



Bluetooth Low Energy Fundamentals

Bluetooth LE course 2026

Bluetooth Low Energy

- Wireless Personal Area Network technology
- Operates in the 2.4GHz ISM (Industrial, Scientific and Medical) band
- Specification defined by the Bluetooth SIG (Special Interest Group)
- Optimized for low-power consumption
 - Racing to idle
 - Low range*
 - Low bandwidth



Bluetooth Low Energy

History

Made for OV & Nordic NCS BLE course



Bluetooth Low Energy

History

Term	Introduced	Means
BR	1.1 (2002)	Basic Rate (1 Mbit/s)
EDR	2.0 (2004)	Enhanced Data Rate (2 and 3 Mbit/s)
HS	3.0 (2009)	High Speed (up to 24 Mbit/s)
LE	4.0 (2010)	Low Energy (1 Mbit/s ultra low power)

Bluetooth Low Energy

History

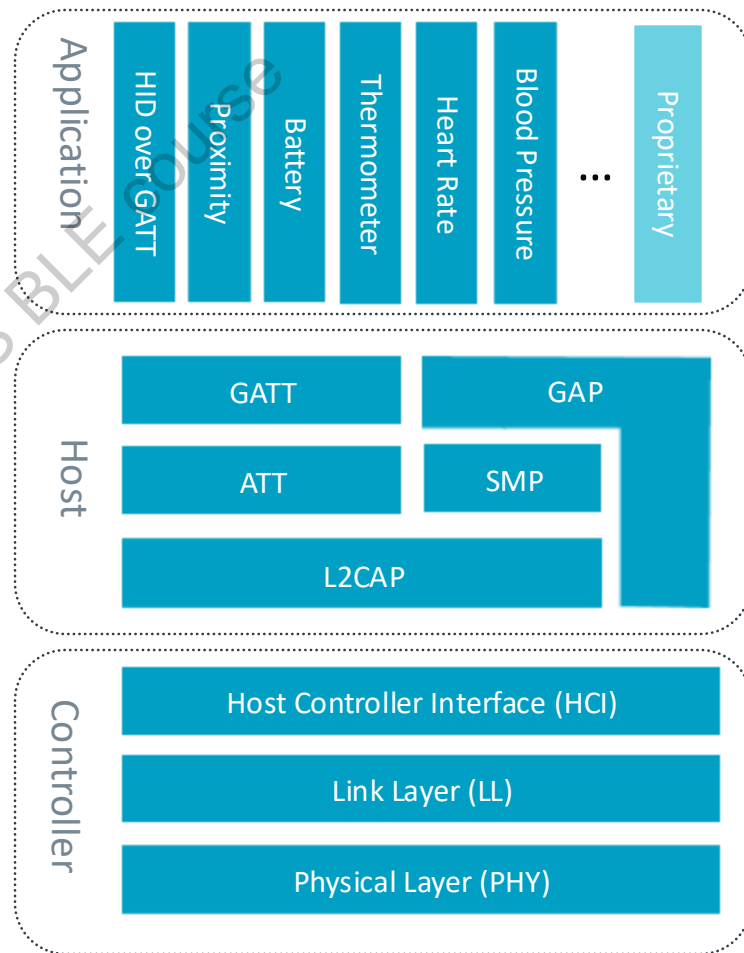
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	5.1 (2019)	Direction Finding
	5.2 (2020)	LE Audio
	6.0 (2024)	Channel Sounding
	6.2 (2025)	Shorter Connection Intervals

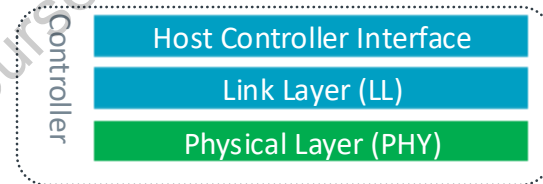
Bluetooth LE Architecture

Split into three main building blocks

- Application
 - User application interfacing with the Bluetooth Low Energy protocol stack.
- Host
 - Upper layers of the Bluetooth protocol stack
- Controller
 - Low layers of the Bluetooth protocol stack, including the radio



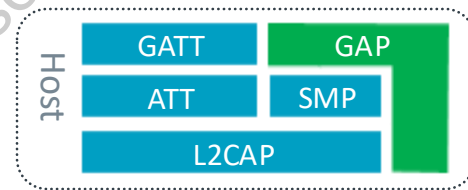
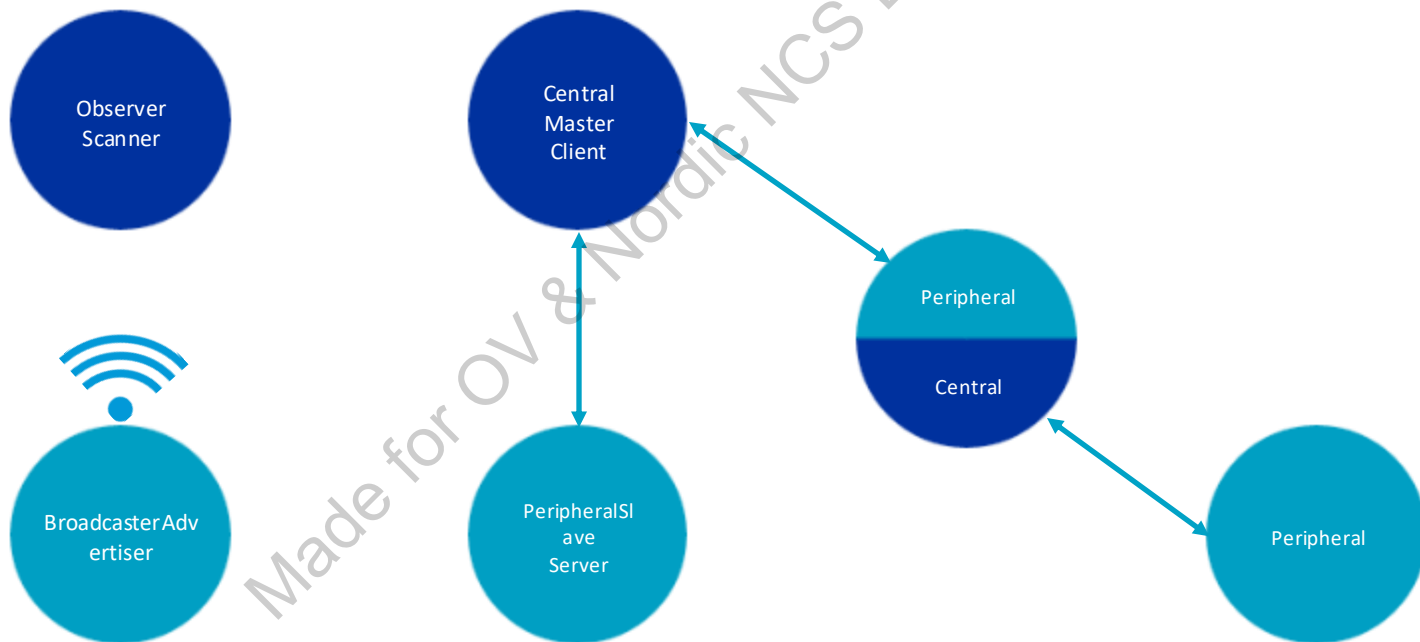
Physical Layer(PHY)



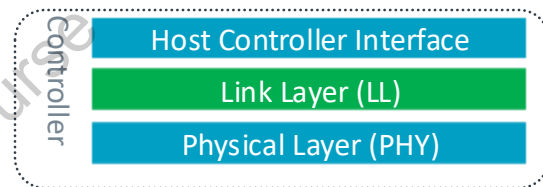
Frequency	LL
2402 MHz	37
2404 MHz	0
2406 MHz	1
2408 MHz	2
2410 MHz	3
2412 MHz	4
2414 MHz	5
2416 MHz	6
2418 MHz	7
2420 MHz	8
2422 MHz	9
2424 MHz	10
2426 MHz	38
2428 MHz	11
2430 MHz	12
2432 MHz	13
2434 MHz	14
2436 MHz	15
2438 MHz	16
2440 MHz	17
2442 MHz	18
2444 MHz	19
2446 MHz	20
2448 MHz	21
2450 MHz	22
2452 MHz	23
2454 MHz	24
2456 MHz	25
2458 MHz	26
2460 MHz	27
2462 MHz	28
2464 MHz	29
2466 MHz	30
2468 MHz	31
2470 MHz	32
2472 MHz	33
2474 MHz	34
2476 MHz	35
2478 MHz	36
2480 MHz	39

- 2.4 GHz ISM band
- Divided into 40 channels from 2.400GHz to 2.4835GHz
- Frequency Hopping Spread Spectrum(FHSS)
- Channel 37, 38 and 39 are used for advertising
- Remaining channels used during connections

Network topology

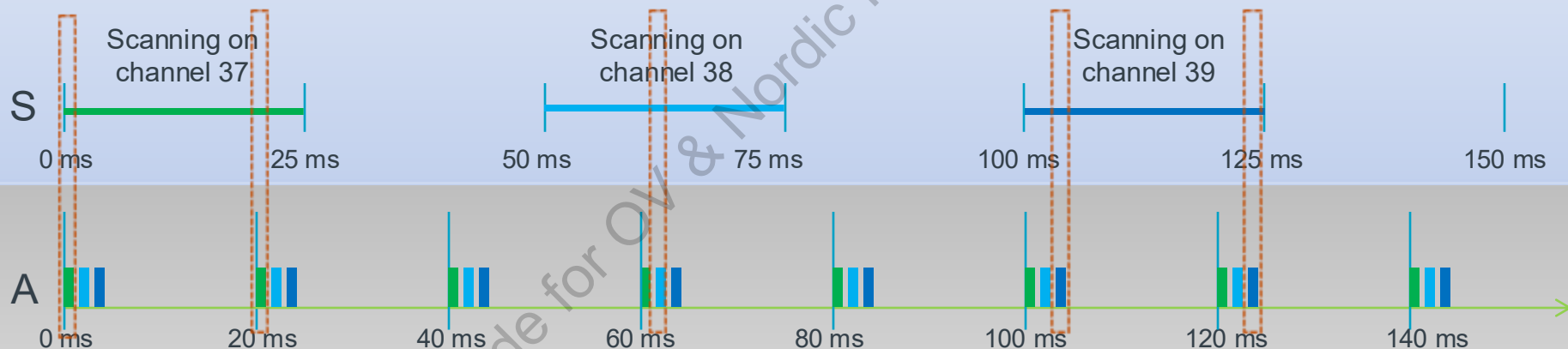


Advertising & Scanning



Scanner scan interval = 50 ms

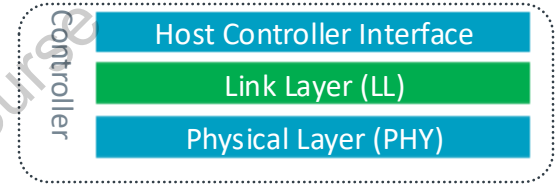
Scanner scan window = 25 ms



Advertising on 37, 38 and 39

Advertiser advertising, interval = 20 ms

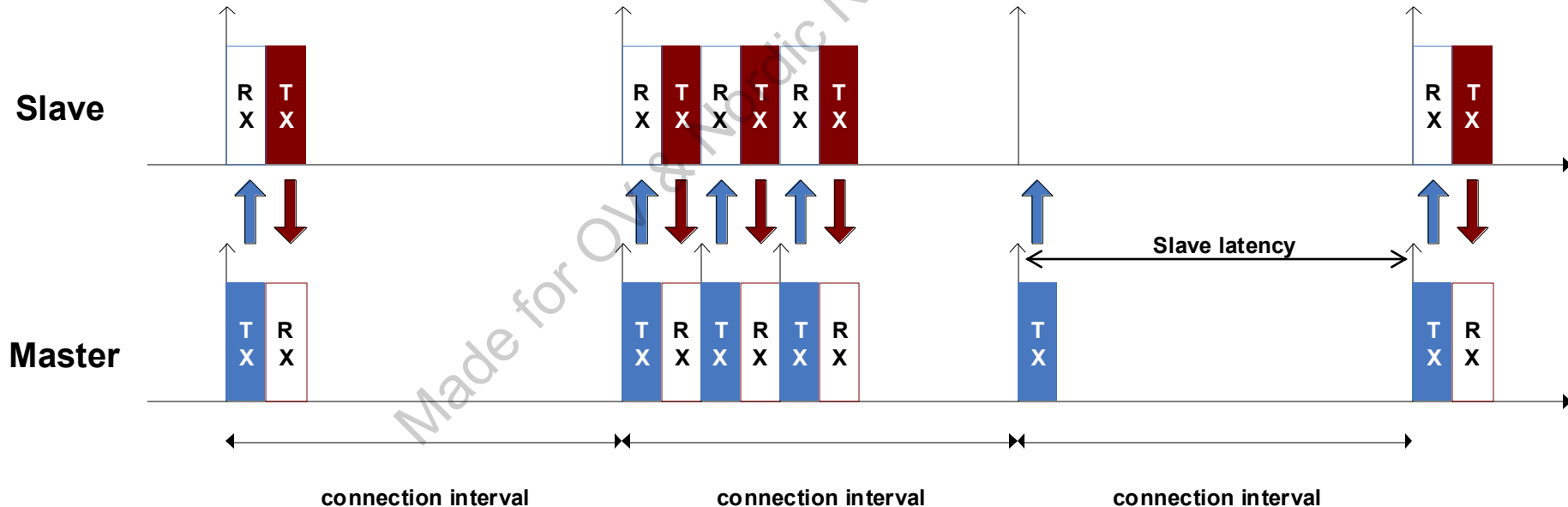
Connection Establishment



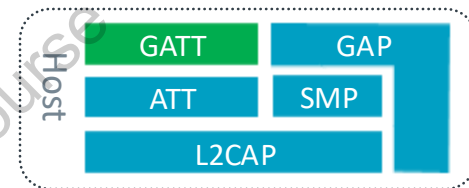
- Master starts scanning for advertising devices that are connectable
- Master initiates the connection process based on data in advertisement packet
- When a suitable advertising device is found, the master sends a connection request packet containing the following:
 - **Frequency hop increment:** *Which channel that should be used for the next connection event*
 - **Connection interval:** *The time between two consecutive connection events*
 - **Slave latency:** *The number of connection events that a slave can choose to skip with out risking disconnecting*
 - **Connection supervision timeout:** *Length of time the master will wait for a response from the slave before the connection is terminated.*

Connection

- Master sends first, slave responds
- Multiple data packets can be sent per connection event occurring at each connection interval
- Connection interval can be from 7.5 ms to 4 seconds

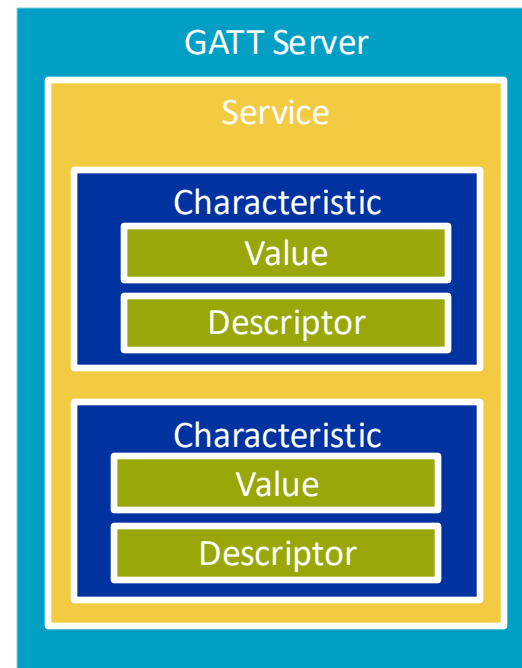


Bluetooth Low Energy – Data Exchange Services, Characteristics and Descriptors



Services, characteristics and descriptors all have an UUID

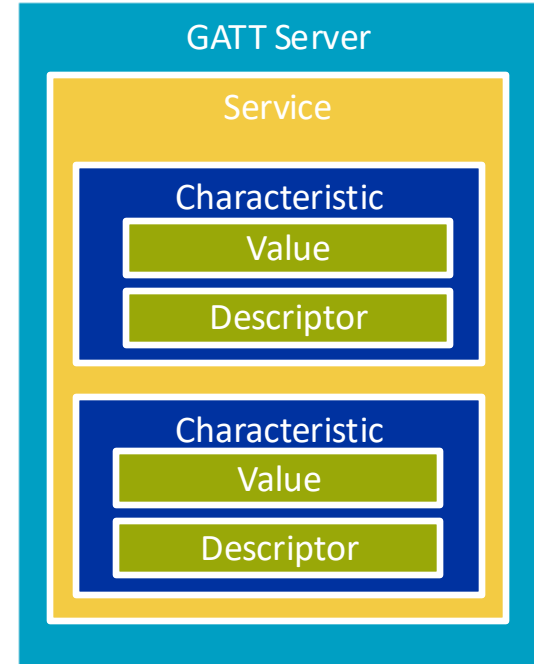
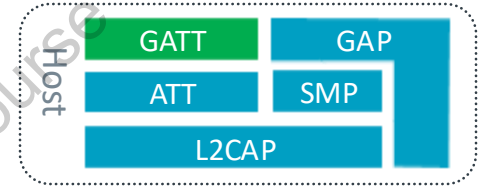
- UUID – Universal Unique Identifier
 - 16-bit short UUID using Bluetooth Base
0000XXXX-0000-1000-8000-00805F9B34FB
 - 128-bit UUID
XXXXXXXX-XXXX-XXXX-XXXX-XXXXXXXXXXXXXX
- In addition, Characteristics have:
 - Descriptor – Read/write permissions, metadata.
 - Value – Data that can be read/written by client



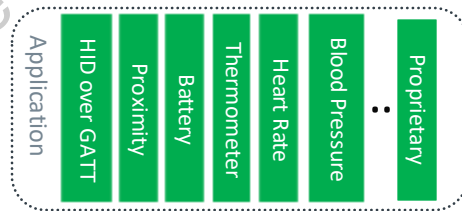
Bluetooth Low Energy

Services, Characteristics and Descriptors

- Services
 - Group of Characteristics
- Characteristics
 - Data containers, e.g. temperature, battery voltage
- Descriptors
 - Additional meta-data of the characteristic, e.g. notifications and indications



Application



- Profile:
 - Collection of services
 - Selects required features from GAP and GATT
- Use-case specific profiles
 - Bluetooth SIG defined, e.g. Heart Rate Profile (Heart Rate Service + Device Information Service)
 - Vendor-specific (proprietary), Apple iBeacon, Google Eddystone
- Key to interoperability



BluetoothTM

Bluetooth Low Energy

Crash course in the Bluetooth Low Energy protocol

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