Creating a Custom Embedded Linux Distribution Using the Yocto Project

Part 2

Building an image, Layers, Images, Build an application

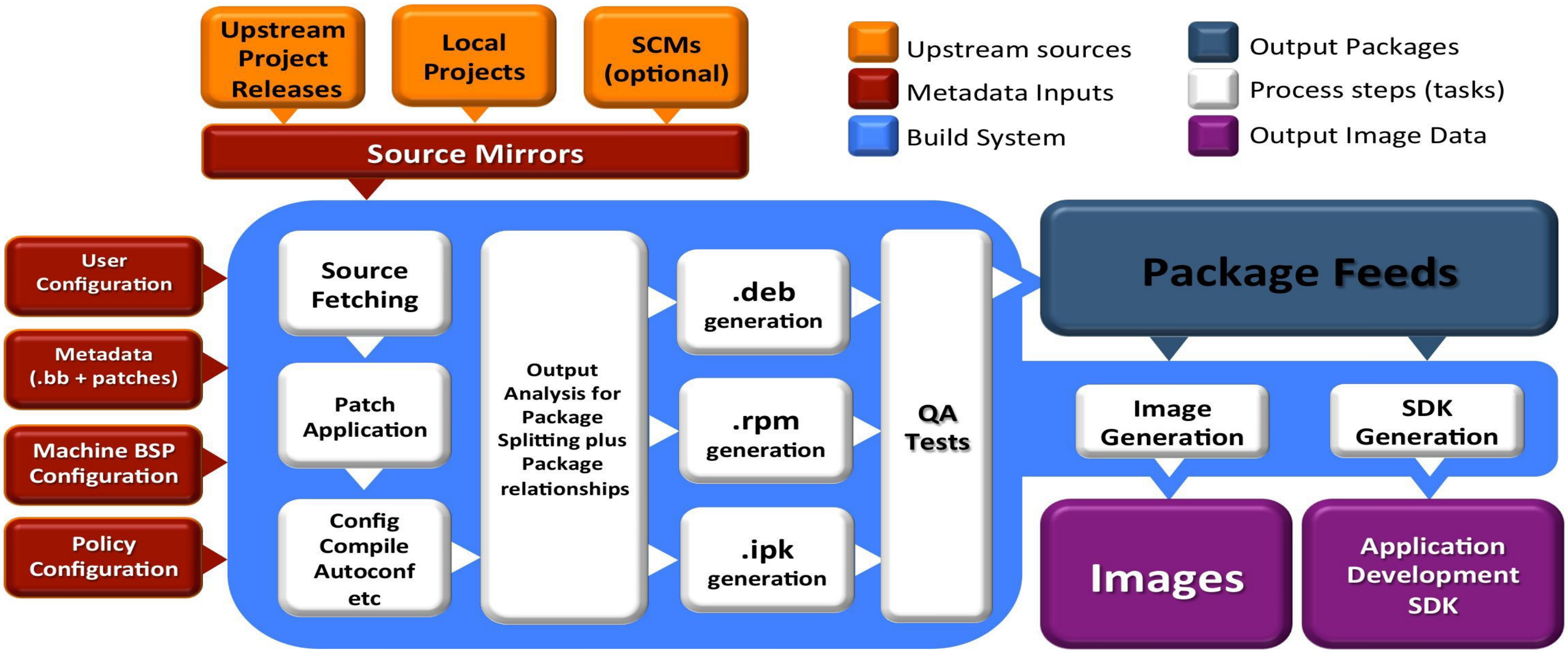
This section will introduce the concept of building an initial system image

BUILDING A FULL EMBEDDED IMAGE WITH YOCTO

Quick Start Guide in one Slide

1. **Download Yocto Project sources:**
   - `$ mkdir yocto; cd yocto`
   - `$ git clone -b kirkstone git://git.yoctoproject.org/poky.git`
2. **Build one of the reference Linux distributions:**
   - `$ source poky/oe-init-build-env mybuild`
   - **Check/Edit '`conf/local.conf`' for sanity (e.g., modify MACHINE = "qemux86-64" or MACHINE = "qemuarm64")**
3. **Build your image:**
   - `mybuild$ bitbake -k core-image-minimal`
4. **Run the image under emulation:**
   - `mybuild$ runqemu qemux86-64`

Build System Workflow



Setting up a Build Directory

- **Start by setting up a build directory**
  - Local configuration
  - Temporary build artifacts
- `$ source ./poky/oe-init-build-env mybuild`
  - Replace *mybuild* with whatever directory name you want to use for your project
- **You need to re-run this script in any new terminal you start (and don't forget the project directory)**

Host System Layout

```
$HOME/yocto/
|--build          (or whatever name you choose)
                  Project build directory
|--downloads      (DL_DIR)
                  Downloaded source cache
|--poky           (Do Not Modify anything in here*)
                  Poky, bitbake, scripts, oe-core, metadata
|--sstate-cache   (SSTATE_DIR)
                  Binary build cache
```

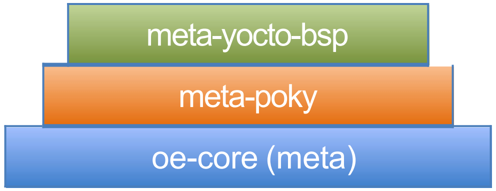
*** We will cover how to use layers to make changes later**

Build Directory Layout

```
$HOME/yocto/build/
|bitbake.lock
|--cache/                     (Bitbake cache files)
|--conf/
|   |--bblayers.conf          (Bitbake layers)
|   |--local.conf             (Local configuration)
|   |--site.conf              (Optional site configuration)
|--tmp/                       (Build artifacts)
```

- **Note: A few files have been items omitted to simplify the presentation on this slide**

Poky Layout



meta-yocto-bsp

meta-poky

oe-core (meta)

```
$HOME/yocto/poky/
|LICENSE
|README
|README.hardware
|--bitbake/                    (The build tool)
|--documentation/
|--meta/                       (oe-core)
|--meta-poky/                  (Poky metadata)
|--meta-yocto-bsp/             (Yocto reference BSPs)
|--oe-init-build-env           (Project setup script)
|--scripts/                    (Scripts and utilities)
```

- **Note: A few files have been items omitted to simplify the presentation on this slide**

Building a Linux Image

- **Create a project directory using:**
  - `$ source oe-init-build-env [build-dir]`
- **Configure build by editing ‘local.conf’**
  - `$ nano $HOME/yocto/build/conf/local.conf`
  - Select appropriate MACHINE type
  - Set shared downloads directory (DL_DIR)
  - Set shared state directory (SSTATE_DIR)
- **Build your selected image**
  - `$ bitbake -k core-image-minimal`

- **(Detailed steps follow…)**

Update Build Configuration

- **Set appropriate MACHINE, DL_DIR and SSTATE_DIR**
- **Add the following to the bottom of ‘conf/local.conf’**

```
MACHINE = "qemuarm64"
DL_DIR = "${TOPDIR}/../downloads"
SSTATE_DIR = "${TOPDIR}/../sstate-cache/${MACHINE}"
```

- **Notice how you can use variables in setting these values**

Building an Embedded Image

- **Choose from one of the available images**
  - This builds an entire embedded Linux distribution
- **The following builds a minimal embedded target**
  - `$ bitbake -k core-image-minimal`
- **On a fast computer the first build may take one or two hours, on a slow machine multiple...**
- **The next time you build it (with no changes) it may take as little as 5 mins**
  - Due to the shared state cache

Booting Your Image with QEMU

- **The *runqemu* script is used to boot the image with QEMU**
- **It auto-detects settings as much as possible, enabling the following command to boot our reference images:**
  - `$ runqemu qemuarm64 [nographic]`
  - (replace qemuarm64 with your value of MACHINE)
- **Using *nographic* disables the video console**
  - E.g., if using a non-graphical session (`ssh`)
- **Your QEMU instance should boot**
- **Quit by closing the QEMU window**
  - Alternatively, you can kill all the processes if something goes wrong
  - `$ killall qemu-system-aarch64`

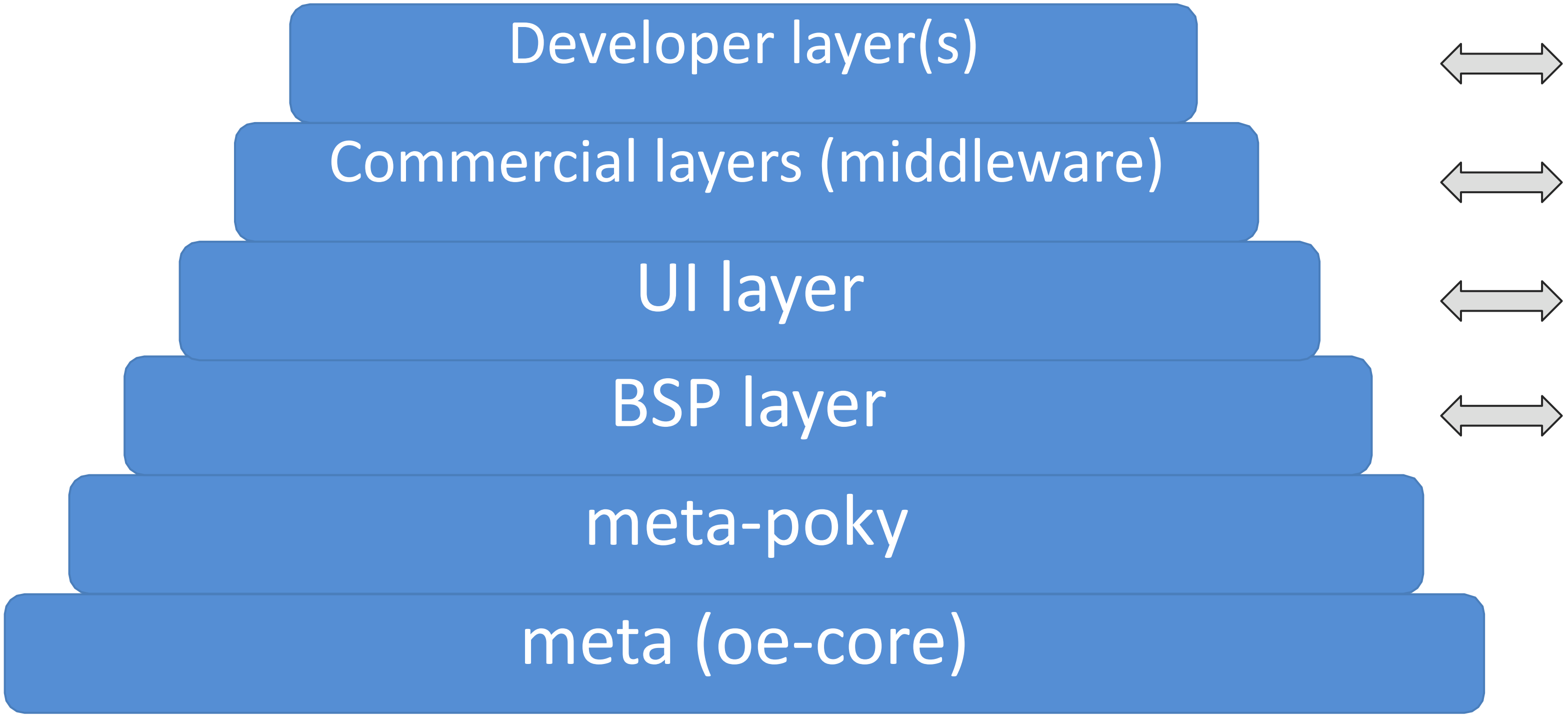
This section will introduce the concept of layers and how important they are in the overall build architecture

LAYERS

Layers

- **Metadata is provided in a series of layers which allow you to override any value without editing the originally provided files**
- **A layer is a logical collection of metadata in the form of recipes**
  - A layer is used to represent oe-core, a Board Support Package (BSP), an application stack, and your new code
- **All layers have a priority and can override policy, metadata and config settings of layers with a lesser priority**

Layer Hierarchy



Board Support Packages

- **BSPs are layers to enable support for specific hardware platforms**
- **Defines machine configuration variables for the board (MACHINE)**
- **Adds machine-specific recipes and customizations**
  - Boot loader
  - Kernel config
  - Graphics drivers (e.g, Xorg)
  - Additional recipes to support hardware features

Notes on using Layers

- When doing development with Yocto, do not edit files within the Poky source tree
- Use a new custom layer for modularity and maintainability
- Layers also allow you to easily port from one version of Yocto/Poky to the next version

Check Existing Layers

- **Before creating a new layer, you should be sure someone has not already created a layer containing the metadata you need**
- **You can see the OpenEmbedded Metadata Index for a list of layers that can be used in the Yocto Project**
  - `https://layers.openembedded.org/`
- **You could find a layer that is identical or close to what you need**

Creating a Custom Layer

- **Layers can be created manually**
  - They all start with “meta-” by convention
- **Be sure to create the directory in an area not associated with the cloned poky repository**
- **Inside your new layer folder, you need to create a ‘conf/layer.conf’ file**
  - It is easiest to take an existing layer configuration file and copy that to your layer’s conf directory and then modify the file as needed.
  - The ‘`meta-yocto-bsp/conf/layer.conf`’ file demonstrates the required syntax

Creating a Custom Layer

- **However, using the bitbake-layers tool is easier**

```
$ cd ~/yocto/
$ yocto$ bitbake-layers create-layer meta-mylayer
```

- **This will create ‘meta-mylayer’ in the current directory**

The New Custom Layer Layout

```
$HOME/yocto/meta-mylayer/
|COPYING.MIT                  (The license file)
|README                       (Starting point for README)
|--conf/
|  |--layer.conf              (Layer configuration file)
|--recipes-example/           (A group of recipes)
|  |--example/                (The example package)
|  |  |example_0.1.bb         (The example recipe)
```

The layer.conf File

```
# We have a conf and classes directory, add to BBPATH
BBPATH .= ":${LAYERDIR}"

# We have recipes-* directories, add to BBFILES
BBFILES += "${LAYERDIR}/recipes-*/*/*.bb \
            ${LAYERDIR}/recipes-*/*/*.bbappend"

BBFILE_COLLECTIONS += "mylayer"
BBFILE_PATTERN_mylayer = "^${LAYERDIR}/"
BBFILE_PRIORITY_mylayer = "6"

LAYERDEPENDS_mylayer = "core"
LAYERSERIES_COMPAT_mylayer = ”kirkstone"
```

Adding the Layer to your Build

- **Layers are added to your build by inserting them into the BBLAYERS variable within your 'bblayers.conf' file**
  - `$HOME/yocto/build/conf/bblayers.conf`

```
BBLAYERS ?= "                                \
       ${HOME}/yocto/poky/meta               \
       ${HOME}/yocto/poky/meta-poky          \
       ${HOME}/yocto/poky/meta-yocto-bsp     \
       ${HOME}/yocto/meta-mylayer            \
       "
```

Adding the Layer to your Build

- Once again, using the bitbake-layers tool is easier
  - `build$ bitbake-layers add-layer $HOME/yocto/meta-mylayer/`
- Check the resulting layer configuration:
  - `$ bitbake-layers show-layers`
- To remove a layer, you can either manually edit the 'bblayers.conf' file or use the bitbake-layers tool
  - `build$ bitbake-layers remove-layer mylayer`
- Explore the bitbake-layers tool with:
  - `$ bitbake-layers --help`

Build Your New Recipe

- **You can now build the new recipe**
  - `$ bitbake example`
- **This will now build the 'example_0.1.bb' recipe**
  - Which is found in `meta-mylayer/recipes-example/example/example_0.1.bb`

This section will introduce the concept of images – recipes which build embedded system images

IMAGES

What is an Image?

- **Building an image creates an entire Linux distribution from source**
  - Compiler, tools, libraries
  - BSP: Bootloader, Kernel
  - Root filesystem:
  - Base OS
  - Services
  - Applications
  - etc.

Available Images

- **The OpenEmbedded build system provides several example images to satisfy different needs**
- **When you issue the *bitbake* command you provide a "top-level" recipe**
  - That essentially begins the build for the type of image you want
- **Display the list of directories within the source directory that contain image recipe files:**
  - `$ ls meta*/recipes*/images/*.bb`

Extending an Image

- **You often need to create your own image recipe in order to add new packages or functionality**
- **With Yocto/OpenEmbedded it is always preferable to extend an existing recipe or inherit a class**
  - The simplest way is to inherit the ‘core-image’ bbclass
  - You add packages to the image by adding them to IMAGE_INSTALL

A Simple Image Recipe

- **Create an ‘images’ directory**
  - `$ mkdir -p ${HOME}/yocto/meta-mylayer/recipes-core/images`
- **Create the image recipe**
  - `$ nano ${HOME}/yocto/meta-mylayer/recipes-core/images/mylayer-image.bb`

A Simple Image Recipe

```
DESCRIPTION = "A core image for mylayer"
LICENSE = "MIT"

# Core files for basic console boot
IMAGE_INSTALL = "packagegroup-core-boot"

# Add our desired packages
IMAGE_INSTALL += "psplash dropbear"

inherit core-image

IMAGE_ROOTFS_SIZE ?= "8192"
```

Build and Boot Your Custom Image

- **Make sure your layer is added to BBLAYERS in ‘bblayers.conf’**
  - (We already did this step in a previous section manually and with bitbake-layers add-layer)
- **Build your custom image:**
  - `$ bitbake mylayer-image`
  - (If your SSTATE_DIR is configured correctly from a previous build this should be quick)
- **Boot the image with QEMU:**
  - `$ runqemu qemuarm64 tmp/deploy/images/qemuarm64/mylayer-image-qemuarm64.ext4 [nographic]`

Build and Boot Your Custom Image

- Verify that dropbear ssh server is present
  - `$ which dropbear`
- If you used the graphical invocation of QEMU, you will see the splash screen on boot

Adding a "hello world" application to our custom image

BUILD AN APPLICATION

Building an Application

- **General procedure:**
  - Write the hello world application (hello.c)
  - Create a recipe for the hello world application
  - Modify the image recipe to add the hello world application to your image
- **What follows is the example of a simple one C file application**
  - Building a more complicated recipe from a tarball would specify how to find the upstream source with the SRC_URI

Add Application Code

- For a simple one C file package, you can add the hello world application source to a directory called *files* in the *hello* package directory

  -
    ```
    $ mkdir -p ${HOME}/yocto/meta-mylayer/recipes-core/hello/files
    ```
- Create the 'hello.c' file

  -
    ```
    $ nano ${HOME}/yocto/meta-mylayer/recipes-core/hello/files/hello.c
    ```

```
#include <stdio.h>

int main(int argc, char **argv) {
    printf("Hello World\n");  return 0;
}
```

Add Application Recipe

- **Write the hello world recipe**
  - `$ nano ${HOME}/yocto/meta-mylayer/recipes-core/hello/files/hello_0.1.bb`

```
DESCRIPTION = "Hello World example"
LICENSE = "MIT"
LIC_FILES_CHKSUM =
"file://${COREBASE}/meta/COPYING.MIT;md5=3da9cfbcb788c80a0384361b4de20420"
S = "${WORKDIR}"
SRC_URI = "file://hello.c"

do_compile() {
     ${CC} ${CFLAGS} ${LDFLAGS} hello.c -o hello
}
```

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Add Application Recipe

- **Write the hello world recipe**
  - `$ nano ${HOME}/yocto/meta-mylayer/recipes-core/hello/files/hello_0.1.bb`

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

Add Application to the Image

- **Modify the image recipe to add the hello world application to your image**

```
DESCRIPTION = "A core image for YPDD"
LICENSE = "MIT"
# Core files for basic console boot
IMAGE_INSTALL = "packagegroup-core-boot"

# Add our desired packages
IMAGE_INSTALL += "psplash dropbear hello"

inherit core-image

IMAGE_ROOTFS_SIZE ?= "8192"
```

Build and Test Application

- **Now (re)build your image recipe**
  - $ bitbake mylayer-image
  - `'hello_1.0.bb'` will be processed because it is in your custom layer and referenced in your image recipe
- **Boot your image using *runqemu*, as before:**

  -
    ```
    $ runqemu qemuarm64
    tmp/deploy/images/qemuarm64/mylayer-image-
    qemuarm64.ext4 [nographic]
    ```
- **You should be able to type “hello” at the command line and see “Hello World”**

Common Gotchas When Getting Started

- **Working behind a network proxy?**
  - Please follow this guide: `https://wiki.yoctoproject.org/wiki/Working_Behind_a_Network_Proxy`
- **Do not try to re-use the same shell environment when moving between copies of the build system**
  - `oe-init-build-env` script appends to your $PATH, its results are cumulative and can cause unpredictable build errors
- **Do not try to share *sstate-cache* between hosts running different Linux distros even if they say it works**