

# Yocto Project Linux Kernel Development Manual



Darren Hart, Intel Corporation <[darren.hart@intel.com](mailto:darren.hart@intel.com)>

---

by Darren Hart  
Copyright © 2010-2014 Linux Foundation

Permission is granted to copy, distribute and/or modify this document under the terms of the Creative Commons Attribution-Share Alike 2.0 UK: England & Wales [<http://creativecommons.org/licenses/by-sa/2.0/uk/>] as published by Creative Commons.

## Note

Due to production processes, there could be differences between the Yocto Project documentation bundled in the release tarball and the Yocto Project Linux Kernel Development Manual [<http://www.yoctoproject.org/docs/1.4.5/kernel-dev/kernel-dev.html>] on the Yocto Project [<http://www.yoctoproject.org>] website. For the latest version of this manual, see the manual on the website.

---

# Table of Contents

1. Introduction .....	1
1.1. Overview .....	1
1.2. Other Resources .....	1
2. Common Tasks .....	3
2.1. Creating and Preparing a Layer .....	3
2.2. Modifying an Existing Recipe .....	3
2.2.1. Creating the Append File .....	3
2.2.2. Applying Patches .....	4
2.2.3. Changing the Configuration .....	4
2.3. Using an Iterative Development Process .....	5
2.3.1. "-dirty" String .....	5
2.3.2. Generating Configuration Files .....	5
2.3.3. Modifying Source Code .....	7
2.4. Working With Your Own Sources .....	8
2.5. Incorporating Out-of-Tree Modules .....	9
2.6. Inspecting Changes and Commits .....	10
2.6.1. What Changed in a Kernel? .....	10
2.6.2. Showing a Particular Feature or Branch Change .....	11
3. Working with Advanced Metadata .....	12
3.1. Overview .....	12
3.2. Using Kernel Metadata in a Recipe .....	12
3.3. Kernel Metadata Location .....	13
3.3.1. Recipe-Space Metadata .....	13
3.3.2. In-Tree Metadata .....	14
3.4. Kernel Metadata Syntax .....	15
3.4.1. Configuration .....	16
3.4.2. Patches .....	16
3.4.3. Features .....	17
3.4.4. Kernel Types .....	17
3.4.5. BSP Descriptions .....	18
3.5. Organizing Your Source .....	20
3.5.1. Encapsulating Patches .....	20
3.5.2. Machine Branches .....	20
3.5.3. Feature Branches .....	21
3.6. SCC Description File Reference .....	22
A. Advanced Kernel Concepts .....	23
A.1. Yocto Project Kernel Development and Maintenance .....	23
A.2. Kernel Architecture .....	23
A.2.1. Overview .....	24
A.2.2. Branching Strategy and Workflow .....	25
A.2.3. Source Code Manager - Git .....	26
B. Kernel Maintenance .....	27
B.1. Tree Construction .....	27
B.2. Build Strategy .....	28
C. Kernel Development FAQ .....	30

---

# Chapter 1. Introduction

## 1.1. Overview

Regardless of how you intend to make use of the Yocto Project, chances are you will work with the Linux kernel. This manual provides background information on the Yocto Linux kernel Metadata [<http://www.yoctoproject.org/docs/1.4.5/dev-manual/dev-manual.html#metadata>], describes common tasks you can perform using the kernel tools, and shows you how to use the kernel Metadata needed to work with the kernel inside the Yocto Project.

Each Yocto Project release has a set of linux-yocto recipes, whose Git repositories you can view in the Yocto Source Repositories [<http://git.yoctoproject.org>] under the "Yocto Linux Kernel" heading. New recipes for the release track the latest upstream developments and introduce newly supported platforms. Previous recipes in the release are refreshed and supported for at least one additional release. As they align, these previous releases are updated to include the latest from the Long Term Support Initiative (LTSI) project. Also included is a linux-yocto development recipe (`linux-yocto-dev.bb`) should you want to work with the very latest in upstream Linux kernel development and kernel Metadata development.

The Yocto Project also provides a powerful set of kernel tools for managing Linux kernel sources and configuration data. You can use these tools to make a single configuration change, apply multiple patches, or work with your own kernel sources.

In particular, the kernel tools allow you to generate configuration fragments that specify only what you must, and nothing more. Configuration fragments only need to contain the highest level visible CONFIG options as presented by the Linux kernel `menuconfig` system. Contrast this against a complete Linux kernel `.config`, which includes all the automatically selected CONFIG options. This efficiency reduces your maintenance effort and allows you to further separate your configuration in ways that make sense for your project. A common split separates policy and hardware. For example, all your kernels might support the `proc` and `sys` filesystems, but only specific boards require sound, USB, or specific drivers. Specifying these configurations individually allows you to aggregate them together as needed, but maintains them in only one place. Similar logic applies to separating source changes.

If you do not maintain your own kernel sources and need to make only minimal changes to the sources, the released recipes provide a vetted base upon which to layer your changes. Doing so allows you to benefit from the continual kernel integration and testing performed during development of the Yocto Project.

If, instead, you have a very specific Linux kernel source tree and are unable to align with one of the official linux-yocto recipes, an alternative exists by which you can use the Yocto Project Linux kernel tools with your own kernel sources.

## 1.2. Other Resources

The sections that follow provide instructions for completing specific Linux kernel development tasks. These instructions assume you are comfortable working with BitBake [<http://developer.berlios.de/projects/bitbake/>] recipes and basic open-source development tools. Understanding these concepts will facilitate the process of working with the kernel recipes. If you find you need some additional background, please be sure to review and understand the following documentation:

- Yocto Project Quick Start [<http://www.yoctoproject.org/docs/1.4.5/yocto-project-qs/yocto-project-qs.html>]
- The "Modifying Temporary Source Code [<http://www.yoctoproject.org/docs/1.4.5/dev-manual/dev-manual.html#modifying-temporary-source-code>]" section in the Yocto Project Development Manual
- The "Understanding and Creating Layers [<http://www.yoctoproject.org/docs/1.4.5/dev-manual/dev-manual.html#understanding-and-creating-layers>]" section in the Yocto Project Development Manual
- The "Modifying the Kernel [<http://www.yoctoproject.org/docs/1.4.5/dev-manual/dev-manual.html#modifying-the-kernel>]" section in the Yocto Project Development Manual.

Finally, while this document focuses on the manual creation of recipes, patches, and configuration files, the Yocto Project Board Support Package (BSP) tools are available to automate this process with existing content and work well to create the initial framework and boilerplate code. For details on these tools, see the "Using the Yocto Project's BSP Tools [<http://www.yoctoproject.org/docs/1.4.5/bsp-guide/bsp-guide.html#using-the-yocto-projects-bsp-tools>]" section in the Yocto Project Board Support Package (BSP) Developer's Guide.

---

# Chapter 2. Common Tasks

This chapter presents several common tasks you perform when you work with the Yocto Project Linux kernel. These tasks include preparing a layer, modifying an existing recipe, iterative development, working with your own sources, and incorporating out-of-tree modules.

## Note

The examples presented in this chapter work with the Yocto Project 1.2.2 Release and forward.

## 2.1. Creating and Preparing a Layer

If you are going to be modifying kernel recipes, it is recommended that you create and prepare your own layer in which to do your work. Your layer contains its own BitBake append files (.bbappend) and provides a convenient mechanism to create your own recipe files (.bb). For details on how to create and work with layers, see the following sections in the Yocto Project Development Manual:

- "Understanding and Creating Layers [<http://www.yoctoproject.org/docs/1.4.5/dev-manual/dev-manual.html#understanding-and-creating-layers>]" for general information on layers and how to create layers.
- "Set Up Your Layer for the Build [<http://www.yoctoproject.org/docs/1.4.5/dev-manual/dev-manual.html#set-up-your-layer-for-the-build>]" for specific instructions on setting up a layer for kernel development.

## 2.2. Modifying an Existing Recipe

In many cases, you can customize an existing linux-yocto recipe to meet the needs of your project. Each release of the Yocto Project provides a few Linux kernel recipes from which you can choose. These are located in the Source Directory [<http://www.yoctoproject.org/docs/1.4.5/dev-manual/dev-manual.html#source-directory>] in meta/recipes-kernel/linux.

Modifying an existing recipe can consist of the following:

- Creating the append file
- Applying patches
- Changing the configuration

Before modifying an existing recipe, be sure that you have created a minimal, custom layer from which you can work. See the "Creating and Preparing a Layer" section for some general resources. You can also see the "Set Up Your Layer for the Build [<http://www.yoctoproject.org/docs/1.4.5/dev-manual/dev-manual.html#set-up-your-layer-for-the-build>]" section of the Yocto Project Development Manual for a detailed example.

### 2.2.1. Creating the Append File

You create this file in your custom layer. You also name it accordingly based on the linux-yocto recipe you are using. For example, if you are modifying the meta/recipes-kernel/linux/linux-yocto\_3.4.bb recipe, the append file will typically be located as follows within your custom layer:

```
<your-layer>/recipes-kernel/linux/linux-yocto_3.4.bbappend
```

The append file should initially contain the following text:

```
FILESEXTRAPATHS [http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-FILES]
```

```
The path ${THISDIR} [http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-THISDIR}/${PN} [http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-PN]
```

expands to "linux-yocto" in the current directory for this example. If you add any new files that modify the kernel recipe and you have extended FILESPATH as described above, you must place the files in your layer in the following area:

```
<your-layer>/recipes-kernel/linux/linux-yocto/
```

## Note

If you are working on a new machine Board Support Package (BSP), be sure to refer to the Yocto Project Board Support Package (BSP) Developer's Guide [<http://www.yoctoproject.org/docs/1.4.5/bsp-guide/bsp-guide.html>].

## 2.2.2. Applying Patches

If you have a single patch or a small series of patches that you want to apply to the Linux kernel source, you can do so just as you would with any other recipe. You first copy the patches to the path added to FILESEXTRAPATHS [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-FILESEXTRAPATHS>] in your .bbappend file as described in the previous section, and then reference them in SRC\_URI [[http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-SRC\\_URI](http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-SRC_URI)] statements.

For example, you can apply a three-patch series by adding the following lines to your linux-yocto .bbappend file in your layer:

```
SRC_URI += "file://0001-first-change.patch"  
SRC_URI += "file://0002-first-change.patch"  
SRC_URI += "file://0003-first-change.patch"
```

The next time you run BitBake to build the Linux kernel, BitBake detects the change in the recipe and fetches and applies the patches before building the kernel.

For a detailed example showing how to patch the kernel, see the "Patching the Kernel [<http://www.yoctoproject.org/docs/1.4.5/dev-manual/dev-manual.html#patching-the-kernel>]" section in the Yocto Project Development Manual.

## 2.2.3. Changing the Configuration

You can make wholesale or incremental changes to the Linux kernel .config file by including a defconfig or by specifying configuration fragments in the SRC\_URI [[http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-SRC\\_URI](http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-SRC_URI)].

If you have a complete Linux kernel .config file you want to use, copy it to a directory named files, which must be in your layer's recipes-kernel/linux directory, and name the file "defconfig". Then, add the following lines to your linux-yocto .bbappend file in your layer:

```
FILESEXTRAPATHS_prepend := "${THISDIR}/files:"  
SRC_URI += "file://defconfig"
```

The SRC\_URI tells the build system how to search for the file, while the FILESEXTRAPATHS [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-FILESEXTRAPATHS>] extends the FILESPATH [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-FILESPATH>] variable (search directories) to include the files directory you created for the configuration changes.

Generally speaking, the preferred approach is to determine the incremental change you want to make and add that as a configuration fragment. For example, if you want to add support for a basic serial console, create a file named 8250.cfg in the files directory with the following content (without indentation):

```
CONFIG_SERIAL_8250=y
```

```
CONFIG_SERIAL_8250_CONSOLE=y
CONFIG_SERIAL_8250_PCI=y
CONFIG_SERIAL_8250_NR_UARTS=4
CONFIG_SERIAL_8250_RUNTIME_UARTS=4
CONFIG_SERIAL_CORE=y
CONFIG_SERIAL_CORE_CONSOLE=y
```

Next, include this configuration fragment and extend the FILESPATH variable in your .bbappend file:

```
FILESEXTRAPATHS_prepend := "${THISDIR}/files:"
SRC_URI += "file://8250.cfg"
```

The next time you run BitBake to build the Linux kernel, BitBake detects the change in the recipe and fetches and applies the new configuration before building the kernel.

For a detailed example showing how to configure the kernel, see the "Configuring the Kernel [<http://www.yoctoproject.org/docs/1.4.5/dev-manual/dev-manual.html#configuring-the-kernel>]" section in the Yocto Project Development Manual.

## 2.3. Using an Iterative Development Process

If you do not have existing patches or configuration files, you can iteratively generate them from within the BitBake build environment as described within this section. During an iterative workflow, running a previously completed BitBake task causes BitBake to invalidate the tasks that follow the completed task in the build sequence. Invalidated tasks rebuild the next time you run the build using BitBake.

As you read this section, be sure to substitute the name of your Linux kernel recipe for the term "linux-yocto".

### 2.3.1. "-dirty" String

If kernel images are being built with "-dirty" on the end of the version string, this simply means that modifications in the source directory have not been committed.

```
$ git status
```

You can use the above Git command to report modified, removed, or added files. You should commit those changes to the tree regardless of whether they will be saved, exported, or used. Once you commit the changes, you need to rebuild the kernel.

To force a pickup and commit of all such pending changes, enter the following:

```
$ git add .
$ git commit -s -a -m "getting rid of -dirty"
```

Next, rebuild the kernel.

### 2.3.2. Generating Configuration Files

You can manipulate the .config file used to build a linux-yocto recipe with the menuconfig command as follows:

```
$ bitbake linux-yocto -c menuconfig
```

This command starts the Linux kernel configuration tool, which allows you to prepare a new .config file for the build. When you exit the tool, be sure to save your changes at the prompt.

The resulting `.config` file is located in `${WORKDIR}` [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-WORKDIR>] under the `linux-${MACHINE}` [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-MACHINE>]-`${KTYPE}` [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-KTYPE>]-build directory. You can use the entire `.config` file as the `defconfig` file as described in the "Changing the Configuration" section.

A better method is to create a configuration fragment using the differences between two configuration files: one previously created and saved, and one freshly created using the `menuconfig` tool.

To create a configuration fragment using this method, follow these steps:

1. Complete a build at least through the kernel configuration task as follows:

```
$ bitbake linux-yocto -c kernel_configme -f
```

2. Copy and rename the resulting `.config` file (e.g. `config.orig`).

3. Run the `menuconfig` command:

```
$ bitbake linux-yocto -c menuconfig
```

4. Prepare a configuration fragment based on the differences between the two files.

Ultimately, the configuration fragment file needs to be a list of Linux kernel `CONFIG_` assignments. It cannot be in `diff` format. Here is an example of a command that creates your configuration fragment file. Regardless of the exact command you use, plan on reviewing the output as you can usually remove some of the defaults:

```
$ diff -Nurp config.orig .config | sed -n "s/^\+//p" > frag.cfg
```

See the "Changing the Configuration" section for information on how to use the output as a configuration fragment.

## Note

You can also use this method to create configuration fragments for a BSP. See the "BSP Descriptions" section for more information.

The kernel tools also provide configuration validation. You can use these tools to produce warnings for when a requested configuration does not appear in the final `.config` file or when you override a policy configuration in a hardware configuration fragment. Here is an example with some sample output of the command that runs these tools:

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

```
...
```

```
NOTE: validating kernel configuration
This BSP sets 3 invalid/obsolete kernel options.
These config options are not offered anywhere within this kernel.
The full list can be found in your kernel src dir at:
meta/cfg/standard/mybsp/invalid.cfg
```

```
This BSP sets 21 kernel options that are possibly non-hardware related.
The full list can be found in your kernel src dir at:
meta/cfg/standard/mybsp/specified_non_hdw.cfg
```

```
WARNING: There were 2 hardware options requested that do not
         have a corresponding value present in the final ".config" file.
```

This probably means you are not't getting the config you wanted. The full list can be found in your kernel src dir at: `meta/cfg/standard/mybsp/mismatch.cfg`

The output describes the various problems that you can encounter along with where to find the offending configuration items. You can use the information in the logs to adjust your configuration files and then repeat the `kernel_configme` and `kernel_configcheck` commands until they produce no warnings.

For more information on how to use the `menuconfig` tool, see the "Using `menuconfig` [<http://www.yoctoproject.org/docs/1.4.5/dev-manual/dev-manual.html#using-menuconfig>]" section in the Yocto Project Development Manual.

### 2.3.3. Modifying Source Code

You can experiment with source code changes and create a simple patch without leaving the BitBake environment. To get started, be sure to complete a build at least through the kernel configuration task:

```
$ bitbake linux-yocto -c kernel_configme -f
```

Taking this step ensures you have the sources prepared and the configuration completed. You can find the sources in the `${WORKDIR}` [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-WORKDIR>]/`linux` directory.

You can edit the sources as you would any other Linux source tree. However, keep in mind that you will lose changes if you trigger the `fetch` task for the recipe. You can avoid triggering this task by not issuing BitBake's `cleanall`, `cleansstate`, or `forced fetch` commands. Also, do not modify the recipe itself while working with temporary changes or BitBake might run the `fetch` command depending on the changes to the recipe.

To test your temporary changes, instruct BitBake to run the `compile` again. The `-f` option forces the command to run even though BitBake might think it has already done so:

```
$ bitbake linux-yocto -c compile -f
```

If the `compile` fails, you can update the sources and repeat the `compile`. Once compilation is successful, you can inspect and test the resulting build (i.e. kernel, modules, and so forth) from the `Build Directory` [<http://www.yoctoproject.org/docs/1.4.5/dev-manual/dev-manual.html#build-directory>]:

```
${WORKDIR}/linux-${MACHINE}-${KTYPE}-build
```

Alternatively, you can run the `deploy` command to place the kernel image in the `tmp/deploy/images` directory:

```
$ bitbake linux-yocto -c deploy
```

And, of course, you can perform the remaining installation and packaging steps by issuing:

```
$ bitbake linux-yocto
```

For rapid iterative development, the edit-compile-repeat loop described in this section is preferable to rebuilding the entire recipe because the installation and packaging tasks are very time consuming.

Once you are satisfied with your source code modifications, you can make them permanent by generating patches and applying them to the `SRC_URI` [<http://www.yoctoproject.org/docs/1.4.5/>

`ref-manual/ref-manual.html#var-SRC_URI`] statement as described in section "Applying Patches" section. If you are not familiar with generating patches, refer to the "Creating the Patch [<http://www.yoctoproject.org/docs/1.4.5/dev-manual/dev-manual.html#creating-the-patch>]" section in the Yocto Project Development Manual.

## 2.4. Working With Your Own Sources

If you cannot work with one of the Linux kernel versions supported by existing linux-yocto recipes, you can still make use of the Yocto Project Linux kernel tooling by working with your own sources. When you use your own sources, you will not be able to leverage the existing kernel Metadata [<http://www.yoctoproject.org/docs/1.4.5/dev-manual/dev-manual.html#metadata>] and stabilization work of the linux-yocto sources. However, you will be able to manage your own Metadata in the same format as the linux-yocto sources. Maintaining format compatibility facilitates converging with linux-yocto on a future, mutually-supported kernel version.

To help you use your own sources, the Yocto Project provides a linux-yocto custom recipe (`linux-yocto-custom.bb`) that uses `kernel.org` sources and the Yocto Project Linux kernel tools for managing kernel Metadata. You can find this recipe in the poky Git repository of the Yocto Project Source Repository [<http://git.yoctoproject.org>] at:

```
poky/meta-skeleton/recipes-kernel/linux/linux-yocto-custom.bb
```

Here are some basic steps you can use to work with your own sources:

1. Copy the `linux-yocto-custom.bb` recipe to your layer and give it a meaningful name. The name should include the version of the Linux kernel you are using (e.g. `linux-yocto-myproject_3.5.bb`, where "3.5" is the base version of the Linux kernel with which you would be working).
2. In the same directory inside your layer, create a matching directory to store your patches and configuration files (e.g. `linux-yocto-myproject`).
3. Edit the following variables in your recipe as appropriate for your project:
  - `SRC_URI` [[http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-SRC\\_URI](http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-SRC_URI)]: The `SRC_URI` should be a Git repository that uses one of the supported Git fetcher protocols (i.e. `file`, `git`, `http`, and so forth). The skeleton recipe provides an example `SRC_URI` as a syntax reference.
  - `LINUX_VERSION` [[http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-LINUX\\_VERSION](http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-LINUX_VERSION)]: The Linux kernel version you are using (e.g. "3.4").
  - `LINUX_VERSION_EXTENSION` [[http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-LINUX\\_VERSION\\_EXTENSION](http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-LINUX_VERSION_EXTENSION)]: The Linux kernel `CONFIG_LOCALVERSION` that is compiled into the resulting kernel and visible through the `uname` command.
  - `SRCREV` [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-SRCREV>]: The commit ID from which you want to build.
  - `PR` [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-PR>]: Treat this variable the same as you would in any other recipe. Increment the variable to indicate to the OpenEmbedded build system that the recipe has changed.
  - `PV` [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-PV>]: The default `PV` assignment is typically adequate. It combines the `LINUX_VERSION` with the Source Control Manager (SCM) revision as derived from the `SRCPV` [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-SRCPV>] variable. The combined results are a string with the following form:

```
3.4.11+git1+68a635bf8dfb64b02263c1ac80c948647cc76d5f_1+218bd8d2022b9852c60d32f0d770931e3
```

While lengthy, the extra verbosity in `PV` helps ensure you are using the exact sources from which you intend to build.

- `COMPATIBLE_MACHINE` [[http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-COMPATIBLE\\_MACHINE](http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-COMPATIBLE_MACHINE)]: A list of the machines supported by your new recipe. This variable in the example recipe is set by default to a regular expression that matches only the empty string, `"(^$)"`. This default setting triggers an explicit build failure. You must change it to match a list of the machines that your new recipe supports. For example, to support the `qemux86` and `qemux86-64` machines, use the following form:

```
COMPATIBLE_MACHINE = "qemux86|qemux86-64"
```

4. Provide further customizations to your recipe as needed just as you would customize an existing linux-yocto recipe. See the "Modifying an Existing Recipe" section for information.

## 2.5. Incorporating Out-of-Tree Modules

While it is always preferable to work with sources integrated into the Linux kernel sources, if you need an external kernel module, the `hello-mod.bb` recipe is available as a template from which you can create your own out-of-tree Linux kernel module recipe.

This template recipe is located in the poky Git repository of the Yocto Project Source Repository [<http://git.yoctoproject.org>] at:

```
poky/meta-skeleton/recipes-kernel/hello-mod/hello-mod_0.1.bb
```

To get started, copy this recipe to your layer and give it a meaningful name (e.g. `mymodule_1.0.bb`). In the same directory, create a directory named `files` where you can store any source files, patches, or other files necessary for building the module that do not come with the sources. Finally, update the recipe as appropriate for the module. Typically you will need to set the following variables:

- `DESCRIPTION` [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-DESCRIPTION>]
- `LICENSE*` [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-LICENSE>]
- `SRC_URI` [[http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-SRC\\_URI](http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-SRC_URI)]
- `PV` [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-PV>]

Depending on the build system used by the module sources, you might need to make some adjustments. For example, a typical module Makefile looks much like the one provided with the `hello-mod` template:

```
obj-m := hello.o

SRC := $(shell pwd)

all:
    $(MAKE) -C $(KERNEL_SRC) M=$(SRC)

modules_install:
    $(MAKE) -C $(KERNEL_SRC) M=$(SRC) modules_install
...
```

The important point to note here is the `KERNEL_SRC` [[http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-KERNEL\\_SRC](http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-KERNEL_SRC)] variable. The class `module.bbclass` sets this variable, as well as the `KERNEL_PATH` [[http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-KERNEL\\_PATH](http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-KERNEL_PATH)] variable to `${STAGING_KERNEL_DIR}` [[http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-STAGING\\_KERNEL\\_DIR](http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-STAGING_KERNEL_DIR)] with the necessary Linux kernel build information to build modules. If your module Makefile uses a different variable, you might want to override the `do_compile()` step, or create a patch to the Makefile to work with the more typical `KERNEL_SRC` or `KERNEL_PATH` variables.

After you have prepared your recipe, you will likely want to include the module in your images. To do this, see the documentation for the following variables in the Yocto Project Reference Manual and set one of them as appropriate in your machine configuration file:

- `MACHINE_ESSENTIAL_EXTRA_RDEPENDS` [[http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-MACHINE\\_ESSENTIAL\\_EXTRA\\_RDEPENDS](http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-MACHINE_ESSENTIAL_EXTRA_RDEPENDS)]
- `MACHINE_ESSENTIAL_EXTRA_RRECOMMENDS` [[http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-MACHINE\\_ESSENTIAL\\_EXTRA\\_RRECOMMENDS](http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-MACHINE_ESSENTIAL_EXTRA_RRECOMMENDS)]
- `MACHINE_EXTRA_RDEPENDS` [[http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-MACHINE\\_EXTRA\\_RDEPENDS](http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-MACHINE_EXTRA_RDEPENDS)]
- `MACHINE_EXTRA_RRECOMMENDS` [[http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-MACHINE\\_EXTRA\\_RRECOMMENDS](http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-MACHINE_EXTRA_RRECOMMENDS)]

modules are often not required for boot and can be excluded from certain build configurations. The following allows for the most flexibility:

```
MACHINE_EXTRA_RRECOMMENDS += "kernel-module-mymodule"
```

Where the value is derived by appending the module filename without the `.ko` extension to the string `"kernel-module-"`.

Because the variable is `RRECOMMENDS` [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-RRECOMMENDS>] and not a `RDEPENDS` [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-RDEPENDS>] variable, the build will not fail if this module is not available to include in the image.

## 2.6. Inspecting Changes and Commits

A common question when working with a kernel is: "What changes have been applied to this tree?" Rather than using `grep` across directories to see what has changed, you can use Git to inspect or search the kernel tree. Using Git is an efficient way to see what has changed in the tree.

### 2.6.1. What Changed in a Kernel?

Following are a few examples that show how to use Git commands to examine changes. These examples are by no means the only way to see changes.

#### Note

In the following examples, unless you provide a commit range, `kernel.org` history is blended with Yocto Project kernel changes. You can form ranges by using branch names from the kernel tree as the upper and lower commit markers with the Git commands. You can see the branch names through the web interface to the Yocto Project source repositories at <http://git.yoctoproject.org/cgit.cgi>.

To see a full range of the changes, use the `git whatchanged` command and specify a commit range for the branch (`<commit>..<commit>`).

Here is an example that looks at what has changed in the `emenlow` branch of the `linux-yocto-3.4` kernel. The lower commit range is the commit associated with the `standard/base` branch, while the upper commit range is the commit associated with the `standard/emenlow` branch.

```
$ git whatchanged origin/standard/base..origin/standard/emenlow
```

To see short, one line summaries of changes use the `git log` command:

```
$ git log --oneline origin/standard/base..origin/standard/emenlow
```

Use this command to see code differences for the changes:

```
$ git diff origin/standard/base..origin/standard/emenlow
```

Use this command to see the commit log messages and the text differences:

```
$ git show origin/standard/base..origin/standard/emenlow
```

Use this command to create individual patches for each change. Here is an example that that creates patch files for each commit and places them in your Documents directory:

```
$ git format-patch -o $HOME/Documents origin/standard/base..origin/standard/emenlow
```

## 2.6.2. Showing a Particular Feature or Branch Change

Tags in the Yocto Project kernel tree divide changes for significant features or branches. The `git show <tag>` command shows changes based on a tag. Here is an example that shows `systemtap` changes:

```
$ git show systemtap
```

You can use the `git branch --contains <tag>` command to show the branches that contain a particular feature. This command shows the branches that contain the `systemtap` feature:

```
$ git branch --contains systemtap
```

---

# Chapter 3. Working with Advanced Metadata

## 3.1. Overview

In addition to supporting configuration fragments and patches, the Yocto Project kernel tools also support rich Metadata [<http://www.yoctoproject.org/docs/1.4.5/dev-manual/dev-manual.html#metadata>] that you can use to define complex policies and Board Support Package (BSP) support. The purpose of the Metadata and the tools that manage it, known as the kern-tools (`kern-tools-native_git.bb`), is to help you manage the complexity of the configuration and sources used to support multiple BSPs and Linux kernel types.

## 3.2. Using Kernel Metadata in a Recipe

The kernel sources in the Yocto Project contain kernel Metadata, which is located in the meta branches of the kernel source Git repositories. This Metadata defines Board Support Packages (BSPs) that correspond to definitions in linux-yocto recipes for the same BSPs. A BSP consists of an aggregation of kernel policy and hardware-specific feature enablements. The BSP can be influenced from within the linux-yocto recipe.

### Note

Linux kernel source that contains kernel Metadata is said to be "linux-yocto style" kernel source. A Linux kernel recipe that inherits from the `linux-yocto.inc` include file is said to be a "linux-yocto style" recipe.

Every linux-yocto style recipe must define the `KMACHINE` [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-KMACHINE>] variable. This variable is typically set to the same value as the `MACHINE` [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-MACHINE>] variable, which is used by BitBake (e.g. "routerstationpro" or "fri2"). Multiple BSPs can reuse the same `KMACHINE` name if they are built using the same BSP description. The "fri2" and "fri2-noemgd" BSP combination in the meta-intel layer is a good example of two BSPs using the same `KMACHINE` value (i.e. "fri2"). See the BSP Descriptions section for more information.

The linux-yocto style recipes can optionally define the following variables:

```
KBRANCH [http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-KBRANCH]  
KERNEL_FEATURES [http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-KERNEL\_FEATURES]  
KBRANCH_DEFAULT [http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-KBRANCH\_DEFAULT]  
LINUX_KERNEL_TYPE [http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-LINUX\_KERNEL\_TYPE]
```

`KBRANCH_DEFAULT` defines the Linux kernel source repository's default branch to use to build the Linux kernel. The value is used as the default for `KBRANCH`, which can define an alternate branch typically with a machine override as follows:

```
KBRANCH_fri2 = "standard/fri2"
```

Unless you specify otherwise, `KBRANCH_DEFAULT` initializes to "master".

`LINUX_KERNEL_TYPE` defines the kernel type to be used in assembling the configuration. If you do not specify a `LINUX_KERNEL_TYPE`, it defaults to "standard". Together with `KMACHINE` [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-KMACHINE>], `LINUX_KERNEL_TYPE` defines the search arguments used by the kernel tools to find the appropriate description within the kernel Metadata with which to build out the sources and configuration. The linux-yocto recipes define "standard", "tiny", and "preempt-rt" kernel types. See the Kernel Types section for more information on kernel types.

During the build, the kern-tools search for the BSP description file that most closely matches the `KMACHINE` and `LINUX_KERNEL_TYPE` variables passed in from the recipe. The tools use the first BSP

description it finds that match both variables. If the tools cannot find a match, they issue a warning such as the following:

```
WARNING: Can't find any BSP hardware or required configuration fragments.
WARNING: Looked at meta/cfg/broken/fri2-broken/hdw_frgs.txt and
        meta/cfg/broken/fri2-broken/required_frgs.txt in directory:
        meta/cfg/broken/fri2-broken
```

In this example, `KMACHINE` was set to "fri2-broken" and `LINUX_KERNEL_TYPE` was set to "broken".

The tools first search for the `KMACHINE` and then for the `LINUX_KERNEL_TYPE`. If the tools cannot find a partial match, they will use the sources from the `KBRANCH` and any configuration specified in the `SRC_URI` [[http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-SRC\\_URI](http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-SRC_URI)].

You can use the `KERNEL_FEATURES` variable to include features (configuration fragments, patches, or both) that are not already included by the `KMACHINE` and `LINUX_KERNEL_TYPE` variable combination. For example, to include a feature specified as "features/netfilter.scc", specify:

```
KERNEL_FEATURES += "features/netfilter.scc"
```

To include a feature called "cfg/sound.scc" just for the `qemux86` machine, specify:

```
KERNEL_FEATURES_append_qemux86 = "cfg/sound.scc"
```

The value of the entries in `KERNEL_FEATURES` are dependent on their location within the kernel Metadata itself. The examples here are taken from the `linux-yocto-3.4` repository where "features" and "cfg" are subdirectories within the `meta/cfg/kernel-cache` directory. For more information, see the "Kernel Metadata Syntax" section.

## Note

The processing of these variables has evolved some between the 0.9 and 1.3 releases of the Yocto Project and associated `kern-tools` sources. The descriptions in this section are accurate for 1.3 and later releases of the Yocto Project.

## 3.3. Kernel Metadata Location

Kernel Metadata can be defined in either the kernel recipe (recipe-space) or in the kernel tree (in-tree). Where you choose to define the Metadata depends on what you want to do and how you intend to work. Regardless of where you define the kernel Metadata, the syntax used applies equally.

If you are unfamiliar with the Linux kernel and only wish to apply a configuration and possibly a couple of patches provided to you by others, the recipe-space method is recommended. This method is also a good approach if you are working with Linux kernel sources you do not control or if you just do not want to maintain a Linux kernel Git repository on your own. For partial information on how you can define kernel Metadata in the recipe-space, see the "Modifying an Existing Recipe" section.

Conversely, if you are actively developing a kernel and are already maintaining a Linux kernel Git repository of your own, you might find it more convenient to work with the kernel Metadata in the same repository as the Linux kernel sources. This method can make iterative development of the Linux kernel more efficient outside of the BitBake environment.

### 3.3.1. Recipe-Space Metadata

When stored in recipe-space, the kernel Metadata files reside in a directory hierarchy below `FILESEXTRAPATHS` [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-FILESEXTRAPATHS>]. For a `linux-yocto` recipe or for a Linux kernel recipe derived by copying and modifying `oe-core/meta-skeleton/recipes-kernel/linux/linux-yocto-custom.bb` to a recipe in your layer, `FILESEXTRAPATHS` is typically set to `${THISDIR}` [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-THISDIR>]/

`${PN}` [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-PN>]. See the "Modifying an Existing Recipe" section for more information.

Here is an example that shows a trivial tree of kernel Metadata stored in recipe-space within a BSP layer:

```
meta-my_bsp_layer/
  |-- recipes-kernel
      |-- linux
          |-- linux-yocto
              |-- bsp-standard.scc
              |-- bsp.cfg
              |-- standard.cfg
```

When the Metadata is stored in recipe-space, you must take steps to ensure BitBake has the necessary information to decide what files to fetch and when they need to be fetched again. It is only necessary to specify the `.scc` files on the `SRC_URI` [[http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-SRC\\_URI](http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-SRC_URI)]. BitBake parses them and fetches any files referenced in the `.scc` files by the `include`, `patch`, or `kconf` commands. Because of this, it is necessary to bump the recipe `PR` [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-PR>] value when changing the content of files not explicitly listed in the `SRC_URI`.

### 3.3.2. In-Tree Metadata

When stored in-tree, the kernel Metadata files reside in the `meta` directory of the Linux kernel sources. The `meta` directory can be present in the same repository branch as the sources, such as "master", or `meta` can be its own orphan branch.

#### Note

An orphan branch in Git is a branch with unique history and content to the other branches in the repository. Orphan branches are useful to track Metadata changes independently from the sources of the Linux kernel, while still keeping them together in the same repository. For the purposes of this document, we will discuss all in-tree Metadata as residing below the `meta/kernel-cache` directory.

Following is an example that shows how a trivial tree of Metadata is stored in a custom Linux kernel Git repository:

```
meta/
  |-- cfg
      |-- kernel-cache
          |-- bsp-standard.scc
          |-- bsp.cfg
          |-- standard.cfg
```

To use a branch different from where the sources reside, specify the branch in the `KMETA` variable in your Linux kernel recipe. Here is an example:

```
KMETA = "meta"
```

To use the same branch as the sources, set `KMETA` to an empty string:

```
KMETA = ""
```

If you are working with your own sources and want to create an orphan `meta` branch, use these commands from within your Linux kernel Git repository:

```
$ git checkout --orphan meta
$ git rm -rf .
$ git commit --allow-empty -m "Create orphan meta branch"
```

## 3.4. Kernel Metadata Syntax

The kernel Metadata consists of three primary types of files: scc<sup>1</sup> description files, configuration fragments, and patches. The scc files define variables and include or otherwise reference any of the three file types. The description files are used to aggregate all types of kernel Metadata into what ultimately describes the sources and the configuration required to build a Linux kernel tailored to a specific machine.

The scc description files are used to define two fundamental types of kernel Metadata:

- Features
- Board Support Packages (BSPs)

Features aggregate sources in the form of patches and configuration fragments into a modular reusable unit. You can use features to implement conceptually separate kernel Metadata descriptions such as pure configuration fragments, simple patches, complex features, and kernel types. Kernel types define general kernel features and policy to be reused in the BSPs.

BSPs define hardware-specific features and aggregate them with kernel types to form the final description of what will be assembled and built.

While the kernel Metadata syntax does not enforce any logical separation of configuration fragments, patches, features or kernel types, best practices dictate a logical separation of these types of Metadata. The following Metadata file hierarchy is recommended:

```
<base>/
  bsp/
  cfg/
  features/
  ktypes/
  patches/
```

The bsp directory contains the BSP descriptions. The remaining directories all contain "features". Separating bsp from the rest of the structure aids conceptualizing intended usage.

Use these guidelines to help place your scc description files within the structure:

- If your file contains only configuration fragments, place the file in the cfg directory.
- If your file contains only source-code fixes, place the file in the patches directory.
- If your file encapsulates a major feature, often combining sources and configurations, place the file in features directory.
- If your file aggregates non-hardware configuration and patches in order to define a base kernel policy or major kernel type to be reused across multiple BSPs, place the file in ktypes directory.

These distinctions can easily become blurred - especially as out-of-tree features slowly merge upstream over time. Also, remember that how the description files are placed is a purely logical organization and has no impact on the functionality of the kernel Metadata. There is no impact because all of cfg, features, patches, and ktypes, contain "features" as far as the kernel tools are concerned.

Paths used in kernel Metadata files are relative to <base>, which is either FILESEXTRAPATHS [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-FILESEXTRAPATHS>] if you

---

<sup>1</sup> scc stands for Series Configuration Control, but the naming has less significance in the current implementation of the tooling than it had in the past. Consider scc files to be description files.

are creating Metadata in recipe-space, or meta/cfg/kernel-cache/ if you are creating Metadata in-tree.

### 3.4.1. Configuration

The simplest unit of kernel Metadata is the configuration-only feature. This feature consists of one or more Linux kernel configuration parameters in a configuration fragment file (.cfg) and an .scc file that describes the fragment.

The Symmetric Multi-Processing (SMP) fragment included in the linux-yocto-3.4 Git repository consists of the following two files:

```
cfg/smp.scc:
    define KFEATURE_DESCRIPTION "Enable SMP"
    kconf hardware smp.cfg

cfg/smp.cfg:
    CONFIG_SMP=y
    CONFIG_SCHED_SMT=y
```

You can find information on configuration fragment files in the "Creating Configuration Fragments [<http://www.yoctoproject.org/docs/1.4.5/dev-manual/dev-manual.html#creating-config-fragments>]" section of the Yocto Project Development Manual and in the "Generating Configuration Files" section earlier in this manual.

KFEATURE\_DESCRIPTION [[http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-KFEATURE\\_DESCRIPTION](http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-KFEATURE_DESCRIPTION)] provides a short description of the fragment. Higher level kernel tools use this description.

The kconf command is used to include the actual configuration fragment in an .scc file, and the "hardware" keyword identifies the fragment as being hardware enabling, as opposed to general policy, which would use the "non-hardware" keyword. The distinction is made for the benefit of the configuration validation tools, which warn you if a hardware fragment overrides a policy set by a non-hardware fragment.

#### Note

The description file can include multiple kconf statements, one per fragment.

As described in the "Generating Configuration Files" section, you can use the following BitBake command to audit your configuration:

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

### 3.4.2. Patches

Patch descriptions are very similar to configuration fragment descriptions, which are described in the previous section. However, instead of a .cfg file, these descriptions work with source patches.

A typical patch includes a description file and the patch itself:

```
patches/mypatch.scc:
    patch mypatch.patch

patches/mypatch.patch:
    <typical-patch>
```

You can create the typical .patch file using `diff -Nurp` or `git format-patch`.

The description file can include multiple patch statements, one per patch.

### 3.4.3. Features

Features are complex kernel Metadata types that consist of configuration fragments (kconf), patches (patch), and possibly other feature description files (include).

Here is an example that shows a feature description file:

```
features/myfeature.scc
  define KFEATURE_DESCRIPTION "Enable myfeature"

  patch 0001-myfeature-core.patch
  patch 0002-myfeature-interface.patch

  include cfg/myfeature_dependency.scc
  kconf non-hardware myfeature.cfg
```

This example shows how the patch and kconf commands are used as well as how an additional feature description file is included.

Typically, features are less granular than configuration fragments and are more likely than configuration fragments and patches to be the types of things you want to specify in the `KERNEL_FEATURES` variable of the Linux kernel recipe. See the "Using Kernel Metadata in a Recipe" section earlier in the manual.

### 3.4.4. Kernel Types

A kernel type defines a high-level kernel policy by aggregating non-hardware configuration fragments with patches you want to use when building a Linux kernels of a specific type. Syntactically, kernel types are no different than features as described in the "Features" section. The `LINUX_KERNEL_TYPE` variable in the kernel recipe selects the kernel type. See the "Using Kernel Metadata in a Recipe" section for more information.

As an example, the `linux-yocto-3.4` tree defines three kernel types: "standard", "tiny", and "preempt-rt":

- "standard": Includes the generic Linux kernel policy of the Yocto Project linux-yocto kernel recipes. This policy includes, among other things, which file systems, networking options, core kernel features, and debugging and tracing options are supported.
- "preempt-rt": Applies the `PREEMPT_RT` patches and the configuration options required to build a real-time Linux kernel. This kernel type inherits from the "standard" kernel type.
- "tiny": Defines a bare minimum configuration meant to serve as a base for very small Linux kernels. The "tiny" kernel type is independent from the "standard" configuration. Although the "tiny" kernel type does not currently include any source changes, it might in the future.

The "standard" kernel type is defined by `standard.scc`:

```
# Include this kernel type fragment to get the standard features and
# configuration values.

# Include all standard features
include standard-nocfg.scc

kconf non-hardware standard.cfg

# individual cfg block section
include cfg/fs/devtmpfs.scc
include cfg/fs/debugfs.scc
include cfg/fs/btrfs.scc
include cfg/fs/ext2.scc
include cfg/fs/ext3.scc
```

```
include cfg/fs/ext4.scc

include cfg/net/ipv6.scc
include cfg/net/ip_nf.scc
include cfg/net/ip6_nf.scc
include cfg/net/bridge.scc
```

As with any .scc file, a kernel type definition can aggregate other .scc files with `include` commands. These definitions can also directly pull in configuration fragments and patches with the `kconf` and `patch` commands, respectively.

## Note

It is not strictly necessary to create a kernel type .scc file. The Board Support Package (BSP) file can implicitly define the kernel type using a `define KTYPE [http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-KTYPE] myktype` line. See the "BSP Descriptions" section for more information.

## 3.4.5. BSP Descriptions

BSP descriptions combine kernel types with hardware-specific features. The hardware-specific portion is typically defined independently, and then aggregated with each supported kernel type. Consider this simple BSP description that supports the "mybsp" machine:

```
mybsp.scc:
    define KMACHINE mybsp
    define KTYPE standard
    define KARCH i386

    kconf mybsp.cfg
```

Every BSP description should define the `KMACHINE` [http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-KMACHINE], `KTYPE` [http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-KTYPE], and `KARCH` [http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-KARCH] variables. These variables allow the OpenEmbedded build system to identify the description as meeting the criteria set by the recipe being built. This simple example supports the "mybsp" machine for the "standard" kernel and the "i386" architecture.

Be aware that a hard link between the `KTYPE` variable and a kernel type description file does not exist. Thus, if you do not have kernel types defined in your kernel Metadata, you only need to ensure that the kernel recipe's `LINUX_KERNEL_TYPE` [http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-LINUX\_KERNEL\_TYPE] variable and the `KTYPE` variable in the BSP description file match.

## Note

Future versions of the tooling make the specification of `KTYPE` in the BSP optional.

If you did want to separate your kernel policy from your hardware configuration, you could do so by specifying a kernel type, such as "standard" and including that description file in the BSP description file. See the "Kernel Types" section for more information.

You might also have multiple hardware configurations that you aggregate into a single hardware description file that you could include in the BSP description file, rather than referencing a single .cfg file. Consider the following:

```
mybsp.scc:
    define KMACHINE mybsp
    define KTYPE standard
    define KARCH i386

    include standard.scc
```

```
include mybsp-hw.scc
```

In the above example, `standard.scc` aggregates all the configuration fragments, patches, and features that make up your standard kernel policy whereas `mybsp-hw.scc` aggregates all those necessary to support the hardware available on the "mybsp" machine. For information on how to break a complete `.config` file into the various configuration fragments, see the "Generating Configuration Files" section.

Many real-world examples are more complex. Like any other `.scc` file, BSP descriptions can aggregate features. Consider the Fish River Island 2 (`fri2`) BSP definition from the `linux-yocto-3.4` Git repository:

```
fri2.scc:
  kconf hardware fri2.cfg

  include cfg/x86.scc
  include features/eg20t/eg20t.scc
  include cfg/dmaengine.scc
  include features/ericsson-3g/f5521gw.scc
  include features/power/intel.scc
  include cfg/efi.scc
  include features/usb/ehci-hcd.scc
  include features/usb/ohci-hcd.scc
  include features/iwlwifi/iwlwifi.scc
```

The `fri2.scc` description file includes a hardware configuration fragment (`fri2.cfg`) specific to the Fish River Island 2 BSP as well as several more general configuration fragments and features enabling hardware found on the machine. This description file is then included in each of the three "fri2" description files for the supported kernel types (i.e. "standard", "preempt-rt", and "tiny"). Consider the "fri2" description for the "standard" kernel type:

```
fri2-standard.scc:
  define KMACHINE fri2
  define KTYPE standard
  define KARCH i386

  include ktypes/standard/standard.scc
  branch fri2

  git merge emgd-1.14

  include fri2.scc

  # Extra fri2 configs above the minimal defined in fri2.scc
  include cfg/efi-ext.scc
  include features/drm-emgd/drm-emgd.scc
  include cfg/vesafb.scc

  # default policy for standard kernels
  include cfg/usb-mass-storage.scc
```

The `include` command midway through the file includes the `fri2.scc` description that defines all hardware enablements for the BSP that is common to all kernel types. Using this command significantly reduces duplication.

This "fri2" standard description introduces a few more variables and commands that are worth further discussion. Notice the `branch fri2` command, which creates a machine-specific branch into which source changes are applied. With this branch set up, the `git merge` command uses Git to merge in a feature branch named "emgd-1.14". You could also handle this with the `patch` command. However, for commonly used features such as this, feature branches are a convenient mechanism. See the "Feature Branches" section for more information.

Now consider the "fri2" description for the "tiny" kernel type:

```
fri2-tiny.scc:
    define KMACHINE fri2
    define KTYPE tiny
    define KARCH i386

    include ktypes/tiny/tiny.scc
    branch fri2

    include fri2.scc
```

As you might expect, the "tiny" description includes quite a bit less. In fact, it includes only the minimal policy defined by the "tiny" kernel type and the hardware-specific configuration required for booting the machine along with the most basic functionality of the system as defined in the base "fri2" description file.

Notice again the three critical variables: KMACHINE, KTYPE, and KARCH. Of these variables, only the KTYPE has changed. It is now set to "tiny".

## 3.5. Organizing Your Source

Many recipes based on the `linux-yocto-custom.bb` recipe use Linux kernel sources that have only a single branch - "master". This type of repository structure is fine for linear development supporting a single machine and architecture. However, if you work with multiple boards and architectures, a kernel source repository with multiple branches is more efficient. For example, suppose you need a series of patches for one board to boot. Sometimes, these patches are works-in-progress or fundamentally wrong, yet they are still necessary for specific boards. In these situations, you most likely do not want to include these patches in every kernel you build (i.e. have the patches as part of the lone "master" branch). It is situations like these that give rise to multiple branches used within a Linux kernel sources Git repository.

Repository organization strategies exist that maximize source reuse, remove redundancy, and logically order your changes. This section presents strategies for the following cases:

- Encapsulating patches in a feature description and only including the patches in the BSP descriptions of the applicable boards.
- Creating a machine branch in your kernel source repository and applying the patches on that branch only.
- Creating a feature branch in your kernel source repository and merging that branch into your BSP when needed.

The approach you take is entirely up to you and depends on what works best for your development model.

### 3.5.1. Encapsulating Patches

if you are reusing patches from an external tree and are not working on the patches, you might find the encapsulated feature to be appropriate. Given this scenario, you do not need to create any branches in the source repository. Rather, you just take the static patches you need and encapsulate them within a feature description. Once you have the feature description, you simply include that into the BSP description as described in the "BSP Descriptions" section.

You can find information on how to create patches and BSP descriptions in the "Patches" and "BSP Descriptions" sections.

### 3.5.2. Machine Branches

When you have multiple machines and architectures to support, or you are actively working on board support, it is more efficient to create branches in the repository based on individual machines. Having machine branches allows common source to remain in the "master" branch with any features specific

to a machine stored in the appropriate machine branch. This organization method frees you from continually reintegrating your patches into a feature.

Once you have a new branch, you can set up your kernel Metadata to use the branch a couple different ways. In the recipe, you can specify the new branch as the KBRANCH to use for the board as follows:

```
KBRANCH = "mynewbranch"
```

Another method is to use the branch command in the BSP description:

```
mybsp.scc:
    define KMACHINE mybsp
    define KTYPE standard
    define KARCH i386
    include standard.scc

    branch mynewbranch

    include mybsp-hw.scc
```

If you find yourself with numerous branches, you might consider using a hierarchical branching system similar to what the linux-yocto Linux kernel repositories use:

```
<common>/<kernel_type>/<machine>
```

If you had two kernel types, "standard" and "small" for instance, and three machines, the branches in your Git repository might look like this:

```
common/base
common/standard/base
common/standard/machine_a
common/standard/machine_b
common/standard/machine_c
common/small/base
common/small/machine_a
```

This organization can help clarify the branch relationships. In this case, `common/standard/machine_a` includes everything in `common/base` and `common/standard/base`. The "standard" and "small" branches add sources specific to those kernel types that for whatever reason are not appropriate for the other branches.

## Note

The "base" branches are an artifact of the way Git manages its data internally on the filesystem: Git will not allow you to use `common/standard` and `common/standard/machine_a` because it would have to create a file and a directory named "standard".

## 3.5.3. Feature Branches

When you are actively developing new features, it can be more efficient to work with that feature as a branch, rather than as a set of patches that have to be regularly updated. The Yocto Project Linux kernel tools provide for this with the `git merge` command.

To merge a feature branch into a BSP, insert the `git merge` command after any branch commands:

```
mybsp.scc:
    define KMACHINE mybsp
    define KTYPE standard
```

```
define KARCH i386
include standard.scc

branch mynewbranch
git merge myfeature

include mybsp-hw.scc
```

## 3.6. SCC Description File Reference

This section provides a brief reference for the commands you can use within an SCC description file (.scc):

- `branch [ref]`: Creates a new branch relative to the current branch (typically `${KTYPE}`) using the currently checked-out branch, or "ref" if specified.
- `define`: Defines variables, such as `KMACHINE`, `KTYPE`, `KARCH`, and `KFEATURE_DESCRIPTION`.
- `include SCC_FILE`: Includes an SCC file in the current file. The file is parsed as if you had inserted it inline.
- `kconf [hardware|non-hardware] CFG_FILE`: Queues a configuration fragment for merging into the final Linux `.config` file.
- `git merge GIT_BRANCH`: Merges the feature branch into the current branch.
- `patch PATCH_FILE`: Applies the patch to the current Git branch.

---

# Appendix A. Advanced Kernel Concepts

## A.1. Yocto Project Kernel Development and Maintenance

Kernels available through the Yocto Project, like other kernels, are based off the Linux kernel releases from <http://www.kernel.org>. At the beginning of a major development cycle, the Yocto Project team chooses its kernel based on factors such as release timing, the anticipated release timing of final upstream `kernel.org` versions, and Yocto Project feature requirements. Typically, the kernel chosen is in the final stages of development by the community. In other words, the kernel is in the release candidate or "rc" phase and not yet a final release. But, by being in the final stages of external development, the team knows that the `kernel.org` final release will clearly be within the early stages of the Yocto Project development window.

This balance allows the team to deliver the most up-to-date kernel possible, while still ensuring that the team has a stable official release for the baseline Linux kernel version.

The ultimate source for kernels available through the Yocto Project are released kernels from `kernel.org`. In addition to a foundational kernel from `kernel.org`, the kernels available contain a mix of important new mainline developments, non-mainline developments (when there is no alternative), Board Support Package (BSP) developments, and custom features. These additions result in a commercially released Yocto Project Linux kernel that caters to specific embedded designer needs for targeted hardware.

Once a kernel is officially released, the Yocto Project team goes into their next development cycle, or upward revision (uprev) cycle, while still continuing maintenance on the released kernel. It is important to note that the most sustainable and stable way to include feature development upstream is through a kernel uprev process. Back-porting hundreds of individual fixes and minor features from various kernel versions is not sustainable and can easily compromise quality.

During the uprev cycle, the Yocto Project team uses an ongoing analysis of kernel development, BSP support, and release timing to select the best possible `kernel.org` version. The team continually monitors community kernel development to look for significant features of interest. The team does consider back-porting large features if they have a significant advantage. User or community demand can also trigger a back-port or creation of new functionality in the Yocto Project baseline kernel during the uprev cycle.

Generally speaking, every new kernel both adds features and introduces new bugs. These consequences are the basic properties of upstream kernel development and are managed by the Yocto Project team's kernel strategy. It is the Yocto Project team's policy to not back-port minor features to the released kernel. They only consider back-porting significant technological jumps - and, that is done after a complete gap analysis. The reason for this policy is that back-porting any small to medium sized change from an evolving kernel can easily create mismatches, incompatibilities and very subtle errors.

These policies result in both a stable and a cutting edge kernel that mixes forward ports of existing features and significant and critical new functionality. Forward porting functionality in the kernels available through the Yocto Project kernel can be thought of as a "micro uprev." The many "micro uprevs" produce a kernel version with a mix of important new mainline, non-mainline, BSP developments and feature integrations. This kernel gives insight into new features and allows focused amounts of testing to be done on the kernel, which prevents surprises when selecting the next major uprev. The quality of these cutting edge kernels is evolving and the kernels are used in leading edge feature and BSP development.

## A.2. Kernel Architecture

This section describes the architecture of the kernels available through the Yocto Project and provides information on the mechanisms used to achieve that architecture.

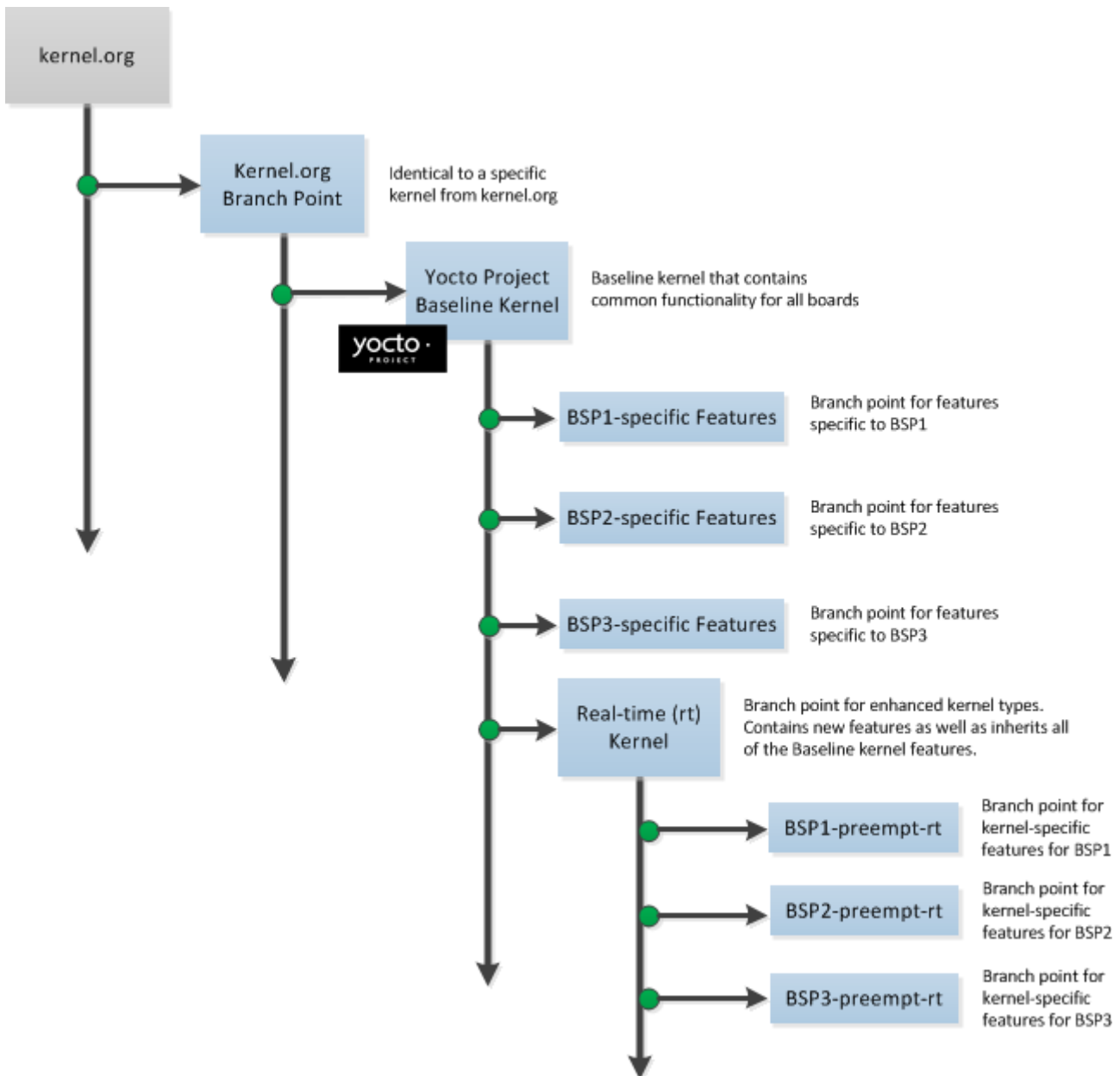
## A.2.1. Overview

As mentioned earlier, a key goal of the Yocto Project is to present the developer with a kernel that has a clear and continuous history that is visible to the user. The architecture and mechanisms used achieve that goal in a manner similar to the upstream `kernel.org`.

You can think of a Yocto Project kernel as consisting of a baseline Linux kernel with added features logically structured on top of the baseline. The features are tagged and organized by way of a branching strategy implemented by the source code manager (SCM) Git. For information on Git as applied to the Yocto Project, see the "Git [<http://www.yoctoproject.org/docs/1.4.5/dev-manual/dev-manual.html#git>]" section in the Yocto Project Development Manual.

The result is that the user has the ability to see the added features and the commits that make up those features. In addition to being able to see added features, the user can also view the history of what made up the baseline kernel.

The following illustration shows the conceptual Yocto Project kernel.



In the illustration, the "Kernel.org Branch Point" marks the specific spot (or release) from which the Yocto Project kernel is created. From this point "up" in the tree, features and differences are organized and tagged.

The "Yocto Project Baseline Kernel" contains functionality that is common to every kernel type and BSP that is organized further up the tree. Placing these common features in the tree this way means features do not have to be duplicated along individual branches of the structure.

From the Yocto Project Baseline Kernel, branch points represent specific functionality for individual BSPs as well as real-time kernels. The illustration represents this through three BSP-specific branches and a real-time kernel branch. Each branch represents some unique functionality for the BSP or a real-time kernel.

In this example structure, the real-time kernel branch has common features for all real-time kernels and contains more branches for individual BSP-specific real-time kernels. The illustration shows three branches as an example. Each branch points the way to specific, unique features for a respective real-time kernel as they apply to a given BSP.

The resulting tree structure presents a clear path of markers (or branches) to the developer that, for all practical purposes, is the kernel needed for any given set of requirements.

## A.2.2. Branching Strategy and Workflow

The Yocto Project team creates kernel branches at points where functionality is no longer shared and thus, needs to be isolated. For example, board-specific incompatibilities would require different functionality and would require a branch to separate the features. Likewise, for specific kernel features, the same branching strategy is used.

This branching strategy results in a tree that has features organized to be specific for particular functionality, single kernel types, or a subset of kernel types. This strategy also results in not having to store the same feature twice internally in the tree. Rather, the kernel team stores the unique differences required to apply the feature onto the kernel type in question.

### Note

The Yocto Project team strives to place features in the tree such that they can be shared by all boards and kernel types where possible. However, during development cycles or when large features are merged, the team cannot always follow this practice. In those cases, the team uses isolated branches to merge features.

BSP-specific code additions are handled in a similar manner to kernel-specific additions. Some BSPs only make sense given certain kernel types. So, for these types, the team creates branches off the end of that kernel type for all of the BSPs that are supported on that kernel type. From the perspective of the tools that create the BSP branch, the BSP is really no different than a feature. Consequently, the same branching strategy applies to BSPs as it does to features. So again, rather than store the BSP twice, the team only stores the unique differences for the BSP across the supported multiple kernels.

While this strategy can result in a tree with a significant number of branches, it is important to realize that from the developer's point of view, there is a linear path that travels from the baseline `kernel.org`, through a select group of features and ends with their BSP-specific commits. In other words, the divisions of the kernel are transparent and are not relevant to the developer on a day-to-day basis. From the developer's perspective, this path is the "master" branch. The developer does not need to be aware of the existence of any other branches at all. Of course, there is value in the existence of these branches in the tree, should a person decide to explore them. For example, a comparison between two BSPs at either the commit level or at the line-by-line code `diff` level is now a trivial operation.

Working with the kernel as a structured tree follows recognized community best practices. In particular, the kernel as shipped with the product, should be considered an "upstream source" and viewed as a series of historical and documented modifications (commits). These modifications represent the development and stabilization done by the Yocto Project kernel development team.

Because commits only change at significant release points in the product life cycle, developers can work on a branch created from the last relevant commit in the shipped Yocto Project kernel. As mentioned previously, the structure is transparent to the developer because the kernel tree is left in this state after cloning and building the kernel.

### A.2.3. Source Code Manager - Git

The Source Code Manager (SCM) is Git. This SCM is the obvious mechanism for meeting the previously mentioned goals. Not only is it the SCM for `kernel.org` but, Git continues to grow in popularity and supports many different work flows, front-ends and management techniques.

You can find documentation on Git at <http://git-scm.com/documentation>. You can also get an introduction to Git as it applies to the Yocto Project in the "Git [<http://www.yoctoproject.org/docs/1.4.5/dev-manual/dev-manual.html#git>]" section in the Yocto Project Development Manual. These referenced sections overview Git and describe a minimal set of commands that allows you to be functional using Git.

#### Note

You can use as much, or as little, of what Git has to offer to accomplish what you need for your project. You do not have to be a "Git Master" in order to use it with the Yocto Project.

---

# Appendix B. Kernel Maintenance

## B.1. Tree Construction

This section describes construction of the Yocto Project kernel source repositories as accomplished by the Yocto Project team to create kernel repositories. These kernel repositories are found under the heading "Yocto Linux Kernel" at <http://git.yoctoproject.org/cgiit.cgi> and can be shipped as part of a Yocto Project release. The team creates these repositories by compiling and executing the set of feature descriptions for every BSP and feature in the product. Those feature descriptions list all necessary patches, configuration, branching, tagging and feature divisions found in a kernel. Thus, the Yocto Project kernel repository (or tree) is built.

The existence of this tree allows you to access and clone a particular Yocto Project kernel repository and use it to build images based on their configurations and features.

You can find the files used to describe all the valid features and BSPs in the Yocto Project kernel in any clone of the Yocto Project kernel source repository Git tree. For example, the following command clones the Yocto Project baseline kernel that branched off of `linux.org` version 3.4:

```
$ git clone git://git.yoctoproject.org/linux-yocto-3.4
```

For another example of how to set up a local Git repository of the Yocto Project kernel files, see the "Yocto Project Kernel [<http://www.yoctoproject.org/docs/1.4.5/dev-manual/dev-manual.html#local-kernel-files>]" bulleted item in the Yocto Project Development Manual.

Once you have cloned the kernel Git repository on your local machine, you can switch to the meta branch within the repository. Here is an example that assumes the local Git repository for the kernel is in a top-level directory named `linux-yocto-3.4`:

```
$ cd ~/linux-yocto-3.4
$ git checkout -b meta origin/meta
```

Once you have checked out and switched to the meta branch, you can see a snapshot of all the kernel configuration and feature descriptions that are used to build that particular kernel repository. These descriptions are in the form of `.scc` files.

You should realize, however, that browsing your local kernel repository for feature descriptions and patches is not an effective way to determine what is in a particular kernel branch. Instead, you should use Git directly to discover the changes in a branch. Using Git is an efficient and flexible way to inspect changes to the kernel.

### Note

Ground up reconstruction of the complete kernel tree is an action only taken by the Yocto Project team during an active development cycle. When you create a clone of the kernel Git repository, you are simply making it efficiently available for building and development.

The following steps describe what happens when the Yocto Project Team constructs the Yocto Project kernel source Git repository (or tree) found at <http://git.yoctoproject.org/cgiit.cgi> given the introduction of a new top-level kernel feature or BSP. These are the actions that effectively create the tree that includes the new feature, patch or BSP:

1. A top-level kernel feature is passed to the kernel build subsystem. Normally, this feature is a BSP for a particular kernel type.
2. The file that describes the top-level feature is located by searching these system directories:
  - The in-tree kernel-cache directories, which are located in `meta/cfg/kernel-cache`
  - Areas pointed to by `SRC_URI` statements found in recipes

For a typical build, the target of the search is a feature description in an `.scc` file whose name follows this format:

```
<bsp_name>-<kernel_type>.scc
```

3. Once located, the feature description is either compiled into a simple script of actions, or into an existing equivalent script that is already part of the shipped kernel.
4. Extra features are appended to the top-level feature description. These features can come from the `KERNEL_FEATURES` [[http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-KERNEL\\_FEATURES](http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-KERNEL_FEATURES)] variable in recipes.
5. Each extra feature is located, compiled and appended to the script as described in step three.
6. The script is executed to produce a series of `meta-*` directories. These directories are descriptions of all the branches, tags, patches and configurations that need to be applied to the base Git repository to completely create the source (build) branch for the new BSP or feature.
7. The base repository is cloned, and the actions listed in the `meta-*` directories are applied to the tree.
8. The Git repository is left with the desired branch checked out and any required branching, patching and tagging has been performed.

The kernel tree is now ready for developer consumption to be locally cloned, configured, and built into a Yocto Project kernel specific to some target hardware.

## Note

The generated `meta-*` directories add to the kernel as shipped with the Yocto Project release. Any add-ons and configuration data are applied to the end of an existing branch. The full repository generation that is found in the official Yocto Project kernel repositories at <http://git.yoctoproject.org/cgit.cgi> is the combination of all supported boards and configurations.

The technique the Yocto Project team uses is flexible and allows for seamless blending of an immutable history with additional patches specific to a deployment. Any additions to the kernel become an integrated part of the branches.

## B.2. Build Strategy

Once a local Git repository of the Yocto Project kernel exists on a development system, you can consider the compilation phase of kernel development - building a kernel image. Some prerequisites exist that are validated by the build process before compilation starts:

- The `SRC_URI` [[http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-SRC\\_URI](http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-SRC_URI)] points to the kernel Git repository.
- A BSP build branch exists. This branch has the following form:

```
<kernel_type>/<bsp_name>
```

The OpenEmbedded build system makes sure these conditions exist before attempting compilation. Other means, however, do exist, such as bootstrapping a BSP.

Before building a kernel, the build process verifies the tree and configures the kernel by processing all of the configuration "fragments" specified by feature descriptions in the `.scc` files. As the features are compiled, associated kernel configuration fragments are noted and recorded in the `meta-*` series of directories in their compilation order. The fragments are migrated, pre-processed and passed to the Linux Kernel Configuration subsystem (`lkc`) as raw input in the form of a `.config` file. The `lkc` uses its own internal dependency constraints to do the final processing of that information and generates the final `.config` file that is used during compilation.

Using the board's architecture and other relevant values from the board's template, kernel compilation is started and a kernel image is produced.

The other thing that you notice once you configure a kernel is that the build process generates a build tree that is separate from your kernel's local Git source repository tree. This build tree has a name that uses the following form, where `{MACHINE}` is the metadata name of the machine (BSP) and "kernel\_type" is one of the Yocto Project supported kernel types (e.g. "standard"):

```
linux-{MACHINE}-<kernel_type>-build
```

The existing support in the `kernel.org` tree achieves this default functionality.

This behavior means that all the generated files for a particular machine or BSP are now in the build tree directory. The files include the final `.config` file, all the `.o` files, the `.a` files, and so forth. Since each machine or BSP has its own separate Build Directory [<http://www.yoctoproject.org/docs/1.4.5/dev-manual/dev-manual.html#build-directory>] in its own separate branch of the Git repository, you can easily switch between different builds.

---

# Appendix C. Kernel Development

## FAQ

### C.1. How do I use my own Linux kernel .config file?

Refer to the "Changing the Configuration" section for information.

### C.2. How do I create configuration fragments?

Refer to the "Generating Configuration Files" section for information.

### C.3. How do I use my own Linux kernel sources?

Refer to the "Working With Your Own Sources" section for information.

### C.4. How do I install/not-install the kernel image on the rootfs?

The kernel image (e.g. `vmlinuz`) is provided by the `kernel-image` package. Image recipes depend on `kernel-base`. To specify whether or not the kernel image is installed in the generated root filesystem, override `RDEPENDS_kernel-base` to include or not include "kernel-image".

See the "Using `.bbappend` Files [<http://www.yoctoproject.org/docs/1.4.5/dev-manual/dev-manual.html#using-bbappend-files>]" section in the Yocto Project Development Manual for information on how to use an append file to override metadata.

### C.5. How do I install a specific kernel module?

Linux kernel modules are packaged individually. To ensure a specific kernel module is included in an image, include it in the appropriate machine `RRECOMMENDS` [<http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-RRECOMMENDS>] variable.

These other variables are useful for installing specific modules:

```
MACHINE_ESSENTIAL_EXTRA_RDEPENDS [http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-MACHINE\_ESSENTIAL\_EXTRA\_RDEPENDS]  
MACHINE_ESSENTIAL_EXTRA_RRECOMMENDS [http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-MACHINE\_ESSENTIAL\_EXTRA\_RRECOMMENDS]  
MACHINE_EXTRA_RDEPENDS [http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-MACHINE\_EXTRA\_RDEPENDS]  
MACHINE_EXTRA_RRECOMMENDS [http://www.yoctoproject.org/docs/1.4.5/ref-manual/ref-manual.html#var-MACHINE\_EXTRA\_RRECOMMENDS]
```

For example, set the following in the `qemux86.conf` file to include the `ab123` kernel modules with images built for the `qemux86` machine:

```
MACHINE_EXTRA_RRECOMMENDS += "kernel-module-ab123"
```

For more information, see the "Incorporating Out-of-Tree Modules" section.

### C.6. How do I change the Linux kernel command line?

The Linux kernel command line is typically specified in the machine config using the `APPEND` variable. For example, you can add some helpful debug information doing the following:

```
APPEND += "printk.time=y initcall_debug debug"
```