AN13009

Wi-Fi Tx Power Management in Linux

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Document information

Information	Content
Keywords	Channel list, scan type, WPA supplicant, configuration file
Abstract	Describes how to configure the Wi-Fi TX power table and Wi-Fi channel list in Linux BSP.

Revision history

Rev	Date	Description
v.1	20201103	Initial version

1 About this document

This application note shows how to configure the Wi-Fi TX power table and Wi-Fi channel list in Linux BSP. It includes information on the commands that can be used to update the power table and channel list. The procedures described in this document overwrite the default values defined in Linux for TX power table and channel list.

It is assumed that the readers have a good understanding of the Linux Kernel CRDA and Wireless Regulatory database practices. Furthermore, it is recommended to review the basic product software architecture before using this document.

Table 1. Reference documents

Document type	Document title
Application note	Compliance and Certification Considerations

2 Introduction

The Wi-Fi power table defines the transmit power levels for the Wi-Fi radio. The power levels are based on regulatory compliance, IEEE 802.11 requirements, and product design constraints.

The TX power table can be adjusted to achieve the highest transmit power level for each Wi-Fi channel, bandwidth and modulation within these constraints. The Wi-Fi power table can be stored in a file, on the device OTP memory, or in the EEPROM.

The Wi-Fi channel list defines the channels allowed for the product. The channel list is determined by regulatory domain and country specific requirements and should be adjusted accordingly. For example, a product certified for use in Europe can operate on channels 1-13 in the 2.4 GHz band, whereas operation in US is restricted to channels 1-11.

Furthermore, there are two channel scan types that can be selected, active or passive. The channel list selection and scan type are configured using wpa_supplicant, a client side software backend connection manager.

This document explains how to configure the TX power table, channel list and scan type using the appropriate configuration files.

3 TX power tables

The TX power tables mentioned in this section can be edited to customize the transmission power levels for each wireless channel as needed, based on the system requirements and Region Domain rules.

The Wi-Fi TX power table may optionally be programmed into OTP memory on the radio.

If you are using a wireless module, please check with the module vendor if the power table has already been programmed in OTP and if the Region Enforcement bit is set.

If the TX power table is already programmed in OTP and the Region Enforcement bit is set, you cannot update the power table using the procedures provided in this document.

If the TX power table has not been programmed in the OTP, then the default TX power value is set to **8 dBm** for all channels and all rate groups. This setting can be overwritten by using the procedures described in the document.

Otherwise, if the *Region Enforcement* bit has not been set by the vendor, the main steps to customize the TX power tables are:

1. Editing the TX Power Table configuration file
2. Converting the configuration file to binary configuration file
3. Loading the wireless driver specifying the binary configuration file

Each step is described hereafter.

3.1 Editing TX power table configuration

The Tx power tables for 2.4 GHz and 5 GHz are stored respectively in `txpwrlimit_2g_cfg_set` and `txpwrlimit_5g_cfg_set` data structures. Both structures are part of *txpwrlimit_cfg.conf* file located in */usr/share/nxp_wireless/bin_mxm_wifiex/config* directory of the BSP file system.

Use the following commands to navigate and edit the file to specify the transmit power levels for the band, channels, modulation rate and bandwidth.

```
cd /usr/share/nxp_wireless/bin_mxm_wifiex/config
vi  txpwrlimit_cfg.conf
```

For each wireless channel, the structures `txpwrlimit_2g_cfg_set` and `txpwrlimit_5g_cfg_set` define the following parameters:

```
ChanTRPC.TlvType:2=ChanTRPC.TlvLength:2={
TLVStartFreq:2=
TLVChanWidth:1=
TLVChanNum:1=
TLVPwr:32=
}
```

where:

Parameter	Description
`TLVType`	Internal parameter set to 0x189. Do not change this value.
`TLVChanNum`	Channel number
`TLVStartFreq`	Set to 2407 for all 2.4 GHz channels. Set to 5000 for all 5 GHz channels.
`TLVChanWidth`	Channel bandwidth in MHz (for example: 20 for 20 MHz, 40 for 40 MHz)
`TLVpwr`	Specifies the TX power table integer values (in dBm) corresponding to rate groups (see Section 3.1.1 "Rate groups"). The structure of this field is: `<data rate group>,<power limit for group>`

3.1.1 Rate groups

The Wi-Fi power table is organized by rate groups and RF channels. To reduce the size of the power table, multiple wireless data rates are grouped into a single rate group. For example, 24 Mbit/s and 36 Mbit/s legacy OFDM rates are combined in a single rate group, and have the same target power level.

Table 2 shows the rate group information for one spatial stream.

Table 2. Rate group information for one spatial stream

Rate group	Description
0	CCK modulation (data rates: 1,2,5.5,11 Mbit/s)
1	OFDM modulation (data rates: 6,9,12,18 Mbit/s)
2	OFDM modulation (data rate: 24,36 Mbit/s)
3	OFDM modulation (data rate: 48,54 Mbit/s)
4	Channel bandwidth 20 MHz, MCS: 0,1,2
5	Channel bandwidth 20 MHz, MCS: 3,4
6	Channel bandwidth 20 MHz, MCS: 5,6,7
7	Channel bandwidth 40 MHz, MCS: 0,1,2
8	Channel bandwidth 40 MHz, MCS: 3,4
9	Channel bandwidth 40 MHz, MCS: 5,6,7
10	QAM256 modulation, channel bandwidth 20 MHz, MCS 8
11	QAM256 modulation, channel bandwidth 40 MHz, MCS 8, 9
12	PSK modulation, channel bandwidth 80 MHz, MCS 0, 1, 2
13	QAM16 modulation, channel bandwidth 80 MHz, MCS 3, 4
14	QAM64 modulation, channel bandwidth 80 MHz, MCS 5, 6, 7
15	QAM256 modulation, channel bandwidth 80 MHz, MCS 8, 9

For example, OFDM modulation with 54 Mbit/s data rate corresponds to the rate group 3.

The number of rate groups supported depends on the capabilities of the device. For example, a 1x1 Wi-Fi 5 (IEEE 802.11ac) device can support 12 rate groups for 2.4 GHz band and 16 rate groups for 5 GHz band. The number of rate groups differs between the two bands because 80 MHz channel bandwidth is only supported in 5 GHz band. Different wireless chipsets have different rate groups.

The following example is Tx power table configuration for channel 2 (TLVChanNum:1=2), with 20 MHz channel bandwidth (TLVChanWidth:1=20). The Tx power table is shown in bold; rate group 0 is set to 18 dBm, rate group 1 is set to 17 dBm and so forth. Since channel 2 belongs to 2.4 GHz band, the structure is part of `txpwrlimit_2g_cfg_set`.

```
ChanTRPC.TlvType:2=0x0189
ChanTRPC.TlvLength:2={
TLVStartFreq:2=2407
TLVChanWidth:1=20
TLVChanNum:1=2
TLVPwr:24='0,18,1,17,2,16,3,14,4,18,5,16,6,14,7,18,8,16,9,14,10,
16,11,16'
}
```

3.1.2 Example 1: Changing Tx power table configuration for 2.4 GHz band and 20 MHz channel bandwidth

This example shows how to edit the power level for rate group 3.

Initially the rate group 3 is set to 14 dBm (bold text):

```
TLVPwr:24='0,18,1,18,2,16,3,14,4,18,5,16,6,14,7,18,8,16,9,14,10,16,11,16'
```

Once edited, the rate group 3 is set to 17 dBm.

```
TLVPwr:24='0,18,1,18,2,16,3,17,4,18,5,16,6,14,7,18,8,16,9,14,10,16,11,16'
```

3.1.3 Example 2: Changing Tx power table configuration for 5 GHz band and 40 MHz channel bandwidth

Similarly to the 2.4 GHz band, the Tx power limits for 5 GHz band can be changed by editing the `txpwrlimit_5g_cfg_set` data structure.

The example below is for channel 44 - 48 in 40 MHz bandwidth (TLVChanWidth=`40` and `TLVChanNum=44`).

Note: *Although 802.11b is not supported in 5 GHz band, we need a placeholder for rate group 0. This example sets the power level to the rate group 0 to zero.*

The power table for the rate group 4 is set to 16 dBm (shown in bold).

```
ChanTRPC.TlvType:2=0x0189
ChanTRPC.TlvLength:2={
TLVStartFreq:2=5000
TLVChanWidth:1=40
TLVChanNum:1=44
TLVPwr:32='0,0,1,16,2,16,3,14,4,16,5,16,6,14,7,16,8,16,9,14,10,15,11,14,12,15,13,
15,14,14,15,13'}
```

To change the value of rate group 4 to 14 dBm, replace the `4,16` entry:

```
TLVPwr:32='0,0,1,16,2,16,3,14,4,14,5,16,6,14,7,16,8,16,9,14,10,15,11,14,12,15,
13,15,14,14,15,13'
```

3.2 Converting TX power table configuration

The Tx power configuration file *txpwrlimit_cfg.conf* has to be converted to a bin format before the wireless driver can use it. The following command uses *mlanutl* utility under */usr/sbin* path of Linux BSP for the conversion.

```
mlanutl <wireless interface> hostcmd <conf_file_name> generate_raw
 <bin_file_name>
```

Where:

Parameter	Definition
wireless interface	Wireless interface to use
conf_file_name	TX Power configuration file, for example *txpwrlimit_cfg.conf*
bin_file_name	Name of the output binary file to be generated

Example

```
cd /usr/sbin
./mlanutl mlan0 hostcmd txpwrlimit.conf generate_raw txpower.bin
```

The output of the command using *mlanutl* is shown below:

```
$ ./mlanutl mlan0 hostcmd ./config/txpwrlimit.conf generate_raw
 txpower.bin
buf_len = 12
buf_len = 12
buf_len = 12
buf_len = 12
buf_len = 12
buf_len = 572
buf_len = 524
buf_len = 780
buf_len = 332
buf_len = 908
```

A fragment of TX power binary file is shown below:

```
txpwrlimit_2g_cfg_set={
fb 00 3c 02 00 00 00 00 01 00 00 00 89 01 24 00
67 09 14 01 00 11 01 0f 02 0f 03 0d 04 0f 05 0f
06 0d 07 0f 08 0f 09 0d 0a 0f 0b 0f 0c 0f 0d 0f
0e 0f 0f 0f 89 01 24 00 67 09 14 02 00 11 01 0f
02 0f 03 0d 04 0f 05 0f 06 0d 07 0f 08 0f 09 0d
0a 0f 0b 0f 0c 0f 0d 0f 0e 0f 0f 0f 89 01 24 00
67 09 14 03 00 11 01 0f 02 0f 03 0d 04 0f 05 0f
06 0d 07 0f 08 0f 09 0d 0a 0f 0b 0f 0c 0f 0d 0f
0e 0f 0f 0f 89 01 24 00 67 09 14 04 00 11 01 0f
02 0f 03 0d 04 0f 05 0f 06 0d 07 0f 08 0f 09 0d
0a 0f 0b 0f 0c 0f 0d 0f 0e 0f 0f 0f 89 01 24 00
67 09 14 05 00 11 01 0f 02 0f 03 0d 04 0f 05 0f
06 0d 07 0f 08 0f 09 0d 0a 0f 0b 0f 0c 0f 0d 0f
0e 0f 0f 0f 89 01 24 00 67 09 14 06 00 11 01 0f
02 0f 03 0d 04 0f 05 0f 06 0d 07 0f 08 0f 09 0d
0a 0f 0b 0f 0c 0f 0d 0f 0e 0f 0f 0f 89 01 24 00
67 09 14 07 00 11 01 0f 02 0f 03 0d 04 0f 05 0f
06 0d 07 0f 08 0f 09 0d 0a 0f 0b 0f 0c 0f 0d 0f
0e 0f 0f 0f 89 01 24 00 67 09 14 08 00 11 01 0f
02 0f 03 0d 04 0f 05 0f 06 0d 07 0f 08 0f 09 0d
0a 0f 0b 0f 0c 0f 0d 0f 0e 0f 0f 0f 89 01 24 00
67 09 14 09 00 11 01 0f 02 0f 03 0d 04 0f 05 0f
06 0d 07 0f 08 0f 09 0d 0a 0f 0b 0f 0c 0f 0d 0f
0e 0f 0f 0f 89 01 24 00 67 09 14 0a 00 11 01 0f
02 0f 03 0d 04 0f 05 0f 06 0d 07 0f 08 0f 09 0d
0a 0f 0b 0f 0c 0f 0d 0f 0e 0f 0f 0f 89 01 24 00
67 09 14 0b 00 11 01 0f 02 0f 03 0d 04 0f 05 0f
06 0d 07 0f 08 0f 09 0d 0a 0f 0b 0f 0c 0f 0d 0f
0e 0f 0f 0f 89 01 24 00 67 09 14 0c 00 11 01 0f
02 0f 03 0d 04 0f 05 0f 06 0d 07 0f 08 0f 09 0d
0a 0f 0b 0f 0c 0f 0d 0f 0e 0f 0f 0f 89 01 24 00
67 09 14 0d 00 11 01 0f 02 0f 03 0d 04 0f 05 0f
06 0d 07 0f 08 0f 09 0d 0a 0f 0b 0f 0c 0f 0d 0f
0e 0f 0f 0f 89 01 24 00 67 09 14 0e 00 0c 01 0c
02 0c 03 0c 04 0c 05 0c 06 0c 07 0c 08 0c 09 0c
0a 0c 0b 0c 0c 0c 0d 0c 0e 0c 0f 0c
}
```

The newly generated binary files must be copied into the wireless firmware directory, which is */lib/firmware/NXP* for Linux systems.

3.3 Loading TX power table configuration

The TX power table binary file can be activated at the wireless driver load time. As mentioned in the previous section, it is necessary that both wireless firmware and TX power table binary files are stored in the wireless firmware directory, which for Linux systems is by default located at */lib/firmware/nxp*.

In the following example, the driver loads *txpower.bin* using `txpwrlimit_cfg` parameter:

```
insmod mlan.ko
insmod sd8xxx.ko txpwrlimit_cfg=nxp/txpower.bin
```

Note: *The actual driver load command can differ versus the one shown above, depending on the wireless device, interface used, and additional parameters used at driver load. Nonetheless, the parameter `txpwrlimit_cfg` is always required to load a TX power table binary file.*

In the case shown above, NXP driver overrides the default TX power limits used by Linux and uses the one specified in the binary file instead.

3.4 Checking TX power table configuration

The command `mlanutl` is used to display the updated TX power table.

Usage:

```
cd /usr/sbin
./mlanutl mlanX get_txpwrlimit <n>
```

Where:

Parameter	Description
`mlanX`	wireless interface to use
`n`	Hexadecimal value to select the Power Table to show 0: Get 2.4G txpwrlimit table 0x1f: Get all 5G txpwrlimit table 0xff: Get both 2G and 5G txpwrlimit table

The following example shows 2.4 GHz TX power table with 12 rate groups per channel:

```
# ./mlanutl mlan0 get_txpwrlimit 0
----------------------------------------
Get txpwrlimit: sub_band=0x0 len=460
StartFreq: 2407
ChanWidth: 20
ChanNum:   1
Pwr:0,8,1,8,2,8,3,8,4,8,5,8,6,8,7,8,8,8,9,8,10,8,11,8
StartFreq: 2407
ChanWidth: 20
ChanNum:   2
Pwr:0,8,1,8,2,8,3,8,4,8,5,8,6,8,7,8,8,8,9,8,10,8,11,8
StartFreq: 2407
ChanWidth: 20
ChanNum:   3
Pwr:0,8,1,8,2,8,3,8,4,8,5,8,6,8,7,8,8,8,9,8,10,8,11,8
StartFreq: 2407
ChanWidth: 20
ChanNum:   4
Pwr:0,8,1,8,2,8,3,8,4,8,5,8,6,8,7,8,8,8,9,8,10,8,11,8
StartFreq: 2407
ChanWidth: 20
ChanNum:   5
Pwr:0,8,1,8,2,8,3,8,4,8,5,8,6,8,7,8,8,8,9,8,10,8,11,8
StartFreq: 2407
ChanWidth: 20
ChanNum:   6
Pwr:0,8,1,8,2,8,3,8,4,8,5,8,6,8,7,8,8,8,9,8,10,8,11,8
StartFreq: 2407
ChanWidth: 20
ChanNum:   7
Pwr:0,8,1,8,2,8,3,8,4,8,5,8,6,8,7,8,8,8,9,8,10,8,11,8
StartFreq: 2407
ChanWidth: 20
ChanNum:   8
Pwr:0,8,1,8,2,8,3,8,4,8,5,8,6,8,7,8,8,8,9,8,10,8,11,8
StartFreq: 2407
ChanWidth: 20
ChanNum:   9
Pwr:0,8,1,8,2,8,3,8,4,8,5,8,6,8,7,8,8,8,9,8,10,8,11,8
StartFreq: 2407
ChanWidth: 20
ChanNum:   10
Pwr:0,8,1,8,2,8,3,8,4,8,5,8,6,8,7,8,8,8,9,8,10,8,11,8
StartFreq: 2407
ChanWidth: 20
ChanNum:   11
Pwr:0,8,1,8,2,8,3,8,4,8,5,8,6,8,7,8,8,8,9,8,10,8,11,8
StartFreq: 2407
ChanWidth: 20
ChanNum:   12
Pwr:0,8,1,8,2,8,3,8,4,8,5,8,6,8,7,8,8,8,9,8,10,8,11,8
StartFreq: 2407
ChanWidth: 20
ChanNum:   13
Pwr:0,8,1,8,2,8,3,8,4,8,5,8,6,8,7,8,8,8,9,8,10,8,11,8
StartFreq: 2414
ChanWidth: 20
ChanNum:   14
Pwr:0,8,1,8,2,8,3,8,4,8,5,8,6,8,7,8,8,8,9,8,10,8,11,8
```

The command output includes the following parameters:

Parameter	Description
`StartFreq`	Set to 2407 for 2.4 GHz channels, and 5000 for 5 GHz channels
`ChanWidth`	Channel width in MHz
`ChanNum`	Channel number
`Pwr`	Power table (see Section 3.1.1 "Rate groups")

4 Channel list and scan type

The *wpa_supplicant* utility is a program that runs in the background and acts as the backend component controlling the wireless connection in client mode. The *wpa_supplicant* tool can be used to establish an open or a secured connection with access points, and to enable advanced configuration features. This section explains how to use *wpa_supplicant* to customize the channel list and global scan type.

Please note that the channel list and scan type settings provided in this section apply only to client mode.

Two scan types are allowed: passive and active. With a passive scan, the client radio listens to each channel for beacons sent periodically by an Access Point (AP); this method usually takes longer than the active scan. During an active scan, the client radio also transmits a probe request and listens for a probe responses from an AP.

4.1 *wpa_supplicant* usage

The *wpa_supplicant* executable located at */usr/sbin* of the Linux BSP can be loaded from the command line using the following syntax:

```
cd /usr/sbin
./wpa_supplicant -i interface -c conf_file [-B] -C socket
```

Where:

Configuration parameter	Description
`-i`	Wireless interface to use
`-c`	Configuration file, under the directory /etc of the BSP filesystem
`-B`	Specify whether to run in the background or not
`-C`	Path of the ctrl_interface socket

To configure the channel list and scan type, edit *wpa_supplicant.conf* file and locate the following configuration settings.

Configuration parameter	Description
`freq_list`	List of allowed channel frequencies, separated by space. If this parameter is not used, then the radio can use all channel frequencies that it is capable of using.
`scan_freq`	List of frequencies to scan, separated by a space. If this parameter is not used, then all channels in `freq_list` are scanned.
`passive_scan`	Selects active or passive scan. 0 = active scan 1 = passive scan The configuration of individual channels is not allowed.

The configuration parameters `freq_list` and `scan_freq` use the center frequency to specify the channels. For example, to enable the connection on channel 44, include `5220` as center frequency in `freq_list`.

Table 3 specifies the center frequencies for 2.4 GHz and 5 GHz bands.

Table 3. Center frequencies for 2.4 GHz and 5 GHz bands

2.4 - 5 GHz channel	Center frequency (MHz)
1	2412
2	2417
3	2422
4	2427
5	2432
6	2437
7	2442
8	2447
9	2452
10	2457
11	2462
12	2467
13	2472
36	5180
40	5200
44	5220
48	5240
52	5260
56	5280
60	5300
64	5320
100	5500
104	5520
108	5540
112	5560
116	5580
120	5600
124	5620
128	5640
132	5660
136	5680
140	5700
144	5720
149	5745
153	5765
157	5785
161	5805
165	5825

4.2 *wpa_supplicant* examples

Example 1

The following configuration example enables channels 36, 40, 44 and 48, with passive scan. As the `scan_freq` parameter is not present, every channel in the `freq_list` is scanned.

```
ctrl_interface=/var/run/wpa_supplicant
Country=US
freq_list=5180 5200 5220 5240
passive_scan=1
network={
ssid="example_SSID”
key_mgmt=WPA-PSK
psk=”example_password”
}
```

Example 2

The following configuration example enables channels 1 through 12, 36, 44, 48 and 149. Channels 1, 6, 11 and 36 are scanned using active scan.

```
ctrl_interface=/var/run/wpa_supplicant
Country=US
freq_list = 2412 2417 2422 2427 2432 2437 2442 2447 2452 2457 2462
 2467 5180 5220 5240 5745
scan_freq = 2412 2437 2462 5180
passive_scan = 0
network={
ssid="wpa3ssid"
key_mgmt=SAE
psk="passhrase"
}
```

5 Acronyms and abbreviations

Table 4.

Acronym	Definition
AP	Access Point
BSP	Board Support Package
CRDA	Central Regulatory Domain Agent
EEPROM	Electrically Erasable Programmable Read-Only Memory
FW	Firmware
IE	Information Element
OTP	One Time Programmable
WLAN	Wireless LAN

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