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WF-102

Wireless Coexistence
(Wi-Fi, Bluetooth, 802.15.4)

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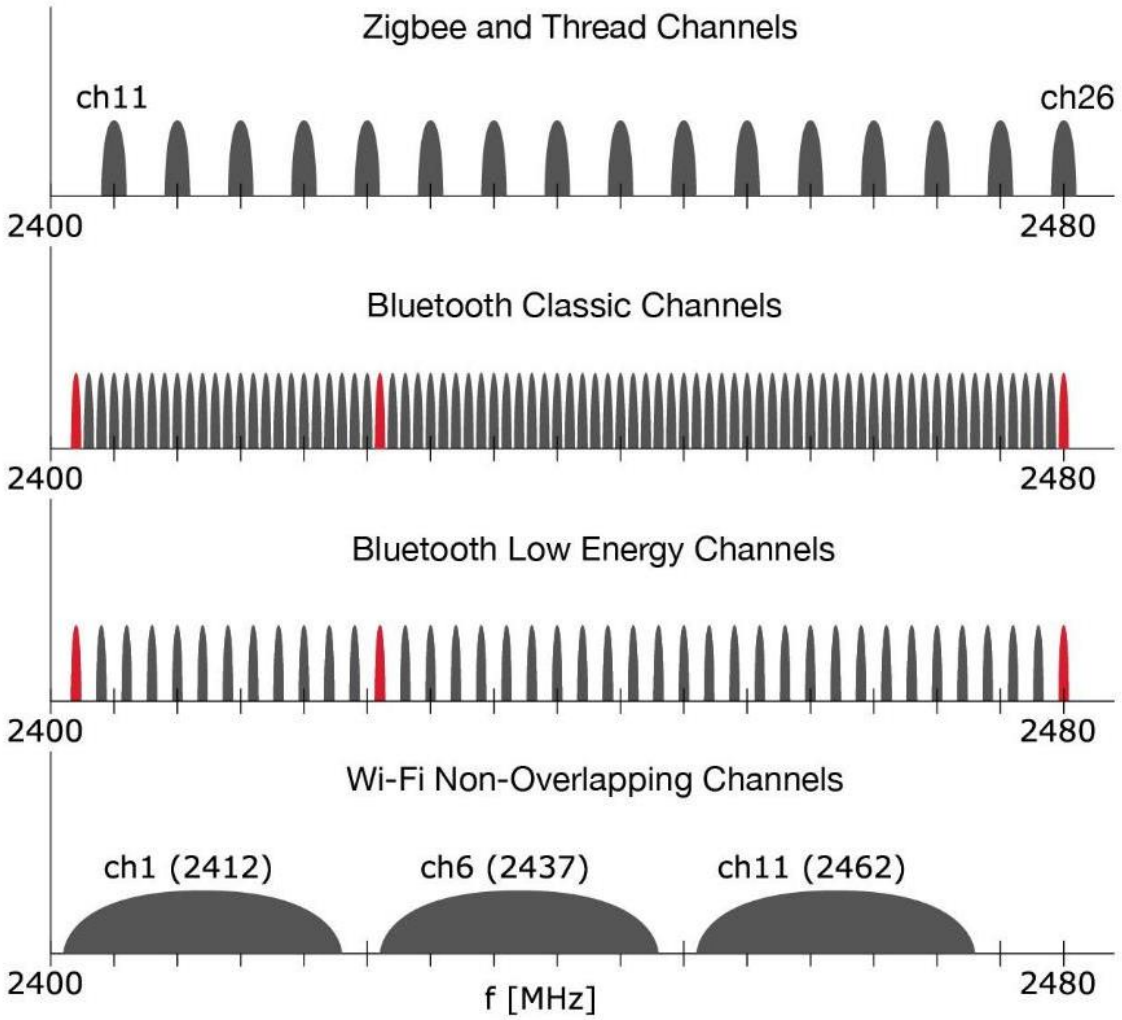
Wireless Coexistence

(Wi-Fi, Bluetooth, 802.15.4)

IoT – Challenges of Wirelessly Connecting Everything

- **Historically wired "devices just worked"**
- **Today everything is connected wirelessly**
- **Wireless space is evolving:**
  - Many devices co-located within radio range
  - High resolution video streaming is the norm
  - Devices are integrating multiple protocols
  - Transmit powers are increasing
  - Many devices using 2.4GHz ISM band
- **People still expect things to work!!!**

Why is there a challenge in the 2.4GHz ISM Band?



- **Multiple wireless protocols share the same 2.4GHz ISM Band: Wi-Fi, Bluetooth, and IEEE 802.15.4 (ZigBee, Thread)**
- **These wireless protocols have different modulation schemes, channel frequencies and bandwidth but overlap when co-located**
- **Signals from one wireless protocol look like unwanted noise for the other protocols**
- **If the desired receive signal is weaker than the noise, the radio will be unable to properly receive messages**

Wireless Coexistence Issues Impact to IoT Devices

END DEVICE / SLEEPY DEVICE

Delayed or missing packets

High rate of retries

Reduced battery life

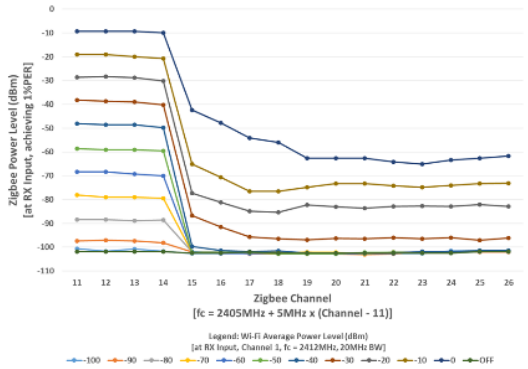
GATEWAY / BORDER ROUTER

Missing devices events

Poor commands responsiveness

Dropped connections

Coexistence and Multiprotocol Concepts



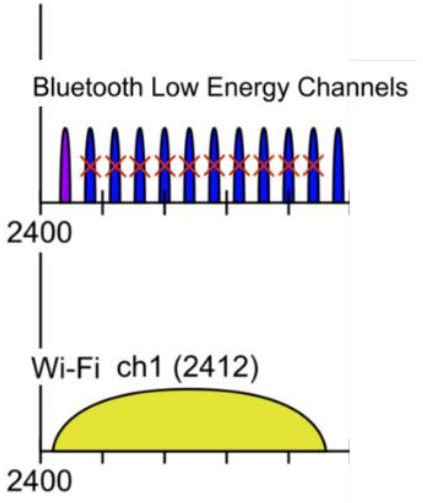
UNMANAGED COEX

Customized run-time radio performance:

Blocking & Selectivity

Adjacent channel rejection

Enhanced MAC features



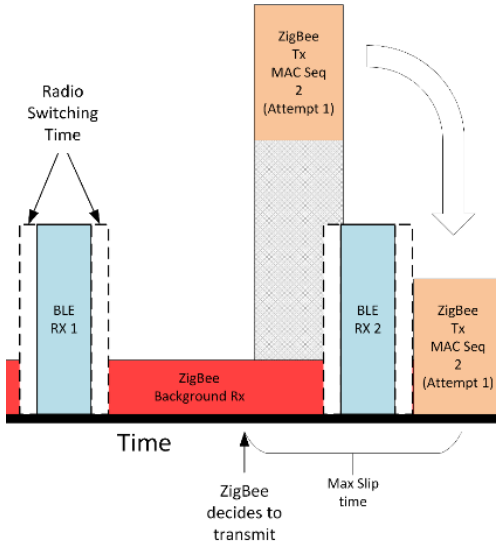
FREQUENCY PLANNING

Bands Planning

Channels Planning

Channel Agility

Frequency Hopping



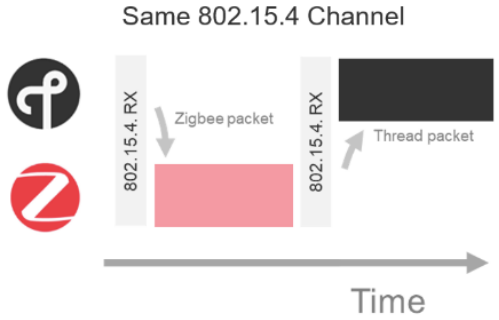
TIME SLICING

Dynamic Multiprotocol

Concurrent Scanning

Selective RX Diversity

Packet Traffic Arbitration



CONCURRENCY

Concurrent Multiprotocol

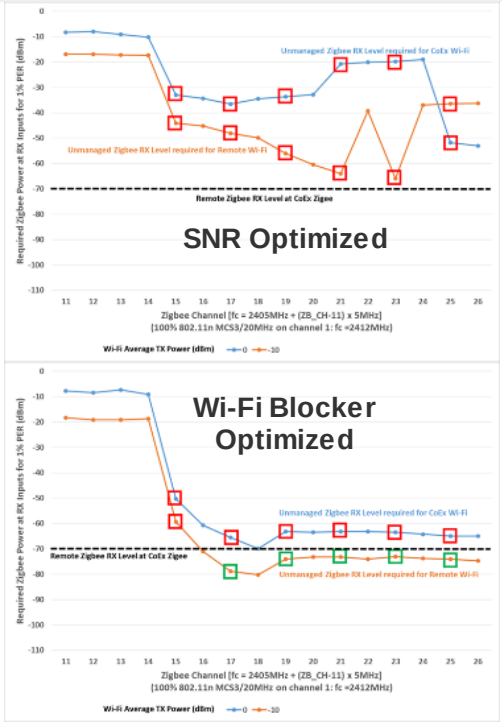
Multi-chip solutions

*** Multi-RF & Multi-Radio**

*** MIMO RX Diversity**

* Not available today, investigating for future products

Unmanaged Coexistence



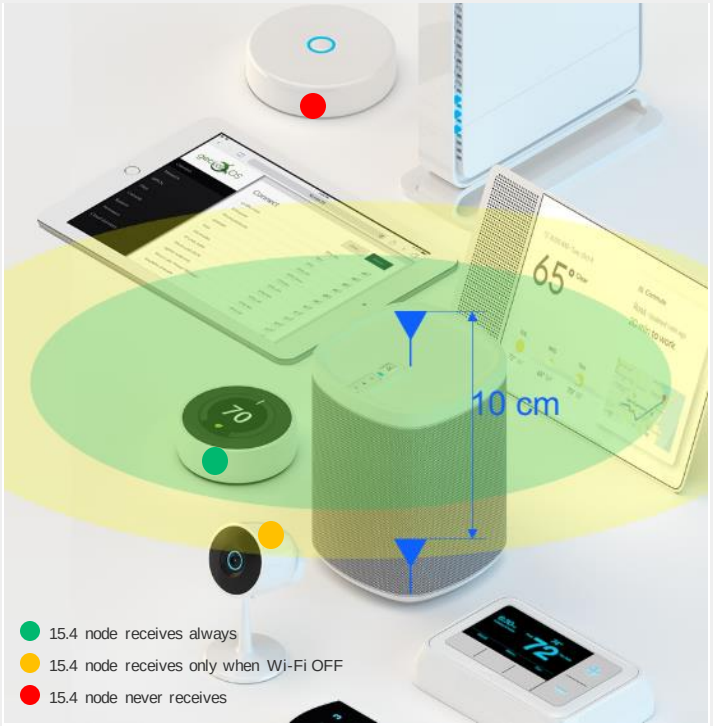
BLOCKING & SELECTIVITY

Identify Wi-Fi interferences w/ RSSI

Detect 15.4 traffic with Signal Identifier

Select SNR PHY vs BLK at run-time

HW Peak Detectors and AGC loops to manage baseband signal distortion

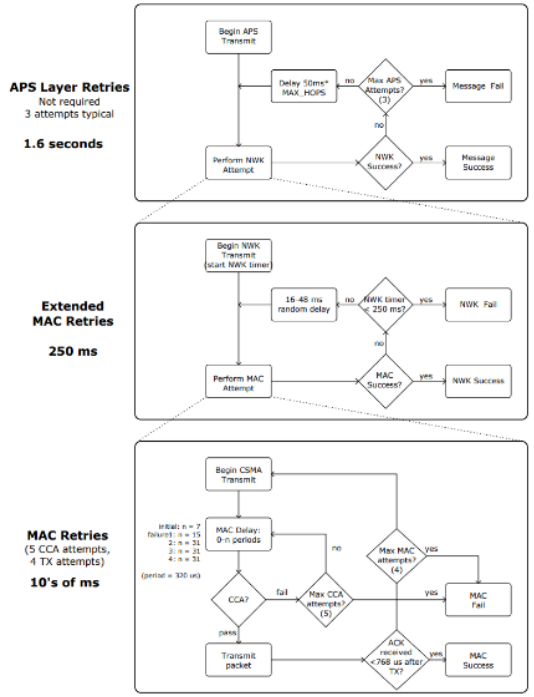


ADJACENT CHANNEL REJECTION

Receive 15.4 traffic up to -45dBm Wi-Fi RSSI on non-overlapping channels

Operate FEM LNAs in bypass mode

Increase antenna isolation for GWs



ENHANCED MAC FEATURES

Extended MAC retries algorithm

Configurable CCA thresholds

Configurable CCA timeouts

Frequency Planning

METHODOLOGY

Bands Planning

- Connect high Wi-Fi traffic devices on 5GHz bands
- Have life critical systems and long-range devices on <1GHz bands

Channel Planning

- Configure 15.4 on further away non-overlapping Wi-Fi Channels
- Operate Wi-Fi with 20MHz Bandwidth

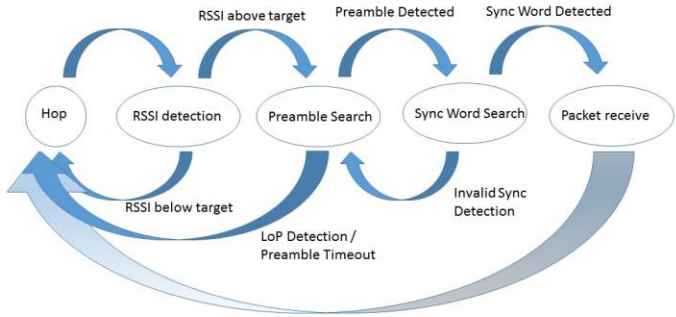
Channel Agility

- Protocols detect interferences and change channel for entire network

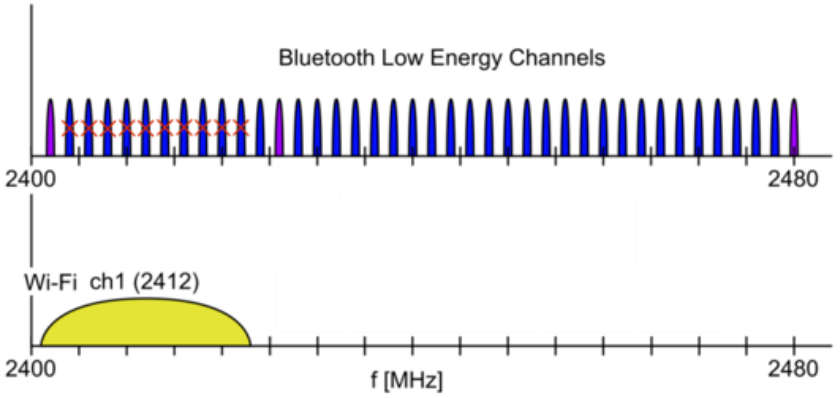
Frequency Hopping

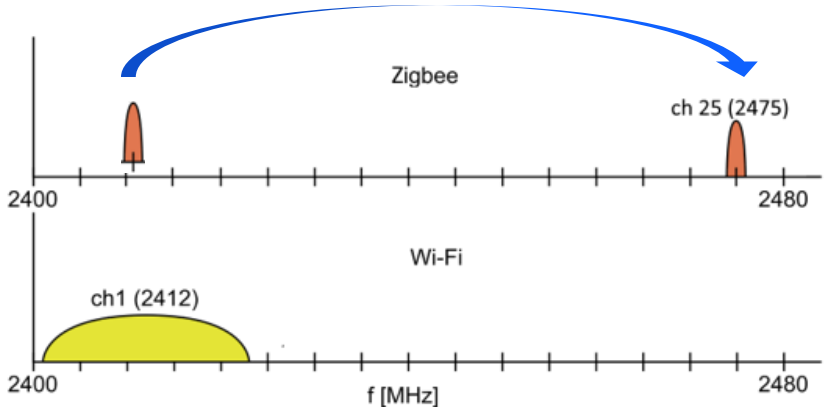
- Protocols constantly change channels based on predefined patterns

CHANNEL AGILITY



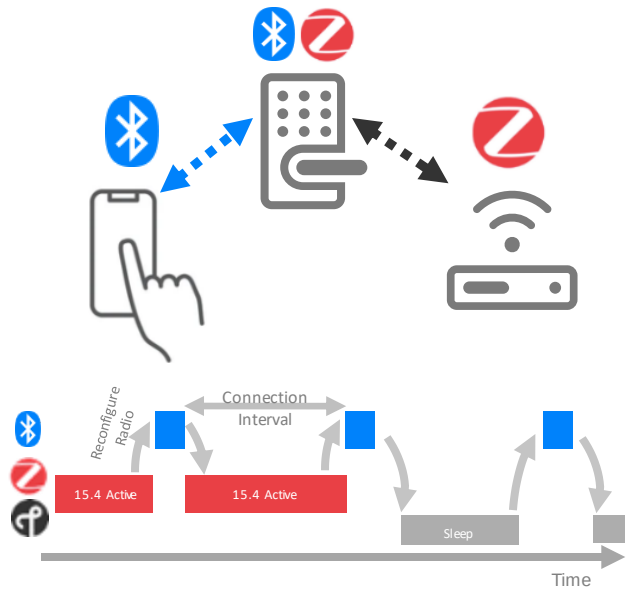
FREQUENCY HOPPING





Bands and Channels Planning

Time Slicing

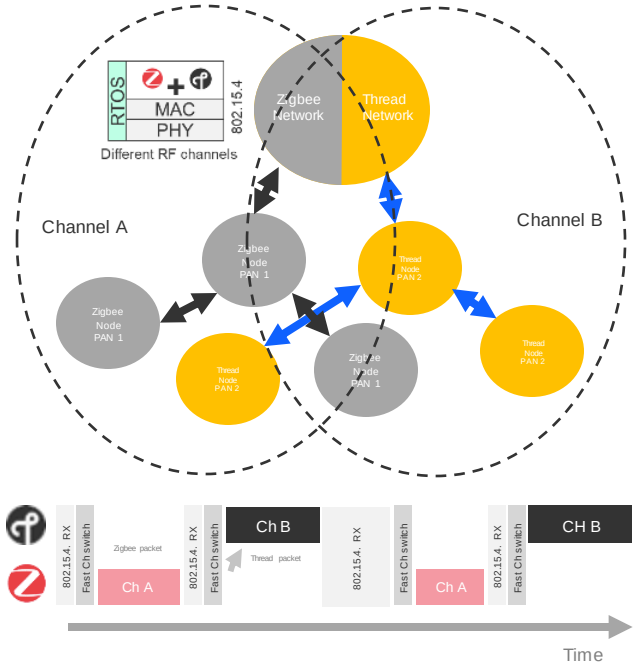


DYNAMIC MULTIPROTOCOL

Time-sliced operation of two protocols using an RTOS

Advanced RAIL Priority Scheduler

Enables direct phone connectivity

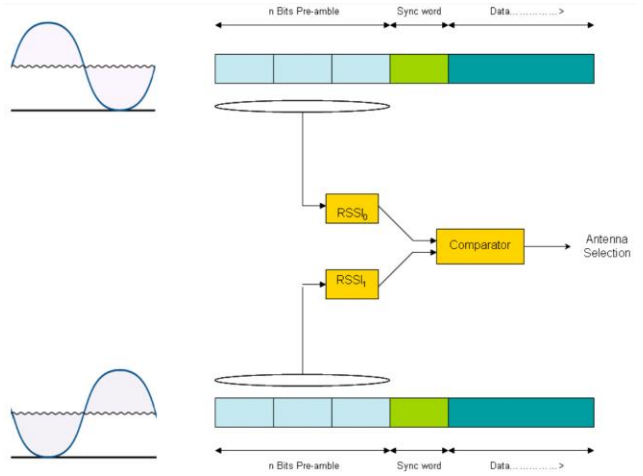


CONCURRENT SCANNING

Concurrent operation of Zigbee and Thread on different 15.4 channels

HW based fast channel switching

Scan 2 channels within 128us without packet losses



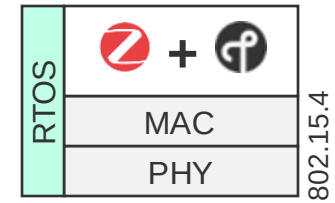
SELECTIVE RX DIVERSITY

Use two antennas ¼ wave apart

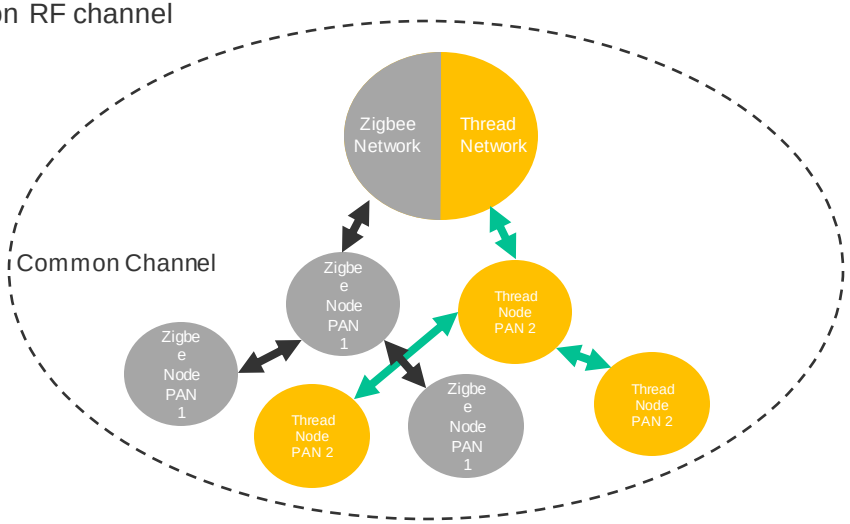
Fast switching during preamble detection to select the best antenna

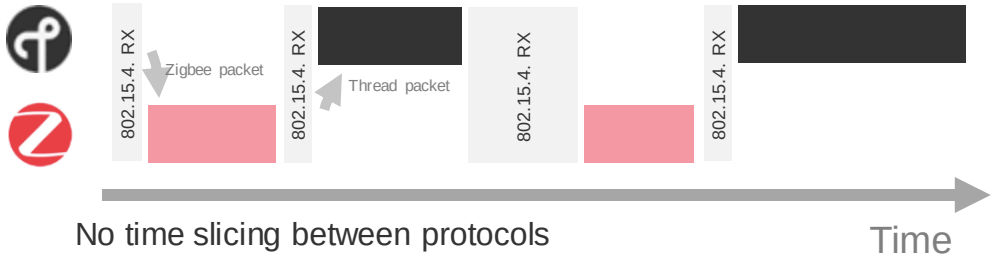
Improve SNR and RSSI to reduce PER for multi-path and/or blocking

Concurrency



Common RF channel





- **Concurrent Multiprotocol**
  - Simultaneous RX/TX operation of Zigbee and Thread on the same channel using common 802.15.4 PHY-MAC
  - RX frames differentiated by PAN IDs
  - Channel access managed by normal 802.15.4 CSMA-CA
  - Functional in SoC, NCP and RCP modes
- **Multi-chip Solutions**
  - Simultaneous RX / TX operation on different channels using one IC per protocol connected via UART / SPI
- *** Multi-RF & Multi-Radio ICs**
  - Simultaneous RX in a single IC using two RF AFEs and one or two modems
  - TX is usually still time sliced due to interferences
- *** MIMO RX Diversity (MRC)**
  - Allows multiplexing wireless medium in space to reduce multi-path fading and increase RX sensitivity
  - Requires two RF AFEs and one or two modems

* Not available today, investigating for future products

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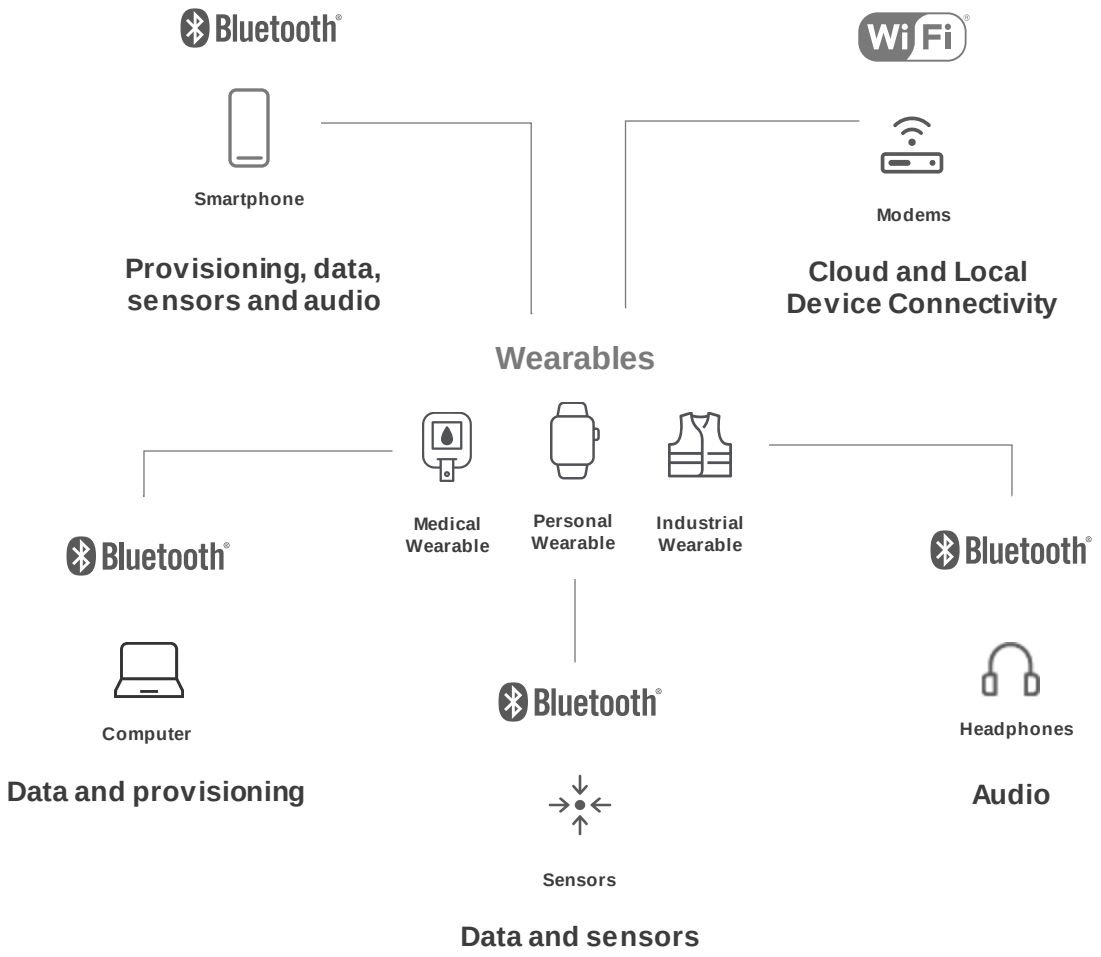
Multiprotocol in Wi-Fi Devices

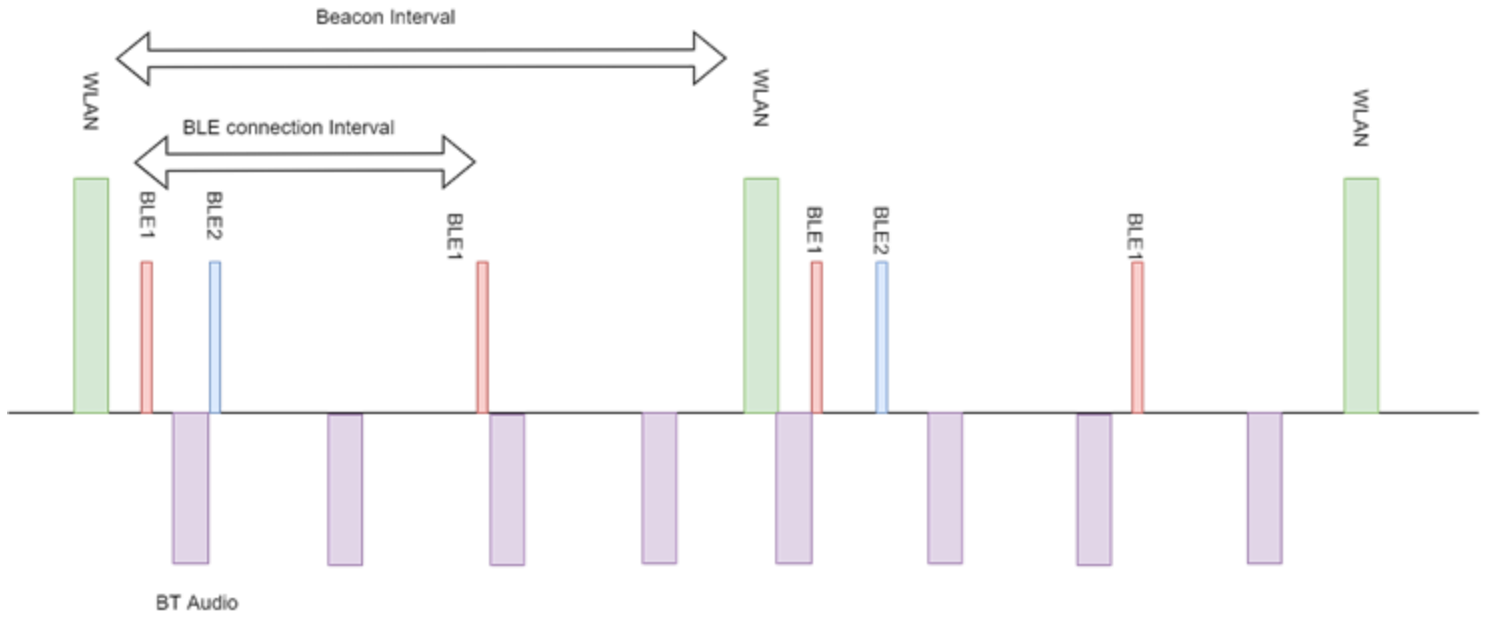
Multiprotocol Wearable Use Case



- Wearable market includes consumer, medical and industrial wearables
- Ultra-low power for longer battery life
- Heavy communication in 2.4 GHz ISM: **Multi-protocol Coexistence** is critical
- Wi-Fi connected to the cloud through AP for downloads, streaming, notifications etc.
- BLE peripheral connections to Smartphones/Tablets
- BLE central connections to sensors
- BT EDR A2DP Source Music Streaming (smart watch use case)
- HFP/A2DP Sink for VR, Voice Calling
- BLE Unicast Audio*

* Not available today, in Roadmap

Multiprotocol Wi-Fi and Bluetooth / BLE



Simultaneous support:

- Wi-Fi sync/music download and ultra-low power during standby associated state(longest battery life)
- 2-BT Classic ACL connections (A2DP headset for streaming, HFP phone connection for voice call/VR)
- BLE: Connection with Sensors(3 Central) + Mobile(2 Peripherals) + Advertising/Scanning

Wi-Fi + Bluetooth / BLE Coexistence

Coex Manager & Radio Scheduler

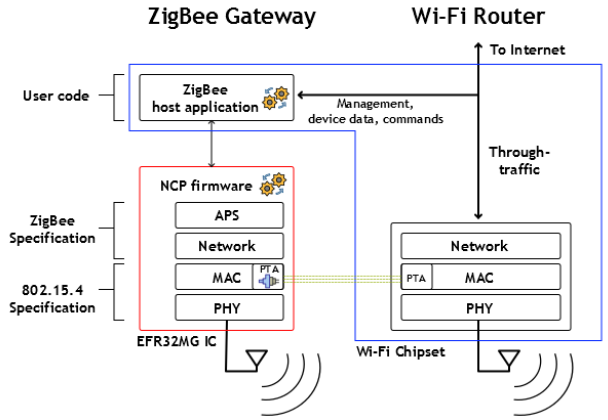
- Multiprotocol logic is managed by Coex Manager Radio scheduler
- Core function is the time slicing among the protocols(Wi-Fi, BT, BLE) on single radio based on the protocol state priorities.
- Allocates radio based on state severity(Critical > Major > Normal) if there are more than one protocols to serve
- If there is a conflict between severities, allocates radio based on default priorities (BLE > BT > WLAN).
- Radio scheduler informs the protocol manager about the next state protocol priority, asking to pause or continue its current operation

Packet Traffic Arbitration for Gateways and Border Routers

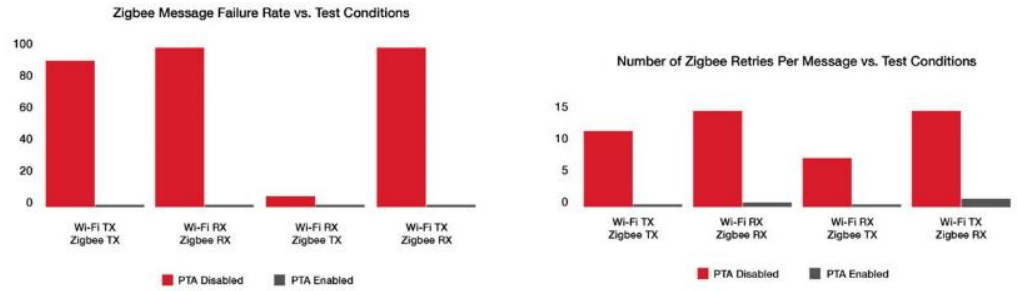
MODE OF OPERATION

- **Separate radio activity in time by coordinating protocols with PTA**
- **Multiple Wiring Options: 1-wire, 2-wire, 3-wire, 4-wire**
- **Multiple advanced PTA Strategies available at Silicon Labs:**
  - REQUEST PWM, PRIORITY, Shared PTA, Radio Hold-off
- **PTA Basics:**
  1. IoT device asserts REQUEST and optionally PRIORITY
  2. Wi-Fi accepts request and asserts GRANT
  3. Wi-Fi device stops transmitting and IoT device can RX/TX
  4. When done IoT device de-asserts REQUEST and Wi-Fi releases GRANT

WI-FI ENABLED IOT GATEWAYS / BR ARCHITECTURE

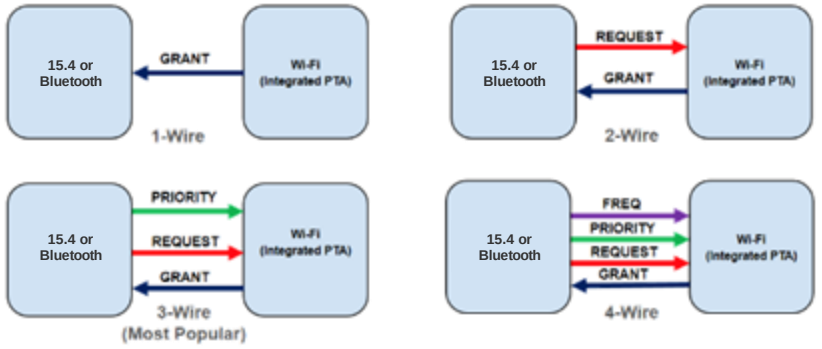


Network Performance w/o vs w/ PTA Enabled



Increased performance with PTA enabled due to reduced retries and packet losses

PACKET TRAFFIC ARBITRATION WIRING OPTIONS



Silicon Labs Multiprotocol and Wireless Coexistence Offering*

	Feature	Protocol Combination		xG1	xG12	xG13	xG21	xG24	MG26	xG28	MG301	RS9116	SiWx917/915
Concurrency	Switched MP	Z-Wave / SideWalk	SoC							□			
		Z-Wave / SideWalk / BLE	SoC							□			
	CMP (1 ch.)	(ZB+OT)	SoC					□			□		
			RCP	□	□	□	□	□					
		ZB NCP + OT RCP					□	□					
	CMP + Conc. Listening	ZB + OT	SoC								□		
			RCP				□	□					
		ZB + OT + BLE	SoC					■					
Time Slicing	Dynamic MP	ZB + BLE	SoC		□	□	□	□			□		
			NCP		□	□	□	□					
			RCP		□	□	□	□					
		OT + BLE	SoC		□	□	□	□			□		
			RCP		□	□	□	□					
		(ZB+OT) + BLE	SoC					□			□		
			RCP		□	□	□	□					
		(ZB + Matter/OT) + BLE	SoC					□	□		□		
		Matter/Wi-Fi + BLE	SoC										□
			NCP/RCP									□	□
		Connect + BLE	SoC		□		□	□		□			
		SideWalk + BLE								□			

□ - GA
□ - Alpha/Beta
□ - Roadmap
■ - Concept

xG → MG / BG /
MG → 15.4, BLE, Connect
BG → BLE, Connect

xG → ZG / FG / SG
ZG → ZW, Wi-SUN, Connect, SW, BLE
FG → Wi-SUN, Connect, SW, BLE
SG → SW

*Till 23Q2

Thank you!