Exploring Multiprotocol Wireless Techniques

2025 tech talks WEBINAR SERIES

MULTIPROTOCOL

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Agenda

01 Why coexistence is inevitable?

02 Managing coexistence

03 Dynamic and Concurrent Multiprotocol

04 The details

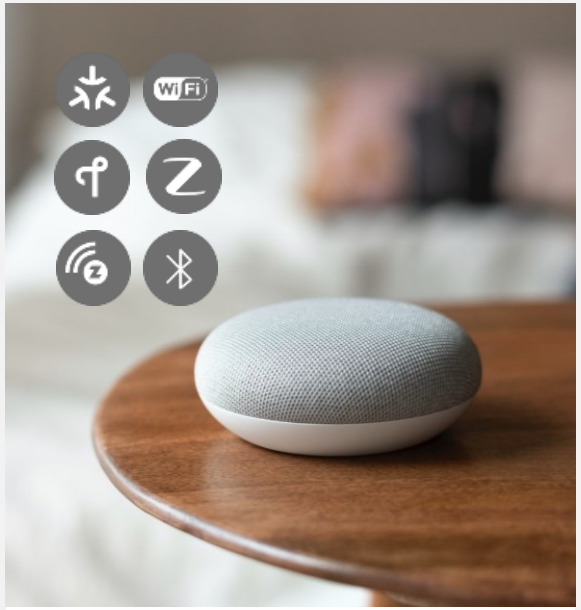
05 Architecture View

06 Silicon Labs Multiprotocol Offerings

Why Coexistence is inevitable?

CO-LOCATION

When deployed in the field, many products are co-located within the radio range



ECOSYSTEM DEMAND

When serving an Ecosystem, a single product is expected to support multiple wireless protocols simultaneously

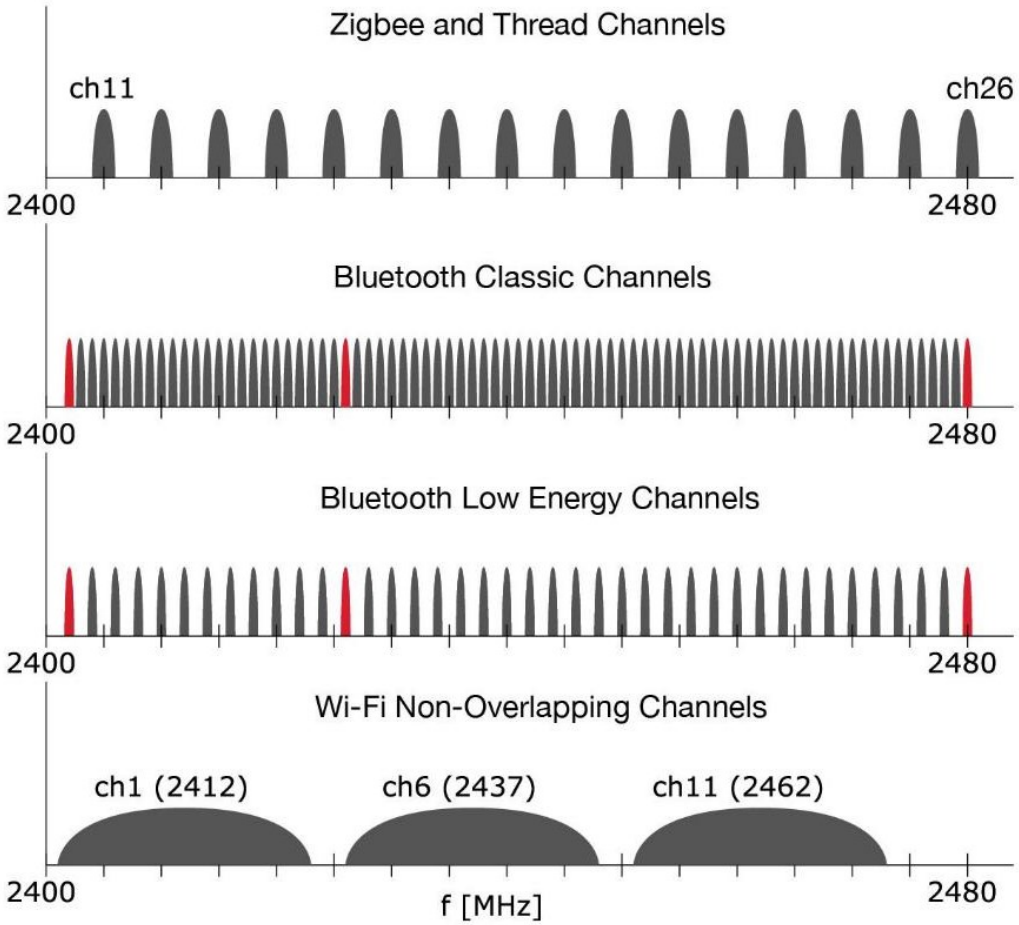
PRODUCT VERSATILITY

To maximize market reach, a single product is typically positioned to serve multiple use cases

PERFORMANCE

To gain a competitive edge, products are expected to provide superior performance via increased Tx power or higher bandwidth

Challenges 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

Impact to IoT Devices

END DEVICE / ACCESSORY

Delayed or missing packets

High rate of retries

Reduced battery life

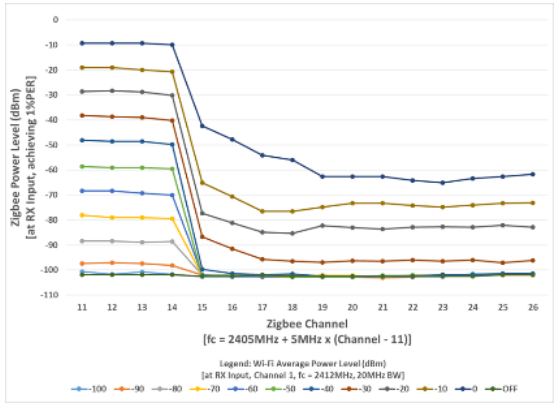
GATEWAY / HUBS

Missing devices events

Poor commands responsiveness

Dropped connections

Managing Coexistence



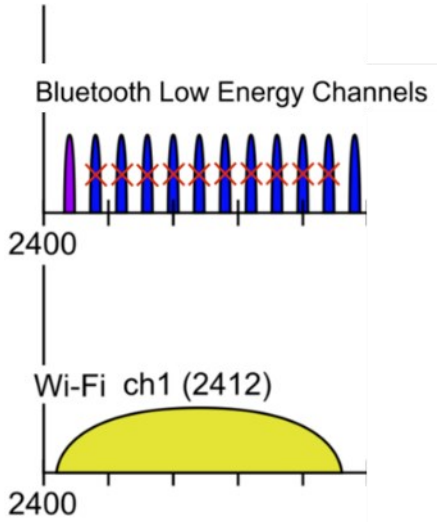
UNMANAGED COEX

Customized run-time radio performance:

Blocking & Selectivity

Adjacent channel rejection

Enhanced MAC features



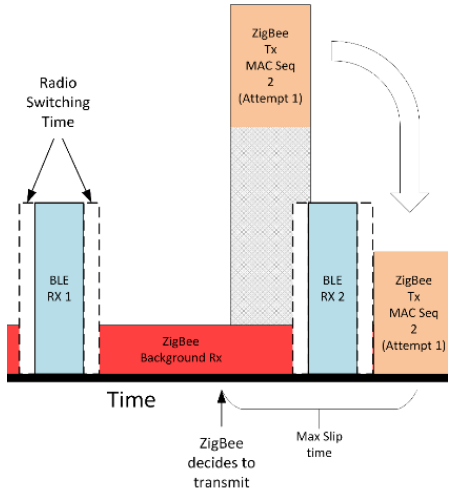
FREQUENCY PLANNING

Bands Planning

Channels Planning

Channel Agility

Frequency Hopping



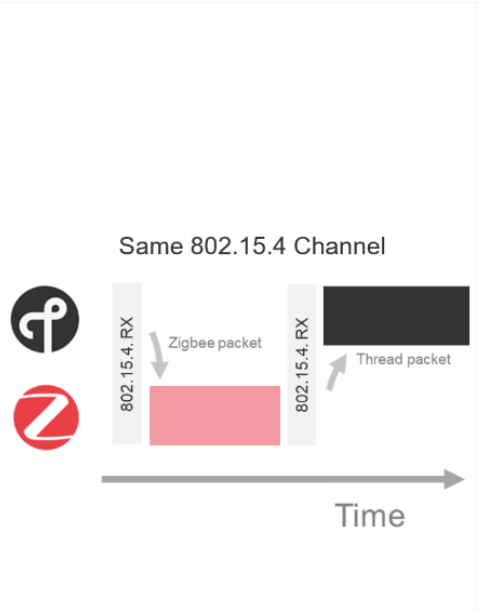
TIME SLICING

Dynamic Multiprotocol

Concurrent Listening

Selective RX Diversity

Packet Traffic Arbitration



CONCURRENCY

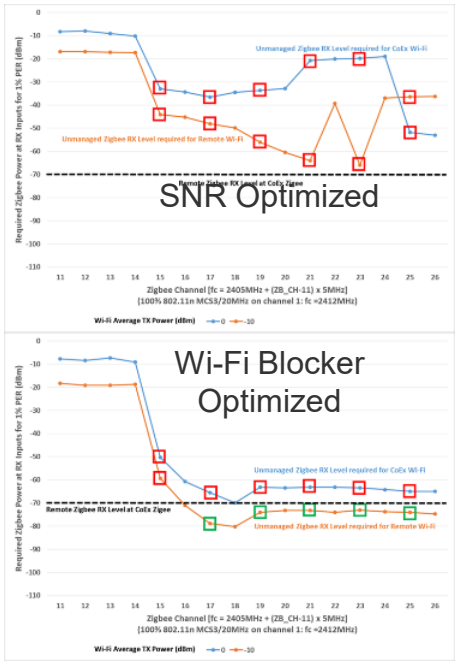
Concurrent Multiprotocol

Multi-chip solutions

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

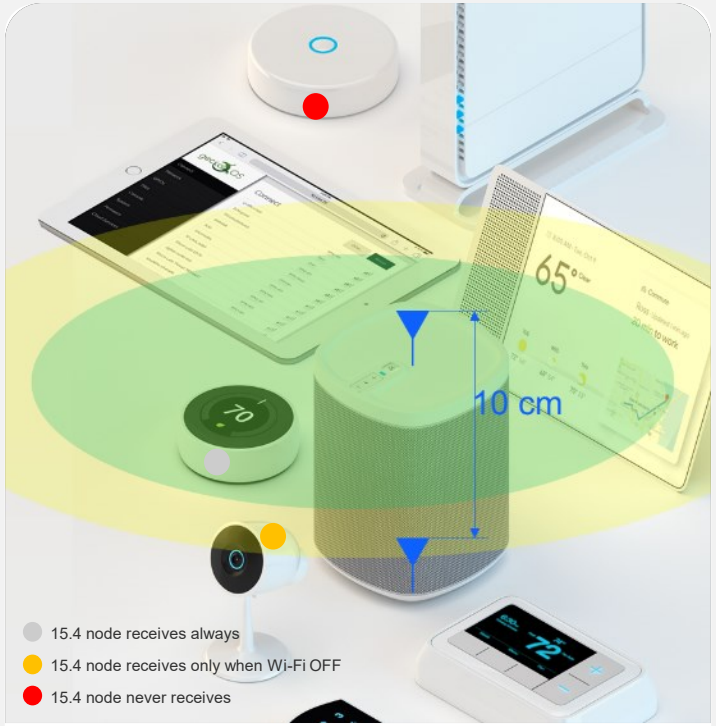
* Not available today, investigating for future products

I. Unmanaged Coexistence



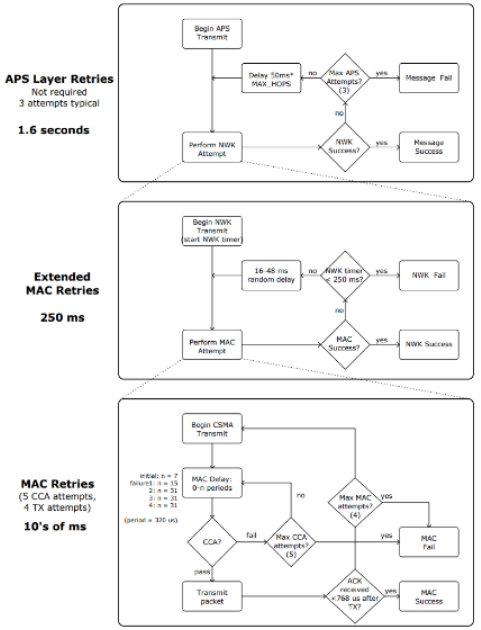
BLOCKING & SELECTIVITY

- 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

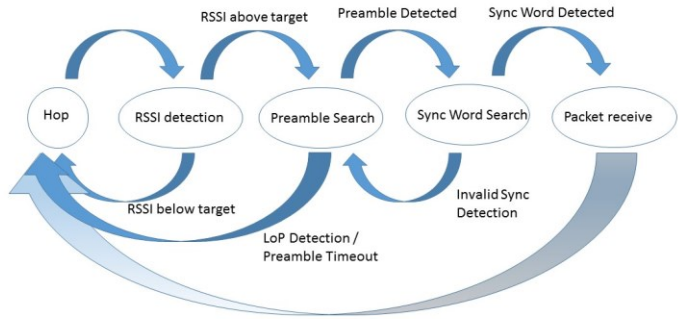
- Extended **MAC retries** algorithm
- Configurable CCA thresholds
- Configurable CCA timeouts

II. Frequency Planning

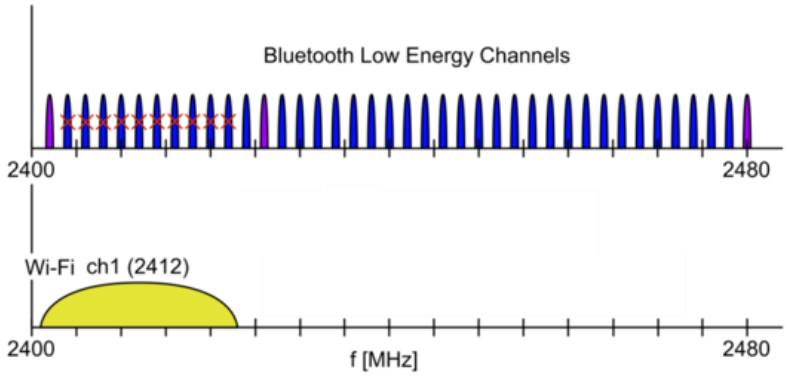
METHODOLOGY

- **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

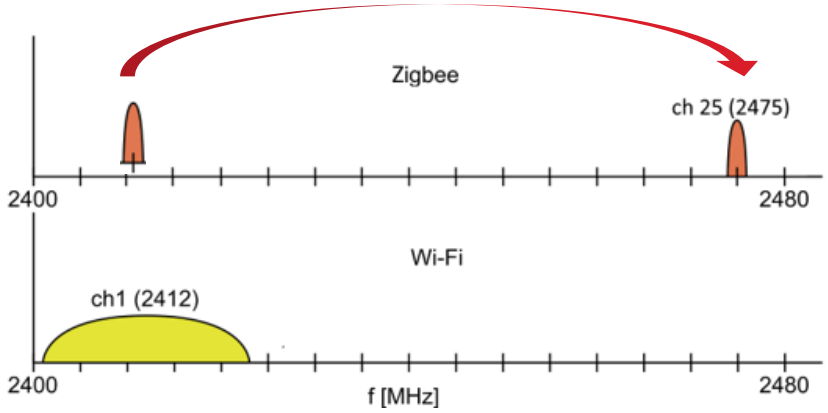
FREQUENCY HOPPING



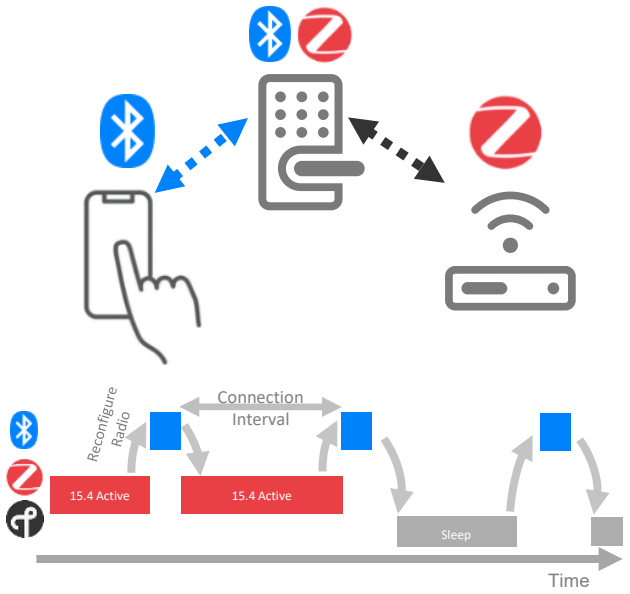
BANDS AND CHANNELS PLANNING



CHANNEL AGILITY

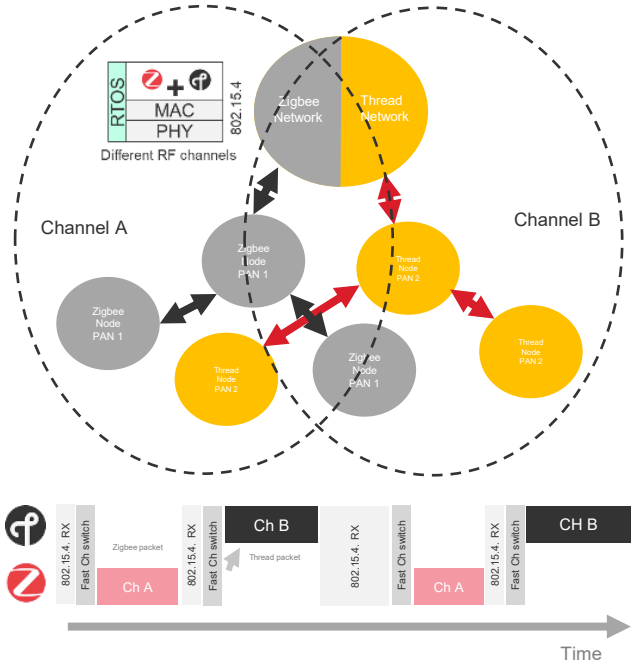


III. Time Slicing



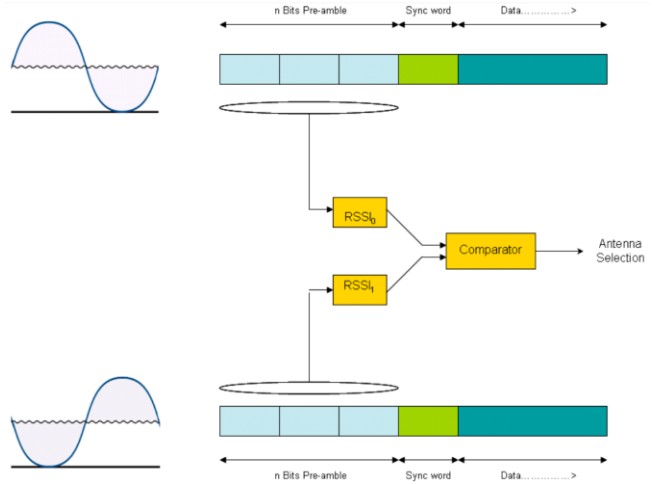
DYNAMIC MULTIPROTOCOL

- Time-sliced operation of two protocols using an RTOS
- Advanced RAIL Priority Scheduler
- Enables direct phone connectivity



CONCURRENT LISTENING

- 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

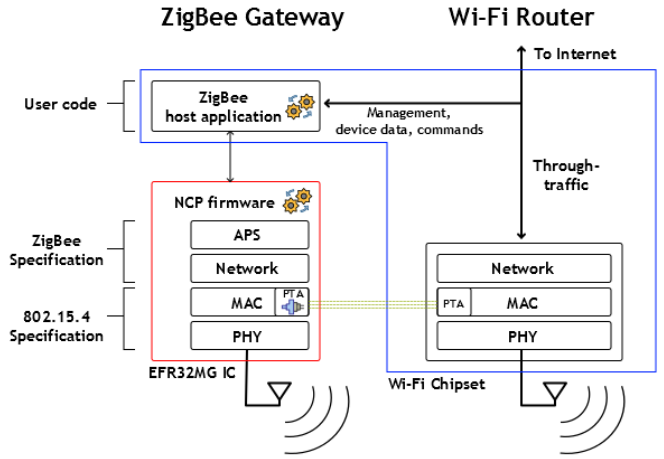
III. Time Slicing - Packet Traffic Arbitration

MODE OF OPERATION

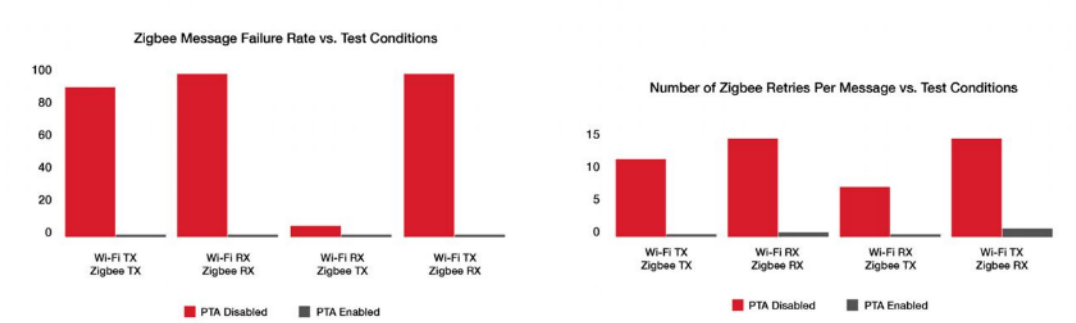
- Separate radio activity in time by coordinating protocols with PTA
- Multiple Wiring Options: 1-wire, 2-wire, 3-wire, 4-wire
- Multiple advanced PTA Strategies available at Silicon Labs:
  - REQUEST PWM, PRIORITY, Shared PTA, Radio Hold-off

- **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

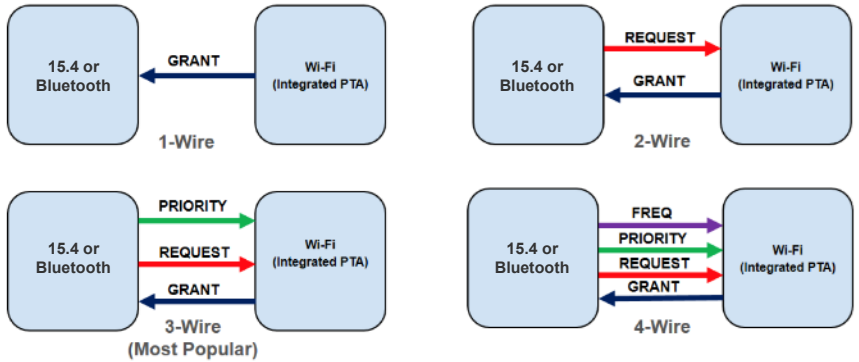


NETWORK PERFORMANCE w/o VS w/ PTA ENABLED

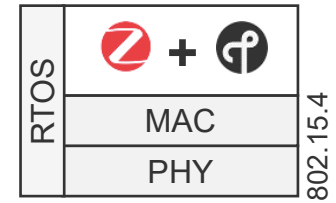


Increased performance with PTA enabled due to reduced retries and packet losses

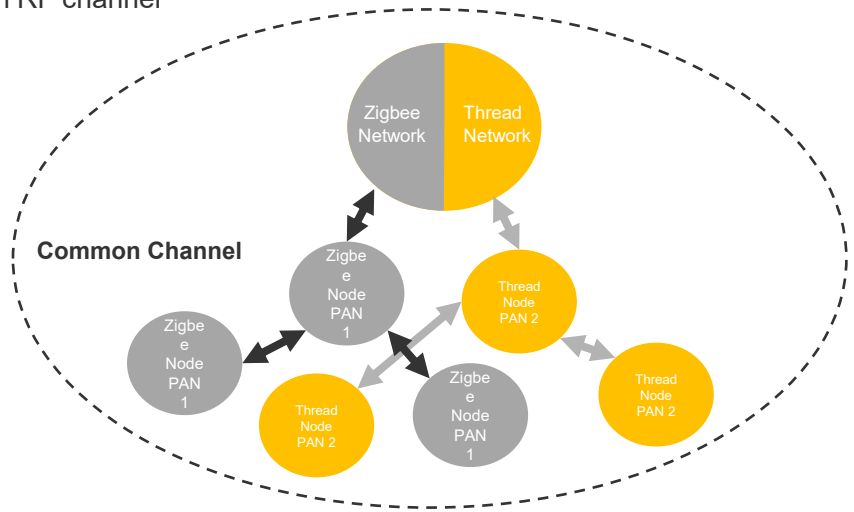
PACKET TRAFFIC ARBITRATION WIRING OPTIONS

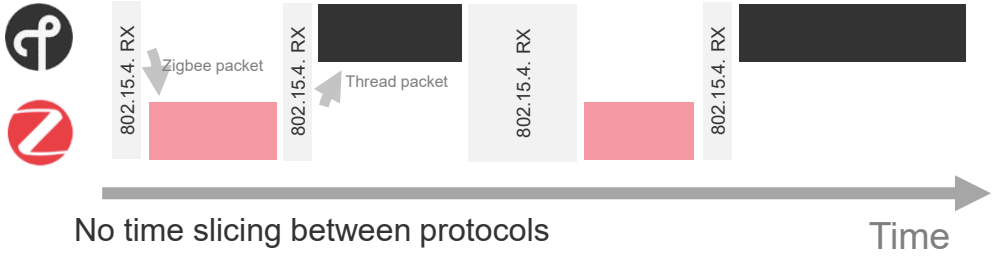


IV. Concurrency



Common RF channel



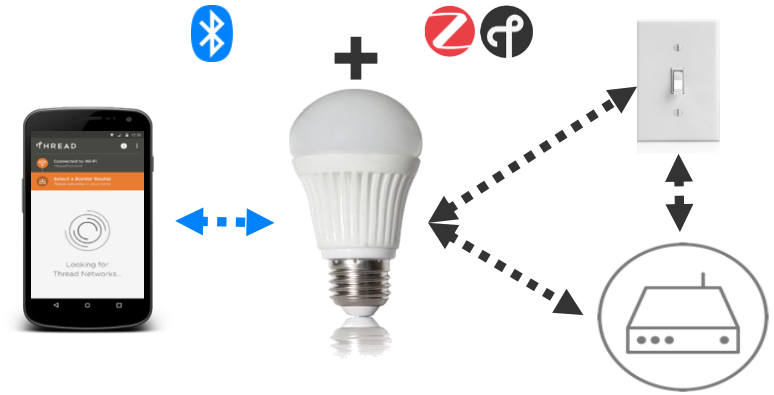


- **Concurrent Multiprotocol**
  - Simultaneous RX/TX operation of Zigbee and Thread on **the same channel** using common 802.15.4 PHY-MAC
  - RX frames differentiated by PAN IDs
  - Channel access managed by normal 802.15.4 CSMA-CA
  - Functional in SoC, NCP and RCP modes
- **Multi-chip Solutions**
  - Simultaneous RX / TX operation on different channels using one IC per protocol connected via UART / SPI
- *** Multi-RF & Multi-Radio ICs (Series-3: Everest)**
  - 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

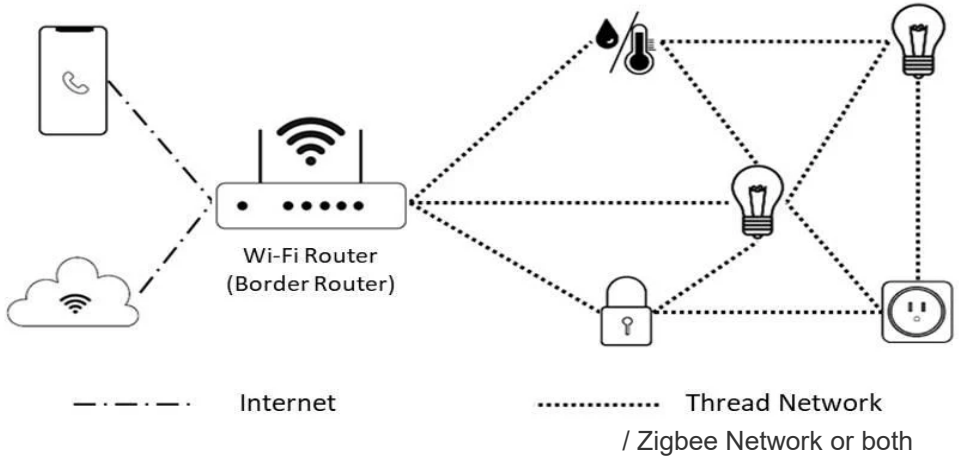
* Not available today, investigating for future products

Common DMP and CMP use cases

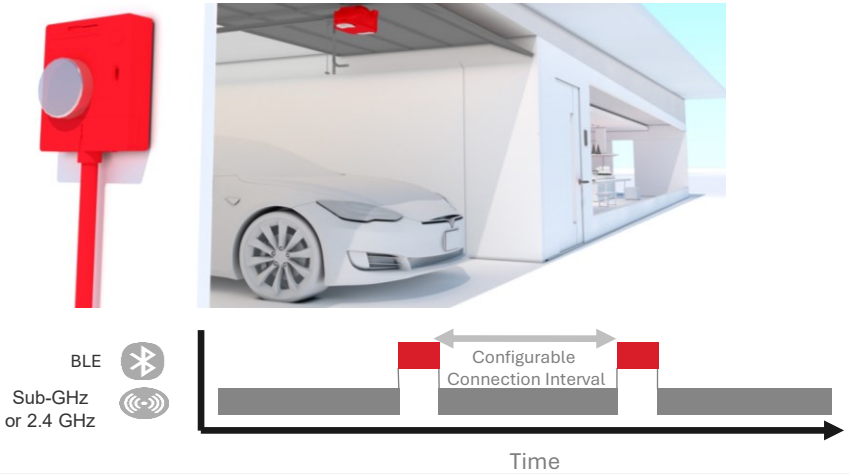
DMP FOR LIGHTING SOLUTIONS



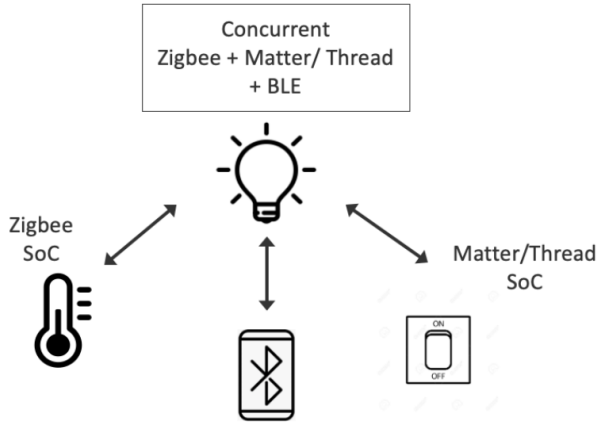
MULTIPROTOCOL GATEWAYS



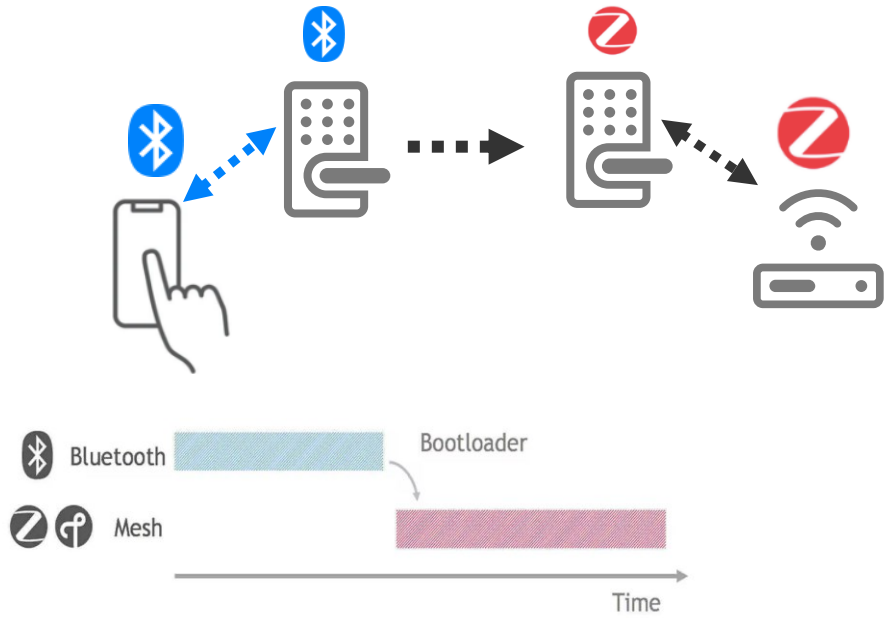
MULTIPROTOCOL SUB-GHZ IOT DEVICES



MULTIPROTOCOL LIGHTING SOLUTIONS

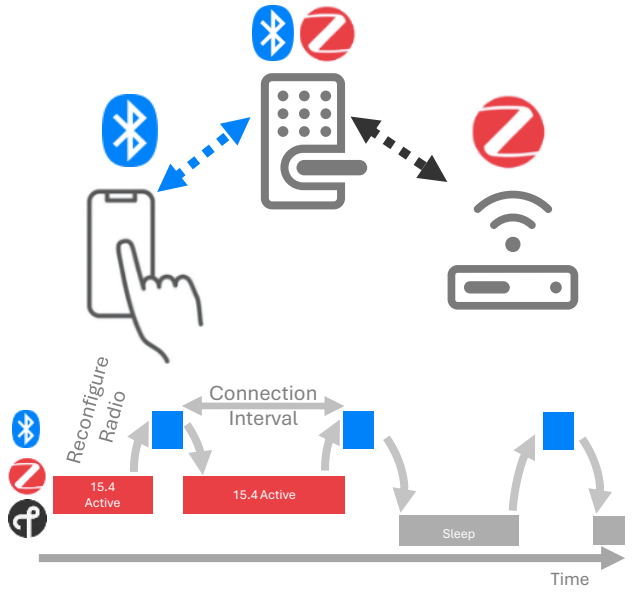


Switched and Dynamic Multiprotocol (SMP v/s DMP)



SWITCHED MULTIPROTOCOL

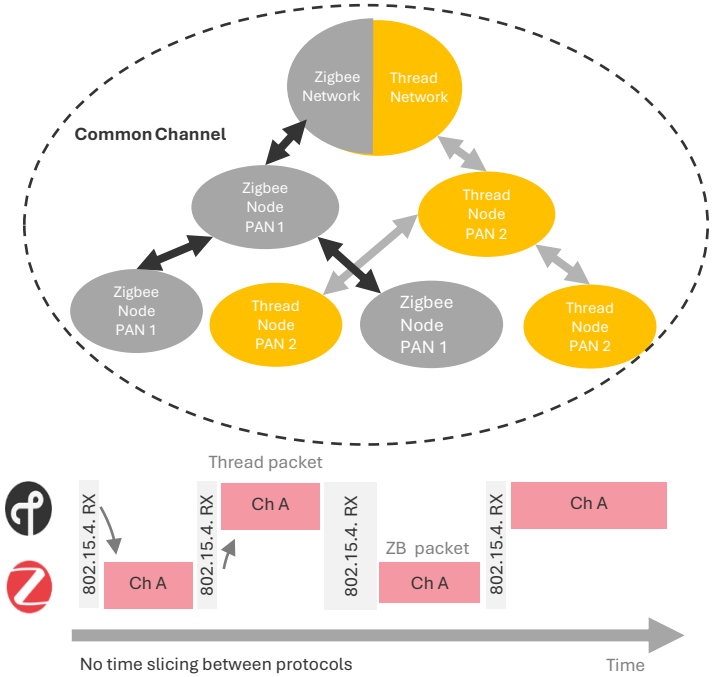
- Bootload the firmware image from one protocol stack to other
- Helps to update devices in the field to changing market needs
- Switching time is usually long (~hundreds of ms)



DYNAMIC MULTIPROTOCOL

- Time-sliced operation of two protocols using an RTOS
- Advanced RAIL Priority Scheduler
- Enables direct phone connectivity

Concurrent Multiprotocol (CMP) & Concurrent Listening



CONCURRENT MULTIPROTOCOL

- Simultaneous TX/RX operation of Zigbee and Thread on **the same 15.4 channel**
- RX frames differentiated by PAN IDs
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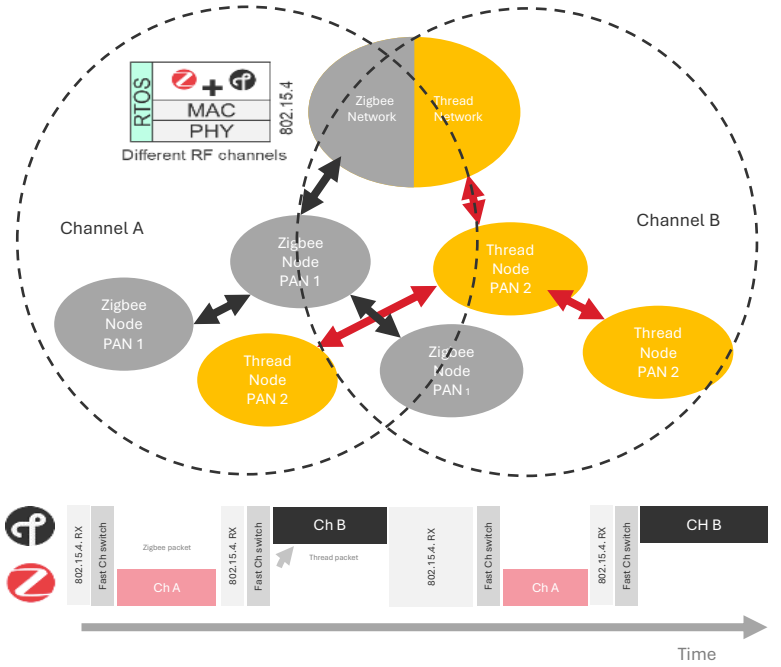


CONCURRENT LISTENING

- Concurrent operation of Zigbee and Thread on different 15.4 channels
- HW based fast channel switching
- Scan 2 channels within 128us without packet losses

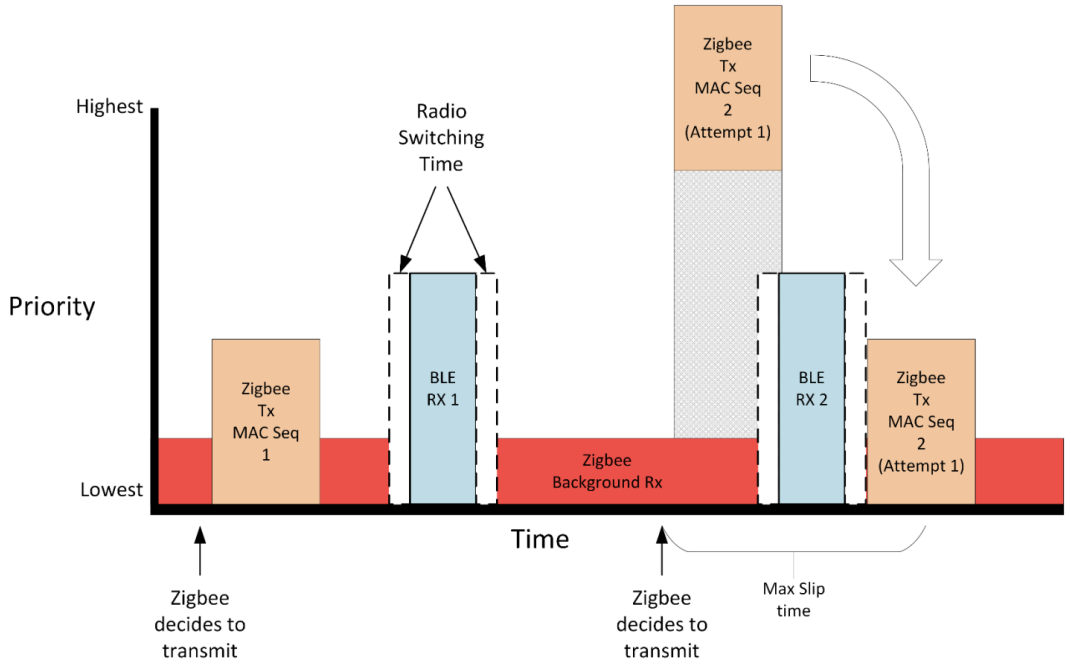
Dynamic Multiprotocol (DMP)

Operation:

- Radio time-sliced to reliably manage multiple protocols
- Used with BLE, in conjunction with a different protocol
- Managed by RAIL Scheduler
- Uses MP RAIL library and RTOS
- Typically, BLE operations get a higher priority but is configurable
- Radio switching time in the order of hundreds of μs

Common Use cases:

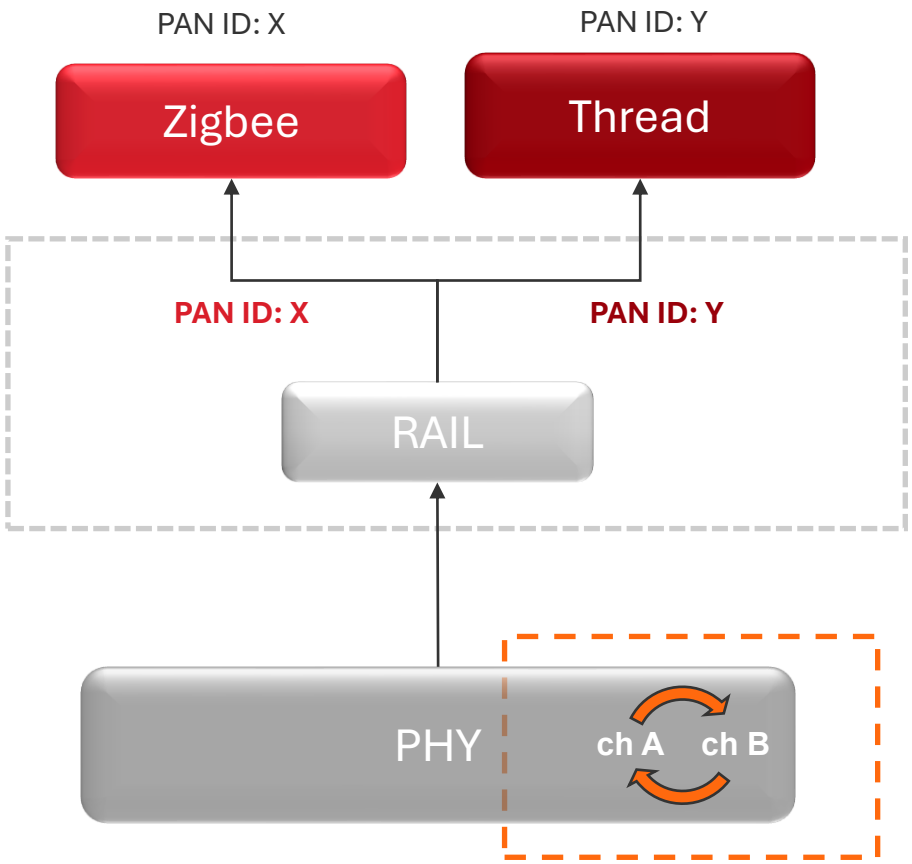
- Commissioning / device on-boarding
- Network diagnostics



Example: DMP BLE + Zigbee

- **Radio operation priorities could be reconfigured based on use case (See UG305)**
- **Can be enabled or disabled on demand**

Concurrent Multiprotocol terminologies



Concurrent Multiprotocol (CMP) :

Ability of Platform to support two 15.4 protocol stacks (such as Zigbee & Thread)

- **Forms basis of CMP.**
- **Can support Zigbee + Zigbee / OT + OT, but with distinct PAN IDs**

MultiPAN support:

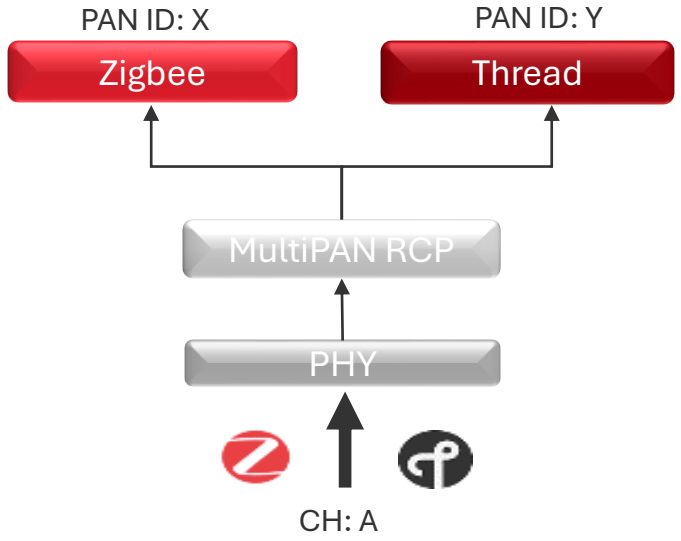
Ability of Platform RAIL to filter packets based on PAN ID.

Concurrent Listening (aka FCS - Fast Channel switching):

Ability of the platform PHY to quickly switch & detect 802.15.4 preambles on separate RF channels using a single radio

Concurrent Multiprotocol (CMP): Series 1 vs Series 2

SERIES 1

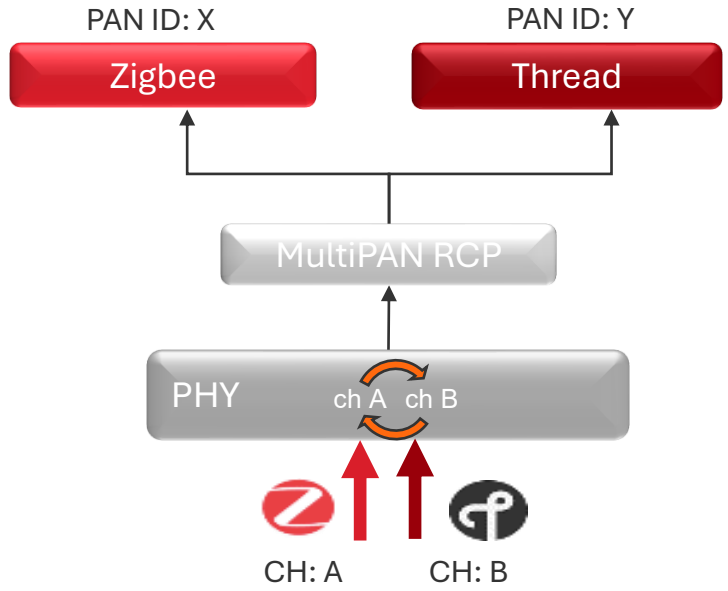


- Enables Zigbee and Thread support using a single radio, but with both operating on the **same** 15.4 channel
- Relies on the **MultiPAN feature**
- Absolute Concurrency

Limited by Specification, where Thread could choose to switch the operating channel ☹

Enables Ecosystem diversity

SERIES 2



- Enables Zigbee and Thread support using a single radio, and with both operating on **separate** 15.4 channels
- Uses **Concurrent Listening** along with **Multi-PAN feature** to support operation on two 15.4 channels.

Concurrent Listening (aka Fast Channel Switching) on Series 2

Concurrent Listening:

- Uses **RX antenna diversity hardware block** with **synth reloading** to switch extremely rapidly between two 15.4 channels, after every ~ 48 µsec
- If a preamble is detected, stays on the channel until completion of the packet.
- Successfully detects a 15.4 packet by listening to at least 2 out of the 8 preamble symbols (32 µs out of 128 µs) on each RF channel.

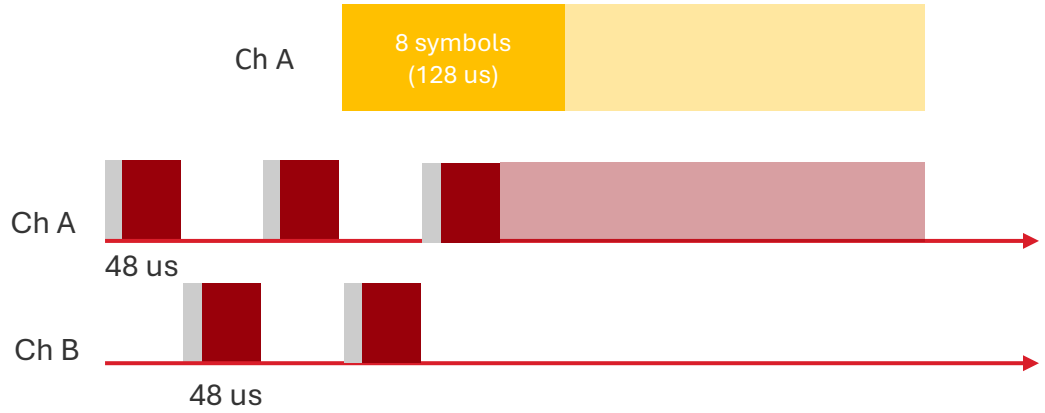
Limitations:

- Slight degradation in Rx sensitivity
- Antenna diversity not available.

Supported Parts & Architecture

- Currently supported on xG21 and xG24, with Zigbee and Thread operating in RCP mode, and xG26 in SoC mode.

Time sliced in principle yet concurrent as radio succeeds to monitor traffic on two 15.4 channels simultaneously, unlike DMP



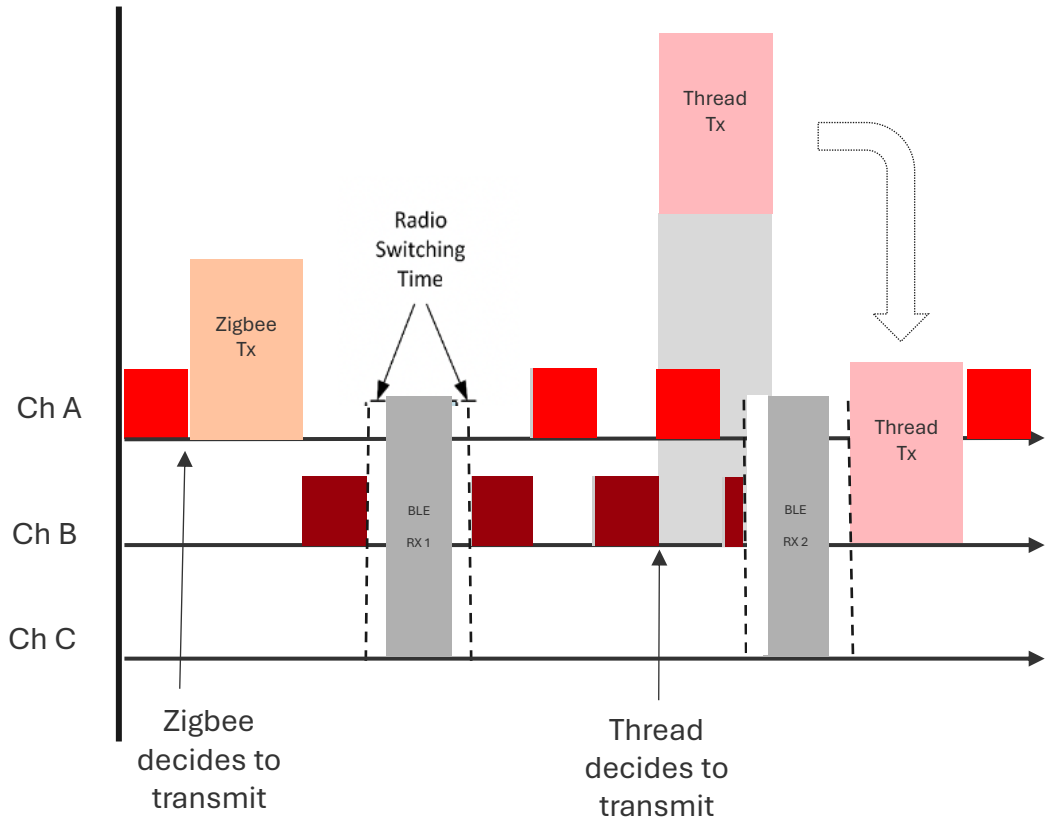
- Load RF synth for channel A & settle (~16 us)
- Listen for preamble (2 symbols, ~32us)
- Load RF synth for channel B and settle (~16 us)
- Listen for preamble (~32us)
- Repeat until preamble detected

Dynamic Multiprotocol (DMP BLE) with CMP (Zigbee + Thread)

DMP BLE + CMP:

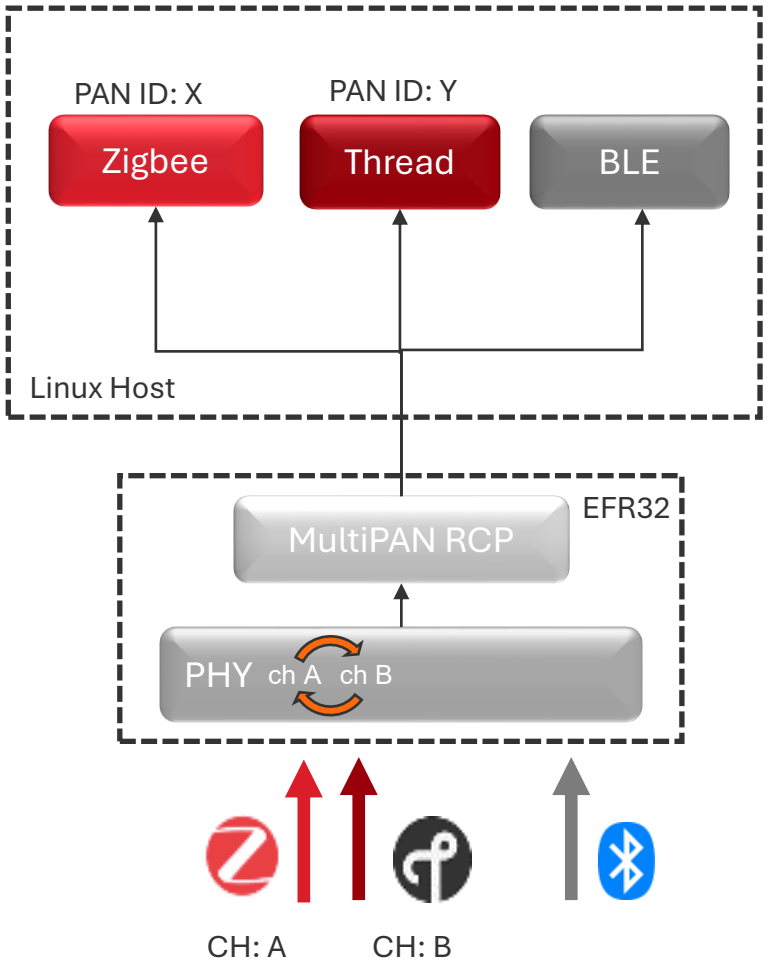
- Extension of BLE DMP with single protocol case
- BLE continues to operate in time-sliced DMP mode, interrupting CMP (Zigbee + Thread) as needed.
- With Concurrent Listening enabled (for Zigbee and Thread to operate on separate channels), the radio rapidly switches between the two 15.4 channels, with switching to BLE channel as configured.
- Does not impact BLE performance

- **Extends capability to support up to 3 protocols**
- **Supports all BLE DMP use cases supported in the single protocol case**



Example: DMP BLE + CMP (Zigbee + Thread)

DMP BLE + CMP (Zigbee + OpenThread) in RCP mode



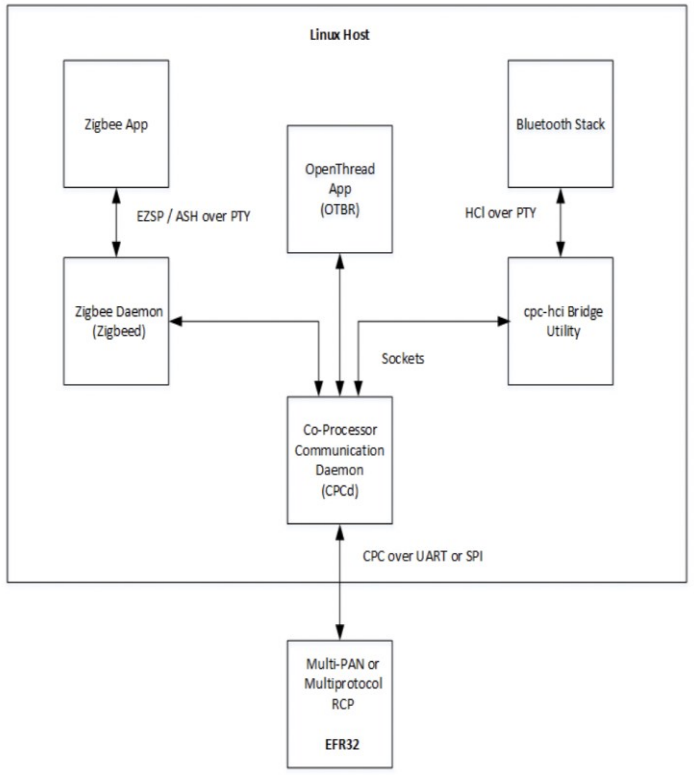
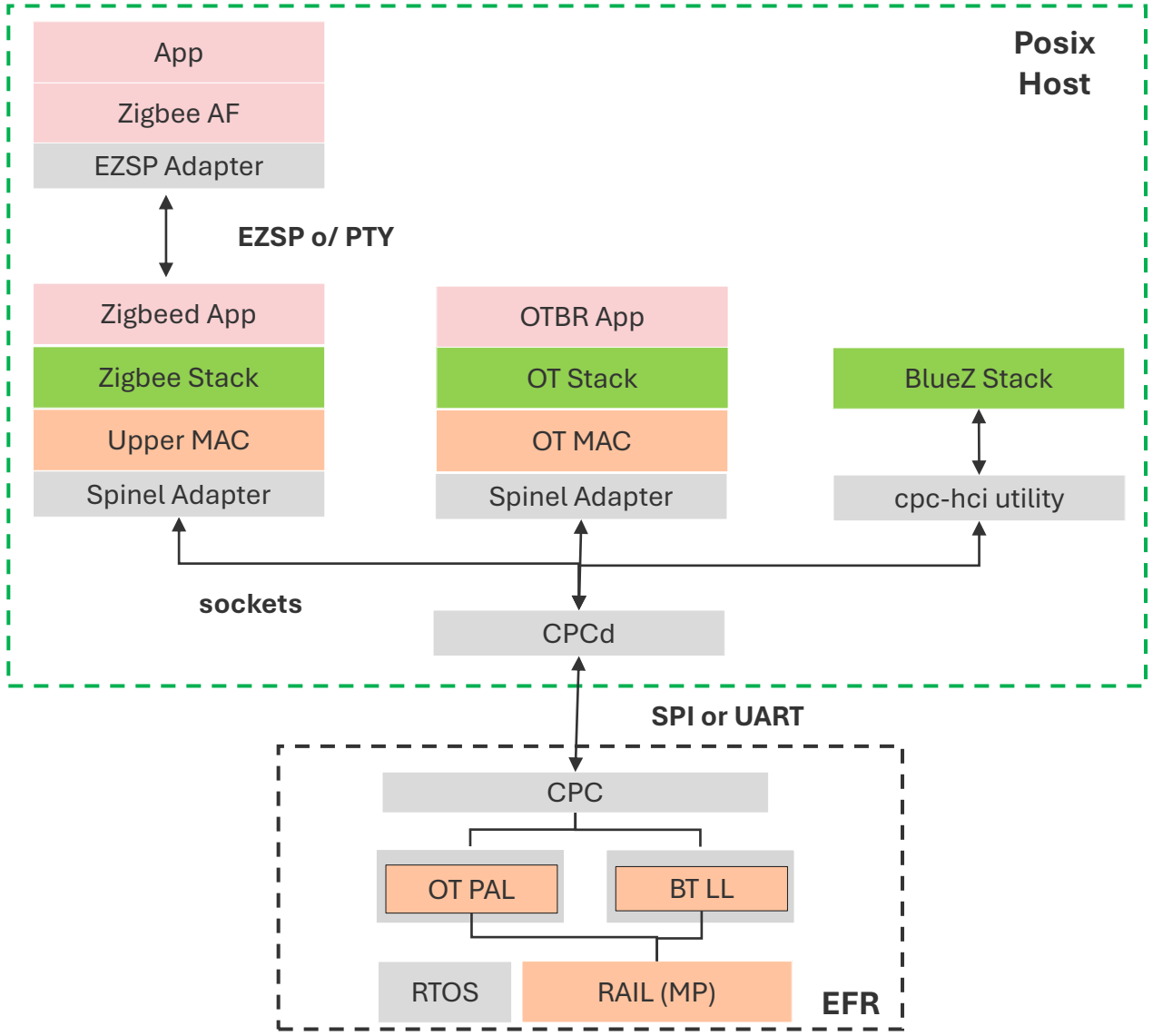


Figure 1-1. System Architecture for the Multiprotocol RCP

Support enabled in RCP mode
- **Low memory requirements**
- **Lowers cost**

- **Zigbeed** - A Linux daemon that runs the Zigbee stack & sends and receives Spinel messages to CPCd over a socket
- A **Zigbee host application** that communicates with Zigbeed using EZSP / ASH over a virtual serial port
- An **OT host application** (like OTBR) which includes the OT stack & which connects to CPCd over a socket
- The **BlueZ BT stack**, which communicates with the Bluetooth Controller on the RCP via the Host Controller Interface (HCI) protocol.
- **CPCd** - A Linux host process that communicates with the co-processor over a UART or SPI
- **Multi-PAN RCP w/ Conc. Listening & DMP** enabled on the EFR32

DMP BLE + CMP (Zigbee + OpenThread) in RCP mode [Architecture view]



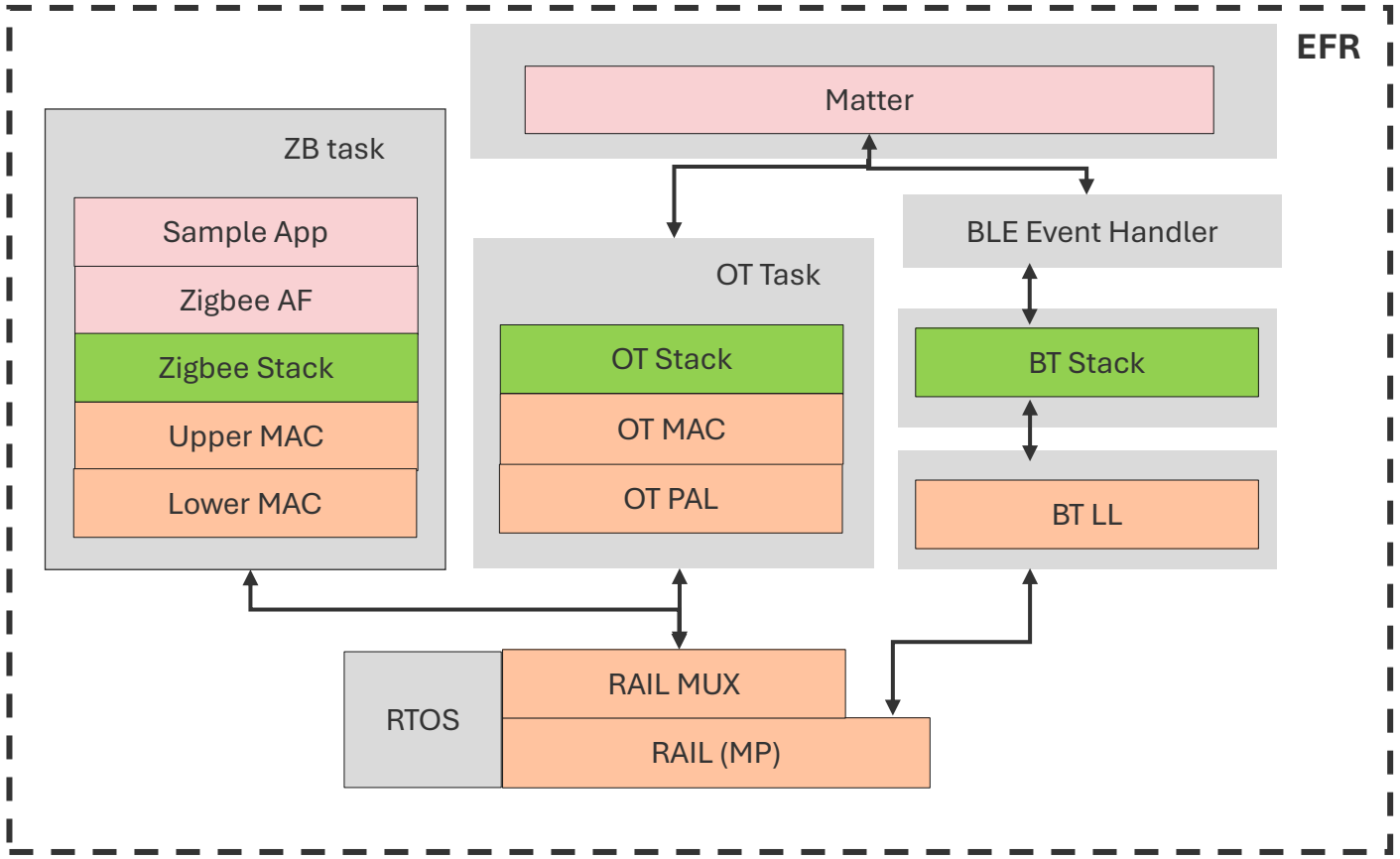
- Zigbee & Thread can operate on:
  - Same ch. (no time slicing) or
  - Different ch. (via concurrent listening)

- Uses MultiPAN feature for filtering 15.4
- Bluetooth operates in DMP mode
- RCP has a flash footprint (~250K)
- RCP App uses RTOS

Common Platform components such as:
- **Wi-Fi coexistence**
- **RTOS**
- **NVM3 & Memory manager**

Enable seamless integration of platform features critical to the application

DMP BLE + CMP (Zigbee + OpenThread) in SoC mode [Architecture view]



- Combines Zigbee + Matter/Thread
- Zigbee & Matter/Thread can operate on same or different channels
- Bluetooth operates in DMP mode
- Uses RTOS
- Supported on xG26, and upcoming Series-3 parts.

BLE + 15.4 Multiprotocol offering

Targeted Applications	Primary Arch	Technology / Stack				Operation Mode	xG21	xG24	xG26	xG27
		BLE	Zigbee	OT	Matter					
Zigbee Lights, Switches, Sensors	SoC	✓	✓			DMP BLE + ZB	✓	✓	✓*	✓
Thread Sensors	SoC	✓		✓		DMP BLE + OT	✓	✓	✓*	
Matter Lights, Switches, Sensors	SoC	✓		✓	✓	DMP BLE + Matter/OT		✓	✓	
Conc. Matter + Zigbee Lights	SoC	✓	✓	✓	✓	CMP (ZB + Matter/OT)			✓	
Gateways, EAP, Appliances, Hubs & Panels	RCP	**BLE LL**	**LMAC**	**LMAC**	**Matter capable**	DMP BLE + CMP 15.4	✓	✓	✓*	
	NCP			✓		OT NCP	✓	✓	✓*	
	NCP	✓	✓			DMP BLE + ZB		✓	✓*	
	NCP RCP		✓	**LMAC**		CMP (ZB NCP + OT RCP)		✓	✓*	

✓* Supported but with Memory spec exceeding (typical) application requirements.

Resources

- Multiprotocol Web page
- Concurrent Multiprotocol Blog
- UG305 Dynamic Multiprotocol User's Guide
- Docs.silab.com Multiprotocol
- UG103.16: Multiprotocol Fundamentals

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Q&A