Wi-Fi FTM RTT Based Positioning System

PART 1

Wi-Fi ranging Technology Background

Wi-Fi ranging technology uses time-of-flight (ToF) measurements to estimate the distance between two Wi-Fi devices. For over a decade this technology has been enabling application developers and other solutions implementers to provide a variety of services, classified under a broad use category called Precise Indoor Location, including indoor navigation, asset tracking, geofencing, network management, access control (locking/unlocking) and emergency services.

Since its introduction, significant progress has been made with new industry standards and subsequent generations of chipsets and end products that support Wi-Fi. This progress has led to greater levels of accuracy and performance, enabling a wide range of potential use cases.

Wi-Fi Round Trip Timing (RTT) ranging technology was first introduced in 2009 as a way to measure the distance between two Wi-Fi devices based on the travel times of a round-trip wireless signal between them.

These travel times, along with the speed of the wireless signal (333 nanoseconds per 100 meters), provided the means to

calculate an estimate of the physical distance between the two devices.

In 2015, Wi-Fi chipsets with 802.11 standards-based Fine Timing Measurement (FTM) technology entered the market.

Currently, the new ESP32 series C and S of devices from Espressif support the WiFi FTM technology.

This project aims to implement a comprehensive software tool to explore remote measurement (via TCP/IP) of timings and distances between WiFi devices, using FTM technology in ESP32-S2 based devices, such as the Franzininho WiFi board.

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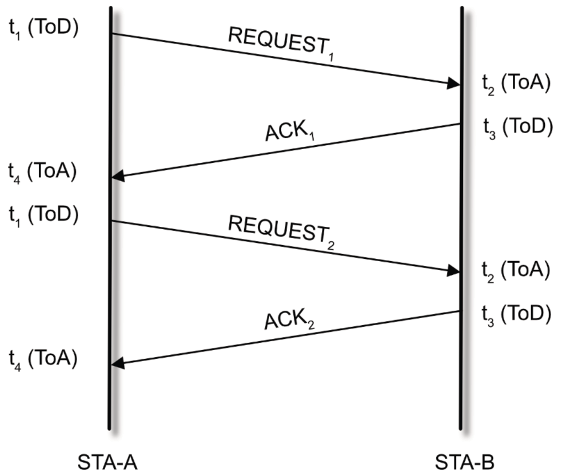
Time-of-Flight (ToF) protocol

Time-of-Flight (ToF) protocol, a new highly-accurate time-based range measurement protocol, providing high accuracy positioning information.

At the base of the ToF protocol there are four timing measurements: two Time of Arrival (ToA) measurements and two Time of Departure (ToD) measurements. These time stamps are denoted t_1, t_2, t_3 and t_4 in figure below, where Station-A sends a packet to Station-B. When these measurements are calculated accurately the ToF is obtained as follows:



$$\text{ToF} = \frac{(t_4 - t_1) - (t_3 - t_2)}{2}$$

The total roundtrip time is ($t_4 - t_1$) and the processing time at STA-B is ($t_3 - t_2$). Subtracting the latter from the former gives us the total time over the air. We obtain the Time-of-Flight by dividing the total time over the air by two. Multiplying ToF by the speed of light gives us the distance between the two stations. In the above figure, an example of such a protocol is given. Station-A calculates the time of departure, denoted by t_1, and Station-B calculates the time of arrival, denoted by t_2. After a short while, typically a few dozens of microseconds, Station-B responds with a second packet, in this case, an Acknowledge packet. Station-B measures the time of departure of the ACK packet, denoted by t_3, and Station-A measures the time of arrival of the ACK packet, denoted by t_4. After transferring t_3 and t_4 from STA-B to STA-A, all the timing measurements are available for calculating the ToF, and an estimation of the distance between the two stations is then obtained.

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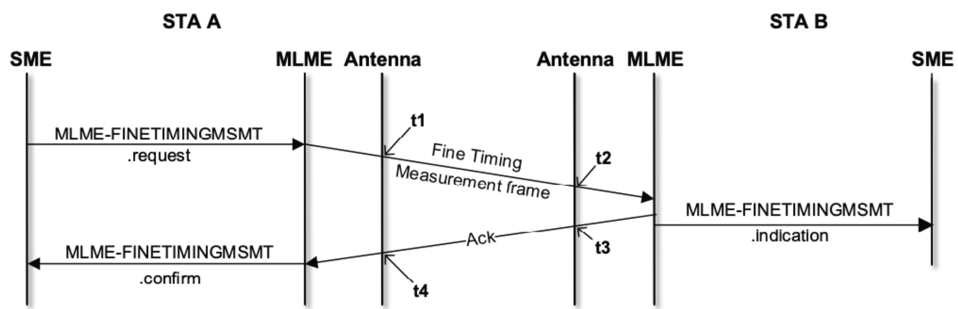
The following set of primitives supports exchange of FTM information from one SME to another:

■ **MLME-FINETIMINGMSMT.request()**	Requests the transmission of a FTM frame to a peer entity.
■ **MLME-FINETIMINGMSMT.confirm()**	Indicates that a FTM frame has been received by the peer STA to which it was sent.
■ **MLME-FINETIMINGMSMT.indication()**	Indicates that a FTM frame has been received and the corresponding Ack frame has been transmitted.

The informative diagram in the following figure depicts various points in time that are of interest to the FTM procedure.



Fine timing measurement primitives and timestamps capture

MLME : *Media Access Control (MAC) Sublayer Management Entity* (where the PHY MAC state machines reside).

SME : Station Management Entity

NOTE 1 : t_1 and t_3 correspond to the point in time at which the start of the preamble for the transmitted frame appears at the transmit antenna connector. An implementation may capture a timestamp during the transmit processing earlier or later than the point at which it actually occurs and offset the value to compensate for the time difference.

NOTE 2 : t_2 and t_4 correspond to the point in time at which the start of the preamble for the incoming frame arrives at the receive antenna connector. Because time is needed to detect the frame and synchronize with its logical structure, an implementation determines when the start of the preamble for the incoming frame arrived at the receive antenna connector by capturing a timestamp some time after it occurred and compensating for the delay by subtracting an offset from the captured value.

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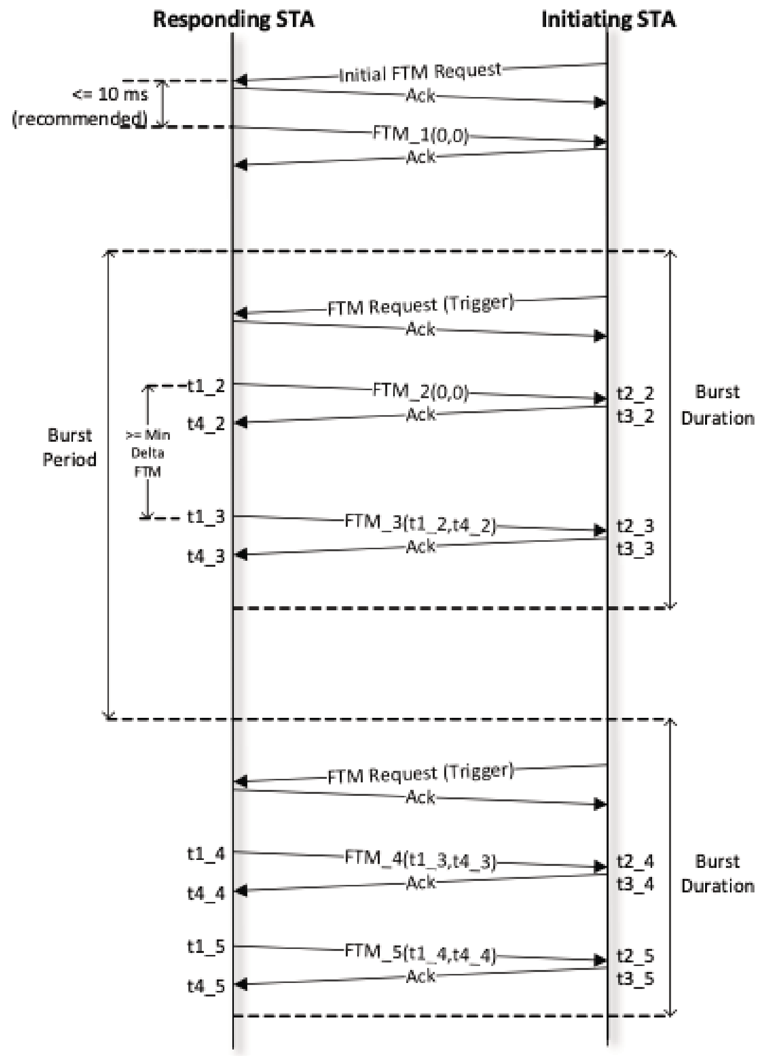
FTM Measurement Exchange

FTM frames are sent during time windows called burst instances. An FTM session is composed of a negotiation, measurement exchange and termination. Consecutive Fine Timing Measurement frames to a given peer STA shall be spaced at least Min Delta FTM apart. Within a burst instance the initiating STA shall perform FTM on each Fine Timing Measurement frame addressed to it, except the last Fine Timing Measurement frame.An FTM session terminates after the last burst instance.

The scheduling parameters of an FTM session are illustrated



Example negotiation and measurement exchange sequence, ASAP=0, and FTMs per Burst = 2

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