

How to Integrate the 60 Series Wi-Fi Module with Open WRT

60 Series Radios

Application Note

v2.0

1 Introduction

This guide provides an example on how to integrate a Ezurio ST60-2230C-P Wi-Fi Module with a Raspberry Pi 4 Compute Module on OpenWRT.

Table 1: ST60 variants

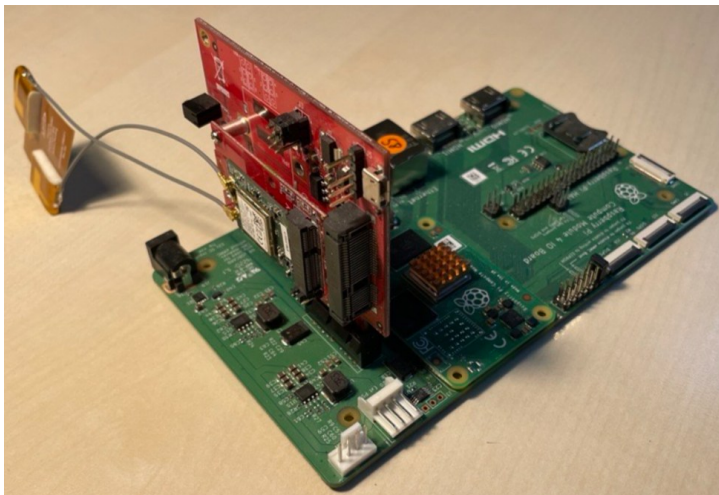
Module Name	Form Factor	Wi-Fi	BT	Part Number
ST60-2230C-P	M.2 2230	PCIe	UART	ST60-2230C-P

Note: This guide deals with the integration of the Wi-Fi portion of the ST60 module only.

2 Requirements

- ST60-2230C-P Wi-Fi module
- Suitable Wifi antenna – e.g. EFD2455A3S-10MH4L
- Raspberry Pi Compute Module 4
- Raspberry Pi Compute Module 4 IO Board
- PCIe x1 to mPCIe adapter – e.g. <http://www.lycom.com.tw/DT-117.htm>
- mPCIe to M2 adapter – e.g. <https://www.getgoods.com/at-en/products/550535/Renkforce-GBIC-1x-M.2-NGFF-1x-Mini-PCI-Express.html>
- Monitor, keyboard, mouse to access Raspeberry Pi
- Development PC with Yocto build environment

Below is a fully equipped RPi4CM board:



3 Build Environment Preparation

1. On page <https://openwrt.org/toh/start> identify the latest supported OpenWRT release for the Raspberry Pi 4 Compute Module.

Brand	Model	Version	Supported Current...	Device Page
Brand	Raspberry Pi 4	Compute Module	Supported Current Re	
Raspberry Pi Foundation	Raspberry Pi 4	Compute Module 4	23.05.0	raspberry_pi

Note: observe the filters in the "Model" and "Version" fields.

2. Follow the instructions on page <https://openwrt.org/docs/guide-developer/toolchain/use-buildsystem>

```
# Download and update the sources
git clone https://git.openwrt.org/openwrt/openwrt.git

alex@ubuntu:~/Projects/buildroot$ git clone https://git.openwrt.org/openwrt/openwrt.git
Cloning into 'openwrt'...
remote: Enumerating objects: 9390, done.
remote: Counting objects: 100% (9390/9390), done.
remote: Compressing objects: 100% (3770/3770), done.
remote: Total 671524 (delta 6104), reused 7906 (delta 5212), pack-reused 662134
Receiving objects: 100% (671524/671524), 192.34 MiB | 6.42 MiB/s, done.
Resolving deltas: 100% (470283/470283), done.
Updating files: 100% (9737/9737), done.
```

```
cd openwrt
...
```

```
git pull

alex@ubuntu:~/Projects/buildroot/openwrt$ git pull
Already up to date.
```

```
# Select a specific code revision
git branch -a
```

```
alex@ubuntu:~/Projects/buildroot/openwrt$ git branch -a
* master
remotes/origin/HEAD -> origin/master
remotes/origin/lede-17.01
remotes/origin/main
remotes/origin/master
remotes/origin/openwrt-18.06
remotes/origin/openwrt-19.07
remotes/origin/openwrt-21.02
remotes/origin/openwrt-22.03
remotes/origin/openwrt-23.05
```

```
git tag
...
v23.05.0
v23.05.0-rc1
v23.05.0-rc2
v23.05.0-rc3
v23.05.0-rc4
v23.05.1
v23.05.2
```

```
git checkout v23.05.0
```

```
alex@ubuntu:~/Projects/buildroot/openwrt$ git checkout v23.05.0
Note: switching to 'v23.05.0'.
```

You are in 'detached HEAD' state. You can look around, make experimental changes and commit them, and you can discard any commits you make in this wser e without impacting any branches by switching back to a branch.

If you want to create a new branch to retain commits you create, you may do so (now or later) by using -c with the switch command. Example:

```
git switch -c <new-branch-name>
```

Or undo this operation with:

```
git switch -
```

Turn off this advice by setting config variable advice.detachedHead to false

```
HEAD is now at bd4f415efa OpenWrt v23.05.0: adjust config defaults
```

```
# Update the feeds
./scripts/feeds update -a
...
```

```
Create index file './feeds/routing.index'
Collecting package info: done
Collecting target info: done
Create index file './feeds/telephony.index'
Collecting package info: done
Collecting target info: done
```

```
./scripts/feeds install -a
...
```

```
Installing package 'sipp' from telephony
Installing package 'sipp' from telephony
Installing package 'siproxd' from telephony
Installing package 'sngrep' from telephony
Installing package 'yate' from telephony
```

```
# Configure the firmware image, mainly to select target
make menuconfig
```

```
alex@ubuntu:~/Projects/buildroot/openwrt$ make menuconfig
Collecting package info: done
tmp/.config-package.in:33662:error: recursive dependency detected!
tmp/.config-package.in:33662: symbol PACKAGE_python3-pymysql depends on PYTHON3_PYMYSQL_SHA_PASSWORD_SUPPORT
feeds/packages/lang/python/pymysql/Config.in:4: symbol PYTHON3_PYMYSQL_SHA_PASSWORD_SUPPORT depends on PACKAGE_python3-pymysql
For a resolution refer to Documentation/kbuild/kconfig-language.rst
subsection "Kconfig recursive dependency limitations"
```

For Raspberry Pi4 CM select target BCM27xx:

```

Target System
Use the arrow keys to navigate this window or press the
hotkey of the item you wish to select followed by the <SPACE
BAR>. Press <?> for additional information about this
^(-)
( ) Atheros AR231x/AR5312
( ) Atheros ATH79
(X) Broadcom BCM27xx
( ) Broadcom BCM47xx/53xx (ARM)
( ) Broadcom BCM47xx/53xx (MIPS)
( ) Broadcom BCM4908 (ARMv8A CPUs Brahma-B53)
v(+)
<Select>      < Help >
```

For Raspberry Pi4 CM select subtarget BCM2711:

```

Subtarget
Use the arrow keys to navigate this window or press the
hotkey of the item you wish to select followed by the <SPACE
BAR>. Press <?> for additional information about this

( ) BCM2708 boards (32 bit)
( ) BCM2709/BCM2710/BCM2711 boards (32 bit)
( ) BCM2710 boards (64 bit)
(X) BCM2711 boards (64 bit)

<Select>    < Help >

```

For Raspberry Pi4 CM select target profile:

```

Target Profile
Use the arrow keys to navigate this window or press the
hotkey of the item you wish to select followed by the <SPACE
BAR>. Press <?> for additional information about this

( ) Multiple devices
(X) Raspberry Pi 4B/400/CM4 (64bit)

<Select>    < Help >

```

Add tar.gz target image format:

```

*** End of the configuration.
*** Execute 'make' to start the build or try 'make help'.

```

```

Target Images
a menu. <Enter> selects submenus ---> (or empty submenu
includes, <N> excludes, <M> modularizes features. P
*) built-in [ ] excluded <M> module < > module cap

[ ] ramdisk ---
*** Root filesystem archives ***
[ ] cpio.gz
[*] tar.gz
*** Root filesystem images ***
[*] ext4 --->
[*] squashfs --->
[*] GZip images
*** Image Options ***
(64) Kernel partition size (in MiB)
(104) Root filesystem partition size (in MiB)
[ ] Make /var persistent

```

```
# Optional: configure the kernel (usually not required)
# Don't, unless have a strong reason to
make -j$(nproc) kernel_menuconfig
```

Note: As not necessary for the first build, this optional step from above OpenWRT guide has been skipped.

```
# Build the firmware image
make -j$(nproc) defconfig download clean world
...
```

```
make[2] package/install
make[2] target/install
make[3] -C target/linux install
make[2] package/index
make[2] json_overview_image_info
make[2] checksum
alex@ubuntu:~/Projects/buildroot/openwrt$
```

Success.

Source: <https://openwrt.org/docs/guide-developer/toolchain/use-buildsystem>

Note: If the build does not complete due to missing packages (e.g. such as flex, bison, ncurses) on your Ubuntu development PC, please install them using "sudo apt-get install <package name>".

4 Locating the OS Image and Writing it to the RPi4 CM

1. Find the newly generated images at:

```
alex@ubuntu:~/Projects/buildroot/openwrt$ cd bin/targets/bcm27xx/bcm2711/

alex@ubuntu:~/Projects/buildroot/openwrt/bin/targets/bcm27xx/bcm2711$ ls -al
total 61580
drwxr-xr-x 3 alex alex    4096 Dez  6 14:53 .
drwxr-xr-x 3 alex alex    4096 Dez  6 11:59 ..
-rw-r--r-- 1 alex alex     130 Dez  6 14:25 config.buildinfo
-rw-r--r-- 1 alex alex     268 Dez  6 14:25 feeds.buildinfo
-rw-r--r-- 1 alex alex 14917525 Dez  6 14:53 openwrt-bcm27xx-bcm2711-rpi-4-ext4-factory.img.gz
-rw-r--r-- 1 alex alex 14918371 Dez  6 14:53 openwrt-bcm27xx-bcm2711-rpi-4-ext4-sysupgrade.img.gz
-rw-r--r-- 1 alex alex    3894 Dez  6 14:53 openwrt-bcm27xx-bcm2711-rpi-4.manifest
-rw-r--r-- 1 alex alex 5992927 Dez  6 14:52 openwrt-bcm27xx-bcm2711-rpi-4-rootfs.tar.gz
-rw-r--r-- 1 alex alex 13589896 Dez  6 14:53 openwrt-bcm27xx-bcm2711-rpi-4-squashfs-factory.img.gz
-rw-r--r-- 1 alex alex 13590742 Dez  6 14:53 openwrt-bcm27xx-bcm2711-rpi-4-squashfs-sysupgrade.img.gz
drwxr-xr-x 2 alex alex    4096 Dez  6 14:53 packages
-rw-r--r-- 1 alex alex    2140 Dez  6 14:53 profiles.json
-rw-r--r-- 1 alex alex    1022 Dez  6 14:53 sha256sums
-rw-r--r-- 1 alex alex      18 Dez  6 14:25 version.buildinfo
```

2. Extract the openwrt-bcm27xx-bcm2711-rpi-4-ext4-factory.img.gz archive:

```
alex@ubuntu:~/Projects/buildroot/openwrt/bin/targets/bcm27xx/bcm2711$ gzip -d openwrt-bcm27xx-bcm2711-rpi-4-ext4-factory.img.gz
alex@ubuntu:~/Projects/buildroot/openwrt/bin/targets/bcm27xx/bcm2711$ ls -al
total 227236
drwxr-xr-x 3 alex alex    4096 Dez  7 10:01 .
drwxr-xr-x 3 alex alex    4096 Dez  6 11:59 ..
-rw-r--r-- 1 alex alex     130 Dez  6 14:25 config.buildinfo
-rw-r--r-- 1 alex alex     268 Dez  6 14:25 feeds.buildinfo
-rw-r--r-- 1 alex alex 184549376 Dez  6 14:53 openwrt-bcm27xx-bcm2711-rpi-4-ext4-factory.img
-rw-r--r-- 1 alex alex 14918371 Dez  6 14:53 openwrt-bcm27xx-bcm2711-rpi-4-ext4-sysupgrade.img.gz
-rw-r--r-- 1 alex alex    3894 Dez  6 14:53 openwrt-bcm27xx-bcm2711-rpi-4.manifest
-rw-r--r-- 1 alex alex 5992927 Dez  6 14:52 openwrt-bcm27xx-bcm2711-rpi-4-rootfs.tar.gz
-rw-r--r-- 1 alex alex 13589896 Dez  6 14:53 openwrt-bcm27xx-bcm2711-rpi-4-squashfs-factory.img.gz
-rw-r--r-- 1 alex alex 13590742 Dez  6 14:53 openwrt-bcm27xx-bcm2711-rpi-4-squashfs-sysupgrade.img.gz
drwxr-xr-x 2 alex alex    4096 Dez  6 14:53 packages
-rw-r--r-- 1 alex alex    2140 Dez  6 14:53 profiles.json
-rw-r--r-- 1 alex alex    1022 Dez  6 14:53 sha256sums
-rw-r--r-- 1 alex alex      18 Dez  6 14:25 version.buildinfo
```

4.1 Connecting the eMMC storage as USB drive to flash the image

You should follow the instructions on this page:

<https://www.jeffgeerling.com/blog/2020/how-flash-raspberry-pi-os-compute-module-4-emmc-usbboot>

to connect the eMMC storage of the RPi4CM as a USB drive to flash the OpenWRT image to it.

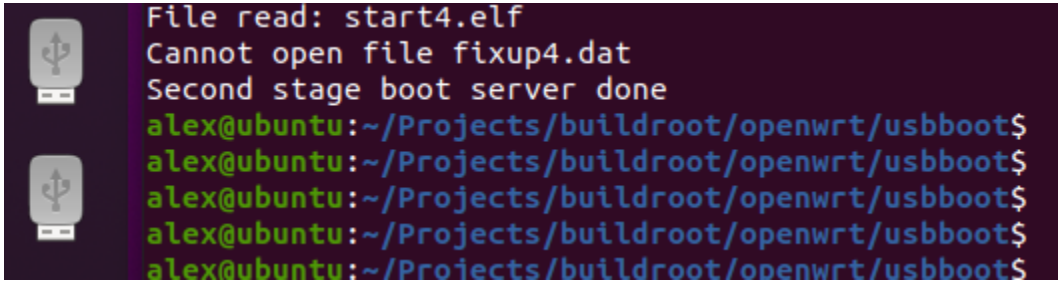
```
alex@ubuntu:~/Projects/buildroot/openwrt$ git clone --depth=1 https://github.com/raspberrypi/usbboot
Cloning into 'usbboot'...
remote: Enumerating objects: 94, done.
remote: Counting objects: 100% (94/94), done.
remote: Compressing objects: 100% (77/77), done.
remote: Total 94 (delta 7), reused 56 (delta 2), pack-reused 0
Unpacking objects: 100% (94/94), 88.62 MiB | 4.65 MiB/s, done.

alex@ubuntu:~/Projects/buildroot/openwrt/usbboot$ make
cc -Wall -Wextra -g -o bin2c bin2c.c
./bin2c msd/bootcode.bin msd/bootcode.h
./bin2c msd/start.elf msd/start.h
./bin2c msd/bootcode4.bin msd/bootcode4.h
./bin2c msd/start4.elf msd/start4.h
cc -Wall -Wextra -g -o rpiboot main.c `pkg-config --cflags --libs libusb-1.0` -DGIT_VER="\922f3863\" -
DPKG_VER="\20221215~105525\"

alex@ubuntu:~/Projects/buildroot/openwrt/usbboot$ ls
bin2c      bootcode4.bin  docs          fmemopen.c  main.c      mass-storage-gadget  Readme.md  recovery.bin  rpi-
imager-embedded  secure-boot-msd      tools
bin2c.c  debian          eeprom-erase  LICENSE     Makefile    msd                  recovery    rpiboot
secure-boot-example  secure-boot-recovery  win32

alex@ubuntu:~/Projects/buildroot/openwrt/usbboot$ sudo ./rpiboot
RPIBOOT: build-date Dec 12 2023 version 20221215~105525 922f3863
Waiting for BCM2835/6/7/2711...
Loading embedded: bootcode4.bin
Sending bootcode.bin
Successful read 4 bytes
Waiting for BCM2835/6/7/2711...
Loading embedded: bootcode4.bin
Second stage boot server
Cannot open file config.txt
Cannot open file pieeprom.sig
Loading embedded: start4.elf
File read: start4.elf
Cannot open file fixup4.dat
Second stage boot server done
```

Now you should see the icons for the internal RPi4CM eMMC memory appearing:



```
File read: start4.elf
Cannot open file fixup4.dat
Second stage boot server done
alex@ubuntu:~/Projects/buildroot/openwrt/usbboot$
alex@ubuntu:~/Projects/buildroot/openwrt/usbboot$
alex@ubuntu:~/Projects/buildroot/openwrt/usbboot$
alex@ubuntu:~/Projects/buildroot/openwrt/usbboot$
alex@ubuntu:~/Projects/buildroot/openwrt/usbboot$
```

Writing the image to the eMMC:

```
alex@ubuntu:~/Projects/buildroot/openwrt/bin/targets/bcm27xx/bcm2711$ sudo dd if=openwrt-bcm27xx-bcm2711-rpi-4-
ext4-factory.img of=/dev/sdb bs=1M conv=sync
176+0 records in
176+0 records out
184549376 bytes (185 MB, 176 MiB) copied, 67,7595 s, 2,7 MB/s
alex@ubuntu:~/Projects/buildroot/openwrt/bin/targets/bcm27xx/bcm2711$
```

```
alex@ubuntu:~/Projects/buildroot/openwrt/bin/targets/bcm27xx/bcm2711$ sudo dd if=openwrt-bcm27xx-bcm2711-rpi-4-ext4-factory.img of=/dev/sdb bs=1M conv=sync
176+0 records in
176+0 records out
184549376 bytes (185 MB, 176 MiB) copied, 67,7595 s, 2,7 MB/s
alex@ubuntu:~/Projects/buildroot/openwrt/bin/targets/bcm27xx/bcm2711$
```

5 Preparing for Boot and First Boot

5.1 Customizing Device Tree settings

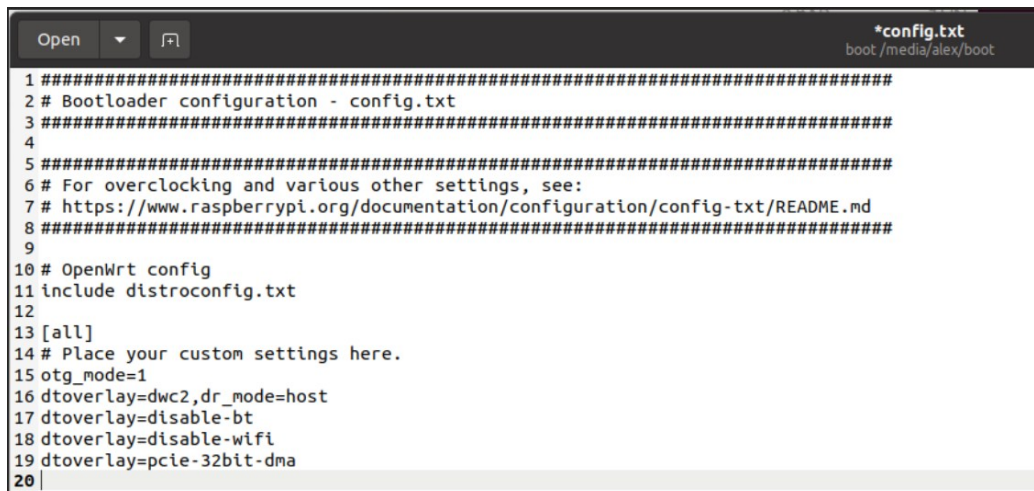
In the Boot partition of the eMMC memory of the RPi4CM make the following changes to the config.txt file:

```
#####
# Bootloader configuration - config.txt
#####

#####
# For overclocking and various other settings, see:
# https://www.raspberrypi.org/documentation/configuration/config-txt/README.md
#####

# OpenWrt config
include distroconfig.txt

[all]
# Place your custom settings here.
otg_mode=1
dtoverlay=dwc2,dr_mode=host
dtoverlay=disable-bt
dtoverlay=disable-wifi
dtoverlay=pcie-32bit-dma
```



```
Open  *config.txt
boot /media/alex/boot

1 #####
2 # Bootloader configuration - config.txt
3 #####
4
5 #####
6 # For overclocking and various other settings, see:
7 # https://www.raspberrypi.org/documentation/configuration/config-txt/README.md
8 #####
9
10 # OpenWrt config
11 include distroconfig.txt
12
13 [all]
14 # Place your custom settings here.
15 otg_mode=1
16 dtoverlay=dwc2,dr_mode=host
17 dtoverlay=disable-bt
18 dtoverlay=disable-wifi
19 dtoverlay=pcie-32bit-dma
20 |
```

"dtoverlay=dwc2,dr_mode=host" and "otg_mode=1" are necessary to enable the USB host ports to be able to operate the RPi4CM with a USB keyboard.

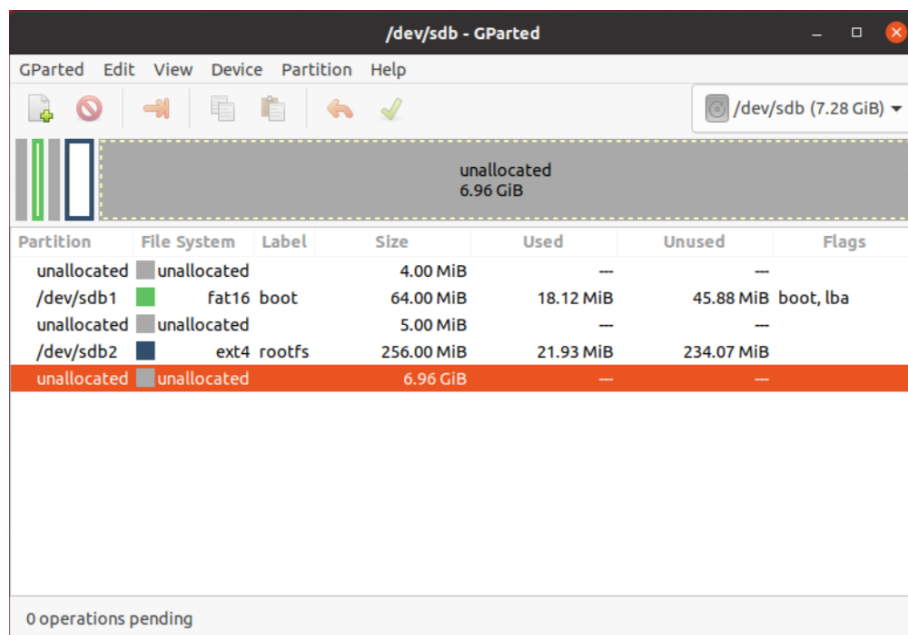
"dtoverlay=pcie-32bit-dma" is required to enable 32bit DMA to operate the ST60-2230-P Wifi module.

"dtoverlay=disable-wifi" and "dtoverlay=disable-bt" is to disable possible on-board radios.

Note: Make sure to save the changes and reboot.

5.2 Increasing rootfs Partition

Use “sudo gparted” to increase the size of the rootfs partition as the original size of around 100Mbyte is not enough to host the additional software that needs to be installed. In this example the size of the partition has been increased to 256Mbyte.



Note: Be *very careful* to perform this action with the correct drive! Failure to do so might result in a bricked development PC.

Increasing the partition size to 512MByte or larger was unsuccessful. But resolving this is beyond the scope of this guide.

5.3 First Boot

Remove the jumper from J2 and the micro-USB cable that was used to flash the RPi4CM.

Note: The function of J2 and the USB cable is described in above mentioned guide from Jeff Geerling.

Connect a HDMI monitor, a keyboard, a 12V power supply and power the board. You should see a screen like the following on your HDMI monitor connected to your RPi4CM:

[illegible]

Note: observe the “Please press Enter to activate this console” message.

6 Driver generation and Firmware placement

6.1 Cross-compiling the drivers

In the OpenWRT top directory make a directory to place the backport driver sources in and change to it:

```
alex@ubuntu:~/Projects/buildroot/openwrt$ mkdir backports
alex@ubuntu:~/Projects/buildroot/openwrt$ cd backports
alex@ubuntu:~/Projects/buildroot/openwrt/backports$
```

Create a file to place the necessary environment variables in and source it:

```
alex@ubuntu:~/Projects/buildroot/openwrt/backports$ cat openwrt_env
# RPi4cm
ARCH=arm64
CROSS_COMPILE=/home/alex/Projects/buildroot/openwrt/staging_dir/toolchain-aarch64_cortex-a72_gcc-12.3.0_musl/bin/aarch64-openwrt-linux-
KLIB_BUILD=/home/alex/Projects/buildroot/openwrt/build_dir/target-aarch64_cortex-a72_musl/linux-bcm27xx_bcm2711/linux-5.15.134
KLIB=/home/alex/Projects/buildroot/openwrt/staging_dir/target-aarch64_cortex-a72_musl/root-bcm27xx/lib/modules

alex@ubuntu:~/Projects/buildroot/openwrt/backports$ source openwrt_env
```

To check all environment variable are correct:

```
alex@ubuntu:~/Projects/buildroot/openwrt/backports$ echo $ARCH
arm64

alex@ubuntu:~/Projects/buildroot/openwrt/backports$ echo $CROSS_COMPILE
/home/alex/Projects/buildroot/openwrt/staging_dir/toolchain-aarch64_cortex-a72_gcc-12.3.0_musl/bin/aarch64-openwrt-linux-

alex@ubuntu:~/Projects/buildroot/openwrt/backports$ echo $KLIB_BUILD
/home/alex/Projects/buildroot/openwrt/build_dir/target-aarch64_cortex-a72_musl/linux-bcm27xx_bcm2711/linux-5.15.134

alex@ubuntu:~/Projects/buildroot/openwrt/backports$ echo $KLIB
/home/alex/Projects/buildroot/openwrt/staging_dir/target-aarch64_cortex-a72_musl/root-bcm27xx/lib/modules
```

Fetch the backport driver sources:

```
alex@ubuntu:~/Projects/buildroot/openwrt/backports$ wget https://github.com/LairdCP/Sterling-60-Release-
Packages/releases/download/LRD-REL-11.39.0.23/backports-laird-11.39.0.23.tar.bz2
--2023-12-12 15:20:06-- https://github.com/LairdCP/Sterling-60-Release-Packages/releases/download/LRD-REL-
11.39.0.23/backports-laird-11.39.0.23.tar.bz2
Resolving github.com (github.com)... 140.82.121.3
Connecting to github.com (github.com)|140.82.121.3|:443... connected.
HTTP request sent, awaiting response... 302 Found
...
Saving to: 'backports-laird-11.39.0.23.tar.bz2'

backports-laird-11.39.0.23.tar.bz2
100%[=====>] 10,46M 12,3MB/s in
0,9s

2023-12-12 15:20:08 (12,3 MB/s) - 'backports-laird-11.39.0.23.tar.bz2' saved [10965529/10965529]

alex@ubuntu:~/Projects/buildroot/openwrt/backports$ ls
backports-laird-11.39.0.23.tar.bz2 openwrt_env
```

Note: At the time of writing, backports version 11.39.0.23 was the latest. For other releases please adapt the "wget link".

Un-zip and un-tar the archive:

```
alex@ubuntu:~/Projects/buildroot/openwrt/backports$ bunzip2 backports-laird-11.39.0.23.tar.bz2

alex@ubuntu:~/Projects/buildroot/openwrt/backports$ ls
backports-laird-11.39.0.23.tar openwrt_env

alex@ubuntu:~/Projects/buildroot/openwrt/backports$ tar xf backports-laird-11.39.0.23.tar -C .

alex@ubuntu:~/Projects/buildroot/openwrt/backports$ ls
backports-laird-11.39.0.23.tar laird-backport-11.39.0.23 openwrt_env
```

Change to the backport directory and issue:

```
alex@ubuntu:~/Projects/buildroot/openwrt/backports$ cd laird-backport-11.39.0.23/
alex@ubuntu:~/Projects/buildroot/openwrt/backports/laired-backport-11.39.0.23$

alex@ubuntu:~/Projects/buildroot/openwrt/backports/laired-backport-11.39.0.23$ make clean

alex@ubuntu:~/Projects/buildroot/openwrt/backports/laired-backport-11.39.0.23$ make defconfig-sterling60_nbt
cc -Wall -Wmissing-prototypes -Wstrict-prototypes -O2 -fomit-frame-pointer -c -o conf.o conf.c
flex -ozconf.lex.c -L zconf.l
bison -ozconf.tab.c -t -l zconf.y
cc -Wall -Wmissing-prototypes -Wstrict-prototypes -O2 -fomit-frame-pointer -c -o zconf.tab.o zconf.tab.c
cc conf.o zconf.tab.o -o conf
#
# configuration written to .config
#

alex@ubuntu:~/Projects/buildroot/openwrt/backports/laired-backport-11.39.0.23$ make
make[5]: 'conf' is up to date.
#
# configuration written to .config
#
Building backport-include/backport/autoconf.h ... done.
CC [M] /home/alex/Projects/buildroot/openwrt/backports/laired-backport-11.39.0.23/compat/main.o
CC [M] /home/alex/Projects/buildroot/openwrt/backports/laired-backport-11.39.0.23/compat/lib-crypto-arc4.o
LD [M] /home/alex/Projects/buildroot/openwrt/backports/laired-backport-11.39.0.23/compat/compat.o

...

CC [M] /home/alex/Projects/buildroot/openwrt/backports/laired-backport-11.39.0.23/net/wireless/cfg80211.mod.o
LD [M] /home/alex/Projects/buildroot/openwrt/backports/laired-backport-11.39.0.23/net/wireless/cfg80211.ko
BTF [M] /home/alex/Projects/buildroot/openwrt/backports/laired-backport-11.39.0.23/net/wireless/cfg80211.ko
Skipping BTF generation for /home/alex/Projects/buildroot/openwrt/backports/laired-backport-11.39.0.23/net/wireless/cfg80211.ko due to unavailability of vmlinux
alex@ubuntu:~/Projects/buildroot/openwrt/backports/laired-backport-11.39.0.23$ find . -name *.ko
./compat/compat.ko
./drivers/net/wireless/laired/lrldmwl/lrldmwl_sdio.ko
./drivers/net/wireless/laired/lrldmwl/lrldmwl.ko
./drivers/net/wireless/laired/lrldmwl/lrldmwl_pcie.ko
./drivers/net/wireless/laired/lrldmwl/lrldmwl_usb.ko
./net/mac80211/mac80211.ko
./net/wireless/cfg80211.ko
```

Notes: If an error is thrown because packages like “flex” or “bison” are missing on your development PC, simply install them with e.g., *sudo apt-get install flex bison*

When building for the first time the output might look slightly different.

The “nbt” in stands for “No-Blue-Tooth”. We only integrate for Wi-Fi; hence BT is not needed.

The “make” process might take quite a bit of time.

6.2 Transferring the drivers and firmware to the target

After build process has finished, issue:

```
alex@ubuntu:~/Projects/buildroot/openwrt/backports/laird-backport-11.39.0.23$ find . -name '*.ko' | xargs tar
cvf backports-openwrt-st60.tar
./compat/compat.ko
./drivers/net/wireless/laird/lrdmwl/lrdmwl_sdio.ko
./drivers/net/wireless/laird/lrdmwl/lrdmwl.ko
./drivers/net/wireless/laird/lrdmwl/lrdmwl_pcie.ko
./drivers/net/wireless/laird/lrdmwl/lrdmwl_usb.ko
./net/mac80211/mac80211.ko
./net/wireless/cfg80211.ko
alex@ubuntu:~/Projects/buildroot/openwrt/backports/laird-backport-11.39.0.23$ ls *.tar
backports-openwrt-st60.tar
```

Download the respective ST60-2230-P firmware file from Github:

```
alex@ubuntu:~/Projects/buildroot/openwrt/backports/laird-backport-11.39.0.23$ wget
https://github.com/LairdCP/Sterling-60-Release-Packages/releases/download/LRD-REL-11.39.0.23/laird-60-radio-
firmware-pcie-uart-11.39.0.23.tar.bz2
```

Extract the .bz2 file:

```
alex@ubuntu:~/Projects/buildroot/openwrt/backports/laird-backport-11.39.0.23$ bunzip2 laird-60-radio-firmware-
pcie-uart-11.39.0.23.tar.bz2
alex@ubuntu:~/Projects/buildroot/openwrt/backports/laird-backport-11.39.0.23$ ls *.tar
backports-openwrt-st60.tar laird-60-radio-firmware-pcie-uart-11.39.0.23.tar
```

and copy the .tar files to a USB stick to copy them to your target:

```
alex@ubuntu:~/Projects/buildroot/openwrt/backports/laird-backport-11.39.0.23$ sudo cp *.tar /media/alex/LAIRD/
alex@ubuntu:~/Projects/buildroot/openwrt/backports/laird-backport-11.39.0.23$ ls /media/alex/LAIRD/*.tar
/media/alex/LAIRD/backports-openwrt-st60.tar /media/alex/LAIRD/laird-60-radio-firmware-pcie-uart-
11.39.0.23.tar
```

Mount that USB stick on your target RPi4CM and install both tar files:

```
mount /dev/sda1 /mnt
```

```
root@OpenWrt:~# mount /dev/sda1 /mnt
[ 60.351432] F2FS-fs (sda1): Magic Mismatch, valid(0xf2f52010) - read(0x0)
[ 60.360171] F2FS-fs (sda1): Can't find valid F2FS filesystem in 1th superblock
[ 60.369811] F2FS-fs (sda1): Magic Mismatch, valid(0xf2f52010) - read(0x0)
[ 60.378054] F2FS-fs (sda1): Can't find valid F2FS filesystem in 2th superblock
[ 60.389940] FAT-fs (sda1): Volume was not properly unmounted. Some data may be corrupt. Please run fsck.
root@OpenWrt:~#
```

```
cd /mnt
ls -al *.tar
```

```
root@OpenWrt:/# cd /mnt
root@OpenWrt:/mnt# ls -al *.tar
-rwxr-xr-x  1 root    root      9615360 Dec 12  2023 backports-openwrt-st60.tar
-rwxr-xr-x  1 root    root      399360 Dec 12  2023 laird-60-radio-firmware-pcie-uart-11.39.0.23.tar
root@OpenWrt:/mnt#
```

```
tar xvf backports-openwrt-st60.tar -C /backports/
```

```
root@OpenWrt:/mnt# tar xvf backports-openwrt-st60.tar -C /backports/
./compat/compat.ko
./net/wireless/cfg80211.ko
./net/mac80211/mac80211.ko
./drivers/net/wireless/laird/lrdmwl/lrdmwl_sdio.ko
./drivers/net/wireless/laird/lrdmwl/lrdmwl_pcie.ko
./drivers/net/wireless/laird/lrdmwl/lrdmwl.ko
./drivers/net/wireless/laird/lrdmwl/lrdmwl_usb.ko
root@OpenWrt:/mnt# ls -al /backports/
drwxr-xr-x  5 root    root      4096 Oct  9 21:49 .
drwxr-xr-x 19 root    root      4096 Oct  9 21:48 ..
drwxr-xr-x  2 root    root      4096 Oct  9 21:51 compat
drwxr-xr-x  3 root    root      4096 Oct  9 21:49 drivers
drwxr-xr-x  4 root    root      4096 Oct  9 21:49 net
root@OpenWrt:/mnt#
```

Note: Files "lrdmwl_sdio.ko" and "lrdmwl_usb.ko" are not required and can be left out or deleted for the sake of saving space on the RPi4CMs eMMC storage.

```
tar xvf laird-60-radio-firmware-pcie-uart-11.39.0.23.tar -C /
```

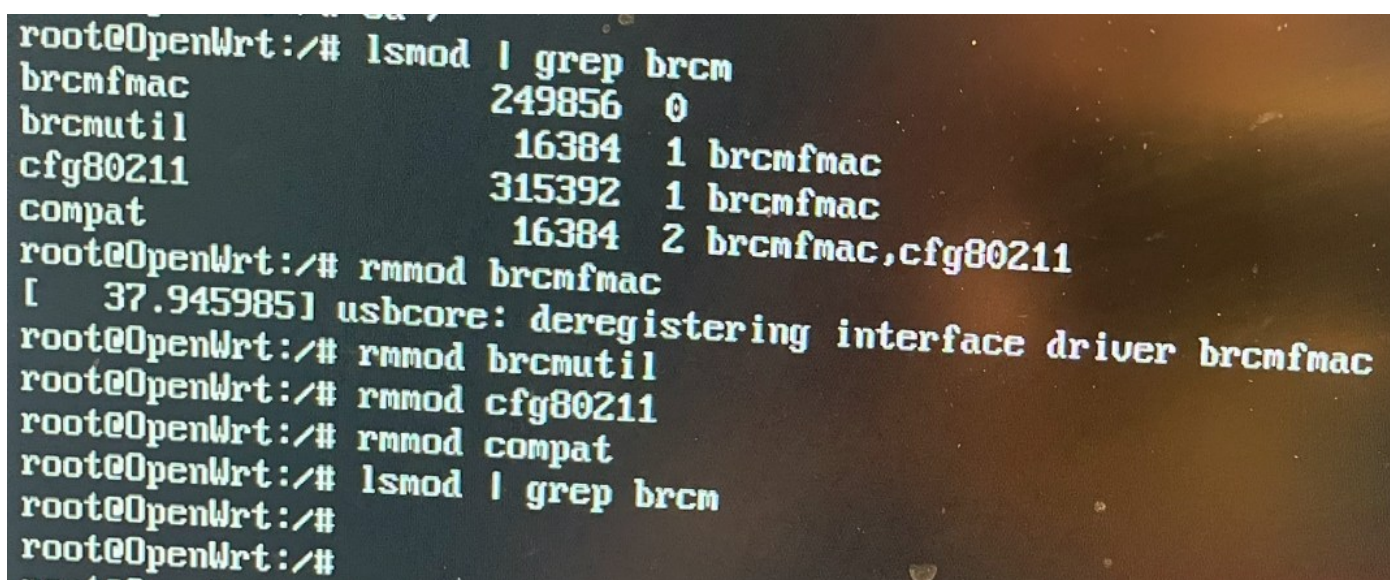
```
root@OpenWrt:/mnt# tar xvf laird-60-radio-firmware-pcie-uart-11.39.0.23.tar -C /
lib/firmware/lrdmwl/88W8997_pcie.bin
lib/firmware/lrdmwl/88W8997_60_pcie_uart_v5.4.53.5.bin
lib/firmware/lrdmwl/regpwr_60.db
lib/firmware/lrdmwl/regpwr.db
lib/firmware/regulatory_60.db
lib/firmware/regulatory.db
root@OpenWrt:/mnt# ls -al /lib/firmware/lrdmwl/
drwxr-xr-x  2 root    root      4096 Oct  9 21:50 .
drwxr-xr-x  6 root    root      4096 Oct  9 21:50 ..
-rw-r--r--  1 root    root      370692 Aug 15 20:01 88W8997_60_pcie_uart_v5.4.53.5.bin
lrwxrwxrwx  1 root    root        34 Oct  9 21:50 88W8997_pcie.bin -> 88W8997_60_pcie_uart_v5.4.53.5.bin
lrwxrwxrwx  1 root    root        12 Oct  9 21:50 regpwr.db -> regpwr_60.db
-rw-r--r--  1 root    root      11808 Aug 15 20:01 regpwr_60.db
root@OpenWrt:/mnt#
```

7 Bringing Up the Wi-Fi Interface

7.1 Removing already loaded drivers (aka kernel modules)

In order for the Ezurio backport drivers to be loaded, already inserted drivers need to be removed:

```
lsmod | grep brcm  
rmmod brcmfmac  
rmmod brcmutil  
rmmod cfg80211  
rmmod compat  
lsmod | grep brcm
```



```
root@OpenWrt:/# lsmod | grep brcm  
brcmfmac                249856  0  
brcmutil                16384  1 brcmfmac  
cfg80211                315392  1 brcmfmac  
compat                  16384  2 brcmfmac,cfg80211  
root@OpenWrt:/# rmmod brcmfmac  
[ 37.945985] usbcore: deregistering interface driver brcmfmac  
root@OpenWrt:/# rmmod brcmutil  
root@OpenWrt:/# rmmod cfg80211  
root@OpenWrt:/# rmmod compat  
root@OpenWrt:/# lsmod | grep brcm  
root@OpenWrt:/#  
root@OpenWrt:/#
```

Note: There is no difference in the names of each driver between the originally loaded drivers and the Ezurio ones. Care needs to be taken not to confuse them.

7.2 Inserting Ezurio's Backport Drivers

```
cd /backports
find . -name *.ko
insmod ./compat/compat.ko
insmod ./net/wireless/cfg80211.ko
insmod ./net/mac80211/mac80211.ko
insmod ./drivers/net/wireless/laird/lrwmwl/lrwmwl.ko
insmod ./drivers/net/wireless/laird/lrwmwl/lrwmwl_pcie.ko
```

```
root@OpenWrt:~# cd backports/
root@OpenWrt:/backports# find . -name *.ko
./compat/compat.ko
./net/wireless/cfg80211.ko
./net/mac80211/mac80211.ko
./drivers/net/wireless/laird/lrwmwl/lrwmwl_sdio.ko
./drivers/net/wireless/laird/lrwmwl/lrwmwl_pcie.ko
./drivers/net/wireless/laird/lrwmwl/lrwmwl.ko
./drivers/net/wireless/laird/lrwmwl/lrwmwl_usb.ko
root@OpenWrt:/backports# insmod ./compat/compat.ko
[ 147.250611] Loading modules backported from Summit Linux version LRD-REL-11.39.0.23-0-gffaa99f4ab70
[ 147.260689] Backport generated by backports.git v11.39.0.23
root@OpenWrt:/backports# insmod ./net/wireless/cfg80211.ko
root@OpenWrt:/backports# insmod ./net/mac80211/mac80211.ko
root@OpenWrt:/backports# insmod ./drivers/net/wireless/laird/lrwmwl/lrwmwl.ko
root@OpenWrt:/backports# insmod ./drivers/net/wireless/laird/lrwmwl/lrwmwl_pcie.ko
[ 235.877816] <<Laird Connectivity 60 Series Wireless Network Driver version 11.39.0.23-P39-20190123>>
[ 235.877913] lrwmwl_pcie 0000:01:00.0: enabling device (0000 -> 0002)
[ 235.896201] ieee80211 phy0: mwl_tx_init() called: ctype=3
[ 235.902765] ieee80211 phy0: TX ring: allocating 640 bytes
[ 235.908719] ieee80211 phy0: TX ring: - base: 000000000c607dd4, pbase: 0x0:2ae00000, len: 280
[ 235.923550] ieee80211 phy0: Starting fw download
[ 235.936752] ieee80211 phy0: lrwmwl: found firmware image <lrwmwl/88W8997_pcie.bin>
[ 236.380642] ieee80211 phy0: FwSize = 370692 downloaded Size = 370692
[ 238.487334] ieee80211 phy0: fw download complete
[ 238.496970] ieee80211 phy0: OTP data len = 0
[ 238.504620] ieee80211 phy0: Radio Type SU60 (0x1)
[ 238.510857] ieee80211 phy0: Num mac 3 : OTP Version (1)
[ 238.516866] ieee80211 phy0: Firmware version: 5.4.53.5
[ 238.522746] ieee80211 phy0: Firmware OTP region: ff, country: 00
[ 238.529486] ieee80211 phy0: Deep Sleep is disabled
[ 238.534965] ieee80211 phy0: 2G enabled, 5G enabled
[ 238.540474] ieee80211 phy0: 2 TX antennas, 2 RX antennas. (00000003)/(00000003)
root@OpenWrt:/backports#
```

7.3 Bringing up the Wi-Fi Interface and Proof Of Work

```
iw dev
ip addr
```

```
root@OpenWrt:/backports# iw dev
phy#0
    Interface wlan0
        ifindex 4
        wdev 0x1
        addr c0:ee:40:42:c7:3c
        type managed
        txpower 0.00 dBm
root@OpenWrt:/backports# ip addr
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN qlen 1000
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
    inet 127.0.0.1/8 scope host lo
        valid_lft forever preferred_lft forever
    inet6 ::1/128 scope host
        valid_lft forever preferred_lft forever
2: eth0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc mq master br-lan state UP qlen 1000
    link/ether dc:a6:32:e3:6d:f7 brd ff:ff:ff:ff:ff:ff
3: br-lan: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc noqueue state UP qlen 1000
    link/ether dc:a6:32:e3:6d:f7 brd ff:ff:ff:ff:ff:ff
    inet 192.168.1.1/24 brd 192.168.1.255 scope global br-lan
        valid_lft forever preferred_lft forever
    inet6 fd0b:ff44:3508::1/60 scope global noprefixroute
        valid_lft forever preferred_lft forever
    inet6 fe80::dea6:32ff:fee3:6df7/64 scope link
        valid_lft forever preferred_lft forever
4: wlan0: <BROADCAST,MULTICAST> mtu 1500 qdisc noop state DOWN qlen 1000
    link/ether c0:ee:40:42:c7:3c brd ff:ff:ff:ff:ff:ff
root@OpenWrt:/backports#
```

Note: This now shows the presence of the "wlan0" Wi-Fi interface.

```
ip link set wlan0 up
iw wlan0 scan | grep SSID
```

```

4: wlan0: <BROADCAST,MULTICAST> mtu 1500 qdisc noop state DOWN qlen 1000
    link/ether c0:ee:40:42:c7:3c brd ff:ff:ff:ff:ff:ff
root@OpenWrt:/backports# iw wlan0 scan | grep ssid
command failed: Network is down (-100)
root@OpenWrt:/backports# ip link set wlan0 up
[ 434.692625] ieee80211 phy0: WMM Turbo=1
root@OpenWrt:/backports# iw wlan0 scan | grep ssid
root@OpenWrt:/backports# iw wlan0 scan | grep SSID
    SSID: homeGuest
    SSID: home24
    SSID: home24
    SSID: homeGuest
    SSID: homeGuest
    SSID: home50
    SSID: home50
    SSID: homeGuest
root@OpenWrt:/backports# _

```

8 When it May be Necessary to Change Kernel Config

8.1 Newer Kernel Versions

The main kernel config, as of 5.19, now requires that `cfg80211` be included so that the networking core layer can support an external `cfg80211` module.

The kernel version in this guide is 5.15.134:

```
root@OpenWrt:/backports# uname -a
Linux OpenWrt 5.15.134 #0 SMP Mon Oct 9 21:45:35 2023 aarch64 GNU/Linux
root@OpenWrt:/backports#
```

Hence it was not necessary to include "Wireless" as "M".

However, kernel configuration can be changed with issuing this command:

```
make -j$(nproc) kernel_menuconfig
```

```
ion

                                Wireless

its submenus ---> (or empty submenus ----). Highlighted letters
xit, <?> for Help, </> for Search. Legend: [*] built-in [ ] ex

--- Wireless
[ ] Wireless extensions
[ ] WEXT_SPY
[ ] WEXT_PRIV
<M> cfg80211 - wireless configuration API
[ ] nl80211 testmode command (NEW)
[ ] enable developer warnings (NEW)
[ ] cfg80211 certification onus
[*] enable powersave by default (NEW)
[ ] cfg80211 DebugFS entries (NEW)
[*] support CRDA (NEW)
[ ] cfg80211 wireless extensions compatibility (NEW)
< > LIB80211
< > LIB80211_CRYPT_WEP
< > LIB80211_CRYPT_CCMP
< > LIB80211_CRYPT_TKIP
< > Generic IEEE 802.11 Networking Stack (mac80211)
```

8.2 If WEXT should become included OpenWRT default kernel config as previously

It is a requirement to have WEXT disabled as it is not supported by Ezurio's backports.

```
--- Wireless
[ ] Wireless extensions
[ ] WEXT_SPY
[ ] WEXT_PRIV
```

9 Revision History

Version	Date	Notes	Contributor(s)	Approver
1.0	21 December 2023	Initial Release	Alexander Mohr	Andy Ross
2.0	15 Apr 2025	Ezurio rebranding	Sue White	Dave Drogowski

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