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Differentiating Bluetooth Low Energy Products

By Exploiting and Exploring Zephyr Bluetooth Controller Implementations

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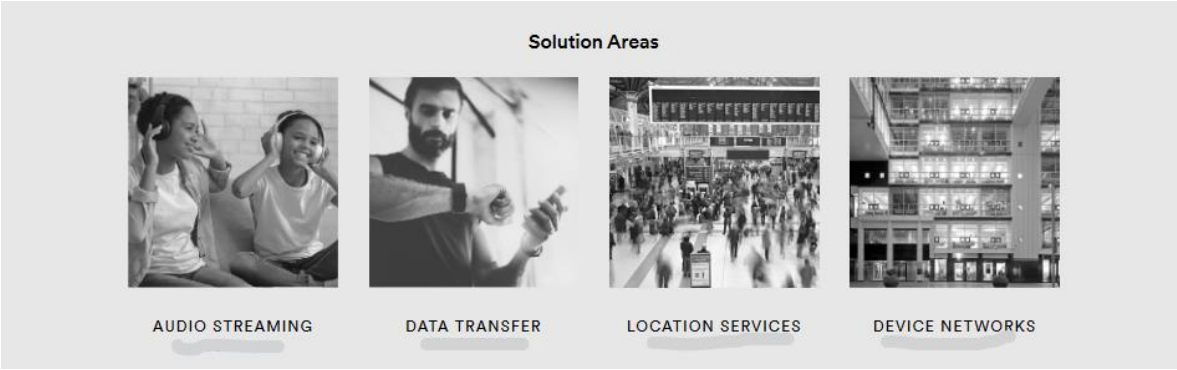
Topics

- Bluetooth Technology
- Zephyr Bluetooth Low Energy and Controller
- Direction Finding Feature
- Isochronous Channels Feature
- Architecture and Enhancements
- Broadcast Isochronous Events
- Connected Isochronous Events
- Power Profiling to illustrate ISO implementation
- Q & A

Bluetooth Technology

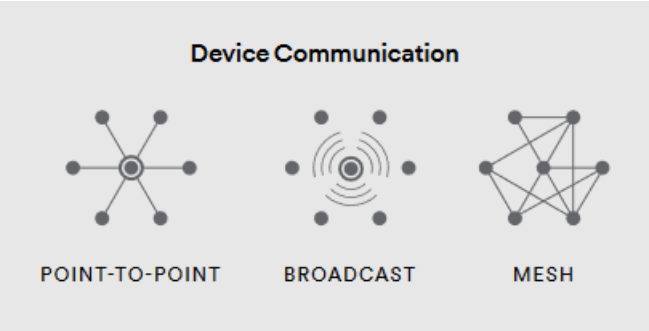
- Bluetooth wireless technology is a **short-range communications system** intended to replace the cable(s) connecting portable and/or fixed electronic devices
- Frequency hopping spread spectrum (FHSS)
- 2.4 GHz ISM band
- Solution Areas
  - Data Transfer
  - Audio Streaming
  - Location Services
  - Device Networks
- Billions of products shipped

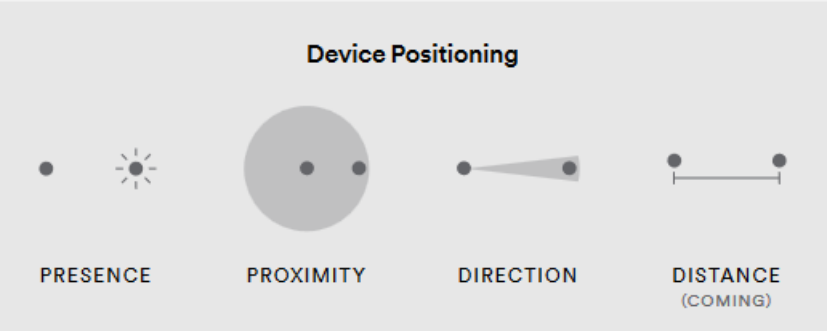


- Image source: https://www.bluetooth.com/wp-content/uploads/Files/Marketing/Bluetooth-Technology-Overview.pdf

Device Communication and Positioning

- Device Communication
  - Point-to-Point
  - Broadcast
  - Mesh
- Device Positioning
  - Presence
  - Proximity
  - Direction
  - Distance

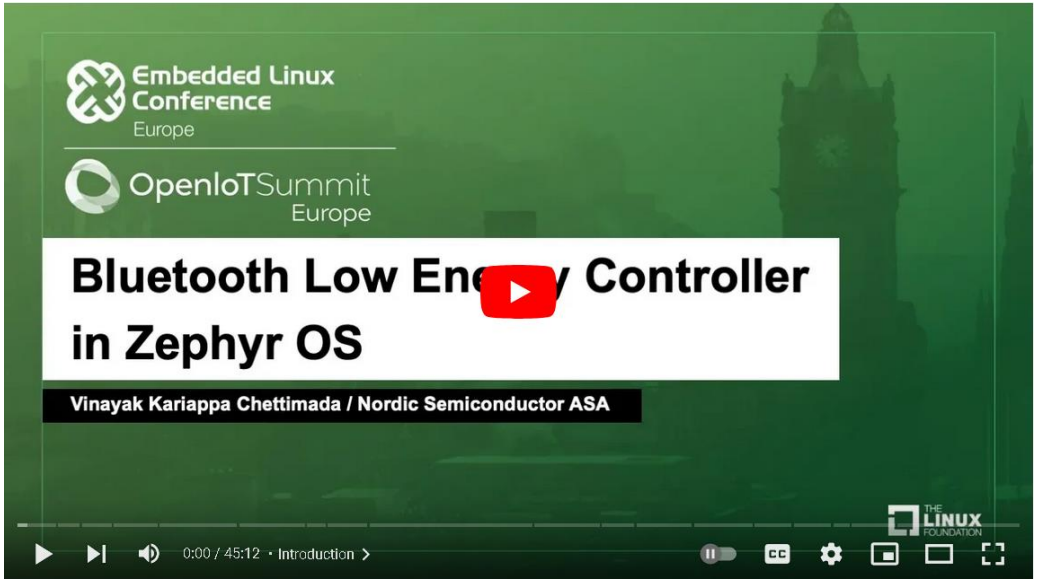




- Image source: https://www.bluetooth.com/wp-content/uploads/Files/Marketing/Bluetooth-Technology-Overview.pdf

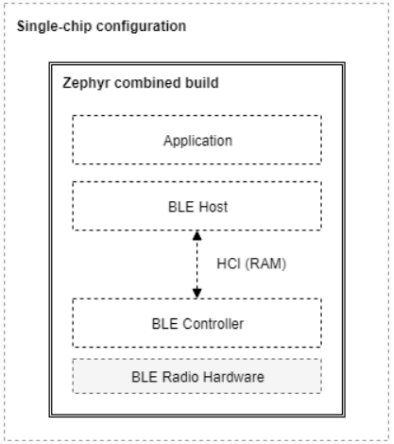
Bluetooth Technology

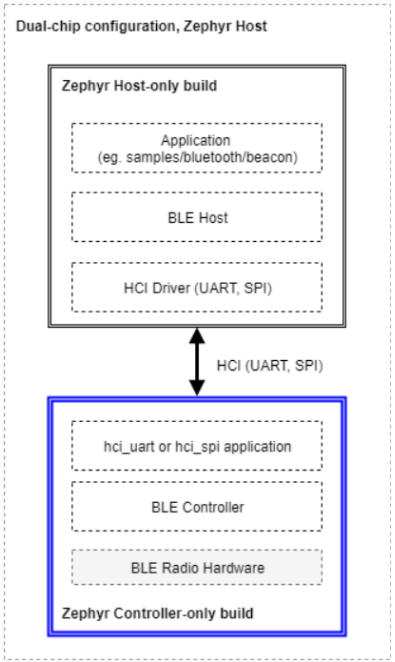
- Details of prior presentation detailing Bluetooth Low Energy Technology can be found here
  - Link: https://www.youtube.com/watch?v=rIicvcriWR8



Exploit Bluetooth Low Energy in Zephyr

- Bluetooth v5.3 compliant
- Highly configurable
  - w.r.t features, buffer sizes/counts etc.
- Portable to all architectures supported by Zephyr
- Supports combinations
  - Host and Controller builds
- Bluetooth Host Support
- Bluetooth Mesh Support





Product Use Cases

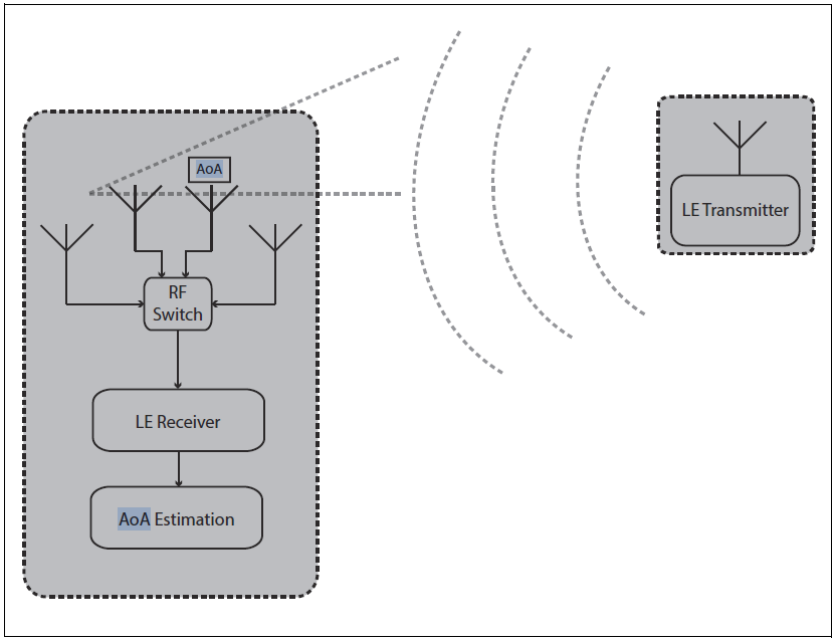
- Beacons, Eddystone
- Proximity tags
- Heart Rate Monitors, Health Thermometers
- HIDs, Keyboards, Mouse
- Sports watches
- Bike equipment
- Activity trackers

Explore Zephyr Bluetooth Low Energy Controller

- What is new in Zephyr Bluetooth Low Energy Controller?
- LE Long Range
  - Coded PHY support
- LE Advertising Extensions
  - LE Periodic Advertising and Synchronization
- Angle of Arrival (AoA) and Angle of Departure (AoD)
- LE Isochronous Channels
  - LE Audio

Direction Finding Feature - Angle of Arrival

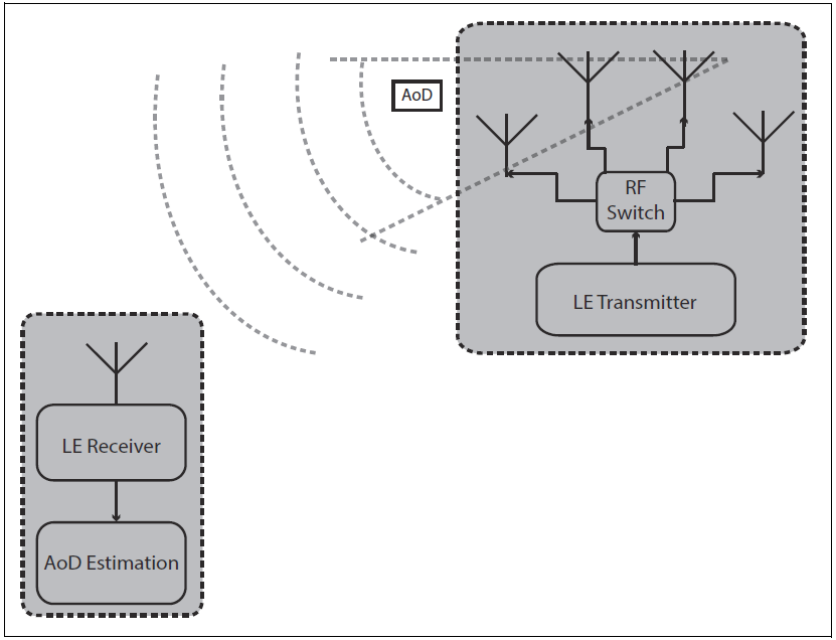
- An LE device can make its direction available for a peer device by **transmitting direction finding enabled packets**
- Using direction information from several transmitters and profile-level information giving their locations, an LE radio can calculate its own position.
- **Angle of Arrival** (AoA) Method
  - **Transmits direction finding enabled packets using a single antenna**



- Source: Bluetooth Core Specification v5.4
  https://www.bluetooth.com/specifications/specs/core-specification-5-4/

Direction Finding - Angle of Departure

- **Angle of Departure** (AoD) Method
- A device consisting of an **RF switch** and **antenna array** can make its angle of departure (AoD) detectable by transmitting direction finding enabled packets, **switching antennae during transmission**



- Source: Bluetooth Core Specification v5.4
  https://www.bluetooth.com/specifications/specs/core-specification-5-4/

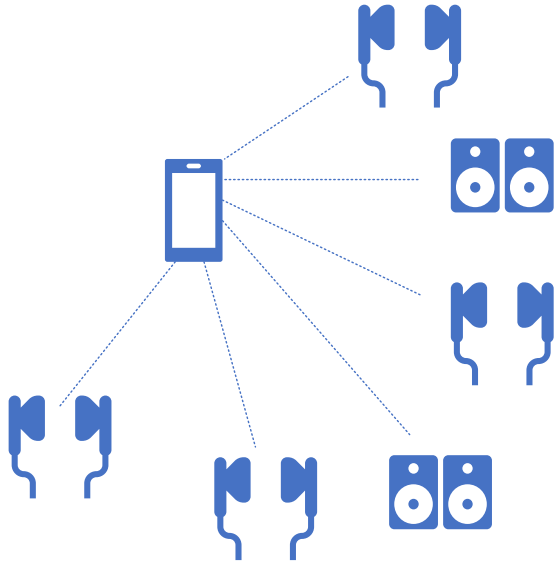
Product Use Cases

- Asset Management
- Indoor Navigation
- Proximity Marketing
- Point of Interest Information
- Personnel tracking
- Personal item finding
- Building and automotive access control

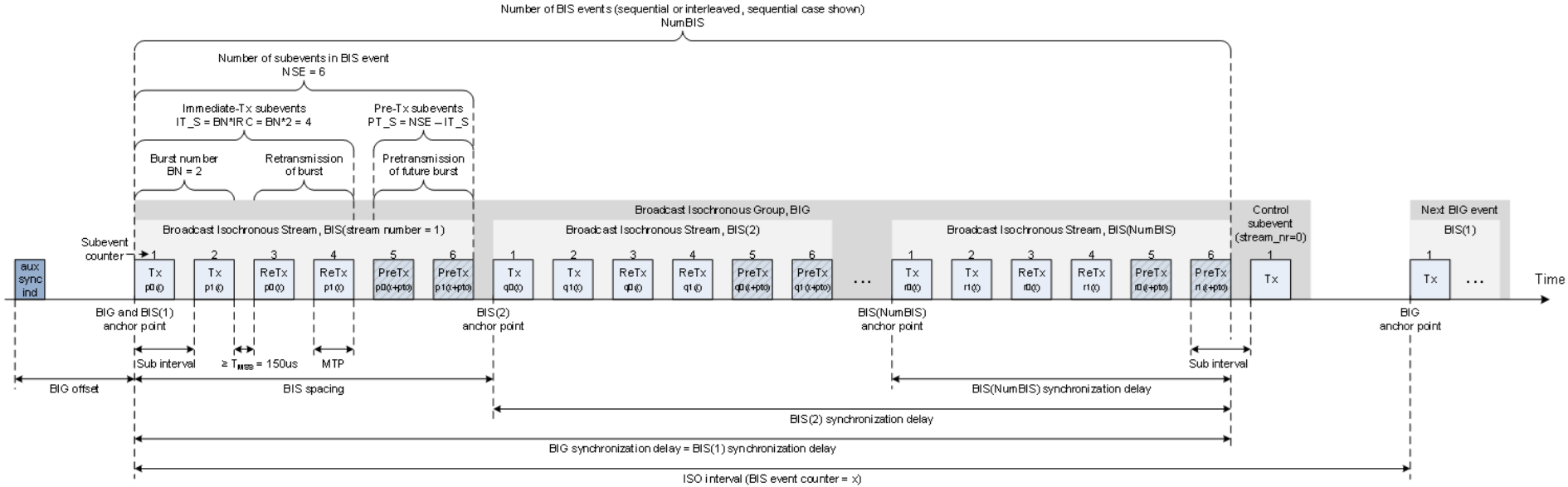
- Source: https://www.bluetooth.com/wp-content/uploads/2022/03/Location_Services_Infographic.pdf

Broadcast Isochronous

- Feature introduced in Bluetooth v5.2
- Two or more devices be able to communicate in a unidirectional and connectionless manner
- Uses extended advertising events, periodic advertising events, and BIG and BIS events
- Clear Text or Encrypted supported

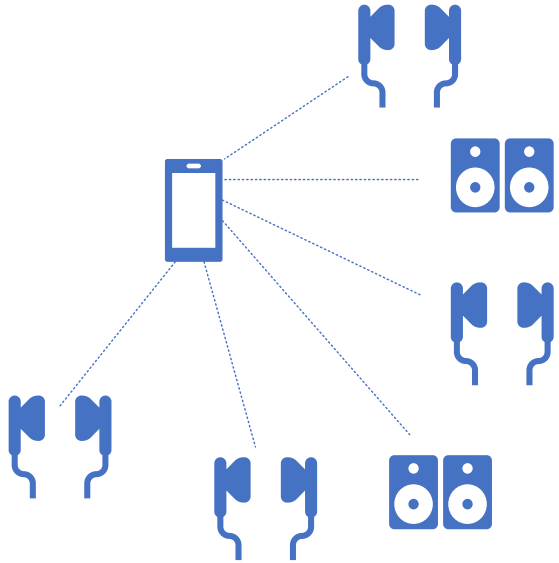


BIG Event



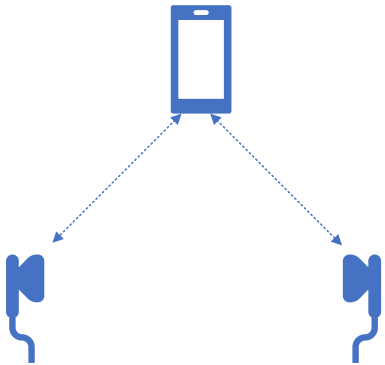
Product Use Cases

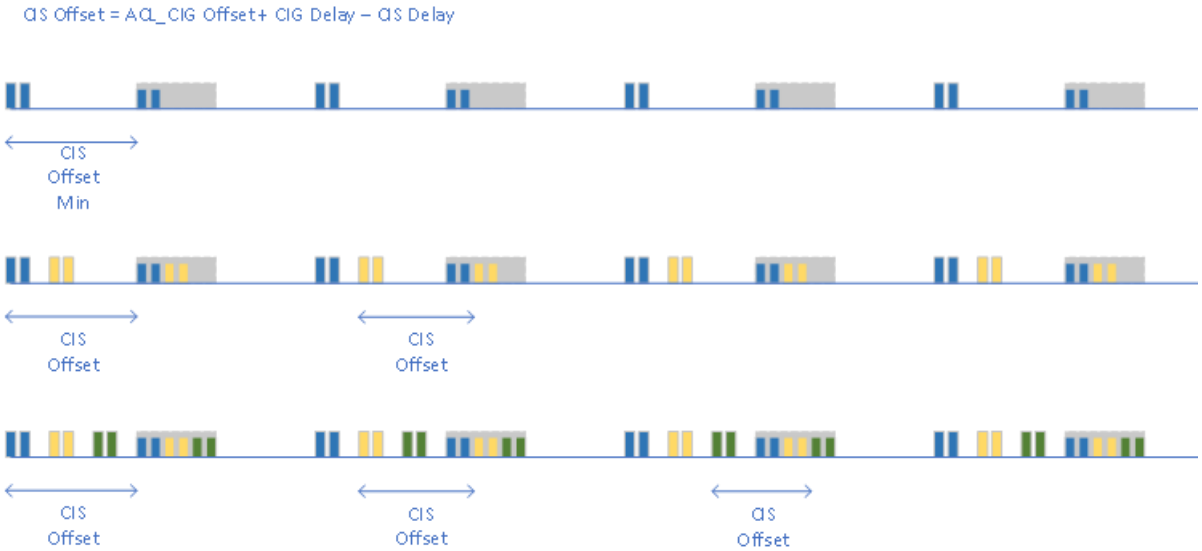
- Synchronized data transfer or playback over large collection of devices placed apart in a location
- Personal audio sharing, multiple earbud pairs listening to same media
- Hearing Aids tune to audio sources in theatres, conferences, lecture halls and airports



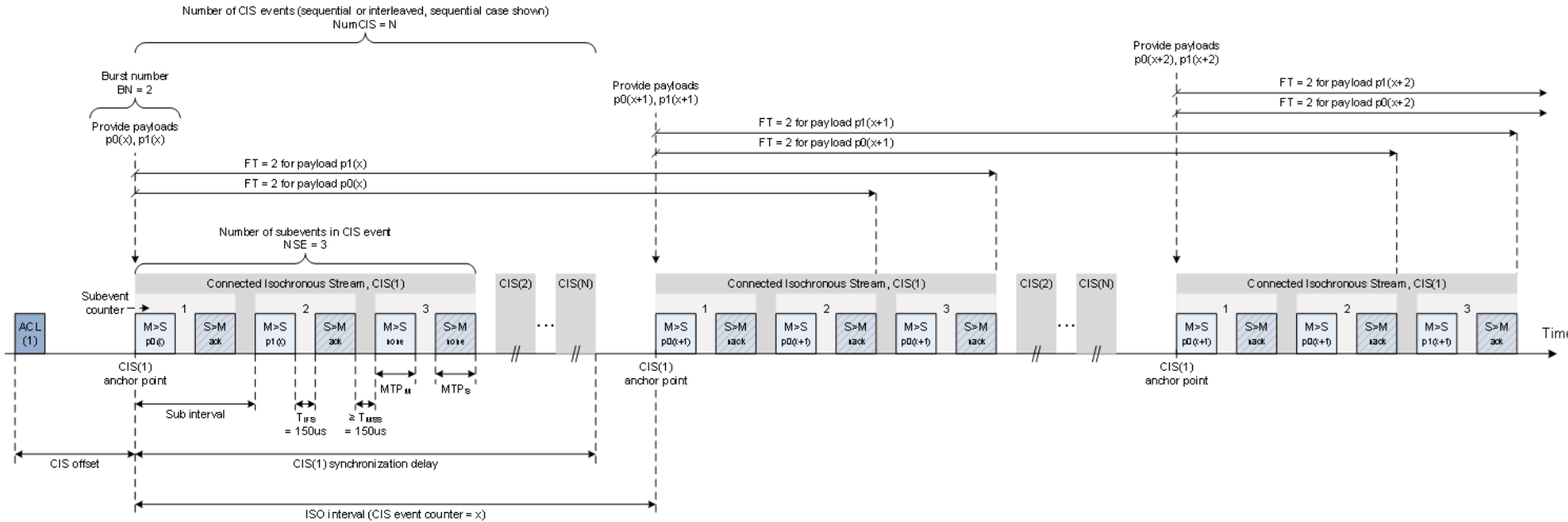
Connected Isochronous

- Data-Symmetric
- Data-Asymmetric
- Point-to-point transport
- Central and Peripheral role





CIG Event



Product Use Cases

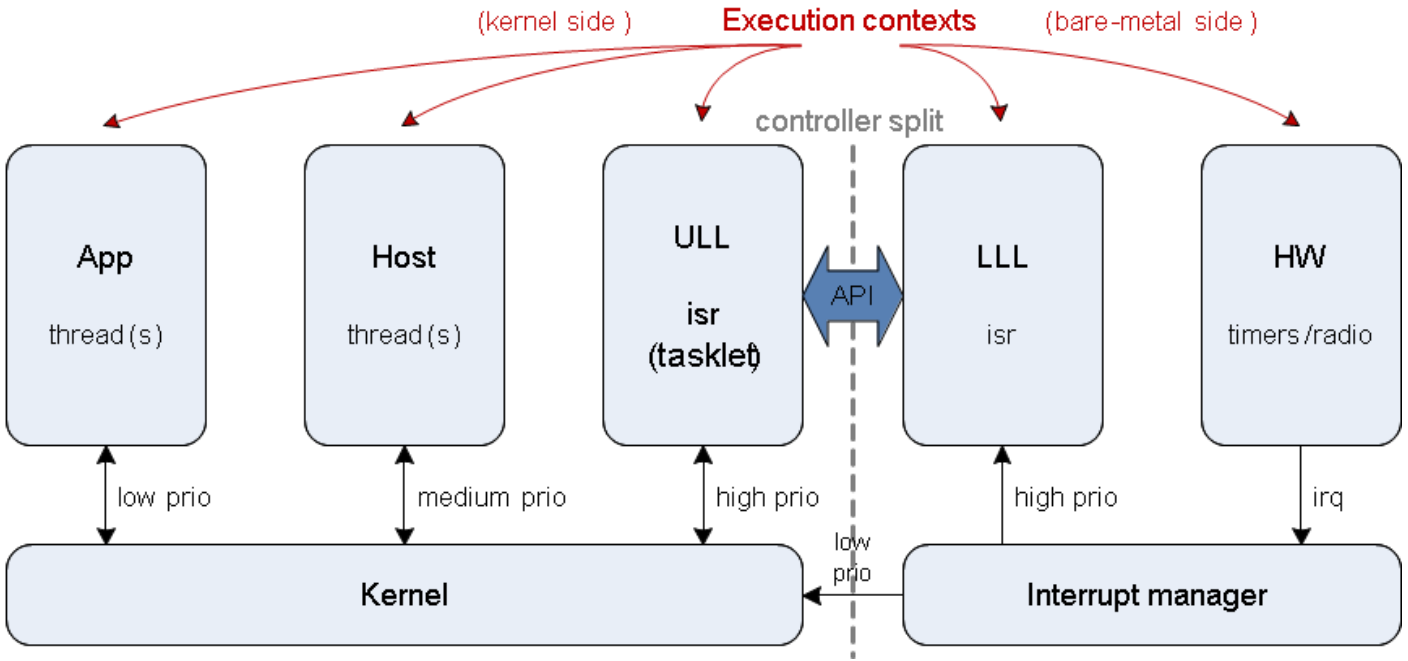
- Audio Use Cases
  - Basic Telephony
  - Low Latency Audio from TV
  - More number of listener in large areas
- Broadcast Audio in public spaces
- Time synchronized sensor eco-systems

- Source: https://www.bluetooth.com/blog/introducing-le-audio-the-use-cases/

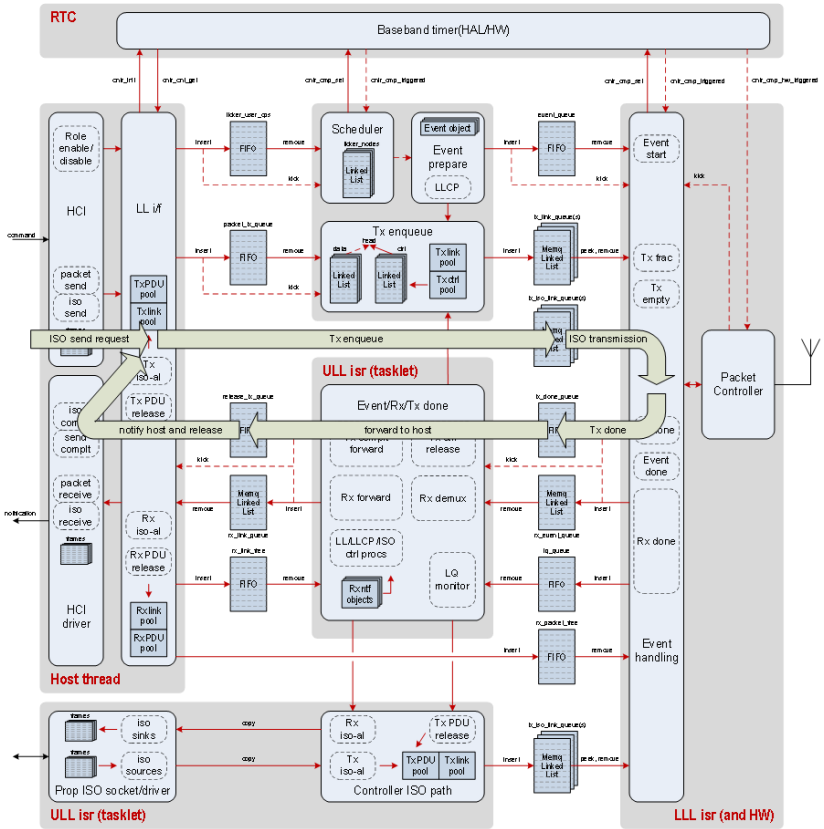
LE Audio

- Details of LE Audio support specifically in Zephyr Project can be found in prior presentation
- https://www.youtube.com/watch?v=brbPao2WM_Y

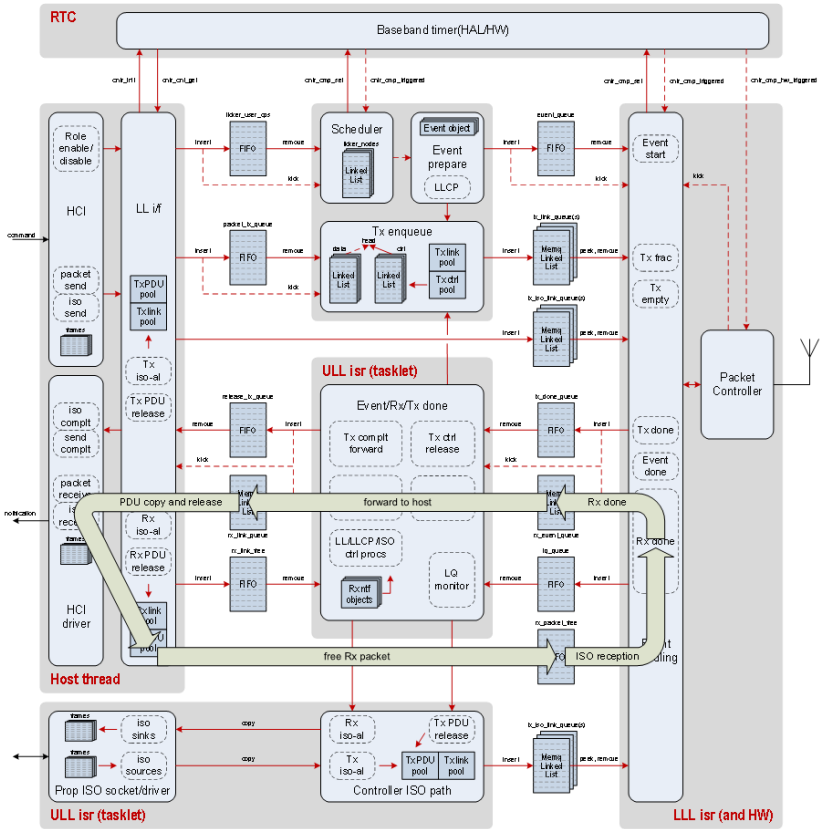
Architecture – Execution Overview



Architecture – ISO Tx Packet Flow

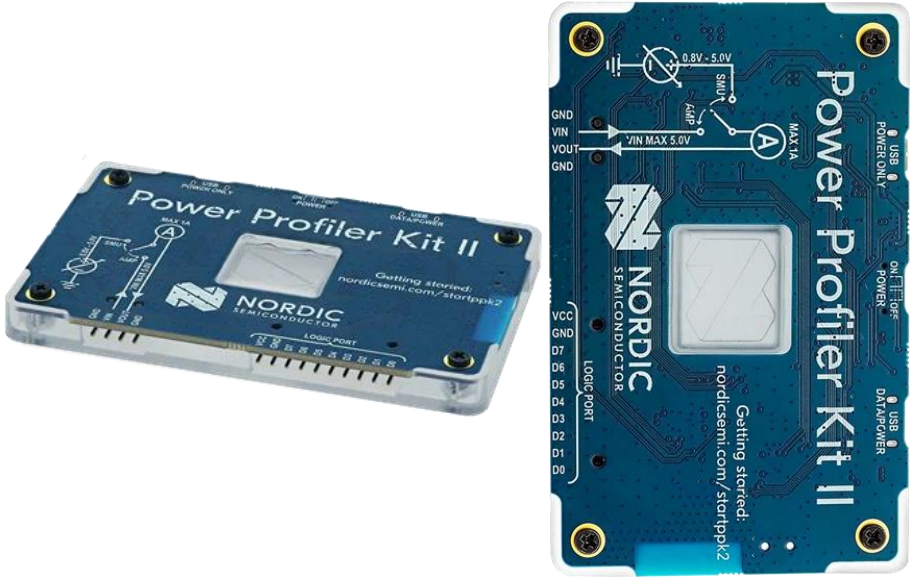


Architecture – ISO Rx Packet Flow

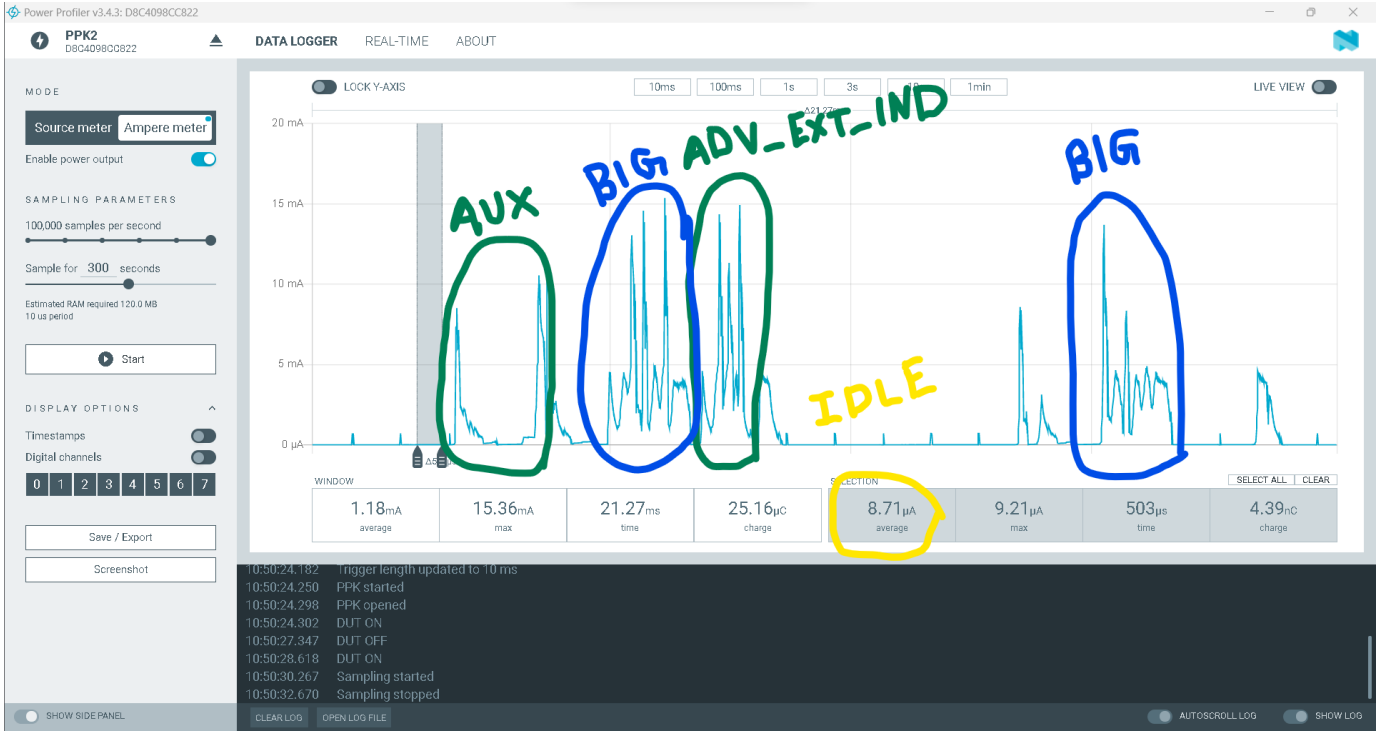


Power Profiling

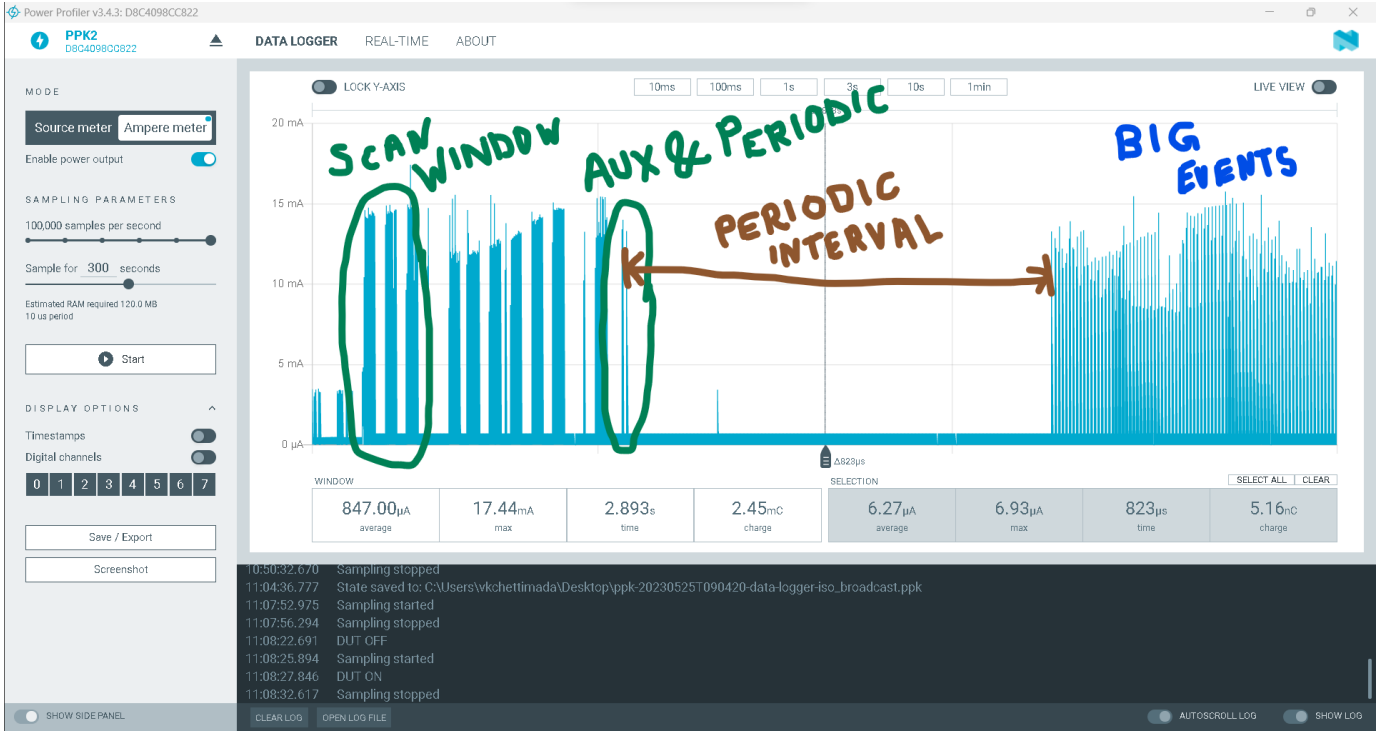
- The Power Profiler Kit II (PPK2) is a standalone unit, which can measure and optionally supply currents all the way from sub-uA and as high as 1A on all Nordic DKs, in addition to external hardware.



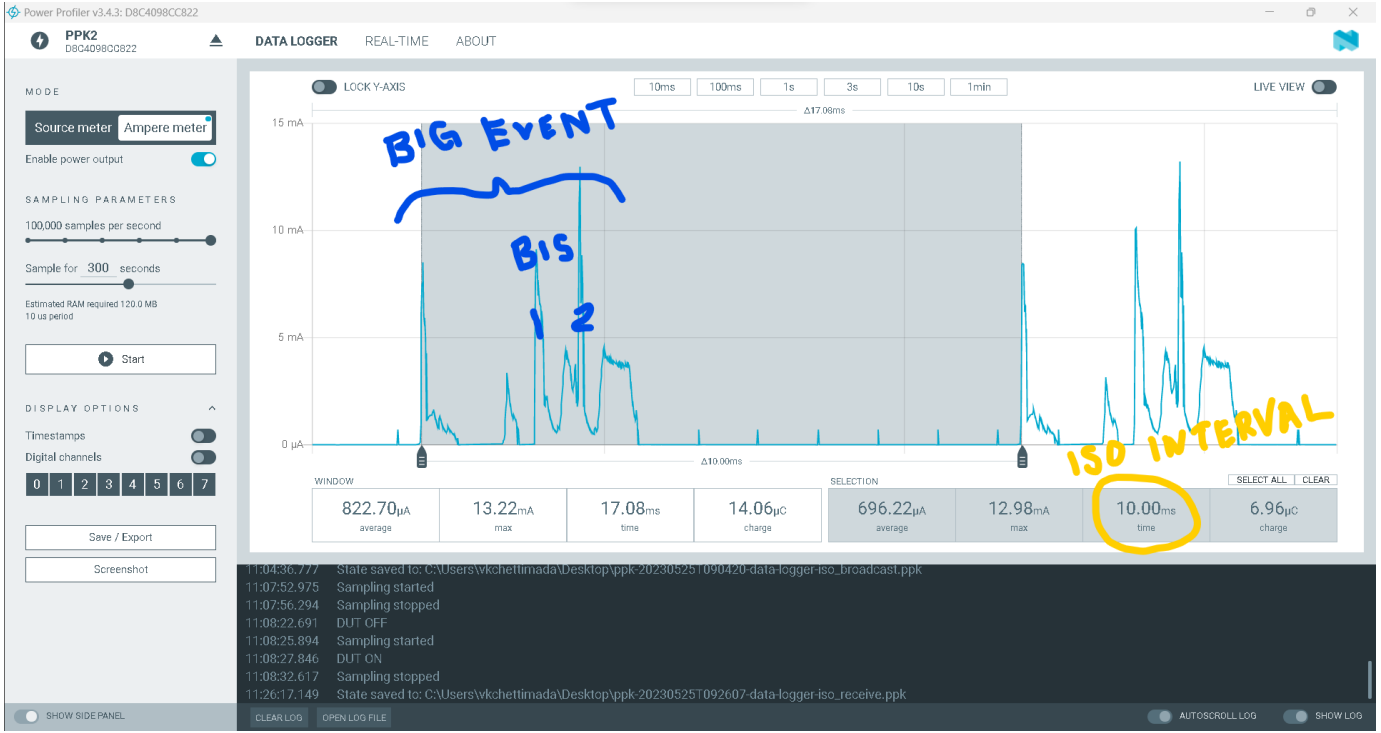
iso_broadcast power profile



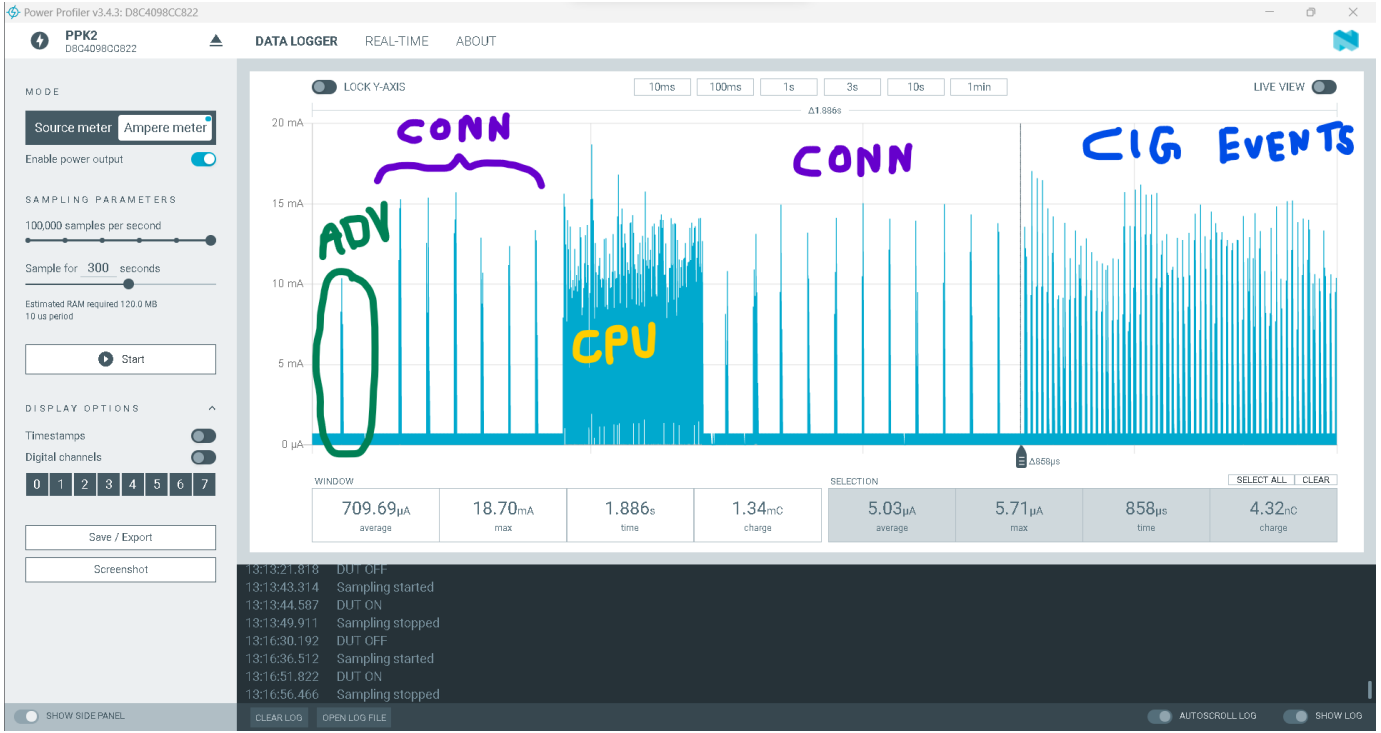
iso_receive sample power profile



iso_receive BIG event power profile

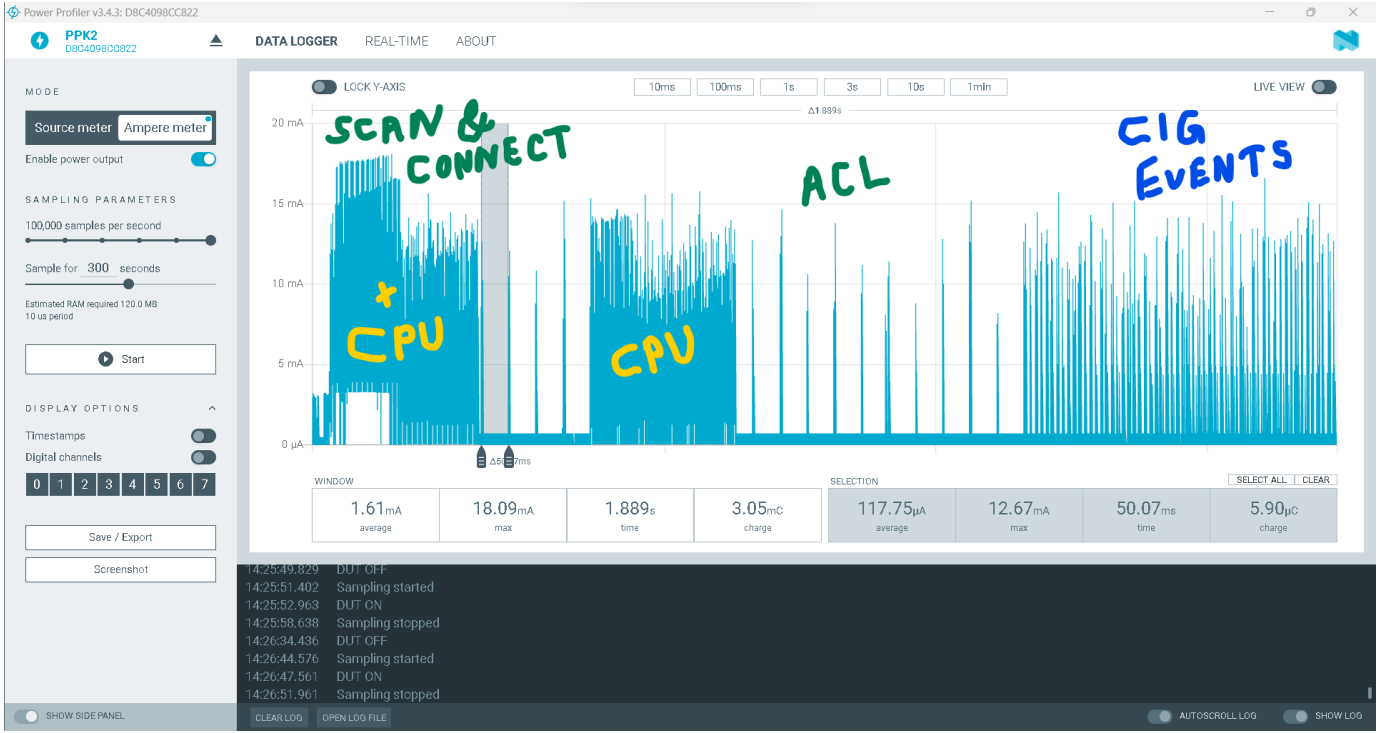


peripheral_iso power profile

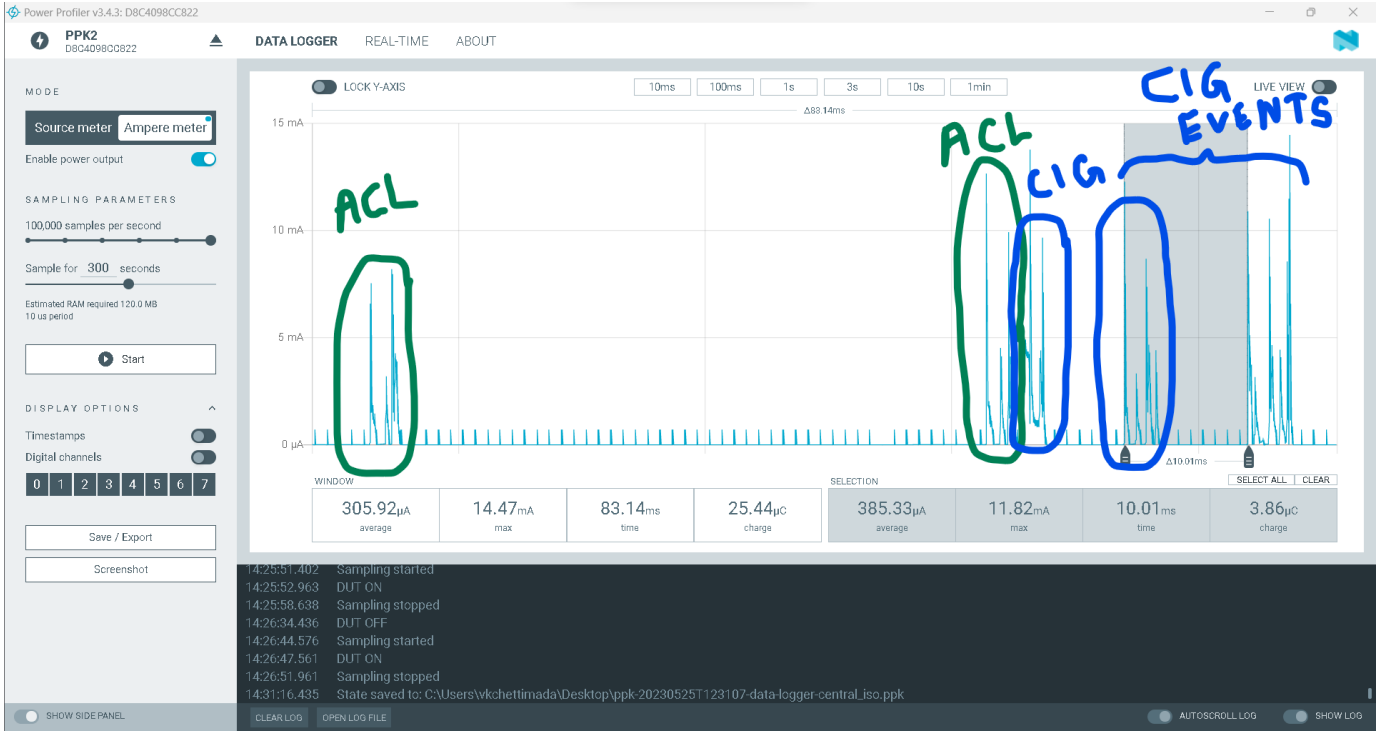


peripheral_iso CIG events power profile

central_iso power profile



central_iso CIG events power profile



Summary

- Zephyr Project has fully open source Bluetooth v5.3 complaint Host and Controller
  - Open Source: Controller, Host, Mesh, Audio, Services and Profile
- Portable to multiple architecture that are supported in Zephyr RTOS
- Community Contributed and a very active developer interaction in interest groups, meetings, mailing list and discord channels
- Implementation changes continuously tested on pull request in CI using physical layer simulations
- Frequent conformance testing by Zephyr Project members
- Best part being the numerous samples very close to product use cases

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