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
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

**Annual Bluetooth® Device Networks Device Shipments**

<table>
<thead>
<tr>
<th>Year</th>
<th>Shipments (Billion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>1.61</td>
</tr>
<tr>
<td>2019</td>
<td>2.66</td>
</tr>
<tr>
<td>2020</td>
<td>3.67</td>
</tr>
<tr>
<td>2021</td>
<td>4.89</td>
</tr>
<tr>
<td>2022</td>
<td>6.21</td>
</tr>
<tr>
<td>2023</td>
<td>7.70</td>
</tr>
<tr>
<td>2024</td>
<td>9.20</td>
</tr>
<tr>
<td>2025</td>
<td>11.3</td>
</tr>
<tr>
<td>2026</td>
<td>1.39</td>
</tr>
<tr>
<td>2027</td>
<td></td>
</tr>
</tbody>
</table>

**Annual CAGR 21%**

**Annual Bluetooth® ESL Shipments**

<table>
<thead>
<tr>
<th>Year</th>
<th>Shipments (Millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2023</td>
<td>334</td>
</tr>
<tr>
<td>2024</td>
<td>100</td>
</tr>
<tr>
<td>2025</td>
<td>100</td>
</tr>
<tr>
<td>2026</td>
<td>100</td>
</tr>
<tr>
<td>2027</td>
<td>100</td>
</tr>
</tbody>
</table>

Data Source: ABI Research, 2023

Source: https://www.bluetooth.com/2023-market-update/
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
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 (=E SL 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:
  - ROUNDUP(200 / 23) = 9
    - => 9 Advertising Intervals x 3 sec = 27 seconds

- Time for Connection & Scanning
  - 3 sec – (50 x 25 ms) = 3 sec – 1.25 sec = 1.75 sec
Example of PAwR Current Consumption

- **Peripheral device use case**
  - Receives Central Device downlink transmission at given Subevent time slot
  - Responses 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
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
Demo Video
Silicon Labs Solution

Bluetooth 5.4 and ESL Profile and Service
A Complete Solution for Bluetooth 5.4 Development

**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

BG22 SoC

- Increasing Features
- Industry-leading energy efficient SoC
  - 32kB RAM, 512kB Flash
  - Support in SoC mode BT 5.4 stack and ESL application

BG24 SoC

- Feature rich device with highest integration
  - Bluetooth 5.4 gateway devices
  - NCP mode
  - SoC mode for micro gateways
  - Largest Flash/RAM
  - High I/O pin count
  - AI/ML hardware accelerator
  - Secure Vault High

BG27 SoC

- Optimized for Bluetooth mesh and Bluetooth LE applications for connected health
  - 64kB RAM, 768kB Flash
  - Support in SoC mode BT 5.4 stack and ESL application
  - Allows larger image storage and more complex applications
  - Coulomb counting

BG21 SoC

- High performance RF for Gateway applications
  - Bluetooth 5.4 gateway devices
  - NCP mode
  - Highest output power in Industry

BGM240S SiP & PCB Modules

SiP & PCB Modules

BG22 SoC

BG27 SoC

BG24 SoC

BG21 SoC

©2023 Silicon Laboratories Inc. All rights reserved.
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
Thank You!