如何在 NVIDIA Jetson Xavier NX 开发板上调试 AIROC™ CYW54591 - KBA235062

1 简介

本文档简要介绍了在 **NVIDIA Jetson Xavier NX 开发板**上调试 **AIROC™ CYW54591 Wi-Fi & Bluetooth®** 组合芯片的步骤。

1.1 操作要求

需了解 Linux 命令和基于 Linux 的文本编辑器，比如 nano/Vim

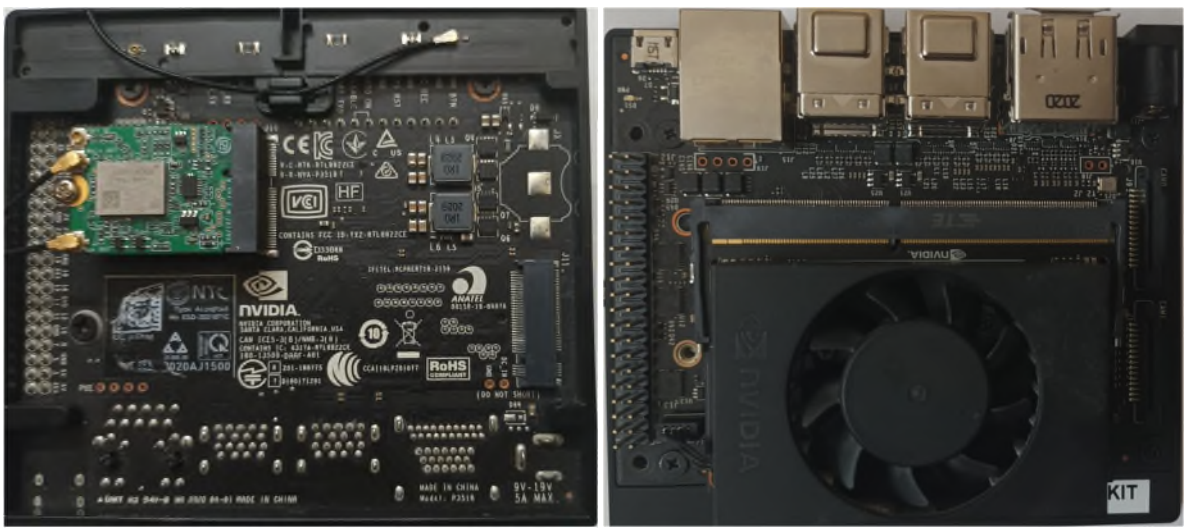
1.2 硬件要求

1. 英伟达 Jetson Xavier NX 开发板，必要的适配器和 USB 线
2. AIROC™ CYW54591 Wi-Fi 模块
3. 电脑 (Ubuntu 16.04.3 LTS)
4. HDMI 显示器
5. USB 键盘
6. USB 鼠标

Note: HDMI 显示器， USB 键盘和鼠标仅用于初期 bootup 创建用户名、密码。

2 硬件连接

- 如下图所示，将 AIROC™ CYW54591 Wi-Fi 芯片连接至 Jetson Xavier NX 开发板上 M.2 Key E Mini-PCIe slot (J10):



3 在 Jetson Xavier NX 开发板上调试 CYW54591

1. 从英伟达官网下载 Linux_for_Tegra (L4T) BSP 包，创建新文件夹，命名为“Jetpack”，将 Linux_for_Tegra (L4T) BSP 包解压并导入到 *Jetpack* 文件夹：

   ```
   $ mkdir Jetpack && cd Jetpack
   ```

2. 从下列地址下载并解压 *patches.zip* 文件：

   ```
   $ wget
   https://developer.nvidia.com/embedded/l4t/r32_release_v6.1/t186/jetson_linux_r32.6.1_aarch64.tbz2
   $ tar -xvf jetson_linux_r32.6.1_aarch64.tbz2
   ```

   ```
   user-muthu@usermuthu-ThinkPad-T460:~/Jetpack$ ls
   jetson_linux_r32.6.1_aarch64.tbz2  Linux_for_Tegra  patches
   user-muthu@usermuthu-ThinkPad-T460:~/Jetpack$
   ```

3. 下载示例根文件系统：

   ```
   $ wget
   https://developer.nvidia.com/embedded/l4t/r32_release_v6.1/t186/tegra_linux_sample-root-filesystem_r32.6.1_aarch64.tbz2
   ```

   ```
   user-muthu@usermuthu-ThinkPad-T460:~/Jetpack$ ls
   jetson_linux_r32.6.1_aarch64.tbz2  Linux_for_Tegra  patches  tegra_linux_sample-root-filesystem_r32.6.1_aarch64.tbz2
   user-muthu@usermuthu-ThinkPad-T460:~/Jetpack$
   ```

4. 安装 L4T 编译的必要编译环境：

   ```
   $ sudo apt-get --yes install git-core build-essential gcc-aarch64-linux-gnu
   ```

5. 下载内核和 bootloader 源码：

   ```
   export L4T_BASE_DIR=`pwd`/Linux_for_Tegra
   export DEFAULT_TAG_NAME="tegra-l4t-r32.6.1"
   export TAG_NAME="$DEFAULT_TAG_NAME"
   $  $L4T_BASE_DIR/source_sync.sh -t $TAG_NAME
   ```

6. 在内核 *defconfig* 文件中添加以下 Wi-Fi FMAC 补丁，禁用默认的 BCMDHD 驱动，启用其他 FMAC 相关的配置:

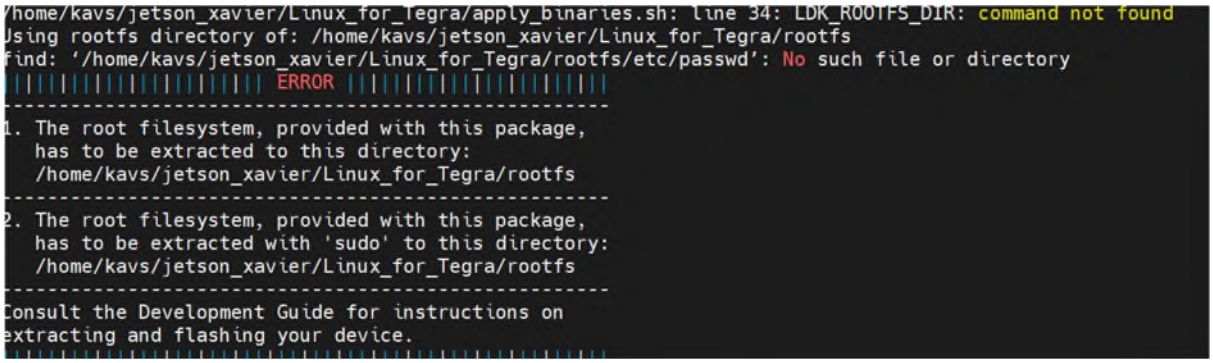
   ```
   export XAVIER_KERNEL_DIR=$L4T_BASE_DIR/sources/kernel/kernel-4.9
   export XAVIER_FMAC_DEFCONFIG_PATCH="./patches/xavier_nx_fmac_defconfig.patch"
   $ patch -d$XAVIER_KERNEL_DIR -p1 -N < $XAVIER_FMAC_DEFCONFIG_PATCH
   ```

7. 在 AARCH64 平台上交叉编译内核源码：

   ```
   export ARCH=arm64
   export CROSS_COMPILE=aarch64-linux-gnu-
   export LOCALVERSION=-tegra
   export KERNEL_SRC_PATH=$L4T_BASE_DIR/sources/kernel/kernel-4.9
   export TEGRA_KERNEL_OUT=$L4T_BASE_DIR/my_bins
   $  mkdir -p $TEGRA_KERNEL_OUT
   $  make -C $KERNEL_SRC_PATH O=$TEGRA_KERNEL_OUT tegra_defconfig && make -C
   $KERNEL_SRC_PATH O=$TEGRA_KERNEL_OUT -j$(nproc)
   ```

8. 将用户自定义包应用到 L4T 包的 rootfs：

```
export L4T_ROOTFS_DIR=$L4T_BASE_DIR/rootfs
$ sudo $L4T_BASE_DIR/apply_binaries.sh
```



如果系统报错，找到第二步中下载的 Jetpack 文件夹，解压示例 rootfs：

```
$ sudo tar -xvf tegra_linux_sample-root-filesystem_r32.6.1_aarch64.tbz2 -C
$L4T_ROOTFS_DIR
$ sudo $L4T_BASE_DIR/apply_binaries.sh
```

9. 生成并替换内核和 DTB：

```
$ cp $TEGRA_KERNEL_OUT/arch/arm64/boot/Image $L4T_BASE_DIR/kernel/.
$ cp $TEGRA_KERNEL_OUT/arch/arm64/boot/dts/* $L4T_BASE_DIR/kernel/dtb/.
```

10. 在 *rootfs* 路径下安装驱动模块：

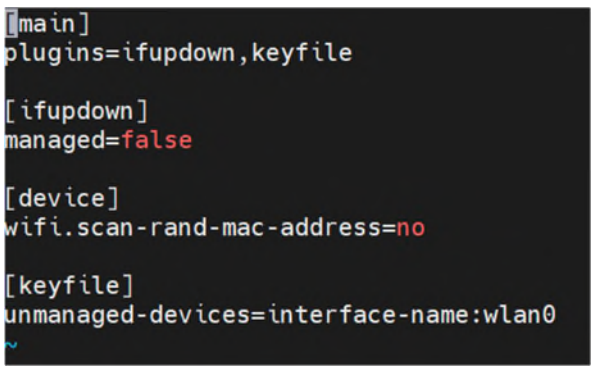
```
$ sudo make -C $KERNEL_SRC_PATH ARCH=arm64 O=$TEGRA_KERNEL_OUT LOCALVERSION=-tegra
INSTALL_MOD_PATH=$L4T_ROOTFS_DIR modules_install
```

11. 将内核配置文件(*.config*)拷贝到 *rootfs* 文件夹：

```
$ sudo cp $TEGRA_KERNEL_OUT/.config $L4T_ROOTFS_DIR/usr/src/linux-headers-4.9.253-
tegra-ubuntu18.04_aarch64/kernel-4.9/.config
```

12. 使用下列命令禁用控制 wlan0 界面的 NetworkManager 服务，打开以下文件 *$L4T_ROOTFS_DIR/etc/NetworkManager/NetworkManager.conf*，添加以下命令：

```
[keyfile]
unmanaged-devices=interface-name:wlan0
```



4 烧录 Jetson Xavier NX 开发板

先进入 Recovery 模式，再烧录 Jetson 开发板。

4.1 Jetson Xavier NX 进入 Recovery 模式

要进入 Recovery 模式，参考以下方式。

4.1.1 如果有控制台访问权限，登录 Jetson 平台

- 运行下列命令，进入 Recovery 模式：

```
$ sudo reboot --force forced-recovery
```

4.1.2 无控制台访问权限

1. 确保已关闭电源且未连接电源适配器。
2. 将 microSD 插入 Jetson Xavier NX [开发套件版本]模组 。
3. 用跳线帽短接 pin，进入强制 Recovery 模式，连接开发板排针[J14]上的第九针[GND]和第十针[FC REC]。
4. 使用 USB Micro-B 接口连接主机与与开发板。
5. 将电源适配器接入电源插孔[J16]。

   强制 Recovery 模式下，设备会自动开机。
6. 在主机终端运行 `lsusb` 命令。

   如果 Jetson 开发板已进入 Recovery 模式，终端上会显示以下输出：

   ```
   Bus 001 Device 010: ID 0955:7e19 NVidia Corp.
   ```
7. 断开跳线帽，退出强制 Recovery 模式。

4.2 用系统镜像烧录开发板

- 运行以下命令

```
$ cd $L4T_BASE_DIR
$ sudo ./flash.sh jetson-xavier-nx-devkit mmcblk0p1
```

刷写镜像需要花费若干分钟，完成后，Jetson Xavier NX 套件会自动重启。

4.3 创建用户名和密码

创建用户名和密码需要使用 HDMI 显示器、USB 键盘和鼠标。

1. 点击以下链接：
   https://developer.nvidia.com/embedded/learn/get-started-jetson-xavier-nx-devkit#setup
2. 要验证 Jetson Xavier NX 的主机 PCIe 控制器是否能检测到 AIROC™ CYW54591 芯片，在目标设备上运行 `lspci` 命令：

```
ifx@ifxhost:~$ lspci
0004:00:00.0 PCI bridge: NVIDIA Corporation Device 1ad1 (rev a1)
0004:01:00.0 Network controller: Broadcom Inc. and subsidiaries Device 4417 (rev 0d)
```

4.4 在 Jetson Xavier 开发板上编译 FMAC 驱动

1. 点击下列链接，下载 *cypress-fmac-v5.10.9-2021_1020.zip* 文件，在 Xavier NX 开发板中创建新文件夹，将下载的文件拷贝到该文件夹。使用 WinSCP 或基于 FTP 的软件。
   https://community.infineon.com/t5/Wi-Fi-Bluetooth-for-Linux/Cypress-Linux-WiFi-Driver-Release-FMAC-2021-10-20/m-p/322639#M2155
2. 解压缩上一步中下载的文件：

```
$ unzip cypress-fmac-v5.10.9-2021_1020.zip
```

可得下列文件:

```
cypress-backports-v5.10.9-2021_1020-module-src.tar.gz
cypress-cirrent-1.60.tar.gz
cypress-devicetree-2021-10-20.tar.gz
cypress-firmware-v5.10.9-2021_1020.tar.gz
cypress-hostap_2_9-1-2021_1020.tar.gz
cypress-patch-v5.10.9-2021_1020.tar.gz
```

3. 在解压缩的文件中提取 *cypress-backports-v5.10.9-2021_1020-module-src.tar.gz* 文件:

   ```
   $ tar -xvf cypress-backports-v5.10.9-2021_1020-module-src.tar.gz
   ```

4. 建立路径，将内核头文件输出至第三步中提取的文件*(v5.10.9-backports)*:

   ```
   $ export MY_KERNEL=/usr/src/linux-headers-4.9.253-tegra-
   ubuntu18.04_aarch64/kernel-4.9/
   ```

5. 从 *defconfigs/brcmfmac* 中指定的 FMAC 驱动配置生成配置文件（*.config*）：

   ```
   $ make KLIB=$MY_KERNEL KLIB_BUILD=$MY_KERNEL defconfig-brcmfmac
   ```

6. 编译，生成内核模块:

   ```
   $ make KLIB=$MY_KERNEL KLIB_BUILD=$MY_KERNEL modules
   ```

   内核模块可见于下列路径:

   ```
   ./compat/compat.ko
   ./net/wireless/cfg80211.ko
   ./drivers/net/wireless/broadcom/brcm80211/brcmutil/brcmutil.ko
   ./drivers/net/wireless/broadcom/brcm80211/brcmfmac/brcmfmac.ko
   ```

7. 将内核模块组复制到新文件夹后，重启设备。

   该文件夹通常命名为 “kernel_module” 。

8. 解压缩 *cypress-firmware-v5.10.9-2021_1020.tar.gz*:

   ```
   $ tar -xvf cypress-firmware-v5.10.9-2021_1020.tar.gz
   ```

   ```
   cyfmac43012-sdio.bin        cyfmac43439-sdio.bin        cyfmac4356-pcie.clm_blob    cyfmac4373-sdio.clm_blob        LICENCE
   cyfmac43012-sdio.clm_blob   cyfmac43439-sdio.clm_blob   cyfmac4356-sdio.bin         cyfmac4373-sdio.industrial.bin  README
   cyfmac43340-sdio.bin        cyfmac43455-sdio.bin        cyfmac4356-sdio.clm_blob    cyfmac4373-usb.bin              versions
   cyfmac43362-sdio.bin        cyfmac43455-sdio.clm_blob   cyfmac43570-pcie.bin        cyfmac54591-pcie.bin
   cyfmac4339-sdio.bin         cyfmac4354-sdio.bin         cyfmac43570-pcie.clm_blob   cyfmac54591-pcie.clm_blob
   cyfmac43430-sdio.bin        cyfmac4354-sdio.clm_blob    cyfmac4373.clm_blob         cyfmac54591-sdio.bin
   cyfmac43430-sdio.clm_blob   cyfmac4356-pcie.bin         cyfmac4373-sdio.bin         cyfmac54591-sdio.clm_blob
   ```

Note: *若*/lib/firmware/cypress *目录已存在，忽略此步骤。*

9. 在*/lib* 路径下创建新文件夹，命名为“firmware”，再在*/firmware* 路径下创建新文件夹，命名为“cypress”：

   ```
   $ sudo mkdir -p /lib/firmware/cypress
   ```

10. 将以下命令拷贝至 */lib/firmware/cypress*:

    - *cyfmac54591-pcie.bin*
    - *cyfmac54591-pcie.clm_blob*
    - *cyfmac54591-pcie.txt*

Note: *cyfmac54591-pcie.txt 是 NVRAM 文件，不包含于 FMAC 发布数据包中，可从模块供应商处获取。1XA(54591)模块的 NVRAM 文件可在以下 Murata GitHub 链接中下载:* ***https://github.com/murata-wireless/cyw-fmac-nvram/blob/master/cyfmac54591-pcie.1XA.txt***

11. 点开第七步创建的 *kernel_module* 文件夹，加载内核模块。加载所有模块前，如果已加载 *cfg80211.ko* 和 *compat.ko*，卸载该模块：

```
sudo rmmod cfg80211.ko
sudo rmmod compat.ko
$  sudo insmod compat.ko
$ sudo insmod cfg80211.ko
$ sudo insmod brcmutil.ko
$ sudo insmod brcmfmac.ko
```

加载模块时应严格按照上述顺序，卸载模块时按照相反的顺序。

12. 验证模块是否完成加载，使用以下代码：

```
$ lsmod
```

```
Module                  Size  Used by
brcmfmac              362179  0
brcmutil               12155  1 brcmfmac
bnep                   19078  2
fuse                  117972  3
zram                   29689  4
xt_conntrack            3979  1
ipt_MASQUERADE          2634  1
nf_nat_masquerade_ipv4     3993  1 ipt_MASQUERADE
nf_conntrack_netlink    33288  0
nfnetlink               9780  2 nf_conntrack_netlink
xt_addrtype             3915  2
iptable_filter          3008  1
iptable_nat             3423  1
nf_conntrack_ipv4      14222  2
nf_defrag_ipv4          2129  1 nf_conntrack_ipv4
nf_nat_ipv4             8176  1 iptable_nat
nf_nat                 25404  2 nf_nat_masquerade_ipv4,nf_nat_ipv4
nf_conntrack          132473  6 nf_conntrack_ipv4,nf_conntrack_netlink,nf_nat_masquerade_ipv4,xt_conntrack,nf_nat_ipv4,nf_nat
br_netfilter           17588  0
overlay                53801  0
nvgpu                1736376  23
userspace_alert         6833  0
cfg80211              835793  1 brcmfmac
compat                122146  2 brcmfmac,cfg80211
ip_tables              21421  2 iptable_filter,iptable_nat
x_tables               38080  5 ip_tables,iptable_filter,ipt_MASQUERADE,xt_addrtype,xt_conntrack
```

13. 使用静态 IP 地址配置网络接口:

```
$ sudo ifconfig wlan0 192.168.1.2 up
```

给 AP 的子网分配一个对应的静态 IP 地址。

14. 使用以下命令验证网络接口:

```
$ ifconfig
```

```
wlan0: flags=4163<UP,BROADCAST,RUNNING,MULTICAST>  mtu 1500
        inet 192.168.1.2  netmask 255.255.255.0  broadcast 192.168.1.255
        inet6 fe80::7274:14ff:fe12:3826  prefixlen 64  scopeid 0x20<link>
        ether 70:74:14:12:38:26  txqueuelen 1000  (Ethernet)
        RX packets 2315  bytes 199954 (199.9 KB)
        RX errors 0  dropped 0  overruns 0  frame 0
        TX packets 2922  bytes 248392 (248.3 KB)
        TX errors 0  dropped 0 overruns 0  carrier 0  collisions 0
```

4.5 将 WLAN 配置为 SoftAP

在用户空间 Linux 守护进程中，推荐使用 *hostapd* 将 WLAN 配置为 SoftAP。*hostapd* 实现了 IEEE 802.11 协议的 AP 管理，支持 IEEE 802.1X/WPA/WPA2/WPA3/EAP 授权、RADIUS 客户端、EAP 服务器和 RADIUS 授权服务器。通过不同配置，*hostapd* 可在以上任一模式中执行。最初，*hostapd* 只用作守护进程，现也支持前端程序，如子程序 *hostapd_cli*。

1. 使用以下命令，安装 *hostapd*:

   ```
   $ sudo apt-get install hostapd
   ```

   安装完成后，自动创建 */etc/hostapd* 文件夹。

   ```
   $ cd /etc/hostapd
   $ sudo vi hostapd.conf
   ```

   例:

   ```
   # Hostapd configuration file for open security 5G 80MHz.
   interface=wlan0
   driver=nl80211
   ctrl_interface=/var/run/hostapd
   ssid=JETSON_XAVIER
   hw_mode=a
   channel=36
   ignore_broadcast_ssid=0
   wmm_enabled=1
   ieee80211ac=1
   vht_oper_chwidth=1
   vht_oper_centr_freq_seg0_idx=42
   ht_capab=[SHORT-GI-20][SHORT-GI-40][HT40+][HT40-]
   vht_capab=[SHORT-GI-80]
   ```

2. 使用以下命令，创建 AP，命名为“JETSON_XAVIER”：

   ```
   $ sudo hostapd ./hostapd.conf -B -dd
   ```

   `-dd` 用于启用调试打印功能。

3. 查看 AP 状态:

   ```
   $ sudo hostapd_cli status
   ```

   如果出现类似以下的错误，运行下列命令，关闭 *hostapd*:

   ```
   ifx@ifx-desktop:/etc/hostapd$ sudo hostapd ./hostapd.conf -B
   Configuration file: ./hostapd.conf
   ctrl_iface exists and seems to be in use - cannot override it
   Delete '/var/run/hostapd/wlan0' manually if it is not used anymore
   Failed to setup control interface for wlan0
   wlan0: Unable to setup interface.
   wlan0: interface state UNINITIALIZED->DISABLED
   wlan0: AP-DISABLED
   hostapd_free_hapd_data: Interface wlan0 wasn't started
   nl80211: deinit ifname=wlan0 disabled_11b_rates=0
   ifx@ifx-desktop:/etc/hostapd$
   ```

   ```
   $ sudo rm -r /var/run/hostapd
   ```

4.6 将 WLAN 配置为 STA

推荐使用 *wpa_supplicant* 。*wpa_supplicant* 是用户空间 Linux 守护进程，用于处理 STA 的 WLAN 认证、关联、断开关联、取消认证过程。与 hostapd 一样，配置 *wpa_supplicant* 的过程很重要。

配置 wpa_supplicant 需要使用文本文件，该文件列出了所有接受的网络和安全策略，包括预共享密钥。该配置文件中的所有文件路径应使用完整的（绝对路径，而不是相对于工作目录的）路径，以允许修改工作目录。

下列为使用 *wpa_supplicant* 配置开放网络的代码示例：

```
# WPA Supplicant with open network security configuration.
ctrl_interface=/var/run/wpa_supplicant
update_config=1
device_name=JETSON-LINUX
device_type=10-0050F204-5
config_methods=virtual_push_button physical_display keyboard
interworking=1

network={
        ssid="[redacted]"
        key_mgmt=NONE
}
```

1. 各种 *wpa_supplicant* 配置，参阅 */etc/wpa_supplicant.conf*:

   ```
   $ sudo vi /etc/wpa_supplicant1.conf
   ```

2. 复制上述代码示例，配置 *wpa_supplicant* 构建开放网络。

3. 完成配置后，启动 *wpa_supplicant*，连接到你的办公室或家庭接入点，继续配置，运行以下命令:

   ```
   $ sudo wpa_supplicant -B -i wlan0 -c /etc/wpa_supplicant1.conf
   ```

   在这行命令中，

   `-B` 用来在后台运行 wpa_supplicant 守护进程

   `-c` 选项用于提供配置文件，在本例中，配置文件是，*wpa_supplicant1.conf*

   `-i` 选项用于选择网络接口

4. 运行以下命令，检查连接的状态:

   $ sudo wpa_cli status

```
Selected interface 'wlan0'
bssid=cc:46:4e:cd:d4:9e
freq=2437
ssid=[redacted]
id=0
mode=station
pairwise_cipher=NONE
group_cipher=NONE
key_mgmt=NONE
wpa_state=COMPLETED
ip_address=192.168.43.4
address=70:74:14:12:38:26
uuid=728b4d1b-4f94-5f78-b5ce-ad683e0dd7e3
```

5. 如果出现类似以下的错误，运行以下命令，关闭 *wpa_supplicant*:

```
$ sudo rm -r /var/run/wpa_supplicant/
removing /var/run/wpa_supplicant/
```

```
ifx@ifx-desktop:/etc$ sudo wpa_supplicant -B -i wlan0 -c /etc/wpa_supplicant1.conf
Successfully initialized wpa_supplicant
ctrl_iface exists and seems to be in use - cannot override it
Delete '/var/run/wpa_supplicant/wlan0' manually if it is not used anymore
Failed to initialize control interface '/var/run/wpa_supplicant'.
You may have another wpa_supplicant process already running or the file was
left by an unclean termination of wpa_supplicant in which case you will need
to manually remove this file before starting wpa_supplicant again.

nl80211: deinit ifname=wlan0 disabled_11b_rates=0
```

4.7 Ping STA 和 SoftAP

Ping STA 和 SoftAP，检查连接状况。

1. STA, 运行以下命令:

```
$ ping -I wlan0 <IP address of softAP>
```

2. SoftAP, 运行以下命令:

```
$ ping -I wlan0 <IP address of STA>
```

5 吞吐量测试

5.1 TCP 吞吐量测试

1. 在 Device-1-TCP 服务器（SoftAP 接口）上运行以下命令:

```
$ iperf -s -f m -i 1 -w 8m -l 8k
```

2. 在 Device-2-TCP 服务器（STA 接口）上运行以下命令:

```
$ iperf -c <TCP Server's WLAN IP address> -i 1 -f m -t 30 -w 8m -l 8k
```

5.2 UDP 吞吐量测试

1. 在 Device-1-UDP 服务器（SoftAP 接口）上运行以下命令:

```
$ iperf -s -u -i 1
```

2. 在 Device-2-UDP 服务器（STA 接口）上运行以下命令:

```
$ iperf -c<UDP Server's WLAN IP address> -u -i 1 -f m -t 30 -b 1200m
```

Revision history

Document version	Date of release	Description of changes
**	2023-03-07	译自英文 KBA235062 rev. *

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