Applying UWB Magic to Enhance User Experiences

QBR – FY23 Q3

UWB-Mobile/IoT/Auto

UWB Market and Application Updates

Qorvo QM357xx Update

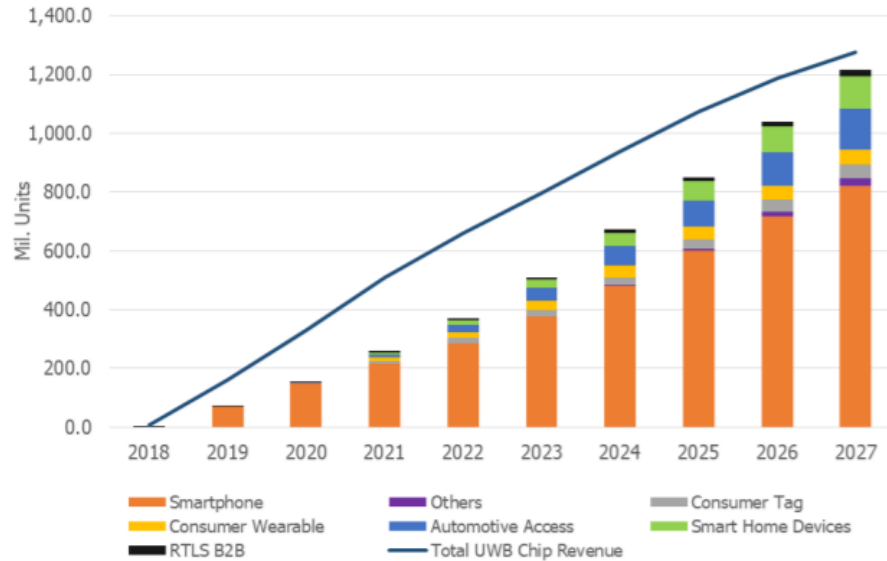Software Architecture & Offering – Mobile
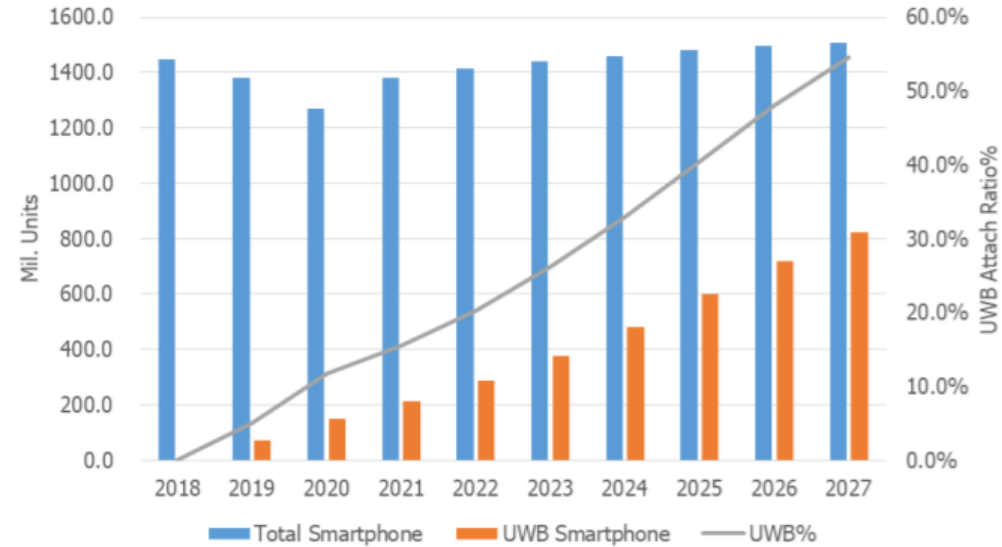
Evaluation Kit for Mobile and IoT

UWB Market and Application Updates

UWB Market Trend

UWB Device Shipment Forecast 2018-2027

UWB Smart Phone Shipment Forecast 2018-2027

UWB Mobile Market Trend

- iPhone will account for 50% of market share in UWB smart phone market by 2024.

- Android UWB smart phones will grow shares in 2023 - 2024.

- Many attractive use cases are under development both at FiRA and at device makers

Mobile Use Cases Projected in CY22-CY24

- CCC keyless entry

- Point & Control

- Find My X/Tag

- Logical access control

- Data transfer (incl. lossless audio streaming)
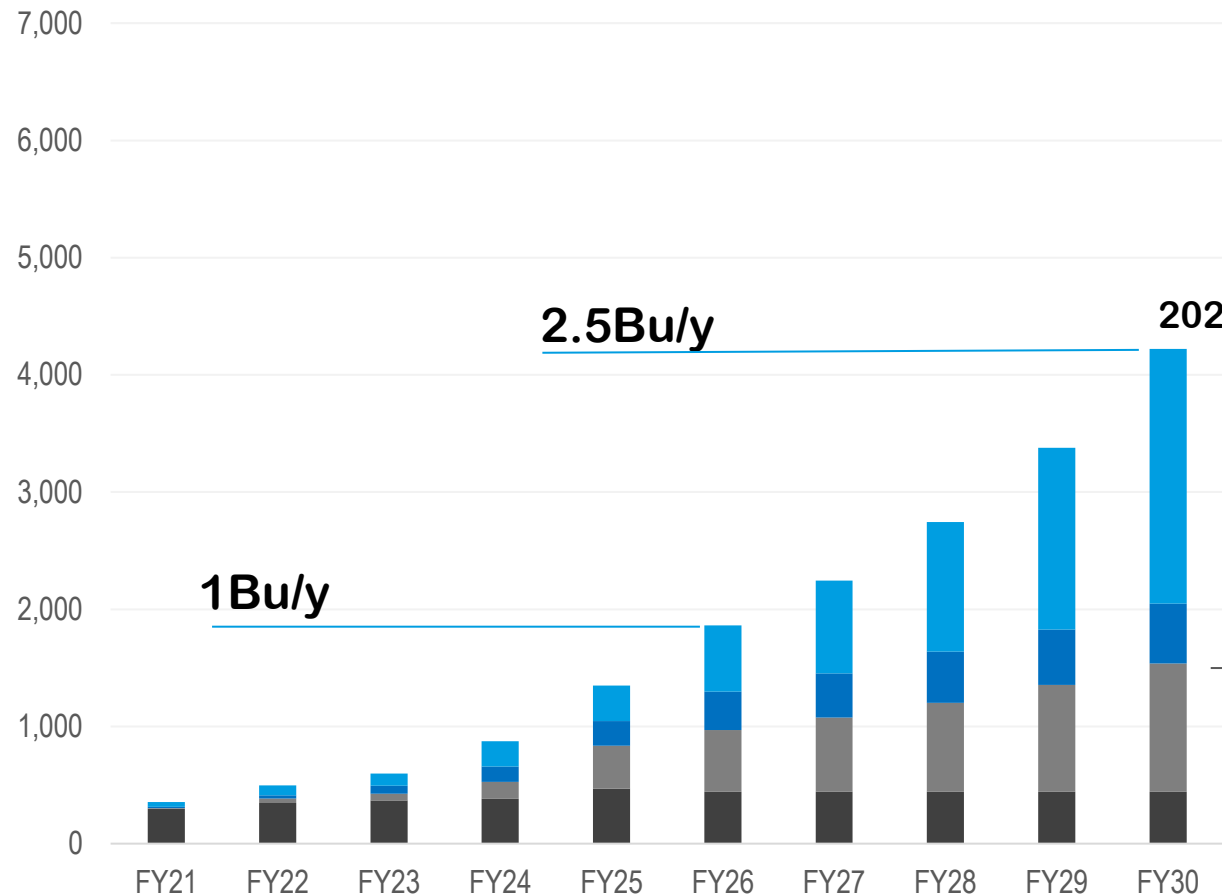
- Transportation fare payment

- Others (FiRA 2.0)

Source: Techno System Research

UWB Market Trend

Mobile Mid-Tier adoption expected in 2y, increasing traction in IoT

2022 UWB Market Forecast (M$)

■ Apple Handsets ■ Non-Apple Handsets ■ Automotive ■ Connected Devices

Connected Devices (IoT)

- Tier one ecosystem providers adopting UWB across their portfolio
- Apple & Google joined FiRa in February 2021
- Wi-Fi infrastructure providers at FiRa and adoption UWB in access points

Mobile

- Point and control, spatial awareness and car access use case are driving mobile adoption

Source: Qorvo Analysis

New User Experiences Are Coming
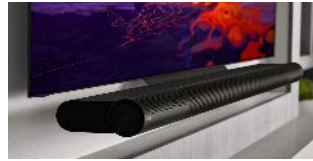
Distance and Angle of Arrival

Personalization
(Follow-Me Audio & Lighting)

Locate My Things

Data Transfer

File transfer
P&C Command
Ultra HD Lossless
Audio Streaming

Precision Spatial Awareness

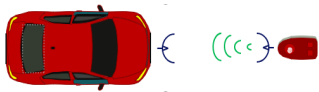**Point-and-Control Single Smart Remote**

Radar

Micro Localization
(Indoor RTLS)

Anti-Spoof Secure Access and Transactions

Car Access

Office/ Home Access

Public Transportation

Logical Access

Contactless Payments

UWB adoption in Android ecosystem

Android UWB ecosystem adoption

Google Pixel 6 launched with Qorvo UWB in Sep 2021

Google Pixel 7 launched with Qorvo UWB in Oct 2022

Impressed by QM357xx performance

Android 12 or newer supports UWB through **Jetpack library** androidx.core.uwb
And now part of Cross Device SDK

Samsung is the first Android OEM to incorporate UWB tech. Available now in the Galaxy family since S20

Xiaomi launched an Android-based TV

Fira and CCC Defines The Use Cases

Standards

CARCONNECTIVITY consortium®

fira | The Power to Be Precise

Use cases

Digital key for car access

Find someone/thing (v2)

Indoor navigation (v2)

Asset tracking (v2)

Point & Control (v2)

Access Control (v1)

Payment (v2.x)

Features

- Double-Sided Two Way Ranging (DS-TWR)
- Dynamic Scrambled Timestamp Sequence (Dynamic STS)
- BPRF
- CH5 & CH9 mandatory
- Many to many

- Contention-based, SS-TWR, non-deferred, static STS

- Down-Link Time Difference Of Arrival(TDOA), static STS

- Up-Link TDOA, static STS

- DS-TWR, AoA OWR, data transfer

- DS-TWR, dynamic STS

- DS-TWR, dynamic STS, contention-based/hybrid scheduling, data transfer

QORVO®

Tier 1s Driving our Key IoT Segments

Large Opportunities Take Time - Best in Class SW Creates Stickiness

Goal

Develop a Portfolio of Connectivity Products Delivered through a Unified SW Ecosystem

Strategy

- **Invest in SW and Support for Stickiness and Scale**
- **Portfolio of products and unified SW environment for variety of customer products**
- **Leverage internal strengths and IP to differentiate**

Opportunity

Market	TAM 2030 (Mu)	Lead Customer and Expands
AR/VR & Gaming	300	Meta > XBOX, amazon, Logitech, Nintendo, PlayStation, HTC VIVE
Access Point	50 Enterprise 250 Consumer	CISCO, Extreme networks, Plume > aruba, belkin, NETGEAR, COMMSCOPE
Home – Hub & Speakers	500	G Nest, mi SONOS > amazon, OPPO, SmartThings, starling
Tags & Things	250	SAMSUNG, MINEW > estimote, ring, Apple

Source: ABI

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New User Experiences Enabled By Qorvo UWB

100's of User Experiences Being Enabled Now! Sipported by DW3000/QM33

Distance and Angle of Arrival

Personalization
(Follow-Me Audio and Lighting)

Locate My Things

Standards Driven

fira

omlox

csa

connectivity
standards
alliance

CARCONNECTIVITY
consortium®

Precision Spatial Awareness

Point-and-Control
Single Smart Remote

Micro Localization
(Indoor RTLS)

Contactless Payments
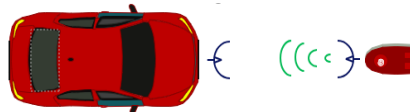
Car Access

Public Transportation

Office/ Home Access

Anti-Spoof Secure Access and Transactions

QORVO

More than Location!

New User Experiences enabled by QM3572x

High Speed & Low Latency Wireless Data Comms
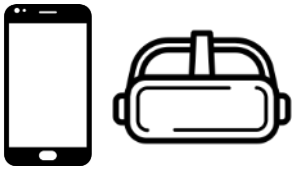
Mobile to XR Video

Mobile File Transfer

Ultra Low Latency Gaming
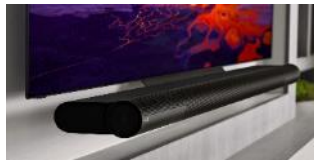
Hi-Fi Atmos Soundbar to Audio Streaming

Software available in Q4 CY22

Roadmap of Extended Functionality

Radar

1 Short Range Presence

2 Long Range Presence
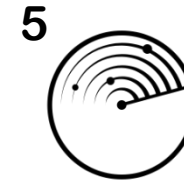
5 Location

4 Gesture

3 Breathing

Software available in Q1 CY23

Qorvo®

UWB for Purpose Built Wireless Data Comm

High Speed, Low Latency, and Low Power

Ultra Low Latency
- 500us latency target
- Minimal header overhead vs BLE and Wi-Fi
- Low time on air
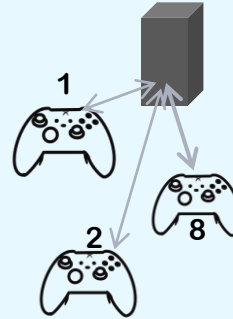
Flexible protocol
- One to many or many to one communication (up to 8)
- Bidirectional full duplex
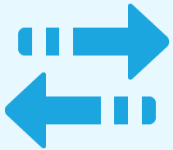
High Speed Data
- 62.4 Mbps PHY
- Maximize throughput with optimized headers
- High bandwidth bidirectional data

Reliable Extended Playtime
- Ultra Low Power TX to save battery life
- Minimum 10m NLOS Range
- No 2.4GHz interference and dropped packets

Preview of UWB Data Comms Use-Cases
Lossless High-Resolution Audio Streaming

Industry trend : High-Res Lossless Audio

Requirements :
Playing High-Res Lossless audio requires up to 9.2Mbps and < 20ms latency.

Solution :
Qorvo UWB offers the best trade-off between data throughput, power consumption and coexistence with other RF

- 10Mbps data throughput sufficient for:
  - Lossless stereo: 24bit / 48KHz / 2 channels (2.3Mbps)
  - *High res* lossless stereo: 24bit / 192KHz / 2 channels (9.2Mbps)
- Audio frame synchronization down to 10 ns
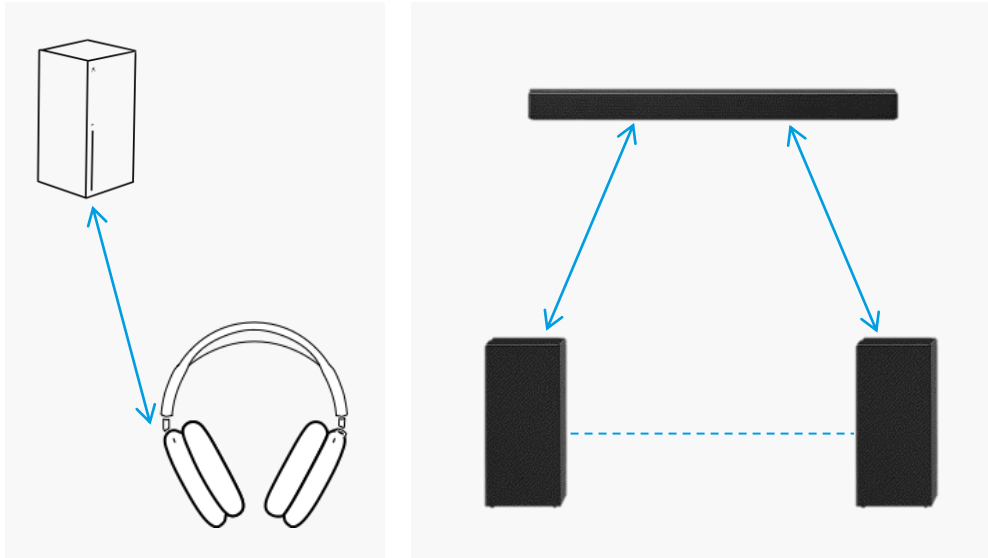
Preview of UWB Data Comms Use-Cases

Current Audio Proof of Concept

Hardware setup

DW3110 Shield

Qorvo Jolie Omni antenna

TI PCM5102A DAC (Rx side)

ST NUCLEO-F429ZI Evaluation Board
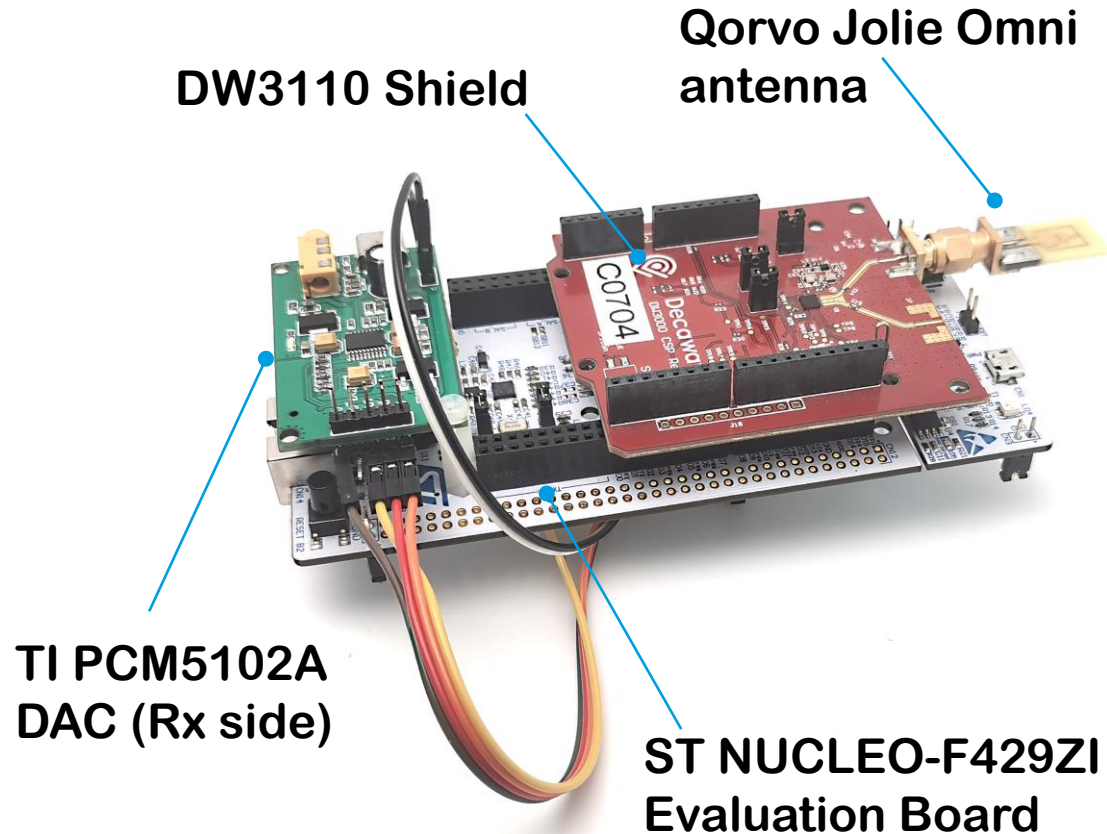
Implemented features

- **Audio quality @ 96KHz * 24 bit * 2 (stereo); 4.6Mbps datarate**
  - 192kHz @ 16b demonstrated, will need different ST part for 192kHz @ 24b * 2; 9.2Mbps stereo

- **Auto ACK & retransmissions**

- **Audio buffer & synchronization**

- **Low latency: 12ms (incl. 10ms buffer)**

QOrvo®

Preview of UWB Data Comms Use-Cases
Ultra-Low Latency Gaming/AR/VR
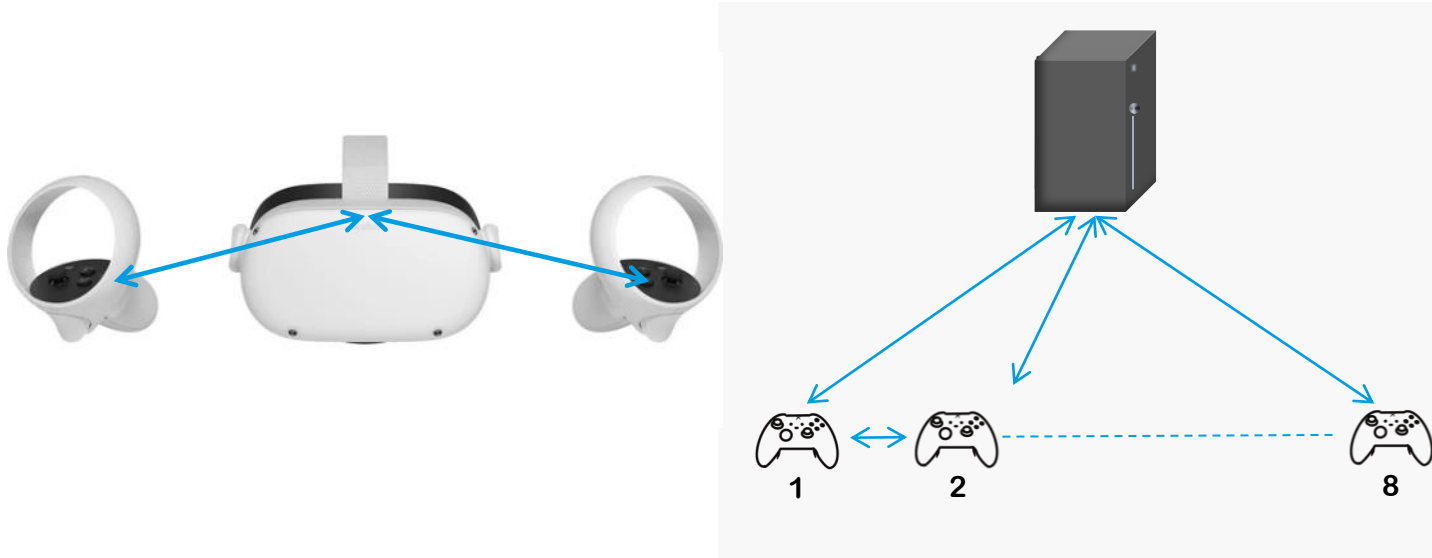
Lower latency at equal or better power consumption than BLE proprietary LL (ESB)

Screen Refresh Rate - Ecosystem trend

- Refresh rate is an important aspect of gamers experience. Trend is going upward from 60 to 90, 120 and soon 240 Hz

Controllers link needs to adapt:

- 29.3us to send 20B of data
- 500us latency target
- Small optimized header relative to BLE and Wi-Fi
- Star topology supporting up to 8 controllers

UWB radar fundamentals
Channel Impulse Response (CIR) estimation

1 UWB pulse synthesis

2 Radio transmission

3 Pulse reflects on (multiple) objects

Tx

Rx

CIR estimation

5

Correlation and integration on known chip sequence

4 Radio reception

Delay ~ 2*range

QOrvo.
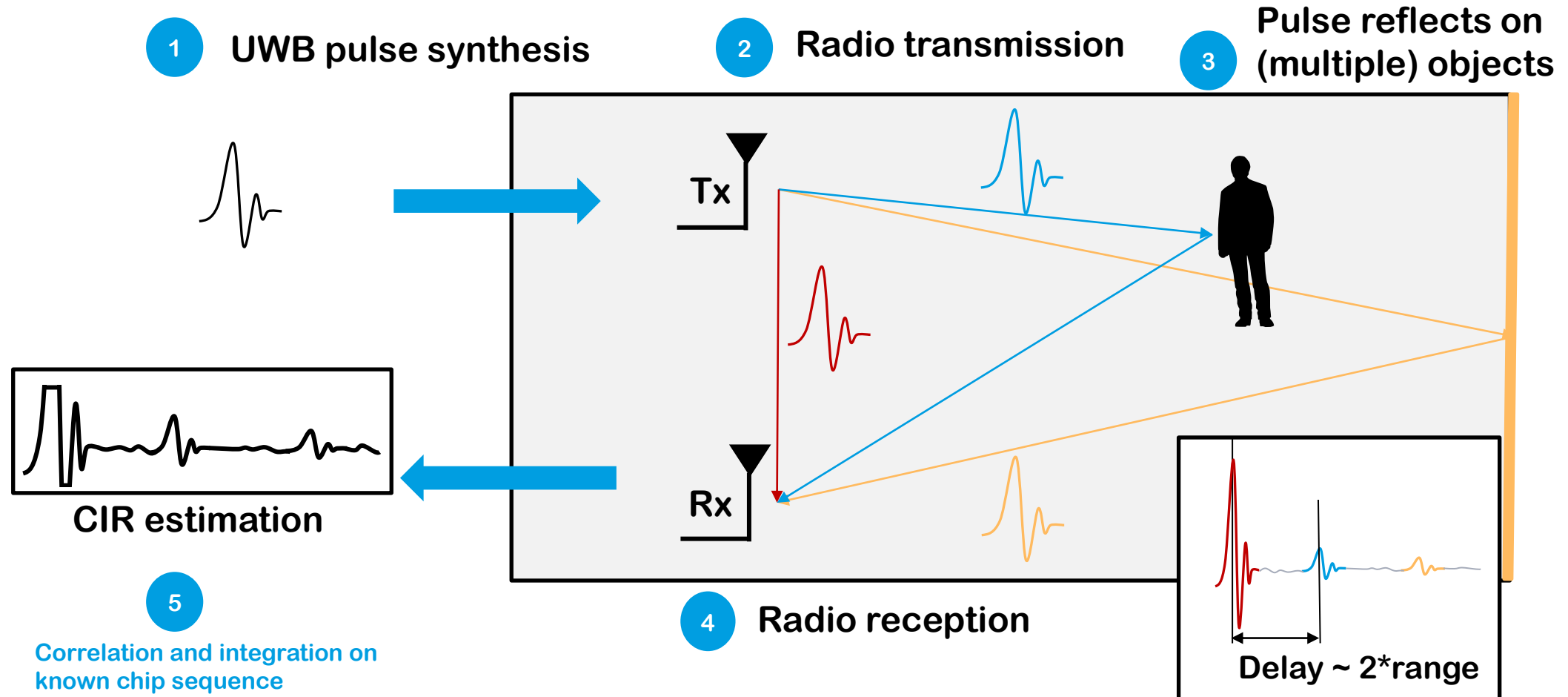
UWB for short range radar

Built-in, efficient, extendable

No BOM cost adder
- A unique IP for radar + communication / ranging
- No specific HW tuning required

Versatile solution
- High precision (measure breathing)
- Up to 10m distance
- Pre-processing possible inside UWB subsystem

Simple integration
- Extend standard UCI interface with radar commands
- Same interface as other UWB functionalities

Low power consumption
- Wideband operates a low TX power $\leq$ -15dBm
- Other radar technologies require higher power

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Preview of UWB Radar Use Cases

Sensing surrounding environment
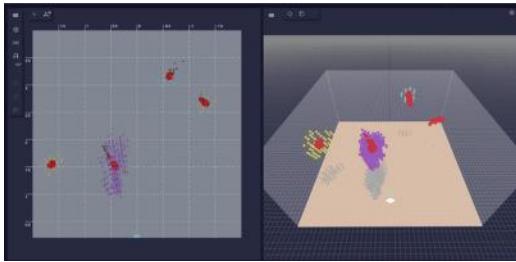
- ## Short range Presence detection
  - Wake-up a device as a person enters the detection zone

- ## In-room Location
  - Locate a person in 2D in a room using 1 device with multiple antennas and/or multiple devices

- ## Gesture recognition
  - Control objects using gesture

- ## Breathing detection
  - Measure human respiration rate

Preview of UWB Radar Use Cases

Existing Python abstraction running on PC

PC

- Radar application
- Classification / AI
- Algorithms / tracking / mapping
- Signal Processing
- Python client

Customer solution

- QM35 provides pre-processed Channel Impulse Response Estimation
- **Customer/3rd party** signal processing & algorithms required for classification

Extended UCI* | fira

QM35xxx

- UCI server
- Radar HAL
- UWB MAC/PHY

Provided by Qorvo
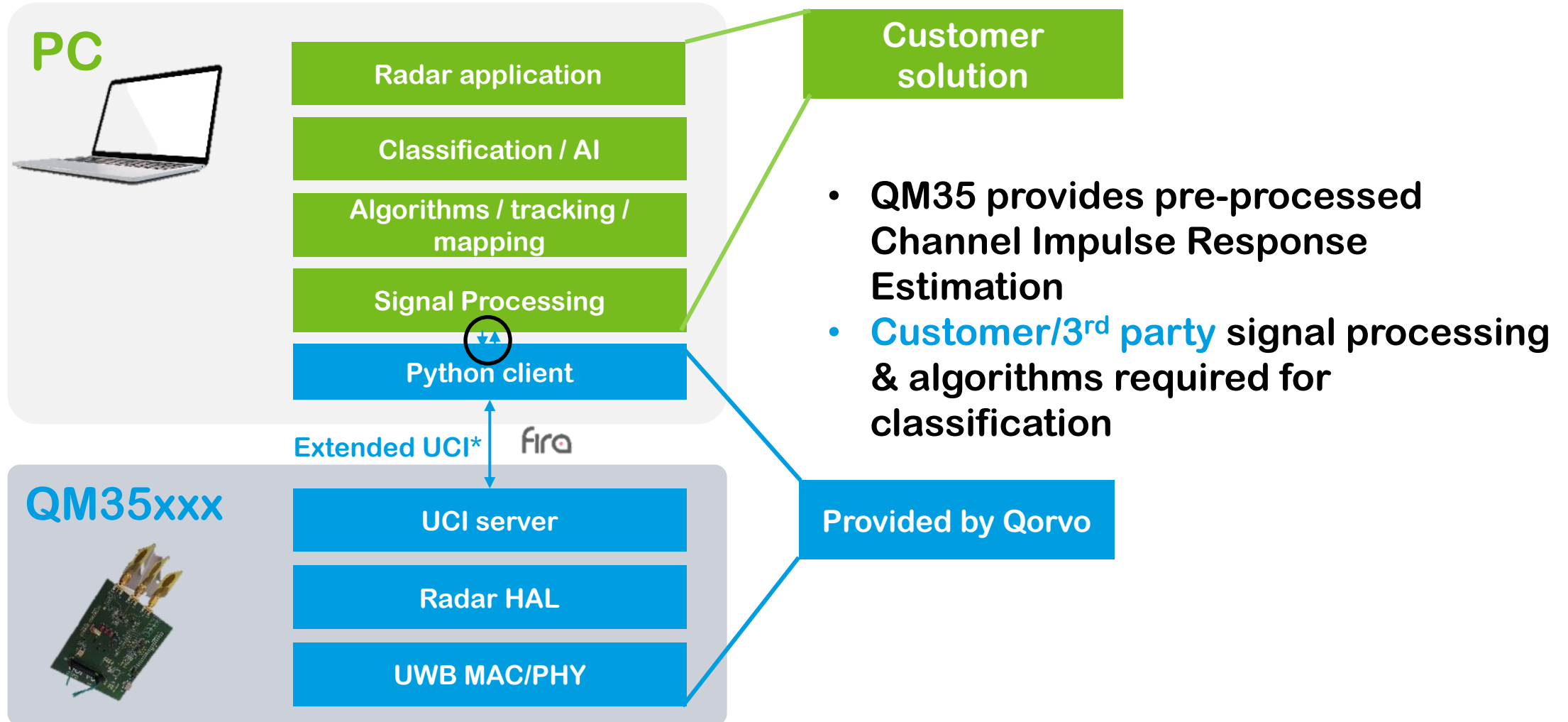
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Qorvo QM357xx Update

Qorvo Unique Offering - QM35720 & QM35725

2 Proposed Radio Options

QM35720
System on a Chip
3.87 x 3.24 x 0.6
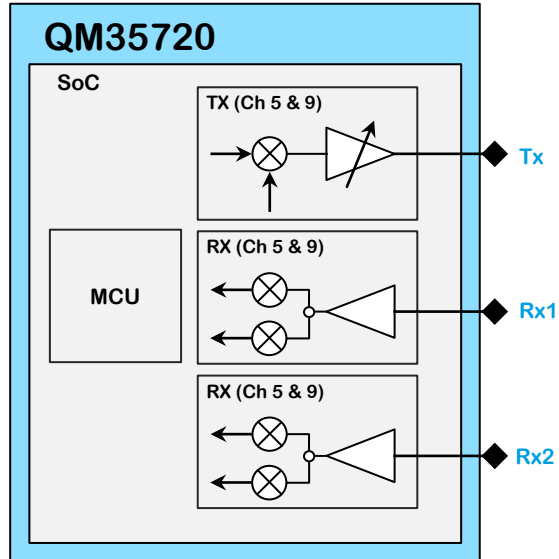
RF FE
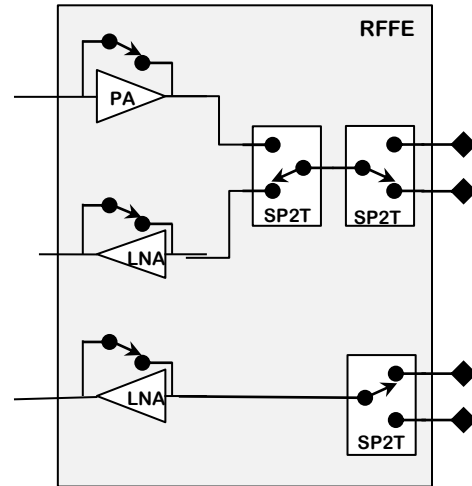
QM35725
System in a Package
4.08 x 3.38 x 0.65
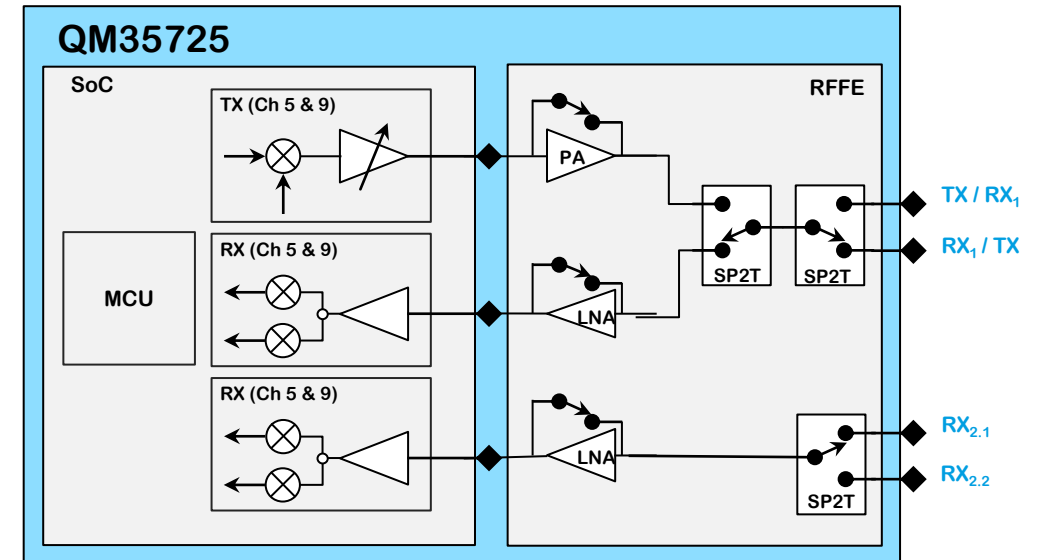
Handles all antenna switching automatically!

QM35725: Qorvo 3ʳᵈ Generation UWB SiP
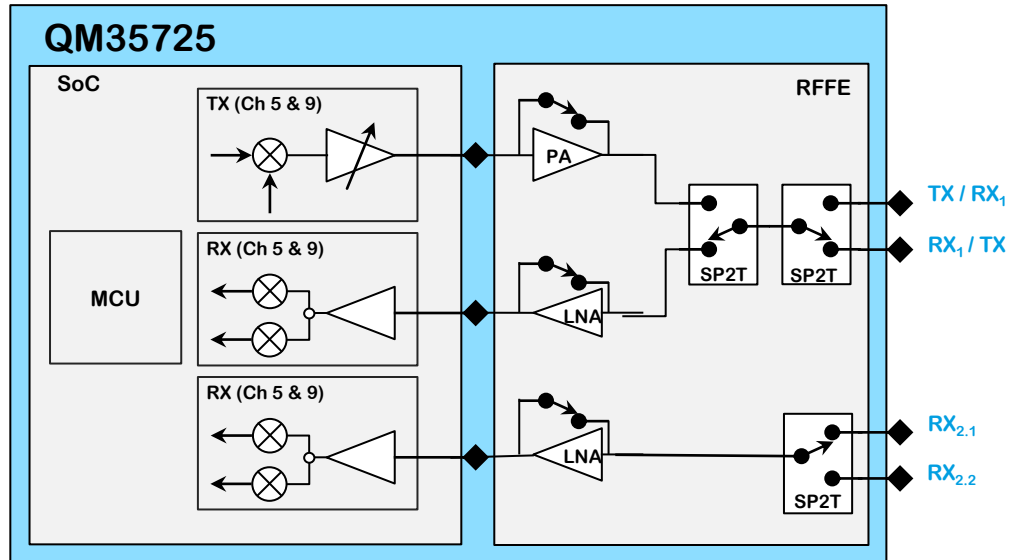
Size	4.08mm x 3.38mm x 0.65mm
Samples (selected customers only)	Available now
EVB board	Available now
Mass Production Ready	Q2 2023

Integrate SoC and RFFE into one compact package to delivery the best RF performance, the lowest power consumption and the smallest PCB area in the market. Turn-key solution to realize CCC car access and Fira ranging use cases

- Unrivaled RF performance:
  - Link budget 104dB - the highest in the market
  - Power consumption is 20%+ lower than competitors
  - Ranging accuracy: ± 6 cm; AoA accuracy: ± 3°
  - 3D AoA with a single frame, handles all antenna switching automatically

- Smallest PCB area: ~ 18mm²

- Various GPIO's & interfaces:
  - Host AP interface: SPI (up to 50MHz)

- Turn-key SW solution
  - FW in MCU managing distance ranging/AoA
  - FTM (SW commands for factory tests and calibration)
  - HAL and UWB Secure Services : Android T
  - SE binding: SCP11a (secure channel)
  - CCC and Fira applets in SE

QM3572x RF Performance

Best RF Performance

			Competition	DW3720	QM35720 (SoC)	QM35725 (SiP)
Rx		RX sensitivity (BPRF single Rx)	-94.5 dBm/500MHz @10% PER	-92 dBm/500MHz @1% PER		
		DC power dissipation (single Rx)	225 mW	132.6 mW	132.6 mW	148.8 mW
Tx		Max mean output power	0dBm	-5 dBm/500 MHz		
		Max peak output power	+10.5dBm/500MHz	+5dBm/500MHz		
		DC power dissipation	216 mW	132 mW	132 mW	218.4 mW
Link Budget		Link Budget	94.5 dB@10%PER	87dB@1%PER		
Ranging		Ranging Accuracy	± 10 cm	± 10 cm	± 6 cm	± 6 cm
AoA		AoA Accuracy & STD	± 10° (>8m) Accuracy: ± 3°	Accuracy: ± 5°	Accuracy: ± 3° @10m STD: <1° (-60° to +60°)	Accuracy: ± 3° @ 10m STD: <1° (-60° to +60°)
		3D AoA	Yes	Yes with 2 frames	Yes with 1 frames	Yes with single frame

Note:
- Parameters are typical number
- AoA STD Test set-up: Embedded App./EVB SoC A0 w/ Jolie antenna as initiator /CH5 & CH9 /Preamble length 64; STS length 64 /With single frame, pure raw data without averaging /@ Power sweep from max to max-30dB

QM3572x RF Performance (cont.)

Best-in-class Solutions for UWB Applications

		Competition	DW3720	QM35720 (SoC)	QM35725 (SiP)	
I/O	SPI	2 x SPI (20MHz)	2 x SPI (up to 40MHz)	2 x HSSPI (50MHz) 2 x SPI (30MHz) 1 x SPI (10MHz)		**Faster I/O**
	I2C	2 x I2C (3.4MHz)	-	2 x I2C (3.4MHz)		
	I3C	1 x I3C (12.5MHz)	-	1 x I3C		
	UART	2 x UART (25MHz)	-	2 x UART		
RF Port	RF Port	1Tx/2Rx	1Tx/1Rx	1Tx/2Rx	1Tx/2Rx	
Form Factor	Package size (mm)	3.07 x 3.79 x 0.49 mm	3.1 x 3.5 x 0.56	3.87 x 3.24 x 0.6	4.08 x 3.38 x 0.63	**Smallest PCB area**
	Real Estate *	27.4 mm^2	25.4 mm^2	26.8 mm^2	18.7 mm^2	

(*): Including switches and filters, PA, LNA and SMD excluded)

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Software Architecture & Offering - Mobile

QM3572x Software Architecture and CCC Support

Android T Implementation
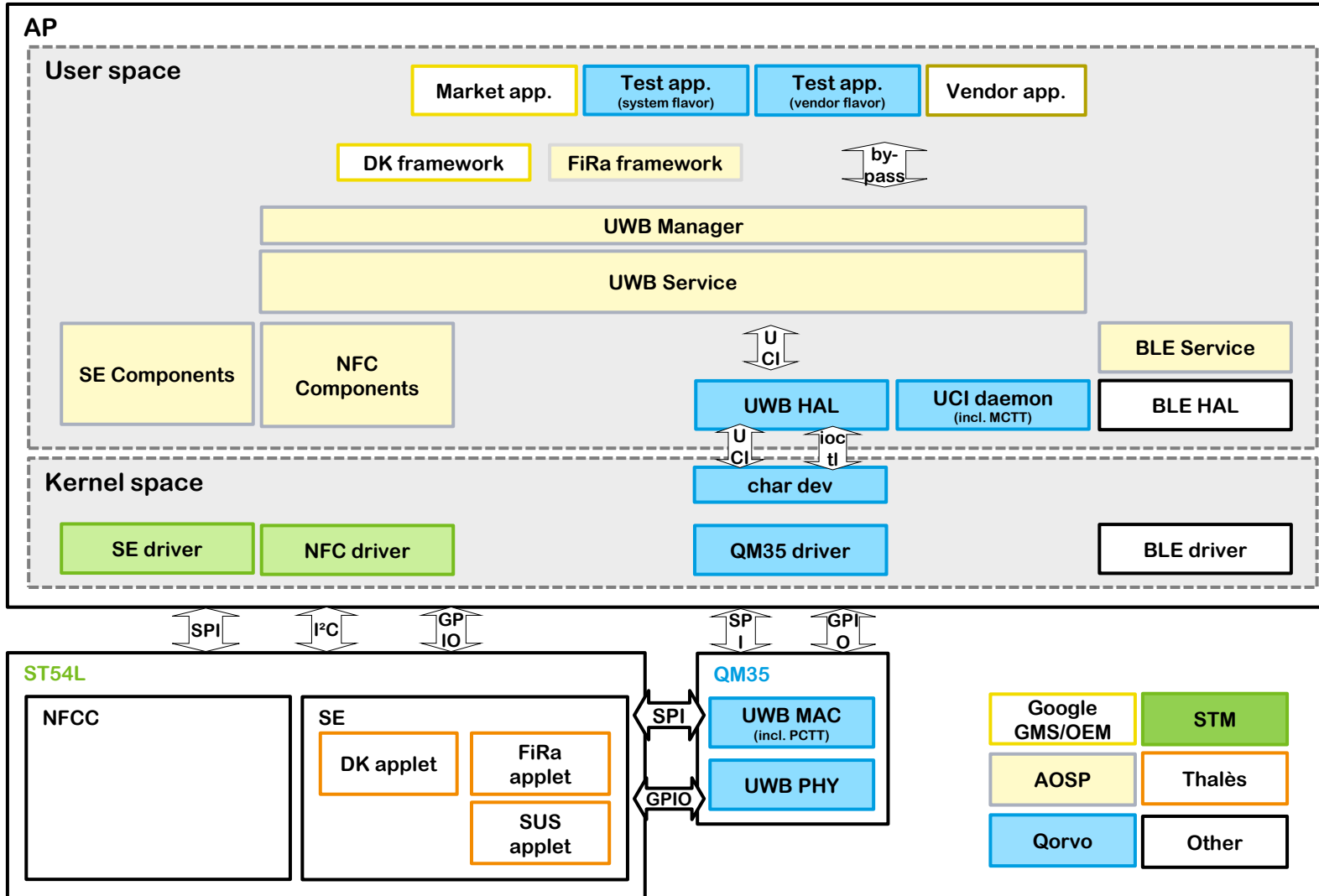
Qorvo Offering:
- Code in MCU: F/W binary (FiRa & CCC MAC, FTM, Crypto, UWB Driver, etc.)
- QM35 Driver (kernel space)
- UWB HAL (user space)
- Test APK (user space)

Google AOSP, Android T/U:
- UWB Service/UWB Manager/Fira Framework in AOSP (*)

Google GMS :
- DK Framework

Secure Element : Support for CCC & FiRa Dynamic STS :
- QM35725 connects to SE via SPI, UWB fetch URSK/RDS keys from SE applet and generates derived keys
- QM35725 and SE secure binding via protocol SCP11a.
- Applets for CCC & FIRa Dynamic STS

(*) : Official release : Q3 2022 for T, and Q3 2023 for U

QORVO

Qorvo partnership with STM for Secure Ranging
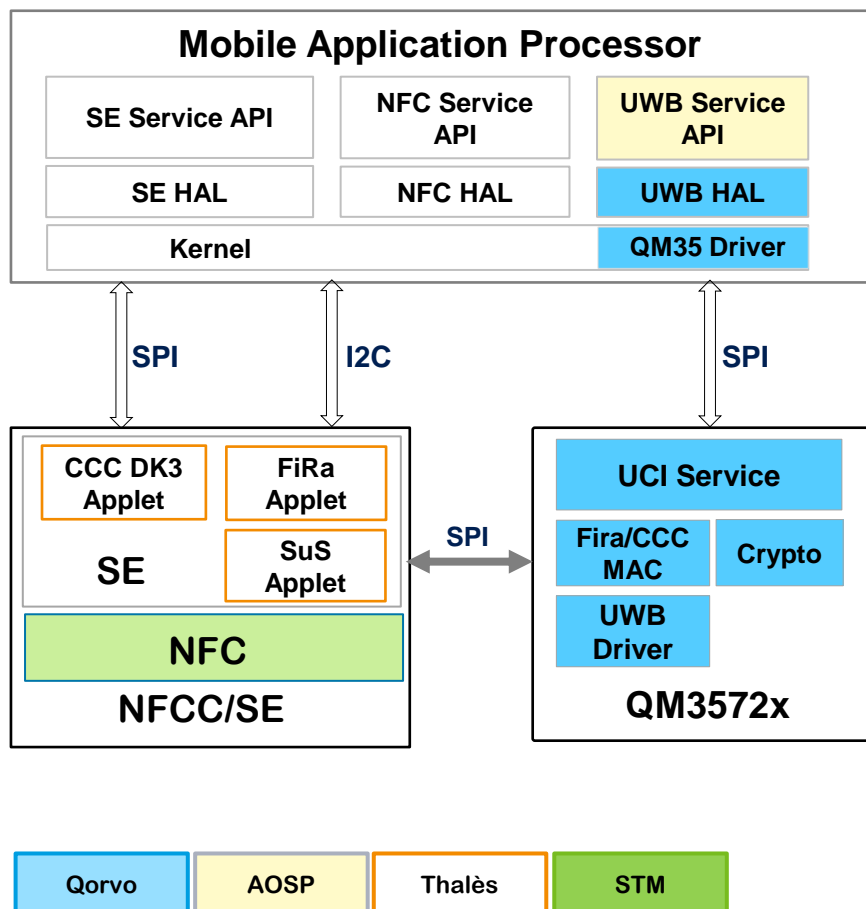
- Smartphones now embed UWB + BLE + NFC
  - UWB: Secure distance & location determination
  - BLE : Out Of Band discovery & negotiation of UWB parameters (per CCC DK3 and FiRA spec)
  - NFC: CCC DK2 backward compatibility & when phone is out of battery

- STM and Qorvo partner: Integrated secure ranging
  - Solution for Google Pixel 6 Pro & Pixel 7 Pro
  - Customer programs under development using QM3572x
  - Joint roadmap

Preview of UWB Radar Use Cases

Existing Python abstraction running on PC

Roadmap of Extended Functionality

PC

Radar application
Classification / AI
Algorithms / tracking / mapping
Signal Processing
Python client

Extended UCI* **fira**

QM35xxx

UCI server
Radar HAL
UWB MAC/PHY

Customer solution

- QM35 provides pre-processed Channel Impulse Response Estimation
- **Customer/3rd party** signal processing & algorithms required for classification

Provided by Qorvo

QorVo.
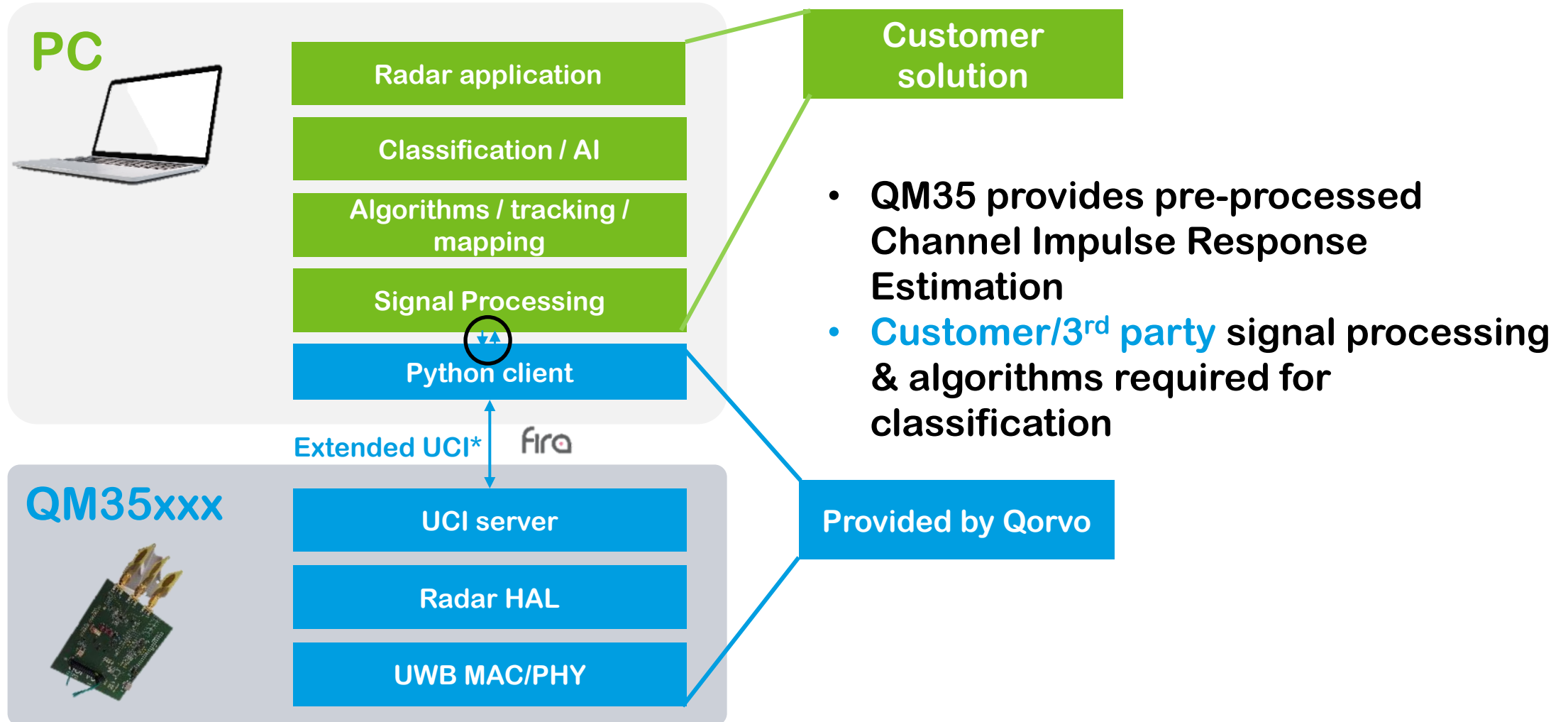
Make the Choice of QM35

8 Key Benefits That Make The Difference

Total Solution

Plug & Play
(Embedded MAC in MCU)

Unrivaled RF Performance
(AoA accuracy, Ranging distance & accuracy etc.)

Ultral Low Power

High Security

High Flexibility

Comply with ww regulation

High Integration Cost Saving

Evaluation Kit for Mobile and IoT

QOΓVO.
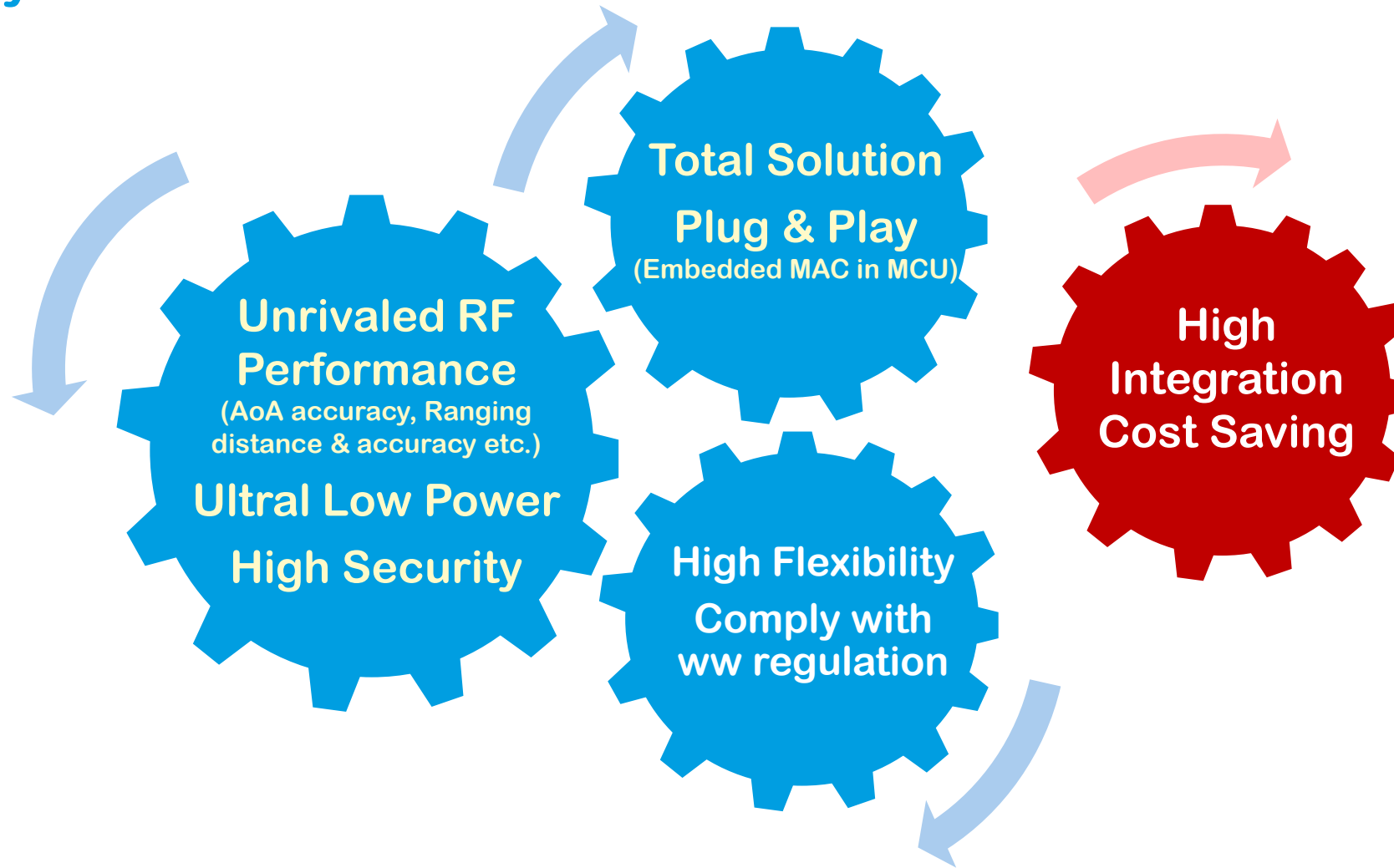
1st test setup - Mobile

DragonBoard +QM3572x EVB for integration and testing under Android

QM35 A0 EVB

Dupont wires
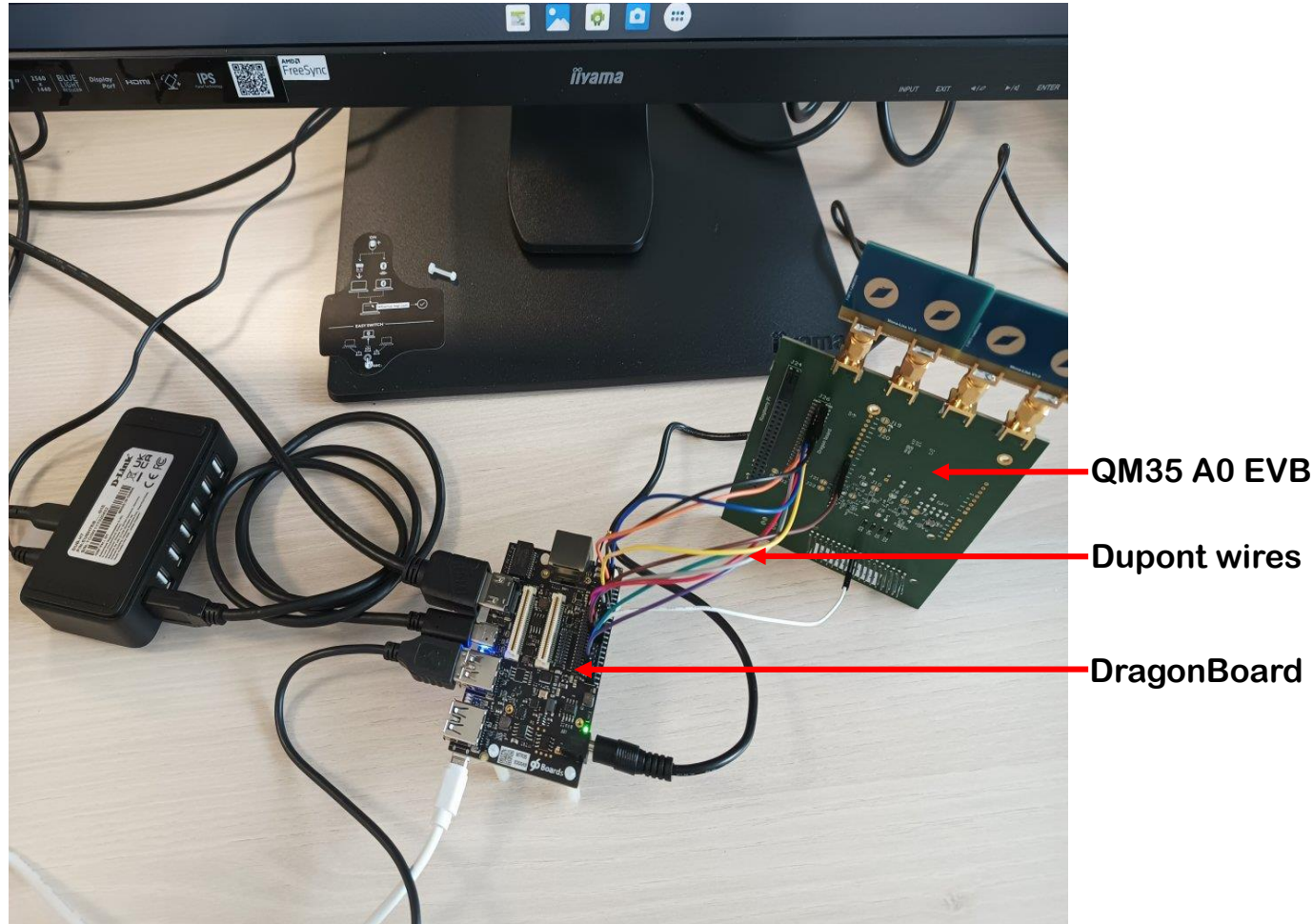
DragonBoard

- Dragon Board plays the role of phone AP controller board, Android SW stack resides on AP on Dragon Board

- PC send commands to Dragon Boards, control UWB Service; PC can also send UCI command to control UCI daemon directly; Dragon Board communicate with QM35 evaluation board via SPI

- Commands will be received by QM35 on the EVB board, and drive the test, e.g. Tx power, Rx sensitivity, PER, AoA, etc. etc.

2nd test setup - IoT

Standalone EVB for Hardware tests thru FTM commands and python scripts

USB to PC

JLink

USB (for 5V pwr supply)

JTAG

Antennae

USB/UART Adapter (3.3V)

3.3V UART link (TX/RX) (GND over USB)

QM35 A0 EVB board

RX Adapter <- -Tx QM35

14 gpio11

TX Adapter --> Rx QM35
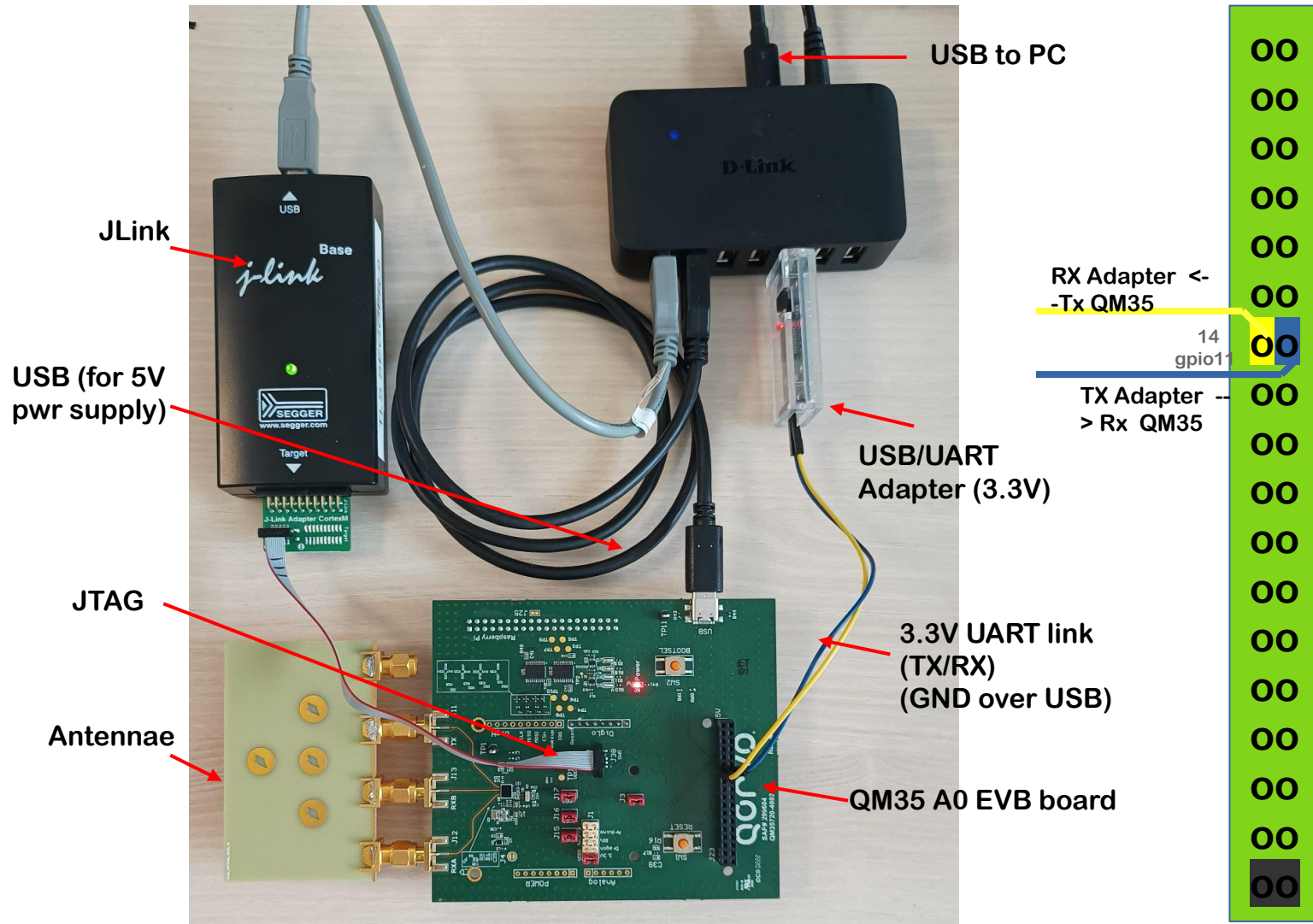
- PC GUI for AoA, Ranging, File/Data transfer, Post processed CIR data for Radar algorithm. Connecting EVB board via UART port (USB/UART).

Automotive – Time for Tier 1 & Tier 2 Collaberation

UWB detection

UWB detection

PHONE

- B
- U
- S
- N

KEY

- B
- U
- S
- N

LEGEND

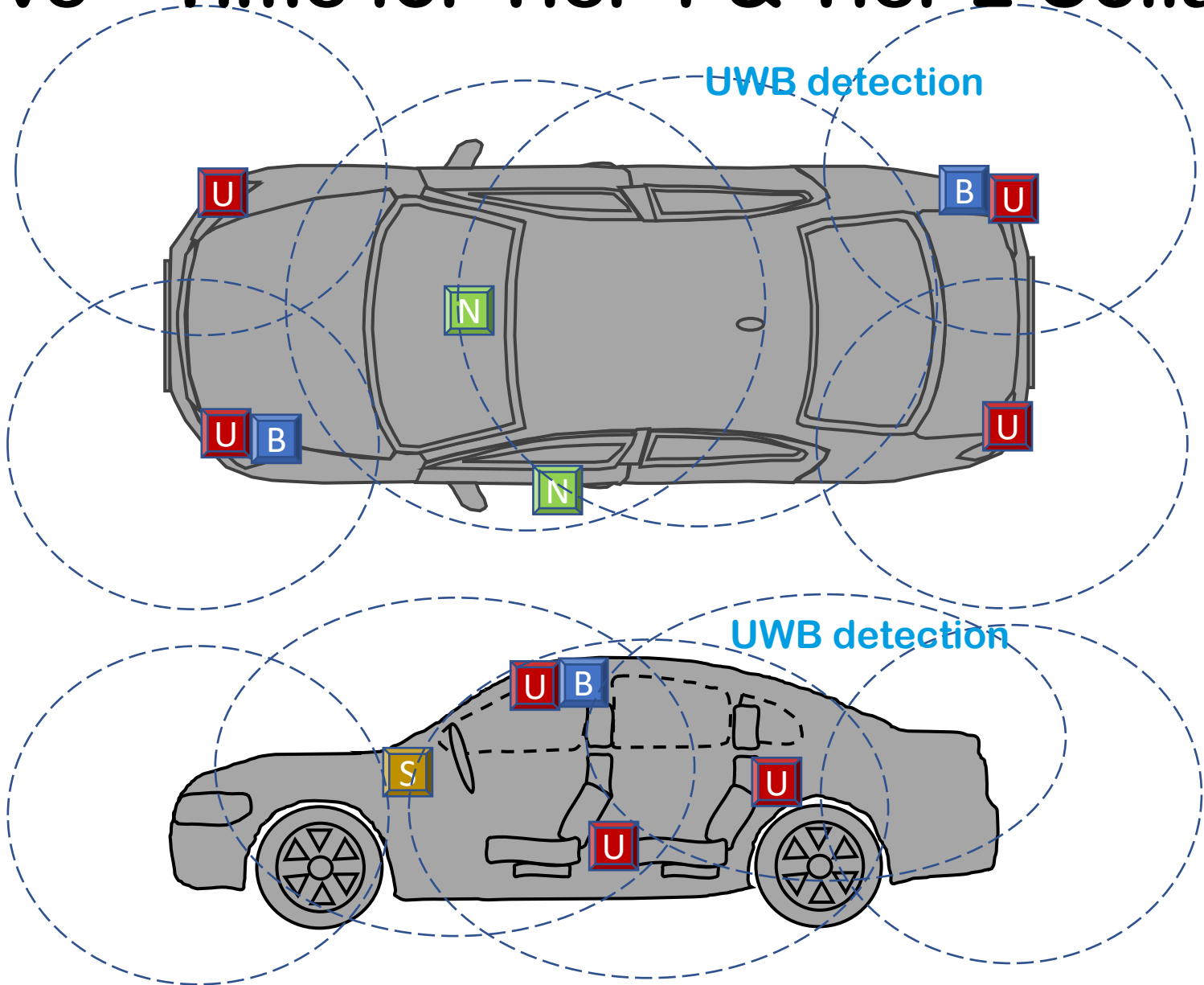|	
B	BLE TRx
N	NFC TRx
S	eSE
U	UWB TRx

Qorvo®

UWB Hardware/Software

Typical automotive implementation

Secure Element & NFC

NFC Antenna

DW3300Q UWB

BLE SoC

BLE Antenna

UWB Ranging with Anchor Nodes

BLE for Network Discovery and UWB Wakeup

Door Handle Start / Stop

CAN UWB BLE   UWB CAN

Body Control Module

HSM / SE   CAN

Master Anchor

CAN UWB BLE

NFC CAN   CAN NFC

CAN UWB   BLE UWB CAN
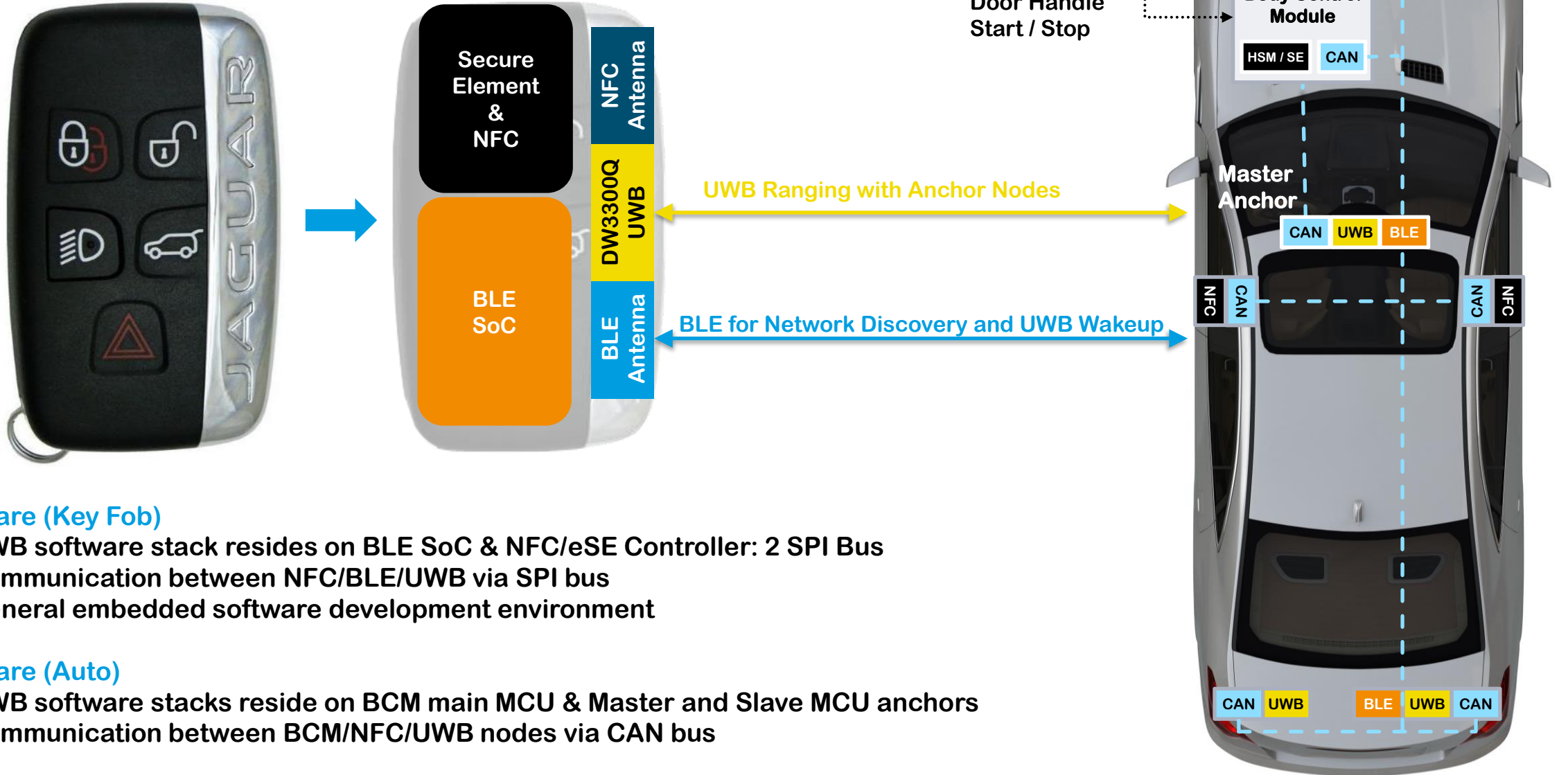
Software (Key Fob)

- UWB software stack resides on BLE SoC & NFC/eSE Controller: 2 SPI Bus
- Communication between NFC/BLE/UWB via SPI bus
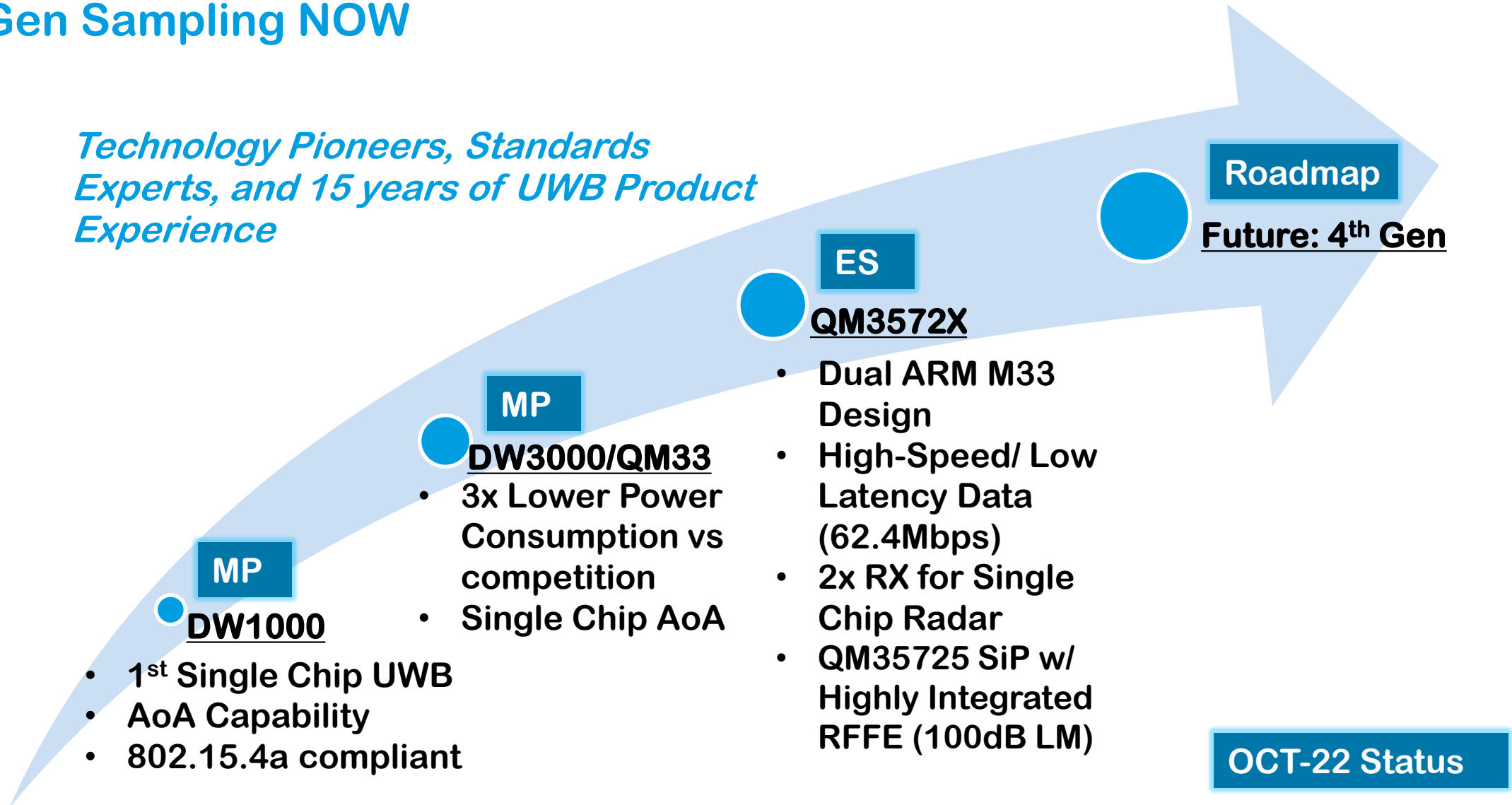- General embedded software development environment

Software (Auto)

- UWB software stacks reside on BCM main MCU & Master and Slave MCU anchors
- Communication between BCM/NFC/UWB nodes via CAN bus

QORVO®

Qorvo Solution Roadmap

3rd Gen Sampling NOW

Technology Pioneers, Standards Experts, and 15 years of UWB Product Experience

Roadmap

Future: 4th Gen

ES

QM3572X

- **Dual ARM M33 Design**
- **High-Speed/ Low Latency Data (62.4Mbps)**
- **2x RX for Single Chip Radar**
- **QM35725 SiP w/ Highly Integrated RFFE (100dB LM)**

MP

DW3000/QM33

- **3x Lower Power Consumption vs competition**
- **Single Chip AoA**

MP

DW1000

- **1st Single Chip UWB**
- **AoA Capability**
- **802.15.4a compliant**

OCT-22 Status

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The Takeaway

Some Food for Thought of IoT Opportunities

- Who are the customers in my active in the 4 key market segments

- Who are the tier-1s in my region? Who are on track to become tier 1?

- How can I influence the Product Owners?

- Which features excite the Product Owners? Precise Location? Radar? Data Comms?

- Can my customer productize with the DW3000/QM33 first?

- If not, what are the must have features on the QM3572x?

QOrVO.

Thank You