NEW RADIO COMMUNICATION FOR NEW ERA

NRC7394 Evaluation Kit User Guide

(Standalone)

Ultra-low power & Long-range Wi-Fi

Ver 1.0
Jul. 17, 2023

NEWRACOM, Inc.

NRC7394 Evaluation Kit User Guide (Standalone)
Ultra-low power & Long-range Wi-Fi

Office

Newracom, Inc.
505 Technology Drive, Irvine, CA 92618 USA
http://www.newracom.com

Contents

1 Overview 6
1.1 HW list 7
1.1.1 NRC7394 module 7
1.1.2 NRC7394 EVB 7
1.2 Kit list 8
1.3 S/W list 8
1.3.1 NRC7394 SDK 8
2 Setup S/W build environment 10
2.1 Toolchain setup 10
2.2 Download SDK 10
2.3 SDK application program 11
2.3.1 Sample application programs 11
2.3.2 Application program project structure 11
2.3.3 Build application program 13
2.3.4 SDK APIsQ 15
2.3.5 Sample applications 16
3 How to download compiled binaries 18
3.1 UART connection between PC and EVB 18
3.2 Upload the unified binary 19
4 Performance Evaluation 21
4.1 Preparation of test binary 21
4.2 Console command 21
4.2.1 WPA 21
4.2.2 DHCP 23
4.2.3 ifconfig 23
4.2.4 IPERF 24
4.2.5 PING 24
5 Abbreviations and acronyms 25
6 Revision history 26

List of Tables

Table 2.1 NRC7394 SDK APIs 15
Table 2.2 Sample applications 16

List of Figures

Figure 1.1 NRC7394 evaluation board (Top view) 6
Figure 1.2 Standalone(XIP) mode configuration 6
Figure 1.3 NRC7394 EVB Power Structure 7
Figure 1.4 NRC7394 hardware set 8
Figure 3.1 COM port in Device Manager 18
Figure 3.2 Standalone firmware downloader 19

1 Overview

This document introduces NEWRACOM's NRC7394 Evaluation kit (EVK). The evaluation kit (EVK) is used to evaluate the performance of the NRC7394 module containing NEWRACOM's IEEE 802.11ah Wi-Fi System on Chip (SoC).

Configure mode switch J4 to 2-3 (XIP write) for host mode as shown in Figure 1.2.

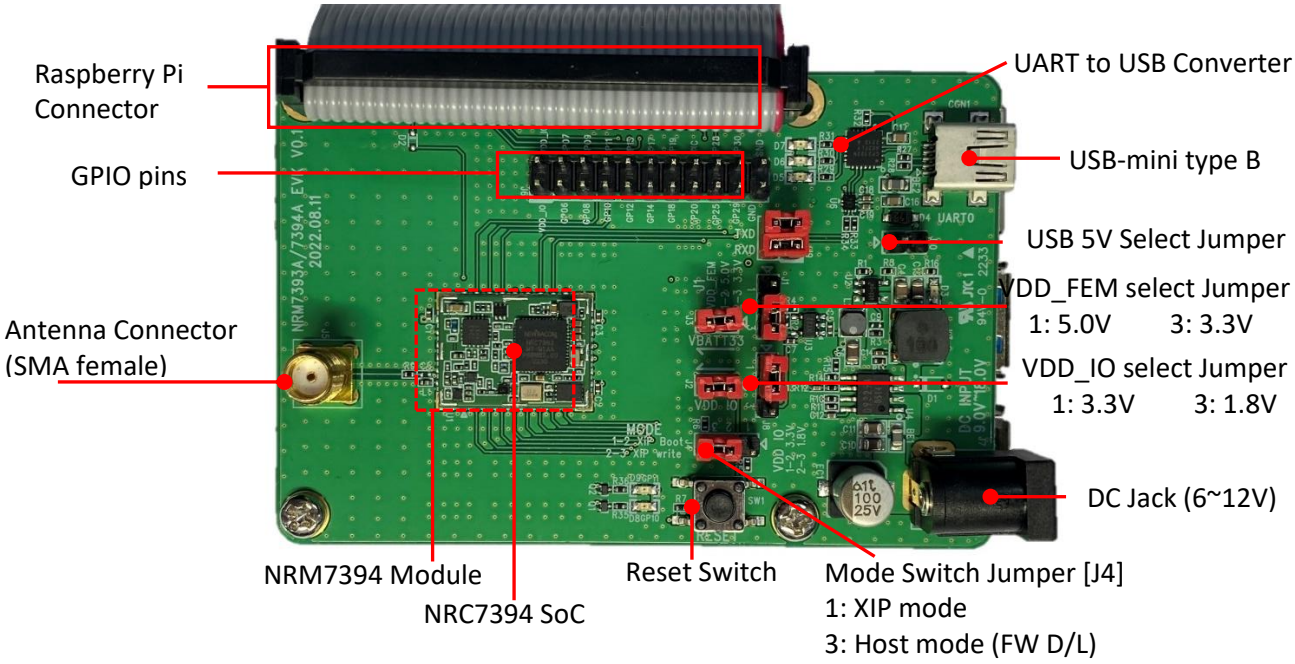

Figure 1.1 NRC7394 evaluation board (Top view)

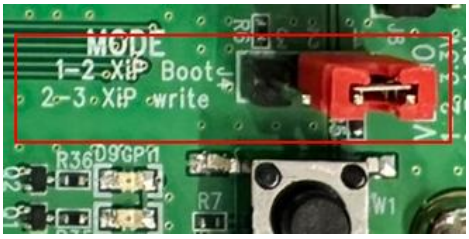

Figure 1.2 Standalone(XIP) mode configuration

1.1 HW list

1.1.1 NRC7394 module

NRC7394 module contains IEEE 802.11ah Wi-Fi SoC solution. It also includes a RF front end module (FEM) to increase transmission power up to +27 dBm. Onboard serial flash memory can be used for over-the-air (OTA) software development and with 32KB cache in the NRC7394 supports the execution in place (XIP) feature.

1.1.2 NRC7394 EVB

NRC7394 EVB mainly offers communication interfaces to sensors or an external host.

DC power adaptor requires voltage range of 6~18V, and more than 1.5A current.

The EVB board has a function of step down the DC input power to each voltage source of the module, and also can supply 5V DC of Raspberry Pi4. Each voltage source of the module has a header type test point for easy current measurement. Refer to the Figure 1.3 for the EVB's power structure.

The board has a built-in USB to serial converter and is connected to UART0, so users can check status logs through the onboard USB mini connector.

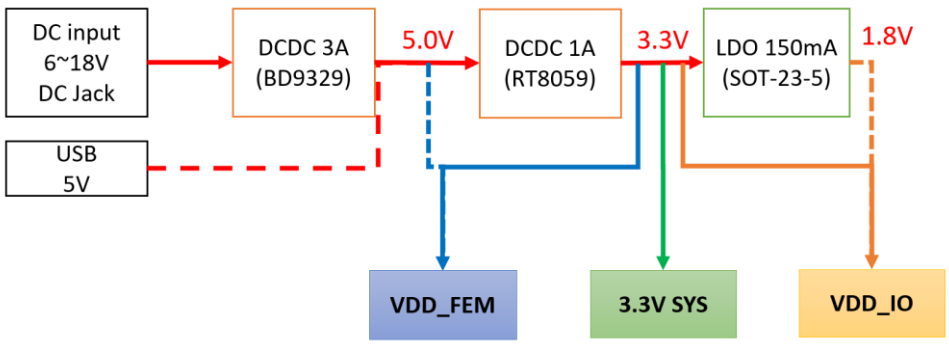

Figure 1.3 NRC7394 EVB Power Structure

1.2 Kit list

NRC7394 EVK includes:

- NRC7394 EVB (NRM7394 module mounted)
- SD card with Linux OS, NRC7394 firmware, Wi-Fi driver, and scripts
- DC 12V (1.5A) power Adaptor
- Antenna (Country frequency)
- USB2.0 mini-B cable
- Raspberry PI4 board (For host mode)

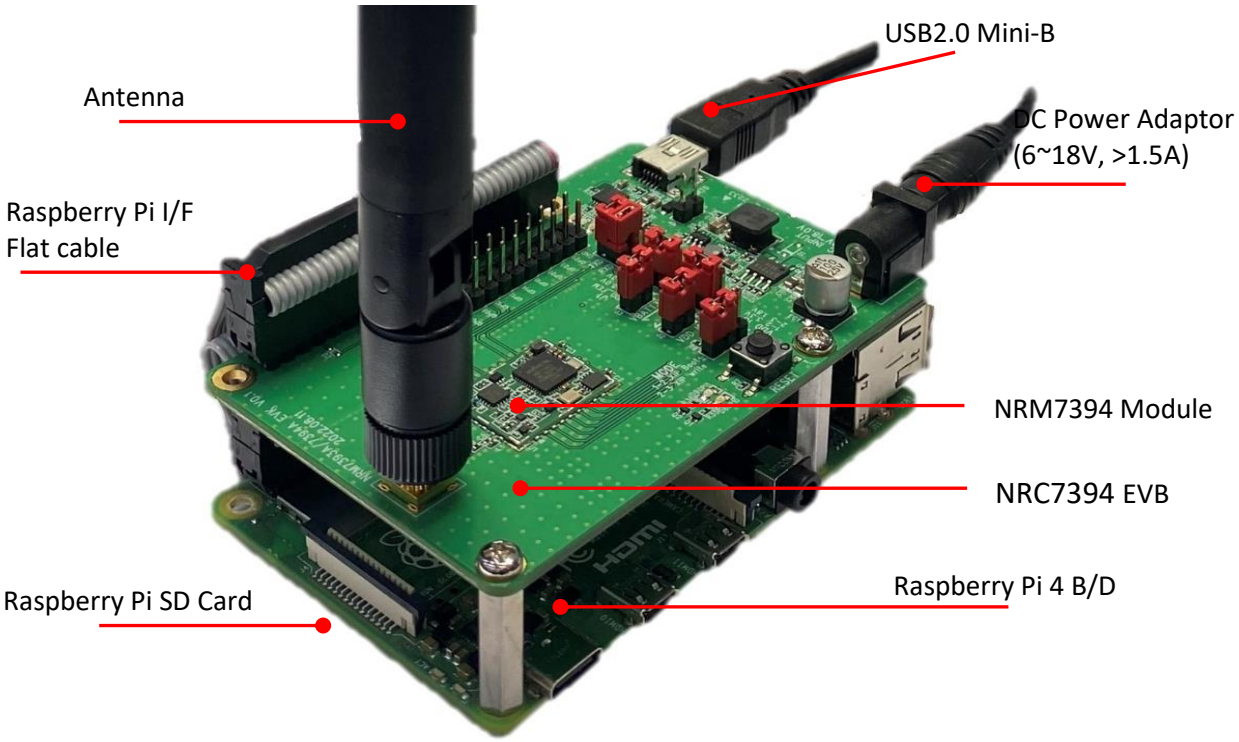

Figure 1.4 NRC7394 hardware set

1.3 S/W list

1.3.1 NRC7394 SDK

The NRC7394 SDK can be used to develop user's application program running on NRC7394 EVB. The SDK includes various types of Application Program Interfaces (APIs) for controlling Wi-Fi connectivity, Transport

Control Protocol/Internet Protocol (TCP/IP) communication, peripherals, timer, etc. In addition, users can attach various sensors on the evaluation board and communicate with them via UART, SPI, or I2C APIs.

As all standalone applications run on FreeRTOS, users can take advantage of FreeRTOS features including multi-tasking, Inter-Task Communication (ITC), memory management, etc.
(Refer to at https://www.freertos.org for more information)

2 Setup S/W build environment

The NRC7394 SDK supports a Linux environment. This chapter describes how to set up the development environment, build a user's application program, and download the binary on the EVB.

2.1 Toolchain setup

GNU ARM embedded toolchain is required to build the user's application program. Note that users should use 64-bit Linux machine to build successfully.

- Ubuntu 18.04 LTS(64-bit PC(AMD64) desktop image) or later
- GCC toolchain for ARM embedded processors
- Download the GNU Arm embedded toolchain
  - ***gcc-arm-none-eabi-10.3-2021.10-x86_64-linux.tar.bz2*** (version must exactly match) https://developer.arm.com/downloads/-/gnu-rm

Before installing the ARM embedded toolchain, users need some additional packages which can be easily installed through the standard package manager (apt-get) for Ubuntu. The following instructions discuss which packages are required, with instructions on how to install them.

```
sudo apt-get update
sudo apt-get install build-essential python2.7 python-pip git lzop
```

Once the required packages are successfully installed, download the GCC toolchain from the ARM developer website, copy the file to $HOME location, and extract it.

```
tar -xvf gcc-arm-none-eabi-10.3-2021.10-x86_64-linux.tar.bz2
```

The GCC toolchain will be extracted into ~/ gcc-arm-none-eabi-10.3-2021.10 directory. If the PATH environmental variable is set as shown below, users can run the GCC toolchai n anywhere without giving the complete path for the toolchain.

```
export PATH=$PATH:$HOME/gcc-arm-none-eabi-10.3-2021.10/bin
```

2.2 Download SDK

Users can download the NRC7394 SDK from GitHub (https://github.com/newracom/nrc7394_sdk.git).

```
git clone https://github.com/newracom/nrc7394_sdk.git
```

The NRC7394 SDK in the repository consists of several subdirectories: doc, lib, make, sdk, bdf, and tools. The doc directory contains all documents for the users, including the user guides. The lib directory holds various third-party library codes including FreeRTOS, LwIP, MbedTLS, etc. along with the SDK modem library. The make and apps directories carry makefiles and sample application programs, respectively. The tool holds the NRC7394 Standalone Firmware Downloader, AT command test tool and a firmware Flash Tool. The bdf directory contains a board data files about TX power control. The board data files depend on target hardware and country.

2.3 SDK application program

2.3.1 Sample application programs

The package offers a range of sample application programs located in the 'nrc7394_sdk/package/standalone/sdk/apps' directory. However, it's important to note that the 'wifi_common' directory within 'sdk/apps' does not contain a sample program itself, but rather consists of header and source files for Wi-Fi connectivity. If users intend to utilize Wi-Fi functionalities, they need to include the appropriate header files in their application program. The 'wifi_common' directory serves as an example, demonstrating how developers can implement their own Wi-Fi operations within their applications.

The 'nrc7394_sdk/package/standalone/sdk/inc' directory houses the API header files for various functionalities such as GPIO, I2C, UART, and more. Specifically, this directory includes only the header files for these APIs, which define the functions, constants, and data structures necessary for utilizing and interacting with the respective features. These header files serve as a reference and must be included in the application program to access the corresponding API functionalities.

2.3.2 Application program project structure

Except for the AT-command application, every project directory has the '.config', ‘Makefile’, and ‘nrc_user_config.h’ file in the project. The main source file should contain the ‘void user_init(void)’ function that serves as the entry point of the application.

The main source file should contain the ‘void user_init(void)’ function that serves as the entry point of the application.

```
├──── sample_tcp_client
│     ├────.config
│     ├──── Makefile
```

```
│   ├──── wifi_user_config.h
│   ├──── sample_tcp_client_version.h
│   └──── sample_tcp_client.c
└──── wifi_common
    ├──── module.mk
    ├──── nvs_config.h
    ├──── wifi_config.h
    ├──── wifi_config_setup.c
    ├──── wifi_config_setup.h
    ├──── wifi_connect_common.c
    └──── wifi_connect_common.h
```

To enable Wi-Fi connectivity example codes, users need to follow the steps below:

- Add the 'include $(SDK_WIFI_COMMON)/module.mk' at the end of the Makefile.
- Add your application source files to the CSRCS variable in the Makefile.

```
CSRCS += \
        sample_tcp_client.c
include $(SDK_WIFI_COMMON)/module.mk
```

To configure the Wi-Fi settings in Wi-Fi connectivity example codes, users should follow the steps outlined below:

- Open the file "wifi_user_config.h" and insert the desired values for the Wi-Fi configuration. These user-defined values should be used instead of configuration options defined in the "wifi_config.h" file.
- Check if there is an existing key in the NVS (Non-Volatile Storage). If a key is found, the corresponding value in the Wi-Fi configuration is replaced with the value stored in the NVS.

Some third-party libraries (CJSON, MQTT, MXML, AWS, etc.) are provided in the package. Users can easily include these libraries by selecting each of them in the '.config' file. For example, if the application requires the MQTT library, the user can simply change ‘n’ to ‘y’ in the '.config' file for use.

```
CONFIG_MQTT    = y
CONFIG_AWS     = n
.............
```

2.3.3 Build application program

Users can use the 'make' command at the standalone directory (nrc7394_sdk/package/standalone) to build the application program. Before running the 'make' command, however, users must create the build-target file (.build-target) which specifies the makefile used for build and the name of the application project.

(Ex) build-target file:

```
MAKEFILE = nrc7394.sdk.release
PARAM := -- APP_NAME=sample_tcp_client
```

Users can create the build-target file by following the instruction below at the standalone directory.

Usage of make command for build-target file:

```
make select target=nrc7394.sdk.release APP_NAME=($APP NAME)
```

For the general application programs, users need to give the name of the application project as the APP_NAME. For example, to build a sample TCP client application, users can write a command as shown below.

```
make select target=nrc7394.sdk.release APP_NAME=sample_tcp_client
```

Once the build-target file is created at the standalone directory, users can run the 'make' command at the same directory. This command will generate the map, elf, and unified binary file of the application program at the 'out/nrc7394/standalone_xip/{project_name}' directory.

The binary file 'nrc7394_standalone_xip_{project_name}.bin' can then be downloaded onto the module.

Build of ATCMD binary:

For AT-command application programs, the pre-defined name of the application should be provided in the following format.

HSPI mode:

```
make select target=nrc7394.sdk.release APP_NAME=ATCMD_HSPI
```

UART mode (without hardware flow control):

```
make select target=nrc7394.sdk.release APP_NAME=ATCMD_UART
```

UART mode (with hardware flow control):

```
make select target=nrc7394.sdk.release APP_NAME=ATCMD_UART_HFC
```

Usage of custom board data file:

There are two methods available for using custom board data in the NRC7394 SDK:

(1) Overwrite the board data file: By replacing the existing board data file

(ex, the bdf/nrc7394/nrc7394_bd.dat file), you can utilize your own custom board data. This involves replacing the original file with your modified version to ensure the SDK uses the updated board data.

(2) Add ALIAS during target selection

When selecting the target, you have the option to add an ALIAS to the custom board data file by using the ".dat" file extension. By placing the custom file in the same location as the original file, you can specify a different board data file for your specific target. This enables the SDK to identify and utilize your custom board data during the compilation and execution process.

```
make select target=nrc7394.sdk.release+custom_bd.dat APP_NAME=sample_tcp_client
```

Both methods provide options for incorporating your own board data into the NRC73944 SDK, allowing for customization and adaptation to specific hardware configurations.

2.3.4 SDK APIsQ

Various SDK APIs in several categories are provided for user application programming as shown in Table 2.1. Please refer to UG-7394-005-Standalone SDK API in the packet for more information.

◈*To print out logs via UART console, the debug UART console must first be enabled by calling the API function, "nrc_uart_console_enable()." Once the console is enabled, users can print the logs out to the UART console using the API function, "nrc_usr_print()."*

Table 2.1 NRC7394 SDK APIs

Category	Description
Wi-Fi	Wi-Fi connection
System	System configuration and Log level
UART	UART peripheral I/O
GPIO	GPIO peripheral I/O
I2C	I2C peripheral I/O
ADC	ADC peripheral I/O
PWM	PWM peripheral I/O
SPI	SPI peripheral I/O
HTTP Client	HTTP Client
FOTA	Firmware Over-The-Air
Power Save	Sleep mode (Modem sleep / Deep sleep)
WPS_PBC	WPS pushbutton
Boradcast FOTA	Broadcast Firmware Over-The-Air

2.3.5 Sample applications

Table 2.2 provides the information of the various sample application programs included in the release package.

Table 2.2 Sample applications

Category	Name	Description
Helloworld	hello_world	Repeatedly print hello message
AT CMD	atcmd	AT commands
Wi-Fi	sample_wifi_state	Repeat Wi-Fi connection and disconnection every 3 seconds
	sample_wps_pbc	Connects to an access point using WPS-PBC (Wi-Fi Protected Setup - Push Button Configuration).
	sample_w5500_eth	The Ethernet bridge mode using the W5500 Ethernet controller (spi)
	sample_w5500_nat	The Ethernet Network Address Translation (NAT) mode using the W5500 Ethernet controller (spi)
	sample_softap_udp_server	Run SoftAP and receive UDP data
	sample_softap_tcp_server	Run SoftAP and receive TCP data
	sample_fota	Run FOTA operation
Protocol	sample_udp_client	Send UDP packets
	sample_udp_server	Receive UDP packets
	sample_tcp_client	Connects to a TCP server and sends packets to it.
	sample_tcp_server	Starts a TCP server, waits for an incoming TCP client connection and receives data from the connected client.
Power save	sample_ps_standalone	Deep sleep operation(i2c)
	sample_ps_schedule	Wakes up at set intervals and transmits sensor data.
	sample_nontim_tcp_client	NonTIM mode deep sleep periodically wakes up to transmit TCP data.
Peripheral	sample_gpio	LED is blinking on board
	sample_uart	Bytes fed into UART CH2
	sample_adc	Communicate with a sensor via ADC
	sample_nvs	Use NVS(Non-volatile Storage) library
	sample_pwm	Enable PWM and configure the PWM duty cycle
	sample_bme680_sensor	Temperature sensor(spi/i2c)
	sample_sgp30_sensor	Air quality sensor(i2c)
	sample_sht30_sensor	Humidity sensor(i2c)
	sample_epd_2in66b	E-paper(i2c)
	sample_hink_e116a07	E-paper(i2c)
	sample_ssd1306	OLED(i2c)
	sample_xa1110_gps	GPS module sample(i2c)
Middleware	sample_xml	Test XML creation and conversion behavior

	sample_json	Test JSON creation and conversion behavior
	sample_aws_iot_sensor	Connects to AWS (Amazon Web Service) and publishes a message.
	Sample_mqtt	Sends data to an MQTT server using the MQTT protocol.
	sample_http	Sends an HTTP request and receives the corresponding response.
	sample_http_server	Runs a SoftAP with an embedded HTTP server
User Scenarios	sample_cmd_user	Retrieves input data via UART and handles it.
	sample_softap_uart_tcp_server	Runs a TCP server in SoftAP mode and facilitates sending/receiving data from UART.
	sample_uart_tcp_client	Runs a TCP client and facilitates sending/receiving data from UART.

3 How to download compiled binaries

The NRC7394 Standalone Firmware Downloader in the ‘tool’ directory can be used to download the unified binary onto the EVB. The steps outlined below explain how to download the binary.

3.1 UART connection between PC and EVB

Connect the PC to the EVB using a UART-USB cable and check the corresponding COM port number using the Device Manager. The COM port number will be required in the next step.

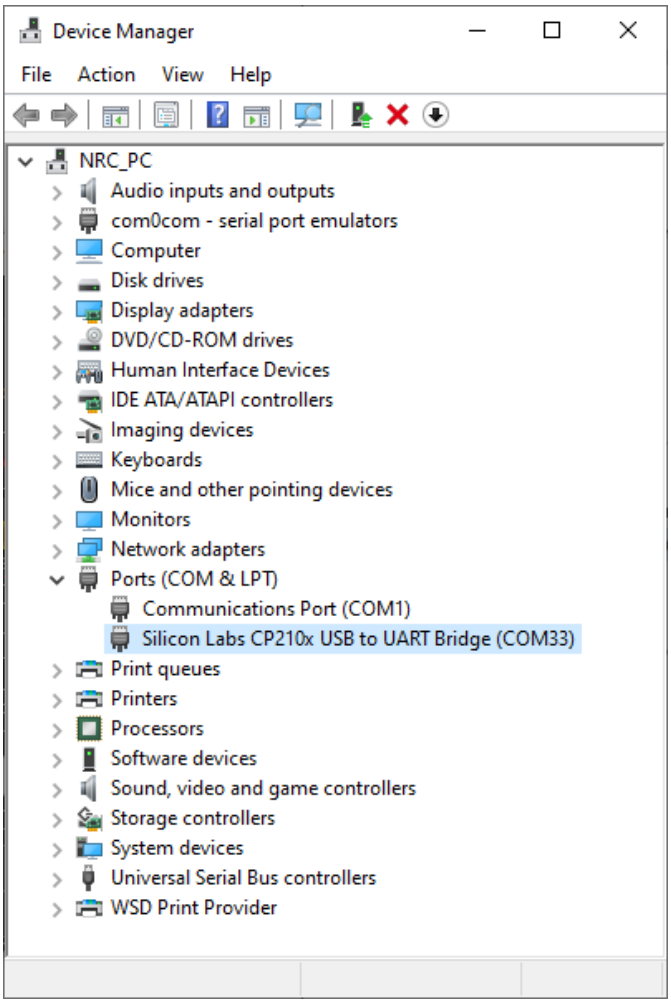

Figure 3.1 COM port in Device Manager

3.2 Upload the unified binary

Launch the NRC7394 Standalone Firmware flash tool and select the correct serial port. Either directly type in the path to the standalone XIP boot and firmware binary or press the '**SET**' button to launch the file selector. The initial bootloader and XIP Boot is located in './firmware/' folder and assigned path automatically. So, the developer does not need to change boot path. MAC addresses (for WLAN0 and WLAN1) can be read from the flash.

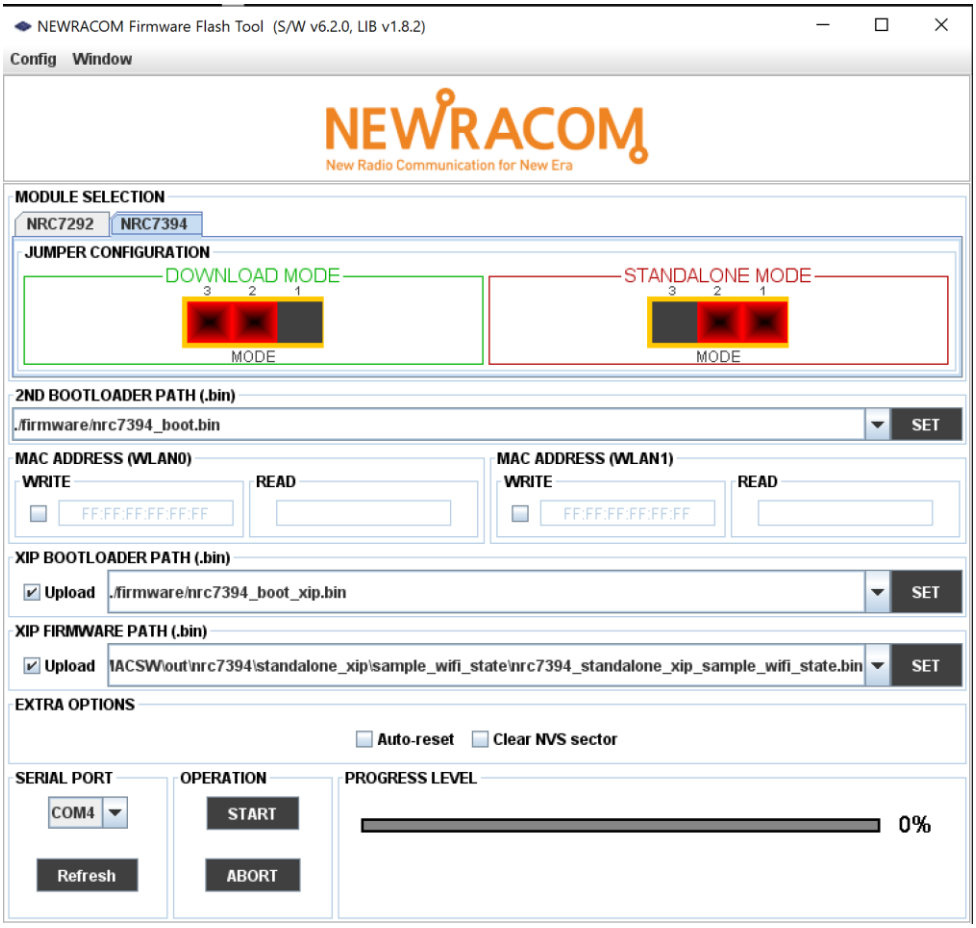

Figure 3.2 Standalone firmware downloader

Before initiating the firmware download process, it is necessary for the developer to change the DIP switch mode to DOWNLOAD MODE by setting it to 'HHHLLH'. To download a unified binary onto the flash memory of the NRC7394 EVB, you can use the NRC7394 Standalone Firmware Downloader, which is included in the release package. For detailed instructions on using the downloader, refer to the guide document located in the 'tools/external/docs/index.html' folder.

There are two types of XIP boot binaries available: the normal boot binary and the 5-waits binary. The normal boot binary operates as expected but requires manual switching of the DIP switch between download mode and standalone mode. On the other hand, the 5-waits binary is specifically designed for use with the standalone mode DIP switch setting. When using the 5-waits binary, it remains in download mode for 5 seconds automatically, eliminating the need for manual switching between download mode and standalone mode. This simplifies the process and allows for a smoother firmware update experience.

The firmware flash tool offers extra features, including the 'Clear NVS sector' and 'Auto-reset' options. Enabling the 'Clear NVS sector' option will erase the NVS (Non-Volatile Storage) data. This option is only checked when the Wi-Fi configuration is modified. On the other hand, selecting the 'Auto-reset' option will cause the firmware to automatically restart once the firmware upload process is finished.

To initiate the download of the chosen binary, click the 'START' button.

4 Performance Evaluation

Iperf is a tool used for network performance measurement and optimization. It offers TCP/UDP client and server functionalities, allowing data streams to be generated to assess the throughput between endpoints. The NRC7394 standalone release package includes programs for Iperf TCP/UDP client and server, leveraging the SDK APIs and LwIP sockets for performance evaluation. The package also enables console commands, enabling developers to conveniently test network performance using the iperf command.

4.1 Preparation of test binary

Test binary for iperf testing could be built in below and download the 'nrc7394_standalone_xip_.bin' in the 'out/nrc7394/standalone_xip/standalone/' folder.

```
make select target=nrc7394.sdk.release
make clean
make
```

4.2 Console command

The console command could be used for Wi-Fi connection and applications such as DHCP client, ifconfig, iperf and ping.

4.2.1 WPA

The wpa cli command is supported. Instead of 'wpa_cli', we use the 'wpa'. The common comands are supported for wifi connection. The command could run such as 'wpa [command] [args]'.

Command	Args	Description
wpa scan		request new BSS scan
wpa scan_results		get latest scan results
wpa add_network		add a network
wpa set_network	<network id> <variable> <value>	set network variables
wpa enable_network	<network id>	enable a network
wpa set country	<country>	set country

(Open Mode)

```
wpa set country US
wpa scan
wpa scan_results
wpa add_network
wpa set_network 0 ssid "AP_SSID"
wpa set_network 0 key_mgmt NONE
wpa enable_network 0
```

(WPA2 Mode)

```
wpa set country US
wpa scan
wpa scan_results
wpa add_network
wpa set_network 0 ssid "AP_SSID"
wpa set_network 0 key_mgmt WPA-PSK
wpa set_network 0 psk "PASSWORD"
wpa enable_network 0
```

(WPA2 Mode)

```
wpa set country US
wpa scan
wpa scan_results
wpa add_network
wpa set_network 0 ssid "AP_SSID"
wpa set_network 0 proto RSN
wpa set_network 0 ieee80211w 2
wpa set_network 0 key_mgmt SAE
wpa set_network 0 sae_password "12345678"
wpa enable_network 0
```

(WPA3-OWE Mode)

```
wpa set country US
wpa scan
wpa scan_results
wpa add_network
wpa set_network 0 ssid "AP_SSID"
wpa set_network 0 proto RSN
wpa set_network 0 ieee80211w 2
wpa set_network 0 key_mgmt OWE
wpa set_network 0 owe_only 0
wpa enable_network 0
```

4.2.2 DHCP

The dhcp command is used for getting IP via DHCP client from DHCP server.

Command	Args	Description
dhcp		request ip address

4.2.3 ifconfig

The Ifconfig is used to configure network interfaces. If no arguments are given, ifconfig displays the status of the currently active interfaces.

Command	args	description
ifconfig	ifconfig <interface> <address> [Options] * [options] -n : netmask -g : gateway -m : MTU size -d : dns1 dns2	Display and configure network interface

4.2.4 IPERF

The iperf command for testing throughput. This application based on only iperf, not iperf3. It supports some madatory options.

Command	args	description
iperf	[-s|-c host] [options] * [options] -b : bandwidth -p : port -t : time ※for stopping iperf based on [-s|-c host] [options] (ex) For stopping the operation, please us 'stop' in below [Start UDP server] iperf -s <host> -u [Stop UDP server] iperf -s <host> -u stop	iperf tcp/udp server&client.

4.2.5 PING

The ping command is used for testing connection.

Command	args	description
ping	-s : symbol size -c: ping number -t: ping time	send ICMP packet for testing connection

5 Abbreviations and acronyms

Abbreviations Acronyms	Definition
ADC	Analog Digital Converter
AP	Access Point
API	Application Program Interface
AWS	Amazon Wed Service
CJSON	C JavaScript Object Notation
EVB	Evaluation Board
EVK	Evaluation Kit
FEM	Front End Module
FOTA	Firmware Over the Air
GPIO	General Purpose Input Output
HTTP	Hypertext Transfer Protocol
IEEE	Institute of Electrical and Electronics Engineers
IP	Internet Protocol
ITC	Inter-Task Communication
I2C	Inter-Integrated Circuit
LAN	Local Area Network
LwIP	Lightweight Internet Protocol
LED	Light Emitting Diode
MQTT	Message Queuing Telemetry Transport
MXML	Music Extensible Markup Language
OTA	Over-the-Air
PWM	Pulse Width Modulation
RPi3	Raspberry Pi 3
RTOS	Real Time Operating System
SDK	Software Development Kit
SoC	System on Chip
SPI	Serial Peripheral Interface
STA	Station
TCP	Transmission Control Protocol
UART	Universal Asynchronous Receive Transmitter
UDP	User Datagram Protocol
USB	Universal Serial Bus
XIP	eXecution In Place

6 Revision history

Revision No	Date	Comments
Ver 1.0	7/17/2023	Initial version