MT793X IoT SDK for Wi-Fi CSI User Guide

Version: 1.2

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Version History

Version	Date	Description
0.1	2021-09-10	Initial draft
1.0	2022-08-17	Added MT793X Wi-Fi CSI API description
1.1	2022-10-12	Added MT793X Wi-Fi CSI additional description
1.2	2022-11-10	Revised MT793X Wi-Fi CSI API specification & CSI parser tool

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1 Introduction

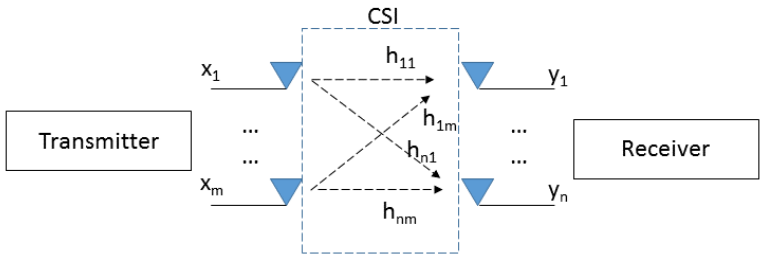
1.1 Background

In wireless communication field, the channel state information (CSI) is used for representing channel situation. As shown in the following equation (1), which is used to model the communication system, *y* represents the received signal, *H* represents the CSI, *x* represents the transmitted signal, and *n* represents the noise. Thus, CSI describes how the signal is transmitted from the transmitter to the receiver. Wi-Fi chip performs channel estimation by the LTF field in the preamble to generate CSI matrix.

$$y = Hx + n \qquad (1)$$

Usually, CSI will be represented by a N x M matrix with complex values as the elements (e.g. The H matrix in (2)). N represents the antenna number for the receiver and M represents the antenna number of the transmitter. In each complex value, the real part describes the amplitude variance, and the imaginary part describes the phase variance.

$$y = \begin{bmatrix} y_1 \\ \cdot \\ \cdot \\ y_n \end{bmatrix}, H = \begin{bmatrix} h_{11} & \cdots & h_{1m} \\ \vdots & \ddots & \vdots \\ h_{n1} & \cdots & h_{nm} \end{bmatrix}, x = \begin{bmatrix} x_1 \\ \cdot \\ \cdot \\ x_m \end{bmatrix}, n = \begin{bmatrix} n_1 \\ \cdot \\ \cdot \\ n_m \end{bmatrix} \qquad (2)$$



Because CSI represents the channel state and the activities in the space (channel) may affect the channel state, this means that it is possible to correlate the activities and the CSI. Due to the characteristics of CSI, in recent years, a lot of research and applications start to adopt CSI for their fancy detection applications (e.g. human motion detection, proximity detection, heartbeat/breathing rate detection, etc.)

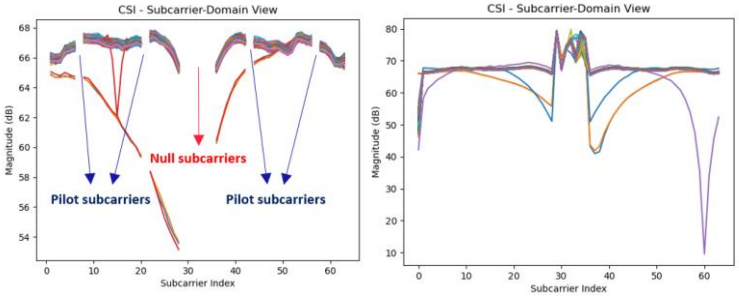
1.2 MT793X CSI Specification

- The CSI is ***uncompressed***
  - CSI consists of signed **14-bit length complex values**
  - Provide a pair of channel frequency response (**CFR**) I/Q values of **all subcarriers**
- The CSI needs to be connected to the AP to work
- Support generating CSI by the reception of **11a/g/n/ac/ax** packets
- Support 5G frequency band. 2G frequency band is not recommended (numerous sources of noise).
- Support data bandwidth **20 MHz** (only supports 1xLTF)
  - DBW 20 MHz: 64 subcarriers
- One packet at a time.
  - The hardware locks the data for processing the current CSI until it is processed, so the next CSI could be obtained only after the current CSI is unlocked.
- Not be supported outside the Table 1-1

Table 1-1. MT793X CSI specification

Category	Item	Value
Capability	Stream	1x1
	PHY pkt type	HE-SU/VHT
		G-HT/M-HT/L-OFDM
	Band	5G
		2G
	DBW	20
CSI Source	QoS	Max sample rate: 30Hz (Depends on the number of CSI sources received)
	Beacon	
Function	Tone mask	0 (Original)
		2 (Tone mask & reorder tones)

- **Note 1**: The CFR is the frequency response of the channel calculated for each measurement channel
- **Note 2**: The subcarrier is a secondary modulated signal frequency modulated into the main frequency to provide an additional channel of transmission
- **Note 3**: The tone mask & reorder tones will filter non-data subcarriers in OFDM, reducing CSI raw data noise. Refer to the following figure for difference with / without tone mask & reorder tones



2 CSI API and CLI

2.1 CSI API and CLI Usage

Use wifi config commands to enable, disable, and configure the CSI functionality. Refer to the following sections for details.

2.1.1 Overview

Wi-Fi API	Wi-Fi CLI
int wifi_config_set_csi(char *pcCommand, int i4TotalLen) pcCommand: string of “csi <opt1><opt2><opt3><opt4>” i4TotalLen: length of pcCommand	wifi config set csi <opt1> <opt2> <opt3> <opt4>

Note. opt2 to opt4 should only be given while opt1 is 2

Command Format

opt1

Table 2-1. MT793X CSI command format

opt1 value	Note
0	Stop capturing CSI data
1	Start capturing CSI data
2	Configure CSI functionality

opt2 to opt4

Table 2-2. MT793X CSI settings format

opt2 value	opt3 value	opt4 value	Note
3: Frame type	0	32: Beacon 34: QoS Data	opt4 value comes from the ***decimal*** value of (subtype + type)[1] Using data QoS is recommended. Other frame type needs to be tested by users.
5: Output format	0: Original format 2: Apply tone mask and reorder tones	N/A	Specify the output format[2]

[1] opt4 is the frame type which comes from the combination of subtype and type of the IEEE 802.11-2016 spec as shown in the Table 2-3 in IEEE802.11-2016:

Table 2-3. IEEE802.11-2016 frame type format

Type value B3 B2	Type description	Subtype value B7 B6 B5 B4	Subtype description
10	Data	1000	QoS Data
00	Management	1000	Beacon

Thus, the frame type values of beacon and QoS data are:

Table 2-4. MT793X CSI frame type

Frame Type	Frame Type Hex Value						Frame Type Decimal Value
	Subtype Value				Type Value		
Beacon	1	0	0	0	0	0	32
QoS Data	1	0	0	0	1	0	34

[2] This configuration is for user to specify the output format. If 0 (original) is specified, the output CSI will consist of all the subcarriers according to the hardware channel bandwidth. If 2 (apply tone mask and reorder subcarriers) is specified, the output will be similar to 0 (original) but the subcarriers in guard band and pilots will be erased to zeros and the remaining subcarriers will be reordered. For the detailed tone mask and reorder rule, refer to the table below:

Table 2-5. MT793X CSI tone mask and reorder rule

	Index	HT/VHT guard band index list	VHT pilot index	LG guard band index
OFDM20	0 to 63	0, 29 to 35	7, 21, 43, 57	0, 27 to 37

CLI Example 1

```
wifi config set csi 2 3 0 34 # Specify the QoS data frame
wifi config set csi 2 5 2 # Apply tone mask and reorder tones
wifi config set csi 1 # Start capturing CSI data
```

After applying above commands, the hardware will work in the following conditions to capture CSI data:

1) Specify the **QoS Data** frame to frame type, so the hardware will calculate CSI while receiving QoS data frames
2) Output: Applies tone mask and reorder tones CSI data
3) Start capturing CSI data

CLI Example 2

```
wifi config set csi 0 # Stop capturing CSI data
```

Stop capturing CSI data

2.2 Obtain CSI Data

2.2.1 Obtain Raw CSI Data

Register a callback function by **wifi_connection_register_event_handler()** to obtain the CSI raw data. Refer to the following example code for the details.

Register Function

```
wifi_connection_register_event_handler(
        (wifi_event_t)WIFI_EVENT_IOT_CSI_DATA_NOTIFICATION,
        (wifi_event_handler_t)mtk_event_handler_sample);
```

wifi_connection_register_event_handler() requires 2 arguments:

1) The first argument is the event ID.
2) The second argument is the callback function for obtaining the CSI raw data.

CSI Event Handler

```
int mtk_event_handler_sample(wifi_event_t event_id, unsigned char
*payload, unsigned int len)
{
        int handled = 0;
        switch (event_id) {
        case  WIFI_EVENT_IOT_CSI_DATA_NOTIFICATION:
                handled = 1;
                if (len > 0 && payload) {
                        // handle the CSI raw data (payload)
                }
                break;
        return handled;
}
```

mtk_event_handler_sample() requires 3 parameters. User could handle the CSI raw data here or in the registered callback function. The CSI raw data is not preserved. The application should store the data somewhere if needed. (parameter **payload** stores the CSI raw data)

1) The first parameter is the event ID.
2) The second parameter is the payload of the corresponding event.
3) The third parameter is the total length of the payload.

2.2.2 CSI Raw Data

Table 2-6. MT793X CSI raw data format

Field	Length (Bytes)	Value	Note
Magic Number	1	0xAC	
Length	2	Length of CSI raw data	Based on the following CSI TLV fields
Variable TLV fields			Please check the following Table 2-7

The lengths of Tag, Length, and Value fields:

Table 2-7. MT793X CSI TLV fields

Field	Length (Bytes)	Note
Tag value	1	
Length	2	Length of CSI TLV fields in unit of Bytes
Value	Variable length	

Table 2-8. MT793X CSI TLV field list

Field	Tag value	Length (Bytes)	Note
Version	0	1	0x0D
Timestamp	2	8	Unit is ms
RSSI	3	1	
SNR	4	1	
Data Bandwidth	5	1	0: BW20
Primary Channel Index	6	1	
Transmitter MAC Address	7	6	
CSI_I	8	2 * DBW subcarriers	

Field	Tag value	Length (Bytes)	Note
CSI_Q	9	2 * DBW subcarriers	
Extra Information	10	4	This field is a bitmap for bringing the information of the CSI Bit 0: Noisy channel (NC). This bit is related to SNR. Refer to SNR value in the CSI event instead of this bit for the application. Bit 1:2 NBI. NBI bits are the narrow band interference indicator. Some tones of the CSI will be affected if any NBI bit is set to 1. Bit 3: ACI_DE_L. ACI_DE_L bit is the adjacent channel interference indicator. The CSI will be different with or without ACI

2.3 CSI Parser Tool

2.3.1 How to parse into text file

Step 1: Execute 'main.py'

Step 2: Choose [2] Produce figures of CSI Library

- Input the CSI folder name, with the relative file path

Step 3: Choose [2] Dump CSI event data only

Show txt file as

```
SEQ: 1
VER: 13
TYPE: 0
CNT: 64
Timestamp: 1163286
RSSI: -49
SNR: 56
DBW: 0
CH IDX: 0
TA: 00:0c:43:26:46:b0
EXTRA: 0
Mean Delay: 0
Peak Time:
Max Energy:
TxPath: 0
RxPath: 0
Frame Mode: 1
Rx Rate: 0
I Data: 0 -1143 -1011 -833 -690 -539 -383 -221 -61 105 258 394 507 604 700 787 860 924 986 1042 1092 1120 1132 1116 1080 1024 976 0
Q Data: 0 1327 1435 1528 1589 1628 1666 1682 1681 1654 1606 1515 1409 1300 1195 1091 977 866 752 644 534 425 303 182 65 -31 -120 0
```

2.3.2 How to plot subcarrier over freq domain

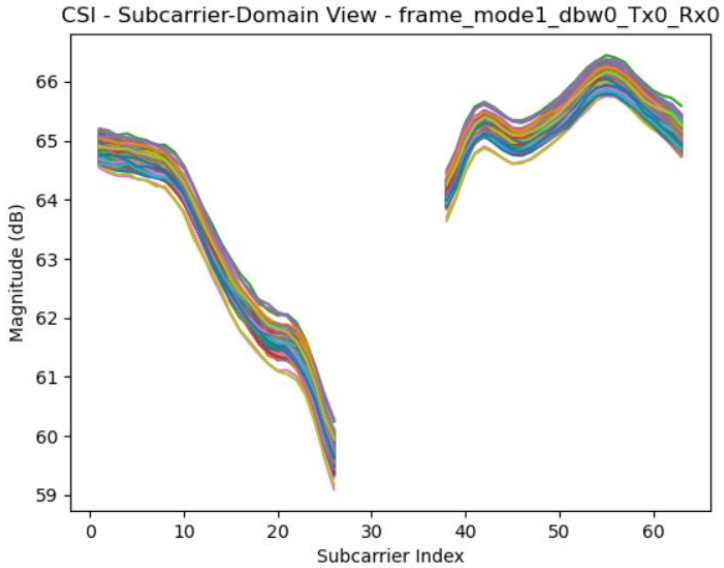
Step 1: Execute 'main.py'

Step 2: Choose [2] Produce figures of CSI Library

- Input the CSI folder name, with the relative file path

Step 3: Choose [4] Plot all subcarrier over freq domain

Show plot as:



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