One Build To Rule Them All: Building FreeRTOS & Linux Using The Yocto Project

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• Heterogeneous Systems
• RTOS + Linux
• Workflows
Outline
OpenEmbedded Development

- FreeRTOS on Yocto
- Newlib + Libgloss
  - tclibc-newlib
- meta-freertos
  - class, recipes
  - BSP vs App
  - QEMU
  - Automated Tests
One Build To Rule Them All

• Multiconfig Builds
• Multiconfig Dependencies
• One Build To Rule Them All
Heterogeneous Devices
Xilinx Versal Architecture

Processing System:

- Application Processing Unit
- Real-Time Processing Unit
Embedded Applications:
• Linux + RTOS
• RTOS
• Linux + Baremetal
• Baremetal

They all use different workflows!
FreeRTOS + The Yocto Project
FreeRTOS + The Yocto Project

ARM on QEMU already on OE-Core BSP versatile92s (qemuarmv5)

ARM Embedded Toolchain[1]:
- GNU C Compiler
- Binutils
- GDB
- Newlib
  - Newlib is a C library intended for use on embedded systems. It is a conglomeration of several library parts, all under free software licenses that make them easily usable on embedded products. [2]


FreeRTOS + The Yocto Project

Previous work:
- Newlib + Libgloss Recipes on OE-Core
- tclibc-newlib (TCLIBC)

Create Layer:
- Meta-FreeRTOS
  - Create DISTRO
  - Application is the OS
  - BSP vs Application
  - Use a class to simply workflows and create abstractions
  - Run automated tests on RTOS applications using the OpenEmbedded testing infrastructure.
FreeRTOS + The Yocto Project

```
DISTRO

DISTRO = "freertos"
DISTRO_NAME = "FreeRTOS"
DISTRO_VERSION = "1.0"

TCLIBC = "newlib"
TCLIBCAPPEND = ""
```
CLASS: freertos-app

# FreeRTOS class
# This class is meant to be inherited by recipes for FreeRTOS apps
# It contains code that would be used by all of them, where every
# recipe would just need to override certain parts
#
# We are getting the FreeRTOS source code from upstream
# We have a BSP repo where we get the portable code from there
# And we get the app code from a different repo
#
# FreeRTOS kernel version (FreeRTOS.h)
FREERTOS_VERSION = "FreeRTOSV10.2.1"

SRC_URI = "
  git://github.com/aws/amazon-freertos.git;name=freertos;destsuffix=freertos; \
  git://github.com/aehs29/FreeRTOS-GCC-ARM926ejs.git;name=bsp;destsuffix=bsp;branch=aehs29/bsp; \
  
"
SRCREV_bsp := "d2b58036f77e3470af56854602c1d701021c2fb9"
SRCREV_freertos := "5bee12b2cd5dabf2c6b3bf394ea41649999a1453"

PV = "${FREERTOS_VERSION}+git${SRCPV}"
S="${WORKDIR}/bsp"
do_configure_prepend(){
    # Copy portable code from bsp repo into FreeRTOS source code
    cp -r %{WORKDIR}/bsp/portable/GCC/ARM926EJ-S/ %{WORKDIR}/freertos/freertos_kernel/portable/GCC/ARM926EJ-S/
}

# QEMU crashes when FreeRTOS is built with optimizations, disable those for now
CFLAGS_remove = "-O2"

# We need to define the port we are using, along with the FreeRTOS source code location
EXTRA_OEMAKE = "PORT=ARM926EJ-S FREERTOS_SRC=../freertos/freertos_kernel/ 'CFLAGS=${CFLAGS} -I../freertos/freertos_kernel"

do_compile(){
    oe_runmake %{EXTRA_OEMAKE}
}

do_install(){
    install -m 755 %{B}/image.bin %{D}/image.bin
    install -m 755 %{B}/image.elf %{D}/image.elf
}

do_deploy(){
    install %{D}/image.bin %{DEPLOYDIR}/${IMAGE_LINK_NAME}.bin
    install %{D}/image.elf %{DEPLOYDIR}/${IMAGE_LINK_NAME}.elf
}

do_image(){
    ;
}
FreeRTOS + The Yocto Project

CLASS

```bash
# QEMU parameters
Q8_SYSTEM_NAME = "qemu-system-arm"
Q8_DEFAULT_KERNEL = "${IMAGE_LINK_NAME}.bin"
Q8_MEM = "-m 128"
Q8_MACHINE = "-M versatilepb"
Q8_OPT_APPEND = "-nographic"
Q8_DEFAULT_FSTYPE = "bin"
Q8_DTB = ""

# This next part is necessary to trick the build system into thinking
# its building an image recipe so it generates the qemu.png
addtask do_deploy after do_write_qemuboot_conf before do_build
addtask do_rootfs before do_deploy after do_install
addtask do_image after do_rootfs before do_build
inherit qemu.png
```
Demo Recipe: freertos-demo

inherit freertos-app

# App can be replaced by using a different repo
SRC_URI += "
  git://github.com/aehs29/FreeRTOS-GCC-ARM926ejs.git;name=app;destsuffix=app;branch=aehs29/app2;
  file://use-newlib-as-libc.patch"

SRCREV_FORMAT = "freertos_bsp_app"
SRCREV_app = "5353ca1b308210b73c2cb4573eb2d02904c96622"

EXTRA_OEMAKE += "APP_SRC=../app/Demo/ 'STAGING_LIBDIR=${STAGING_LIBDIR}'"

ARM926 Port: [1] https://github.com/jkovacic/FreeRTOS-GCC-ARM926ejs

Extra functionality: Task can be woken up by notification using xTaskNotify API
Demo Recipe: freertos-demo-local

inherit freertos-app

# App can be replaced by using a different repo
SRC_URI += " "
   file://FreeRTOSConfig.h \n   file://app_config.h \n   file://init.c \n   file://main.c \n   file://print.c \n   file://print.h \n   file://receive.c \n   file://receive.h \n   file://startup.s \n   file://LICENSE.txt \n   file://use-newlib-as-libc.patch 
",

EXTRA_OEMAKE += "APP_SRC=${WORKDIR}/ 'STAGING_LIBDIR=${STAGING_LIBDIR}''"
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Meta layer file hierarchy:
To reproduce the video demo, perform the instructions from the README on the layer repository:

https://github.com/aehs29/meta-freertos
One Build To Rule Them All
You can use a single bitbake command to build multiple images or packages for different targets where each image or package requires a different configuration (multiple configuration builds). [1] https://www.yoctoproject.org/docs/latest/mega-manual/mega-manual.html
7.10.2.2. Enabling Multiple Configuration Build Dependencies

Sometimes dependencies can exist between targets (multiconfigs) in a multiple configuration build. For example, suppose that in order to build a core-image-sato image for an "x86" multiconfig, the root filesystem of an "arm" multiconfig must exist. This dependency is essentially that the do_image task in the core-image-sato recipe depends on the completion of the do_rootfs task of the core-image-minimal recipe.

To enable dependencies in a multiple configuration build, you must declare the dependencies in the recipe using the following statement form:

```
task_or_package[mcdepeends] = "mc:from_multiconfig:to_multiconfig:recipe_name:task_on_which_to_depend"
```

To better show how to use this statement, consider the example scenario from the first paragraph of this section. The following statement needs to be added to the recipe that builds the core-image-sato image:

```
do_image[mcdepeends] = "mc:x86:arm:core-image-minimal:do_rootfs"
```
Future Work

• Multiconfig Optimizations
  – Shared State Cache *
  – Parsing
• Support more Architectures/Ports on Meta-FreeRTOS
• Fine Tuning Meta-FreeRTOS
• Upstream tests and CI
Takeaways

• The Yocto Project / Bitbake provides scalability
• FreeRTOS was just used as a test case
• Support more OSs/Applications on Yocto?
• Unify workflows across teams
• Control over toolchain and get reproducibility
Thanks!
Q & A