist, Buildroot, OpenWRT, and more.
- ▶ Today, two solutions are emerging as the most popular ones
  - ▶ **Yocto/OpenEmbedded**  
Builds a complete Linux distribution with binary packages. Powerful, but somewhat complex, and quite steep learning curve.
  - ▶ **Buildroot**  
Builds a root filesystem image, no binary packages. Much simpler to use, understand and modify.

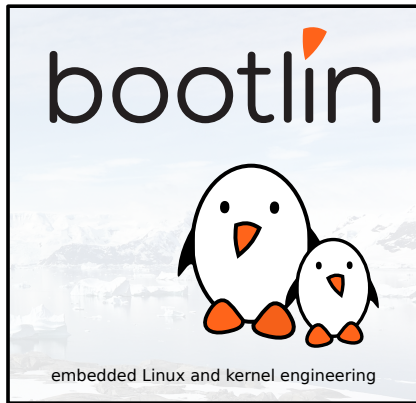


## Yocto Project and Poky reference system overview

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## The Yocto Project overview



- ▶ The Yocto Project is a set of templates, tools and methods that allow to build custom embedded Linux-based systems.
- ▶ It is an open source project initiated by the Linux Foundation in 2010 and is still managed by one of its fellows: Richard Purdie.

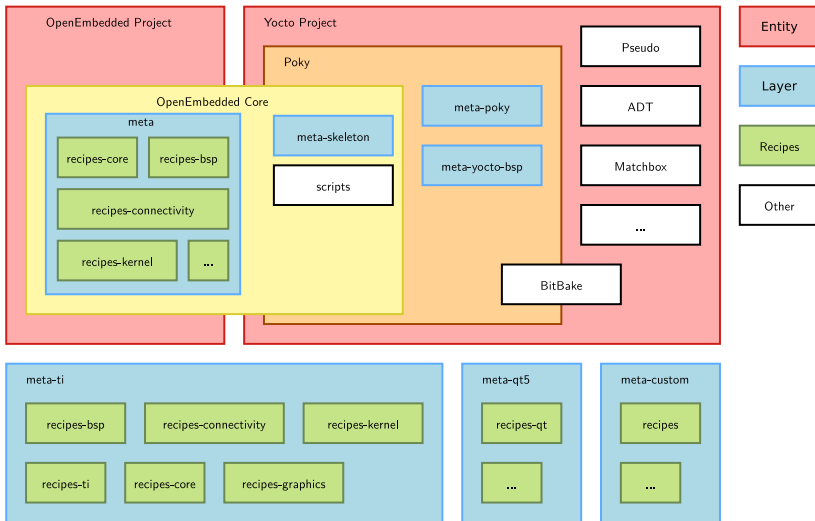


- ▶ The core components of the Yocto Project are:
  - ▶ BitBake, the *build engine*. It is a task scheduler, like `make`. It interprets configuration files and recipes (also called *metadata*) to perform a set of tasks, to download, configure and build specified applications and filesystem images.
  - ▶ OpenEmbedded-Core, a set of base *layers*. It is a set of recipes, layers and classes which are shared between all OpenEmbedded based systems.
  - ▶ Poky, the *reference system*. It is a collection of projects and tools, used to bootstrap a new distribution based on the Yocto Project.





# The Yocto Project lexicon





- ▶ Organization of OpenEmbedded-Core:
  - ▶ *Recipes* describe how to fetch, configure, compile and package applications and images. They have a specific syntax.
  - ▶ *Layers* are sets of recipes, matching a common purpose. For Texas Instruments board support, the *meta-ti* layer is used.
  - ▶ Multiple layers are used within a same distribution, depending on the requirements.
  - ▶ It supports the ARM, MIPS (32 and 64 bits), PowerPC and x86 (32 and 64 bits) architectures.
  - ▶ It supports QEMU emulated machines for these architectures.



# The Yocto Project lexicon

- ▶ The Yocto Project is **not used as** a finite set of layers and tools.
- ▶ Instead, it provides a **common base** of tools and layers on top of which custom and specific layers are added, depending on your target.
- ▶ The main required element is **Poky**, the reference system which includes OpenEmbedded-Core. Other available tools are optional, but may be useful in some cases.



## Example of a Yocto Project based BSP

- ▶ To build images for a BeagleBone Black, we need:
  - ▶ The Poky reference system, containing all common recipes and tools.
  - ▶ The *meta-ti* layer, a set of Texas Instruments specific recipes.
- ▶ All modifications are made in the *meta-ti* layer. Editing Poky is a **no-go!**
- ▶ We will set up this environment in the lab.

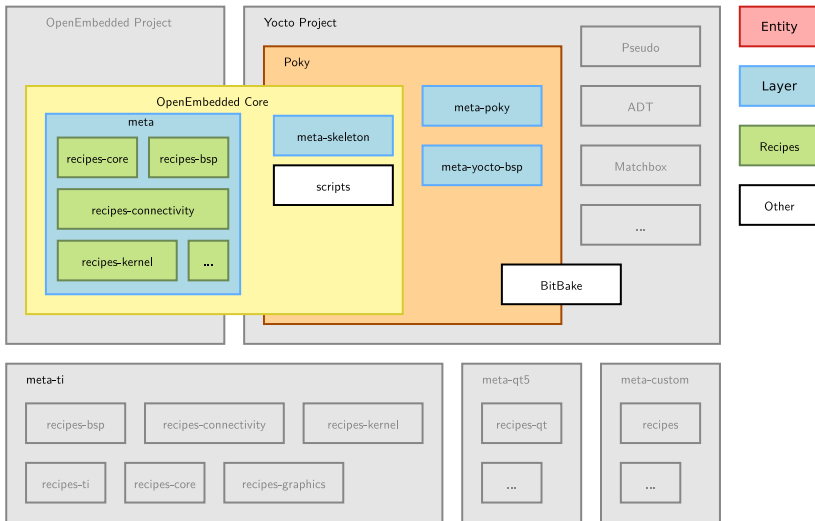


## The Poky reference system overview



# Download the Poky reference system

- ▶ All official projects part of the Yocto Project are available at <https://git.yoctoproject.org/cgit/>
- ▶ To download the Poky reference system:  
`git clone -b dunfell git://git.yoctoproject.org/poky.git`





[bitbake/](#) Holds all scripts used by the BitBake command. Usually matches the stable release of the BitBake project.

[documentation/](#) All documentation sources for the Yocto Project documentation. Can be used to generate nice PDFs.

[meta/](#) Contains the OpenEmbedded-Core metadata.

[meta-skeleton/](#) Contains template recipes for BSP and kernel development.





**meta-poky/** Holds the configuration for the Poky reference distribution.

**meta-yocto-bsp/** Configuration for the Yocto Project reference hardware board support package.

**LICENSE** The license under which Poky is distributed (a mix of GPLv2 and MIT).

**oe-init-build-env** Script to set up the OpenEmbedded build environment. It will create the build directory. It takes an optional parameter which is the build directory name. By default, this is `build`. This script has to be sourced because it changes environment variables.

**scripts** Contains scripts used to set up the environment, development tools, and tools to flash the generated images on the target.



- ▶ Documentation for the current sources, compiled as a "mega manual", is available at: <https://www.yoctoproject.org/docs/current/mega-manual/mega-manual.html>
- ▶ Variables in particular are described in the variable glossary: <https://www.yoctoproject.org/docs/current/ref-manual/ref-manual.html#ref-variables-glossary>

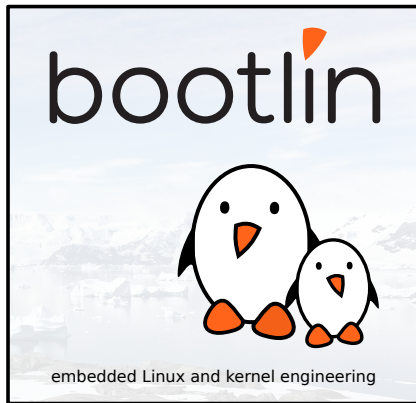


## Using Yocto Project - basics

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## Environment setup



# Environment setup

- ▶ All Poky files are left unchanged when building a custom image.
- ▶ Specific configuration files and build repositories are stored in a separate build directory.
- ▶ A script, `oe-init-build-env`, is provided to set up the build directory and the environment variables (needed to be able to use the `bitbake` command for example).



- ▶ Modifies the environment: has to be sourced!
- ▶ Adds environment variables, used by the build engine.
- ▶ Allows you to use commands provided in Poky.
- ▶ `source ./oe-init-build-env [builddir]`
- ▶ Sets up a basic build directory, named `builddir` if it is not found. If not provided, the default name is `build`.



## Common targets

- ▶ Common targets are listed when sourcing the script:
  - `core-image-minimal` A small image to boot a device and have access to core command line commands and services.
  - `core-image-sato` Image with Sato support. Sato is a GNOME mobile-based user interface.
  - `meta-toolchain` Generates the cross-toolchain in an installable format.
  - `meta-ide-support` Generates the cross-toolchain and additional tools (gdb, qemu, ...) for IDE integration.



## Exported environment variables

**BUILDDIR** Absolute path of the build directory.

**PATH** Contains the directories where executable programs are located.  
Absolute paths to `scripts/` and `bitbake/bin/` are prepended.





## Available commands

**bitbake** The main build engine command. Used to perform tasks on available recipes (download, configure, compile...).

**bitbake-\*** Various specific commands related to the BitBake build engine.



## The build/ directory 1/2

`conf/` Configuration files. Image specific and layer configuration.

`downloads/` Downloaded upstream tarballs of the recipes used in the builds.

`sstate-cache/` Shared state cache. Used by all builds.

`tmp/` Holds all the build system outputs.



## The `build/` directory 2/2

`tmp/buildstats/` Build statistics for all packages built (CPU usage, elapsed time, host, timestamps...).

`tmp/deploy/` Final output of the build.

`tmp/deploy/images/` Contains the complete images built by the OpenEmbedded build system. These images are used to flash the target.

`tmp/work/` Set of specific work directories, split by architecture. They are used to unpack, configure and build the packages. Contains the patched sources, generated objects and logs.

`tmp/sysroots/` Shared libraries and headers used to compile applications for the target but also for the host.



# Configuring the build system



## The `build/conf/` directory

- ▶ The `conf/` directory in the `build` one holds build specific configuration.
  - `bblayers.conf` Explicitly list the available layers.
  - `local.conf` Set up the configuration variables relative to the current user for the build. Configuration variables can be overridden there.



## Configuring the build

- ▶ The `conf/local.conf` configuration file holds local user configuration variables:
  - BB\_NUMBER\_THREADS** How many tasks BitBake should perform in parallel.  
Defaults to the number of CPUs on the system.
  - PARALLEL\_MAKE** How many processes should be used when compiling.  
Defaults to the number of CPUs on the system.
  - MACHINE** The machine the target is built for, e.g. `beaglebone`.



# Building an image



# Compilation

- ▶ The compilation is handled by the BitBake *build engine*.
- ▶ Usage: `bitbake [options] [recipeName/target ...]`
- ▶ To build a target: `bitbake [target]`
- ▶ Building a minimal image: `bitbake core-image-minimal`
  - ▶ This will run a full build for the selected target.





# Practical lab - First Yocto build



- ▶ Download the sources
- ▶ Set up the environment
- ▶ Configure the build
- ▶ Build an image

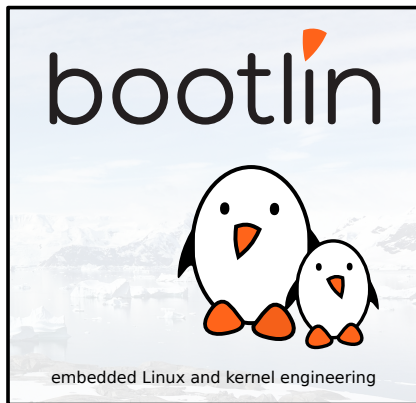


## Using Yocto Project - advanced usage

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# Advanced build usage and configuration

- ▶ Select package variants.
- ▶ Manually add packages to the generated image.
- ▶ Run specific tasks with BitBake.



## A little reminder

- ▶ *Recipes* describe how to fetch, configure, compile and install applications.
- ▶ These tasks can be run independently (if their dependencies are met).
- ▶ All available packages in Poky are not selected by default in the images.
- ▶ Some packages may provide the same functionality, e.g. OpenSSH and Dropbear.



# Advanced configuration



# Overview

- ▶ The OpenEmbedded build system uses configuration variables to hold information.
- ▶ Configuration settings are in upper-case by convention, e.g. `CONF_VERSION`
- ▶ To make configuration easier, it is possible to prepend, append or define these variables in a conditional way.
- ▶ All variables can be overridden or modified in `$BUILDDIR/conf/local.conf`



# Methods and conditions 1/4

- ▶ Append the keyword `_append` to a configuration variable to add values **after** the ones previously defined (without space).
  - ▶ `IMAGE_INSTALL_append = " dropbear"` adds `dropbear` to the packages installed on the image.
- ▶ Append the keyword `_prepend` to add values **before** the ones previously defined (without space).
  - ▶ `FILESEXTRAPATHS_prepend := "${THISDIR}/${PN}:"` adds the folder to the set of paths where files are located (in a recipe).



## Methods and conditions 2/4

- ▶ Append the keyword `_remove` to a configuration variable to remove all occurrences of a value within a configuration variable.
  - ▶ `IMAGE_INSTALL_remove = "i2c-tools"`
- ▶ Append the machine name to only define a configuration variable for a given machine. It tries to match with values from `MACHINEOVERRIDES` which include `MACHINE` and `SOC_FAMILY`.
  - ▶ `KERNEL_DEVICETREE_beaglebone = "am335x-bone.dtb"` tells to use the kernel device tree `am335x-bone.dtb` only when the machine is `beaglebone`.





## Methods and conditions 3/4

- ▶ The previous methods can be combined.
- ▶ If we define:
  - ▶ `IMAGE_INSTALL = "busybox mtd-utils"`
  - ▶ `IMAGE_INSTALL_append = " dropbear"`
  - ▶ `IMAGE_INSTALL_append_beaglebone = " i2c-tools"`
- ▶ The resulting configuration variable will be:
  - ▶ `IMAGE_INSTALL = "busybox mtd-utils dropbear i2c-tools"` if the machine being built is beaglebone.
  - ▶ `IMAGE_INSTALL = "busybox mtd-utils dropbear"` otherwise.



## Methods and conditions 4/4

- ▶ The most specific variable takes precedence.

- ▶ Example:

```
IMAGE_INSTALL_beaglebone = "busybox mtd-utils i2c-tools"  
IMAGE_INSTALL = "busybox mtd-utils"
```

- ▶ If the machine is beaglebone:

- ▶ `IMAGE_INSTALL = "busybox mtd-utils i2c-tools"`

- ▶ Otherwise:

- ▶ `IMAGE_INSTALL = "busybox mtd-utils"`



# Operators 1/2

- ▶ Various operators can be used to assign values to configuration variables:
  - = expand the value when using the variable
  - := immediately expand the value
  - += append (with space)
  - =+ prepend (with space)
  - .= append (without space)
  - =. prepend (without space)
  - ?= assign if no other value was previously assigned
  - ??= same as previous, with a lower precedence



## Operators 2/2

- ▶ Avoid using +=, =+, .= and =. in `$BUILDDIR/conf/local.conf` due to ordering issues.
  - ▶ If += is parsed before ?=, the latter will be discarded.
  - ▶ Using `_append` unconditionally appends the value.



# Packages variants



# Introduction to package variants

- ▶ Some packages have the same purpose, and only one can be used at a time.
- ▶ The build system uses **virtual packages** to reflect this. A virtual package describes functionalities and several packages may provide it.
- ▶ Only one of the packages that provide the functionality will be compiled and integrated into the resulting image.



## Variant examples

- ▶ The virtual packages are often in the form `virtual/<name>`
- ▶ Example of available virtual packages with some of their variants:
  - ▶ `virtual/bootloader`: `u-boot`, `u-boot-ti-staging...`
  - ▶ `virtual/kernel`: `linux-yocto`, `linux-yocto-tiny`, `linux-yocto-rt`, `linux-ti-staging...`
  - ▶ `virtual/libc`: `glibc`, `musl`, `newlib`
  - ▶ `virtual/xserver`: `xserver-xorg`



# Package selection

- ▶ Variants are selected thanks to the `PREFERRED_PROVIDER` configuration variable.
- ▶ The package names **have to** suffix this variable.
- ▶ Examples:
  - ▶ `PREFERRED_PROVIDER_virtual/kernel ?= "linux-ti-staging"`
  - ▶ `PREFERRED_PROVIDER_virtual/libgl = "mesa"`





## Version selection

- ▶ By default, Bitbake will try to build the provider with the highest version number, unless the recipe defines `DEFAULT_PREFERENCE = "-1"`
- ▶ When multiple package versions are available, it is also possible to explicitly pick a given version with `PREFERRED_VERSION`.
- ▶ The package names **have to** suffix this variable.
- ▶ `%` can be used as a wildcard.
- ▶ Example:
  - ▶ `PREFERRED_VERSION_linux-yocto = "3.10\%"`
  - ▶ `PREFERRED_VERSION_python = "2.7.3"`



## Packages



- ▶ The set of packages installed into the image is defined by the target you choose (e.g. `core-image-minimal`).
- ▶ It is possible to have a custom set by defining our own target, and we will see this later.
- ▶ When developing or debugging, adding packages can be useful, without modifying the recipes.
- ▶ Packages are controlled by the `IMAGE_INSTALL` configuration variable.



# Exclusion

- ▶ The list of packages to install is also filtered using the `PACKAGE_EXCLUDE` variable.
- ▶ However, if a package needs installing to satisfy a dependency, it will still be selected.



# The power of BitBake



# Common BitBake options

- ▶ BitBake can be used to run a full build for a given target with `bitbake [target]`.
- ▶ But it can be more precise, with optional options:
  - c <task> execute the given task
  - s list all locally available packages and their versions
  - f force the given task to be run by removing its stamp file
  - world keyword for all recipes
  - b <recipe> execute tasks from the given recipe (without resolving dependencies).



- ▶ `bitbake -c listtasks virtual/kernel`
  - ▶ Gives a list of the available tasks for the recipe providing the package `virtual/kernel`. Tasks are prefixed with `do_`.
- ▶ `bitbake -c menuconfig virtual/kernel`
  - ▶ Execute the task `menuconfig` on the recipe providing the `virtual/kernel` package.
- ▶ `bitbake -f dropbear`
  - ▶ Force the `dropbear` recipe to run all tasks.
- ▶ `bitbake world --runall=fetch`
  - ▶ Download all recipe sources and their dependencies.
- ▶ For a full description: `bitbake --help`



## shared state cache

- ▶ BitBake stores the output of each task in a directory, the shared state cache. Its location is controlled by the `SSTATE_DIR` variable.
- ▶ This cache is used to speed up compilation.
- ▶ Over time, as you compile more recipes, it can grow quite big. It is possible to clean old data with:

```
$ ./scripts/sstate-cache-management.sh --remove-duplicated -d \  
--cache-dir=<SSTATE_DIR>
```





# Practical lab - Advanced Yocto configuration



- ▶ Modify the build configuration
- ▶ Customize the package selection
- ▶ Experiment with BitBake
- ▶ Mount the root file system over NFS

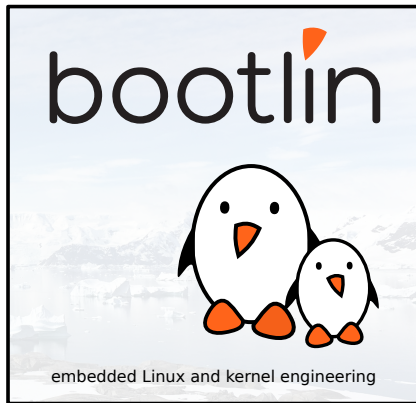


## Writing recipes - basics

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Corrections, suggestions, contributions and translations are welcome!

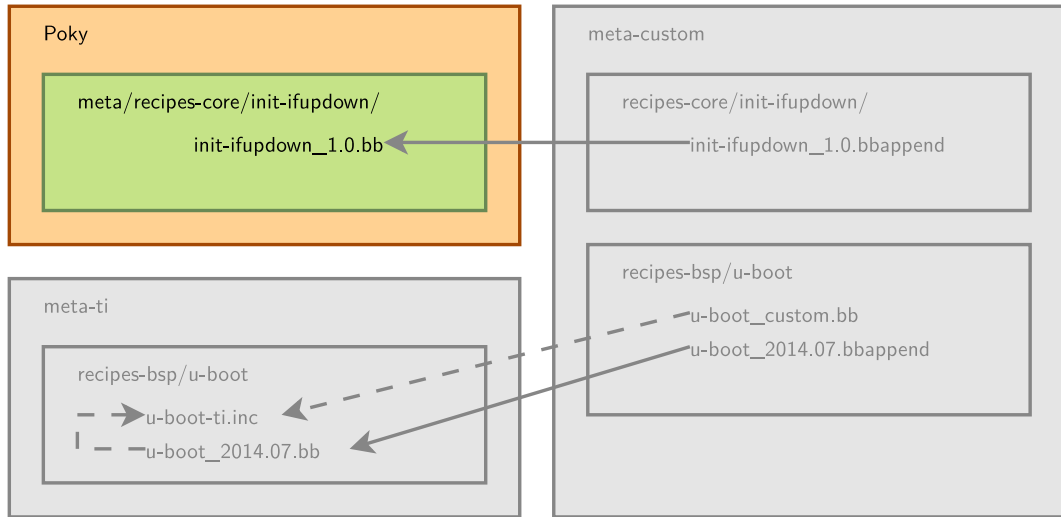




# Recipes: overview



# Recipes





- ▶ Recipes describe how to handle a given application.
- ▶ A recipe is a set of instructions to describe how to retrieve, patch, compile, install and generate binary packages for a given application.
- ▶ It also defines what build or runtime dependencies are required.
- ▶ The recipes are parsed by the BitBake build engine.
- ▶ The format of a recipe file name is `<application-name>_<version>.bb`



## Content of a recipe

- ▶ A recipe contains configuration variables: name, license, dependencies, path to retrieve the source code...
- ▶ It also contains functions that can be run (fetch, configure, compile...) which are called **tasks**.
- ▶ Tasks provide a set of actions to perform.
- ▶ Remember the `bitbake -c <task> <target>` command?



- ▶ To make it easier to write a recipe, some variables are automatically available:
  - PN** package name, as specified in the recipe file name
  - PV** package version, as specified in the recipe file name
  - PR** package revision, defaults to `r0`
- ▶ The recipe name and version usually match the upstream ones.
- ▶ When using the recipe `bash_4.2.bb`:
  - ▶ `${PN}` = "bash"
  - ▶ `${PV}` = "4.2"

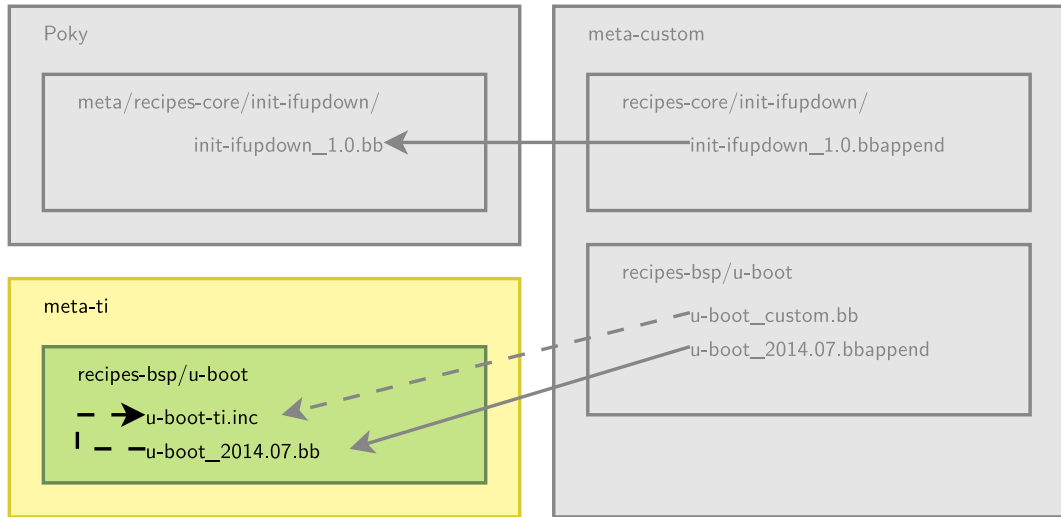


# Organization of a recipe





# Organization of a recipe





# Organization of a recipe

- ▶ Many applications have more than one recipe, to support different versions. In that case the common metadata is included in each version specific recipe and is in a `.inc` file:
  - ▶ `<application>.inc`: version agnostic metadata.
  - ▶ `<application>_<version>.bb`: require `<application>.inc` and version specific metadata.
- ▶ We can divide a recipe into three main parts:
  - ▶ The header: what/who
  - ▶ The sources: where
  - ▶ The tasks: how



# The header

- Configuration variables to describe the application:
  - DESCRIPTION** describes what the software is about
  - HOMEPAGE** URL to the project's homepage
  - PRIORITY** defaults to `optional`
  - SECTION** package category (e.g. `console/utils`)
  - LICENSE** the application's license



# The source locations: overview

- ▶ We need to retrieve both the raw sources from an official location and the resources needed to configure, patch or install the application.
- ▶ `SRC_URI` defines where and how to retrieve the needed elements. It is a set of URI schemes pointing to the resource locations (local or remote).
- ▶ URI scheme syntax: `scheme://url;param1;param2`
- ▶ `scheme` can describe a local file using `file://` or remote locations with `https://`, `git://`, `svn://`, `hg://`, `ftp://`...
- ▶ By default, sources are fetched in `$BUILDDIR/downloads`. Change it with the `DL_DIR` variable in `conf/local.conf`



# The source locations: remote files 1/2

- ▶ The `git` scheme:
  - ▶ `git://<url>;protocol=<protocol>;branch=<branch>`
  - ▶ When using `git`, it is necessary to also define `SRCREV`. If `SRCREV` is a hash or a tag not present in master, the branch parameter is mandatory. When the tag is not in any branch, it is possible to use `nobranch=1`
- ▶ The `http`, `https` and `ftp` schemes:
  - ▶ `https://example.com/application-1.0.tar.bz2`
  - ▶ A few variables are available to help pointing to remote locations:  
`${SOURCEFORGE_MIRROR}`, `${GNU_MIRROR}`, `${KERNELORG_MIRROR}`...
  - ▶ Example: `${SOURCEFORGE_MIRROR}/<project-name>/${PN}-${PV}.tar.gz`
  - ▶ See `meta/conf/bitbake.conf`



## The source locations: remote files 2/2

- ▶ An md5 or an sha256 sum must be provided when the protocol used to retrieve the file(s) does not guarantee their integrity. This is the case for `https`, `http` or `ftp`.

```
SRC_URI[md5sum] = "97b2c3fb082241ab5c56ab728522622b"  
SRC_URI[sha256sum] = "..."
```

- ▶ It's possible to use checksums for more than one file, using the `name` parameter:

```
SRC_URI = "http://example.com/src.tar.bz2;name=tarball \  
          http://example.com/fixes.patch;name=patch"
```

```
SRC_URI[tarball.md5sum] = "97b2c3fb082241ab5c56..."  
SRC_URI[patch.md5sum]   = "b184acf9eb39df794ffd..."
```



## The source locations: local files

- ▶ All local files found in `SRC_URI` are copied into the recipe's working directory, in `$BUILDDIR/tmp/work/`.
- ▶ The searched paths are defined in the `FILESPATH` variable.

```
FILESPATH = "${@base_set_filespath([  
    "${FILE_DIRNAME}/${PN}",  
    "${FILE_DIRNAME}/${PN}-${PV}",  
    "${FILE_DIRNAME}/files"], d)}
```

```
FILESOVERRIDES = "${MACHINEOVERRIDES}:${DISTROOVERRIDES}"
```

- ▶ The `base_set_filespath(path)` function uses its `path` parameter, `FILESETRAPATHS` and `FILESOVERRIDES` to fill the `FILESPATH` variable.
- ▶ Custom paths and files can be added using `FILESETRAPATHS` and `FILESOVERRIDES`.
- ▶ Prepend the paths, as the order matters.



## The source locations: tarballs

- ▶ When extracting a tarball, BitBake expects to find the extracted files in a directory named `<application>-<version>`. This is controlled by the `S` variable. If the directory has another name, you must explicitly define `S`.
- ▶ If the scheme is `git`, `S` must be set to `${WORKDIR}/git`





## The source locations: license files

- ▶ License files must have their own checksum.
- ▶ `LIC_FILES_CHKSUM` defines the URI pointing to the license file in the source code as well as its checksum.

```
LIC_FILES_CHKSUM = "file://gpl.txt;md5=393a5ca..."  
LIC_FILES_CHKSUM = \  
    "file://main.c;beginline=3;endline=21;md5=58e..."  
LIC_FILES_CHKSUM = \  
    "file://${COMMON_LICENSE_DIR}/MIT;md5=083..."
```

- ▶ This allows to track any license update: if the license changes, the build will trigger a failure as the checksum won't be valid anymore.



## Dependencies 1/2

- ▶ A recipe can have dependencies during the build or at runtime. To reflect these requirements in the recipe, two variables are used:
  - DEPENDS** List of the recipe build-time dependencies.
  - RDEPENDS** List of the package runtime dependencies. Must be package specific (e.g. with `_${PN}`).
- ▶ `DEPENDS = "recipe-b"`: the local `do_configure` task depends on the `do_populate_sysroot` task of recipe-b.
- ▶ `RDEPENDS_${PN} = "recipe-b"`: the local `do_build` task depends on the `do_package_write_<archive-format>` task of recipe b.



## Dependencies 2/2

- ▶ Sometimes a recipe have dependencies on specific versions of another recipe.
- ▶ BitBake allows to reflect this by using:
  - ▶ `DEPENDS = "recipe-b (>= 1.2)"`
  - ▶ `RDEPENDS_${PN} = "recipe-b (>= 1.2)"`
- ▶ The following operators are supported: `=`, `>`, `<`, `>=` and `<=`.
- ▶ A graphical tool can be used to explore dependencies or reverse dependencies:
  - ▶ `bitbake -g -u taskexp core-image-minimal`



# Tasks

Default tasks already exists, they are defined in classes:

- ▶ do\_fetch
- ▶ do\_unpack
- ▶ do\_patch
- ▶ do\_configure
- ▶ do\_compile
- ▶ do\_install
- ▶ do\_package
- ▶ do\_rootfs

You can get a list of existing tasks for a recipe with:

```
bitbake <recipe> -c listtasks
```



## Writing tasks 1/2

- ▶ Functions use the sh shell syntax, with available OpenEmbedded variables and internal functions available.
  - D The destination directory (root directory of where the files are installed, before creating the image).
  - WORKDIR** the recipe's working directory
- ▶ Syntax of a task:

```
do_task() {  
    action0  
    action1  
    ...  
}
```



► Example:

```
do_compile() {  
    oe_runmake  
}  
  
do_install() {  
    install -d ${D}${bindir}  
    install -m 0755 hello ${D}${bindir}  
}
```



## Modifying existing tasks

Tasks can be extended with `_prepend` or `_append`

```
do_install_append() {  
    install -d ${D}${sysconfdir}  
    install -m 0644 hello.conf ${D}${sysconfdir}  
}
```



## Adding new tasks

Tasks can be added with `addtask`

```
do_mkimage () {  
    uboot-mkimage ...  
}
```

```
addtask do_mkimage after do_compile before do_install
```





# Applying patches



## Patches use cases

Patches can be applied to resolve build-system problematics:

- ▶ To support old versions of a software: bug and security fixes.
- ▶ To fix cross-compilation issues.
  - ▶ In certain simple cases the `-e` option of `make` can be used.
  - ▶ The `-e` option gives variables taken from the environment precedence over variables from `Makefiles`.
  - ▶ Helps when an upstream `Makefile` uses hardcoded `CC` and/or `CFLAGS`.
- ▶ To apply patches before they get their way into the upstream version.



## The source locations: patches

- ▶ Files ending in `.patch`, `.diff` or having the `apply=yes` parameter will be applied after the sources are retrieved and extracted, during the `do_patch` task.

```
SRC_URI += "file://joystick-support.patch \  
           file://smp-fixes.diff \  
           "
```

- ▶ Patches are applied in the order they are listed in `SRC_URI`.
- ▶ It is possible to select which tool will be used to apply the patches listed in `SRC_URI` variable with `PATCHTOOL`.
- ▶ By default, `PATCHTOOL` = 'quilt' in Poky.
- ▶ Possible values: `git`, `patch` and `quilt`.



# Resolving conflicts

- ▶ The `PATCHRESOLVE` variable defines how to handle conflicts when applying patches.
- ▶ It has two valid values:
  - ▶ `noop`: the build fails if a patch cannot be successfully applied.
  - ▶ `user`: a shell is launched to resolve manually the conflicts.
- ▶ By default, `PATCHRESOLVE = "noop"` in `meta-poky`.



# Example of a recipe



# Hello world recipe

```
DESCRIPTION = "Hello world program"
HOMEPAGE = "http://example.net/hello/"
PRIORITY = "optional"
SECTION = "examples"
LICENSE = "GPLv2"

SRC_URI = "git://git.example.com/hello;protocol=https"
SRCREV = "2d47b4eb66e705458a17622c2e09367300a7b118"
S = "${WORKDIR}/git"
LIC_FILES_CHKSUM = \
    "file://hello.c;beginline=3;endline=21;md5=58e..."
```

```
do_compile() {
    oe_runmake
}
do_install() {
    install -d ${D}${bindir}
    install -m 0755 hello ${D}${bindir}
}
```



Example of a recipe with a version agnostic part



```
SUMMARY = "GNU file archiving program"
HOMEPAGE = "https://www.gnu.org/software/tar/"
SECTION = "base"

SRC_URI = "${GNU_MIRROR}/tar/tar-${PV}.tar.bz2"

do_configure() { ... }

do_compile() { ... }

do_install() { ... }
```





```
require tar.inc
```

```
LICENSE = "GPLv2"
```

```
LIC_FILES_CHKSUM = \  
    "file://COPYING;md5=59530bdf33659b29e73d4adb9f9f6552"
```

```
SRC_URI += "file://avoid_heap_overflow.patch"
```

```
SRC_URI[md5sum] = "c6c4f1c075dbf0f75c29737faa58f290"
```



```
require tar.inc
```

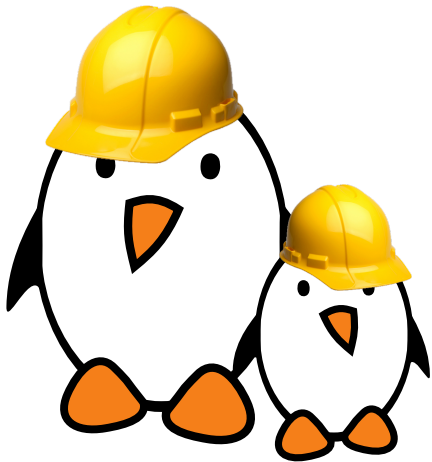
```
LICENSE = "GPLv3"
```

```
LIC_FILES_CHKSUM = \  
    "file://COPYING;md5=d32239bcb673463ab874e80d47fae504"
```

```
SRC_URI[md5sum] = "2cee42a2ff4f1cd4f9298eeeb2264519"
```



## Practical lab - Add a custom application



- ▶ Write a recipe for a custom application
- ▶ Integrate it in the image

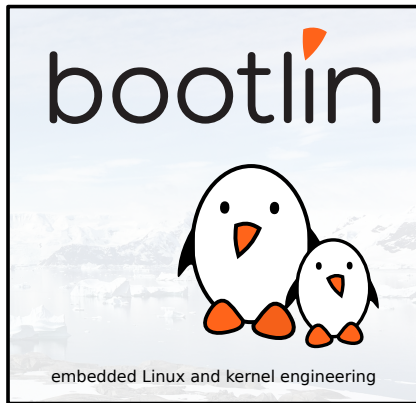


## Writing recipes - advanced

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# Extending a recipe



# Introduction to recipe extensions

- ▶ It is a good practice **not** to modify recipes available in Poky.
- ▶ But it is sometimes useful to modify an existing recipe, to apply a custom patch for example.
- ▶ The BitBake *build engine* allows to modify a recipe by extending it.
- ▶ Multiple extensions can be applied to a recipe.

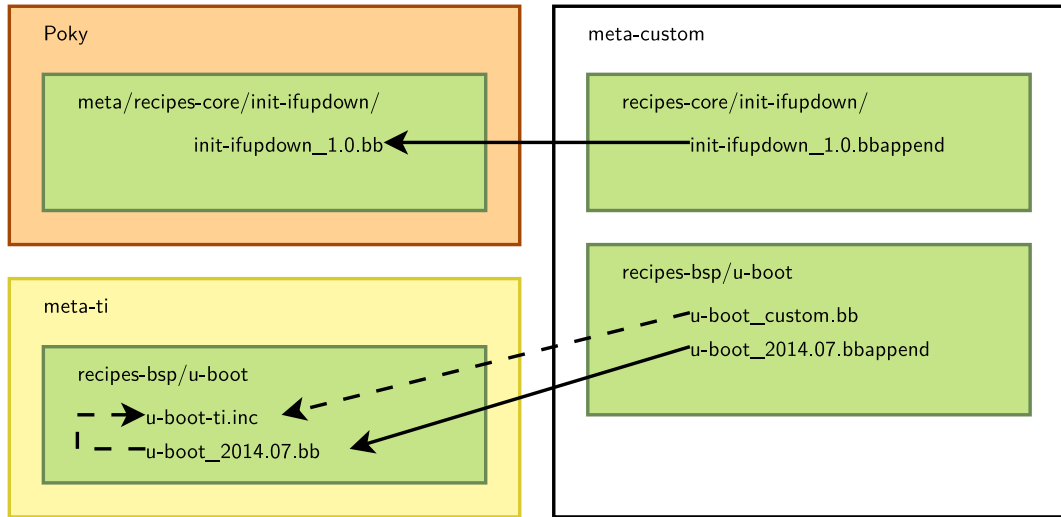


# Introduction to recipe extensions

- ▶ Metadata can be changed, added or appended.
- ▶ Tasks can be added or appended.
- ▶ Operators are used extensively, to add, append, prepend or assign values.



# Extend a recipe







## Extend a recipe

- ▶ The recipe extensions end in `.bbappend`
- ▶ Append files must have the same root name as the recipe they extend.
  - ▶ `example_0.1.bbappend` applies to `example_0.1.bb`
- ▶ Append files are **version specific**. If the recipe is updated to a newer version, the append files must also be updated.
- ▶ If adding new files, the path to their directory must be prepended to the `FILESEXTRAPATHS` variable.
  - ▶ Files are looked up in paths referenced in `FILESEXTRAPATHS`, from left to right.
  - ▶ Prepending a path makes sure it has priority over the recipe's one. This allows to override recipes' files.



# Append file example



# Hello world append file

```
FILESEXTRAPATHS_prepend := "${THISDIR}/files:"
```

```
SRC_URI += "file://custom-modification-0.patch \  
            file://custom-modification-1.patch \  
            "
```



# Advanced recipe configuration



## Advanced configuration

- ▶ In the real world, more complex configurations are often needed because recipes may:
  - ▶ Provide virtual packages
  - ▶ Inherit generic functions from classes



# Providing virtual packages

- ▶ BitBake allows to use virtual names instead of the actual package name. We saw a use case with *package variants*.
- ▶ The virtual name is specified through the `PROVIDES` variable.
- ▶ Several recipes can provide the same virtual name. Only one will be built and installed into the generated image.
- ▶ `PROVIDES = "virtual/kernel"`



# Classes



# Introduction to classes

- ▶ Classes provide an abstraction to common code, which can be re-used in multiple recipes.
- ▶ Common tasks do not have to be re-developed!
- ▶ Any metadata and task which can be put in a recipe can be used in a class.
- ▶ Classes extension is `.bbclass`
- ▶ Classes are located in the `classes` folder of a layer.
- ▶ Recipes can use this common code by inheriting a class:
  - ▶ `inherit <class>`





# Common classes

- ▶ Common classes can be found in `meta/classes/`
  - ▶ `base.bbclass`
  - ▶ `kernel.bbclass`
  - ▶ `autotools.bbclass`
  - ▶ `autotools-brokensep.bbclass`
  - ▶ `cmake.bbclass`
  - ▶ `native.bbclass`
  - ▶ `systemd.bbclass`
  - ▶ `update-rc.d.bbclass`
  - ▶ `useradd.bbclass`
  - ▶ ...



# The base class

- ▶ Every recipe inherits the base class automatically.
- ▶ Contains a set of basic common tasks to fetch, unpack or compile applications.
- ▶ Inherits other common classes, providing:
  - ▶ Mirrors definitions: `DEBIAN_MIRROR`, `GNU_MIRROR`, `KERNELORG_MIRROR`...
  - ▶ The ability to filter patches by `SRC_URI`
  - ▶ Some tasks: `clean`, `listtasks` or `fetch`.
- ▶ Defines `oe_runmake`, using `EXTRA_OEMAKE` to use custom arguments.



# The kernel class

- ▶ Used to build Linux kernels.
- ▶ Defines tasks to configure, compile and install a kernel and its modules.
- ▶ The kernel is divided into several packages: `kernel`, `kernel-base`, `kernel-dev`, `kernel-modules`...
- ▶ Automatically provides the virtual package `virtual/kernel`.
- ▶ Configuration variables are available:
  - ▶ `KERNEL_IMAGETYPE`, defaults to `zImage`
  - ▶ `KERNEL_EXTRA_ARGS`
  - ▶ `INITRAMFS_IMAGE`



# The autotools class

- ▶ Defines tasks and metadata to handle applications using the autotools build system (autoconf, automake and libtool):
  - ▶ `do_configure`: generates the configure script using `autoreconf` and loads it with standard arguments or cross-compilation.
  - ▶ `do_compile`: runs `make`
  - ▶ `do_install`: runs `make install`
- ▶ Extra configuration parameters can be passed with `EXTRA_OECONF`.
- ▶ Compilation flags can be added thanks to the `EXTRA_OEMAKE` variable.



## Example: use the autotools class

```
DESCRIPTION = "Print a friendly, customizable greeting"
HOMEPAGE = "https://www.gnu.org/software/hello/"
PRIORITY = "optional"
SECTION = "examples"
LICENSE = "GPLv3"

SRC_URI = "${GNU_MIRROR}/hello/hello-${PV}.tar.gz"
SRC_URI[md5sum] = "67607d2616a0faaf5bc94c59dca7c3cb"
SRC_URI[sha256sum] = "ecbb7a2214196c57ff9340aa71458e1559abd38f6d8d169666846935df191ea7"
LIC_FILES_CHKSUM = "file://COPYING;md5=d32239bcb673463ab874e80d47fae504"

inherit autotools
```



# The useradd class

- ▶ This class helps to add users to the resulting image.
- ▶ Adding custom users is required by many services to avoid running them as root.
- ▶ `USERADD_PACKAGES` must be defined when the `useradd` class is inherited. Defines the list of packages which needs the user.
- ▶ Users and groups will be created before the packages using it perform their `do_install`.
- ▶ At least one of the two following variables must be set:
  - ▶ `USERADD_PARAM`: parameters to pass to `useradd`.
  - ▶ `GROUPADD_PARAM`: parameters to pass to `groupadd`.



## Example: use the useradd class

```
DESCRIPTION = "useradd class usage example"
PRIORITY = "optional"
SECTION = "examples"
LICENSE = "MIT"

SRC_URI = "file://file0"
LIC_FILES_CHKSUM = "file://${COREBASE}/meta/files/common-licenses/MIT;md5=0835ade698e0bc..."

inherit useradd

USERADD_PACKAGES = "${PN}"
USERADD_PARAM = "-u 1000 -d /home/user0 -s /bin/bash user0"

do_install() {
    install -m 644 file0 ${D}/home/user0/
    chown user0:user0 ${D}/home/user0/file0
}
```



# Binary packages





## Specifics for binary packages

- ▶ It is possible to install binaries into the generated root filesystem.
- ▶ Set the `LICENSE` to `CLOSED`.
- ▶ Use the `do_install` task to copy the binaries into the root file system.



# BitBake file inclusions



# Locate files in the build system

- ▶ Metadata can be shared using included files.
- ▶ `BitBake` uses the `BBPATH` to find the files to be included. It also looks into the current directory.
- ▶ Three keywords can be used to include files from recipes, classes or other configuration files:
  - ▶ `inherit`
  - ▶ `include`
  - ▶ `require`



# The `inherit` keyword

- ▶ `inherit` can be used in recipes or classes, to inherit the functionalities of a class.
- ▶ To inherit the functionalities of the `kernel` class, use: `inherit kernel`
- ▶ `inherit` looks for files ending in `.bbclass`, in `classes` directories found in `BBPATH`.
- ▶ It is possible to include a class conditionally using a variable: `inherit ${FOO}`



# The `include` and `require` keywords

- ▶ `include` and `require` can be used in all files, to insert the content of another file at that location.
- ▶ If the path specified on the `include` (or `require`) path is relative, BitBake will insert the first file found in `BBPATH`.
- ▶ `include` does not produce an error when a file cannot be found, whereas `require` raises a parsing error.
- ▶ To include a local file: `include ninvaders.inc`
- ▶ To include a file from another location (which could be in another layer):  
`include path/to/file.inc`



# Debugging recipes



# Debugging recipes

- ▶ For each task, logs are available in the `temp` directory in the work folder of a recipe.
- ▶ A development shell, exporting the full environment can be used to debug build failures:

```
$ bitbake -c devshell <recipe>
```

- ▶ To understand what a change in a recipe implies, you can activate build history in `local.conf`:

```
INHERIT += "buildhistory"  
BUILDHISTORY_COMMIT = "1"
```

Then use the `buildhistory-diff` tool to examine differences between two builds.

- ▶ `./scripts/buildhistory-diff`



# Network usage





# Source fetching

- ▶ BitBake will look for files to retrieve at the following locations, in order:
  1. `DL_DIR` (the local download directory).
  2. The `PREMIRRORS` locations.
  3. The upstream source, as defined in `SRC_URI`.
  4. The `MIRRORS` locations.
- ▶ If all the mirrors fail, the build will fail.



# Mirror configuration in Poky

```
PREMIRRORS ??= "\
```

```
bzr://.*/.* http://downloads.yoctoproject.org/mirror/sources/ \n \  
cvs://.*/.* http://downloads.yoctoproject.org/mirror/sources/ \n \  
git://.*/.* http://downloads.yoctoproject.org/mirror/sources/ \n \  
hg://.*/.* http://downloads.yoctoproject.org/mirror/sources/ \n \  
osc://.*/.* http://downloads.yoctoproject.org/mirror/sources/ \n \  
p4://.*/.* http://downloads.yoctoproject.org/mirror/sources/ \n \  
svk://.*/.* http://downloads.yoctoproject.org/mirror/sources/ \n \  
svn://.*/.* http://downloads.yoctoproject.org/mirror/sources/ \n"
```

```
MIRRORS =+ "\
```

```
ftp://.*/.* http://downloads.yoctoproject.org/mirror/sources/ \n \  
http://.*/.* http://downloads.yoctoproject.org/mirror/sources/ \n \  
https://.*/.* http://downloads.yoctoproject.org/mirror/sources/ \n"
```



# Configuring the mirrors

- ▶ It's possible to prepend custom mirrors, using the PREMIRRORS variable:

```
PREMIRRORS_prepend = "\n\ngit://.*/. * http://www.yoctoproject.org/sources/ \n \n\nftp://.*/. * http://www.yoctoproject.org/sources/ \n \n\nhttp://.*/. * http://www.yoctoproject.org/sources/ \n \n\nhttps://.*/. * http://www.yoctoproject.org/sources/ \n"
```

- ▶ Another solution is to use the own-mirrors class:

```
INHERIT += "own-mirrors"\nSOURCE_MIRROR_URL = "http://example.com/my-source-mirror"
```



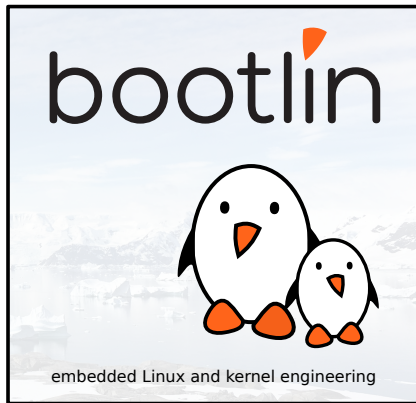
## Forbidding network access

- ▶ You can use `BB_GENERATE_MIRROR_TARBALLS = "1"` to generate tarballs of the git repositories in `DL_DIR`
- ▶ You can also completely disable network access using `BB_NO_NETWORK = "1"`
- ▶ Or restrict BitBake to only download files from the `PREMIRRORS`, using `BB_FETCH_PREMIRRORONLY = "1"`



## Layers

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## Introduction to layers

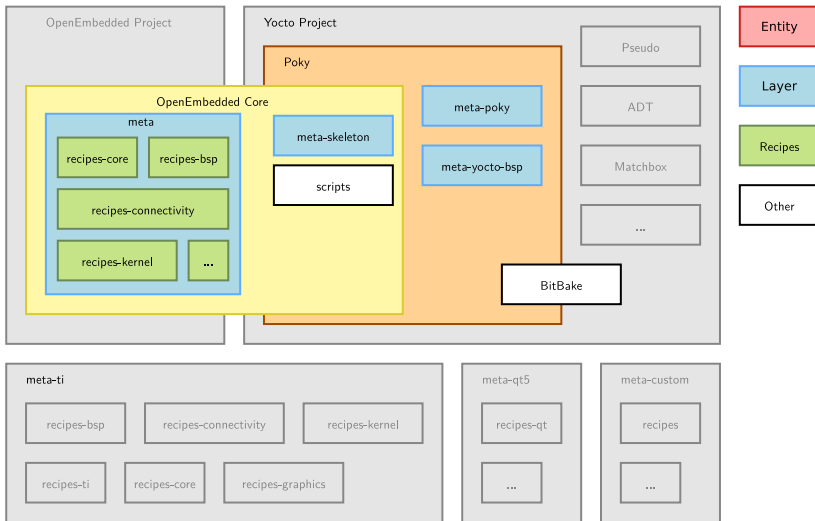


# Layers' principles

- ▶ The OpenEmbedded *build system* manipulates *metadata*.
- ▶ Layers allow to isolate and organize the metadata.
  - ▶ A layer is a collection of recipes.
- ▶ It is a good practice to begin a layer name with the prefix `meta-`.



# Layers in Poky





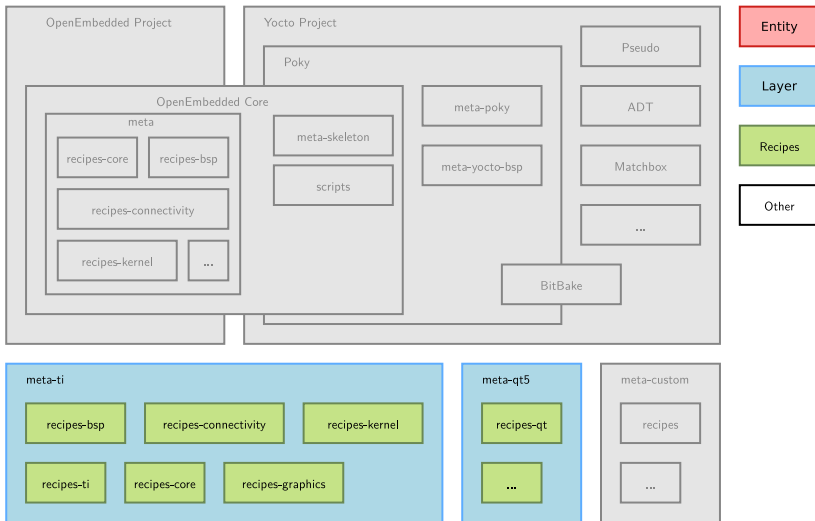


# Layers in Poky

- ▶ The Poky *reference system* is a set of basic common layers:
  - ▶ meta
  - ▶ meta-skeleton
  - ▶ meta-poky
  - ▶ meta-yocto-bsp
- ▶ Poky is not a final set of layers. It is the common base.
- ▶ Layers are added when needed.
- ▶ When making modifications to the existing recipes or when adding new ones, it is a good practice not to modify Poky. Instead you can create your own layers!



# Third party layers





# Integrate and use a layer 1/3

- ▶ A list of existing and maintained layers can be found at <https://layers.openembedded.org/layerindex/branch/master/layers/>
- ▶ Instead of redeveloping layers, always check the work hasn't been done by others.
- ▶ It takes less time to download a layer providing a package you need and to add an append file if some modifications are needed than to do it from scratch.



## Integrate and use a layer 2/3

- ▶ The location where a layer is saved on the disk doesn't matter.
  - ▶ But a good practice is to save it where all others layers are stored.
- ▶ The only requirement is to let BitBake know about the new layer:
  - ▶ The list of layers BitBake uses is defined in `$BUILDDIR/conf/bblayers.conf`
  - ▶ To include a new layer, add its absolute path to the `BBLAYERS` variable.
  - ▶ BitBake parses each layer specified in `BBLAYERS` and adds the recipes, configurations files and classes it contains.



## Integrate and use a layer 3/3

- ▶ The `bitbake-layers` tool is provided alongside `bitbake`.
- ▶ It can be used to inspect the layers and to manage `$BUILDDIR/conf/bblayers.conf`:
  - ▶ `bitbake-layers show-layers`
  - ▶ `bitbake-layers add-layer meta-custom`
  - ▶ `bitbake-layers remove-layer meta-qt5`



## Some useful layers

- ▶ Many SoC specific layers are available, providing support for the boards using these SoCs. Some examples: `meta-ti`, `meta-freescale` and `meta-raspberrypi`.
- ▶ Other layers offer to support applications not available in the Poky reference system:
  - ▶ `meta-browser`: web browsers (Chromium, Firefox).
  - ▶ `meta-filesystems`: support for additional filesystems.
  - ▶ `meta-gstreamer10`: support for GStreamer 1.0.
  - ▶ `meta-java` and `meta-oracle-java`: Java support.
  - ▶ `meta-linaro-toolchain`: Linaro toolchain recipes.
  - ▶ `meta-qt5`: QT5 modules.
  - ▶ `meta-realtime`: real time tools and test programs.
  - ▶ `meta-telephony` and many more...

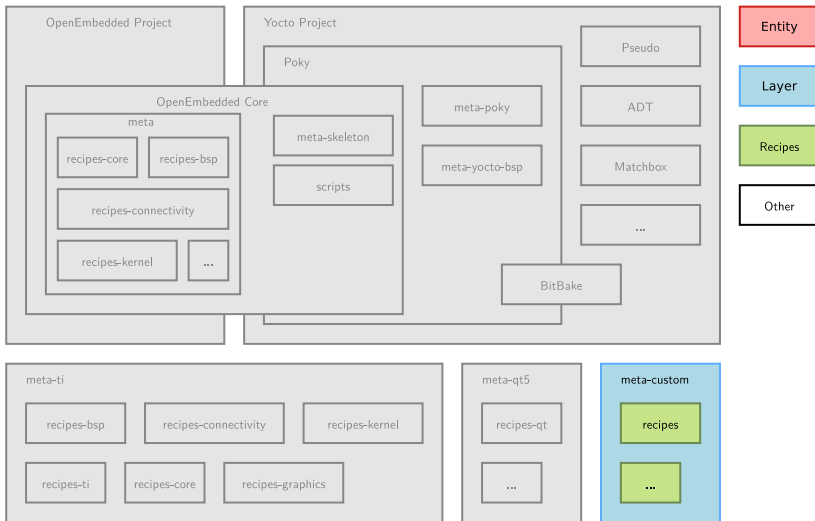
Notice that some of these layers do not come with all the Yocto branches. The `meta-browser` did not have a krogoth branch, for example.



## Creating a layer



# Custom layer







## Create a custom layer 1/2

- ▶ A layer is a set of files and directories and can be created by hand.
- ▶ However, the `bitbake-layers create-layer` command helps us create new layers and ensures this is done right.
- ▶ `bitbake-layers create-layer -p <PRIORITY> <layer>`



## Create a custom layer 2/2

- ▶ The layer created will be pre-filled with the following files:
  - `conf/layer.conf` The layer's configuration. Holds its priority and generic information. No need to modify it in many cases.
  - `COPYING.MIT` The license under which a layer is released. By default MIT.
  - `README` A basic description of the layer. Contains a contact e-mail to update.
- ▶ By default, all metadata matching `./recipes-*/*/*.bb` will be parsed by the BitBake *build engine*.



## Use a layer: best practices

- ▶ Do not copy and modify existing recipes from other layers. Instead use append files.
- ▶ Avoid duplicating files. Use append files or explicitly use a path relative to other layers.
- ▶ Save the layer alongside other layers, in `OEROOT`.
- ▶ Use `LAYERDEPENDS` to explicitly define layer dependencies.
- ▶ Use `LAYERSERIES_COMPAT` to define the Yocto version(s) with which the layer is compatible.



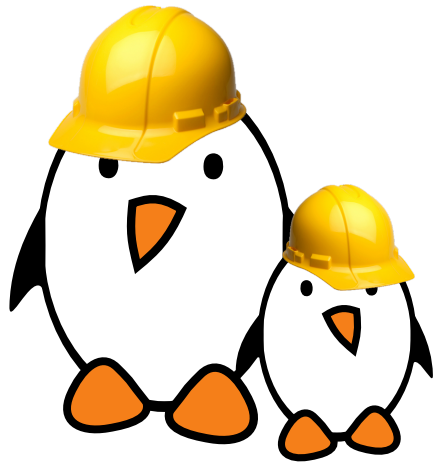
## Practical lab - Create a custom layer



- ▶ Create a layer from scratch
- ▶ Add recipes to the new layer
- ▶ Integrate it to the build



## Practical lab - Extend a recipe



- ▶ Apply patches to an existing recipe
- ▶ Use a custom configuration file for an existing recipe
- ▶ Extend a recipe to fit your needs

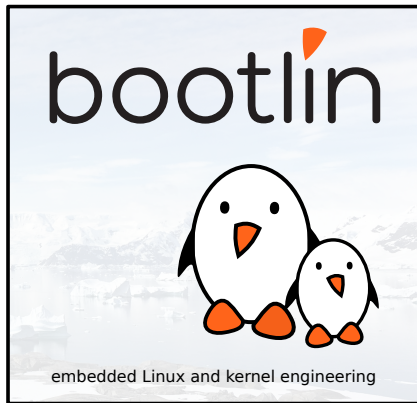


## BSP Layers

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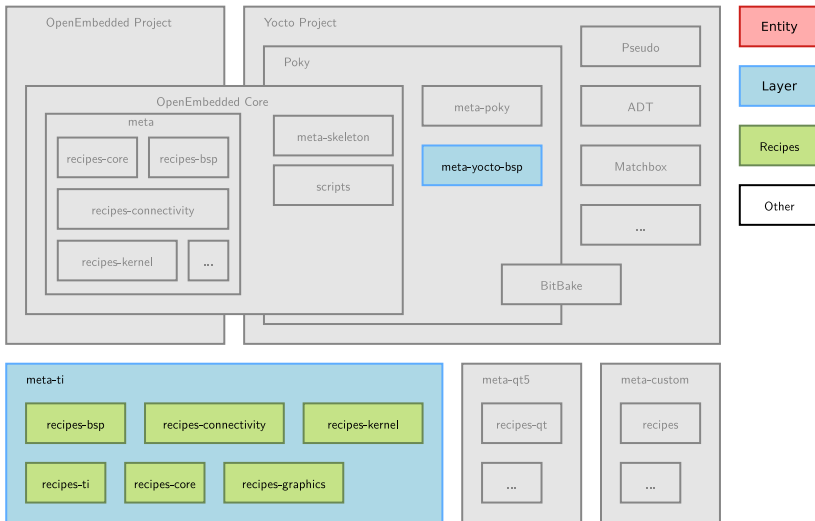




# Introduction to BSP layers in the Yocto Project



# BSP layers







# Overview

- ▶ BSP layers are device specific layers. They hold metadata with the purpose of supporting specific hardware devices.
- ▶ BSP layers describe the hardware features and often provide a custom kernel and bootloader with the required modules and drivers.
- ▶ BSP layers can also provide additional software, designed to take advantage of the hardware features.
- ▶ As a layer, it is integrated into the build system as we previously saw.
- ▶ A good practice is to name it `meta-<bsp_name>`.



## BSP layers Specifics

- ▶ BSP layers are a subset of the layers.
- ▶ In addition to package recipes and build tasks, they often provide:
  - ▶ Hardware configuration files (`machines`).
  - ▶ Bootloader, kernel and display support and configuration.
  - ▶ Pre-built user binaries.



## Hardware configuration files



## Overview 1/2

- ▶ A layer provides one machine file (hardware configuration file) per machine it supports.
- ▶ These configuration files are stored under `meta-<bsp_name>/conf/machine/*.conf`
- ▶ The file names correspond to the values set in the `MACHINE` configuration variable.
  - ▶ `meta-ti/conf/machine/beaglebone.conf`
  - ▶ `MACHINE = "beaglebone"`
- ▶ Each machine should be described in the `README` file of the BSP.



## Overview 2/2

- ▶ The hardware configuration file contains configuration variables related to the architecture and to the machine features.
- ▶ Some other variables help customize the kernel image or the filesystems used.



# Machine configuration

**TARGET\_ARCH** The architecture of the device being built.

**PREFERRED\_PROVIDER\_virtual/kernel** The default kernel.

**MACHINE\_FEATURES** List of hardware features provided by the machine, e.g.  
`usb gadget usbhost screen wifi`

**SERIAL\_CONSOLES** Speed and device for the serial console to attach. Passed to the kernel as the `console` parameter, e.g. `115200;ttyS0`

**KERNEL\_IMAGETYPE** The type of kernel image to build, e.g. `zImage`



- ▶ Lists the hardware features provided by the machine.
- ▶ These features are used by package recipes to enable or disable functionalities.
- ▶ Some packages are automatically added to the resulting root filesystem depending on the feature list.
- ▶ The feature `bluetooth`:
  - ▶ Asks the `bluez` daemon to be built and added to the image.
  - ▶ Enables bluetooth support in `ConnMan`.



```
# Common definitions for cfa-10036 boards
include conf/machine/include/imx-base.inc
include conf/machine/include/tune-arm926ejs.inc

SOC_FAMILY = "mxs:mx28:cfa10036"

PREFERRED_PROVIDER_virtual/kernel ?= "linux-cfa"
PREFERRED_PROVIDER_virtual/bootloader ?= "barebox"
IMAGE_BOOTLOADER = "barebox"
BAREBOX_BINARY = "barebox"
IMAGE_FSTYPES_mxs = "tar.bz2 barebox.mxsboot-sdcard sdcard.gz"
IMXBOOTLETS_MACHINE = "cfa10036"

KERNEL_IMAGETYPE = "zImage"
KERNEL_DEVICETREE = "imx28-cfa10036.dtb"
# we need the kernel to be installed in the final image
IMAGE_INSTALL_append = " kernel-image kernel-devicetree"
SDCARD_ROOTFS ?= "${DEPLOY_DIR_IMAGE}/${IMAGE_NAME}.rootfs.ext3"
SERIAL_CONSOLE = "115200 ttyAMA0"
MACHINE_FEATURES = "usb gadget usbhost vfat"
```





```
#@TYPE: Machine
#@NAME: Crystalfontz CFA-10057
#@SOC: i.MX28
#@DESCRIPTION: Machine configuration for CFA-10057, also called CFA-920
#@MAINTAINER: Alexandre Belloni <alexandre.belloni@bootlin.com>

include conf/machine/include/cfa10036.inc

KERNEL_DEVICETREE += "imx28-cfa10057.dtb"

MACHINE_FEATURES += "touchscreen"
```



## Bootloader



## Default bootloader 1/2

- ▶ By default the bootloader used is the mainline version of U-Boot, with a fixed version (per Poky release).
- ▶ All the magic is done in `meta/recipes-bsp/u-boot/u-boot.inc`
- ▶ Some configuration variables used by the U-Boot recipe can be customized, in the machine file.



## Default bootloader 2/2

**SPL\_BINARY** If an SPL is built, describes the name of the output binary. Defaults to an empty string.

**UBOOT\_SUFFIX** `bin` (default) or `img`.

**UBOOT\_MACHINE** The target used to build the configuration.

**UBOOT\_ENTRYPOINT** The bootloader entry point.

**UBOOT\_LOADADDRESS** The bootloader load address.

**UBOOT\_MAKE\_TARGET** Make target when building the bootloader. Defaults to `all`.



# Customize the bootloader

- ▶ It is possible to support a custom U-Boot by creating an extended recipe and to append extra metadata to the original one.
- ▶ This works well when using a mainline version of U-Boot.
- ▶ Otherwise it is possible to create a custom recipe.
  - ▶ Try to still use `meta/recipes-bsp/u-boot/u-boot.inc`



# Kernel



# Linux kernel recipes in Yocto

- ▶ There are basically two ways of compiling a kernel in the Yocto Project:
  - ▶ By using the `linux-yocto` packages, provided in Poky.
  - ▶ By using a fully custom kernel recipe.
- ▶ The kernel used is selected in the machine file thanks to:  
`PREFERRED_PROVIDER_virtual/kernel`
- ▶ Its version is defined with: `PREFERRED_VERSION_<kernel_provider>`



# Linux Yocto 1/4

- ▶ `linux-yocto` is a generic set of recipes for building mainline Linux kernel images.
- ▶ `PREFERRED_PROVIDER_virtual/kernel = "linux-yocto"`
- ▶ `PREFERRED_VERSION_linux-yocto = "3.14\%"`





- ▶ Like other appended recipes, patches can be added by filling `SRC_URI` with `.patch` and/or `.diff` files.
- ▶ The kernel configuration must also be provided, and the file containing it must be called `defconfig`.
  - ▶ This can be generated from a Linux source tree, by using `make savedefconfig`
  - ▶ The configuration can be split in several files, by using the `.cfg` extension. It is the best practice when adding new features:

```
SRC_URI += "file:///defconfig      \  
           file:///nand-support.cfg \  
           file:///ethernet-support.cfg"
```



- ▶ Configuration fragments can be generated directly with the `bitbake` command:
  1. Configure the kernel following its recipe instructions:

```
bitbake -c kernel_configme linux-yocto
```
  2. Edit the configuration: `bitbake -c menuconfig linux-yocto`
  3. Save the configuration differences: `bitbake -c diffconfig linux-yocto`
    - ▶ The differences will be saved at `$WORKDIR/fragment.cfg`
- ▶ After integrating configuration fragments into the appended recipe, you can check everything is fine by running:

```
bitbake -c kernel_configcheck -f linux-yocto
```



- ▶ Another way of configuring `linux-yocto` is by using *Advanced Metadata*.
- ▶ It is a powerful way of splitting the configuration and the patches into several pieces.
- ▶ It is designed to provide a very configurable kernel.
- ▶ The full documentation can be found at  
<https://www.yoctoproject.org/docs/2.5/kernel-dev/kernel-dev.html#kernel-dev-advanced>



# Linux Yocto: Kernel Metadata 1/4

- ▶ Kernel Metadata is a way to organize and to split the kernel configuration and patches in little pieces each providing support for one feature.
- ▶ Two main configuration variables help taking advantage of this:

`LINUX_KERNEL_TYPE` standard (default), `tiny` or `preempt-rt`

- ▶ `standard`: generic Linux kernel policy.
- ▶ `tiny`: bare minimum configuration, for small kernels.
- ▶ `preempt-rt`: applies the `PREEMPT_RT` patch.

`KERNEL_FEATURES` List of features to enable. Features are sets of patches and configuration fragments.



## Linux Yocto: Kernel Metadata 2/4

- ▶ Kernel Metadata can be stored in the `linux-yocto` recipe space.
- ▶ It must be under `$FILESEXTRAPATHS`. A best practice is to follow this directory hierarchy:

- `bsp/`
  - `cfg/`
  - `features/`
  - `ktypes/`
  - `patches/`

- ▶ Kernel Metadata are divided into 3 file types:
  - ▶ Description files, ending in `.scd`
  - ▶ Configuration fragments
  - ▶ Patches



## Linux Yocto: Kernel Metadata 3/4

- ▶ Kernel Metadata description files have their own syntax, used to describe the feature provided and which patches and configuration fragments to use.
- ▶ Simple example, `features/smp.scc`

```
define KFEATURE_DESCRIPTION "Enable SMP"  
  
kconf hardware smp.cfg  
patch smp-support.patch
```

- ▶ To integrate the feature into the kernel image:  
`KERNEL_FEATURES += "features/smp.scc"`



► .scc syntax description:

`branch <ref>` Create a new branch relative to the current one.

`define` Defines variables.

`include <scc file>` Include another description file. Parsed inline.

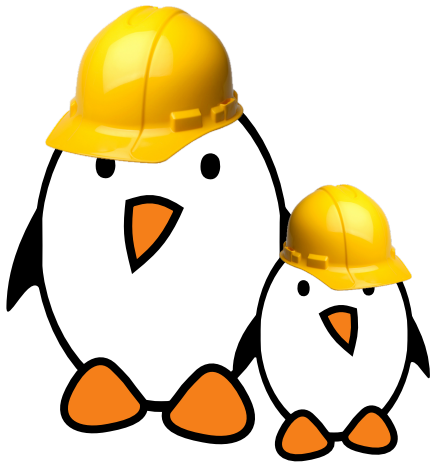
`kconf [hardware|non-hardware] <cfg file>` Queues a configuration fragment, to merge it into Linux's `.config`

`git merge <branch>` Merge branch into the current git branch.

`patch <patch file>` Applies patch file to the current git branch.



# Practical lab - Create a custom machine configuration



- ▶ Write a machine configuration
- ▶ Understand how the target architecture is chosen



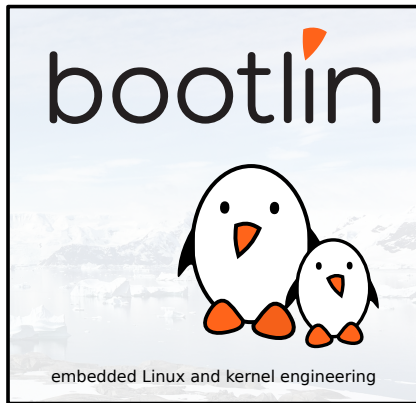


## Distro Layers

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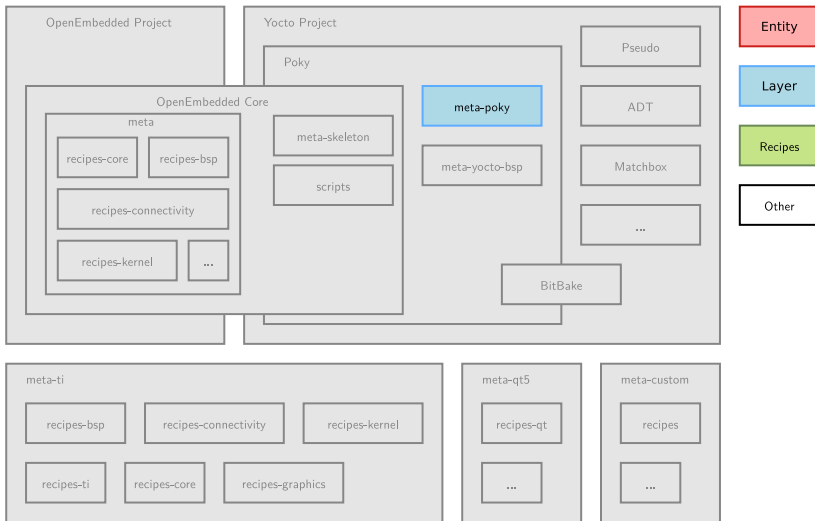




## Distro Layers



# Distro layers





# Distro layers

- ▶ You can create a new distribution by using a Distro layer.
- ▶ This allows to change the defaults that are used by Poky.
- ▶ It is useful to distribute changes that have been made in `local.conf`



## Best practice

- ▶ A distro layer is used to provide policy configurations for a custom distribution.
- ▶ It is a best practice to separate the distro layer from the custom layers you may create and use.
- ▶ It often contains:
  - ▶ Configuration files.
  - ▶ Specific classes.
  - ▶ Distribution specific recipes: initialization scripts, splash screen...



## Creating a Distro layer

- ▶ The configuration file for the distro layer is `conf/distro/<distro>.conf`
- ▶ This file must define the `DISTRO` variable.
- ▶ It is possible to inherit configuration from an existing distro layer.
- ▶ You can also use all the `DISTRO_*` variables.
- ▶ Use `DISTRO = "<distro>"` in `local.conf` to use your distro configuration.

```
require conf/distro/poky.conf
```

```
DISTRO = "distro"
```

```
DISTRO_NAME = "distro description"
```

```
DISTRO_VERSION = "1.0"
```

```
MAINTAINER = "..."
```



# Toolchain selection

- ▶ The toolchain selection is controlled by the `TCMODE` variable.
- ▶ It defaults to `"default"`.
- ▶ The `conf/distro/include/tcmode-${TCMODE}.inc` file is included.
  - ▶ This configures the toolchain to use by defining preferred providers and versions for recipes such as `gcc`, `binutils`, `*libc...`
- ▶ The providers' recipes define how to compile or/and install the toolchain.
- ▶ Toolchains can be built by the build system or external.



## Sample files

- ▶ A distro layer often contains `sample files`, used as templates to build key configurations files.
- ▶ Example of `sample files`:
  - ▶ `bblayers.conf.sample`
  - ▶ `local.conf.sample`
- ▶ In Poky, they are in `meta-poky/conf/`.
- ▶ The `TEMPLATECONF` variable controls where to find the samples.
- ▶ It is set in `${OEROOT}/.templateconf`.





## Release management



# Release management

There are multiple tasks that OE/bitbake based projects let you do on your own to ensure build reproducibility:

- ▶ Code distribution and project setup.
- ▶ Release tagging

A separate tool is needed for that, usual solutions are:

- ▶ combo-layer, as done by Poky:  
<https://wiki.yoctoproject.org/wiki/Combo-layer>
- ▶ git submodules + setup script. Great example in YOE:  
<https://github.com/YoeDistro/yoe-distro>
- ▶ repo and `templateconf` or setup script
- ▶ kas



# Distribute the distribution

- ▶ A good way to distribute a distribution (Poky, custom layers, BSP, `.templateconf...`) is to use Google's `repo`.
- ▶ `Repo` is used in Android to distribute its source code, which is split into many `git` repositories. It's a wrapper to handle several `git` repositories at once.
- ▶ The only requirement is to use `git`.
- ▶ The `repo` configuration is stored in `manifest` file, usually available in its own `git` repository.
- ▶ It could also be in a specific branch of your custom layer.
- ▶ It only handles fetching code, handling `local.conf` and `bblayers.conf` is done separately



# Manifest example

```
<?xml version="1.0" encoding="UTF-8"?>
<manifest>
  <remote name="yocto-project" fetch="git.yoctoproject.org" />
  <remote name="private" fetch="git.example.net" />

  <default revision="dunfell" remote="private" />

  <project name="poky" remote="yocto-project" />
  <project name="meta-ti" remote="yocto-project" />
  <project name="meta-custom" />
  <project name="meta-custom-bsp" />
  <project path="meta-custom-distro" name="distro">
    <copyfile src="templateconf" dest="poky/.templateconf" />
  </project>
</manifest>
```



## Retrieve the project using repo

```
$ mkdir my-project; cd my-project  
$ repo init -u https://git.example.net/manifest.git  
$ repo sync -j4
```

- ▶ `repo init` uses the `default.xml` manifest in the repository, unless specified otherwise.
- ▶ You can see the full `repo` documentation at <https://source.android.com/source/using-repo.html>.



To tag a release, a few steps have to be taken:

- ▶ Optionally tag the custom layers
- ▶ For each project entry in the manifest, set the revision parameter to either a tag or a commit hash.
- ▶ Commit and tag this version of the manifest.

- ▶ Specific tool developed by Siemens for OpenEmbedded:  
<https://github.com/siemens/kas>
- ▶ Will fetch layers and build the image in a single command
- ▶ Uses a single JSON or YAML configuration file part of the custom layer
- ▶ Can generate and run inside a Docker container
- ▶ Can setup `local.conf` and `bblayers.conf`



# kas configuration

```
header:  
  version: 8  
machine: mymachine  
distro: mydistro  
target:  
  - myimage  
  
repos:  
  meta-custom:  
  
  bitbake:  
    url: "https://git.openembedded.org/bitbake"  
    refspec: "1.46"  
  
  openembedded-core:  
    url: "https://git.openembedded.org/openembedded-core"  
    refspec: dunfell  
    layers:  
      meta:
```





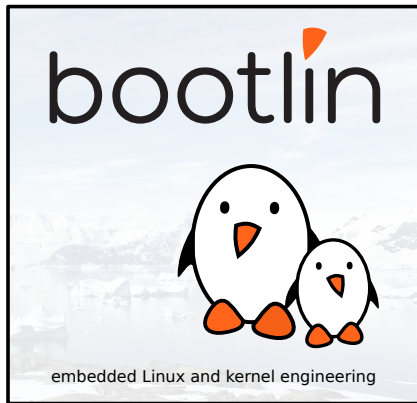
# kas configuration

```
meta-freescale:  
  url: "https://github.com/Freescale/meta-freescale"  
  refspec: dunfell  
  
meta-openembedded:  
  url: http://git.openembedded.org/meta-openembedded  
  refspec: dunfell  
  layers:  
    meta-oe:  
    meta-python:  
    meta-networking:
```



## Images

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## Introduction to images



## Overview 1/3

- ▶ An `image` is the top level recipe and is used alongside the `machine` definition.
- ▶ Whereas the `machine` describes the hardware used and its capabilities, the `image` is architecture agnostic and defines how the root filesystem is built, with what packages.
- ▶ By default, several images are provided in Poky:
  - ▶ `meta*/recipes*/images/*.bb`



## Overview 2/3

► Common images are:

`core-image-base` Console-only image, with full support of the hardware.

`core-image-minimal` Small image, capable of booting a device.

`core-image-minimal-dev` Small image with extra tools, suitable for development.

`core-image-x11` Image with basic X11 support.

`core-image-rt` `core-image-minimal` with real time tools and test suite.



## Overview 3/3

- ▶ An `image` is no more than a recipe.
- ▶ It has a description, a license and inherits the `core-image` class.



# Organization of an image recipe

- ▶ Some special configuration variables are used to describe an image:
  - IMAGE\_BASENAME** The name of the output image files. Defaults to `${PN}`.
  - IMAGE\_INSTALL** List of packages and package groups to install in the generated image.
  - IMAGE\_ROOTFS\_SIZE** The final root filesystem size.
  - IMAGE\_FEATURES** List of features to enable in the image.
  - IMAGE\_FSTYPES** List of formats the OpenEmbedded build system will use to create images.
  - IMAGE\_LINGUAS** List of the locales to be supported in the image.
  - IMAGE\_PKGTYPE** Package type used by the build system. One of `deb`, `rpm`, `ipk` and `tar`.
  - IMAGE\_POSTPROCESS\_COMMAND** Shell commands to run at post process.



## Example of an image

```
require recipes-core/images/core-image-minimal.bb
```

```
DESCRIPTION = "Example image"
```

```
IMAGE_INSTALL += "ninvaders"
```

```
IMAGE_FSTYPES = "tar.bz2 cpio squashfs"
```

```
LICENSE = "MIT"
```





## Image types



- ▶ Configures the resulting root filesystem image format.
- ▶ If more than one format is specified, one image per format will be generated.
- ▶ Image formats instructions are delivered in Poky, thanks to `meta/classes/image_types.bbclass`
- ▶ Common image formats are: ext2, ext3, ext4, squashfs, squashfs-xz, cpio, jffs2, ubifs, tar.bz2, tar.gz...



## Creating an image type

- ▶ If you have a particular layout on your storage (for example bootloader location on an SD card), you may want to create your own image type.
- ▶ This is done through a class that inherits from `image_types`.
- ▶ It has to define a function named `IMAGE_CMD_<type>`.

- ▶ `wic` is a tool that can create a flashable image from the compiled packages and artifacts.
- ▶ It can create partitions.
- ▶ It can select which files are located in which partition through the use of plugins.
- ▶ The final image layout is described in a `.wks` file.
- ▶ It can be extended in any layer.
- ▶ Usage example:

```
WKS_FILE = "imx-uboot.wks"  
IMAGE_FSTYPES = "wic.bmap wic"
```



## Package groups



# Overview

- ▶ Package groups are a way to group packages by functionality or common purpose.
- ▶ Package groups are used in image recipes to help building the list of packages to install.
- ▶ They can be found under `meta*/recipes-core/packagegroups/`
- ▶ A package group is yet another recipe.
- ▶ The prefix `packagegroup-` is always used.



# Common package groups

- ▶ packagegroup-core-boot
- ▶ packagegroup-core-buildessential
- ▶ packagegroup-core-nfs-client
- ▶ packagegroup-core-nfs-server
- ▶ packagegroup-core-tools-debug
- ▶ packagegroup-core-tools-profile



## Example

```
./meta/recipes-core/packagegroups/packagegroup-core-tools-debug.bb:
```

```
SUMMARY = "Debugging tools"
```

```
LICENSE = "MIT"
```

```
inherit packagegroup
```

```
RDEPENDS_${PN} = "\
```

```
gdb \
```

```
gdbserver \
```

```
strace"
```





## Practical lab - Create a custom image



- ▶ Write an image recipe
- ▶ Choose the packages to install

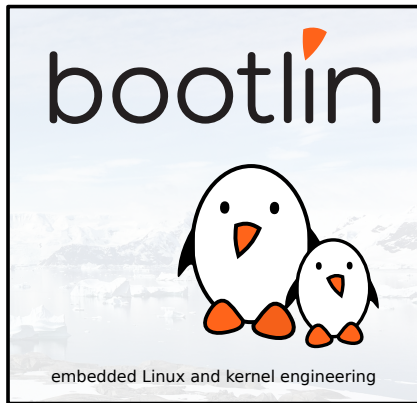


## Licensing

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## Managing licenses



# Tracking license changes

- ▶ The license of an external project may change at some point.
- ▶ The `LIC_FILES_CHKSUM` tracks changes in the license files.
- ▶ If the license's checksum changes, the build will fail.
  - ▶ The recipe needs to be updated.

```
LIC_FILES_CHKSUM = "                                \  
    file://COPYING;md5=...                          \  
    file://src/file.c;beginline=3;endline=21;md5=..."
```

- ▶ `LIC_FILES_CHKSUM` is mandatory in every recipe, unless `LICENSE` is set to `CLOSED`.



## Package exclusion

- ▶ We may not want some packages due to their licenses.
- ▶ To exclude a specific license, use `INCOMPATIBLE_LICENSE`
- ▶ To exclude all GPLv3 packages:

```
INCOMPATIBLE_LICENSE = "GPLv3"
```

- ▶ License names are the ones used in the `LICENSE` variable.



# Commercial licenses

- ▶ By default the build system does not include commercial components.
- ▶ Packages with a commercial component define:

```
LICENSE_FLAGS = "commercial"
```

- ▶ To build a package with a commercial component, the package must be in the `LICENSE_FLAGS_WHITELIST` variable.
- ▶ Example, `gst-plugins-ugly`:

```
LICENSE_FLAGS_WHITELIST = "commercial_gst-plugins-ugly"
```



## Listing licenses

OpenEmbbeded will generate a manifest of all the licenses of the software present on the target image in `$BUILDDIR/tmp/deploy/licenses/<image>/license.manifest`

```
PACKAGE NAME: busybox
PACKAGE VERSION: 1.31.1
RECIPE NAME: busybox
LICENSE: GPLv2 & bzip2-1.0.6
```

```
PACKAGE NAME: dropbear
PACKAGE VERSION: 2019.78
RECIPE NAME: dropbear
LICENSE: MIT & BSD-3-Clause & BSD-2-Clause & PD
```



## Providing license text

To include the license text in the root filesystem either:

- ▶ Use `COPY_LIC_DIRS = "1"` and `COPY_LIC_MANIFEST = "1"`
- ▶ or use `LICENSE_CREATE_PACKAGE = "1"` to generate packages including the license and install the required license packages.





## Providing sources

OpenEmbedded provides the `archiver` class to generate tarballs of the source code:

- ▶ Use `INHERIT += "archiver"`
- ▶ Set the `ARCHIVER_MODE` variable, the default is to provide patched sources. To provide configured sources:

```
ARCHIVER_MODE[src] = "configured"
```

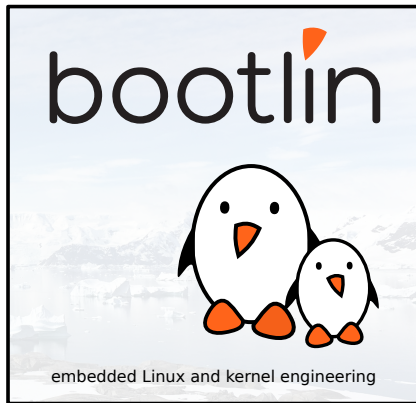


## Writing recipes - going further

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# Packages features



# Benefits

- ▶ Features can be built depending on the needs.
- ▶ This allows to avoid compiling all features in a software component when only a few are required.
- ▶ A good example is `ConnMan`: Bluetooth support is built only if there is Bluetooth on the target.
- ▶ The `PACKAGECONFIG` variable is used to configure the build on a per feature granularity, for packages.



- ▶ `PACKAGECONFIG` takes the list of features to enable.
- ▶ `PACKAGECONFIG[feature]` takes up to four arguments, separated by commas:
  1. Argument used by the configuration task if the feature is enabled (`EXTRA_OECONF`).
  2. Argument added to `EXTRA_OECONF` if the feature is disabled.
  3. Additional build dependency (`DEPENDS`), if enabled.
  4. Additional runtime dependency (`RDEPENDS`), if enabled.
- ▶ Unused arguments can be omitted or left blank.



## Example: from ConnMan

```
PACKAGECONFIG ??= "wifi openvpn"
```

```
PACKAGECONFIG[wifi] = "--enable-wifi,           \  
                      --disable-wifi,          \  
                      wpa-supPLICant,          \  
                      wpa-supPLICant"
```

```
PACKAGECONFIG[bluez] = "--enable-bluetooth,      \  
                      --disable-bluetooth,      \  
                      bluez5,                   \  
                      bluez5"
```

```
PACKAGECONFIG[openvpn] = "--enable-openvpn,      \  
                      --disable-openvpn,        \  
                      ,                          \  
                      openvpn"
```



# Conditional features



# Conditional features

- ▶ Some values can be set dynamically, thanks to a set of functions:
- ▶ `bb.utils.contains(variable, checkval, trueval, falseval, d)`: if `checkval` is found in `variable`, `trueval` is returned; otherwise `falseval` is used.
- ▶ Example:

```
PACKAGECONFIG ??= "
    ${@bb.utils.contains('DISTRO_FEATURES', 'wifi', 'wifi', '', d)} \
    ${@bb.utils.contains('DISTRO_FEATURES', 'bluetooth', 'bluetooth', '', d)} \
    ${@bb.utils.contains('DISTRO_FEATURES', '3g', '3g', '', d)}"
```





# Python tasks



# Tasks in Python

- ▶ Tasks can be written in Python when using the keyword `python`.
- ▶ The `d` variable is accessible, and represents the BitBake datastore (where variables are stored).
- ▶ Two modules are automatically imported:
  - ▶ `bb`: to access BitBake's internal functions.
  - ▶ `os`: Python's operating system interfaces.
- ▶ You can import other modules using the keyword `import`.
- ▶ Anonymous Python functions are executed during parsing.



# Accessing the datastore with Python

- ▶ The `d` variable is accessible within Python tasks.

`d.getVar("X", expand=False)` Returns the value of `X`.

`d.setVar("X", "value")` Set `X`.

`d.appendVar("X", "value")` Append value to `X`.

`d.prependVar("X", "value")` Prepend value to `X`.

`d.expand(expression)` Expand variables in expression.



# Python task example

# Anonymous function

```
python () {  
    if d.getVar("FOO", True) == "example":  
        d.setVar("BAR", "Hello, World.")  
}
```

# Task

```
python do_settime() {  
    import time  
  
    d.setVar("TIME", time.strftime('%Y%m%d', time.gmtime()))  
}
```



# Variable flags



## Variable flags

- ▶ *Variable flags* are used to store extra information on tasks and variables.
- ▶ They are used to control task functionalities.
- ▶ A number of these flags are already used by BitBake:
  - ▶ `dirs`: directories that should be created before the task runs. The last one becomes the work directory for the task.
  - ▶ `noexec`: disable the execution of the task.
  - ▶ `nostamp`: do not create a *stamp* file when running the task. The task will always be executed.
  - ▶ `doc`: task documentation displayed by *listtasks*.

```
do_settime[noexec] = "1"
```

```
do_compile[nostamp] = "1"
```

```
do_settime[doc] = "Set the current time in ${TIME}"
```



# Root filesystem creation



# Files and directories selection

- ▶ The `FILES` variable controls the list of files and directories to be placed into packages.
- ▶ It must be package specific (e.g. with `_${PN}`).
- ▶ In Poky, defaults to:

```
FILES_${PN} = \  
    "${bindir}/* ${sbindir}/* ${libexecdir}/* ${libdir}/lib*${SOLIBS} \  
    ${sysconfdir} ${sharedstatedir} ${localstatedir} \  
    ${base_bindir}/* ${base_sbindir}/* \  
    ${base_libdir}/*${SOLIBS} \  
    ${base_prefix}/lib/udev/rules.d ${prefix}/lib/udev/rules.d \  
    ${datadir}/${BPN} ${libdir}/${BPN}/* \  
    ${datadir}/pixmaps ${datadir}/applications \  
    ${datadir}/idl ${datadir}/omf ${datadir}/sounds \  
    ${libdir}/bonobo/servers"
```

- ▶ To prevent configuration files to be overwritten during the Package Management System update process, use `CONFFILES`.





# Root filesystem generation

- ▶ Image generation overview:
  1. The rootfs is created using packages.
  2. One or more images files are created, depending on the `IMAGE_FSTYPES` value.
- ▶ The rootfs creation is specific to the `IMAGE_PKGTYPE` value. It should be defined in the image recipe, otherwise the first valid package type defined in `PACKAGE_CLASSES` is used.
- ▶ All the magic is done in `meta/classes/rootfs_${IMAGE_PKGTYPE}.bbclass`



## Example: rootfs creation with .deb packages

```
rootfs_deb_do_rootfs () {  
    [...]  
  
    export INSTALL_ROOTFS_DEB="${IMAGE_ROOTFS}"  
  
    [...]  
  
    apt update  
    apt ${APT_ARGS} install ${package_to_install} \  
        --force-yes --allow-unauthenticated  
  
    [...]  
}
```



# Splitting packages



# Benefits

- ▶ Packages can be split.
- ▶ Useful when a single remote repository provides multiple binaries or libraries.
- ▶ The list of packages to provide is defined by the `PACKAGES` variable.
- ▶ The `FILES` variable is often used to split the output into packages.



## Example

- ▶ The `kexec` tools provides `kexec` and `kdump`:

```
require kexec-tools.inc
export LDFLAGS = "-L${STAGING_LIBDIR}"
EXTRA_OECONF = " --with-zlib=yes"

SRC_URI[md5sum] = \
    "b9f2a3ba0ba9c78625ee7a50532500d8"
SRC_URI[sha256sum] = "... "

PACKAGES =+ "kexec kdump"

FILES_kexec = "${sbindir}/kexec"
FILES_kdump = "${sbindir}/kdump"
```



## Default packages

- By default several packages are produced automatically:

```
PACKAGES = "${PN}-dbg ${PN}-staticdev \  
           ${PN}-dev ${PN}-doc ${PN}-locale ${PN}"
```

- For each of these packages a FILES variable is defined in meta/conf/bitbake.conf:

```
FILES_${PN}-dev = \  
    "${includedir} ${FILES_SOLIBSDEV} ${libdir}/*.la \  
    ${libdir}/*.o ${libdir}/pkgconfig ${datadir}/pkgconfig \  
    ${datadir}/aclocal ${base_libdir}/*.o \  
    ${libdir}/${BPN}/*.la ${base_libdir}/*.la"  
FILES_${PN}-dbg = "/usr/lib/debug /usr/src/debug"
```

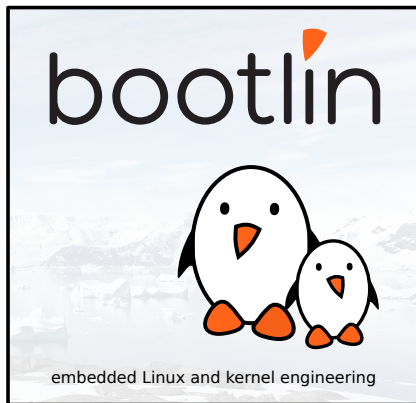


## Application development workflow

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## Recommended workflows

- ▶ Different development workflows are possible given the needs:
  - ▶ Low-level application development (bootloader, kernel).
  - ▶ Application development.
  - ▶ Temporary modifications on an external project (bug fixes, security fixes).
- ▶ Three workflows exists for theses needs: the `SDK`, `devtool` and `quilt`.





## The Yocto Project SDK



- ▶ An SDK (Software Development Kit) is a set of tools allowing the development of applications for a given target (operating system, platform, environment...).
- ▶ It generally provides a set of tools including:
  - ▶ Compilers or cross-compilers.
  - ▶ Linkers.
  - ▶ Library headers.
  - ▶ Debuggers.
  - ▶ Custom utilities.



# Advantages

- ▶ The Yocto Project is often used to build images for embedded targets.
  - ▶ This often requires a special toolchain, to cross compile the software.
  - ▶ Some libraries headers may be specific to the target and not available on the developers' computers.
- ▶ A self-sufficient environment makes development easier and avoids many errors.
- ▶ Long manuals are not necessary, the only thing required is the SDK!
- ▶ Using the SDK to develop an application limits the risks of dependency issues when running it on the target.



# The Yocto Project SDK

- ▶ The Poky reference system is used to generate images, by building many applications and doing a lot of configuration work.
  - ▶ When developing an application, we only care about the application itself.
  - ▶ We want to be able to develop, test and debug easily.
- ▶ The Yocto Project SDK is an application development SDK, which can be generated to provide a full environment compatible with the target.
- ▶ It includes a toolchain, libraries headers and all the needed tools.
- ▶ This SDK can be installed on any computer and is self-contained. The presence of Poky is not required for the SDK to fully work.



- ▶ Two different SDKs can be generated:
  - ▶ A generic SDK, including:
    - ▶ A toolchain.
    - ▶ Common tools.
    - ▶ A collection of basic libraries.
  - ▶ An image-based SDK, including:
    - ▶ The generic SDK.
    - ▶ The sysroot matching the target root filesystem.
    - ▶ Its toolchain is self-contained (linked to an SDK embedded libc).
- ▶ The SDKs generated with Poky are distributed in the form of a shell script.
- ▶ Executing this script extracts the tools and sets up the environment.



# The generic SDK

- ▶ Mainly used for low-level development, where only the toolchain is needed:
  - ▶ Bootloader development.
  - ▶ Kernel development.
- ▶ The recipe `meta-toolchain` generates this SDK:
  - ▶ `bitbake meta-toolchain`
- ▶ The generated script, containing all the tools for this SDK, is in:
  - ▶ `$BUILDDIR/tmp/deploy/sdk`
  - ▶ Example:  
`poky-glibc-x86_64-meta-toolchain-cortexa8hf-neon-toolchain-2.5.sh`
- ▶ The SDK will be configured to be compatible with the specified `MACHINE`.



# The image-based SDK

- ▶ Used to develop applications running on the target.
- ▶ One task is dedicated to the process. The task behavior can vary between the images.
  - ▶ `populate_sdk`
- ▶ To generate an SDK for `core-image-minimal`:
  - ▶ `bitbake -c populate_sdk core-image-minimal`
- ▶ The generated script, containing all the tools for this SDK, is in:
  - ▶ `$BUILDDIR/tmp/deploy/sdk`
  - ▶ Example:  
`poky-glibc-x86_64-core-image-minimal-cortexa8hf-neon-toolchain-2.5.sh`
- ▶ The SDK will be configured to be compatible with the specified `MACHINE`.



# SDK format

- ▶ Both SDKs are distributed as bash scripts.
- ▶ These scripts self extract themselves to install the toolchains and the files they provide.
- ▶ To install an SDK, retrieve the generated script and execute it.
  - ▶ The script asks where to install the SDK. Defaults to `/opt/poky/<version>`
  - ▶ Example: `/opt/poky/2.5`

```
$ ./poky-glibc-x86_64-meta-toolchain-cortexa8hf-neon-toolchain-2.5.sh
Poky (Yocto Project Reference Distro) SDK installer version 2.5
=====
Enter target directory for SDK (default: /opt/poky/2.5):
You are about to install the SDK to "/opt/poky/2.5". Proceed[Y/n]?
Extracting SDK.....done
Setting it up...done
SDK has been successfully set up and is ready to be used.
Each time you wish to use the SDK in a new shell session, you need to source
the environment setup script e.g.
$ . /opt/poky/2.5/environment-setup-cortexa8hf-neon-poky-linux-gnueabi
```





# Use the SDK

- ▶ To use the SDK, a script is available to set up the environment:

```
$ cd /opt/poky/2.5  
$ source ./environment-setup-cortexa8hf-neon-poky-linux-gnueabi
```

- ▶ The `PATH` is updated to take into account the binaries installed alongside the SDK.
- ▶ Environment variables are exported to help using the tools.



# SDK installation

`environment-setup-cortexa8hf-neon-poky-linux-gnueabi` Exports environment variables.

`site-config-cortexa8hf-neon-poky-linux-gnueabi` Variables used during the toolchain creation

`sysroots` SDK binaries, headers and libraries. Contains one directory for the host and one for the target.

`version-cortexa8hf-neon-poky-linux-gnueabi` Version information.



# SDK environment variables

**CC** Full path to the C compiler binary.

**CFLAGS** C flags, used by the C compiler.

**CXX** C++ compiler.

**CXXFLAGS** C++ flags, used by **CXX**

**LD** Linker.

**LDFLAGS** Link flags, used by the linker.

**ARCH** For kernel compilation.

**CROSS\_COMPILE** For kernel compilation.

**GDB** SDK GNU Debugger.

**OBJDUMP** SDK objdump.

► To see the full list, open the environment script.



## Examples

- ▶ To build an application for the target:

```
$ $CC -o example example.c
```

- ▶ The `LDFLAGS` variable is set to be used with the C compiler (`gcc`).
  - ▶ When building the Linux kernel, unset this variable.

```
$ unset LDFLAGS  
$ make menuconfig  
$ make
```



## Devtool



# Overview

- ▶ `Devtool` is a set of utilities to ease the integration and the development of OpenEmbedded recipes.
- ▶ It can be used to:
  - ▶ Generate a recipe for a given upstream application.
  - ▶ Modify an existing recipe and its associated sources.
  - ▶ Upgrade an existing recipe to use a newer upstream application.
- ▶ `Devtool` adds a new layer, automatically managed, in `$BUILDDIR/workspace/`.
- ▶ It then adds or appends recipes to this layer so that the recipes point to a local path for their sources. In `$BUILDDIR/workspace/sources/`.
  - ▶ Local sources are managed by `git`.
  - ▶ All modifications made locally should be committed.



There are three ways of creating a new devtool project:

- ▶ To create a new recipe: `devtool add <recipe> <fetchuri>`
  - ▶ Where `recipe` is the recipe's name.
  - ▶ `fetchuri` can be a local path or a remote *uri*.
- ▶ To modify an existing recipe: `devtool modify <recipe>`
- ▶ To upgrade a given recipe: `devtool upgrade -V <version> <recipe>`
  - ▶ Where `version` is the new version of the upstream application.



Once a `devtool` project is started, commands can be issued:

- ▶ `devtool edit-recipe <recipe>`: edit recipe in a text editor (as defined by the `EDITOR` environment variable).
- ▶ `devtool build <recipe>`: build the given recipe.
- ▶ `devtool build-image <image>`: build image with the additional `devtool` recipes' packages.





- ▶ `devtool deploy-target <recipe> <target>`: upload the recipe's packages on target, which is a live running target with an SSH server running (user@address).
- ▶ `devtool update-recipe <recipe>`: generate patches from git commits made locally.
- ▶ `devtool reset <recipe>`: remove recipe from the control of devtool. Standard layers and remote sources are used again as usual.



## Quilt



# Overview

- ▶ Quilt is a utility to manage patches which can be used without having a clean source tree.
- ▶ It can be used to create patches for recipes already available in the build system.
- ▶ Be careful when using this workflow: the modifications won't persist across builds!



# Using Quilt

1. Find the recipe working directory in `$BUILDDIR/tmp/work/`.
2. Create a new Quilt patch: `$ quilt new topic.patch`
3. Add files to this patch: `$ quilt add file0.c file1.c`
4. Make the modifications by editing the files.
5. Test the modifications: `$ bitbake -c compile -f recipe`
6. Generate the patch file: `$ quilt refresh`
7. Move the generated patch into the recipe's directory.



# Practical lab - Create and use a Poky SDK



- ▶ Generate an SDK
- ▶ Compile an application for the target in the SDK

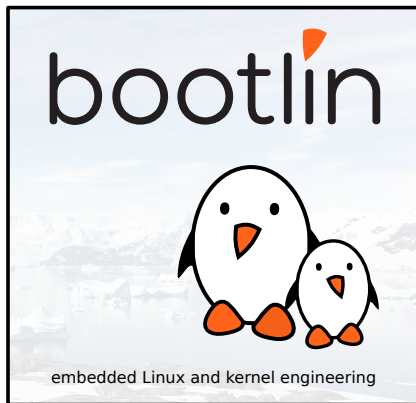


## Runtime Package Management

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# Introduction

- ▶ BitBake always builds packages selected in `IMAGE_INSTALL`.
- ▶ The packages are used to generate the root filesystem.
- ▶ It is also possible to update the system at runtime using these packages, for many use cases:
  - ▶ In-field security updates.
  - ▶ System updates over the wire.
  - ▶ System, packages or configuration customization at runtime.
  - ▶ Remote debugging.
- ▶ Using the Runtime Package Management is an optional feature.
- ▶ We'll use the IPK package format as an example in the following slides.



# Requirements

- ▶ First of all, you need a server to serve the packages to a private subnet or over the Internet. Packages are typically served over `https` or `http`.
- ▶ Specific tools are also required on the target, and must be shipped on the product. They should be included into the images generated by the build system.
- ▶ These tools will be specific to the package type used.
  - ▶ This is similar to Linux distributions: Debian is using `.deb` related tools (`dpkg`, `apt...`) while Fedora uses `.rpm` related ones (`yum`).





## Build configuration



## Build configuration 1/2

- ▶ The `PACKAGE_CLASSES` variable controls which package format to use. More than one can be used.
- ▶ Valid values are `package_rpm`, `package_deb`, `package_ipk`.
- ▶ By default Poky uses the RPM format, while OpenEmbedded-Core uses the IPK one.
- ▶ Example:
  - ▶ `PACKAGE_CLASSES = "package_ipk"`
  - ▶ `PACKAGE_CLASSES = "package_rpm package_deb"`



## Build configuration 2/2

To install the required tools on the target, there are two possible solutions:

- ▶ By adding `package-management` to the images features.
  - ▶ The required tool will be installed on the target.
  - ▶ The package database corresponding to the build will be installed as well.
- ▶ Or by manually adding the required tools in `IMAGE_INSTALL`. For example, to use the IPK format we need `opkg`.



# Build considerations

- ▶ The Runtime Package Management uses package databases to store information about available packages and their version.
- ▶ Whenever a build generates a new package or modifies an existing one, the package database must be updated.
- ▶ `$ bitbake package-index`
- ▶ Be careful: BitBake does not properly schedule the `package-index` target. You must use this target alone to have a consistent package database.
  - ▶ `$ bitbake ninvaders package-index` won't necessarily generate an updated package database.



## Package server configuration



## Apache2 example setup

Apache2 HTTP setup for IPK packages. This should go in  
`/etc/apache2/sites-enabled/package-server.conf`.

```
<VirtualHost *:80>
    ServerName packages.example.net

    DocumentRoot /path/to/build/tmp/deploy/ipk
    <Directory /path/to/build/tmp/deploy/ipk>
        Options +Indexes
        Options Indexes FollowSymLinks
        Order allow,deny
        allow from all
        AllowOverride None
        Require all granted
    </Directory>
</VirtualHost>
```



## Target configuration



# The IPK runtime management software

- ▶ The IPK runtime management software is `opkg`.
- ▶ It can be configured using configurations files ending in `.conf` in `/etc/opkg/`.
- ▶ This configuration helps `opkg` to find the package databases you want to use.
- ▶ For example, with our previously configured package server:

```
src/gz all http://packages.example.net/all
src/gz armv7a http://packages.example.net/armv7a
src/gz beaglebone http://packages.example.net/beaglebone
```

- ▶ This can be automatically generated by defining the `PACKAGE_FEED_URIS`, `PACKAGE_FEED_BASE_PATHS` and `PACKAGE_FEED_ARCHS` variables





- ▶ `opkg update`: fetch and update the package databases, from the remote package servers.
- ▶ `opkg list`: list available packages.
- ▶ `opkg upgrade`: upgrade all installed packages.
- ▶ `opkg upgrade <package>`: upgrade one package explicitly.
- ▶ `opkg install <package>`: install a specific package.



## opkg upgrade over an unstable network

- ▶ To avoid upgrade issues when downloading packages from a remote package server using an unstable connection, you can first download the packages and then proceed with the upgrade.
- ▶ To do this we must use a cache, which can be defined in the `opkg` configuration with: `option cache /tmp/opkg-cache.`

```
# opkg update
# opkg --download-only upgrade
# opkg upgrade
```

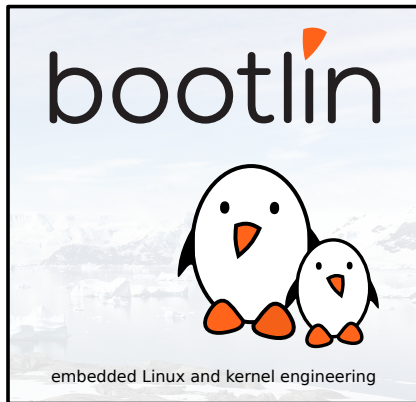


## Yocto Project Resources

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# Yocto Project documentation

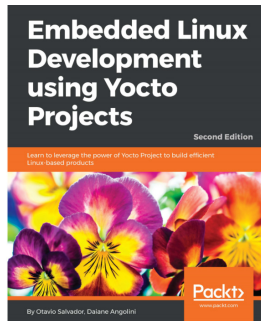
- ▶ <https://www.yoctoproject.org/documentation>
- ▶ Wiki: [https://wiki.yoctoproject.org/wiki/Main\\_Page](https://wiki.yoctoproject.org/wiki/Main_Page)
- ▶ <http://recipes.yoctoproject.org>



## Useful Reading (1)

Embedded Linux Development with Yocto Project - Second Edition, Nov 2017

- ▶ <https://www.packtpub.com/virtualization-and-cloud/embedded-linux-development-using-yocto-projects-second-edition>
- ▶ By Otavio Salvador and Daiane Angolini
- ▶ From basic to advanced usage, helps writing better, more flexible recipes. A good reference to jumpstart your Yocto Project development.



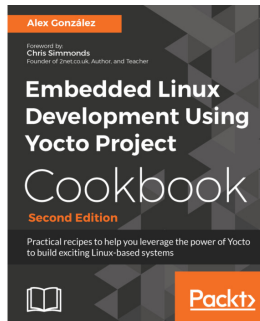


## Useful Reading (2)

### Embedded Linux Projects Using Yocto Project Cookbook - Second Edition, January 2018

- ▶ <https://www.packtpub.com/virtualization-and-cloud/embedded-linux-development-using-yocto-project-cookbook-second-edition>
- ▶ By Alex González
- ▶ A set of recipes that you can refer to and solve your immediate problems instead of reading it from cover to cover.

See our review: <https://bit.ly/1GgVmCB>



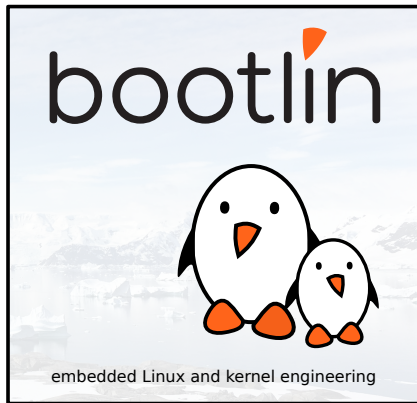


## Last slides

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Thank you!  
And may the Source be with you