

# Qualcomm Technologies

## Wi-Fi Ranging:

Delivering ranging and location technologies of tomorrow today

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@qualcomm

Qualcomm

# Global Wi-Fi Leader

# #1

Global Wi-Fi  
Market Share <sup>1</sup>

# 5B+

Wi-Fi chipsets  
shipped since 2015 <sup>2</sup>



<sup>1</sup> Source: ABI Research, Q4'2021

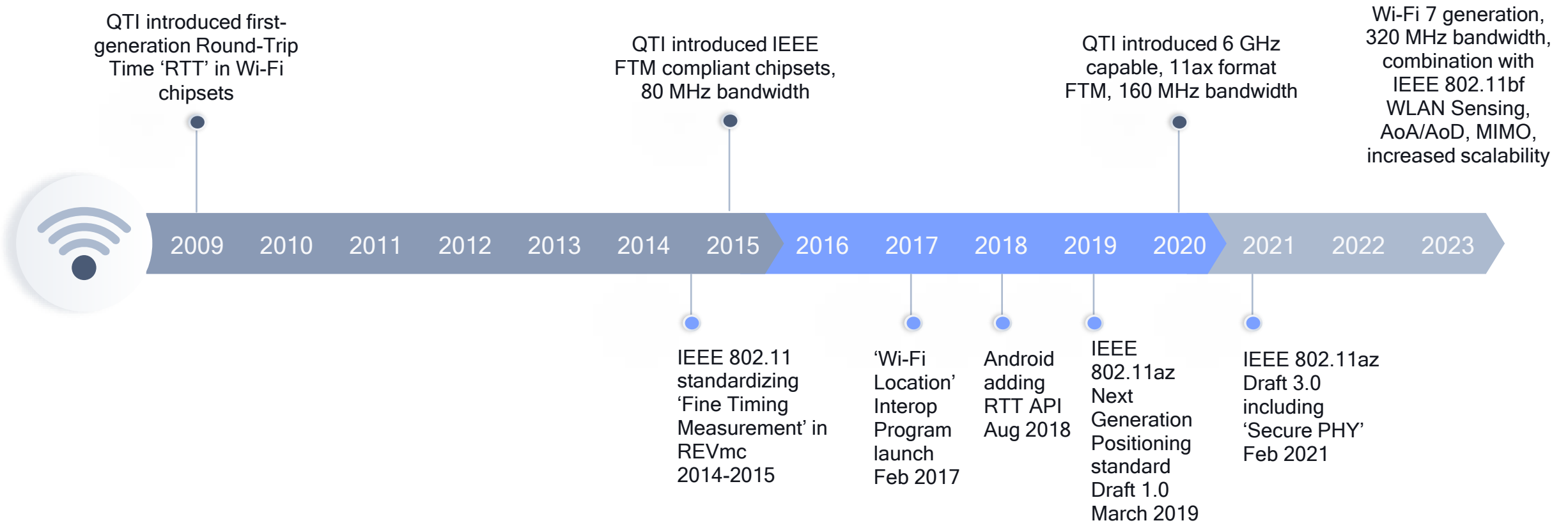
<sup>2</sup> Source: Qualcomm Technologies, Inc.

# Wi-Fi Ranging Technology

- Uses **Time-of-Flight** measurements to estimate the distance between two Wi-Fi devices.
- For **over a decade**, has been enabling application developers to provide a variety of ranging and location services.
- Has been shipped by Qualcomm Technologies in **billions of devices globally**.
- Has been extensively tested by Qualcomm Technologies across two scenarios, **Indoor Line of Sight** and **Automotive Non-Line of Sight**, and is demonstrated to offer **decimeter-level accuracies** in real-world scenarios.



# History and Status of Wi-Fi Ranging Technology



A brief timeline of Qualcomm Technologies

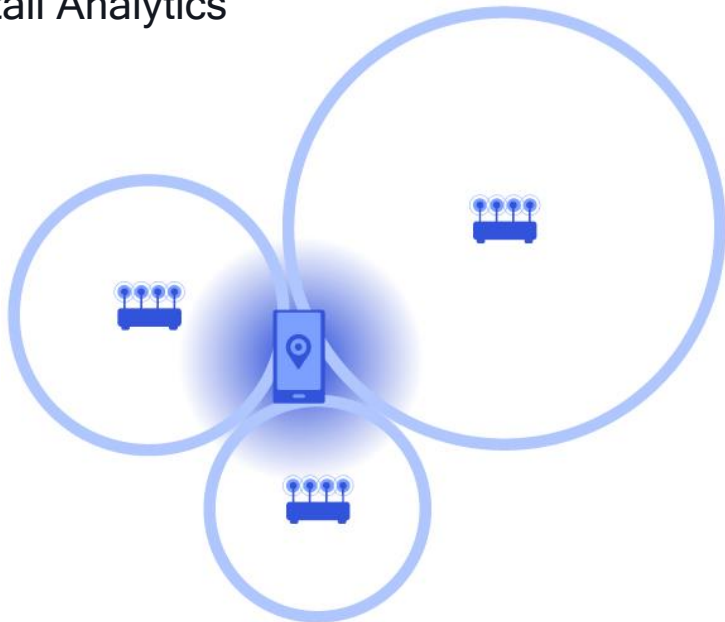
Wi-Fi Ranging Technology evolution and the overall industry

# Uses of Wi-Fi Ranging Technology

## • Infrastructure Use Cases

Use trilateration to pinpoint the location of a mobile device by measuring the distance between the device and multiple access points

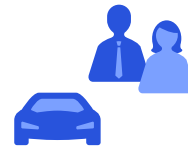
- Asset Tracking
- Indoor Navigation Assistance
- Geofencing
- Network Management
- Retail Analytics



## • Peer-to-Peer Use Cases

Securely measure the distance between two Wi-Fi devices

- Access Control
- Device Finding and Asset Tracking
- Device Operation
- Electronic Ticketing
- Geofencing
- Home Automation Control
- Social Gaming



Access Control



Asset Tracking

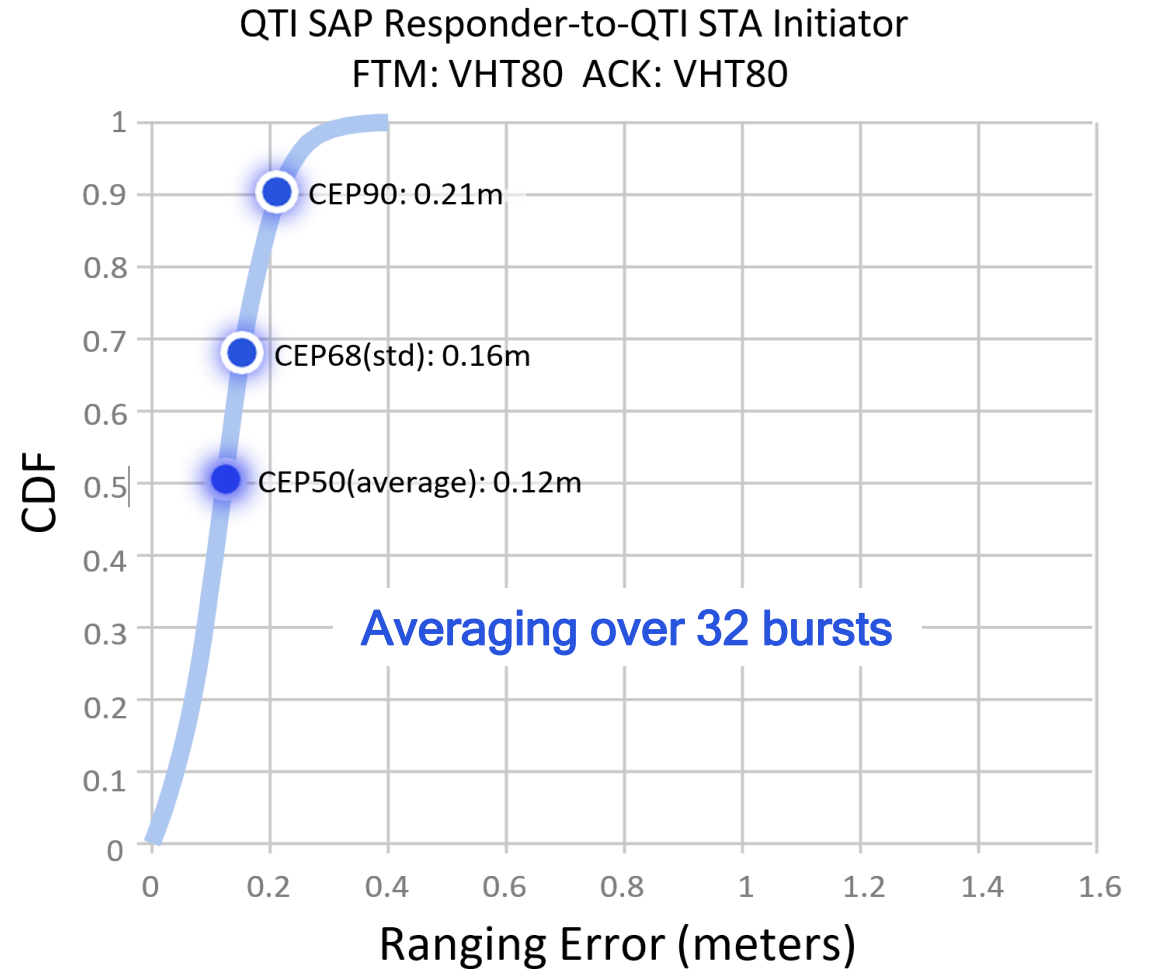
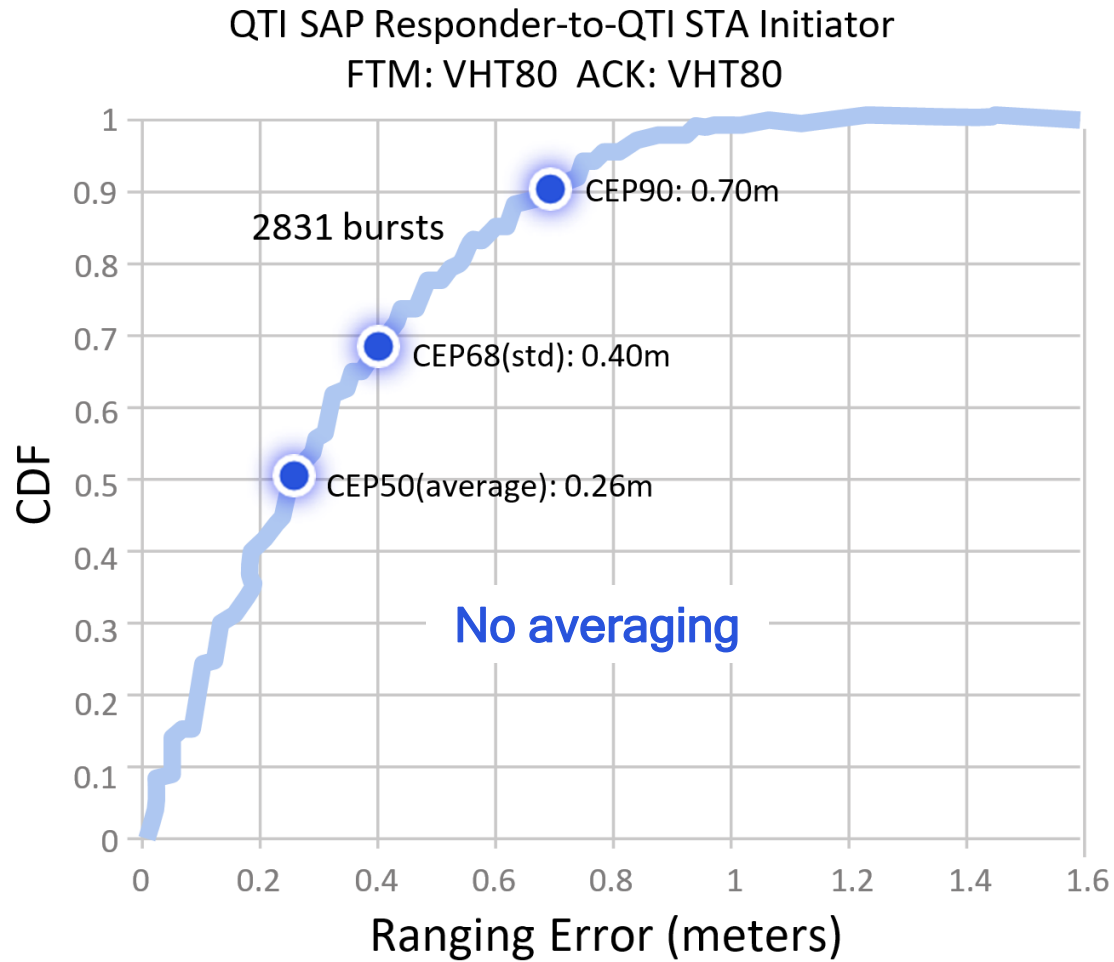


Device Operation

# Drivers of Ranging Performance

Ranging Performance Driver	Explanation
<b>Frequency Bandwidth</b>	With each doubling of the bandwidth, ranging error roughly halves when comparing between the 20/40/80/160 MHz frequency bands.
<b>Multi-Antenna</b>	Using multiple antennas reduces ranging error. For example, a configuration that uses two receive antennas can enable a nearly 30% lower ranging error than a configuration with only one receive antenna.
<b>Transmit Power</b>	A device's transmit power determines how far its wireless signals can travel. Sufficient transmit power is required to effectively conduct distance measurements at range and in non-line of sight conditions. Transmit power is affected by regulatory limits and battery consumption considerations.
<b>Receiver Sensitivity</b>	A device's receiver sensitivity determines the minimum signal strength it can detect. Receiver sensitivity is mainly driven by the frequency bandwidth used (in terms of MHz) and the quality of the receiver, with quality being determined by both the inherent noise it generates and the level at which a received signal can be identified for the ranging estimate.

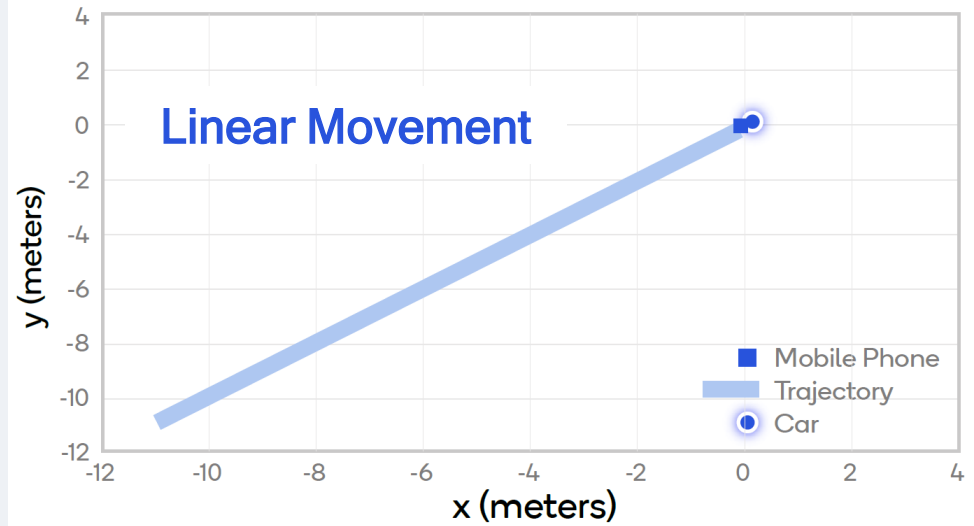
# Enhancing Ranging Accuracy - Averaging



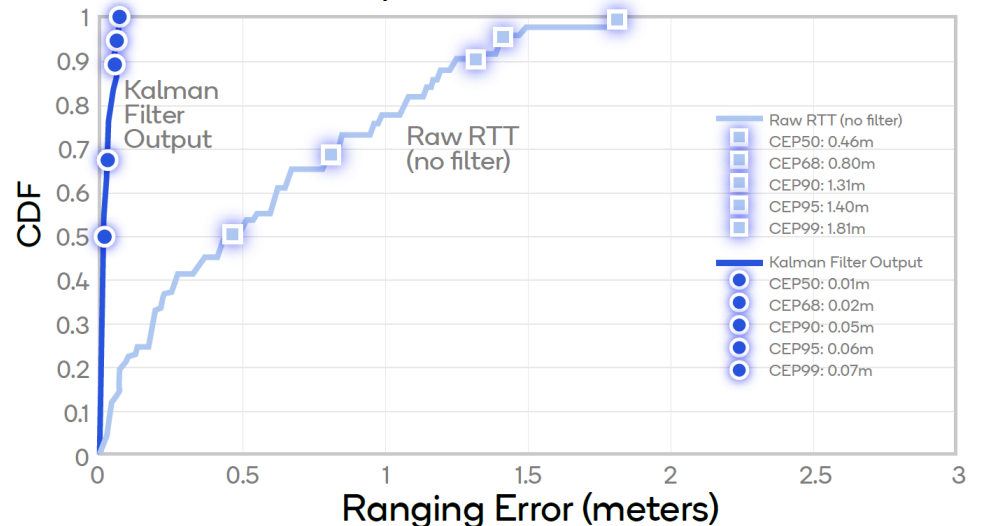
# Location Tracking Algorithm

Kalman Filtering

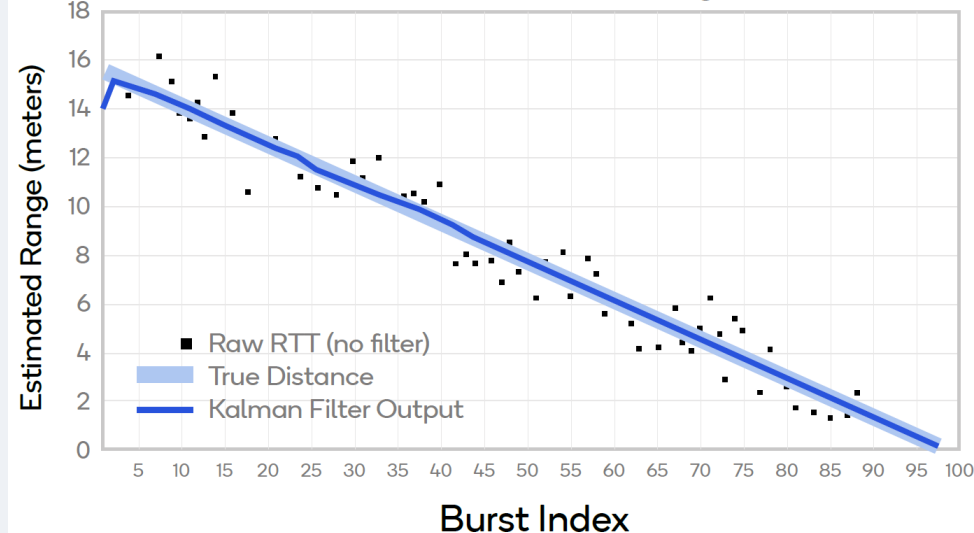
### Simulation of Movement



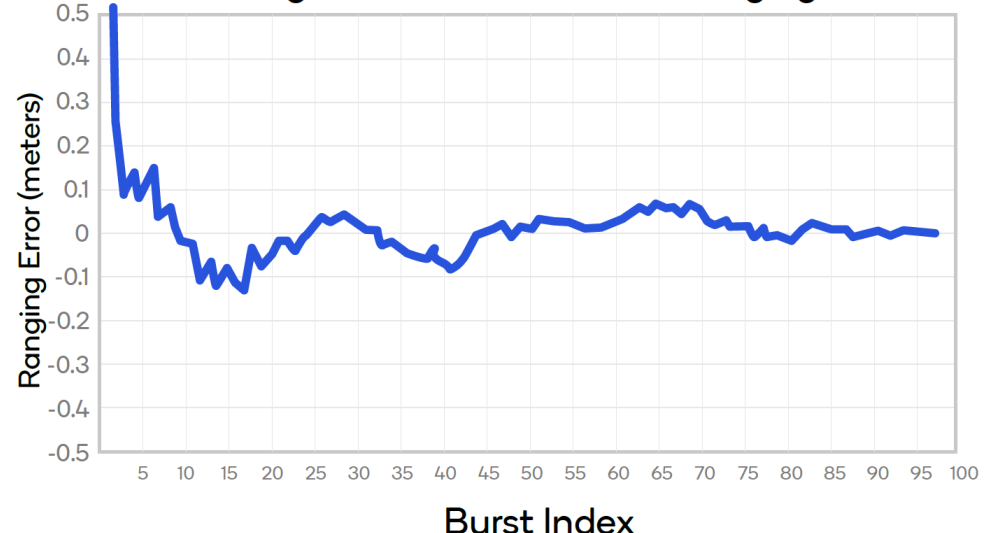
### Comparison of CDF in NLOS




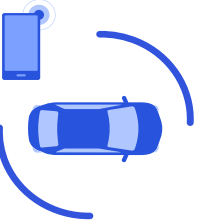

### Comparison of Estimated Range in NLOS



### Convergence of Kalman Filter Ranging Error





	<b>Scenario</b>	<b>90% Accuracy</b>	<b>99% Accuracy</b>
	<b>Linear Movement</b>	5 cm	7 cm
	<b>Circular Movement</b>	4 cm	6 cm
	<b>Stationary</b>	4 cm	7 cm

Location Tracking Algorithm - Different Movements

# Near Term Innovations in Wi-Fi Ranging Technology

		Benefits			
New Capability		Increased Accuracy	Enhanced Security	Enhanced Scalability	Extended Use Case Support
IEEE 802.11az Next Generation Positioning	Wider bandwidths (e.g. 320 MHz)	X			
	MIMO Multi-Antenna technology	X			
	Angle of Arrival/Angle of Departure	X			X
	Secure Ranging (PHY & MAC)		X		X
	Trigger-based Multi-User Ranging			X	
IEEE 802.11bf WLAN Sensing	Passive Location			X	
	Combined use with Wi-Fi Sensing		X		X

# Qualcomm Technologies Wi-Fi FTM Technology is a **performance leader in ranging accuracy**

- **Over a decade of technology development experience**
- **Proprietary techniques** that increase performance
- Development and implementation of FTM Technology for both **Wi-Fi Access Points** and **Wi-Fi Clients**
- **Long-standing experience in supporting OEM customers** with the integration and calibration of Wi-Fi FTM



# Using MATLAB to Develop Wi-Fi Ranging Technology

- Fixed-point modeling of the transmit and receive paths
- Algorithm design and parameters optimization
- Performance simulations and prediction of KPIs (Key Performance Indicator)
- Hardware design verification at block and system levels
- Product-level functionality and accuracy validation

Qualcomm Technologies Wi-Fi Systems team uses MATLAB to optimize and verify Wi-Fi Ranging Technology through different phases of development.

# Qualcomm® Wi-Fi Ranging: delivering ranging and location technologies of tomorrow today

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Christine Zhang, Ali Raissinia, Rolf de Vegt.



**Qualcomm® Wi-Fi Ranging:  
Delivering ranging and location  
technologies of tomorrow today.**

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Qualcomm Technologies, Inc. (QTI)  
San Jose, July 2021

Qualcomm Wi-Fi is a product of Qualcomm Technologies, Inc. and/or its subsidiaries.

Download the whitepaper at:  
[Qualcomm.com/Ranging](https://www.qualcomm.com/Ranging)

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