Bluetooth® Low Energy & Zigbee

Multi-protocol Concurrency

- Fundamentals and hands-on Practice

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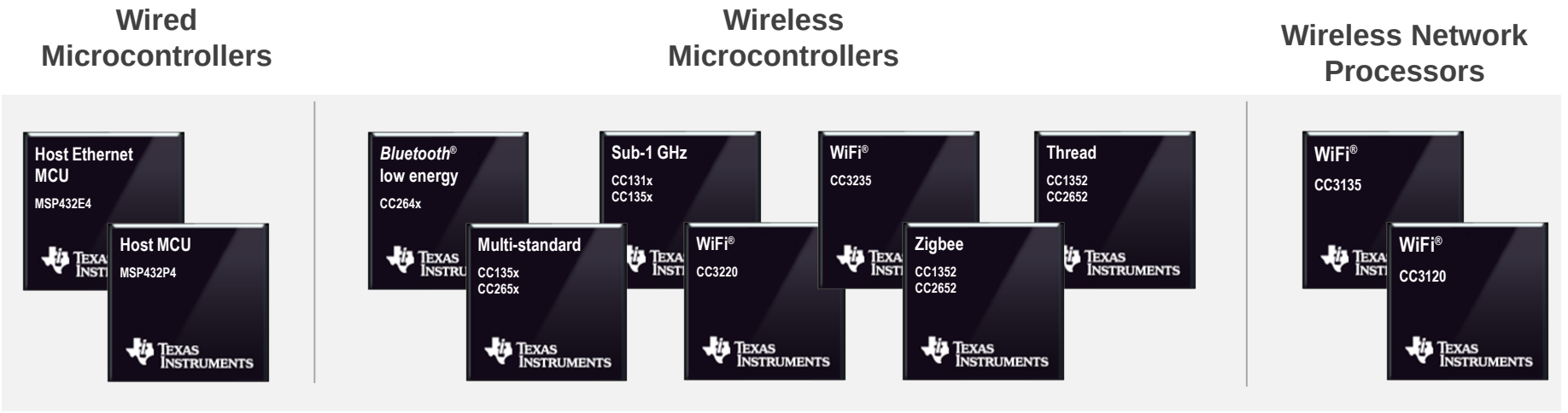
SimpleLink™ MCU platform



100% code reuse

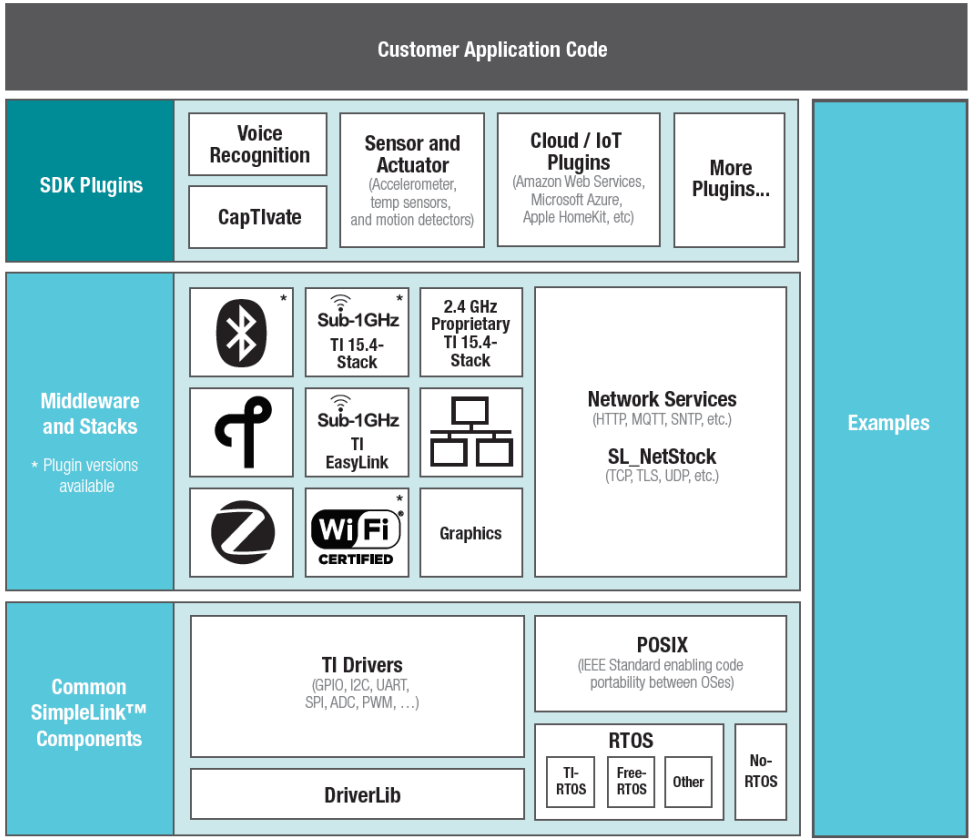
SDK

Common software

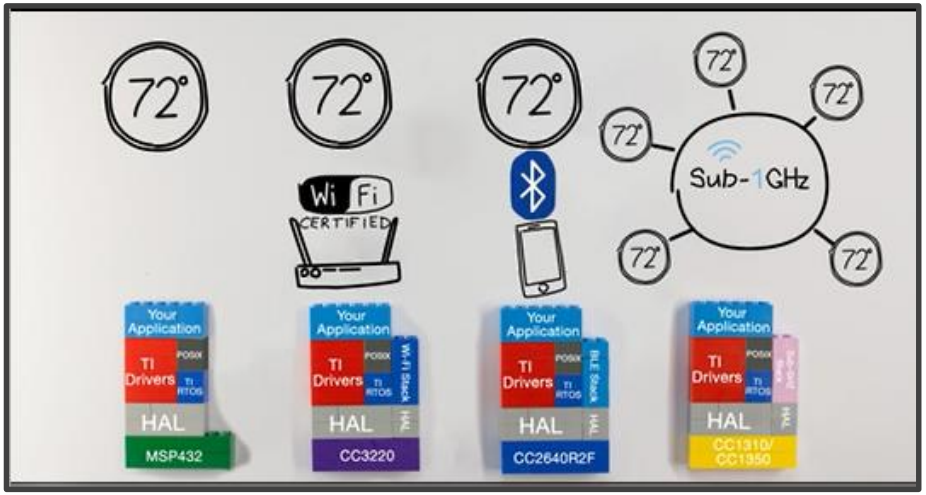
The SimpleLink™ SDK

The SimpleLink SDK is designed for simplified development within one environment using industry standard APIs, TI Drivers, and TI RTOS to provide a robust foundation for application development

- 100% application code compatibility across SimpleLink MCU portfolio
- TI Drivers offers standardized set of functional APIs for integrated peripherals
- Integrated TI-RTOS, a robust, intelligent kernel for complete, out-of-the-box development
- POSIX-compatible APIs offer flexible OS/kernels support
- Encryption-enabled security features
- IoT stacks and plugins to add functionality to your design



Invest once, reuse effortlessly



Bluetooth®

Full-featured Bluetooth 5 solutions

Features all mode Bluetooth 5 certified support, automotive-qualified wireless MCUs, and has the industry's smallest full-featured Bluetooth 5 solution.

BLE overview

View our BLE products

Sub-1GHz

Ultra-low power long-range star network

Out-of-box star network solution, multi-year operation on coin cell battery. Programmable ultra-low power sensor controller interface.

Sub-1GHz overview

View our Sub-1GHz product

Wi Fi CERTIFIED

Dual-core and low power SoCs

FIPS-verified ICs optimized for low power. Enhanced application and network security capabilities.

Wi-Fi overview

View our Wi-Fi products

zigbee

Certified mesh network

Zigbee 3.0-certified with lowest power integrated +20dBm PA and green power support.

Zigbee overview

View our Zigbee products

THREAD

Self-healing low-power mesh network

Lowest power thread platform. OpenThread stack support. Optimized router examples available in SimpleLink academy.

Thread overview

View our Thread products

Multi-standard

Concurrent wireless protocol operation

Concurrent multi-protocol & multi-band. BLE + Zigbee or BLE + Sub-1 GHz. Pre-built multi-protocol manager with flexible priority scheduler.

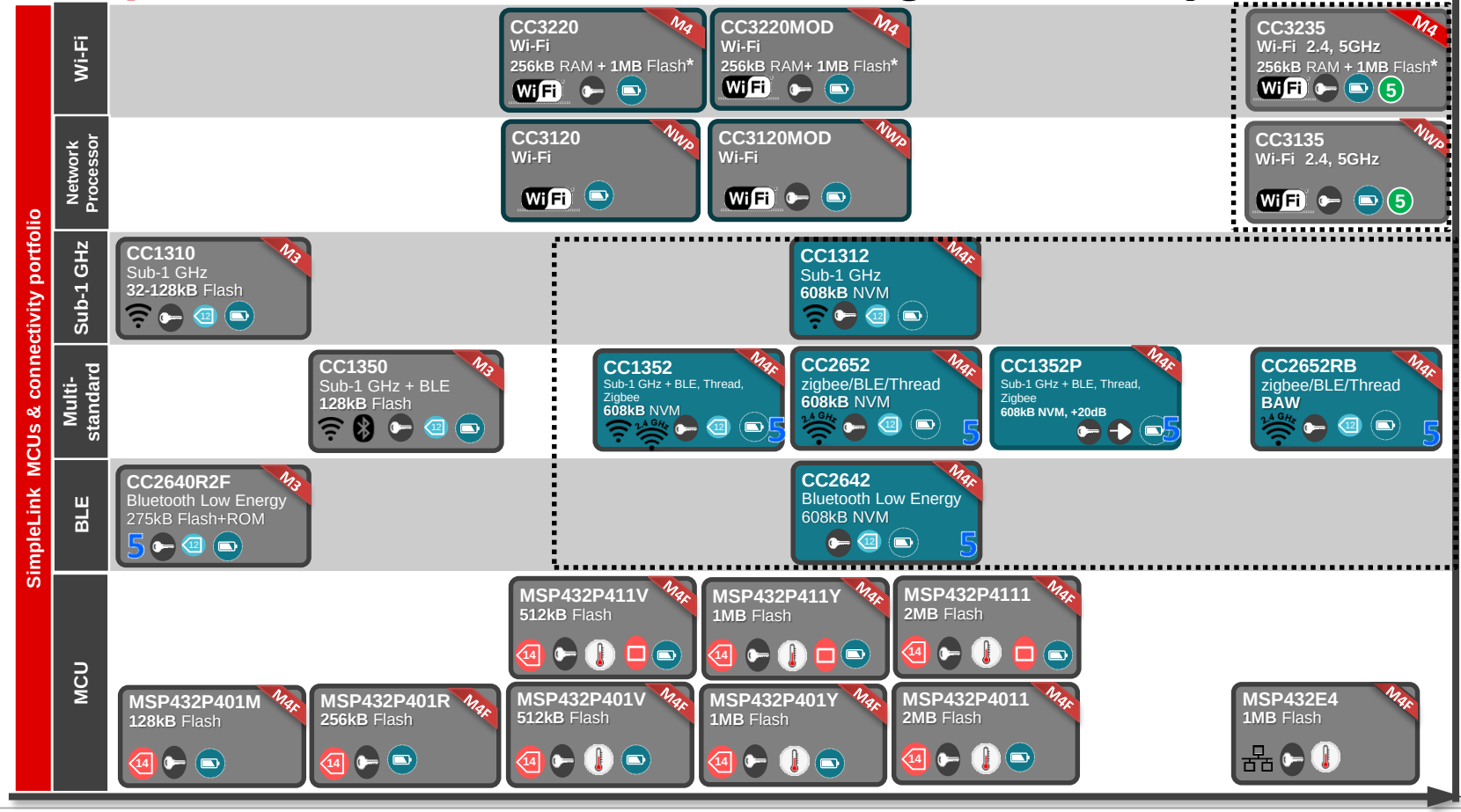
Multi-standard overview

Multi-standard products

SDK

[Learn more about SimpleLink code portability]

SimpleLink™ Portfolio redefining scalability



More memory
Multi-step approach from 32kB to 2MB

More integration
Sensor controller, precision ADC, PA, coexistence and multiple wired/wireless

Easier to use
Comprehensive software, complete reference designs, and SimpleLink Academy training

Key Features

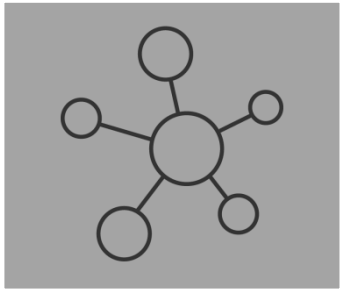
- Bluetooth 5 support
- 2.4 GHz support
- Sub-1 GHz support
- Low power operation
- Security accelerators
- Wi-Fi support
- 5GHz-Dual Band
- Ethernet MAC & PHY
- 14 bit ADC
- Integrated PA
- 105 deg. C
- Display support
- 12 bit ADC

Development
Sampling
Production

Texas Instruments

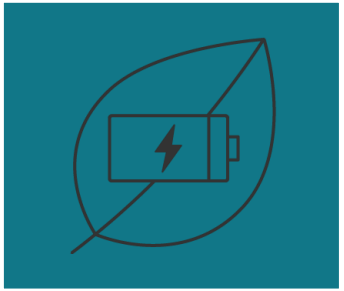
Why TI SimpleLink™ MCUs?

Scale



- Breadth of wireless technologies
- Concurrent multi-protocol
- Multi-band SD radio for LP IoT
- Dual-band Wi-Fi

Conserve



- Low energy radios
- Extended range
- ULP Sensor Controller
- Wi-Fi LP IoT
- Best-in-class standby

Secure

- FIPS 140-Level 1
- Offload CPU bandwidth – HW crypto accelerators
- Secure boot

Innovate

- BAW: First crystal-less wireless SoC
- Future-proof with 5GHz Wi-Fi

SimpleLink™ CC26xx hardware platform

SimpleLink™ Multi-standard CC26x2R

Key features and benefits

Connect the building, home and grid

with the lowest-power, multi-standard devices for Bluetooth 5, Thread and Zigbee

Consistently the lowest power in the industry – 10-year operation on a coin cell battery

- ✓ Ultra-low power sensor controller
- ✓ 0.8uA standby current

Expanded applications - enhanced features and more memory

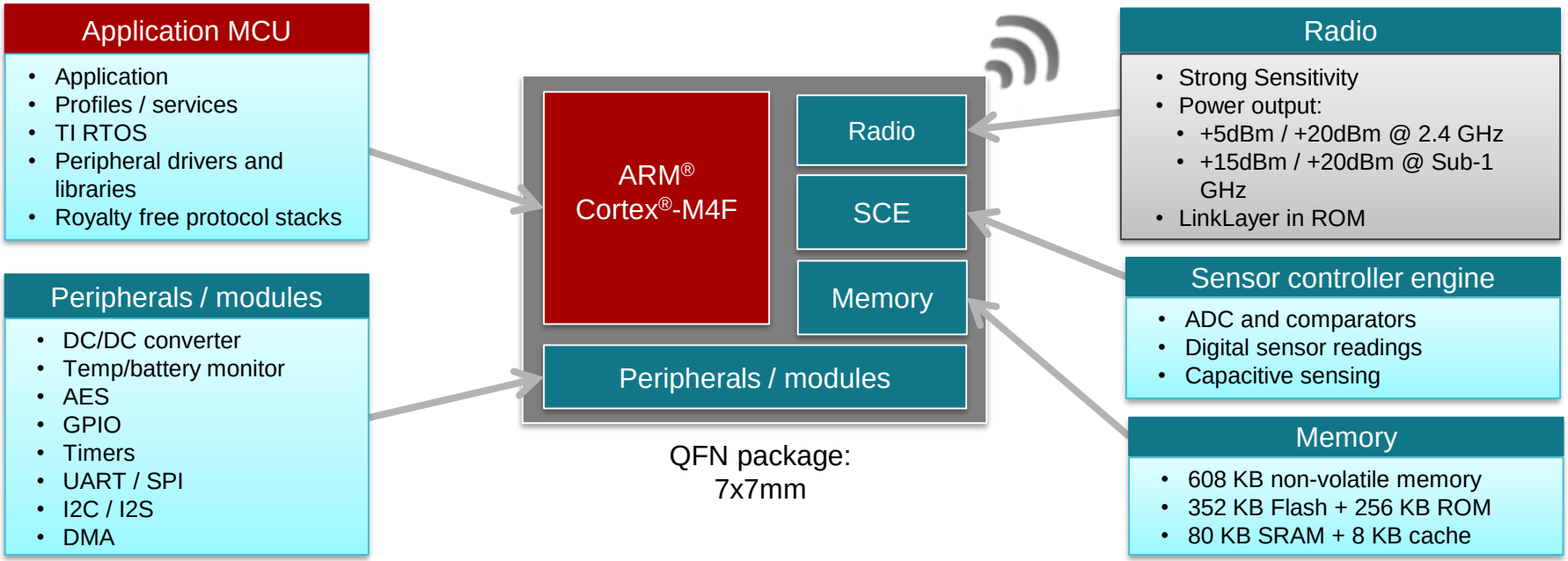
- ✓ Multi-standard support for Bluetooth® 5, Thread, and Zigbee
- ✓ 608 KB of non-volatile memory including 352KB flash, 256KB ROM (with BLE stack embedded), 80KB RAM
- ✓ Hardware security accelerators – AES-256, ECC and RSA public key, SHA2-512, True Random Number Generator (TRNG)

Fast time to market - comprehensive software offerings and training

- ✓ SimpleLink SDK with code portability to the SimpleLink platform devices
- ✓ SimpleLink Academy training environment

SimpleLink CC26x2R

One architecture, several technologies

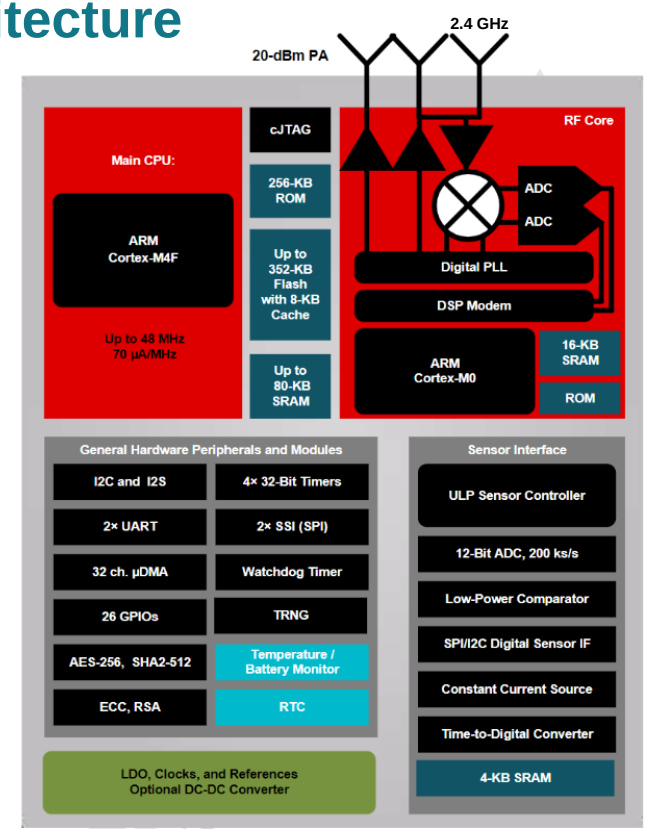


THREAD

Bluetooth® Low Energy

zigbee

SimpleLink CC26x2R
Architecture



Key Features

More memory
- 608 KB non-volatile memory
- 352kB kB Flash memory for application code + 256 KB ROM
- 80kB SRAM
- Device is equivalent to a 512kB device (including BLE5 stack, TI-RTOS, 15.4 High layer MAC in ROM)

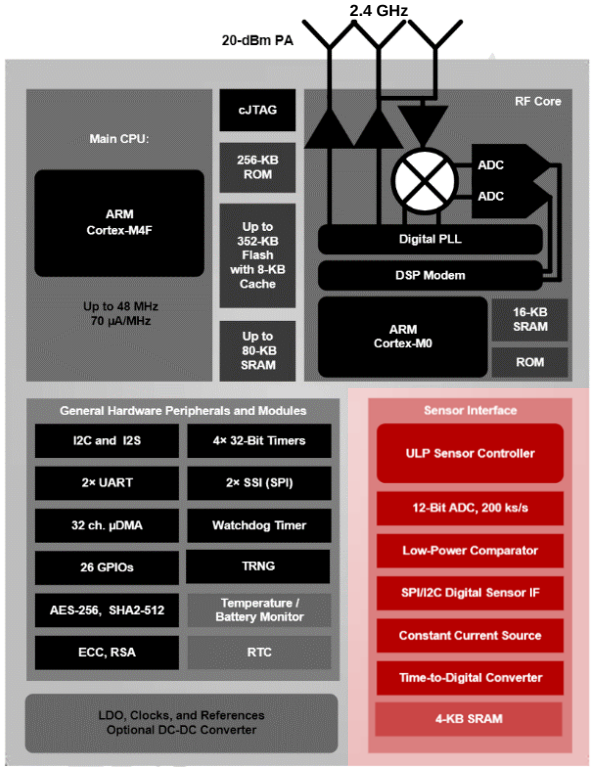
More peripherals
- Enhanced security (hardware acceleration, AES-128/256, SHA2-512, ECC, RSA-2048)
- 1 Additional UART

Lower power
- Faster start-up times
- Standby current as low as 0.9uA
- Ultra-low power sensor controller with current consumption as low as 1 uA during operation

More processing power
- ARM Cortex M4F core (1-cycle MAC, SIMD, floating-point)
- 7x7mm pin compatible with CC2640R2F

SimpleLink CC26x2R

Sensor controller



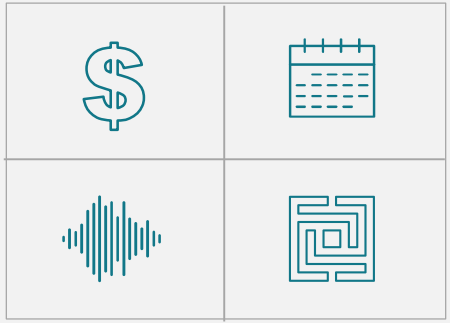
SPI reading - Wake ups per second	Cortex-M4, 48 MHz	Sensor controller, 24 MHz	Sensor controller, 2 MHz
1	2.4 uA	1.5	1.0 uA
20	25.4 uA	4.0 uA	1.4 uA
100	119 uA	15.6 uA	3.0 uA

Example application	Power consumption
Flow metering	**16-Hz:** 1.7 uA
Motion detector monitoring output from a PIR	**Reading Comp A @ 100 Hz:** 1.9 uA
Thermostat external temp sensor reporting back to main thermostat	**ADC sampling @ 1Hz:** 1uA

TI BAW – Crystal-less wireless MCU

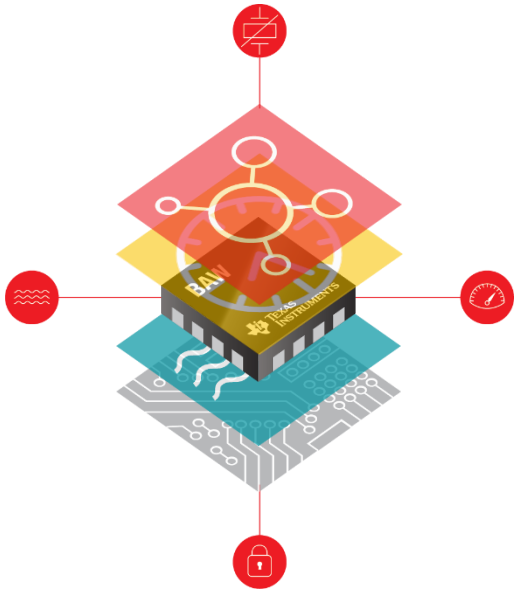
Current obstacles

Limitations of current clocking and quartz crystal devices



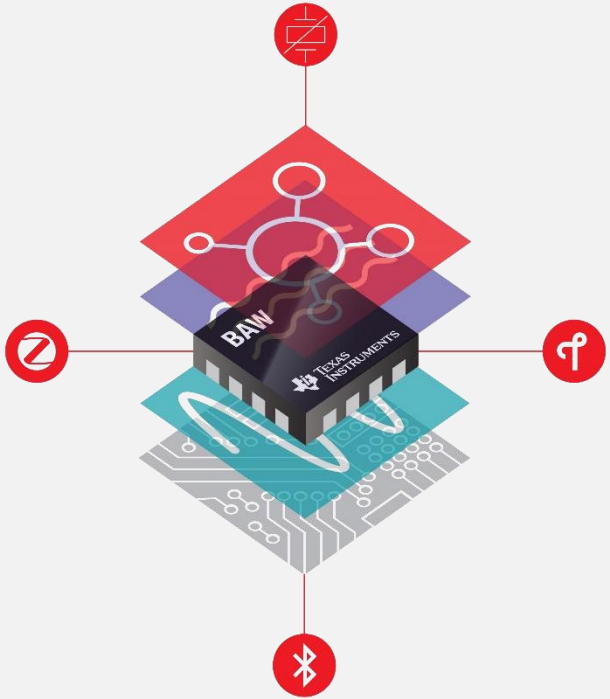
Going crystal-less is the next step in IoT evolution

Advancements in BAW technology propel us to the future

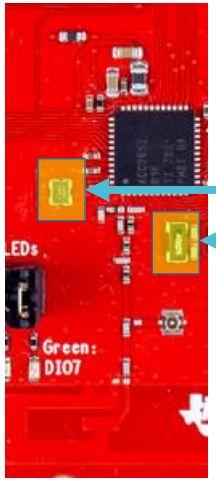


- ✓ Increased performance
- ✓ Simpler
- ✓ Lower cost
- ✓ Smaller size

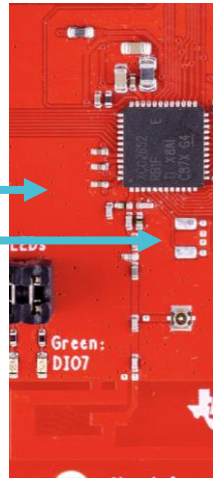
TI BAW – Crystal-less wireless MCU



Design with crystal



Design with BAW technology



12%

area savings with TI's BAW technology

ti.com/simplelink-baw

Featured Technologies

Bluetooth® 5

What's new with Bluetooth® 5?

Longer range, higher speed, more data, diverse applications.

Longer range

4x range

- 6 dB improved sensitivity through coding – same TX/RX current
- Whole-house coverage (1.5km range)

Learn more

Higher speeds

2x speed

- 500% increase in data throughput vs. Bluetooth 4.0 (2Mbps mode)
- CC2640R2F supports even higher throughput up to 5Mbps (proprietary)

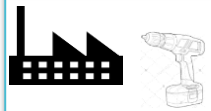
The secret to moving faster

Increased broadcasting capacity

8x data

- Transmit more intelligent data over a beacon (up to 248 bytes)
- Enable rich location/navigation applications

Explore Bluetooth 5

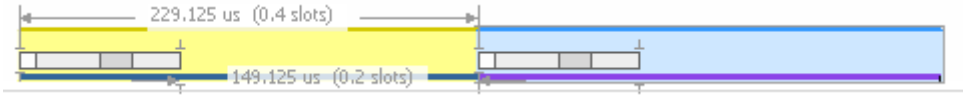
Home / building automation	Health / medical	Applicances	Retail	Logistics	Automotive	Industrial
						
Door locks, beacons smoke detectors, door bells, lights	Glucose monitors, patient monitors, drug delivery	Coffee-maker, vacuum, HVAC	EPOS card readers EPOS printers handheld transaction terminals	Anti-lost tags, asset tracking personnel locator	Remote keyless entry (RKE), passive-entry passive-start (PEPS), wire replacement	Power tools, e-meters, sensors

Bluetooth® 5: higher speed

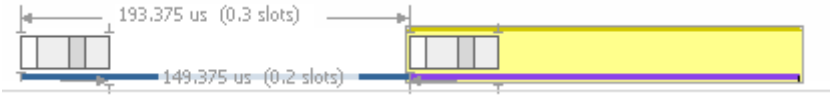
- Double symbol rate compared to 1M
- Almost half the energy consumption per frame
- Twice as fast?
  - Still inter-frame spacing of 150µs contributing to overhead
    - On the other hand, can use data-length extension

“Empty PDU” connection event

1M



2M



Master
(Samsung S8)

Slave
(CC2642)

Bluetooth® 5: higher speed

New 2Mbps LE PHY mode

- 2x throughput compared to BT4.x LE
  - 2 MSymbol/s rate un-coded
  - Backwards compatible with BLE4.x 1Mbps devices since LE Controllers negotiate link speed

BLE 4.0/4.1	BLE 4.2	BLE 5.0
• 1Mbps PHY • 27 byte PDU 305 kbps	• 1Mbps PHY • 27-255 byte PDU with Data Length Extension 780 kbps	• 2Mpbs PHY • 27-255 byte PDU with Data Length Extension 1.4 Mbps

Maximum throughput (LE) by specification

Bluetooth® 5: longer range

Increased receiver performance with LE-coded PHY

- Bluetooth Low Energy 4.x uses 1Mbps un-coded PHY
  - 1:1 ratio between transmitted data bits and over-the-air modulated symbols
  - Single bit error in transmission requires re-transmission of entire PDU (CRC error)
  - Good for low-noise or shorter range communication
- Bluetooth 5 introduces *Coded PHY* rates of 500kbps and 125kbps
  - Uses Forward Error Correction (FEC) to code the payload data bits 1:2
  - This can be used as is with a data rate of 500 kbps (N = 2 coding)
  - The bits can be expanded 1:4 (a ‘0’ expands to ‘0011’ and a ‘1’ is expanded to ‘1100’)
  - Gives a data rate of 125 kpbs (N = 8 coding)
  - More over-the-air modulated symbols are used for each actual data bit. This makes it easier for the receiver to distinguish the signal over noise and sensitivity improves
  - RX current consumption is unchanged compared to un-coded PHY

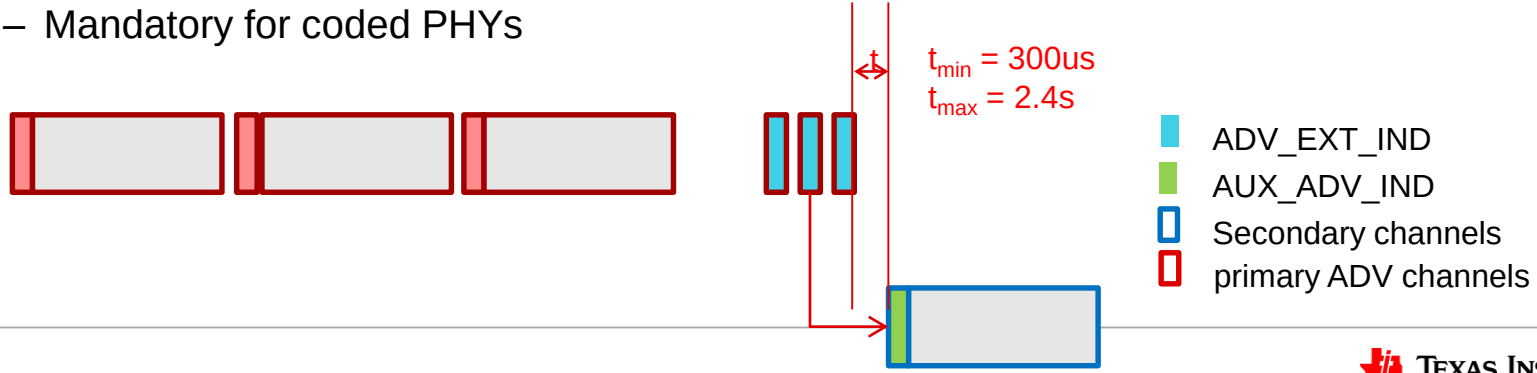
Bluetooth® link budget improvement

- RF link budget is the ratio between the transmit RF power and the receiver sensitivity level
- Link budget can be increased by:
  - Increasing output power
    - Which will increase current consumption
      - Current consumption typically increases signifincantly above 0 dBm for available BLE wireless MCUs
    - Data rate is unchanged
  - Improving receiver sensitivity through coding techniques
    - Current consumption is unchanged
    - Data rate is reduced
    - Leveraged in BT5 Coded PHYs (500 kbps and 125 kbps)

Bluetooth® 5: advertisement extension

- Legacy Bluetooth Low Energy advertisement
  - Primary channels: 37, 38, 39
  - PDU size 6-37 bytes at 100ms non-connectable or 20ms connectable max rate
  - PHY: 1Mbps only

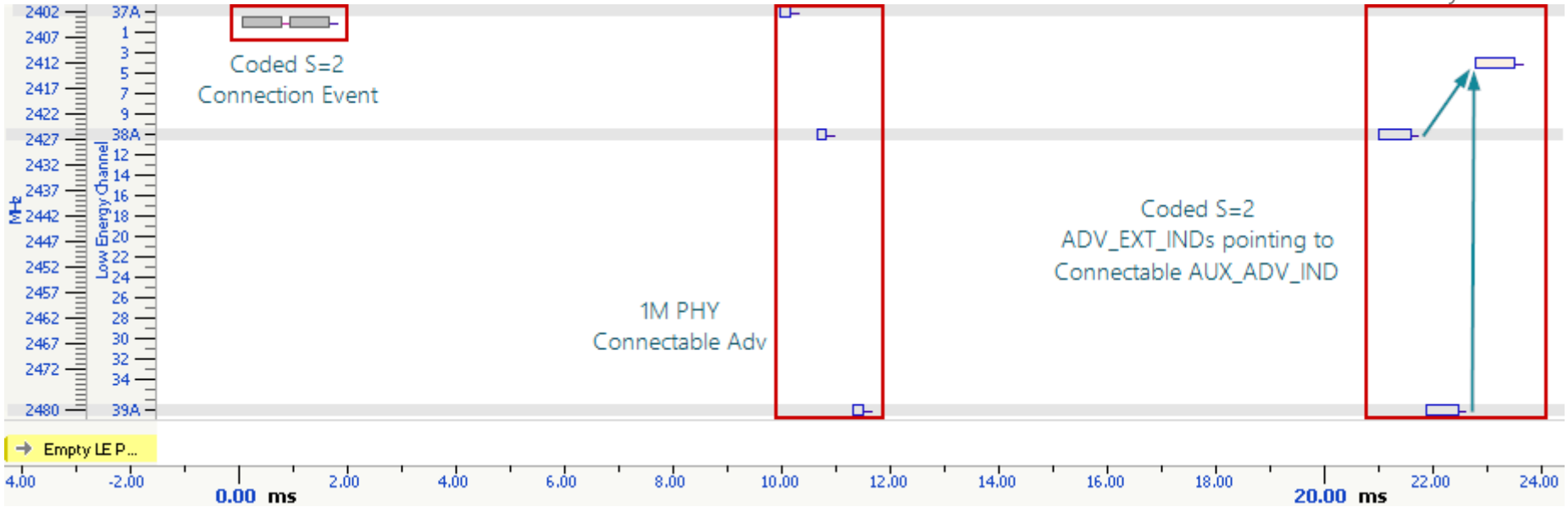
- New advertising channel extension PDU: **ADV_EXT_IND**
  - Allows up to 248 byte ADV payload by offloading payload to data channels
  - Supports any PHY
  - Reduces traffic on ADV channels
  - Mandatory for coded PHYs



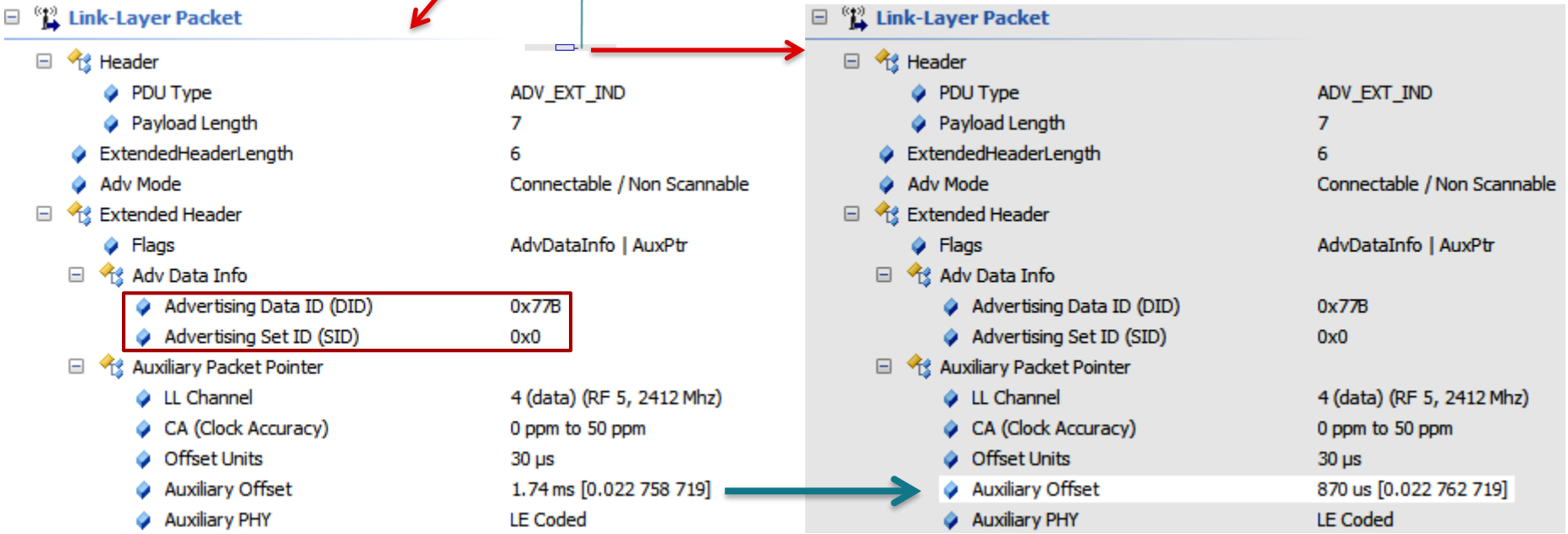
Advertisement extensions (AE)

- Simple peripheral
  - Connection event on coded PHY
  - Connectable advertising on 1M and coded.

Screenshot from Ellisys Tracker



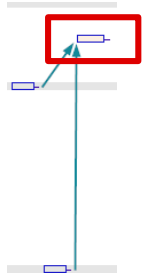
ADV_EXT_IND coded PHY pointer to coded



- No advertiser address but has data ID and det ID to prevent unneeded scans

AUX_ADV_IND – coded PHY data / pointee

- Like a normal advertisement
- Extra headers
  - Can point to even more data
  - Does not have to include adv addr



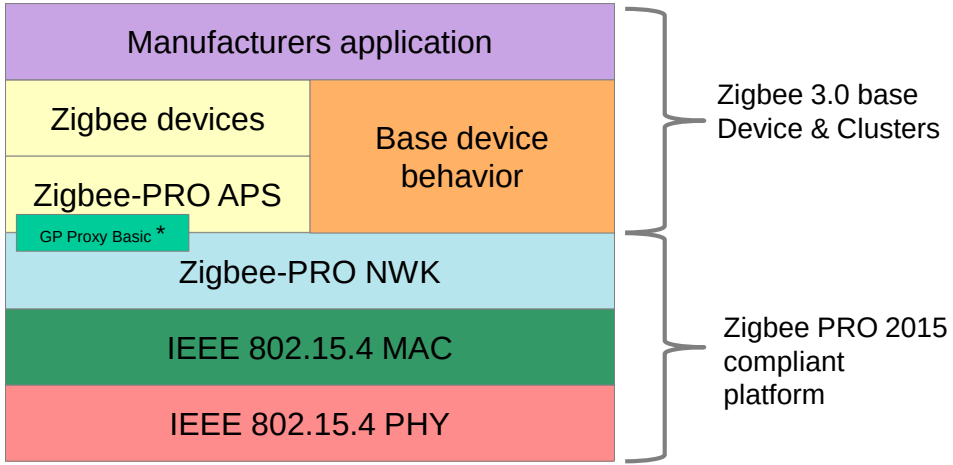
Link-Layer Packet

Header	
PDU Type	AUX_ADV_IND
TxAdd	Public
Payload Length	17
ExtendedHeaderLength	9
Adv Mode	Connectable / Non Scannable
Extended Header	
Flags	AdvA | AdvDataInfo | Adv Data
Advertising Address	00:17:E7:9F:61:27
Adv Data Info	
Advertising Data ID (DID)	0x77B
Advertising Set ID (SID)	0x0
Advertising Data	
Raw Adv Data	02 01 06 03 02 F0 FF
Flags	
LE Limited Discoverable Mode	No
LE General Discoverable Mode	Yes
BR/EDR Not Supported	Yes
Simultaneous LE and BR/EDR (Controller)	No
Simultaneous LE and BR/EDR (Host)	No
Service Uuids (More available)	
Uuid 1	0xFFF0

Featured Technologies

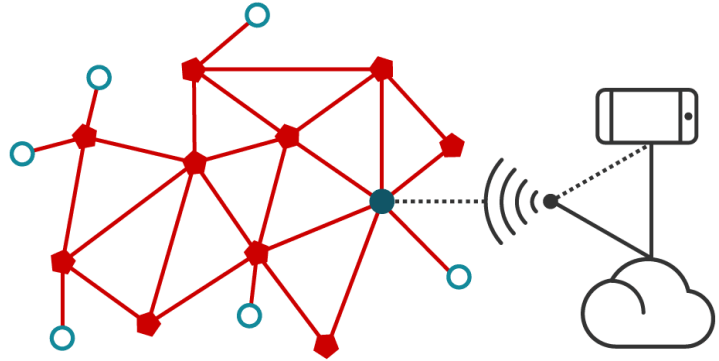
TI’s dynamic multi-protocol manager (DMM)

What is Zigbee?
Architecture and technical details



*Zigbee Green Power Proxy Basic is required for all routing devices

Zigbee software architecture



Zigbee Coordinator

- Starts the network
- Routes the packets
- Manages security
- Associates routers and end devices
- Example: smart hub, heating central

Zigbee Router

- Routes packets
- Associates routers and end devices
- Example: light

Zigbee End Device

- Battery powered
- Typically asleep
- Does not route packets
- Example: light switch

Zigbee mesh network topology

What is Zigbee?
Device types

Coordinator

- Monitoring & control
- HVAC
- Smart home controller
- Gateway

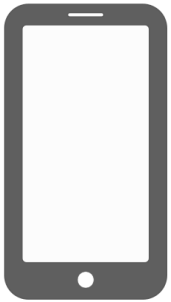
Routers

- Lights
- Shades/blinds
- Fans
- Smart appliances
- Thermostat
- Garage door
- Displays
- Smoke/Gas detectors

End devices

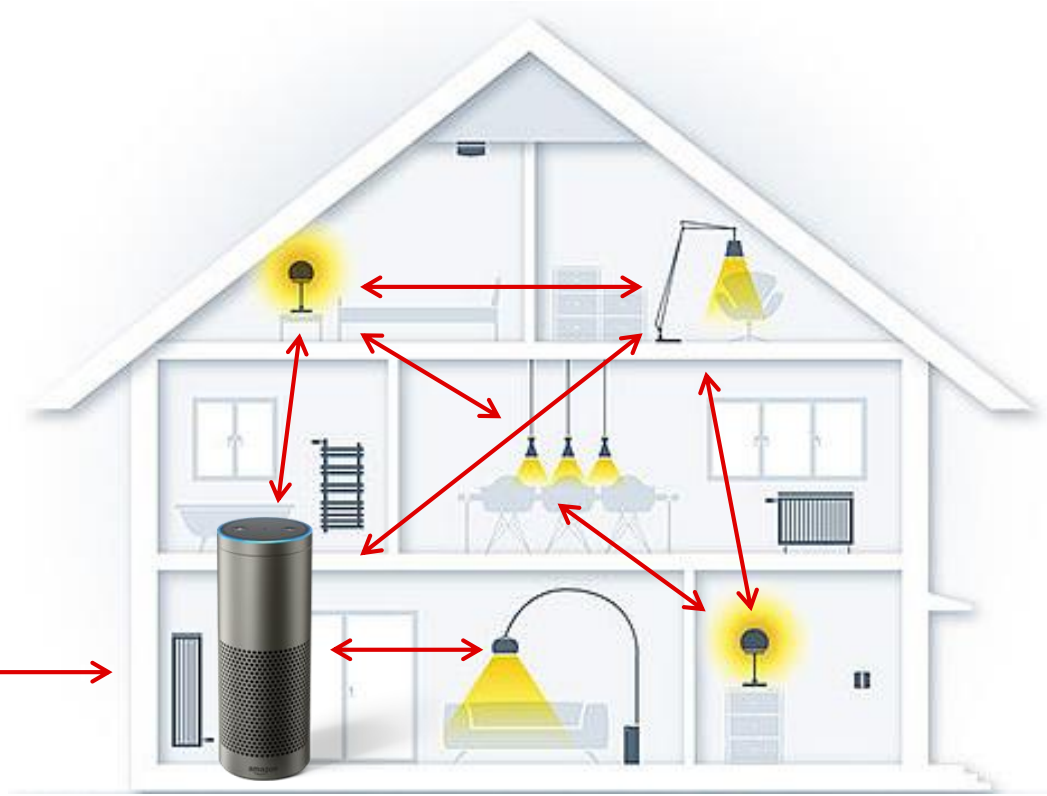
- Portable switches
- Door/window/motion sensor
- Ambient sensors
- Smoke/gas detectors (battery powered)

DMM in building automation



BLE

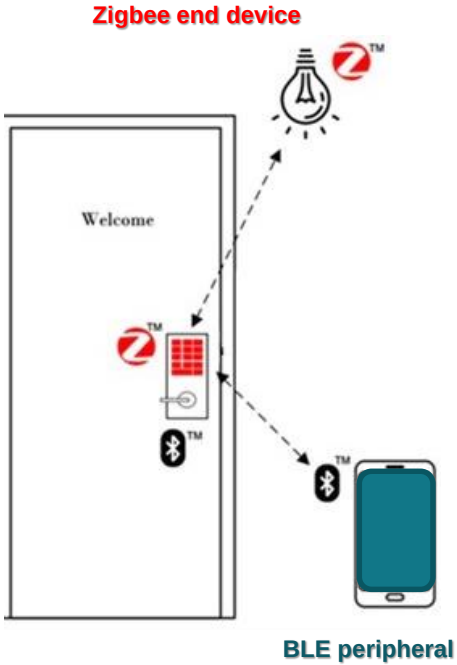
Zigbee



Existing Zigbee home network

Zigbee + Bluetooth® Low Energy: 1 chip, multi-protocol solution

Introducing the dynamic multi-protocol manager

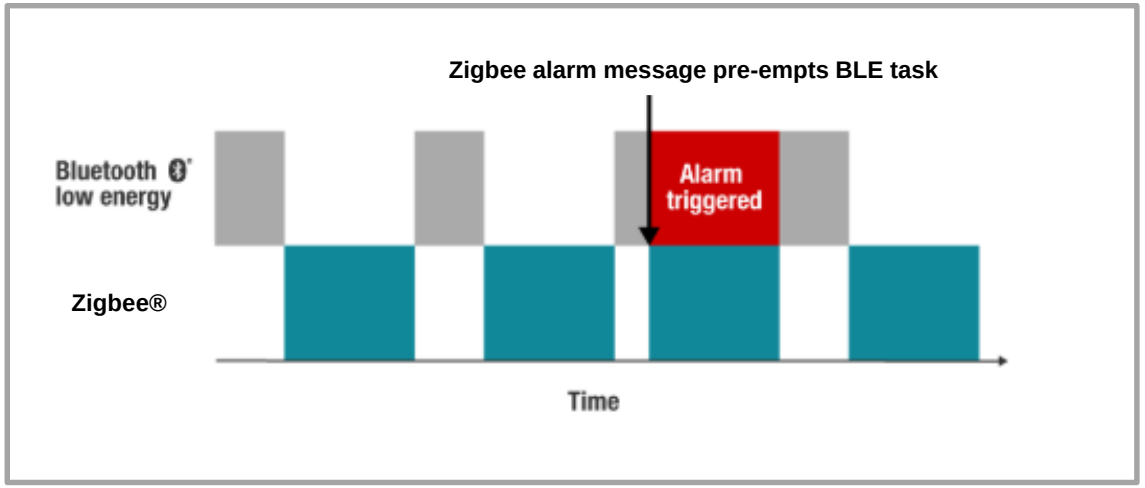


- Previously, this system could require 3 separate products:

- Now with the DMM, TI has a multi-protocol solution with only one chip:

Future-proof:
Add concurrent mode *Bluetooth*® Low Energy to your network

- Powered by innovative software IP - dynamic multi-protocol manager
- Allows multiple stacks to run on the same device running concurrently
- Uses a policy manger and scheduler to dynamically arbitrate the RF resource
- Makes scheduling decisions based on the current policy decision which the developer can change to suit their needs

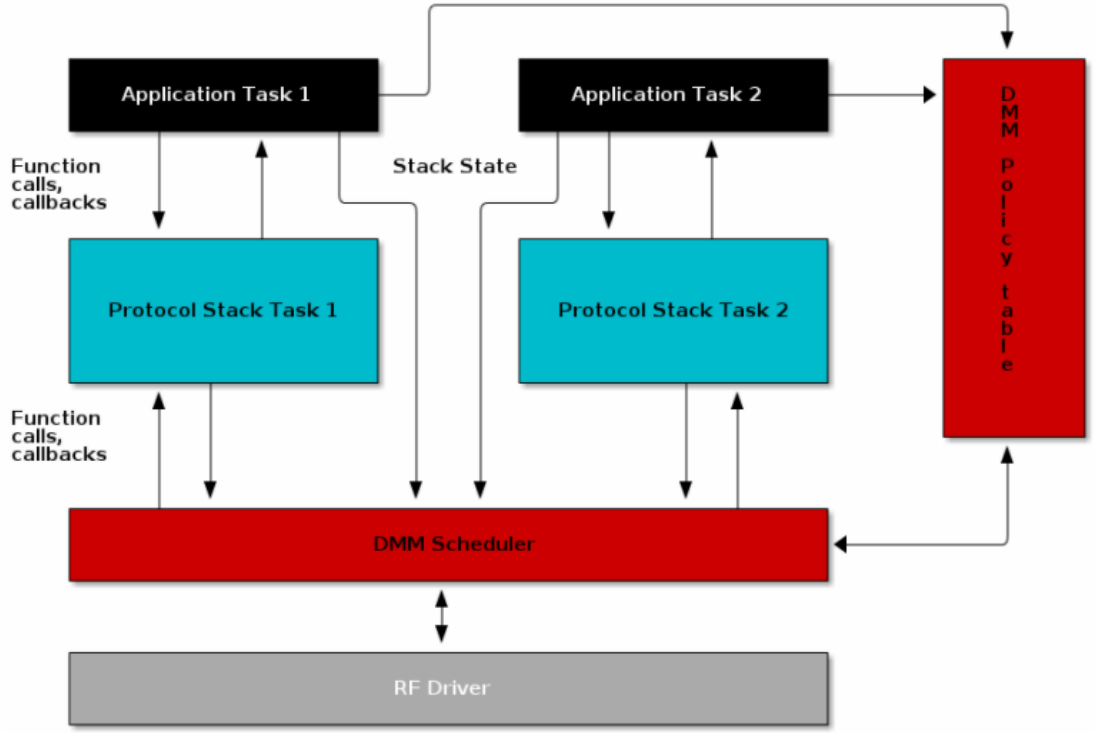


DMM architecture overview

- The DMM will intercept calls to the RF driver & can potentially modify the order in which commands are scheduled based on requirements of the stack & application

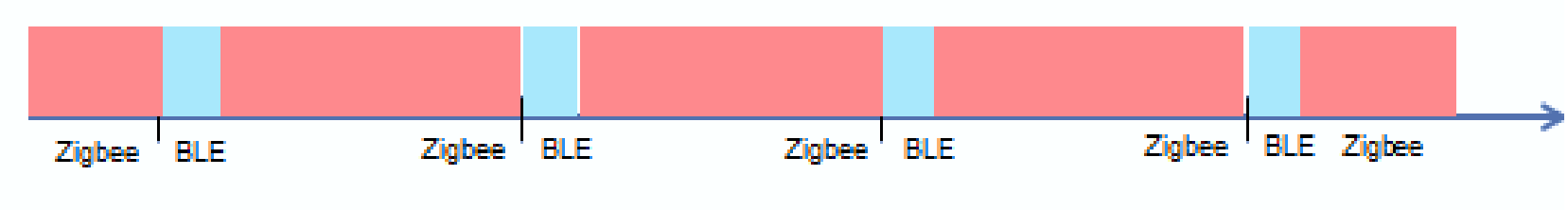
- The scheduler will inspect the command sent to the RF driver & based on policy will:
  - Schedule command as is
  - Cancel command
  - Change priority of command based on current policy & stack state

- PHY Switchover Time 400 usec (600 usec application level)



Bluetooth® Low Energy + Zigbee: 1 chip, multi-protocol solution

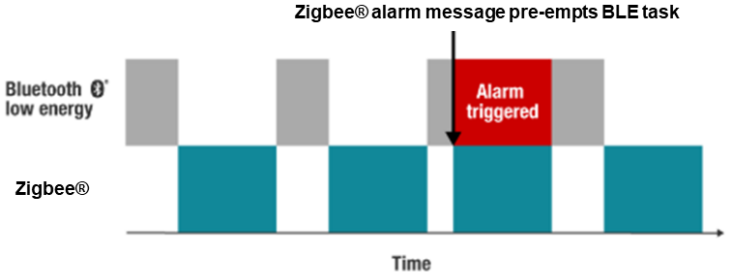
- Using TI's multi-protocol solution, the DMM can allow Zigbee and BLE to run concurrently on a single chip.
- For example, adding a light switch into a Zigbee home network becomes highly simplified by using a BLE interface.
- With a Zigbee end device, you can add BLE connectivity to your phone. This end device will be in RX most of the time, and BLE will have periodic connection events.

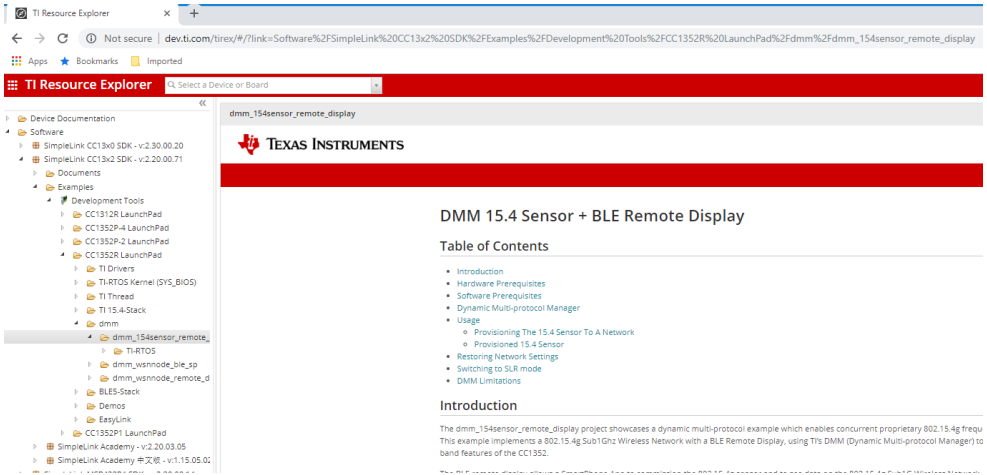


Hands-on:
Bluetooth® Low Energy + Zigbee

Bluetooth® Low Energy + second network concurrent mode available today

- Web landing page
- Technical note
- SW examples (BLE + Sub-1GHz, BLE + Zigbee)

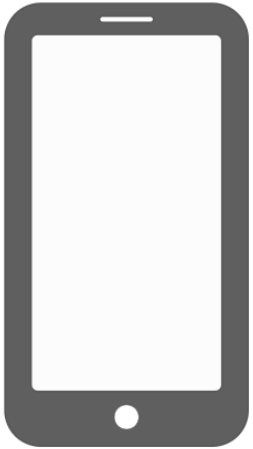




Step 0: set Up

Zigbee coordinator light

Zigbee end device and
DMM switch



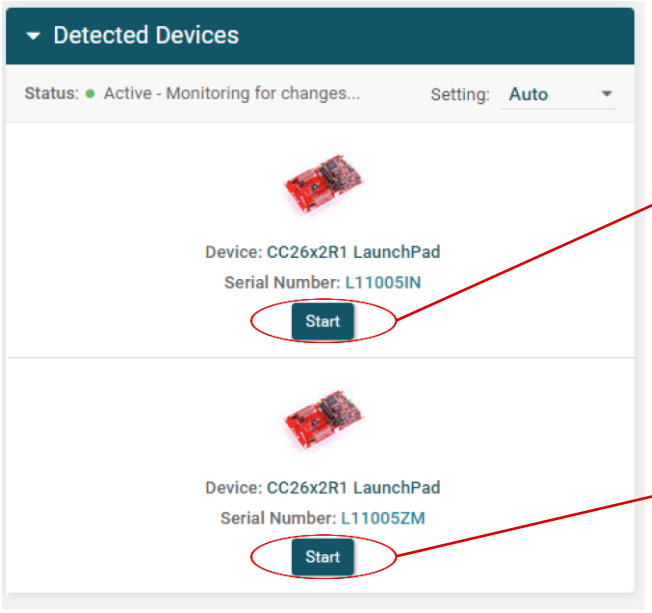
BLE peripheral

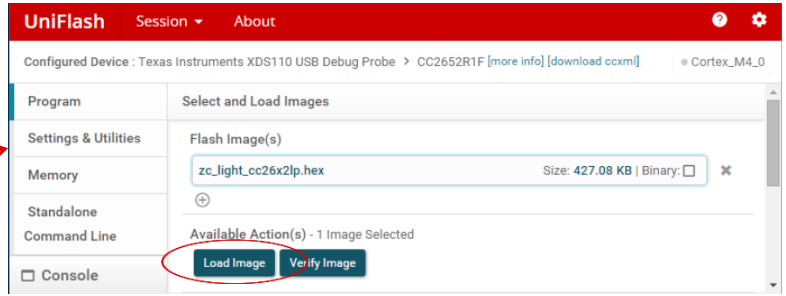
Start with 2 CC2652R devices:

- One is a Zigbee coordinator light (we will denote as ZCL)
- The other is the DMM switch and Zigbee end device (we will denote as ZED)

Step 1: flash the devices

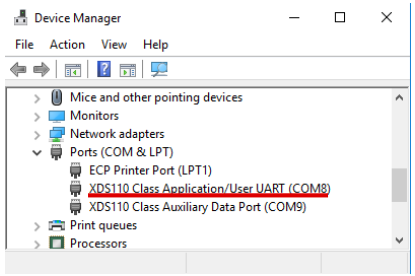
- Flash with the binary files provided using Uniflash
- Flash one device with the DMM Switch Application and the other with the ZigBee coordinator light application provided in the `images/` directory

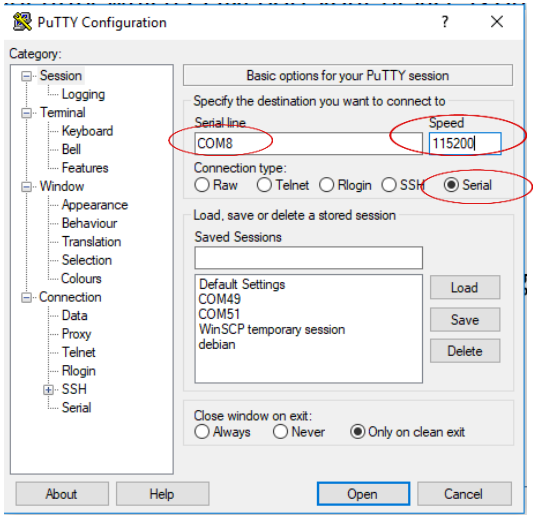




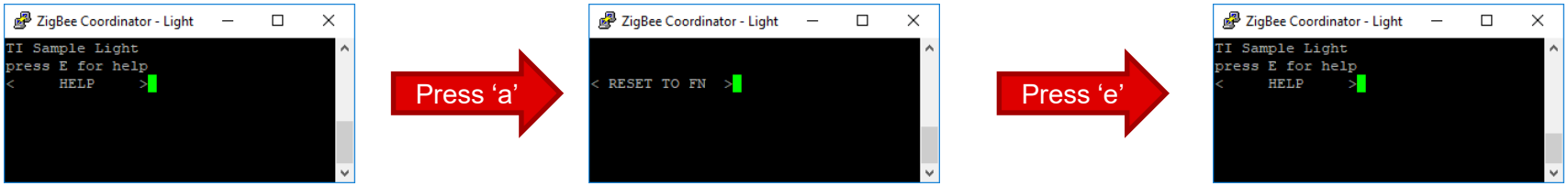
Step 1: flash the devices (cont.)

- After the devices have been flashed open up a putty session to view the serial output for **BOTH** device.
  - Use the windows Device Manager to identify which COM port your device is on.



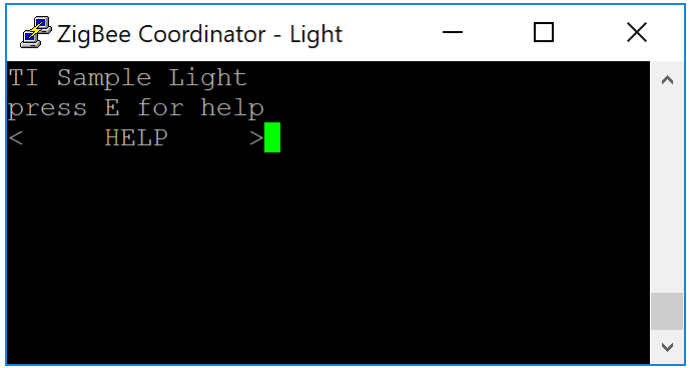


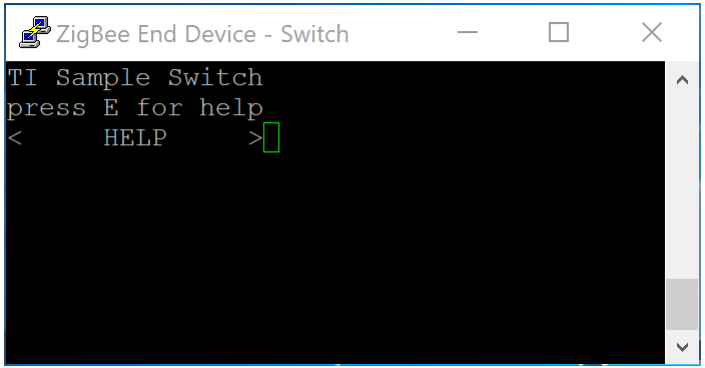
- Verify **BOTH** devices have a cleared non-volatile storage section by ‘Resting to factory new’



Step 1: flash the devices (cont.)

- You have now flashed a Zigbee coordinator light application and a Zigbee end device switch application!

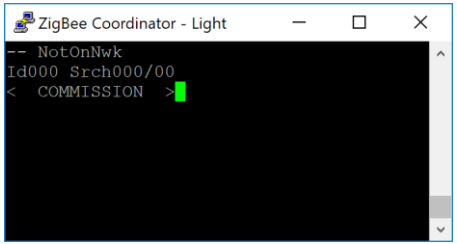




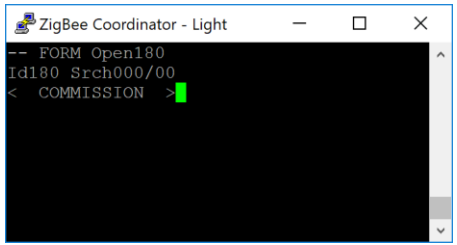
- Please press ‘e’ while on in this menu to learn how to navigate the Zigbee menus.

Step 2: open Zigbee network for connections

- Navigate to the “COMMISSION” menu on the coordinator device:



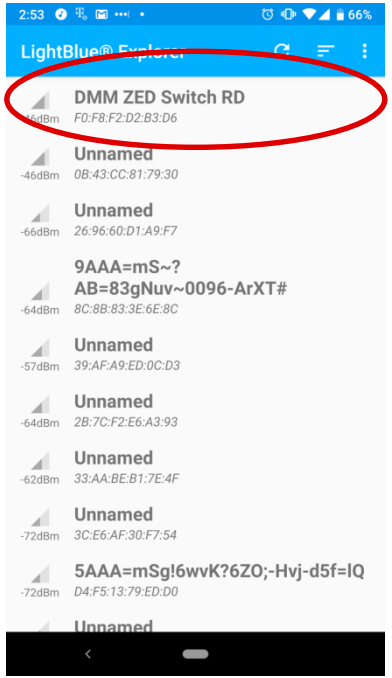
- After selecting the “COMMISSION” menu item, the network will be open for new devices to join for 180 seconds:



- The coordinator board light will blink green here to indicate that it is open for connections

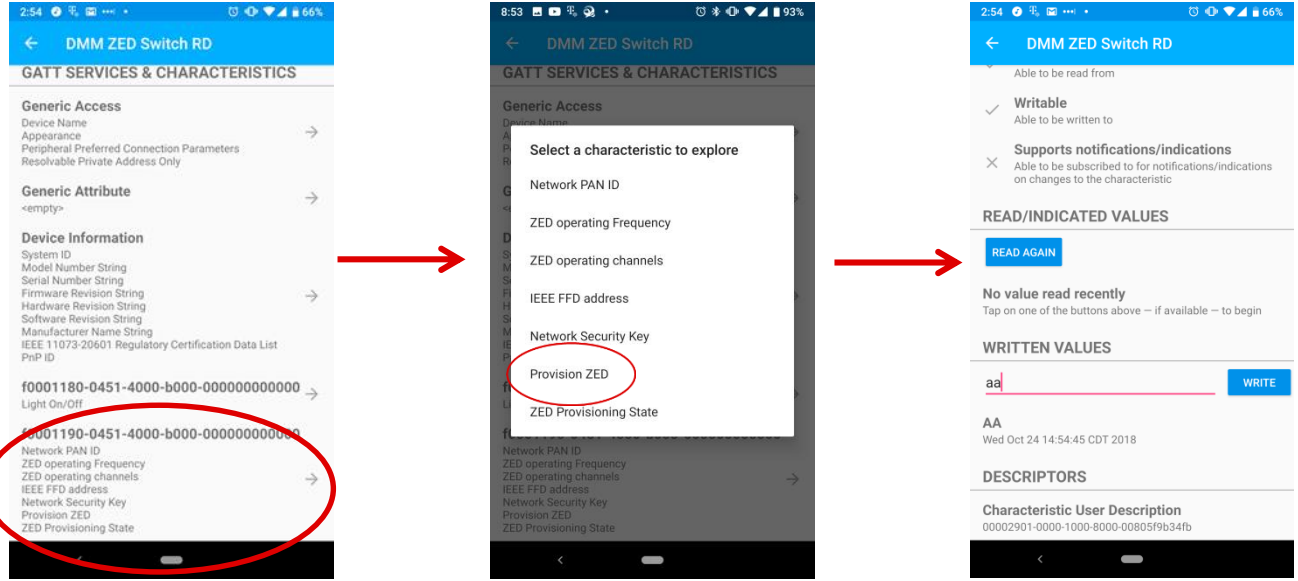
Step 3: connect to BLE on your phone

- Open the LightBlue app (available on both iOS and Android), and select the DMM ZED Switch



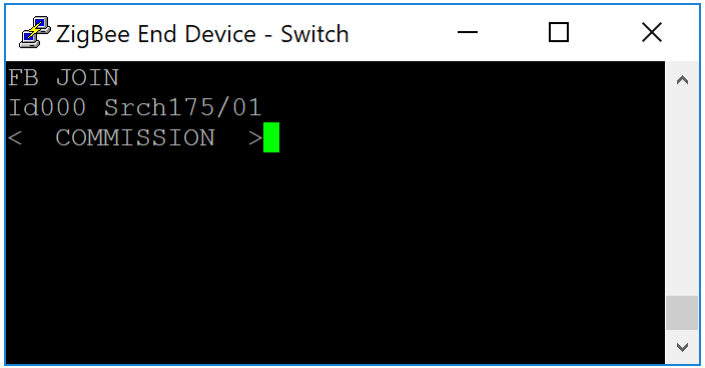
Step 4: provision the switch

- After connecting to the DMM switch, scroll down and select the provisioning characteristic
- Write a value of “aa” to the switch



Step 4: provision the switch

When the switch has joined the network, the green LED on the ZED board will turn on, and this will display on the terminal to indicate that the switch is connected to the light

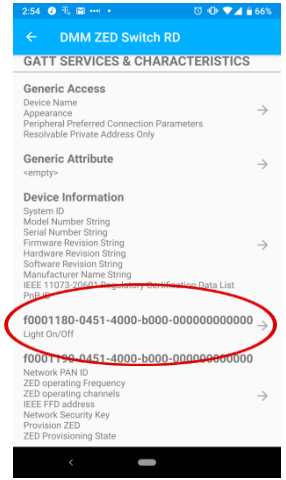


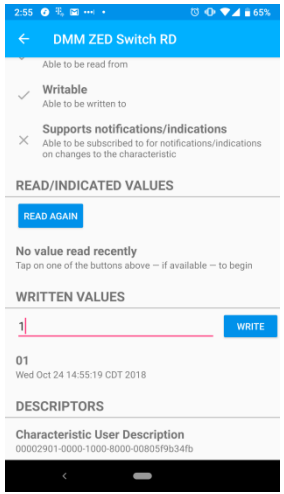
Note: If your switch has joined a network but is not controlling your light correctly – it might be on the wrong network

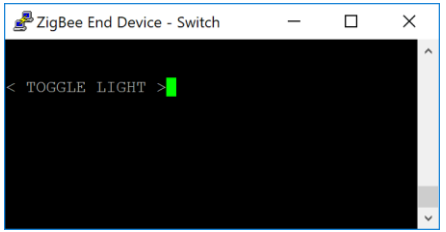
To resolve, check PAN ID to make sure that the network matches, and that you are connected to your own coordinator light

Step 5: turn light on and off

- Go back to the DMM switch page in the LightBlue app, and select the “on/off” characteristic
- Write a value of “1” to the “on/off” characteristic
- The ZED switch UI will move over to the 'TOGGLE LIGHT' menu, and the ZCL red LED should turn on:

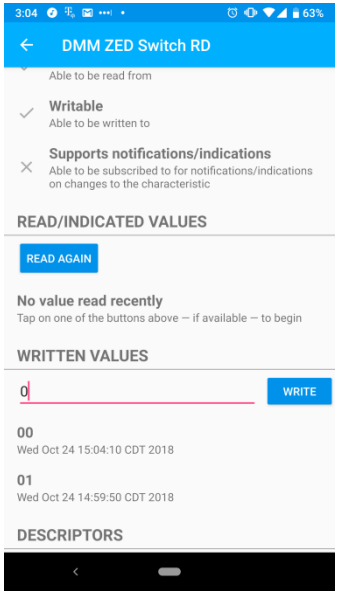






Step 5: turn light on and off

- Similarly, try writing a value of “0” to the “on/off” characteristic
- The ZCL red LED should turn off:



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