AN14044

Wi-Fi Location™ Using IEEE 802.11mc and IEEE 802.11az

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Document information

Information	Content
Keywords	AN14044, Fine Time Measurement (FTM), Next Generation Position (NGP), Station (STA), Access Point (AP), Mobile AP, measurement, exchange, FTM session
Abstract	This document provides the steps to get instantaneous distance between a station and an access point using IEEE 802.11mc and IEEE 802.11az Wi-Fi standards.

1 About this document

Wi-Fi Location™ is first introduced in IEEE 802.11mc as a minor feature. This feature is now known as Enhanced Distributed Channel Access (EDCA) ranging and then in IEEE 802.11az (second generation, Non-trigger-based (NTB) ranging and Trigger-based (TB) ranging variants) as a standalone amendment. Wi-Fi Location™ is a technology that locates a device within a network by measuring the Time-of-Flight (ToF) of IEEE 802.11 frames.

This feature is based on the Fine Timing Measurement (FTM) protocol and enables a Wi-Fi Station (STA) to estimate its distance relative to one or more fixed position Wi-Fi Access Points (APs) in the network. These measurements can then be used by an application in the mobile device to determine its location, a process called triangulation. Read more about the IEEE 802.11mc and IEEE 802.11az standards in ref.[2] and ref.[3].

This document explains the steps for a STA to use Wi-Fi Location™ to measure the distance from a single fixed position AP using the IEEE 802.11mc or 802.11az standard.

1.1 Supported products

- AW611 (ref.[6])
- IW611 (ref.[7])
- IW612 (ref.[8])
- AW692 (ref.[9])
- AW693 (ref.[10])
- IW693 (ref.[11])
- IW623 (ref.[12]

Note: *In the following sections, the supported devices are referred as Wireless System-on-chip (SoC).*

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2 Comparison between 802.11mc and 802.11az

Table 1 compares 802.11mc and 802.11az.

Table 1. Comparison between 802.11mc and 802.11z

802.11mc	802.11az
Wi-Fi 5 based • All measurements are simple management frame exchanges. • No scalability enablement.	Wi-Fi 6 based • Trigger-based (TB) ranging variant uses Orthogonal Frequency Division Multiple Access (OFDMA) and Uplink Messaging Unit Multiple Input Multiple Output (UL-MU MIMO) to aggregate multiple STAs efficiently. • Enables scalability in busy environments.
Overhead • Measurements are taken in bursts. STA must stay on the channel during the burst duration. • Number of bursts and periodicity fixed after negotiation.	Flexibility and efficiency • STA controls when to schedule measurements, and can adjust without overhead. • Each measurement is compact and requires limited time on the channel.
Limited MIMO support (RX diversity only)	Full MIMO support (RX and TX diversity by using Sounding packets) to improve accuracy limitations due to multipath
No security • No MAC level encryption (uses public action frames only) • Vulnerable to PHY level attacks	Security enhancements • MAC level encryption of negotiation and measurement reporting using Protected Management Frames (PMF) as part of WPA3 in a connected state • MAC level encryption in unassociated state using PASN[1] • Optional PHY Level protection against tampering[2]

[1] PASN is not addressed in this document.
[2] The supported devices listed in Section 1.1 "Supported products" do not support PHY Level protection.

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3 Supported modes

The IEEE 802.11az standard includes two variants:

- Non-trigger based ranging: The basic variant. See Section 5 "Non-trigger based ranging (802.11az) sequence of operation".
- Trigger-based ranging: The scalability enabled variant. This variant is not discussed in the document.

Note: *EDCA 802.11mc ranging is supported as a legacy mode.*

Table 2 shows STA supported modes.

Table 2. STA supported modes

	Non-trigger based 802.11az ranging	Trigger-based 802.11az ranging	EDCA 802.11mc ranging
Initiator STA	Yes	Yes[1]	Yes
Responder STA	Yes	No	Yes

[1] Validated with an in-house AP that supports trigger-based responder.

Table 3 shows Mobile AP supported modes.

Table 3. Mobile AP supported modes

	Non-trigger based 802.11az ranging	Trigger-based 802.11az ranging	EDCA 802.11mc Ranging
Initiator Mobile AP	No	No	No
Responder Mobile AP	Yes	No	Yes

In addition, both 802.11mc and 802.11az support the following two modes:

- Unassociated: Initiator and Responder are not connected. Both take measurements given the MAC address and channel.
- Associated: Initiator and Responder are connected and take measurements.

Note: *This document covers Initiator as STA, Responder as Mobile AP, non-trigger based ranging, and associated/unassociated.*

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4 EDCA ranging (802.11mc) sequence of operation

This section describes the sequence of the FTM session for EDCA ranging (802.11mc). The distance is measured during the FTM session.

1. The Initiator (STA) starts the Wi-Fi Location™ process by issuing an FTM Start Request including:
   - The requested protocol version with the relevant parameter element
   - The parameter element with the protocol-specific parameters
   - The number of **Burst** instances requested for an FTM Session (Burst Exponent)
   - The timing of consecutive Burst instances (**Burst Period)**
   - The number of FTM measurements in a burst (**FTM per Burst**)
   - The minimum amount of time between FTM measurements in a Burst (**min_delta**)
   - The maximum duration of an FTM session (**Burst Duration**)
   - The format and bandwidth to be used in FTM measurements (**BW**)
2. The Responder (AP) replies with an Acknowledgment (ACK).
3. The Responder (AP) sends an initial FTM frame as a response (and receives an ACK by the STA). The initial FTM frame contains the same parameter element as the FTM Start Request, and a status code, which indicates that the FTM session is accepted. The initial FTM frame can also be used as a first measurement, which is called As Soon As Possible (ASAP) mode. This document focuses on this case.
4. Four timestamps are generated: T1, T2, T3, and T4 (Figure 1). The timestamps are used to estimate the Round-trip Time (RTT) and clock offset. The distance is estimated from the RTT by assuming that the ToF is symmetric on both transmissions.
   - T1 is the time of departure (ToD) of the FTM frame.
   - T4 is the time of arrival (ToA) of the ACK.
   - T2 is the ToA of the FTM frame.
   - T3 is the ToD of the ACK.
   - T1 and T4 are recorded at the Responder AP.
   - T2 and T3 are recorded at the Initiator STA.
5. Each consecutive measurement consists of the Responder AP sending another FTM frame, and the initiator STA replying with an ACK. The FTM frame carries the previous T1/T4 timestamps.
6. The Burst ends when the configured measurements are complete. If multiple Bursts are negotiated, the next Burst starts with the Initiator STA sending another FTM Request packet to signal the start of the next burst. The new FTM Request does not carry a parameter element.

Definitions

- The **Burst Duration** is the total time duration for the exchange of all the FTM frames of one Burst.
- The time between each FTM measurement is **min_delta**.

Note: *The number of* ***Bursts*** *in a* ***Burst Duration*** *and the* ***Burst Duration*** *are configurable. Refer to Section 7 "FTM configuration file".*

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Figure 1 shows the flow diagram for a single FTM Burst.

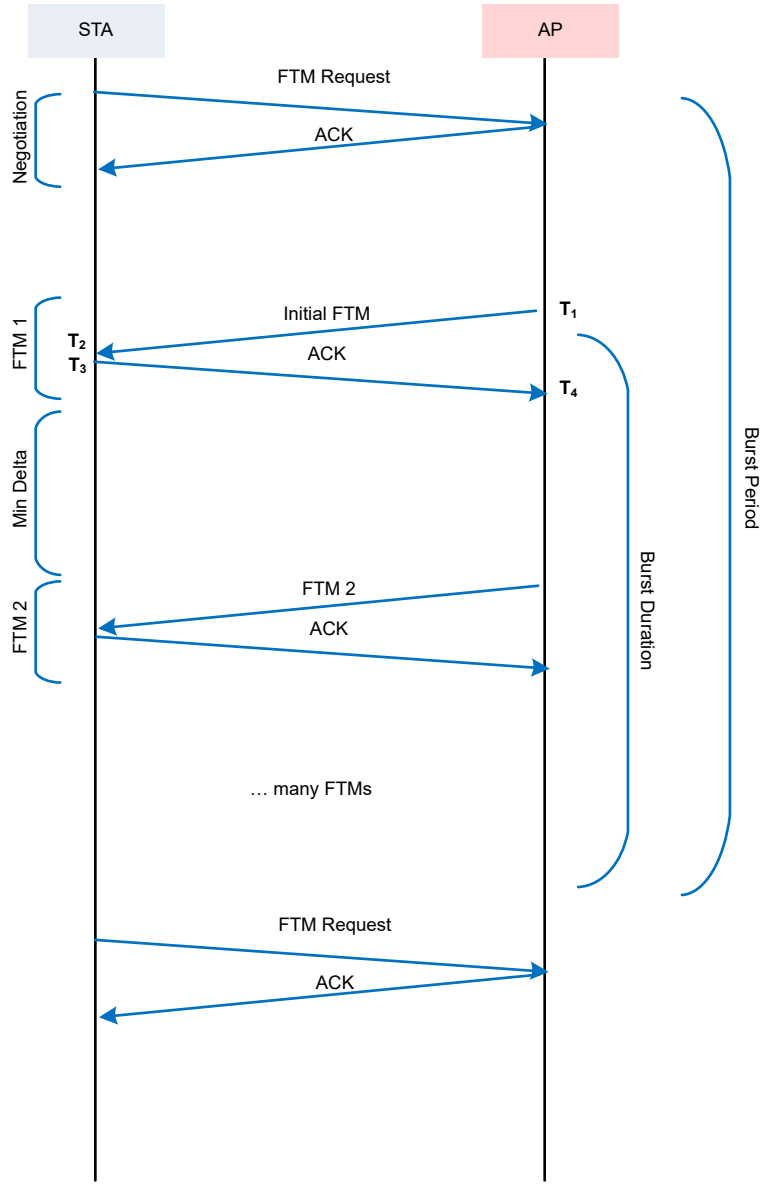

Figure 1. FTM session flow diagram for 802.11mc

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5 Non-trigger based ranging (802.11az) sequence of operation

This section describes the sequence of the FTM session for the non-trigger based ranging variant of 802.11az. The distance is measured during the FTM session.

1. The Initiator STA starts the Wi-Fi Location™ process by issuing an FTM Start Request packet that includes:
   - The bandwidth to use for the measurements (affects the accuracy)
   - The number of TX antennas/streams to use to send the null data packets (NDPs) (affects the accuracy)
   - The min/max times between consecutive measurement exchanges
   - The requested protocol version (includes the parameter element (NTB/TB))
   - The protocol-specific parameters (included in the parameter element)
2. The Responder AP Acknowledges (ACK) the FTM Start Request.
   - Within 10 ms, the Responder AP replies with an initial FTM frame (IFTM) that includes a matching parameter element.
   - The parameter element has a status code that indicates whether the request is accepted or not.
   - The Responder AP can update parameter element values based on its capabilities and/or preferences.
3. The protocol starts.
4. The Initiator STA sends a Null Data Packet Announcement (NDP-A) frame, followed by a Null Data Packet (NDP). The Responder AP responds with an NDP and a Location Measurement Report (LMR) frame.
   - The NDPs generate the Time-of-Departure (ToD) and Time-of-arrival (ToA) timestamps. When each device transmits its packet, these timestamps record the exact time. For convenience, we refer to the first NDP as Initiator-to-Responder (I2R) NDP, and the second NDP as Responder-to-Initiator (R2I) NDP.
5. Four timestamps are generated: T1, T2, T3, and T4 (Figure 2). The timestamps estimate the RTT and clock offset.
   - T1 is the Time of Departure (ToD) of the Initiator-to-Responder (I2R) Null Data Packet (NDP).
   - T4 is the Time of Arrival (ToA) of the Responder-to-Initiator NDP.
   - T1 and T4 are recorded at the Initiator STA.
   - T2 is the ToA of the Initiator-to-Responder NDP.
   - T3 is the ToD of the Responder-to-Initiator NDP.
   - T2 and T3 are recorded at the Responder AP.

   By default, the Responder AP includes T2 and T3 in the LMR frame it sends to the Initiating STA. The distance is estimated from the RTT by assuming that the time-of-flight is symmetric on both transmissions.
   Note: *Optionally, the negotiation can include a second Location Measurement Report (LMR) made from the Initiating STA to the Responding AP. This report allows both sides to estimate the distance (not discussed here).*
6. When the configured measurements are complete, the Initiator STA sends another FTM Request packet to signal the end of the measurement exchange.

Definitions

- The sequence from Start FTM Request to FTM Stop Request constitutes a **Session**.
- The Initiator can start another **Session** by issuing a new FTM Start Request.
- A collection of one or more **Measurements (Exchanges)** constitutes an FTM **Session**.

Note: *The number of **Measurements** in a **Session** and the second LMR are configurable. Refer to Section 7 "FTM configuration file".*

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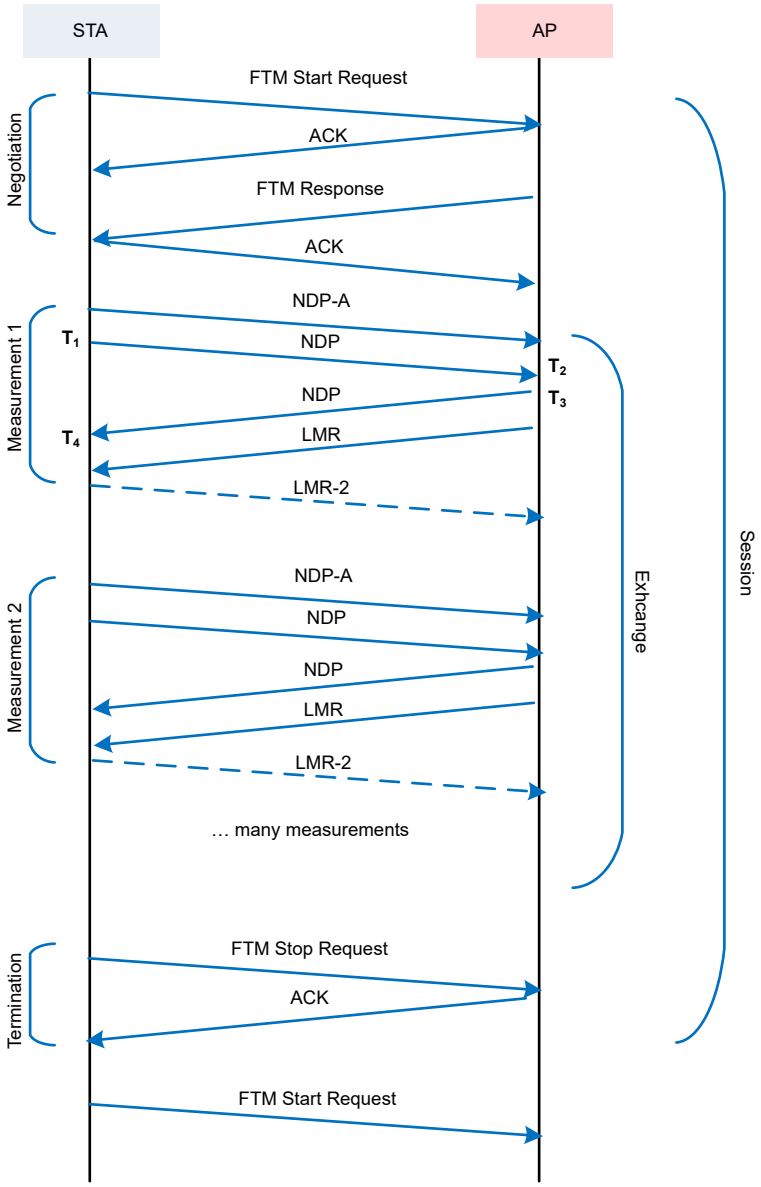
Figure 2 shows the flow diagram for a single FTM session.



Note: LMR-2 is optional and marked with a dashed line.

Figure 2. FTM session flow diagram for 802.11az

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6 Distance calculation

In Figure 1 and Figure 2, the times are marked as T_1, T_2, T_3, T_4.

In EDCA ranging:

- T_1 = Timestamp of when the AP (Responder) transmitted the FTM packet
- T_2 = Timestamp of when STA (Initiator) received the FTM packet
- T_3 = Timestamp of when the STA (Initiator) transmitted the ACK
- T_4 = Timestamp of when the AP (Responder) received the ACK

In non-trigger based ranging:

- T_1 = Timestamp of when the STA (Initiator) transmitted the I2R packet
- T_2 = Timestamp of when the AP (Responder) received I2R packet
- T_3 = Timestamp of when the AP (Responder) transmitted the R2I NDP
- T_4 = Timestamp of when the STA (Initiator) received the R2I NDP

The timestamps are used to measure the RTT and to calculate the distance between the STA and AP. Each measurement outputs a distance value calculated as.

$RTT = \{ (T_4 - T_1) - (T_3 - T_2) \}$

Distance = (RTT) ÷ 2 × (Speed-of-Electromagnetic-Waves)

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7 FTM configuration file

The configuration file `ftm.conf` is used to configure FTM measurements. The file is located in `/bin_wlan/config` directory of the software package.

`ftm.conf` includes four parts:

- DOT11MC_CFG={…}: 802.11mc parameters
- LCI ={…}: Reserved
- CIVIC_LOC ={…}: Reserved
- DOT11AZ_RANGING_CFG ={…}: 802.11az parameters

Configuring 802.11mc does not affect 802.11az measurement and vice versa.

7.1 802.11mc parameters

Table 4. 802.11mc parameters in *ftm.conf* file

Parameter	Value
BURST_EXP	Exponents of numbers of burst instances are requested for the FTM session 0 =2^0= 1 1 =2^1= 2 2 =2^2= 4 … Set to 0 (default).
BURST_DURATION	Burst duration 0 – 1= reserved 2 = 250 µs 3 = 500 µs 4 = 1 ´ms 5 = 2 ms 6 = 4 ms 7 = 8 ms 8 = 16 ms 9 = 32 ms 10 = 64 ms 11 = 128 ms (recommended) 12 - 14 = reserved Set to 11 (128 ms).
MIN_DELTA	Minimum time between consecutive FTM in 100 µs Default is 10 (1 ms). Set to 35 (3.5 ms) (recommended).
IS_ASAP	The initiator and responder also decide the nature of the measurement. 1 = ASAP in request (default, recommended) 0 = non-ASAP in request
FTM_PER_BURST	FTM frames per burst Set to 10 (recommended).

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Table 4. 802.11mc parameters in *ftm.conf* file*...continued***

Parameter	Value
BW	Bandwidth (a higher bandwidth provides higher accuracy) Match with the bandwidth of the target AP (20 MHz, 40 MHz, or 80 MHz) For 2.4 GHz: 9 = HT20 For 5 GHz 9 = HT20 (default) 10 = VHT20 11 = HT40 12 = VHT40 13 = VHT80 (recommended for Wi-Fi® 5/6 devices) For 6 GHz only: 17 = HE20 18 = HE40 19 = HE80 (recommended for Wi-Fi® 6E devices)
BURST_PERIOD	Burst period in units of 100 ms Set to 5 (500 ms).

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7.2 802.11az parameters

Table 5. 802.11az parameters in `ftm.conf` file

Parameter	Value
FORMAT_BW	Format bandwidth Match with the bandwidth of the target AP (20 MHz, 40 MHz, or 80 MHz) 0 = HE20 (default) 1 = HE40 2 = HE80 (recommended)
MAX_I2R_STS_UPTO80	Number of spatial streams (SS) supported by Initiating STA M = SS of STA 0 = 1 SS (default and only choice for 1x1 STA) 1 = 2 SS (recommended for 2x2 STA) Set as M – 1 (encoded value).
MAX_R2I_STS_UPTO80	Number of spatial streams supported by the target AP. A higher number of spatial streams provides higher accuracy N = SS of AP 1 = 2 SS (default) 3 = 4 SS (recommended) Set as N – 1 (encoded value).
AZ_MEASUREMENT_FREQ	Number of exchanges per second (integers only) 1 = default and minimum 5 = five exchanges per second (recommended)
AZ_NUMBER_OF_MEASUREMENTS	Number of measurements per exchange 1 = minimum 6 = default 10 = recommended 255 = maximum
I2R_LMR_FEEDBACK	LMR feedback Both Responder and Initiator must agree on this parameter. 0 = LMR sent from Responder to Initiator only (default) 1 = LMR sent from Responder to Initiator and LMR-2 sent from Initiator to Responder 2 = Allow Responder to decide 0 or 1 If the Responder is set to 0 and the Initiator to 1, or vice versa; the Responder and Initiator do not agree on sending LMR-2. In this case, the negotiation is terminated. Set to 0 (default).

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8 Commands

`mlanwls` commands are used to configure and run FTM sessions. In i.MX Linux BSPs based on Linux kernel 6.18.2 and later, the mlanwls binary is preinstalled under `/bin/mlanwls`. The same binary is also included in the software release package available on the wireless connectivity product page on nxp.com, under the `/bin_wlan` directory. For more details, refer to README_MLANWLS located in the `/bin_wlan` directory of the software release package.

Note: *The `mlanwls` application configuration file and README are not part of the current Linux BSP "lf-6.18.2_1.0.0" release. To download them separately, refer to Wireless_Patch_Release_v0.1. Future Linux BSP releases include these components by default.*

8.1 mlanwls version

This document is based on mlanwls version 5.7.

8.2 dot11mc_unassoc_ftm_cfg

This command is used at the Responder/AP to enable or disable the configuration for 802.11mc and 802.11az FTM frames exchanges in an unassociated state. This command must be executed on the Responder side before starting the event mode (it is disabled by default).

```
./mlanwls <interface> ftm dot11mc_unassoc_ftm_cfg <enable>
```

Table 6. Command parameters

Parameter	Command description
`interface`	Wi-Fi interface uap0)
`enable`	0 = disable unassociated FTM 1 = enable unassociated FTM

If no parameters are given, a get action is performed.

Note: *The command configures both 802.11mc and 802.11az unassociated/associated despite being labeled as 802.11mc.*

8.3 ftm session_cfg

This command is used to select the protocol for the FTM session (802.11mc/802.11az) and set the configurations for the FTM session (feeding the parameters through the `.conf` file).

```
./mlanwls mlanX ftm session_cfg <ftm_protocol> <config_file>
```

Table 7. Command parameters

Parameter	Command description
`ftm protocol`	0 = DOT11mc (802.11mc) 1 = DOT11az_ntb (802.11az NTB) 2 = DOT11az_tb (802.11az TB)
`config_file`	Full path of configuration file containing 802.11mc and 802.11az parameters

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8.4 ftm session_ctrl

This command starts or stops the FTM session with a target AP. It also specifies the number of exchanges in the session. This command must be executed after ftm session_cfg command.

```
./mlanwls <interface> ftm session_ctrl <action> <chan> <mac_address> <loop_cnt>
 <wifi_device_number>
```

Table 8. Command parameters

Parameter	Command description
interface	Wi-Fi interface mlan0 = STA 1 mmlan0 = STA 2 (for AW692/AW693/IW693/IW623 only)
action	Start/Stop FTM session 1 = Start 11mc/11az FTM with associated Peer AP in open mode 2 = Stop FTM session 3 = Start secure 11az FTM with peer AP associated in WPA3 mode using encrypted FTM frames 4 = Start 11az/11mc FTM with unassociated state 5 = Start secure 802.11az FTM with AP in unassociated state after establishing PASN to encrypt FTM frames[1] 6 = Start 11mc/11az FTM with unassociated Peer STA
channel	Operating channel of the target AP (STA can communicate with AP on this channel). For 6 GHz channels on AW693, append “e” to the channel number. An example is 37e.
mac_address	MAC address of the target AP
loop_cnt	Number of FTM exchanges in the session 0 = Infinite number of exchanges 1 = Run one exchange (default). N > 1 = Run N exchanges.
wifi_device_number	Wi-Fi radio number 0 = MAC1 for STA 1 or Mobile AP 1 (default and for AW611, IW611, and IW612) 1 = MAC2 for STA 2 or Mobile AP 2 (for AW692/AW693/IW693/IW623 only)

[1] PASN is not addressed in this document.

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9 Setup

To evaluate the Wi-Fi Location™ feature using the 802.11az/802.11mc standard, one STA and one AP are required. This document focuses on using two sets of NXP Wireless SoC and i.MX host platforms. One set operates as STA and the other set operates as Mobile AP.

Two sets of the following are needed:

- One NXP Wireless SoC
- One i.MX host platform
- Two dipole antennas
- One 5V DC power adapter for i.MX host platform
- One micro-USB cable for console access to i.MX host platform
- One USB-C cable to flash the board support package (BSP) to i.MX host platform

To ensure an accurate and stable FTM reading, the STA and AP must be placed in Line of Sight (LOS).

To bring up Wi-Fi, see ref.[4] and ref.[5].

Read more about advanced configurations of Wi-Fi in ref.[1].

Note: *Download the latest NXP Wireless SoC software version on nxp.com, and check that 802.11mc and 802.11az are supported in the release note.*

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10 Procedure

This section details the steps to run Wi-Fi Location™ in an unassociated or associated mode and non-trigger based state using 802.11mc or 802.11az standard.

Note: *The AP must support 802.11mc/802.11az for the STA to perform Wi-Fi Location™.*

10.1 Responder (Mobile AP mode)

Bring up the uAP on one of the supported wireless products and enable Wi-Fi Location™.

For more information, refer to the section *Bring-up of Wi-Fi* in ref.[4] and ref.[5].

Step 1 – Bring-up Wi-Fi.

```
insmod mlan.ko
insmod moal.ko fw_name=nxp/<wifi_firmware>.bin.se cfg80211_wext=0xf auto_ds=2 ps_mode=2
 host_mlme=1 cal_data_cfg=none
```

Step 2 – Create a hostapd file with configurations for the Mobile AP `hostapd.conf`.

Example of `hostapd.conf` content for Wi-Fi 6, Channel 36, 80 MHz bandwidth, WPA3, Country code US:

```
interface=uap0
driver=nl80211
ctrl_interface=/var/run/hostapd
ctrl_interface_group=0
ieee80211d=1
ieee80211h=1
country_code=US
beacon_int=100
dtim_period=1
wmm_enabled=1
uapsd_advertisement_enabled=1
wmm_ac_bk_cwmin=4
wmm_ac_bk_cwmax=10
wmm_ac_bk_aifs=7
wmm_ac_bk_txop_limit=0
wmm_ac_bk_acm=0
wmm_ac_be_aifs=3
wmm_ac_be_cwmin=4
wmm_ac_be_cwmax=10
wmm_ac_be_txop_limit=0
wmm_ac_be_acm=0
wmm_ac_vi_aifs=2
wmm_ac_vi_cwmin=3
wmm_ac_vi_cwmax=4
wmm_ac_vi_txop_limit=94
wmm_ac_vi_acm=0
wmm_ac_vo_aifs=2
wmm_ac_vo_cwmin=2
wmm_ac_vo_cwmax=3
wmm_ac_vo_txop_limit=47
wmm_ac_vo_acm=0
ssid=11az-11mc-demo
ignore_broadcast_ssid=0
hw_mode=a
channel=36
auth_algs=1
max_num_sta=10
ieee80211n=1
require_ht=0
ht_capab=[LDPC][SHORT-GI-20][SHORT-GI-40][HT40+]
ieee80211ac=1
```


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```
require_vht=0
vht_capab=[RXLDPC][SHORT-GI-80][MAX-A-MPDU-LEN-EXP7][RX-ANTENNA-PATTERN][TX-ANTENNA-
PATTERN]
vht_oper_chwidth=1
vht_oper_centr_freq_seg0_idx=42
ieee80211ax=1
he_bss_color=1
he_oper_chwidth=1
he_oper_centr_freq_seg0_idx=42
auth_algs=1
ieee80211w=2
wpa_key_mgmt=SAE
wpa=2
wpa_pairwise=CCMP
sae_groups=19 20 21
sae_require_mfp=1
sae_anti_clogging_threshold=10
sae_password=1234567890
vendor_elements=dd0800A0400000020023
assocresp_elements=dd0800A0400000020023
interworking=1
access_network_type=2
internet=0
venue_group=10
venue_type=1
```

Step 3 – Start hostapd in the background with `hostapd.conf`.

```
hostapd ./hostapd.conf &
```

Step 4 – Configure unassociated/associated FTM.

- Enable unassociated FTM.

```
./mlanwls uap0 ftm dot11mc_unassoc_ftm_cfg 1
```

- Disallow unassociated FTM.

```
./mlanwls uap0 ftm dot11mc_unassoc_ftm_cfg 0
```

Step 5 – Enable 802.11mc and 802.11az so that the Mobile AP can respond to FTM packets.

```
./mlanwls uap0 event &
```


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10.2 Associated initiator (STA mode)

On one NXP Wireless SoC, follow the steps below to bring-up STA, associate to AP, and measure the distance using 802.11az.

For more information, refer to the section *Bring-up of Wi-Fi* in ref.[4] and ref.[5].

Step 1 – Bring up Wi-Fi.

```
insmod mlan.ko
insmod moal.ko fw_name=nxp/<wifi_firmware>.bin.se cfg80211_wext=0xf auto_ds=2 ps_mode=2
 host_mlme=1 cal_data_cfg=none
```

Step 2 – Create a configuration file named `wpa_supp.conf` and match the SSID and password of the Mobile AP.

Example of `wpa_supp.conf` content:

```
ctrl_interface=/var/run/wpa_supplicant
network={
ssid="11az-11mc-demo" #set to Mobile AP SSID
scan_ssid=1key_mgmt=SAE
proto=RSN
pairwise=CCMP
group=CCMP
sae_password="1234567890" #set to Mobile AP password
ieee80211w=2
}
```

Step 3 – Start `wpa_supplicant` in the background with `wpa-supp.conf`.

```
wpa_supplicant -Dnl80211 -i mlan0 -c ./wpa-supp.conf &
```

Step 4 – Check the connection.

```
iw mlan0 link
```

Command output example:

```
Connected to 3c:51:0e:6f:f3:69 (on mlan0)
SSID: test
freq: 5825
RX: 254 bytes (2 packets)
TX: 2736 bytes (25 packets)
signal: -55 dBm
rx bitrate: 12.0 MBit/s
tx bitrate: 78.0 MBit/s VHT-MCS 8 VHT-NSS 1
bss flags:
dtim period: 1
beacon int: 100
```

Step 5 – Modify the `ftm.conf` configuration file in the `bin_XXXX/config` subfolder with desired configurations. Refer to Section 7 "FTM configuration file".

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Step 6 – Configure an FTM session.

Command for 802.11mc:

```
./mlanwls mlan0 ftm session_cfg 0 ./ftm.conf
```

Command for 802.11az:

```
./mlanwls mlan0 ftm session_cfg 1 ./ftm.conf
```

Step 7 – Start secure FTM on the channel and MAC address of the AP.

Command for 802.11mc:

```
./mlanwls mlan0 ftm session_ctrl 1 <channel> <mac_address> 10 0
```

Note: *802.11mc does not support secure FTM even when associated in WPA3.*

Command for 802.11az:

```
./mlanwls mlan0 ftm session_ctrl 3 <channel> <mac_address> 10 0
```

For AW692/AW693/IW693 and IW623 only:

```
./mlanwls mmlan0 ftm session_ctrl 3 <channel> <mac_address> 10 1
```

Following the FTM start, output logs are printed on the STA console. Refer to Output Logs.

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10.3 Unassociated initiator (STA mode)

On one NXP Wireless SoC, follow the steps below to bring-up STA, associate to AP, and measure the distance using 802.11az.

For more information, refer to the section *Bring-up of Wi-Fi* in ref.[4] and ref.[5].

Step 1 – Bring up Wi-Fi.

```
insmod mlan.ko
insmod moal.ko fw_name=nxp/<wifi_firmware>.bin.se cfg80211_wext=0xf auto_ds=2 ps_mode=2
 host_mlme=1 cal_data_cfg=none
```

Step 2 – Bring up the mlan0 interface.

```
ifconfig mlan0 up
```

Step 3 – Modify the `ftm.conf` configuration file available in `bin_XXXX/config` directory. Refer to Section 7 "FTM configuration file".

Step 4 – Configure an FTM session.

Command for 802.11mc:

```
./mlanwls mlan0 ftm session_cfg 0 ./ftm.conf
```

Command for 802.11az:

```
./mlanwls mlan0 ftm session_cfg 1 ./ftm.conf
```

Step 5 – Start FTM on the channel and MAC address of the AP.

```
./mlanwls mlan0 ftm session_ctrl 4 <channel> <mac_address> 10 0
```

For AW692/AW693/IW693 and IW623 only:

```
./mlanwls mmlan0 ftm session_ctrl 4 <channel> <mac_address> 10 1
```

Following FTM start, output logs are printed on the STA console. Refer to Output Logs.

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11 Output logs

Table 9 shows an example of output logs from the STA side (initiator of the FTM session).

Two types of distances are printed in the logs:

1. Raw data: each measurement outputs a distance value (calculated using the method described in Section 6 "Distance calculation").
2. Computed distance: at the end of each exchange, NXP proprietary algorithm processes all the distances from the individual measurements and prints a computed distance.

From the output logs, take either the raw data from individual measurements or take the NXP processed data computed at the end of each exchange.

In addition, the distance calculated from the last individual measurement is automatically stored at `/var/www/mwu.log`. This value gets overwritten by the next measurement.

Note: *For the `mwu.log` to be not generated, create the directory `/var/www/` with read, write, and execute permissions on the host platform.*

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Table 9. Output log example

```
---------------------------------------------------------------------
------- NXP Wifi Location Service (WLS) v5.7 ------
---------------------------------------------------------------------
[INFO] Initializing App
[INFO] Netlink number = 31
[INFO] Unassociated FTM Session Started on 149 channel with Peer BA:F4:4F:B8:E9:85
EVENT: MLAN_WLS Processing results: format VHT(80), Rx/Tx 2/1, -15923 | 15697 (1011083|600051), TSF 4971fa25
SUCCESS
EVENT: MLAN_WLS Processing results: format VHT(80), Rx/Tx 2/1, -16026 | 15806 (1011083|600051), TSF 4972037f
SUCCESS
[INFO] Event received for interface mlan0 EventID: 0x86 SubeventID:6
Distance from Measurement 1
FTM distance report (MAC BA:F4:4F:B8:E9:85), TSF 4971fa1d, distance 0.68 meters
EVENT: MLAN_WLS Processing results: format VHT(80), Rx/Tx 2/1, -15923 | 15710 (1011083|600051), TSF 49720bb6
SUCCESS
[INFO] Event received for interface mlan0 EventID: 0x86 SubeventID:6
Distance from Measurement 2
FTM distance report (MAC BA:F4:4F:B8:E9:85), TSF 49720377, distance 0.68 meters
[INFO] Event received for interface mlan0 EventID: 0x86 SubeventID:6
Distance from Measurement 3
FTM distance report (MAC BA:F4:4F:B8:E9:85), TSF 49720bae, distance 0.69 meters
EVENT: MLAN_WLS Processing results: format VHT(80), Rx/Tx 2/1, -15821 | 15609 (1011083|600051), TSF 49721b71
SUCCESS
EVENT: MLAN_WLS Processing results: format VHT(80), Rx/Tx 2/1, -15975 | 15755 (1011083|600051), TSF 497223b0
SUCCESS
[INFO] Event received for interface mlan0 EventID: 0x86 SubeventID:6
Distance from Measurement 4
FTM distance report (MAC BA:F4:4F:B8:E9:85), TSF 49721b69, distance 0.68 meters
EVENT: MLAN_WLS Processing results: format VHT(80), Rx/Tx 2/1, -16282 | 16027 (1011083|600051), TSF 497227f7
SUCCESS
EVENT: MLAN_WLS Processing results: format VHT(80), Rx/Tx 2/1, -16128 | 15892 (1011083|600051), TSF 49722c5a
SUCCESS
[INFO] Event received for interface mlan0 EventID: 0x86 SubeventID:6
Distance from Measurement 5
FTM distance report (MAC BA:F4:4F:B8:E9:85), TSF 497223a8, distance 0.69 meters
EVENT: MLAN_WLS Processing results: format VHT(80), Rx/Tx 2/1, -15975 | 15753 (1011083|600051), TSF 497230aa
SUCCESS
EVENT: MLAN_WLS Processing results: format VHT(80), Rx/Tx 2/1, -15872 | 15613 (1011083|600051), TSF 497234fc
SUCCESS
[INFO] Event received for interface mlan0 EventID: 0x86 SubeventID:6
Distance from Measurement 6
FTM distance report (MAC BA:F4:4F:B8:E9:85), TSF 497227ef, distance 0.68 meters
[INFO] Event received for interface mlan0 EventID: 0x86 SubeventID:0
FTM Session Complete (MAC BA:F4:4F:B8:E9:85)
11mc: Bursts started 1, Measurements completed 6
Computed Distance
======================
Average ToF: 2282 ps
Average Clockoffset:1774215 ns
Distance: 0.68 meters
[INFO] Command session_ctrl processed. Return:0
```


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12 Abbreviations

Table 10. Abbreviations

Abbreviation	Definition
ACK	Acknowledgment
AP	Access Point
ASAP	As Soon As Possible
BSP	Board Support Package
EDCA	Enhanced Distributed Channel Access
EVB	Evaluation Board
FTM	Fine Time Measurement
LMR	Location Measurement Report
LOS	Line of Sight
NDP	Null Data Packet
NDP-A	Null Data Packet Announcement
NGP	Next Generation Position
NTB	Non-trigger Based
MU-MIMO	Multi-user Multiple Input Multiple Output
OFDMA	Orthogonal Frequency Division Multiple Access
Req	Request
RTT	Round-trip Time
SIFS	Short Interframe Space
SoC	System-on-chip
SS	Spatial Stream
STA	Station
TB	Trigger-based
ToA	Time of Arrival
ToD	Time of Departure
TxOP	Transmit Opportunity
UL-MU MIMO	Uplink Messaging Unit Multiple Input Multiple Output

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13 References

[1] Reference manual – RM00297: Linux Software Reference Manual for Wireless Connectivity (link)
[2] Specification – IEEE Std 802.11™ – 2020 – see 11.21.6 Fine Timing Measurement (FTM) procedure
[3] Specification – IEEE Std 802.11az™ – 2022
[4] User manual – UM11794: Getting Started with IW612 Evaluation Board and i.MX 8M Mini Running Linux OS (link)
[5] User manual – UM11953: Getting Started with AW692/AW693 Evaluation Board and i.MX 8M Running Linux OS (link)
[6] Webpage – AW611: 2.4/5 GHz dual-band 1x1 Wi-Fi 6 (802.11ax) + Bluetooth Automotive Solution (link)
[7] Webpage – IW611: 2.4/5 GHz dual-band 1x1 Wi-Fi 6 (802.11ax) + Bluetooth Solution (link)
[8] Webpage – IW612: 2.4/5 GHz dual-band 1x1 Wi-Fi 6 (802.11ax) + Bluetooth + 802.15.4 Tri-radio Solution (link)
[9] Webpage – AW692: 2x2 single-band (5 GHz) Concurrent Dual Wi-Fi 6, 1x1 (2.4 GHz) Wi-Fi 6, and Bluetooth Combo Solution (link)
[10] Webpage – AW693: 2x2 dual-band (5-7 GHz), 1x1 (2.4 GHz) Concurrent Dual Wi-Fi 6/6E, and Bluetooth Combo Solution (link)
[11] Webpage – IW693: 2x2 dual-band (5-7 GHz), 1x1 (2.4 GHz) Concurrent Dual Wi-Fi 6/6E, and Bluetooth Combo Solution (link)
[12] Webpage - IW623: 2x2 Tri-band (2.4G/5/6 GHz) Wi-Fi 6E and Bluetooth Combo Solution (link)

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15 Revision history

Table 11. Revision history

Document ID	Release date	Description
AN14044 v.3.0	29 April 2026	• Document changed from NDA to public. • Section 1.1 "Supported products": updated for IW623 and IW693 • Section 7 "FTM configuration file": updated file path • Section 8 "Commands": updated path and added a note • Section 8.1 "mlanwls version": added • Section 8.2 "dot11mc_unassoc_ftm_cfg": updated description and command • Section 8.3 "ftm session_cfg": added command description • Section 8.4 "ftm session_ctrl": updated new parameter option for Dot11az_tb • Section 10.1 "Responder (Mobile AP mode)": updated Step 4 • Section 11 "Output logs": updated table with output from mlanwls v5.7 • Section 13 "References": updated for IW623 and IW693
AN14044 v.2.0	25 February 2025	Editorial change: renamed "micro AP (uAP)" to "Mobile AP". • Section 1 "About this document": update. • Section 1.1 "Supported products": added AW692 and AW693. • Section 3 "Supported modes": Table 2 "STA supported modes": updated information for Responder STA. • Section 7.1 "802.11mc parameters": – BURST_DURATION: updated unit for parameter valued. – BW: added information for 2.4 GHz and 6. GHz, added recommendation for Wi-Fi® 5/6 devices. • Section 7.2 "802.11az parameters": – updated value description for MAX_I2R_STS_UPTO80, MAX_R2I_STS_UPTO80, and I2R_LMR_FEEDBACK. • Section 8.2 "dot11mc_unassoc_ftm_cfg": updated command description. • Section 8.4 "ftm session_ctrl": updated command syntax, parameters, and descriptions. • Section 9 "Setup": updated. • Section 10.1 "Responder (Mobile AP mode)": – added information for AW692 and AW693. – updated Step 1. • Section 10.2 "Associated initiator (STA mode)": – added information for AW692 and AW693. – updated Step 1, 5, and 7. • Section 10.3 "Unassociated initiator (STA mode)": – added information for AW692 and AW693. – updated Step 1, 3, and 5. • Section 9 "Setup": updated. • Section 11 "Output logs": updated Table 9. • Section 12 "Abbreviations": updated. • Section 13 "References": updated. • Section 14 "Note about the source code in the document": updated.
AN14044 v.1.0	29 April 2024	• Initial version.

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