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BT-203

Everything You Need to Know About Bluetooth 5.4

Petteri Paatsila | August 22-24th, 2023



Agenda

- 01 Why Bluetooth 5.4?
- 02 Bluetooth 5.4 new features
- 03 Demo on BT ESL
- 04 Silicon Labs Offering
- 05 Summary

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Target Markets and Use Cases

Why Bluetooth 5.4?



- Need for standardized large scale star networks
 - Capability to host thousands of nodes
 - Encrypted data traffic
 - Ultra-low power consumption
 - Driven by electronic shelf label (ESL) market
- Enhancements
 - Optimizing access to secure data
 - Better control for LE Coded PHY for extended advertising

Bluetooth 5.4 – Target Markets & Use Cases



SMART RETAIL

- Electronics Shelf Labels
- Shelf Sensors



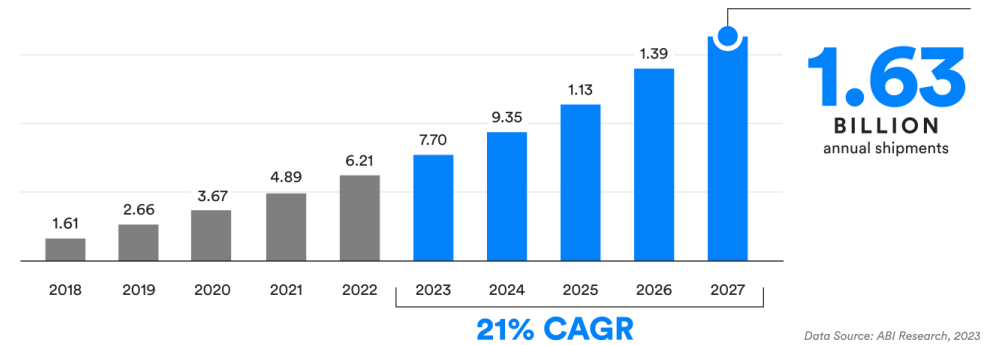
INDUSTRIAL

- Manufacturing & Logistics
- Digital Signage
- Asset monitoring

Source: <https://www.bluetooth.com/2023-market-update/>

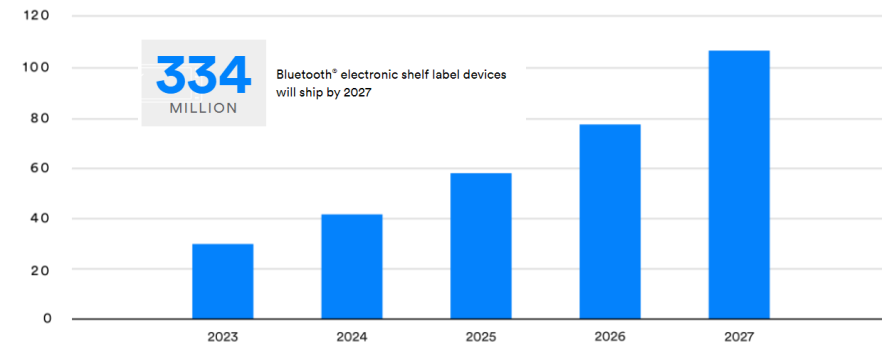
Annual Bluetooth® Device Networks Device Shipments

NUMBERS IN BILLIONS

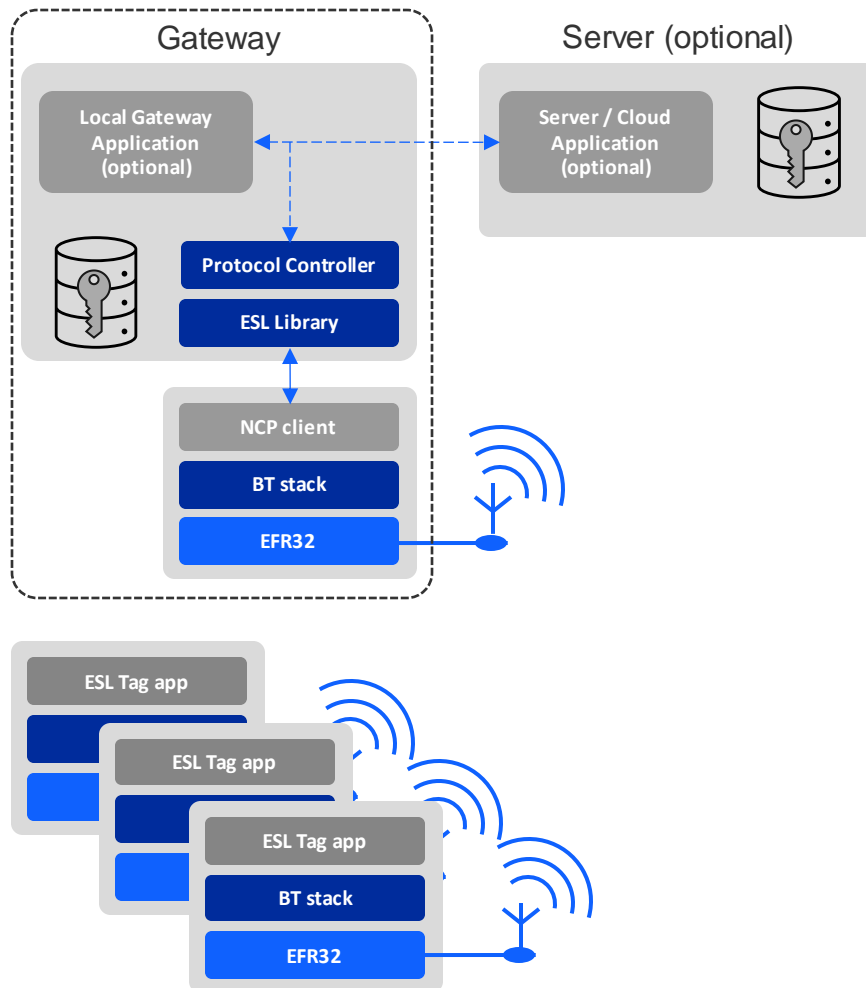


Annual Bluetooth® ESL Shipments

NUMBERS IN MILLIONS



Use Case – Electronics Shelf Label (ESL)



ESL system operation

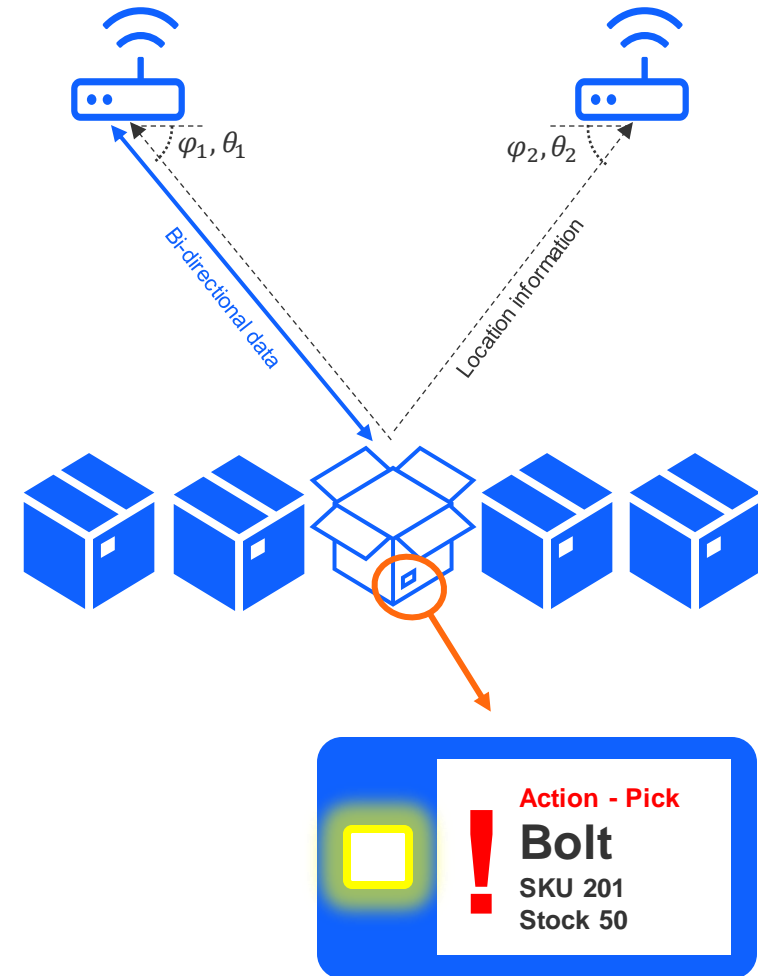
- Server
 - Hosting a cloud application
 - Managing an ESL system including load balancing and secure keys
 - Provide pricing information and generating the ESL display images
- Gateway
 - Managing a star network and connection to the ESL tags that are allocated to it
 - Communicates to cloud
 - Contains an access point radio
- ESL tag
 - Battery operated device exposing pricing and product information to consumers
 - Wireless connection to gateway

Benefits of Bluetooth

- Standardized communication between access point radio and ESL tag with Bluetooth ESL Profile and Service
- Capability to implement large scale bi-directional one to many network addressing 32 thousands ESL tags with a single access point radio
- Fully encrypted data traffic

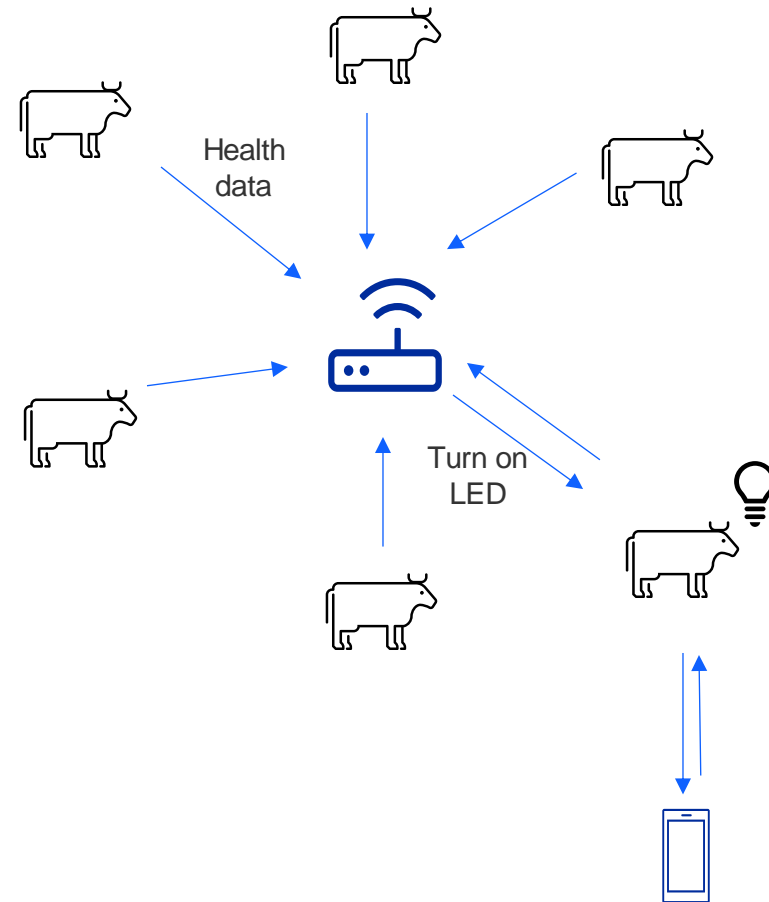
Use case – Manufacturing and Logistics

- Manufacturing and logistics use case
 - Core system structure similar with ESL
 - Indicate storage box content and stock status
 - Light guided operations
 - Improve worker efficiency
 - Pick by light for item picking operations
 - Put by light for replenishment operations
 - Location services
 - Indicate location of moving items
- Benefits of Bluetooth
 - Ultra-low power bi-directional large-scale networking
 - Fully encrypted data traffic
 - Bluetooth offered location services



Use case – Agriculture

- Cattle tags
 - Animal health data – temperature, movements, analytics
 - Two-way comms to aid in identification, OTA updates
 - No display, no HMI
- Benefits of Bluetooth
 - Standardized low-power protocol
 - Mobile device for point-to-point connection for commissioning, data downloads
 - Coded PHY for extended range
 - Location services
- Bluetooth v5.4 features
 - PAwR – keep devices in sync while enabling long sleep periods and two-way communication
 - EAD - protect the advertisement data and network from malicious attempts



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New Features

Bluetooth 5.4 and ESL Profile and Service

Bluetooth 5.4 New Features



Periodic Advertising with Responses (PAWR)

Provides energy efficient, large-scale, and bi-directional one-to-many communication topology



Encrypted Advertising Data (EAD)

Feature to the secure broadcasting of data in advertising packets



LE GATT Security Levels Characteristic

Devices can indicate the security mode and level required for all their GATT functionality to be available



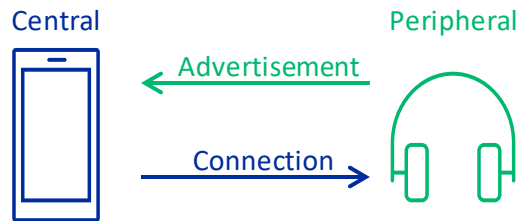
Advertising Coding Selection

The Host can specify which of two supported long range coding options are used with LE extended advertising

Advertising Modes in Bluetooth 5.4

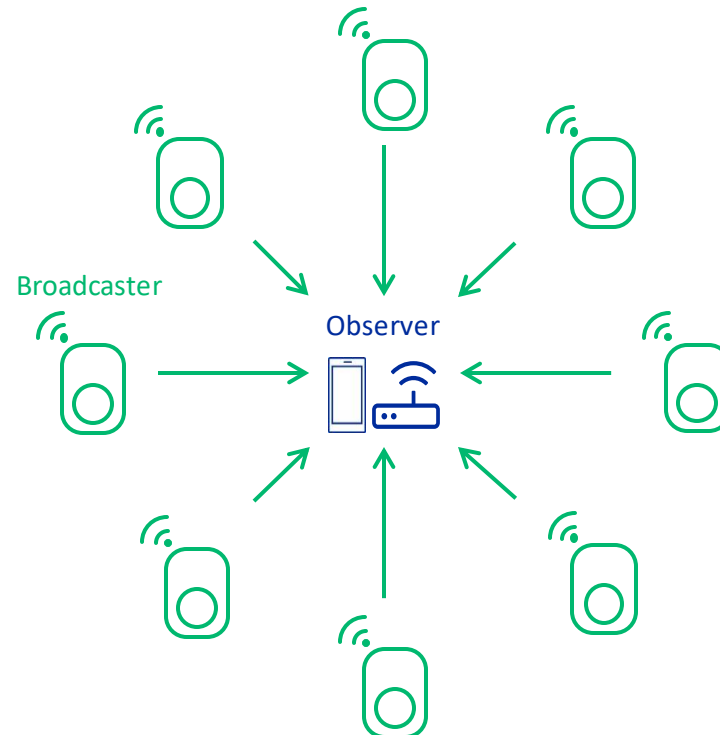
Advertising for Connection

(irregular, unidirectional)



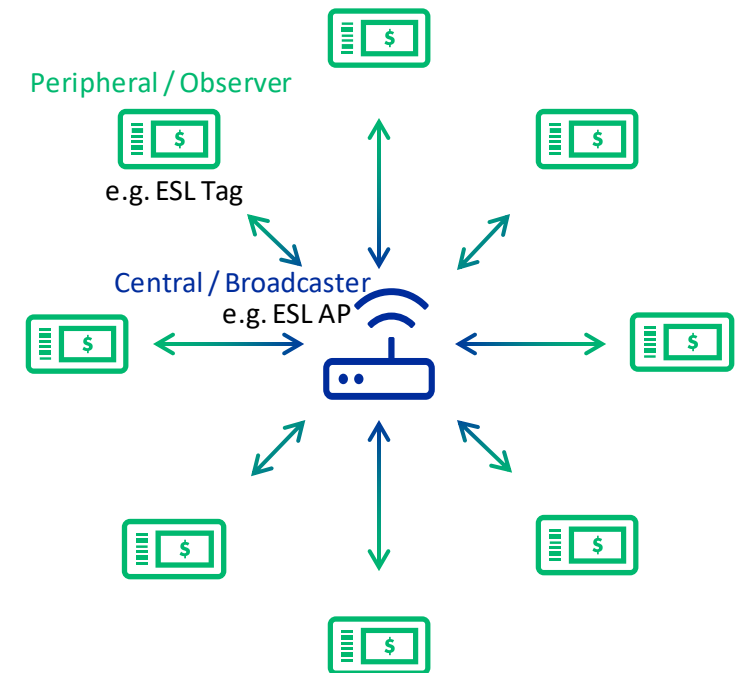
One-way "Beaconing"

(regular, unidirectional)



Periodic Advertising with Responses

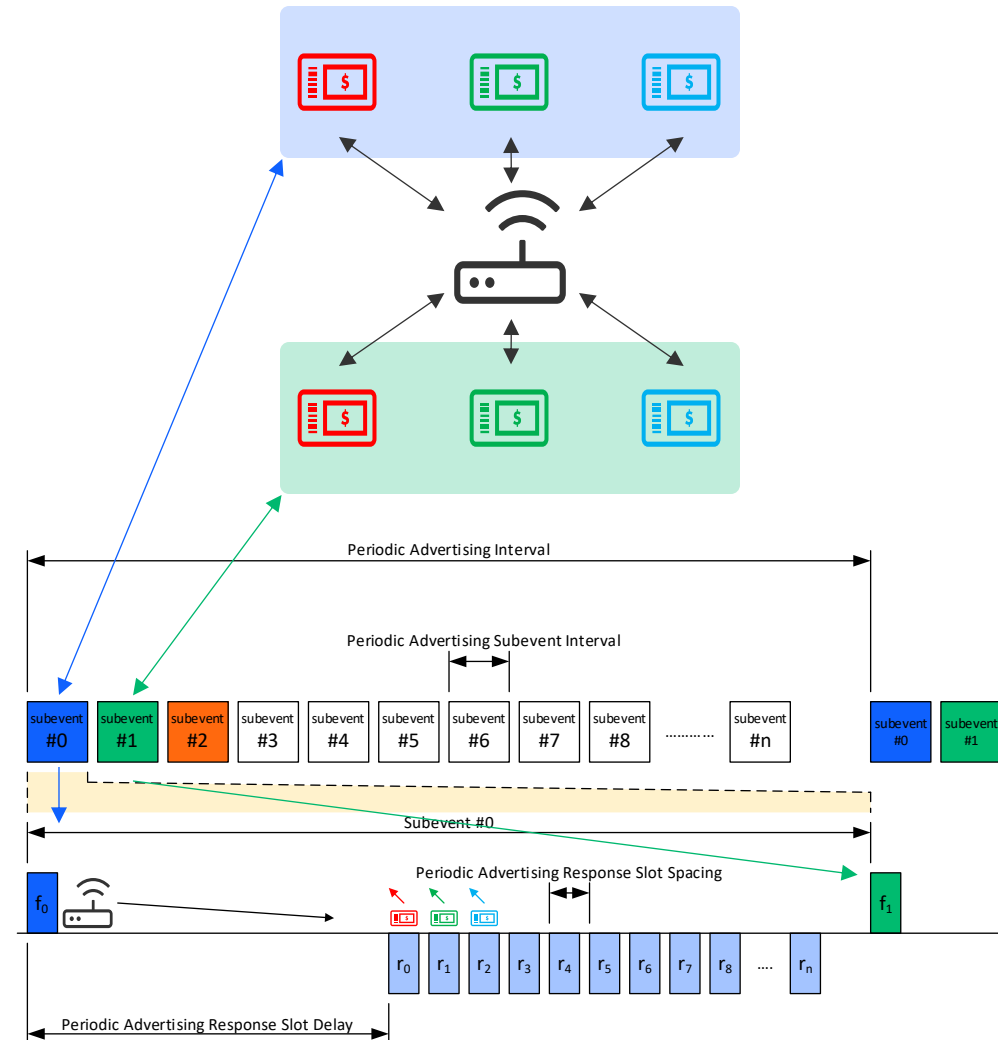
(regular, bidirectional)



New mode enabling "Synchronized" mode network. Used by BT ESL.

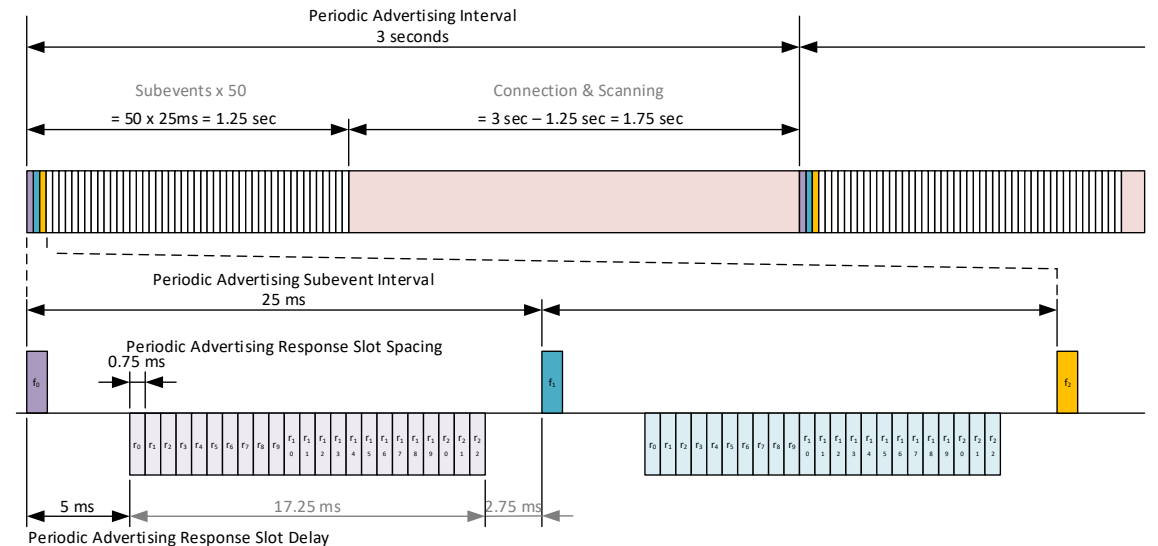
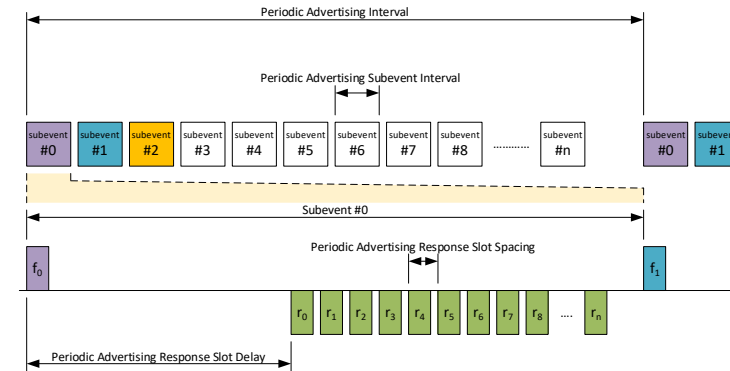
Periodic Advertisement with Responses (PAwR) Explained

- PAwR train setup
 - Sets timing parameters
 - Configure number of Subevents and Response Slots
- Subevents
 - Each Peripheral (ESL) belongs to one Subevent
 - Maximum 128 Subevents (ESL Group)
 - 255 unique ESLs in one ESL Group
 - Total max 32,640 Peripherals in the network
- Inside a Subevent
 - All Peripherals in one Subevent receive the Central Device transmission (downlink)
 - ▶ Keeps up the synchronization to the PAwR train
 - ▶ Transmits downlink payload data
 - Each Peripheral has its own Response Slot to reply (uplink)

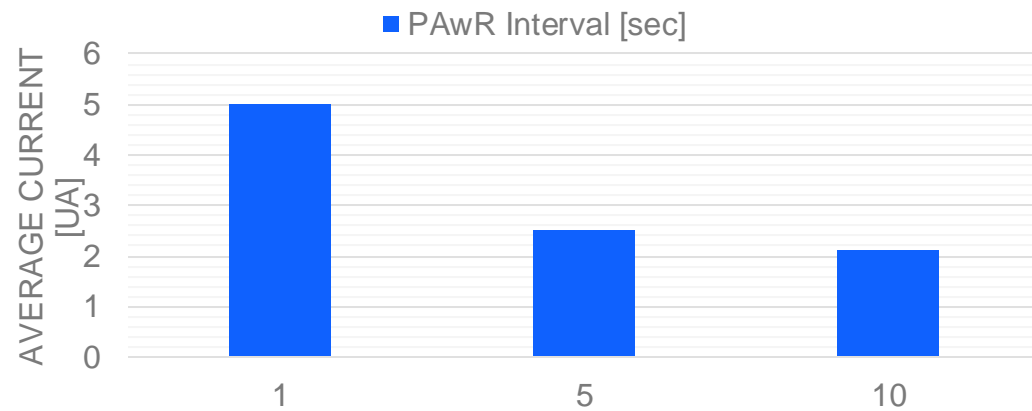
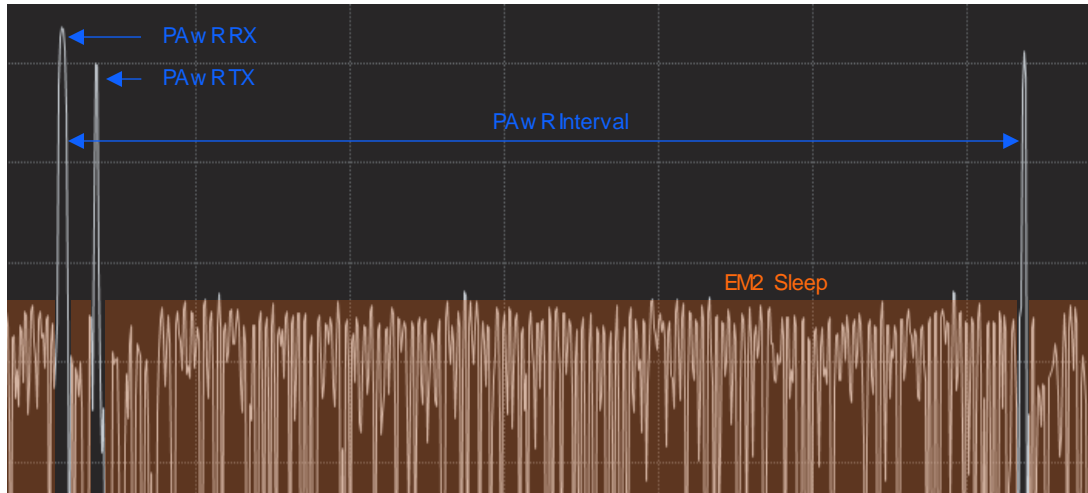


PAwR Example with 10000 ESLs and 3 second latency

- Number Subevents
 - 50
- Number of Response Slots (= ESL per Group)
 - 200
- Periodic Advertising Interval
 - 3 seconds
- Response Slot Duration
 - 0.75 ms
 - ESL Max Payload = 72 bytes => 0.75ms including T_IFS (1Mbps PHY)
- Periodic Advertising Subevent Interval
 - 25 ms
 - 5 ms Periodic Advertisement Response Slot Delay
 - 23 Response Slots x 0.75 ms = 17.25 ms for Response Slots
 - 2.75 ms gap between Subevents
- Single ESL Access Time
 - 3 seconds
- Total Time to access 10000 ESLs:
 - $\text{ROUNDUP}(200 / 23) = 9$
=> 9 Advertising Intervals x 3 sec = 27 seconds
- Time for Connection & Scanning
 - $3 \text{ sec} - (50 \times 25 \text{ ms}) = 3 \text{ sec} - 1.25 \text{ sec} = 1.75 \text{ sec}$



Example of PAwR Current Consumption



Peripheral device use case

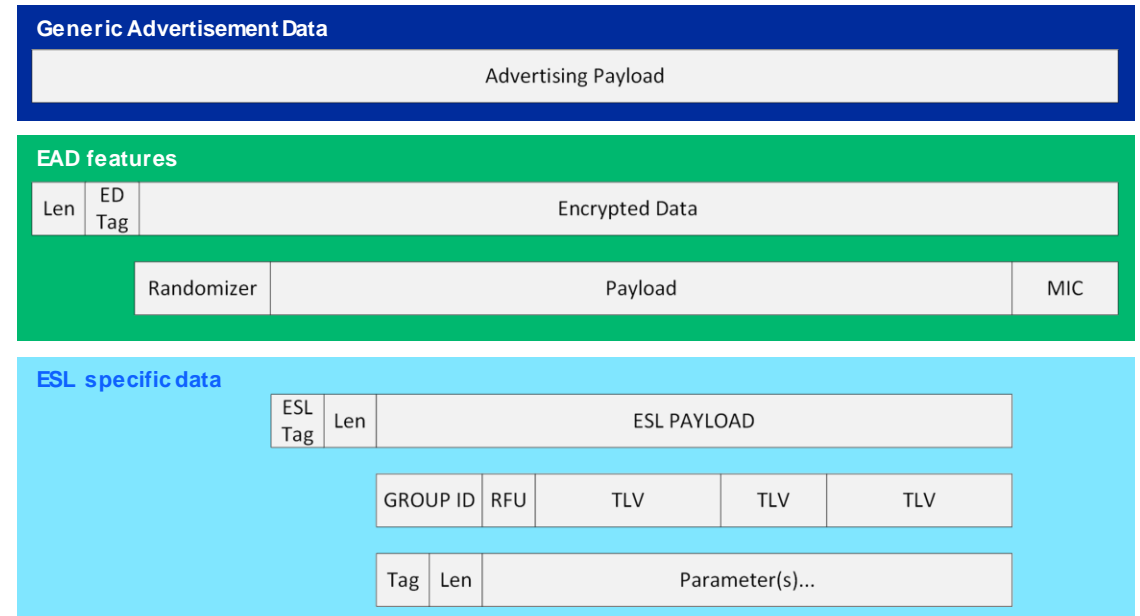
- Receives Central Device downlink transmission at given Subevent time slot
- Responds uplink at given Response Slot
- Remains in sleep mode rest of time

Measurement condition

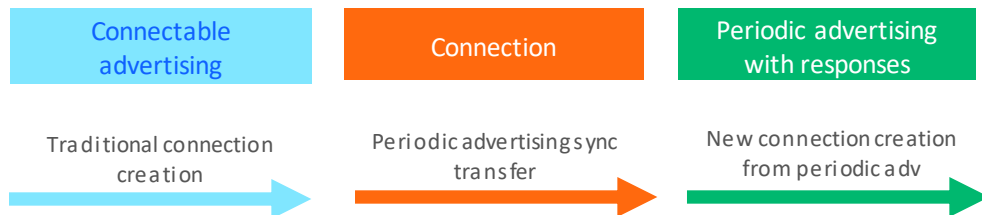
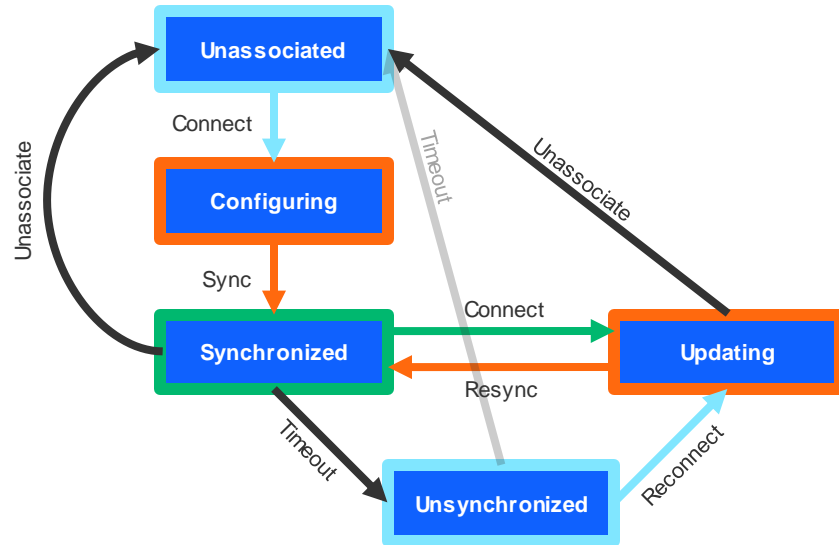
- MG22 Radio Board
- Vinput 3.0V, DC/DC in use
- SoC Current only
- TX 0dBm
- LFXO accuracy 50ppm

Encrypted Advertisement Data (EAD) Feature

- **New Encrypted Advertising Data feature**
 - Provides a standardized way for communicating encrypted data in advertising, scan response and EIR packets
 - Share securely associated encryption key material
- **Encrypted Data Keys and encryption**
 - Key exchange happens through an encrypted and authenticated ACL connection only
 - 128-bit session key
 - In ESL context AP Sync Key and ESL Response Key
 - 64-bit Initialization Vector (IV) value
 - CCM algorithm is used to encrypt and authenticate the data
- **EAD in Advertisement Payload**
 - New Encrypted Data type
 - Indicated by a new assigned data type number in ED Tag
 - Randomizer (40-bits) helps with the message encryption
 - New value is generated every time the payload value changes
 - Payload and MIC fields are encrypted
 - Message integrity checked with help of 32-bit MIC data

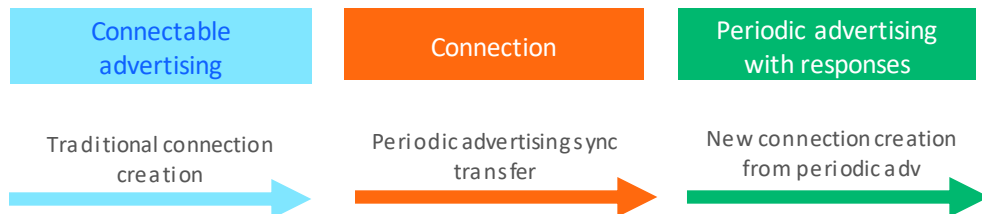
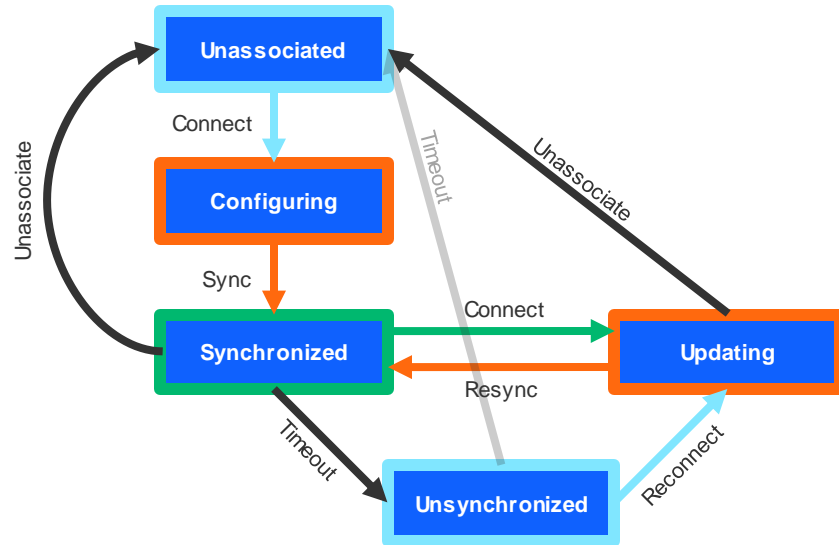


Bluetooth ESL Profile and Service



- ESL messages can be categorized into two distinct categories
 - Connection-oriented
 - Synchronization commands
- Connection-oriented commands are used over standard BLE connections.
 - Configuring the node
 - Controlling the synchronization of the node
 - Updating the stored images on the node
- Synchronization commands are used when ESL Node is synchronized to AP Periodic Advertisement
 - Include commands such as controlling LEDs, controlling displayed images and reading sensor data

Bluetooth ESL Profile and Service – Characteristics and Commands



ESL Characteristics

- Configure
 - ESL Address
 - AP Sync Key Material
 - ESL Response Key Material
 - ESL Current Absolute Time
- Obtain
 - Display Information
 - Image Information
 - Sensor Information
 - LED Information
- ESL Control Point
 - Write Command, receive Response

ESL Commands

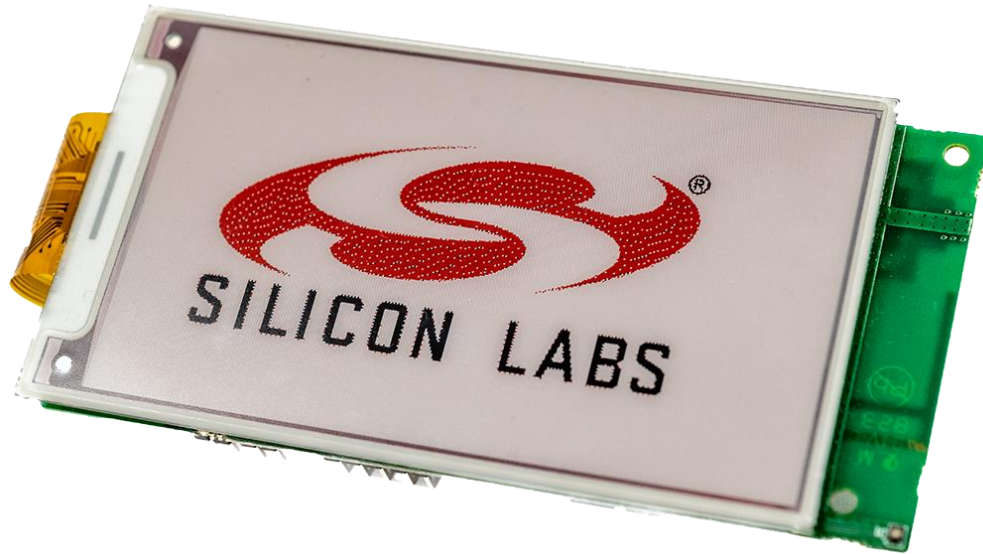
- Ping
- Unassociate from AP
- Service Reset
- Factory Reset
- Update Complete
- Read Sensor Data
- Refresh Display
- Display Image
- Display Timed Image
- LED Control
- LED Timed Control
- Vendor-specific Tag

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Bluetooth ESL Demo

Taking benefit of Bluetooth 5.4 features


ESL Virtual Reference Design



- Hardware
 - BG22 Bluetooth SoC
 - EFR32BG22C224F512GM40
 - External 8M-BIT Flash (optional additional storage)
 - ePaper Display interface with target 3.7" displays
 - User interaction
 - RGB LED
 - User and Reset buttons
 - Active NFC Tag
 - Accelerometer
 - Energy source
 - 2x CR2450 batteries
 - Support for external power source
 - Pin headers for development purposes
 - Low cost 2-layer PCB
- Software
 - Bluetooth ESL support
 - Simplicity Studio 5 support with debug interface
 - Example applications
- Design is available in Silabs GitHub

Demo with Silicon Labs Bluetooth ESL

- Demo setup
- Configuration
- Operation
- Current consumption



SILICON LABS

AN1419: *Bluetooth*[®] LE Electronic Shelf Label

The Bluetooth Special Interest Group released the Electronic Shelf Label (ESL) profile and service specification at the beginning of 2023. With the essential additions in the Bluetooth Core Specification version 5.4 (e.g., Periodic Advertising with Responses and Encrypted Advertising Data), the ESL specification defines a standardized use of Bluetooth Low Energy (BLE) in electronic shelf labels.

This document introduces the Bluetooth - SoC ESL Tag example project, accompanied by an Access Point host application through examples, which describes the essential features of the BLE ESL. In addition, this document also describes how the ESL network can be configured, through multiple examples. And finally, the document also describes the first steps for how to modify the sample application, extending it to use an additional, or different, display, and using non-volatile memory for storing images.

KEY POINTS

- Preparing the ESL Tags and access point
- Using the ESL
- Extending the ESL example with an additional display

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Demo Video

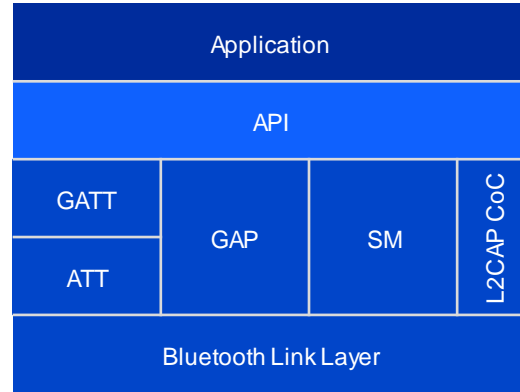
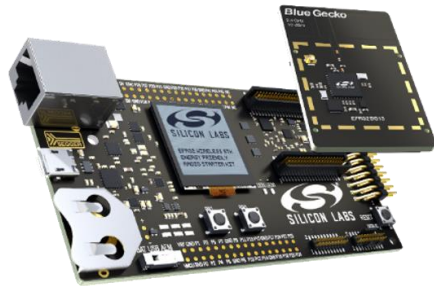


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Silicon Labs Solution

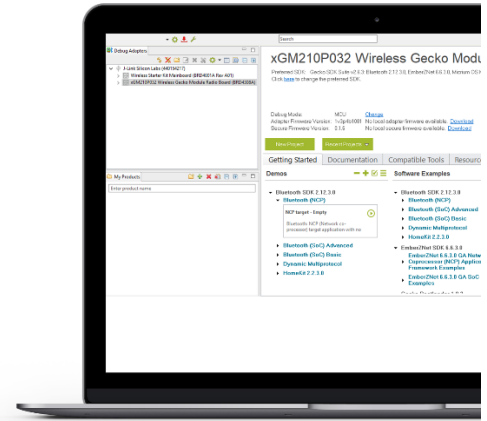
Bluetooth 5.4 and ESL Profile and Service

A Complete Solution for Bluetooth 5.4 Development



```

Python
20/Jan 14:31:53.438: BLE - INFO - Write request, length: 2048
20/Jan 14:31:53.827: BLE - INFO - Transfer finished, result: 0
20/Jan 14:31:53.837: BLE - DEBUG - [Event] Image sent
20/Jan 14:31:53.857: BLE - DEBUG - [Event] Connected
20/Jan 14:31:53.874: AP - INFO - Image sent
20/Jan 14:31:53.874: AP - INFO - Image sent to the device
20/Jan 14:31:53.874: AP - INFO - Image update 1 Image/Bluetooth
20/Jan 14:31:59.003: AP - INFO - [Command] Display type matches object type
20/Jan 14:31:59.004: BLE - INFO - [Command] Write Image
20/Jan 14:31:59.004: BLE - INFO - Starting image transfer using OTS
20/Jan 14:31:59.087: BLE - INFO - Write request, length: 2048
20/Jan 14:31:59.588: BLE - INFO - Transfer finished, result: 0
20/Jan 14:31:59.588: BLE - DEBUG - [Event] Image sent
20/Jan 14:31:59.588: BLE - DEBUG - [Event] Connected
20/Jan 14:31:59.533: AP - INFO - Image sent
20/Jan 14:31:59.534: AP - INFO - Image sent to the device
20/Jan 14:37:29.136: BLE - INFO - [Command] Button Press
20/Jan 14:37:29.136: BLE - INFO - Connection prepared for sync transfer
20/Jan 14:37:31.493: BLE - INFO - Connection closed
20/Jan 14:37:31.493: BLE - INFO - [Event] Idle
20/Jan 14:37:31.493: BLE - INFO - Connection closed, reason: 0x1013
20/Jan 14:37:31.536: AP - INFO - [Event] Connection closed
20/Jan 14:37:31.536: AP - INFO - [Event] Idle
[TAG] BLE Address: 8C:F6:81:88:82:4C
[TAG] ESL Address: 2 (0x0002)
[TAG] ESL ID: 2
[TAG] Group ID: 0
[TAG] AP sync key: *** (Set)
[TAG] Response key: **** (Set)
[TAG] Absolute Time: Last time set to 783567
[TAG] Display: [R] width: 128 height: 128 type: 255
[TAG] Max Image Index: [R] Present input voltage
[TAG] Sensors: [R] Present device operating temperature
[TAG] [R] Device firmware version
[TAG] [R] Date of manufacture
[TAG] [R] Device operating temperature range specification
[TAG] [R] Silicon readout counter
[TAG] [R] Present ambient temperature
[TAG] [R] Silicon button
[TAG] LED Info: [R] Colored, current color: RGB(333)
[TAG] PnP Info: Vendor: Silicon Labs Product_ID: 0x351 Product_version: 0x000
[TAG] Link status: Synchronized (0x0000)
-----
list 0
There's no advertising tag.
list 0
There's no connected tag.
list 0
[TAG] BLE Address: 8C:F6:81:88:82:4C ESL Address: 1
[TAG] BLE Address: 8C:F6:81:88:82:4C ESL Address: 2
There are 2 synchronized tags.
display_image 2 0 0
20/Jan 14:37:31.821: AP - DEBUG - [Event] PNP subsequent data request
20/Jan 14:37:31.821: BLE - INFO - [Command] set periodic advertisement data
20/Jan 14:37:31.930: AP - DEBUG - [Event] PNP response
20/Jan 14:37:31.930: AP - INFO - Response received in subsequent slot 0
20/Jan 14:37:31.930: AP - INFO - Reply from ESL ID 2, in group 0
20/Jan 14:37:31.931: AP - INFO - Display state response: Display_Index: 0 Image_Index: 0 (0x12000)
    
```



SOC, MODULES, DEV KITS

Multiple physical interfaces to support advanced development and debugging

- UART, Ethernet, USB
- LCD, LED, buttons

STACK SOFTWARE

In-house developed stack

Bluetooth 5.4

Support for PAwR, EAD, PAST, CoC, BT ESL Service and Profile

All security features supported

ESL ACCESS POINT DEMO

Python and C based ESL AP

ESL Library (GATT, OTS & NCP Events)

EFR32 radio with NCP

DEVELOPMENT TOOLS

Simplicity Studio

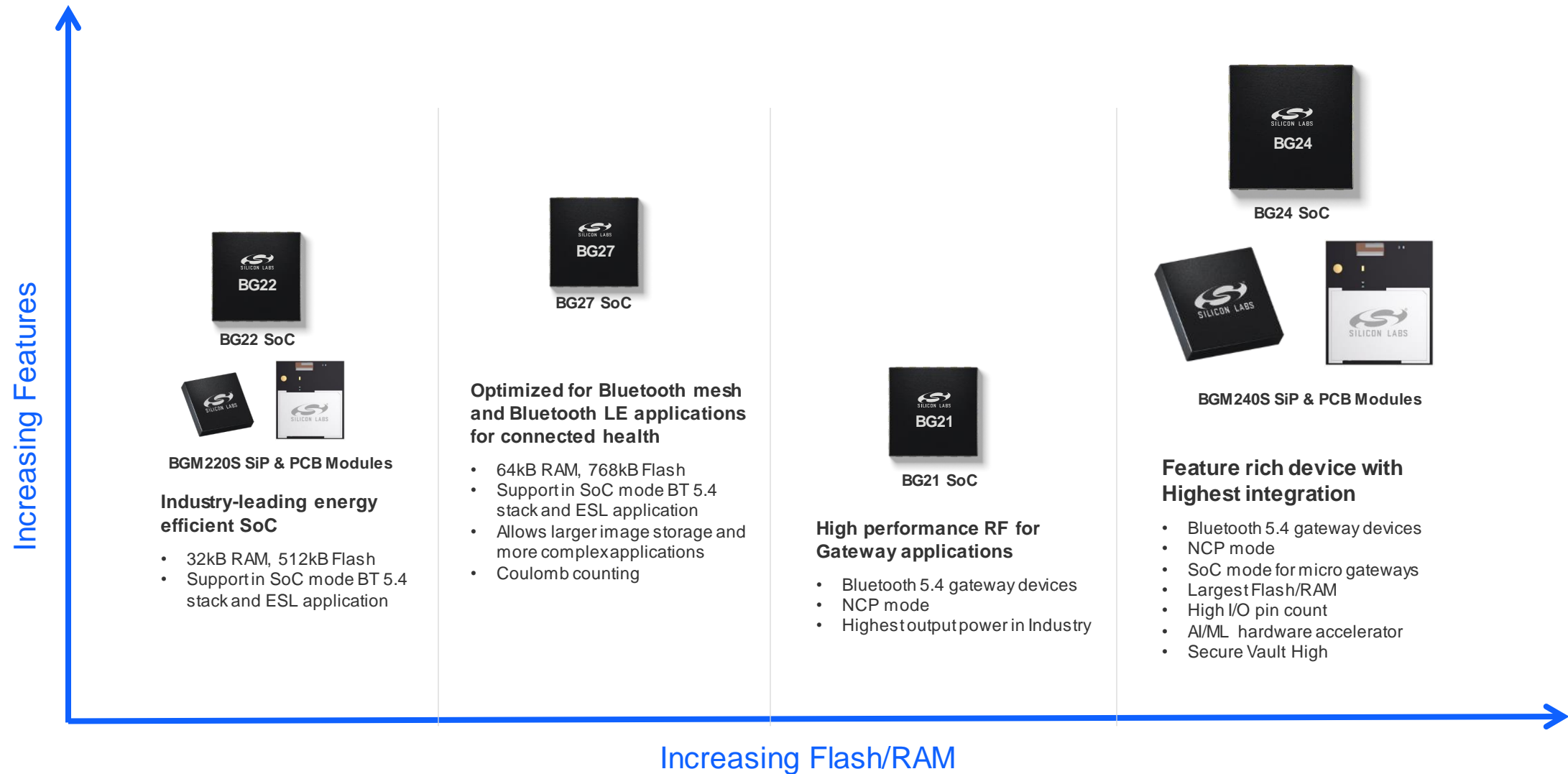
BT 5.4 NCP and SoC

BT ESL Example

Energy Profiler



Key SoCs and Modules



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Summary

Summary



- Bluetooth 5.4 introduces standardized support for large scale star networks
- Requirement is driven by Smart Retail market with electronic shelf label (ESL)
- Industrial applications like Manufacturing & Logistics and Asset monitoring benefits from the same features
- Key features are Periodic Advertisement with Response (PAwR) and Encrypted Advertising Data (EAD)
- Bluetooth 5.4 and ESL support is out for you to download with Simplicity Studio GSDK 4.3

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BT-203

Thank You!

