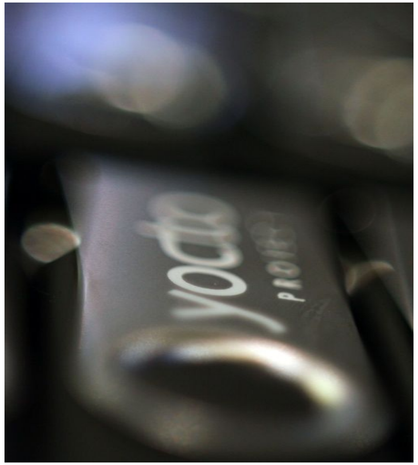
E-ALE ELC 2018

Learn Bitbake with Yocto Project



Tom King
Behan Webster
The Linux Foundation
Mar 15, 2018

The URL for this presentation

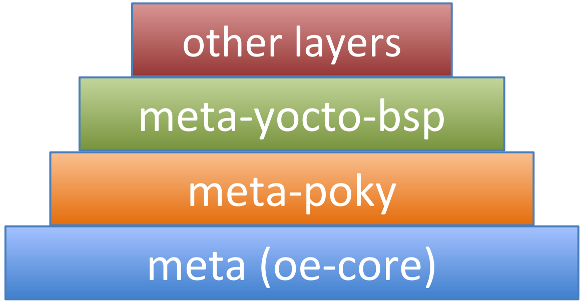
https://goo.gl/RcmEqL

Yocto/Openembedded Terms

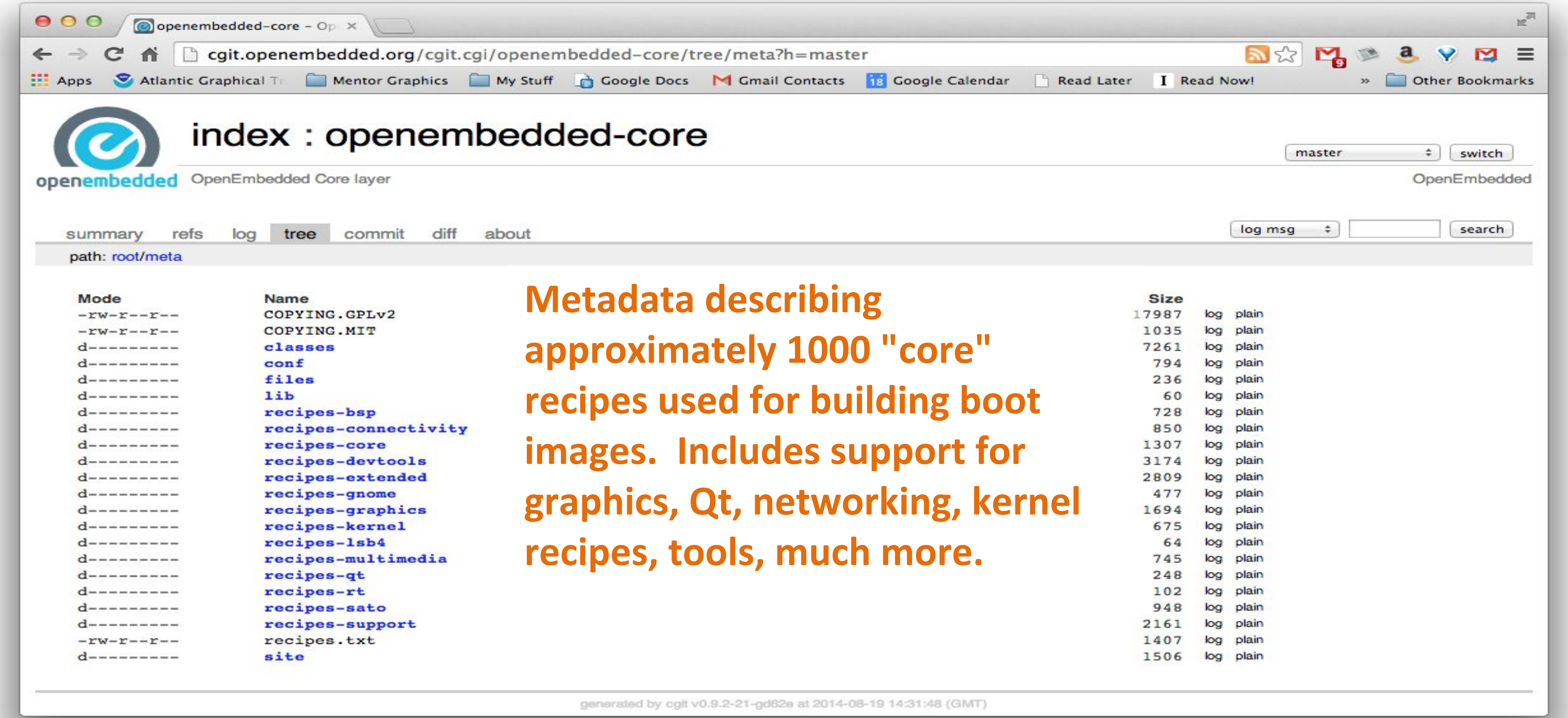
- **Yocto Project** is a large collaboration project
- **OpenEmbedded** is providing most metadata
- **Bitbake** is the build tool
- **Poky** is the Yocto Project's reference distribution
  - Poky contains a version of bitbake and oe-core from which you can start your project

Yocto Project Overview

- **Collection of tools and methods enabling**
  - Rapid evaluation of embedded Linux on many popular off-the-shelf boards
  - Easy customization of distribution characteristics
- **Supports x86, ARM, MIPS, Power**
- **Based on technology from the OpenEmbedded Project**
- **Layer architecture allows for easy re-use of code**



Yocto is based on OpenEmbedded-core



cgit.openembedded.org/cgit.cgi/openembedded-core/tree/meta?h=master

index : openembedded-core

OpenEmbedded Core layer

path: root/meta

```
Mode          Name                    Size
-rw-r--r--    COPYING.GPLv2          17987  log  plain
-rw-r--r--    COPYING.MIT             1035  log  plain
d---------    classes                 7261  log  plain
d---------    conf                     794  log  plain
d---------    files                    236  log  plain
d---------    lib                       60  log  plain
d---------    recipes-bsp              728  log  plain
d---------    recipes-connectivity     850  log  plain
d---------    recipes-core            1307  log  plain
d---------    recipes-devtools        3174  log  plain
d---------    recipes-extended        2809  log  plain
d---------    recipes-gnome            477  log  plain
d---------    recipes-graphics        1694  log  plain
d---------    recipes-kernel           675  log  plain
d---------    recipes-lsb4              64  log  plain
d---------    recipes-multimedia       745  log  plain
d---------    recipes-qt               248  log  plain
d---------    recipes-rt               102  log  plain
d---------    recipes-sato             948  log  plain
d---------    recipes-support         2161  log  plain
-rw-r--r--    recipes.txt             1407  log  plain
d---------    site                    1506  log  plain
```

generated by cgit v0.9.2-21-gd62e at 2014-08-19 14:31:48 (GMT)

Metadata describing approximately 1000 "core" recipes used for building boot images. Includes support for graphics, Qt, networking, kernel recipes, tools, much more.

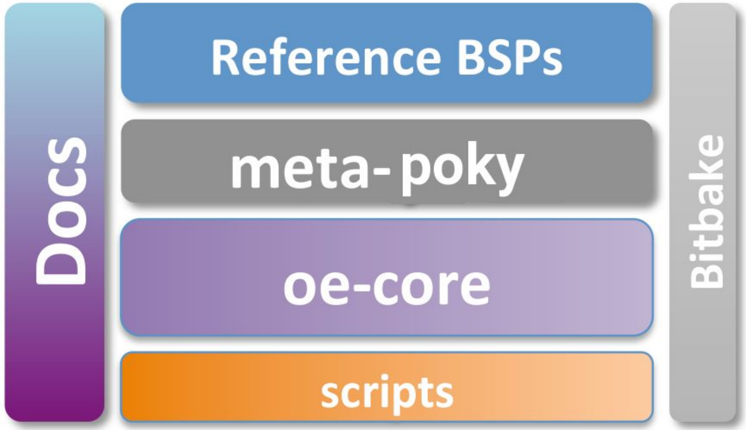
What is Bitbake?

- **Bitbake**
  - Powerful and flexible build engine (Python)
  - Reads metadata
  - Determines dependencies
  - Schedules tasks

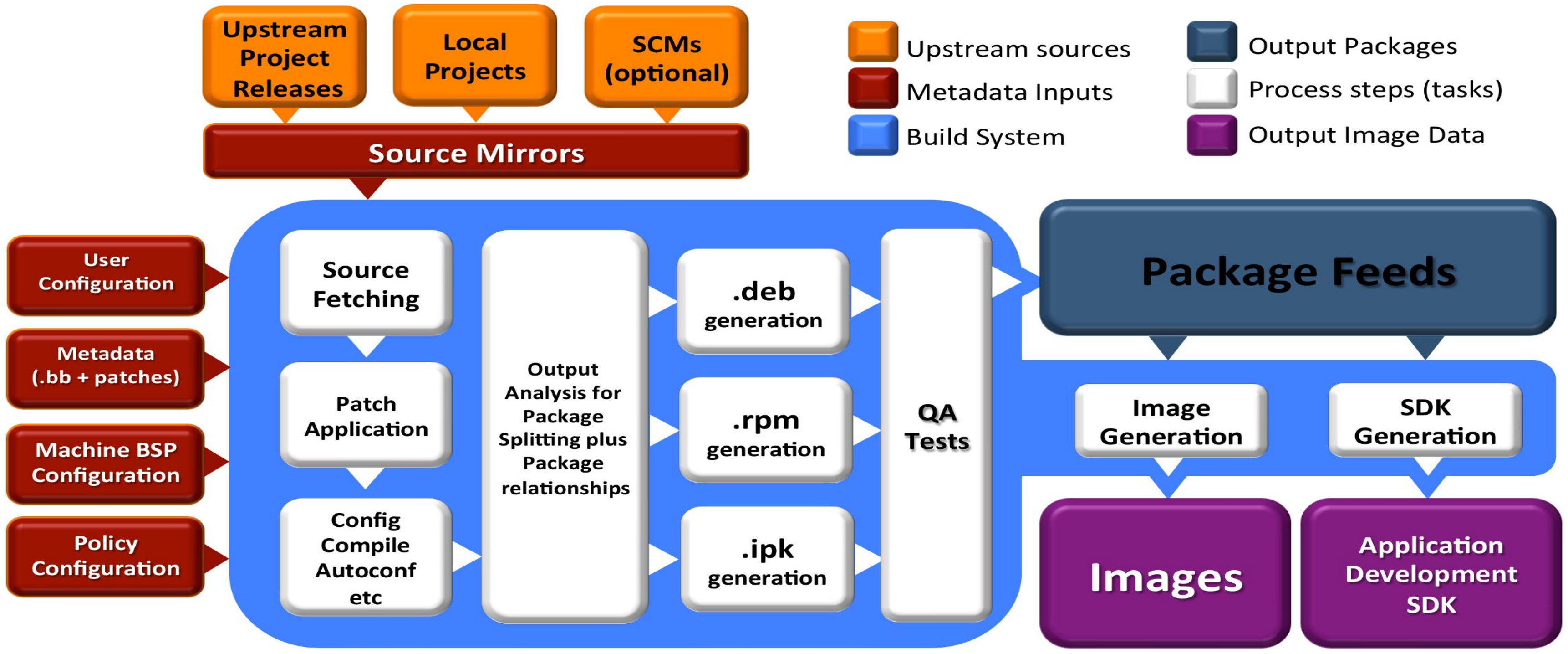
Metadata – a structured collection of "recipes" which tell BitBake what to build, organized in layers

Poky Reference Distro

- **Contains core components**
  - Bitbake tool: A python-based build engine
  - Build scripts (infrastructure)
  - Foundation package recipes (**oe-core**)
  - meta-poky (Contains distribution policy)
  - Reference BSPs
  - Yocto Project documentation



Build System Workflow

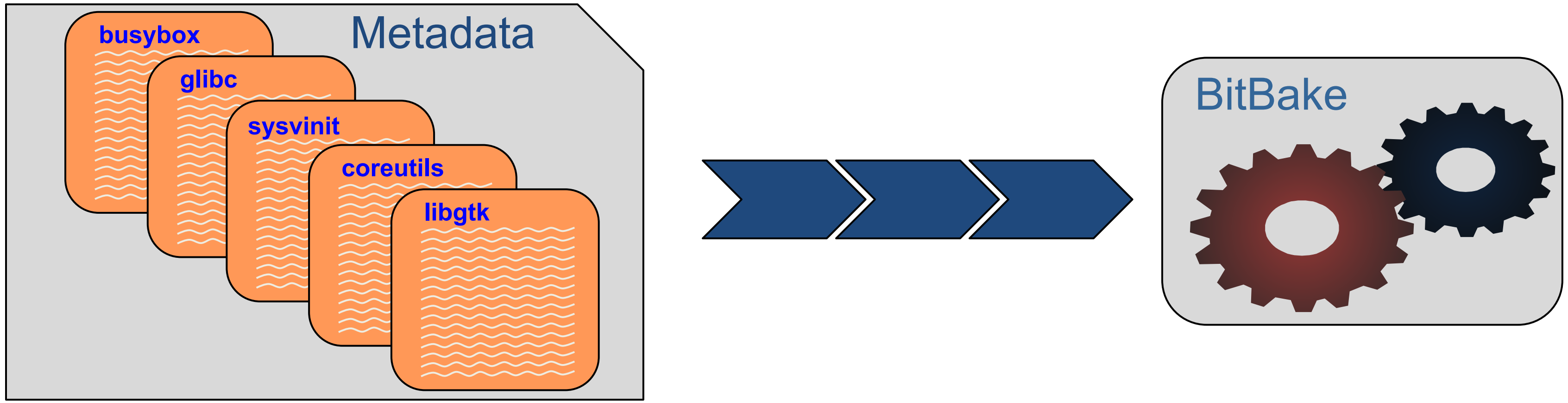


BITBAKE

This section will introduce the concept of the bitbake build tool and how it can be used to build recipes

Metadata and bitbake

- Most common form of metadata: The Recipe(*.bb files)
- A *Recipe* provides a "list of ingredients" and "cooking instructions"
- Defines settings and a set of tasks used by bitbake to build binary packages



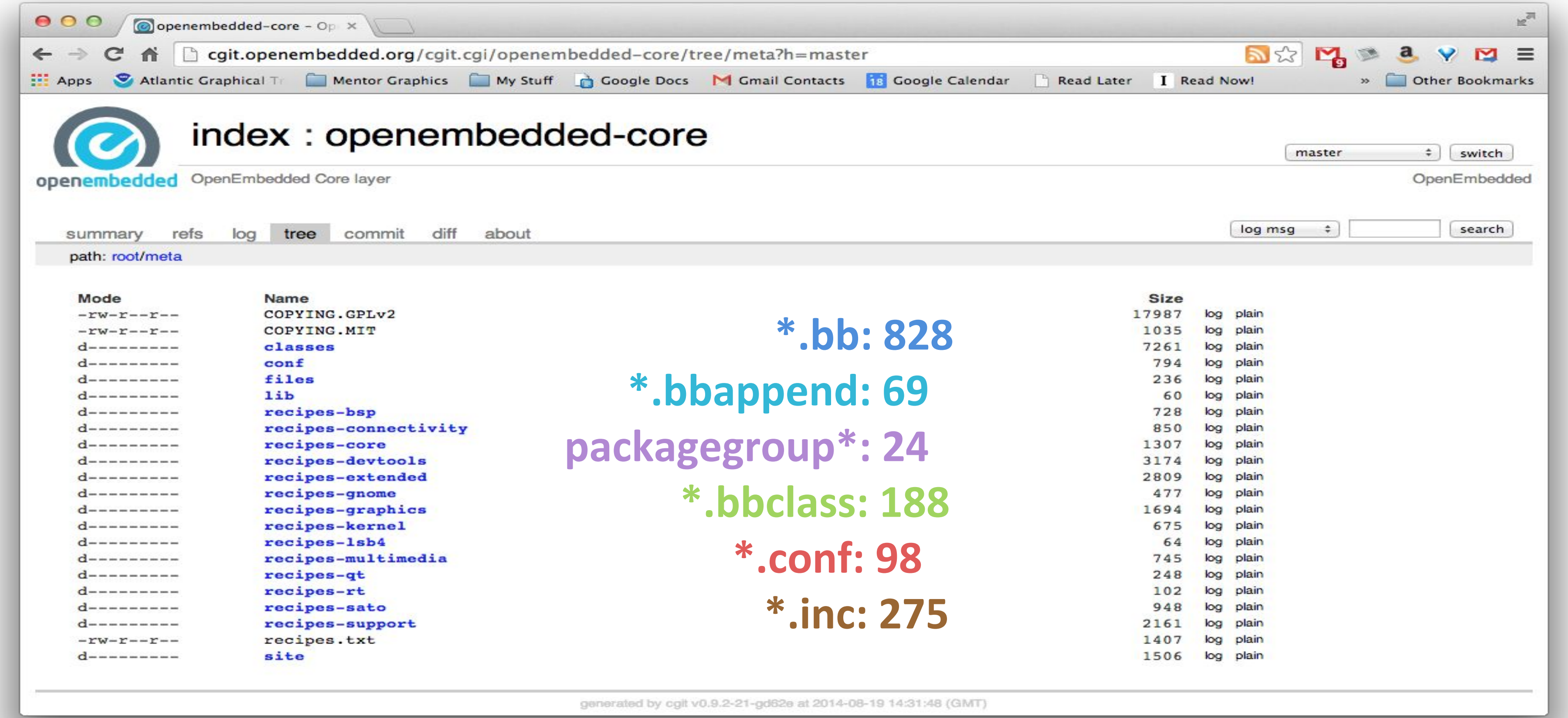
What is Metadata?

- **Metadata exists in four general categories:**
- **Recipes (*.bb)**
  - Usually describe build instructions for a single package
- **PackageGroups (special *.bb)**
  - Often used to group packages together for a FS image
- **Classes (*.bbclass)**
  - Inheritance mechanism for common functionality
- **Configuration (*.conf)**
  - Drives the overall behavior of the build process

Other Metadata

- **Append files (*.bbappend)**
  - Define additional metadata for a similarly named .bb file
  - Can add or override previously set values
- **Include files (*.inc)**
  - Files which are used with the *`include`* directive
  - Include files are typical found via the `BBPATH` variable

OE-CORE Breakdown



cgit.openembedded.org/cgit.cgi/openembedded-core/tree/meta?h=master

index : openembedded-core

OpenEmbedded Core layer

path: root/meta

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d---------	recipes-bsp	728	log	plain
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d---------	recipes-extended	2809	log	plain
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d---------	recipes-graphics	1694	log	plain
d---------	recipes-kernel	675	log	plain
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d---------	recipes-multimedia	745	log	plain
d---------	recipes-qt	248	log	plain
d---------	recipes-rt	102	log	plain
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d---------	recipes-support	2161	log	plain
-rw-r--r--	recipes.txt	1407	log	plain
d---------	site	1506	log	plain

generated by cgit v0.9.2-21-gd62e at 2014-08-19 14:31:48 (GMT)

*.bb: 828

*.bbappend: 69

packagegroup*: 24

*.bbclass: 188

*.conf: 98

*.inc: 275

Introduction to Bitbake

- ***Bitbake*** **is a task executor and scheduler**
- **By default the *build* task for the specified recipe is executed**

```
$ bitbake myrecipe
```

- **You can indicate which task you want run**

```
$ bitbake -c clean myrecipe
$ bitbake -c cleanall myrecipe
```

- **You can get a list of tasks with**

```
$ bitbake -c listtasks myrecipe
```

Bitbake is a Task Scheduler

- Bitbake builds recipes by scheduling build tasks in parallel

  `$ bitbake recipe`

  This looks for `recipe_*.bb` in `BBFILES`
- Each recipe defines build tasks, each which can depend on other tasks
- Recipes can also depend on other recipes, meaning more than one recipe may be built
- Tasks from more than one recipe are often executed in parallel at once on multi-cpu build machines

Building Recipes

- **By default the highest version of a recipe is built** (can be overridden with `DEFAULT_PREFERENCE` or `PREFERRED_VERSION` metadata)

```
$ bitbake myrecipe
```

- **You can specify the version of the package you want built (version of upstream source)**

```
$ bitbake myrecipe-1.0
```

- **You can also build a particular revision of the package metadata**

```
$ bitbake myrecipe-1.0-r0
```

- **Or you can provide a recipe file to build**

```
$ bitbake -b mydir/myrecip.bb
```

Building Images

- **When you do a really big build, running with *--continue* (*-k*) means bitbake will proceed as far as possible after finding an error**

```
$ bitbake -k core-image-minimal
```

  - **When running a long build (e.g. overnight) you want as much of the build done as possible before debugging issues**

- **Running bitbake normally will stop on the first error found**

```
$ bitbake core-image-minimal
```

- ***We'll look at debugging recipe issue later...***

Running Bitbake: Default Tasks*

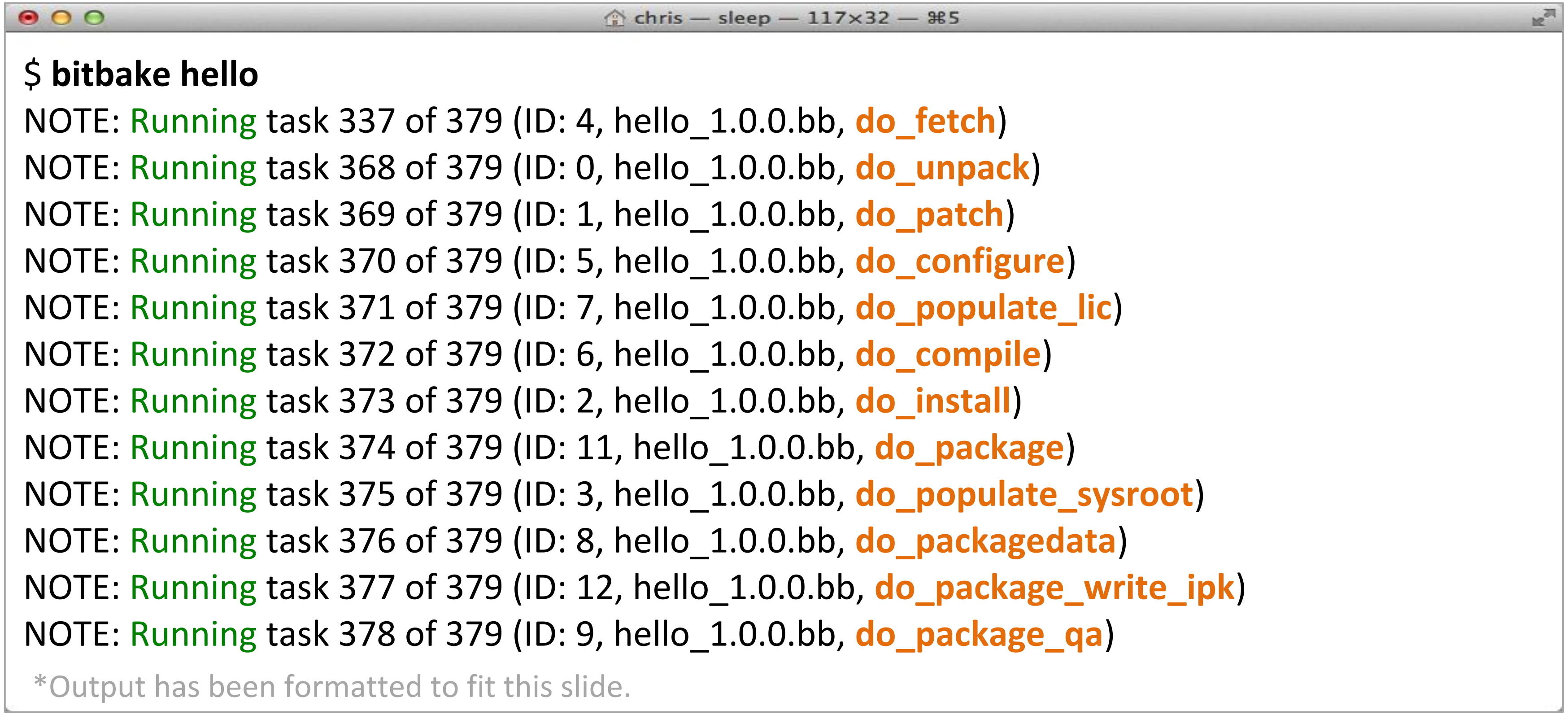
`do fetch`	**Locate and download source code**
`do unpack`	**Unpack source into working directory**
`do patch`	**Apply any patches**
`do configure`	**Perform any necessary pre-build configuration**
`do compile`	**Compile the source code**
`do install`	**Installation of resulting build artifacts in WORKDIR**
`do populate sysroot`	**Copy artifacts to sysroot**
`do package *`	**Create binary package(s)**

Note: to see the list of all possible tasks for a recipe, do this:

```
$ bitbake -c listtasks <recipe_name>
```

*Simplified for illustration

Running Bitbake: Task Log


chris — sleep — 117×32 — ⌘5

```
$ bitbake hello
NOTE: Running task 337 of 379 (ID: 4, hello_1.0.0.bb, do_fetch)
NOTE: Running task 368 of 379 (ID: 0, hello_1.0.0.bb, do_unpack)
NOTE: Running task 369 of 379 (ID: 1, hello_1.0.0.bb, do_patch)
NOTE: Running task 370 of 379 (ID: 5, hello_1.0.0.bb, do_configure)
NOTE: Running task 371 of 379 (ID: 7, hello_1.0.0.bb, do_populate_lic)
NOTE: Running task 372 of 379 (ID: 6, hello_1.0.0.bb, do_compile)
NOTE: Running task 373 of 379 (ID: 2, hello_1.0.0.bb, do_install)
NOTE: Running task 374 of 379 (ID: 11, hello_1.0.0.bb, do_package)
NOTE: Running task 375 of 379 (ID: 3, hello_1.0.0.bb, do_populate_sysroot)
NOTE: Running task 376 of 379 (ID: 8, hello_1.0.0.bb, do_packagedata)
NOTE: Running task 377 of 379 (ID: 12, hello_1.0.0.bb, do_package_write_ipk)
NOTE: Running task 378 of 379 (ID: 9, hello_1.0.0.bb, do_package_qa)
```

*Output has been formatted to fit this slide.

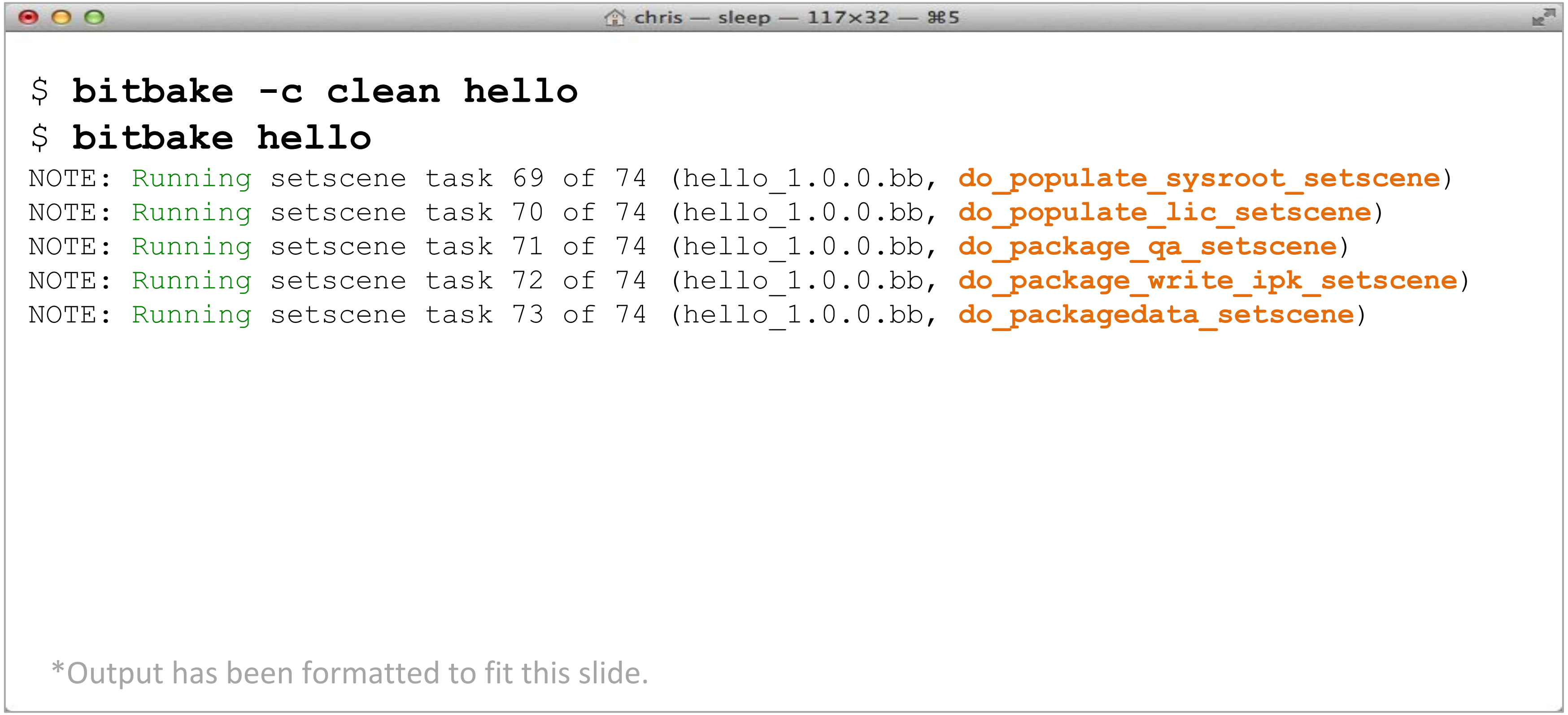
*Simplified for illustration

SSTATE CACHE

- **Several bitbake tasks can use past versions of build artefacts if there have been no changes since the last time you built them**

do_packagedata	Creates package metadata used by the build system to generate the final packages
do_package	Analyzes the content of the holding area and splits it into subsets based on available packages and files
do_package_write_rpm	Creates the actual RPM packages and places them in the Package Feed area
do_populate_lic	Writes license information for the recipe that is collected later when the image is constructed
do_populate_sysroot	Copies a subset of files installed by do_install into the sysroot in order to make them available to other recipes

Simple recipe build from sstate cache*



```
$ bitbake -c clean hello
$ bitbake hello
NOTE: Running setscene task 69 of 74 (hello_1.0.0.bb, do_populate_sysroot_setscene)
NOTE: Running setscene task 70 of 74 (hello_1.0.0.bb, do_populate_lic_setscene)
NOTE: Running setscene task 71 of 74 (hello_1.0.0.bb, do_package_qa_setscene)
NOTE: Running setscene task 72 of 74 (hello_1.0.0.bb, do_package_write_ipk_setscene)
NOTE: Running setscene task 73 of 74 (hello_1.0.0.bb, do_packagedata_setscene)
```

*Output has been formatted to fit this slide.

*Simplified for illustration

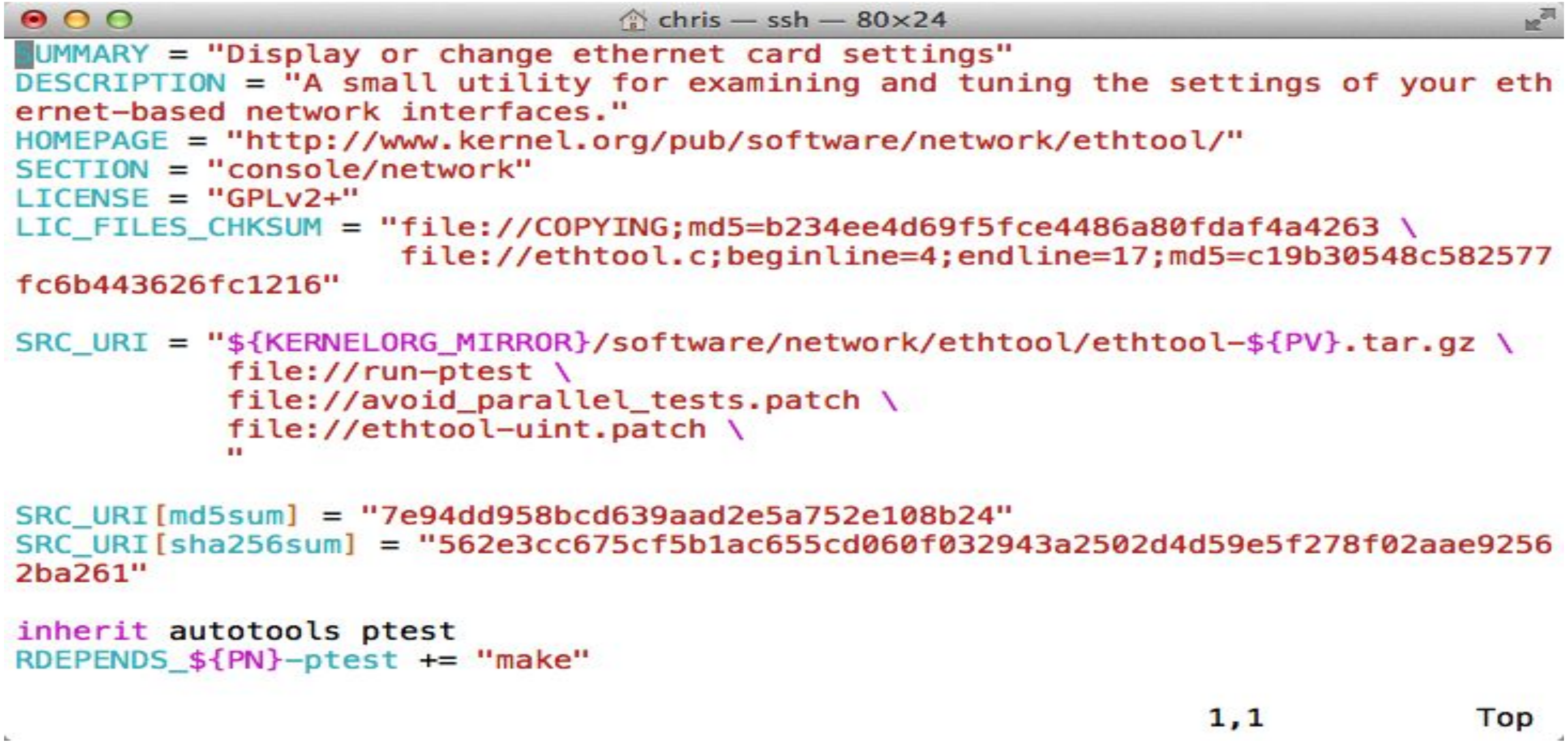
RECIPES

This section will introduce the concept of metadata and recipes and how they can be used to automate the building of packages

What is a Recipe?

- **A recipe is a set of instructions for building packages, including:**
  - Where to obtain the upstream sources and which patches to apply (this is called “*fetching*”)
    - `SRC_URI`
  - Dependencies (on libraries or other recipes)
    - `DEPENDS, RDEPENDS`
  - Configuration/compilation options
    - `EXTRA_OECONF, EXTRA_OEMAKE`
  - Define which files go into what output packages
    - `FILES_*`

Example Recipe – ethtool_3.15.bb


chris — ssh — 80×24

```
SUMMARY = "Display or change ethernet card settings"
DESCRIPTION = "A small utility for examining and tuning the settings of your eth
ernet-based network interfaces."
HOMEPAGE = "http://www.kernel.org/pub/software/network/ethtool/"
SECTION = "console/network"
LICENSE = "GPLv2+"
LIC_FILES_CHKSUM = "file://COPYING;md5=b234ee4d69f5fce4486a80fdaf4a4263 \
                    file://ethtool.c;beginline=4;endline=17;md5=c19b30548c582577
fc6b443626fc1216"

SRC_URI = "${KERNELORG_MIRROR}/software/network/ethtool/ethtool-${PV}.tar.gz \
           file://run-ptest \
           file://avoid_parallel_tests.patch \
           file://ethtool-uint.patch \
           "

SRC_URI[md5sum] = "7e94dd958bcd639aad2e5a752e108b24"
SRC_URI[sha256sum] = "562e3cc675cf5b1ac655cd060f032943a2502d4d59e5f278f02aae9256
2ba261"

inherit autotools ptest
RDEPENDS_${PN}-ptest += "make"

                                                          1,1           Top
```

What can a Recipe Do?

- **Build software from source code:**
  - Host tools, compiler, utilities
  - Target Bootloader, Kernel, etc
  - Target Libraries, interpreters, etc
  - Target Userspace applications
- **Package Groups**
- **Full System Images**

Examining Recipes: bc

- **Look at 'bc' recipe:**
- **Found in**

  poky/meta/recipes-extended/bc/bc_1.06.bb

  - Uses LIC_FILES_CHKSUM and SRC_URI checksums
  - Note the DEPENDS build dependency declaration indicating that this package depends on `flex` to build

Examining Recipes: bc.bb

```
SUMMARY = "Arbitrary precision calculator language"
HOMEPAGE = "http://www.gnu.org/software/bc/bc.html"

LICENSE = "GPLv2+ & LGPLv2.1"
LIC_FILES_CHKSUM = "file://COPYING;md5=94d55d512a9ba36caa9b7df079bae19f \
                    file://COPYING.LIB;md5=d8045f3b8f929c1cb29a1e3fd737b499 \
                    file://bc/bcdefs.h;endline=31;md5=46dffdaf10a99728dd8ce358e45d46d8 \
                    file://dc/dc.h;endline=25;md5=2f9c558cdd80e31b4d904e48c2374328 \
                    file://lib/number.c;endline=31;md5=99434a0898abca7784acfd36b8191199"
SECTION = "base"
DEPENDS = "flex"

SRC_URI = " ${GNU_MIRROR}/bc/bc-${PV}.tar.gz \
            file://fix-segment-fault.patch "
SRC_URI[md5sum] = "d44b5dddebd8a7a7309aea6c36fda117"
SRC_URI[sha256sum] = "4ef6d9f17c3c0d92d8798e35666175ecd3d8efac4009d6457b5c99cea72c0e33"

inherit autotools texinfo update-alternatives

ALTERNATIVE_${PN} = "dc"
ALTERNATIVE_PRIORITY = "100"
BBCLASSEXTEND = "native"
```

Building upon bbclass

- **Use inheritance for common design patterns**
- **Provide a class file (.bbclass) which is then inherited by other recipes (.bb files)**

```
inherit autotools
```

- Bitbake will include the *autotools.bbclass* file
- Found in a *classes* directory via the `BBPATH`

Examining Recipes: flac

- **Look at 'flac' recipe**
- **Found in**

  `poky/meta/recipes-multimedia/flac/flac_1.3.2.bb`

  - Inherits from both *autotools* and *gettext*
  - Customizes autoconf configure options (`EXTRA_OECONF`) based on "TUNE" features
  - Breaks up output into multiple binary packages
    - See PACKAGES var. This recipe produces additional packages with those names, while the FILES_* vars specify which files go into these additional packages

Examining Recipes: flac.bb

```
SUMMARY = "Free Lossless Audio Codec"
DESCRIPTION = "FLAC stands for Free Lossless Audio Codec, a lossless audio compression format."
HOMEPAGE = "https://xiph.org/flac/"
BUGTRACKER = "http://sourceforge.net/p/flac/bugs/"
SECTION = "libs"
LICENSE = "GFDL-1.2 & GPLv2+ & LGPLv2.1+ & BSD"
LIC_FILES_CHKSUM = "file://COPYING.FDL;md5=ad1419ecc56e060eccf8184a87c4285f \
                    file://src/Makefile.am;beginline=1;endline=17;md5=09501c864f89dfc7ead65553129817ca \
                    file://COPYING.GPL;md5=b234ee4d69f5fce4486a80fdaf4a4263 \
                    file://src/flac/main.c;beginline=1;endline=18;md5=09777e2934947a36f13568d0beb81199 \
                    file://COPYING.LGPL;md5=fbc093901857fcd118f065f900982c24 \
                file://src/plugin_common/all.h;beginline=1;endline=18;md5=f56cb4ba9a3bc9ec6102e8df03215271 \
                    file://COPYING.Xiph;md5=b59c1b6d7fc0fb7965f821a3d36505e3 \
                    file://include/FLAC/all.h;beginline=65;endline=70;md5=64474f2b22e9e77b28d8b8b25c983a48"
DEPENDS = "libogg"
SRC_URI = "http://downloads.xiph.org/releases/flac/${BP}.tar.xz"
SRC_URI[md5sum] = "454f1bfa3f93cc708098d7890d0499bd"
SRC_URI[sha256sum] = "91cfc3ed61dc40f47f050a109b08610667d73477af6ef36dcad31c31a4a8d53f"
```

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Examining Recipes: flac.bb (con't)

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```
CVE_PRODUCT = "libflac"
inherit autotools gettext
EXTRA_OECONF = "--disable-oggtest \
                --with-ogg-libraries=${STAGING_LIBDIR} \
                --with-ogg-includes=${STAGING_INCDIR} \
                --disable-xmms-plugin \
                --without-libiconv-prefix \
                ac_cv_prog_NASM="" \
                "
EXTRA_OECONF += "${@bb.utils.contains("TUNE_FEATURES", "altivec", " --enable-altivec", " --disable-altivec",
d)}"
EXTRA_OECONF += "${@bb.utils.contains("TUNE_FEATURES", "core2", " --enable-sse", "", d)}"
EXTRA_OECONF += "${@bb.utils.contains("TUNE_FEATURES", "corei7", " --enable-sse", "", d)}"
PACKAGES += "libflac libflac++ liboggflac liboggflac++"
FILES_${PN} = "${bindir}/*"
FILES_libflac = "${libdir}/libFLAC.so.*"
FILES_libflac++ = "${libdir}/libFLAC++.so.*"
FILES_liboggflac = "${libdir}/libOggFLAC.so.*"
FILES_liboggflac++ = "${libdir}/libOggFLAC++.so.*"
```

Grouping Local Metadata

- **Sometimes sharing metadata between recipes is easier via an *include file***

```
include file.inc
```

  - Will include `.inc` file if found via BBPATH
  - Can also specify an absolute path
  - If not found, will continue without an error

```
require file.inc
```

  - Same as an include
  - Fails with an error if not found

Examining Recipes: ofono

- **Look at 'ofono' recipe(s):**
- **Found in**

  `poky/meta/recipes-connectivity/ofono/ofono_1.19.bb`

  - Splits recipe into common `.inc` file to share common metadata between multiple recipes
  - Sets a conditional build configuration options through the `PACKAGECONFIG` var based on a `DISTRO_FEATURE` (in the `.inc` file)
  - Sets up an init service via do_install_append()
  - Has a `_git` version of the recipe (not shown)

Examining Recipes: ofono.bb

```
require ofono.inc

SRC_URI  = "\
  ${KERNELORG_MIRROR}/linux/network/${BPN}/${BP}.tar.xz \
  file://ofono \
"
SRC_URI[md5sum] = "a5f8803ace110511b6ff5a2b39782e8b"
SRC_URI[sha256sum] =
"a0e09bdd8b53b8d2e4b54f1863ecd9aebe4786477a6cbf8f655496e8edb31c81"

CFLAGS_append_libc-uclibc = " -D_GNU_SOURCE"
```

Examining Recipes: ofono.inc

```
HOMEPAGE = "http://www.ofono.org"
SUMMARY  = "open source telephony"
DESCRIPTION = "oFono is a stack for mobile telephony devices on Linux. oFono supports speaking to telephony devices through
specific drivers, or with generic AT commands."
LICENSE  = "GPLv2"
LIC_FILES_CHKSUM = "file://COPYING;md5=eb723b61539feef013de476e68b5c50a \
                    file://src/ofono.h;beginline=1;endline=20;md5=3ce17d5978ef3445def265b98899c2ee"

inherit autotools pkgconfig update-rc.d systemd bluetooth

DEPENDS  = "dbus glib-2.0 udev mobile-broadband-provider-info"

INITSCRIPT_NAME = "ofono"
INITSCRIPT_PARAMS = "defaults 22"

PACKAGECONFIG ??= "\
          ${@bb.utils.filter('DISTRO_FEATURES', 'systemd', d)} \
          ${@bb.utils.contains('DISTRO_FEATURES', 'bluetooth', 'bluez', '', d)} \
          "
PACKAGECONFIG[systemd] = "--with-systemdunitdir=${systemd_unitdir}/system/,--with-systemdunitdir="
PACKAGECONFIG[bluez] = "--enable-bluetooth, --disable-bluetooth, ${BLUEZ}"
```

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Examining Recipes: ofono.inc

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```
EXTRA_OECONF += "--enable-test"

SYSTEMD_SERVICE_${PN} = "ofono.service"

do_install_append() {
  install -d ${D}${sysconfdir}/init.d/
  install -m 0755 ${WORKDIR}/ofono ${D}${sysconfdir}/init.d/ofono

  # Ofono still has one test tool that refers to Python 2 in the shebang
  sed -i -e '1s,#!.*python.*,#!${bindir}/python3,' ${D}${libdir}/ofono/test/set-ddr

}

PACKAGES =+ "${PN}-tests"
RDEPENDS_${PN} += "dbus"
RRECOMMENDS_${PN} += "kernel-module-tun mobile-broadband-provider-info"

FILES_${PN} += "${systemd_unitdir}"
FILES_${PN}-tests = "${libdir}/${BPN}/test"
RDEPENDS_${PN}-tests = "python3 python3-pygobject python3-dbus"
```

WHEN THINGS GO WRONG

Some useful tools to help guide you when something goes wrong

Bitbake Environment

- **Each recipe has its own environment which contains all the variables and methods required to build that recipe**
- **You've seen some of the variables already**
  - DESCRIPTION, SRC_URI, LICENSE, S, LIC_FILES_CHKSUM, do_compile(), do_install()
- **Example**
  - S = "${WORKDIR}"
  - What does this mean?

Examine a Recipe's Environment

- **To view a recipe's envrionment**

```
$ bitbake -e myrecipe
```

- **Where is the source code for this recipe"**

```
$ bitbake -e virtual/kernel | grep “^S=”
S="${HOME}/yocto/build/tmp/work-shared/qemuarm/kernel-source"
```

- **What file was used in building this recipe?**

```
$ bitbake -e netbase | grep “^FILE=”
FILE="${HOME}/yocto/poky/meta/recipes-core/netbase/netbase_5.3.bb"
```

Examine a Recipe's Environment (cont'd)

- **What is this recipe's full version string?**

```
$ bitbake -e netbase | grep “^PF=”
PF="netbase-1_5.3-r0"
```

- **Where is this recipe's BUILD directory?**

```
$ bitbake -e virtual/kernel | grep “^B=”
B="${HOME}/yocto/build/tmp/work/qemuarm-poky-linux-\
gnueabi/linux-yocto/3.19.2+gitAUTOINC+9e70b482d3\
_473e2f3788-r0/linux-qemuarm-standard-build"
```

- **What packages were produced by this recipe?**

```
$ bitbake -e virtual/kernel | grep “^PACKAGES=”
PACKAGES="kernel kernel-base kernel-vmlinux kernel-image \
kernel-dev kernel-modules kernel-devicetree"
```

BitBake Log Files

- **Every build produces lots of log output for diagnostics and error chasing**
  - Verbose log of bitbake console output:
    - Look in …/tmp/log/cooker/<machine>

```
$ cat tmp/log/cooker/qemuarm/20160119073325.log  | grep 'NOTE:.*task.*Started'
NOTE: recipe hello-1.0.0-r0: task do_fetch: Started
NOTE: recipe hello-1.0.0-r0: task do_unpack: Started
NOTE: recipe hello-1.0.0-r0: task do_patch: Started
NOTE: recipe hello-1.0.0-r0: task do_configure: Started
NOTE: recipe hello-1.0.0-r0: task do_populate_lic: Started
NOTE: recipe hello-1.0.0-r0: task do_compile: Started
NOTE: recipe hello-1.0.0-r0: task do_install: Started
NOTE: recipe hello-1.0.0-r0: task do_populate_sysroot: Started
NOTE: recipe hello-1.0.0-r0: task do_package: Started
NOTE: recipe hello-1.0.0-r0: task do_packagedata: Started
NOTE: recipe hello-1.0.0-r0: task do_package_write_rpm: Started
NOTE: recipe hello-1.0.0-r0: task do_package_qa: Started
NOTE: recipe ypdd-image-1.0-r0: task do_rootfs: Started
```

BitBake Per-Recipe Log Files

- **Every recipe produces lots of log output for diagnostics and debugging**
- **Use the Environment to find the log files for a given recipe:**

```
$ bitbake -e hello | grep “^T=”
T="${HOME}yocto/build/tmp/work/armv5e-poky-linux-gnueabi/hello/1.0.0-r0/temp"
```

- **Each task that runs for a recipe produces "log" and "run" files in**

  ${WORKDIR}/temp

BitBake Per-Recipe Log Files

```
$ cd ${T} (See definition of T in previous slide)
$ find . -type l -name 'log.*'
./log.do_package_qa
./log.do_package_write_rpm
./log.do_package
./log.do_fetch
./log.do_populate_lic
./log.do_install
./log.do_configure
./log.do_unpack
./log.do_populate_sysroot
./log.do_compile
./log.do_packagedata
./log.do_patch
```

These files contain the output of the respective tasks for each recipe

BitBake Per-Recipe Log Files

```
$ cd ${T} (See definition of T in previous slide)
$ find . -type l -name 'run.*'
./run.do_fetch
./run.do_patch
./run.do_configure
./run.do_populate_sysroot
./run.do_package_qa
./run.do_unpack
./run.do_compile
./run.do_install
./run.do_packagedata
./run.do_populate_lic
./run.do_package
./run.do_package_write_rpm
```

These files contain the commands executed which produce the build results

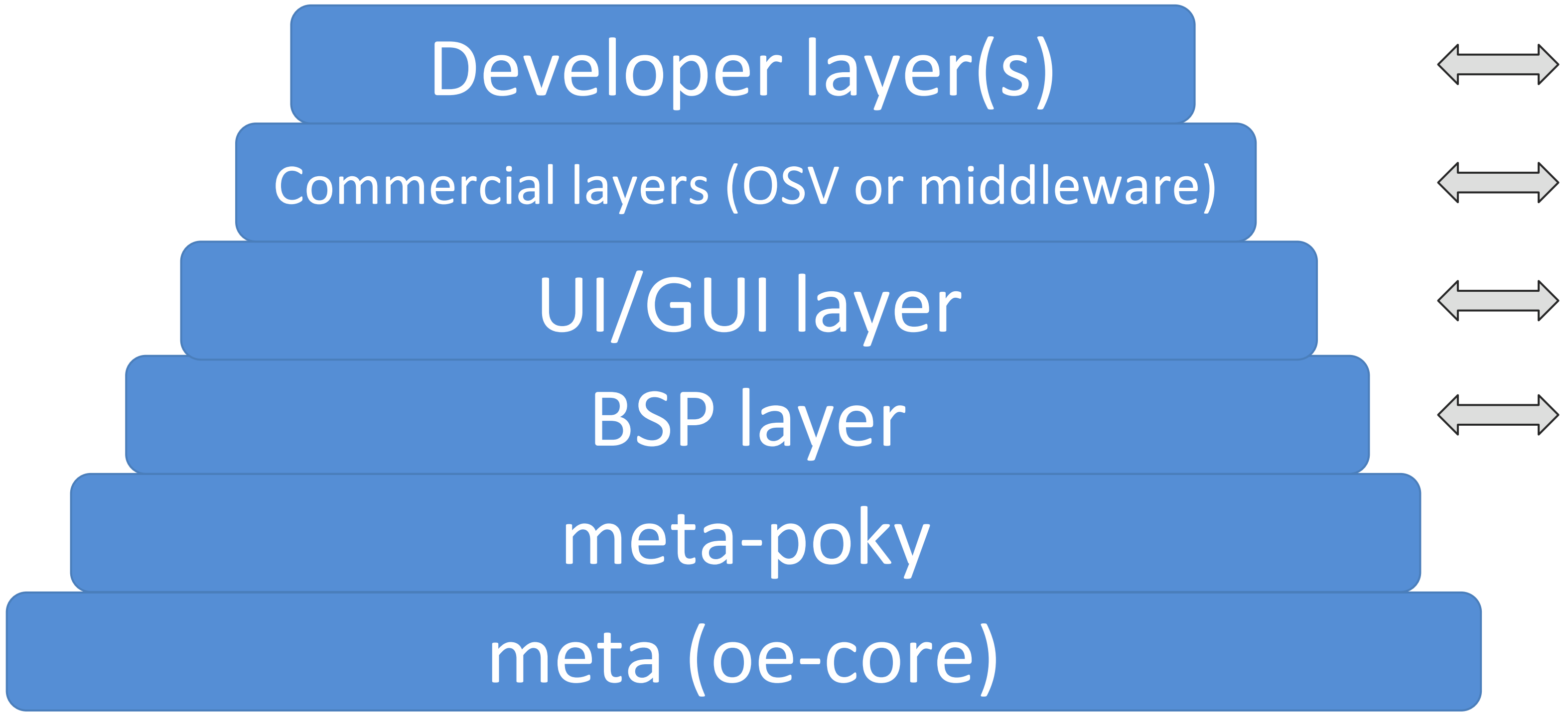
LAYERS

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

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



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**
- `http://layers.openembedded.org` `<<---- This site is your friend`

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

IMAGES

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

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/build/meta-ypdd/recipes-core/images
```

➢ **Create the image recipe**

```
$ vi ${HOME}/yocto/build/meta-ypdd/recipes-core/images/ypdd-image.bb
```

```
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"

inherit core-image

IMAGE_ROOTFS_SIZE ?= "8192"
```

LAB

BUILDING A FULL EMBEDDED IMAGE WITH Bitbake

Workflow

1. **Download Yocto Project sources:**

```
$ mkdir e-ale ; cd e-ale
$ wget http://downloads.yoctoproject.org/releases/yocto/yocto-2.3.2/poky-pyro-17.0.2.tar.bz2
$ tar xf poky-pyro-17.0.2.tar.bz2
```

   - Can also use git and checkout a known branch e.g. morty

```
$ git clone -b pyro git://git.yoctoproject.org/poky.git
```

2. **Build one of the reference Linux distributions:**

```
$ source poky/oe-init-build-env  build
```

   - Check/Edit local.conf for sanity (e.g. modify MACHINE = "qemux86" or MACHINE = "qemuarm")

```
$ bitbake -k core-image-minimal
```

3. **Run the image under emulation:**

```
$ runqemu qemuarm
```

4. **Profit!!!   (well… actually there is more work to do...)**

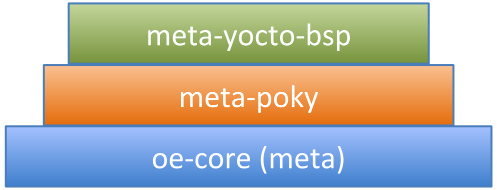
Host System Layout

```
$HOME/e-ale/
 |---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**

Poky(reference) Layout

```
$HOME/e-ale/poky/
|---LICENSE
|---README
|---README.hardware
|---bitbake/            (The build tool)
|---documentation/
|---meta/               (oe-core)
|---meta-poky/          (Yocto distro 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 facility the presentation on this slide

Setting up a Build Directory

- **Start by setting up a build directory**
  - Local configuration
  - Temporary build artifacts

```
$ cd $HOME/e-ale/
$ source ./poky/oe-init-build-env build
```

- **Replace *build* 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)**

Build directory Layout

```
$HOME/e-ale/build/
|---bitbake.lock
|---cache/                 (bitbake cache files)
|---conf/
|    |--bblayers.conf      (bitbake layers)
|    |--local.conf         (local configuration)
|    `--site.conf          (optional site conf)
`---tmp/                   (Build artifacts)
```

Note: A few files have been items omitted to facility the presentation on this slide

Configuring Layers

- Layers are added to your build by inserting them into the BBLAYERS variable within your bblayers file

  `$HOME/e-ale/build/conf/bblayers.conf`

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

Configure local.conf

- **local.conf setup:**
  - Configure build by editing local.conf
  - `$HOME/e-ale/build/conf/local.conf`
    - Select appropriate `MACHINE` type (target)
    - Set shared downloads directory (`DL_DIR`)
    - Set shared state directory (`SSTATE_DIR`)

```
MACHINE = "qemuarm"
DL_DIR ?= "$HOME/e-ale/DOWNLOADS"
SSTATE_DIR ?= "$HOME/e-ale/SSTATE"
PACKAGE_CLASSES ?= "package_deb"
INHERIT += "rm_work"
```

Building an Embedded Image

- This builds an entire embedded Linux distribution
- Choose from one of the available Images
- The following builds a minimal embedded target

```
$ bitbake -k core-image-minimal
```

- On a fast computer the first build may take the better part of an hour 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 qemuarm [nographic]
  ```

  - Use nographic if using a non-graphical session (ssh), do not type the square brackets
- Replace *qemuarm* with your value of `MACHINE`
- Your QEMU instance should boot
- Quit by closing the qemu window
- If using “nographic”, kill it from another terminal:

  ```
  $ killall qemu-system-arm
  ```

Build and Boot Your Custom Image

- Verify that dropbear ssh server is present

```
$ which dropbear
```

- If you used the graphical invocation of QEMU using VNC viewer, you will see the splash screen on boot.

BUILD AN APPLICATION

Adding a "hello world" application to our custom image

Building an Application

- **General procedure:**
  - Write hello world application (hello.c)
  - Create recipe for hello world application
  - Modify image recipe to add 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

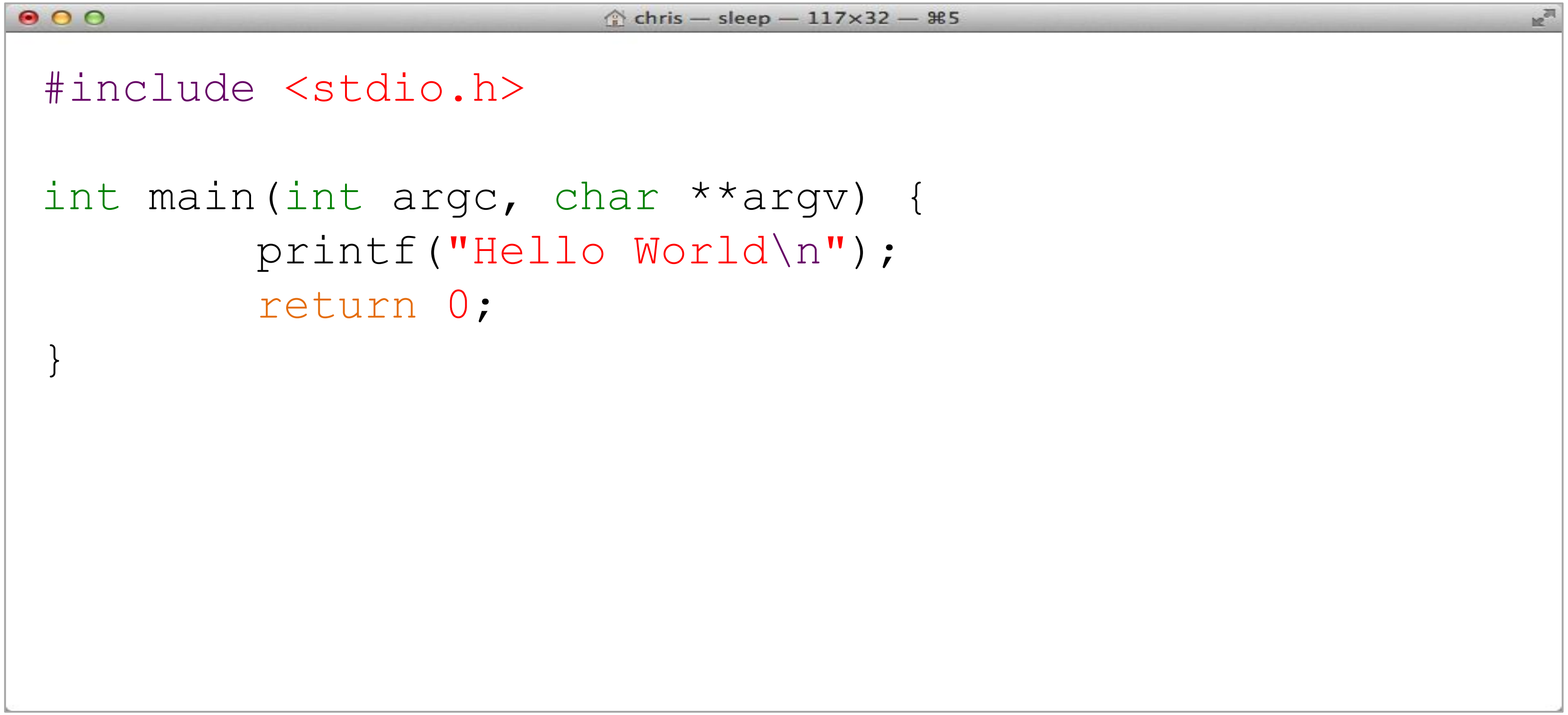
- **For a simple one C file package, you can add the hello application source to a directory called *files* in the *hello* package directory**

```
$ mkdir -p ${HOME}/e-ale/hello-recipe/files

$ vi ${HOME}/e-ale/hello-recipe/files/hello.c
```

Application Code

$ vi hello-recipe/files/hello.c



```
#include <stdio.h>

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

Add Application Recipe

- Write hello world recipe
- Create directory to hold the recipe and associated files

```
$ mkdir -p ${HOME}/e-ale/hello-recipe
```

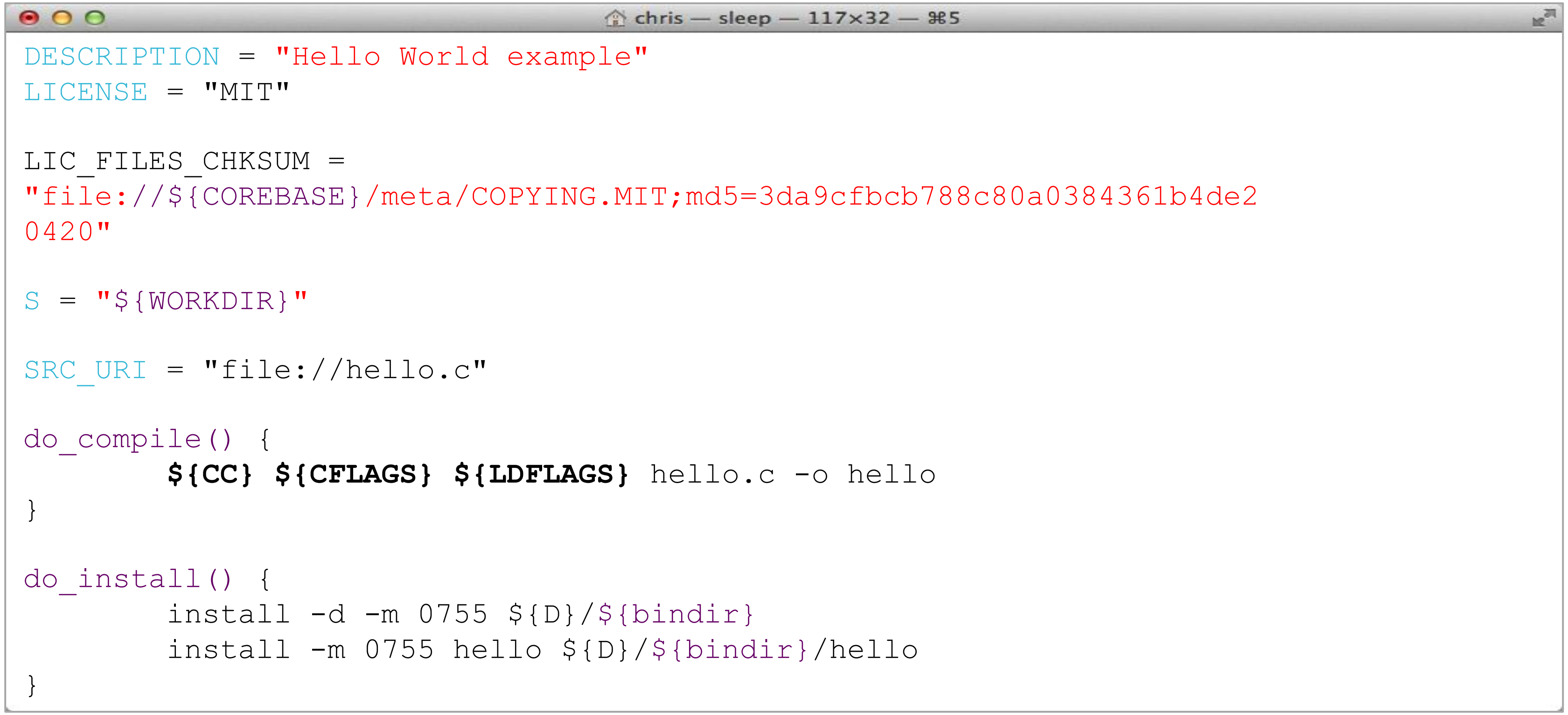
  - (We actually did this already in the previous step)

- Create hello_1.0.bb (next slide)

```
$ vi
${HOME}/e-ale/hello-recipe/hello_1.0.bb
```

Application Recipe

```
$ vi ${HOME}/e-ale/hello-recipe/hello_1.0.bb
```



```
DESCRIPTION = "Hello World example"
LICENSE = "MIT"

LIC_FILES_CHKSUM =
"file://${COREBASE}/meta/COPYING.MIT;md5=3da9cfbcb788c80a0384361b4de2
0420"

S = "${WORKDIR}"

SRC_URI = "file://hello.c"

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

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

Embedded Linux Development with Yocto Project
Training from The Linux Foundation

Want to learn how to use Yocto Project like a Pro?
https://training.linuxfoundation.org/

Embedded Linux Platform Development with Yocto Project
http://bit.ly/eldyocto

TIPS HINTS AND OTHER RESOURCES

The following slides contain reference material that will help you climb the Yocto Project learning curve

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, it's 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

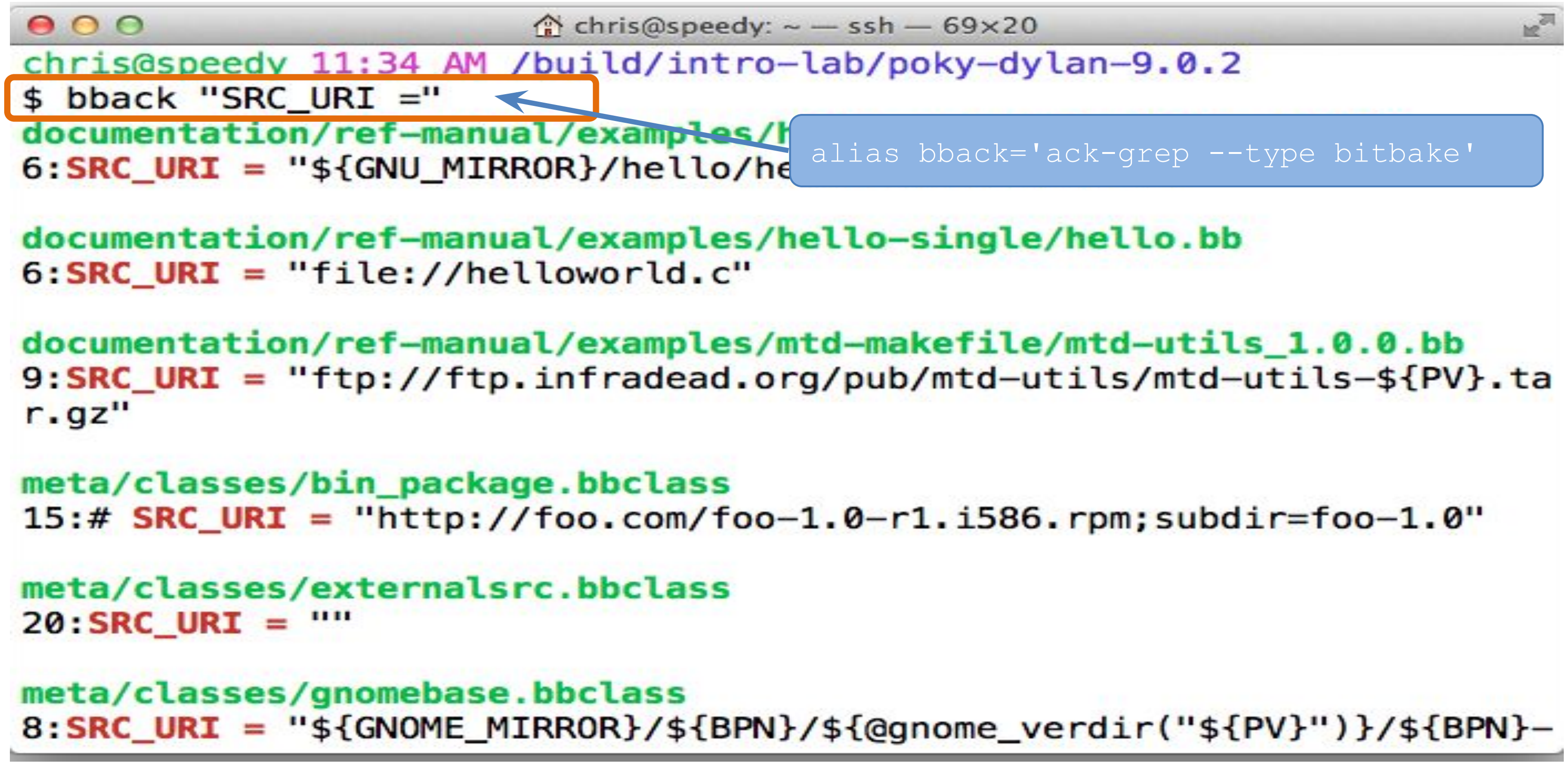
Project Resources

- The Yocto Project is an open source project, and aims to deliver an open standard for the embedded Linux community and industry
- Development is done in the open through public mailing lists: openembedded-core@lists.openembedded.org, poky@yoctoproject.org, and yocto@yoctoproject.org
- And public code repositories:
- http://git.yoctoproject.org and
- http://git.openembedded.org
- Bug reports and feature requests
- http://bugzilla.yoctoproject.org

Tip: ack-grep

- **Much faster than grep for the relevant use cases**
- **Designed for code search**
- **Searches only relevant files**
  - Knows about many types: C, asm, perl
  - By default, skips .git, .svn, etc.
  - Can be taught arbitrary types
- **Perfect for searching metadata**

Tip: ack-grep



```
chris@speedy 11:34 AM /build/intro-lab/poky-dylan-9.0.2
$ bback "SRC_URI ="
documentation/ref-manual/examples/h
6:SRC_URI = "${GNU_MIRROR}/hello/he

documentation/ref-manual/examples/hello-single/hello.bb
6:SRC_URI = "file://helloworld.c"

documentation/ref-manual/examples/mtd-makefile/mtd-utils_1.0.0.bb
9:SRC_URI = "ftp://ftp.infradead.org/pub/mtd-utils/mtd-utils-${PV}.ta
r.gz"

meta/classes/bin_package.bbclass
15:# SRC_URI = "http://foo.com/foo-1.0-r1.i586.rpm;subdir=foo-1.0"

meta/classes/externalsrc.bbclass
20:SRC_URI = ""

meta/classes/gnomebase.bbclass
8:SRC_URI = "${GNOME_MIRROR}/${BPN}/${@gnome_verdir("${PV}")}/${BPN}-
```

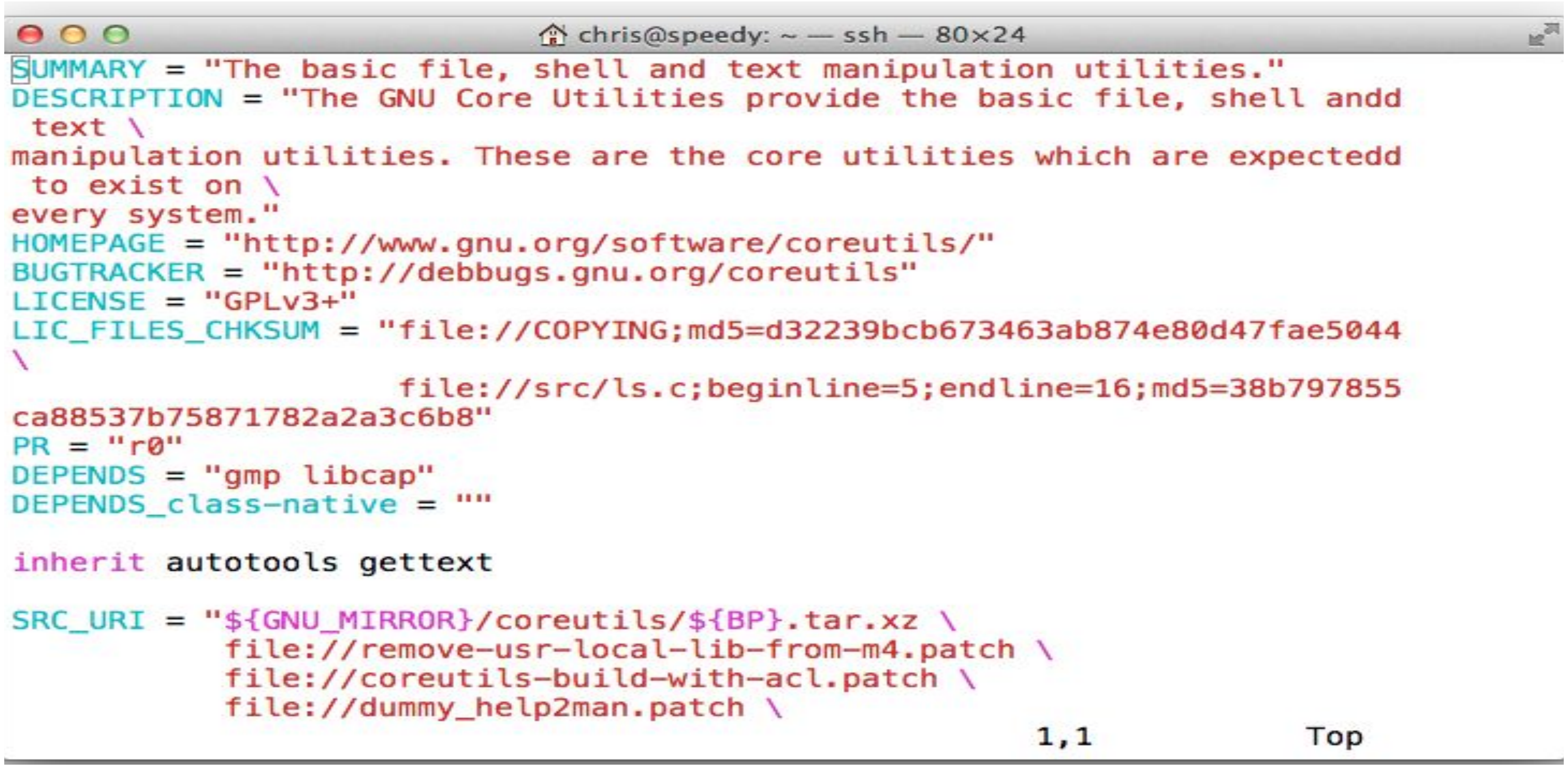
```
alias bback='ack-grep --type bitbake'
```

TIP: VIM Syntax Highlighting

- https://github.com/openembedded/bitbake/tree/master/contrib/vim
- Install files from the above repo in ~/.vim/
- Add "syntax on" in ~/.vimrc

```
$ tree ~/.vim/
/Users/chris/.vim/
├── ftdetect
│   └── bitbake.vim
├── ftplugin
│   └── bitbake.vim
├── plugin
│   └── newbb.vim
└── syntax
    └── bitbake.vim
```

TIP: VIM Syntax Highlighting



```
SUMMARY = "The basic file, shell and text manipulation utilities."
DESCRIPTION = "The GNU Core Utilities provide the basic file, shell andd
 text \
manipulation utilities. These are the core utilities which are expectedd
 to exist on \
every system."
HOMEPAGE = "http://www.gnu.org/software/coreutils/"
BUGTRACKER = "http://debbugs.gnu.org/coreutils"
LICENSE = "GPLv3+"
LIC_FILES_CHKSUM = "file://COPYING;md5=d32239bcb673463ab874e80d47fae5044
\
                    file://src/ls.c;beginline=5;endline=16;md5=38b797855
ca88537b75871782a2a3c6b8"
PR = "r0"
DEPENDS = "gmp libcap"
DEPENDS_class-native = ""

inherit autotools gettext

SRC_URI = "${GNU_MIRROR}/coreutils/${BP}.tar.xz \
           file://remove-usr-local-lib-from-m4.patch \
           file://coreutils-build-with-acl.patch \
           file://dummy_help2man.patch \
                                                            1,1           Top
```

The other boards ...

dragonboard in one Slide

The dragonboard uses a 3rd-party repository.

1. **Download repo tool:**

```
$ mkdir -p ${HOME}/bin
$ curl https://storage.googleapis.com/git-repo-downloads/repo > ${HOME}/bin/repo
$ chmod a+x ${HOME}/bin/repo
$ export PATH=${HOME}/bin:${PATH}
```

2. **Download the repositories with repo:**

```
$ mkdir oe-qcom && cd oe-qcom
$ repo init -u https://github.com/96boards/oe-rpb-manifest.git -b pyro
$ repo sync
$ source setup-environment          # SELECT the dragonboard
```

3. **Build the image:**

```
$ bitbake core-image-minimal
```

4. **Profit!!!   (well… actually there is more work to do...)**

YP for the beaglebone

The following section introduces the beaglebone as example hardware.

PocketBeagle in one Slide

1. **Download poky tool:**

```
$ mkdir -p ${HOME}/myproject
$ cd ${HOME}/myproject
$ wget -nd -c "http://downloads.yoctoproject.org/releases/yocto/yocto-2.3.2/poky-pyro-17.0.2.tar.bz2"
$ tar -xf poky-pyro-17.0.2.tar.bz2
```

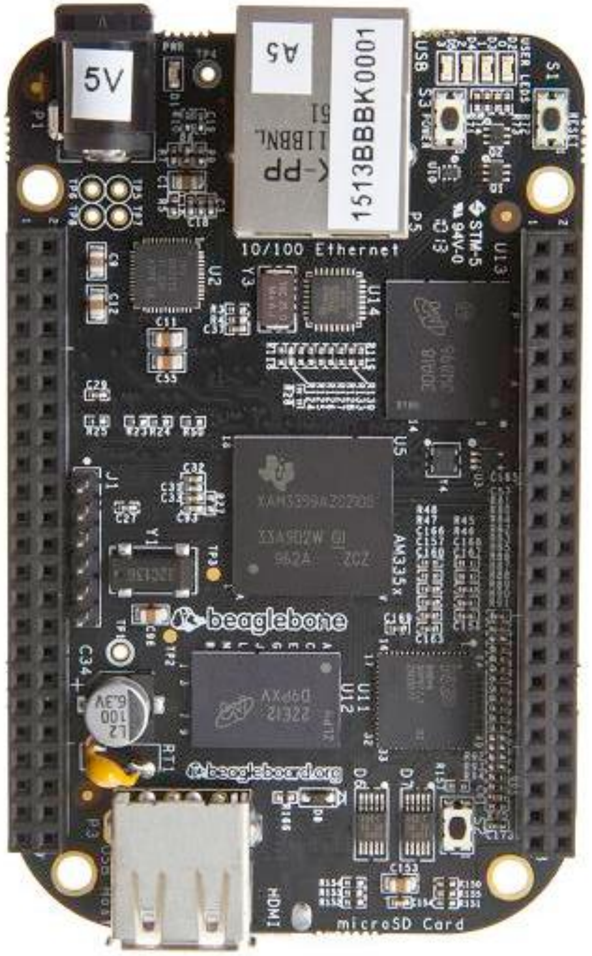
2. **Configure:**$

```
$ source poky-morty-17.0.2/oe-init-build-env mybuild
$ echo 'MACHINE = "beaglebone" '  >> conf/local.conf
```

3. **Build the image:**

```
$ bitbake core-image-minimal
```

4. **Profit!!!   (well… actually there is more work to do...)**


5V
A5
1513BBBK0001
10/100 Ethernet
beaglebone
beagleboard.org
microSD Card
HDMI

End

HAVE FUN and thank you for joining !

BITBAKE REFERENCE

Recipe Operators

A = “foo”	(late assignment)
B ?= “0t”	(default value)
C ??= “abc”	(late default)
D := “xyz”	(Immediate assignment)

A .= “bar”	→	“foobar”	(append)
B =. “WO”	→	“W00t”	(prepend)
C += “def”	→	“abc def”	(append)
D =+ “uvw”	→	“uvw xyz”	(prepend)

More Recipe Operators

A = “foo”

A_append = “bar” → “foobar”

B = “0t”

B_prepend = “WO” → “W00t”

OVERRIDES = “os:arch:machine”

A = “abc”

A_os = “ABC” (Override)

A_append_arch = “def” (Conditional append)

A_prepend_os = “XYZ” (Conditional prepend)

Bitbake Variables/Metadata

- **These are set automatically by bitbake**
  - **`TOPDIR`** – The build directory
  - **`LAYERDIR`** – Current layer directory
  - **`FILE`** – Path and filename of file being processed
- **Policy variables control the build**
  - **`BUILD_ARCH`** – Host machine architecture
  - **`TARGET_ARCH`** – Target architecture
  - And many others...

Build Time Metadata

- **`PN`** – **Pakage name (“myrecipe”)**
- **`PV`** – **Package version (1.0)**
- **`PR`** – **Package Release (r0)**
- **`P`** `= “${PN}-${PV}”`
- **`PF`** `= “${PN}-${PV}-${PR}”`
- **`FILE_DIRNAME`** – Directory for `FILE`
- **`FILESPATH`** `= "${FILE_DIRNAME}/${PF}:\`
- `${FILE_DIRNAME}/${P}:\`
- `${FILE_DIRNAME}/${PN}:\`
- `${FILE_DIRNAME}/files:${FILE_DIRNAME}`

Build Time Metadata

- **TOPDIR - The build directory**
- **TMPDIR** = “${TOPDIR}/tmp”
- **WORKDIR** = ${TMPDIR}/work/${PF}”
- **S** = “${WORKDIR}/${P}” (Source dir)
- **B** = “${S}” (Build dir)
- **D** = “${WORKDIR}/${image}” (Destination dir)
- **DEPLOY_DIR** = “${TMPDIR}/deploy”
- **DEPLOY_DIR_IMAGE** = “${DEPLOY_DIR}/images”

Dependency Metadata

- **Build time package variables**
  - **`DEPENDS`** – Build time package dependencies
  - **`PROVIDES`** `= "${P} ${PF} ${PN}"`
- **Runtime package variables**
  - **`RDEPENDS`** – Runtime package dependencies
  - **`RRECOMMENDS`** – Runtime recommended packages
  - **`RSUGGESTS`** – Runtime suggested packages
  - **`RPROVIDES`** – Runtime provides
  - **`RCONFLICTS`** – Runtime package conflicts
  - **`RREPLACES`** – Runtime package replaces

Common Metadata

- **Variables you commonly set**
  - **`SUMMARY`** – Short description of package/recipe
  - **`HOMEPAGE`** – Upstream web page
  - **`LICENSE`** – Licenses of included source code
  - **`LIC_FILES_CHKSUM`** – Checksums of license files at time of packaging (checked for change by build)
  - **`SRC_URI`** – URI of source code, patches and extra files to be used to build packages. Uses different fetchers based on the URI.
  - **`FILES`** – Files to be included in binary packages