CEVA

CEVA TECHNOLOGY
SYMPOSIUM SERIES

12th YEAR

Next Gen. Connectivity for IoT: Wi-Fi 6 and Bluetooth 5.1 demystified

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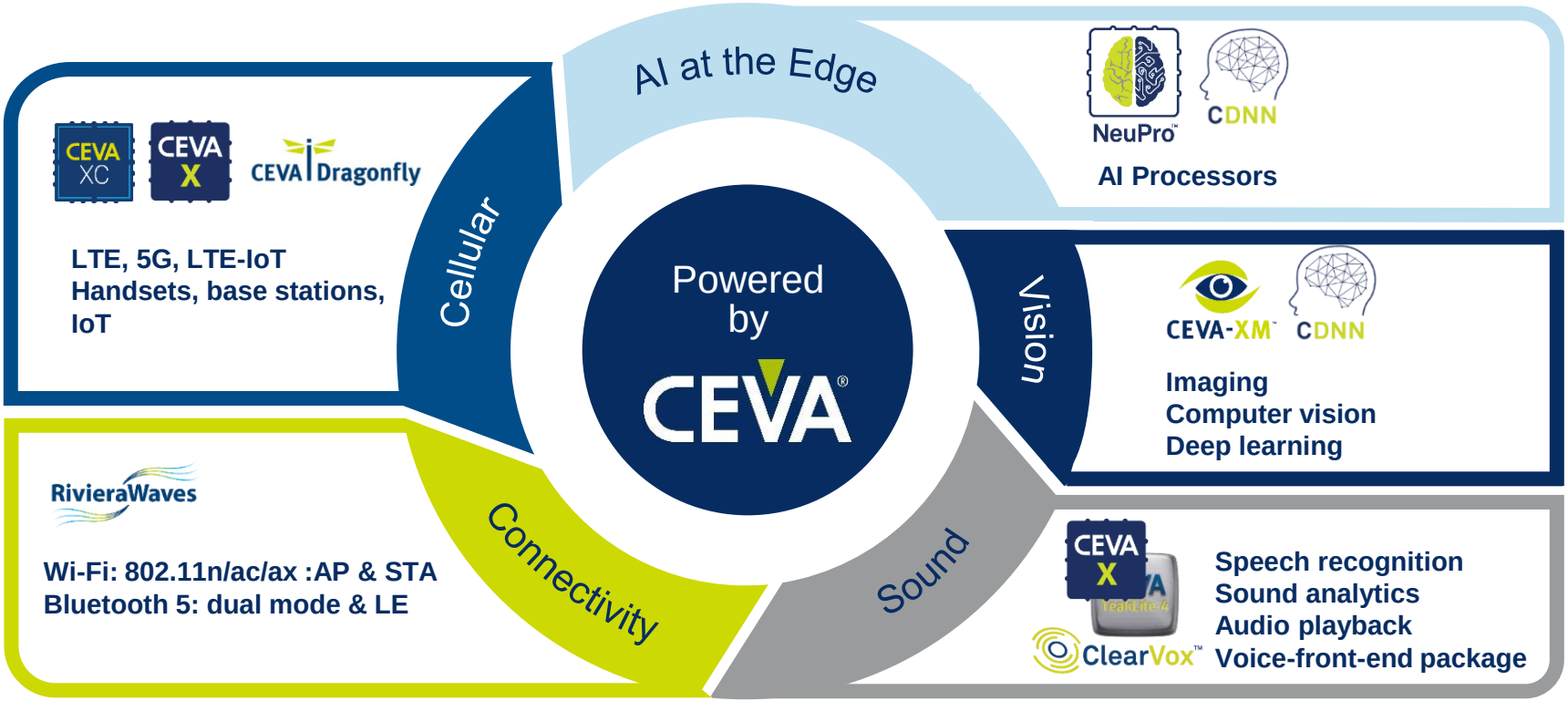
Director Connectivity BU, CEVA

Agenda

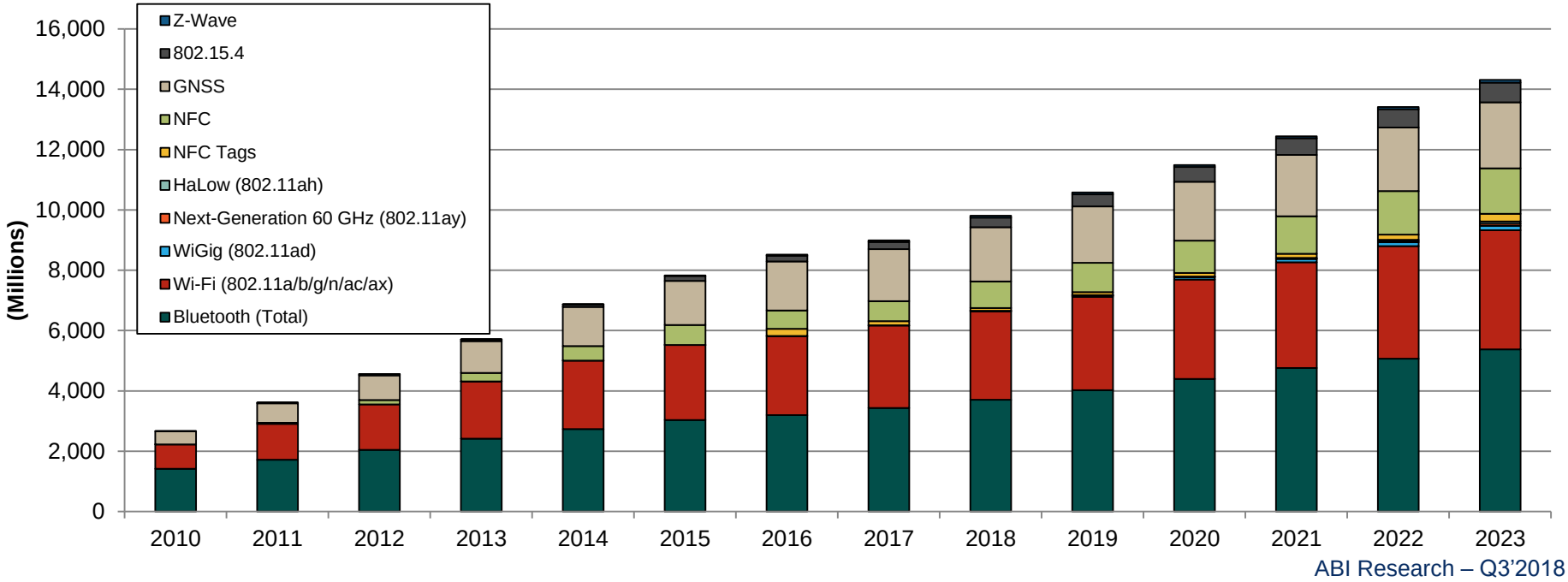
- Market data
- Wi-Fi 6 for IoT
- Bluetooth 5.1 for IoT

CEVA IP Portfolio



Complemented by Tool Chain, Algorithms, Libraries, HW accelerators & Neural Network Software Framework

Wireless Connectivity Shipment

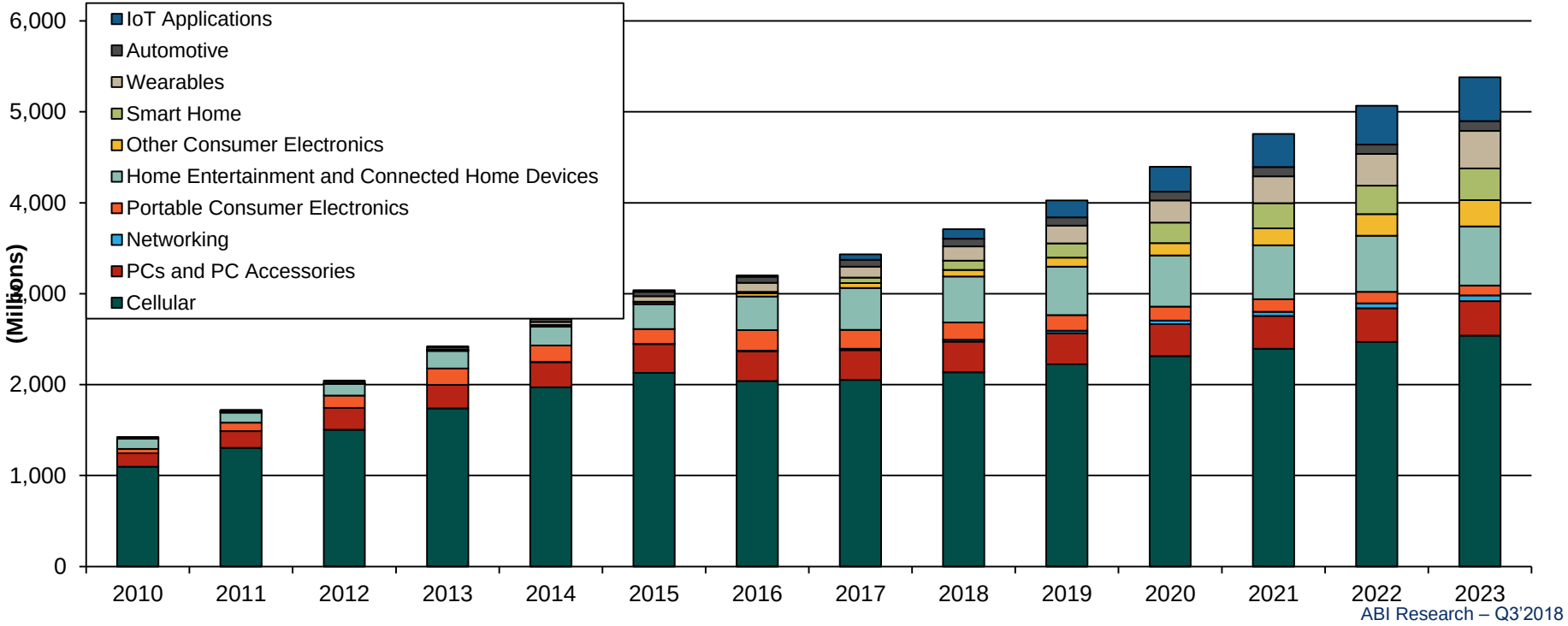


ABI Research – Q3'2018

BT is the most popular Wireless Technology

Wi-Fi is 2nd

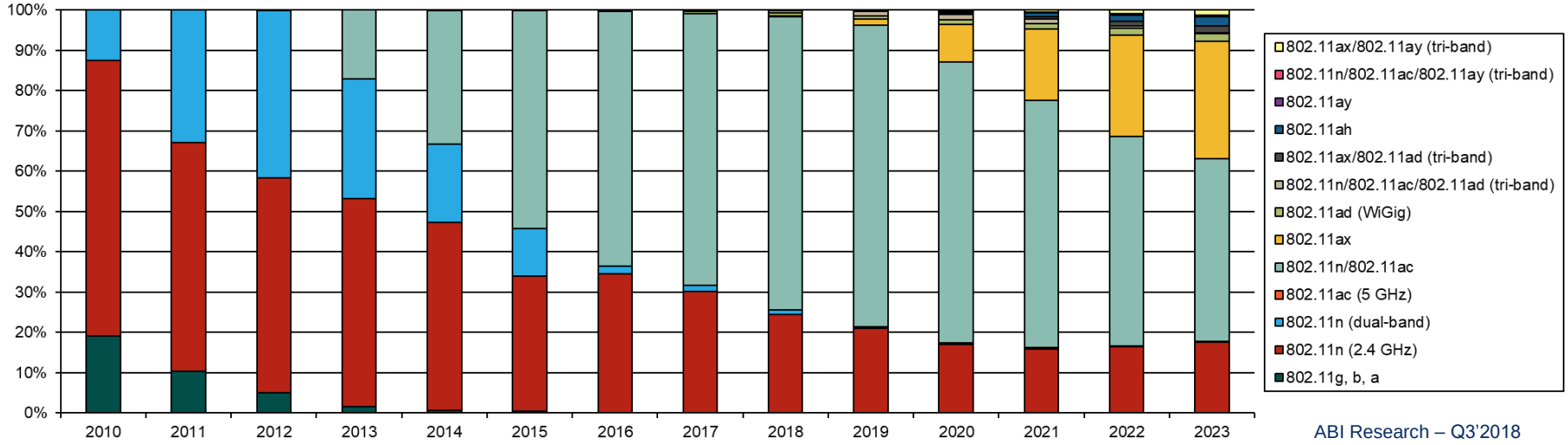
Bluetooth Devices shipment



ABI Research – Q3'2018

Cellular, Smart & Connected Home, wearable and IoT are the biggest market segments

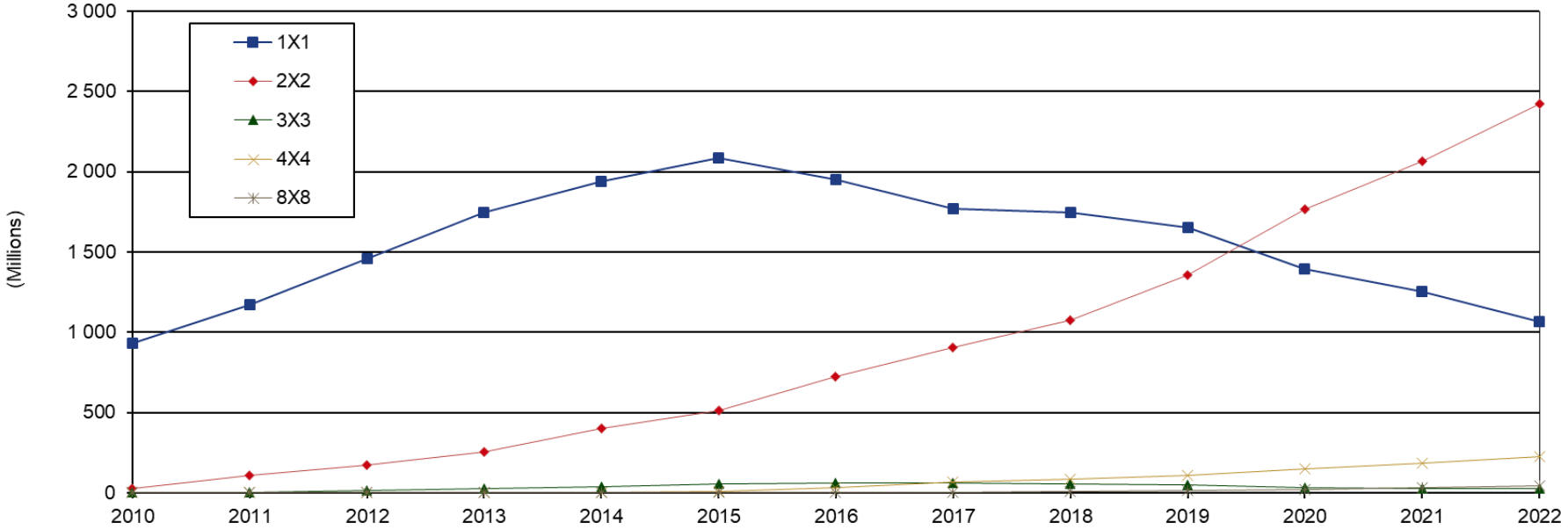
Wi-Fi chipsets shipment by protocol



ABI Research – Q3'2018

- 802.11ax replacing 802.11n & ac
- Still opportunities for 802.11n

Wi-Fi chipsets shipment by MIMO config



ABI Research – Q4'2018

MIMO 2x2 to exceed 1x1 by 2020

(Smartphone, tablet, PC, laptop)

Why Bluetooth and Wi-Fi are good for IoT?

	Bluetooth	Wi-Fi
Ubiquity	+++	+++
Connectivity to internet	+++ (through hub, e.g. smart phone, AP)	+++
Security	+++	+++
Robustness, Reliability	+++	+++
Low Power	+++	++ (11n, 11ax)
Range	+++ (BLE 5 long range)	+++ (11ax long range)
Mesh	+++	++
Localization	+++ (BLE 5.1 AoA/AoD)	++
Dense environment	++	+++ (11ax)
Data rate	+	+++

Agenda

- Market data
- Wi-Fi 6 for IoT
- Bluetooth 5.1 for IoT

New naming approach by Wi-Fi Alliance

- Easy identification of Wi-Fi generations
  - Wi-Fi 6: 802.11ax (mid 2019)
  - Wi-Fi 5: 802.11ac
  - Wi-Fi 4: 802.11n
  - Wi-Fi 1-3: 802.11a/b/g

Wi Fi 6™
CERTIFIED
(not yet official)

- Easy identification of type of connection on devices

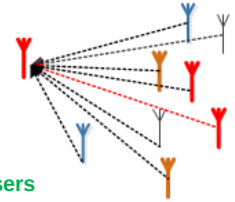
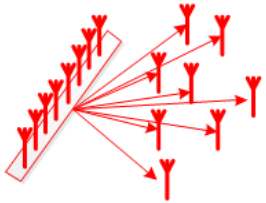
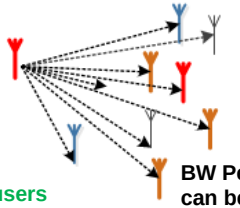
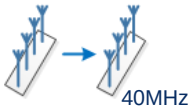
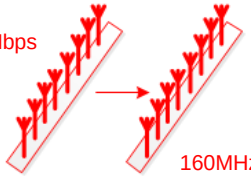
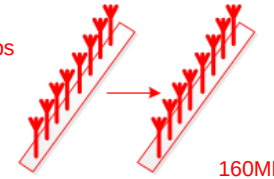
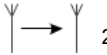
The Evolution of Wi-Fi up to 802.11ax

Wi-Fi 6 (11ax) benefits:

- **Better efficiency in crowded environments**
  4X better throughput per user when competing for bandwidth
- **Higher peak data rates**
  25% faster than the today's leading 11ac standard
- **Backward compatible**
  Coexist with older networks, accelerate as they upgrade
- **More power-efficient**
  Extends battery life in user devices

Wi-Fi Alliance new naming → Wi-Fi 1-3 | Wi-Fi 4 | Wi-Fi 5 | Wi-Fi 6

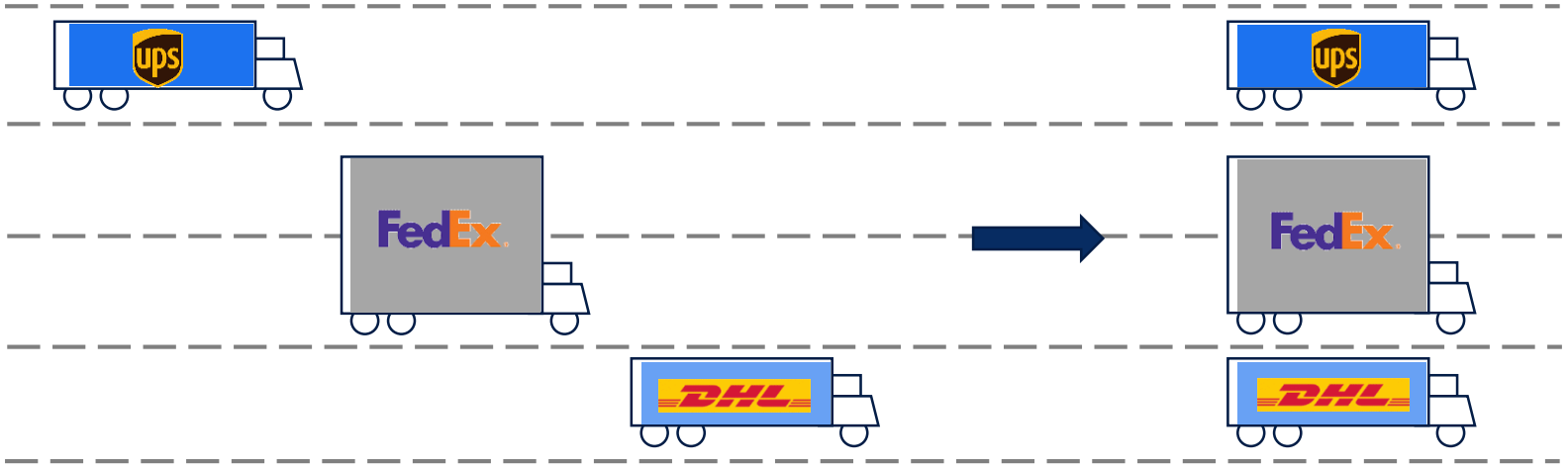
Wi-Fi Standard Evolution at a Glance

Standard	11abg	11n	11ac	11ax
Uplink Capabilities				 1x1: Up to **74 users** 8x8: Up to **296 users**
Downlink Capabilities			 Up to **8 users**	 1x1: Up to **74 users** 8x8: Up to **296 users** **BW Per User can be <20MHz** **➔ Allow MU with 1x1**
Max throughput configuration		600Mbps  40MHz	6933Mbps  160MHz	9607Mbps  160MHz
Minimal configuration	 20MHz	 20MHz	 80MHz	 20MHz

Wi-Fi 6 / 802.11ax: High Efficiency Wi-Fi

- Backward compatible with 802.11a/b/g/n/ac
- Dual band 2.4/5GHz
- Increase 4X the average throughput per user in high density user environments
  - E.g. airports, stadiums, …
- Data rate 25% faster thanks to 1024QAM
- Downlink and uplink multi-user MIMO (MU-MIMO)
  - Up to 8 STAs can transmit to the AP simultaneously on different spatial streams
- Bandwidth sharing thanks to Orthogonal Frequency Division Multiple Access (OFDMA)
  - Up to 37 simultaneous users per 80MHz channel, per spatial stream

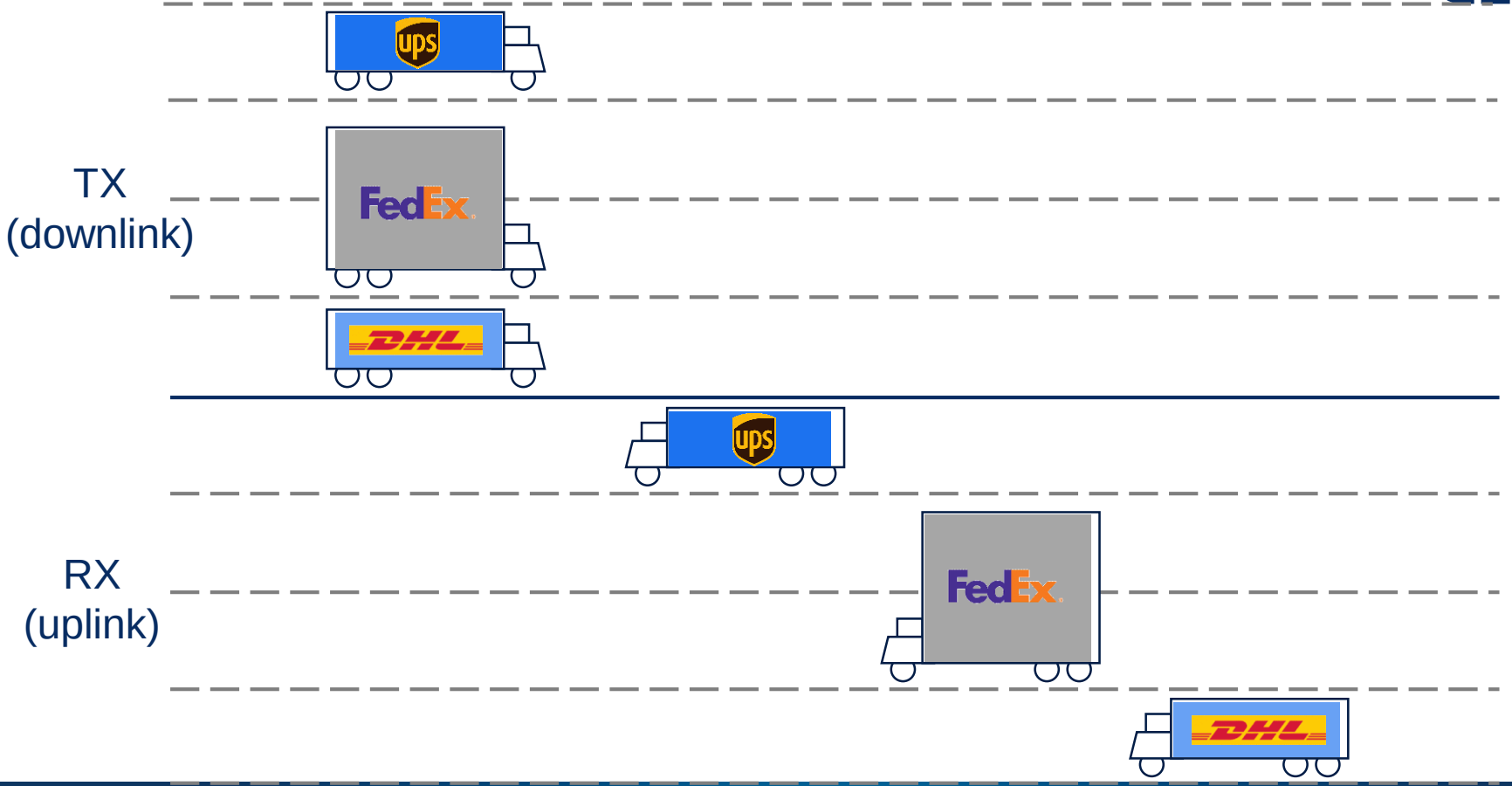
MU-MIMO for better efficiency



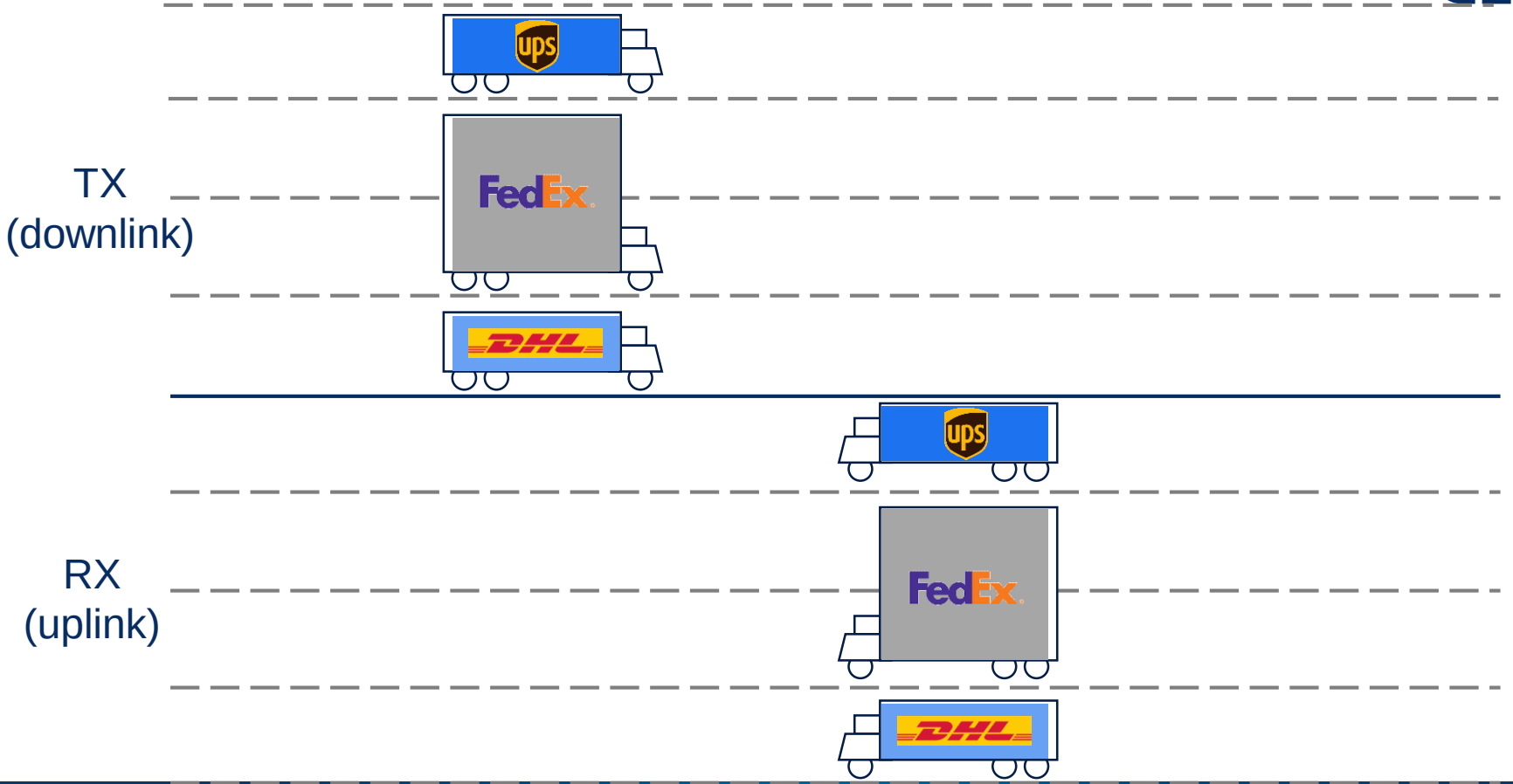
MIMO
(802.11n - Wi-Fi 4)

MU-MIMO
(802.11ac/ax – Wi-Fi 5 / 6)

802.11ac Wave 2 MU-MIMO

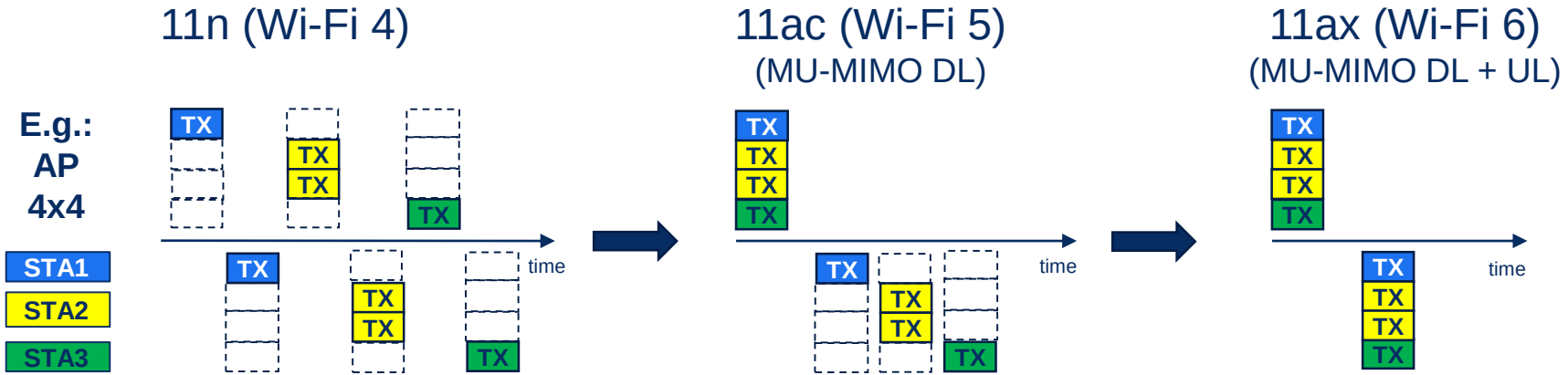


802.11ax MU-MIMO



MU-MIMO for better network efficiency

- Downlink and uplink multi-user MIMO (MU-MIMO)
  - Up to 8 STAs can transmit to the AP simultaneously on different spatial streams



Loss of network bandwidth (unused spatial stream)

OFDMA for better efficiency

- 802.11n/ac (OFDM): a mail delivery truck servicing just one customer at a time…
- 802.11ax (OFDMA): a mail delivery truck servicing several customers

ASUS RT-AX88U router

OFDMA for better efficiency

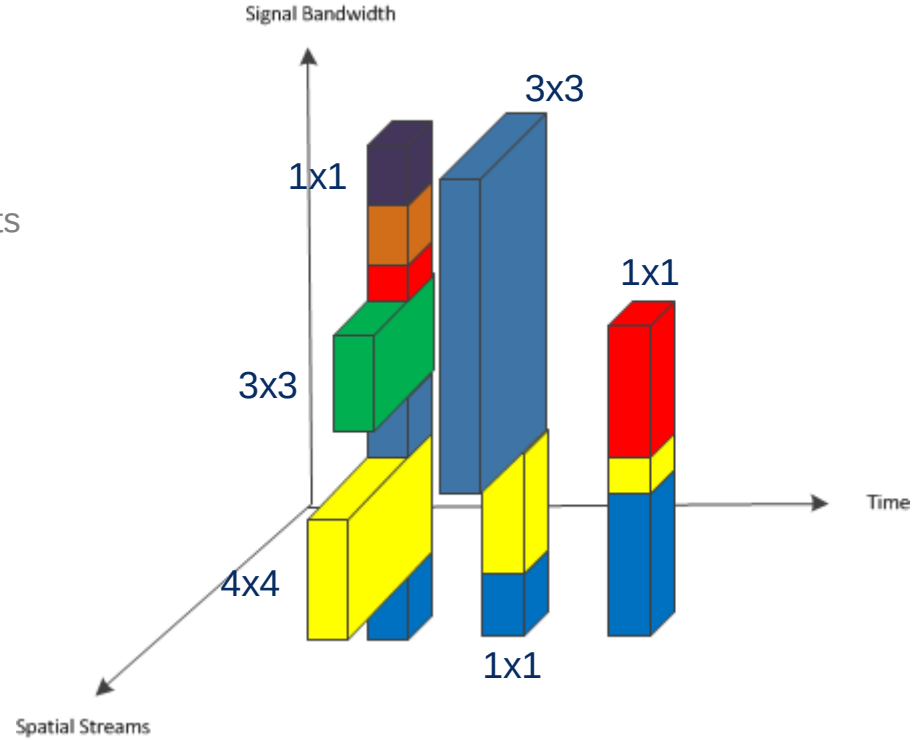
- 802.11n/ac (OFDM): a mail delivery truck servicing just one customer at a time…
- 802.11ax (OFDMA): a mail delivery truck servicing several customers

OFDM (11n/ac) - Wi-Fi 4/5

OFDMA (11ax) - Wi-Fi 6

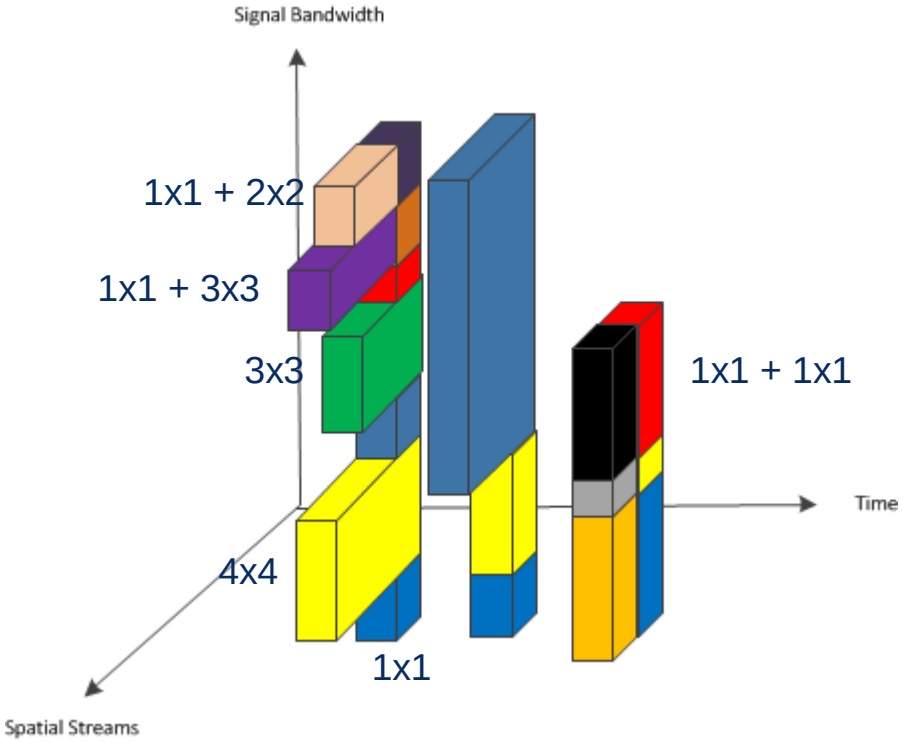
OFDMA: Additional Efficiency

- Share of bandwidth within one (SISO) or several (MIMO) spatial streams
- OFDMA 11ax DownLink:
  - AP transmits to several STA simultaneously
  - The 80MHz band is divided into several Resource Units (RU) associated to STAs
  - Each STA get a share of the 80MHz band
    - E.g. red STA gets 1 RU, yellow STA 4 RU, etc…
- OFDMA 11ax Uplink:
  - Symmetrical to OFDMA 11ax DL
  - AP receives RUs from several STAs at the same time, i.e. all STA transmit simultaneously to the AP at the same time slot



MU-MIMO OFDMA

- MU-MIMO OFDMA 11ax DownLink & UpLink is a mix of:
  - Spatial Multi-User (similar to 11ac)
  - Resource Unit (RU) Multi-User



802.11ax: optimized for low power IoT

- Profile defined for 20MHz-only STA
  - low power
- 2MHz Channels thanks to OFDMA
  - better coexistence with Bluetooth and 802.15.4, lower data rate, longer battery life
- Improved traffic flow, channel access and power management
  - E.g. TWT (Target Wake Time)
- Long range mode (slow data rate)
  - Good for smart building, smart metering
- Do not impact network efficiency
  - unlike low power 11n devices

802.11ax to replace 802.11n & 11ah for low power IoT

RW Wi-Fi Solutions

Wi-Fi High Performance

802.11n 2x2, 802.11ac, ax 1x1 / 2x2

Low power and full performance solutions
- MAC HW + FullMAC SW
- HW Modem for lowest size and power

Wi-Fi Low Power

802.11n, ax (STA 20/40MHz) 1x1

Lowest power and lowest die cost solutions
- MAC HW + FullMAC SW
- Modem: HW for lowest size and power, or CEVA-XC5 based SDM for highest flexibility (11n 20MHz only)

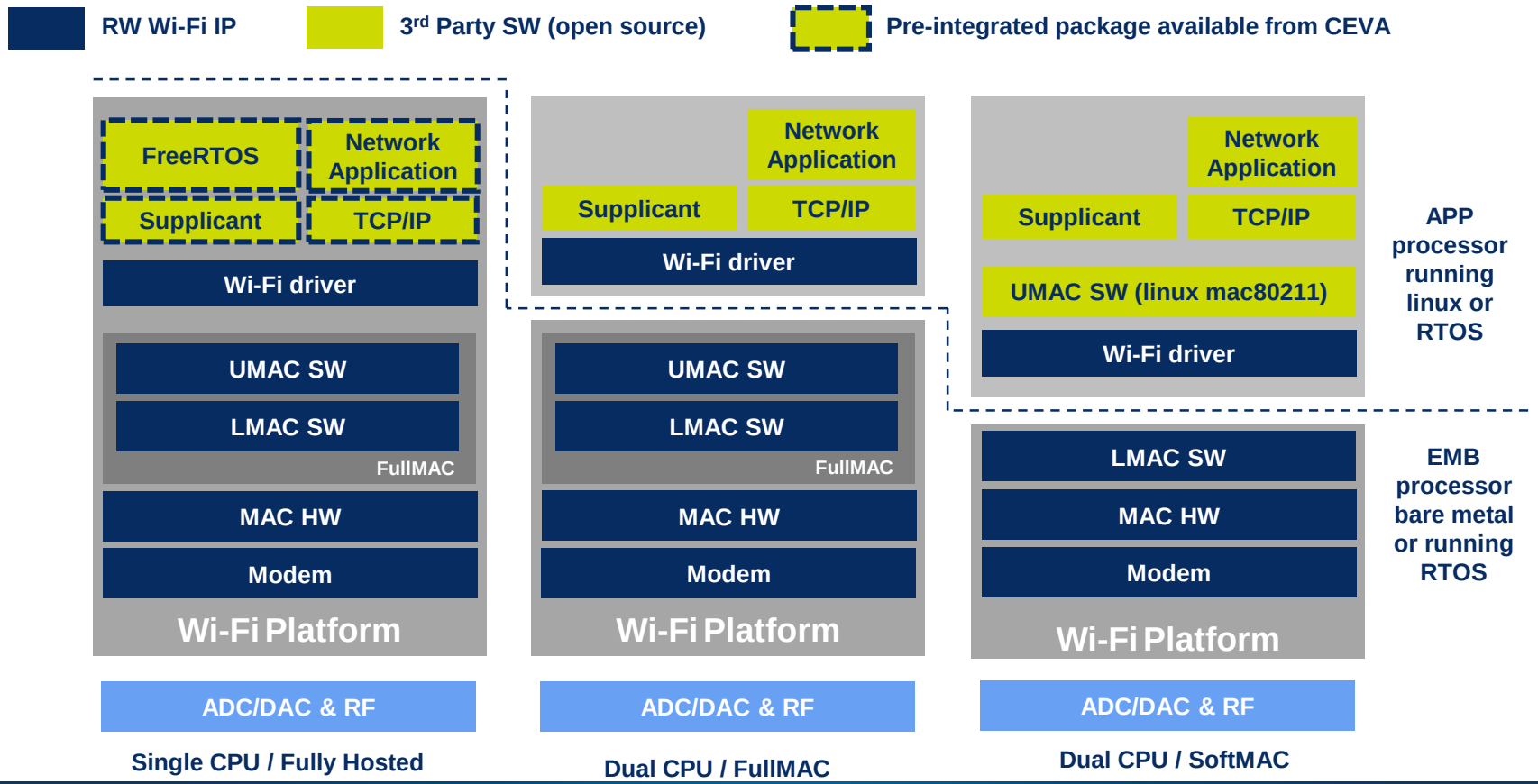
RivieraWaves

Wi-Fi Multi-Gig

802.11ac, ax 4x4

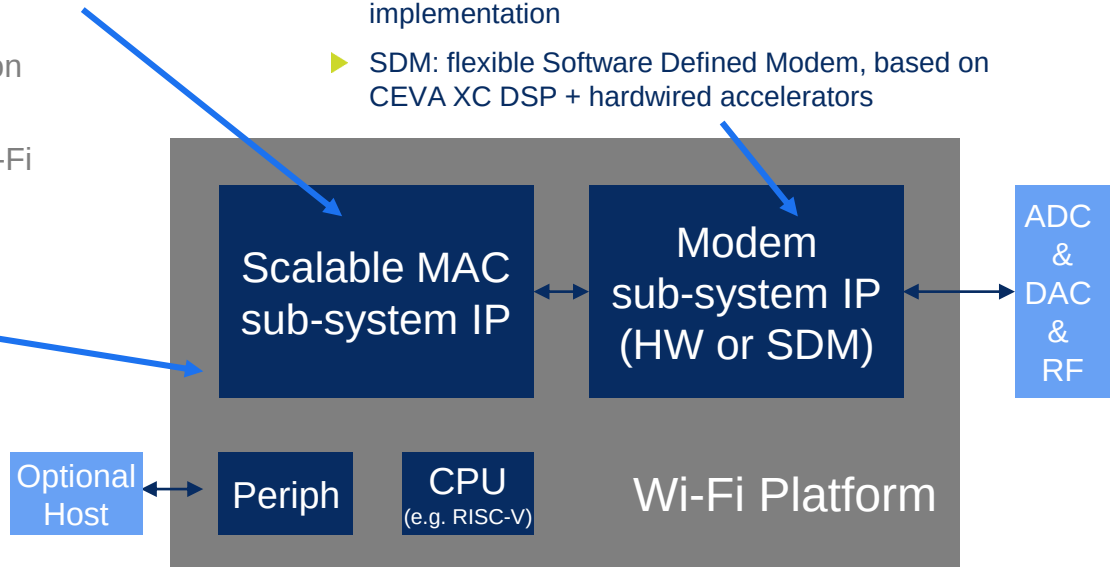
Highest throughput solutions up to 2.4Gbps
- MAC HW + FullMAC SW
- CEVA-XC based SDM for highest flexibility

RW Wi-Fi HW+SW Architecture



RW Wi-Fi IP Platforms

- **A single scalable MAC HW core with software protocol stacks**
  - LMAC or FullMAC (LMAC+UMAC) or Fully Hosted
  - Low power, scalable clock frequency & memory requirement
  - Software with low MIPS requirement running on any 32-bit CPU
  - When CEVA-DSP used, it can execute the Wi-Fi software stack as well as other things such as always on, audio or sensor processing
- **Fully integrated turnkey platform**
  - Low power and scalable
  - Peripherals, bus system and memory interfaces
  - 32-bit CPU agnostic
  - Can be provided with embedded RISC-V processor
- **Selection of optimized modems**
  - **For each Wi-Fi version / configuration**
  - **2 flavors available:**
    - HW MDM: low power and low gate count hardwired implementation
    - SDM: flexible Software Defined Modem, based on CEVA XC DSP + hardwired accelerators



Agenda

- Market data
- Wi-Fi 6 for IoT
- Bluetooth 5.1 for IoT

Bluetooth 5 – The Latest Generation

- Bluetooth 5 ratified on December 6th, 2016, bringing:
  - LE 2Mbps data rate
  - LE Long range
  - LE Advertising Extension
  - LE Channel Selection #2
  - LE High duty cycle Non-Connectable Advertising
  - BR/EDR Slot Availability Mask (coexistence with LTE)
- RivieraWaves BLE5 & BTDM5 IPs available (already licensed many times)
  - Strong market demand
  - Bluetooth 5 qualified devices already hitting the market, e.g. OnSemi RSL10
    - https://www.design-reuse.com/news/41510/ceva-bluetooth-5-low-energy-ip-on-semiconductor-radio-soc.html

Madrid Release (Bluetooth 5.1)

- Code named Madrid release, may be ratified in Jan 2019
- Madrid Release does not include audio over BLE (part of Milan release, Q4'19)

Major Madrid features

- **Direction Finding - AoA/AoD (HW impact)**
  - Accurate Indoor localization and Asset Tracking
- **Advertising Channel Index Changes**
  - Improvement for Bluetooth MESH
- **GATT caching**
  - Reduce packet exchange, improve power consumption

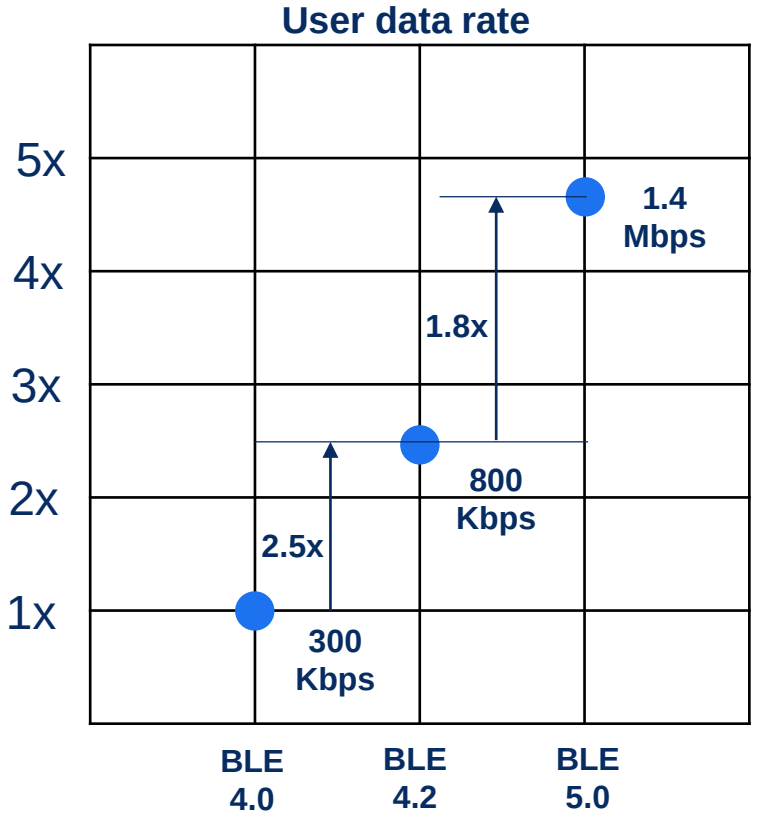
Minor Madrid features

- **Minor Functional Enhancements #1**
  - Mandatory feature. Errata on previous generation
- **Periodic Adv Sync Transfer**
  - A device can get parameters of a broadcasting source without connecting to this source. Needed for future ISO
- **Control Length Extension**
  - Extension of control packets length. Needed for future ISO

Madrid release is for smart home / smart building

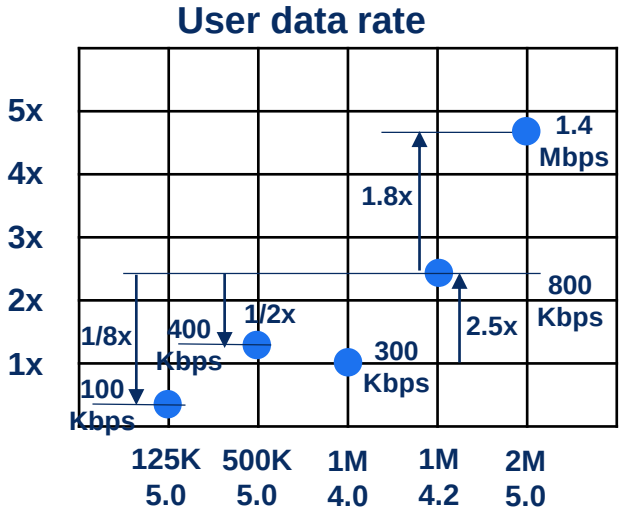
BLE5: double the speed

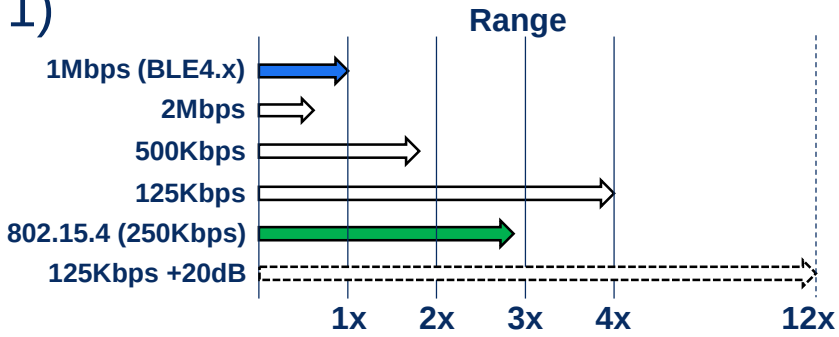
- 1Mbps → 2Mbps GFSK modulation
- 2x Data Transfer without increase of power consumption
- Same data transfer in half the time so half the power consumption
- Shorter packets over the air → more devices sharing the medium



BLE5: quadruple the range, at least

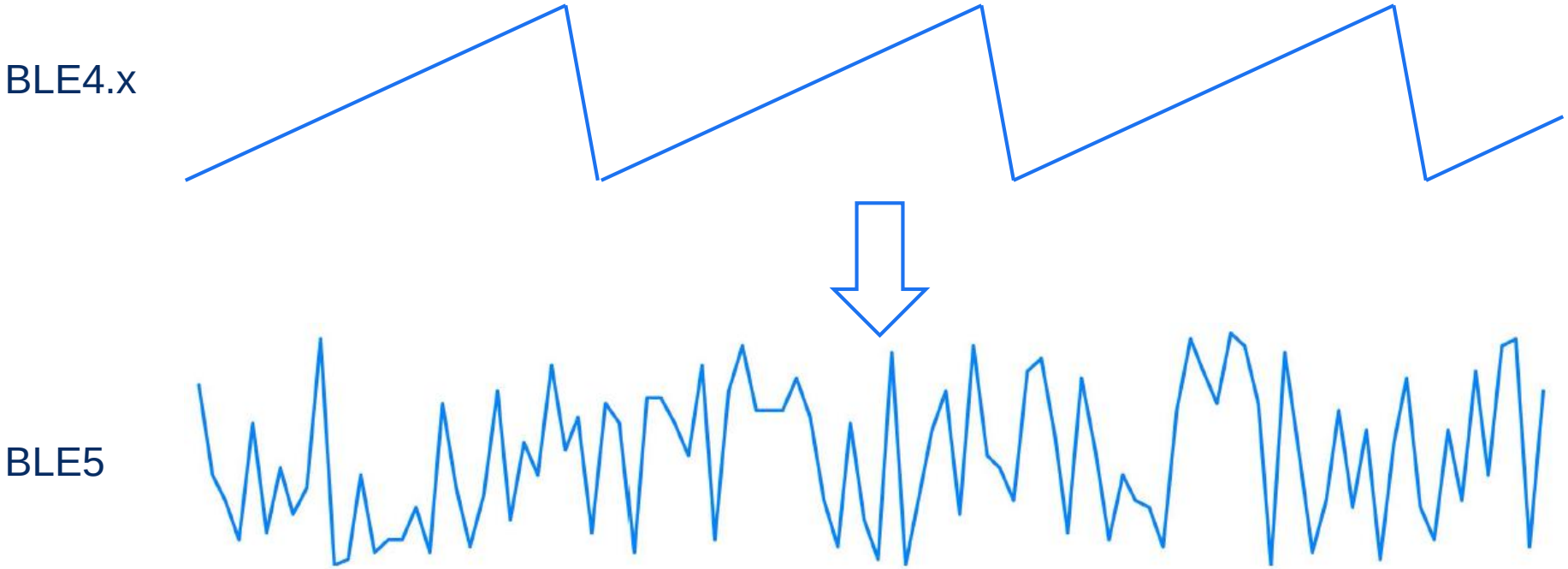
- BLE4.x is PAN, with a few 10 meters range with max +10dB output power (class 1.5)
- BLE5 is 4 times longer range without power increase but slower data rate
  - 3dB better than 802.15.4
- BLE5 allows +20dB output power (class 1)
  - 12 X longer range than BLE4.x
- Can reach 1 km range!





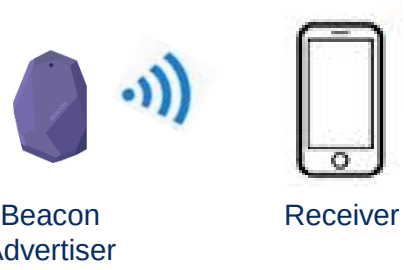
BLE5: Better frequency hopping

- Better usage of the 40 channels, in a pseudo random way
  - More robust, lower risk of collision



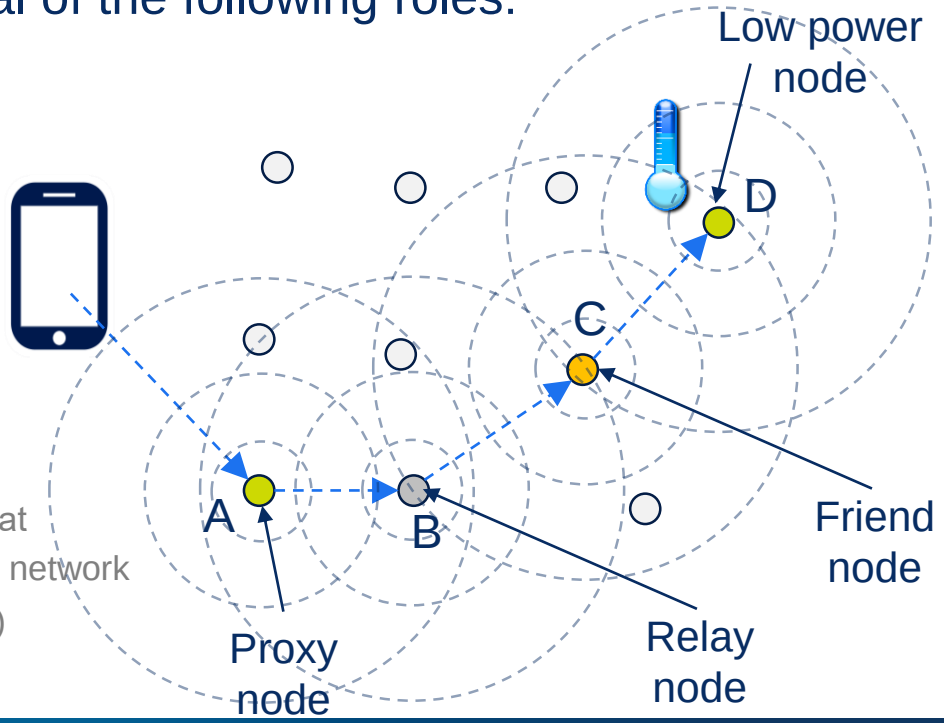
BLE5: 800% increase data advertising

- In BLE there are 40 channels
  - 3 for advertising, 37 for data
- In BLE4.x the advertising / beaconing is done on the 3 advertising channels
  - These channels can become highly congested in case of crowded environment or when a lot of data needs to be advertised
- BLE5 solve this issue by offloading the 3 advertising channels and use the 37 data channels



Bluetooth Mesh

- Bluetooth mesh use Advertising (broadcasting) methodology
- Mesh Nodes can have one or several of the following roles:
  - Relay Node
    - Retransmit received message
  - Low Power Node (LPN)
    - Low duty cycle to conserve energy
    - On wake up, poll Friend node
  - Friend Node
    - Stores messages addressed to LPN
    - Delivers the message when polled by LPN
  - Proxy Node (optional)
    - Enables “old” BLE devices (e.g. smartphone) that do not support Advertising to interact with mesh network
    - Expose both Adv and GATT interfaces (bearers)



BLE5.1: Direction Finding / extension of beacon capability

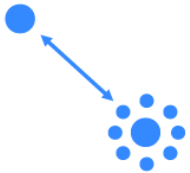
Connectionless AoD

- Accurate indoor positioning
- Fixed transmitters broadcast AoD signals (through array of antennas) and mobile devices (single antenna) receive the signals, measure and calculate their own positions
- Used by Indoor Positioning profile

Connection Oriented AoA

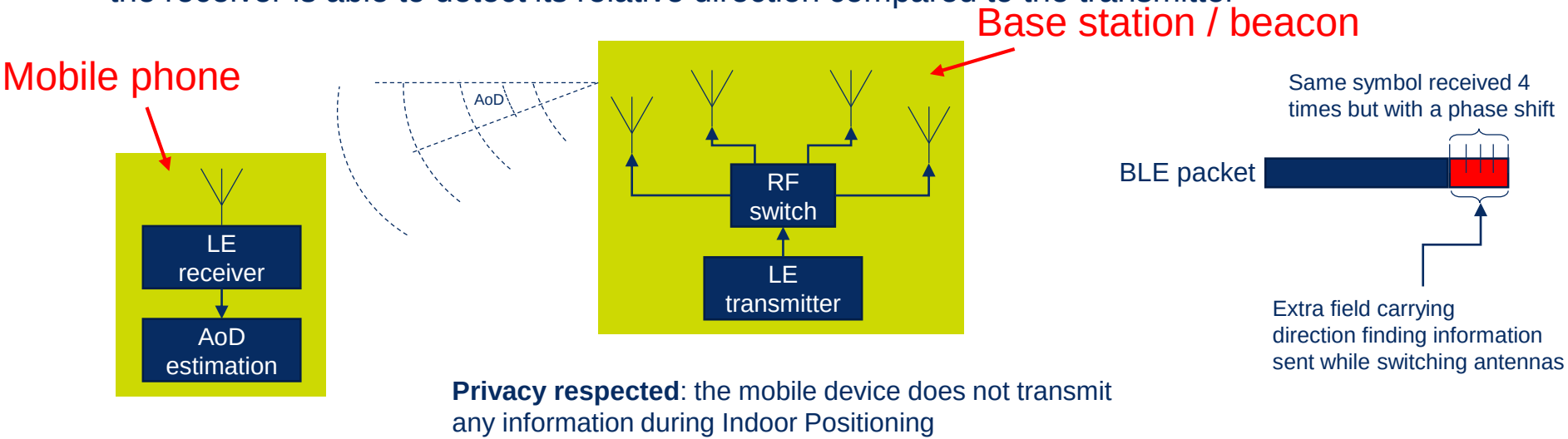
- Accurate asset tracking purposes
  - Asset Tracking using infrastructure networks
  - Direction Tracking of Personal Assets
  - Continuous Direction Tracking of Users
  - Configuring Asset Tags
- Used by Asset Tracking profile

< 1m accuracy



AoD principles (connectionless)

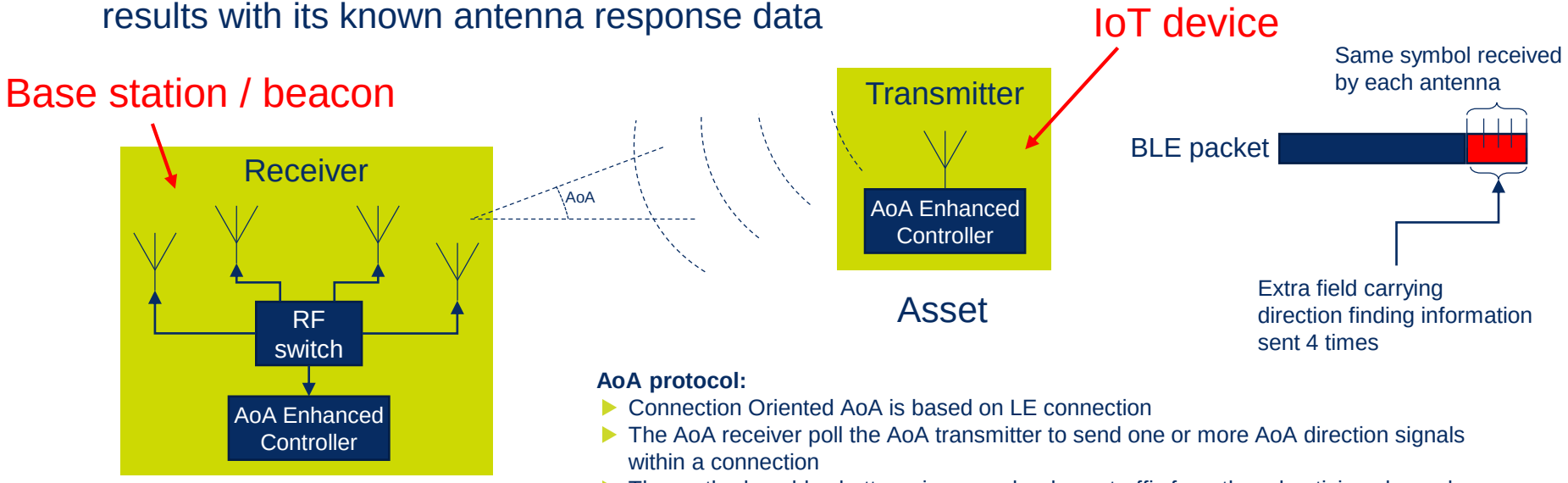
- The AoD transmitter has an antenna array. The transmitter sends particular signals while switching its antenna elements in a sequence
- The receiver (with a single antenna) measures the signals sent from each antenna element, and compares the results with the known antenna response data of the transmitter. Therefore, the receiver is able to detect its relative direction compared to the transmitter



Privacy respected: the mobile device does not transmit any information during Indoor Positioning

AoA principles (connected mode)

- The single antenna AoA transmitter sends particular LE signals
- The AoA receiver has an antenna array. The receiver switches its antenna elements in a sequence during the reception. The receiver measures the signals from each antenna element and is able to detect the relative direction of the transmitter by comparing the results with its known antenna response data

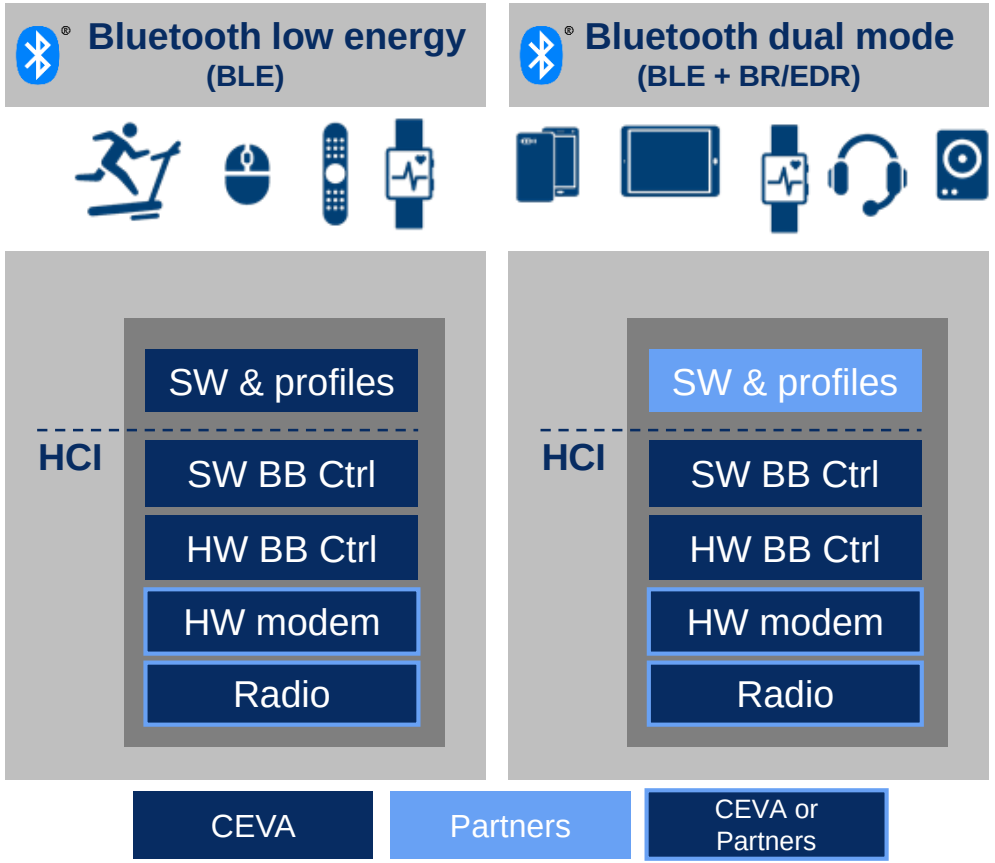


AoA protocol:

- Connection Oriented AoA is based on LE connection
- The AoA receiver poll the AoA transmitter to send one or more AoA direction signals within a connection
- The method enables better privacy and reduces traffic from the advertising channels

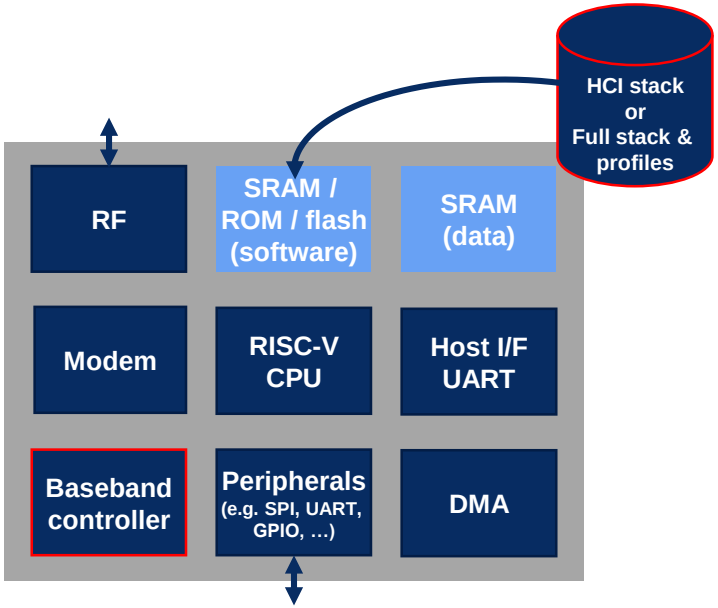
RW Bluetooth offering

- Unique and comprehensive offering for both Bluetooth low energy and Bluetooth dual mode:
  - Baseband controller
  - Software protocol stack
  - Modem
  - Radio
  - Integrated platform with embedded RISC-V processor
- Full BLE software stack with a comprehensive list of profiles
  - Including mesh and audio over BLE
- HCI BTDM software, interoperable with 3rd party BTDM host stack and profiles from:
  - BlueDroid: Android / Wear / Things
  - BlueZ: linux
  - IVT
  - OpenSynergy
  - A&W
  - Tempow



BlueGrip: Bluetooth RISC-V based platform

- Integrated platform available for both Bluetooth low energy and Bluetooth dual mode composed of
  - AHB bus system
  - peripherals (SPI, UART, GPIO, timers, interrupt controller, …)
  - memory interfaces
  - Embedded 32-bit RISC-V processor
- Comprehensive solution to
  - Speed up SoC design
  - Reduce development and production cost
  - Reduce time to market
- No need to license 3rd party commercial processor



Takeaways

- Wi-Fi 6 (802.11ax) benefits for IoT
  - Higher efficiency (4x) in dense environment
  - No network impact
  - Long range
  - Low power
- Bluetooth 5.1 benefits for IoT
  - Low power
  - Long range
  - Mesh
  - Accurate indoor localization and asset tracking

Thank You

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