



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

# Bluetooth Low Energy

## History

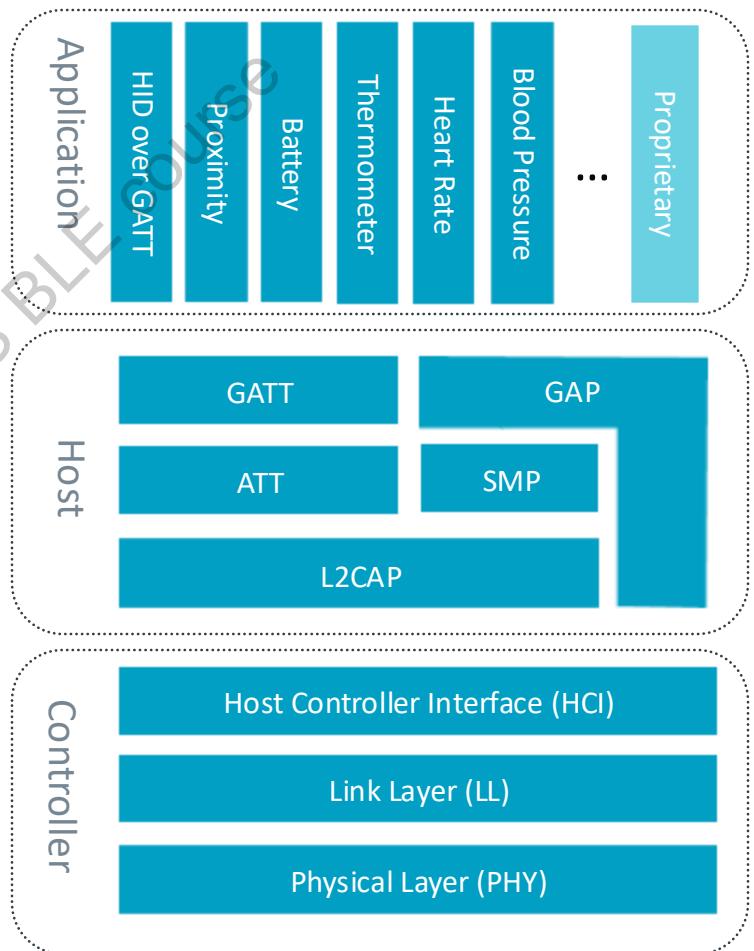
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	<b>4.2 (2014)</b>	LESC, DLE, Privacy 1.2, ++
	<b>5.0 (2016)</b>	High Speed(2 Mbit/s), Long Range, LE Adv. Extensions, LE Channel Selection Algorithm #2, Increased max power, ++

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

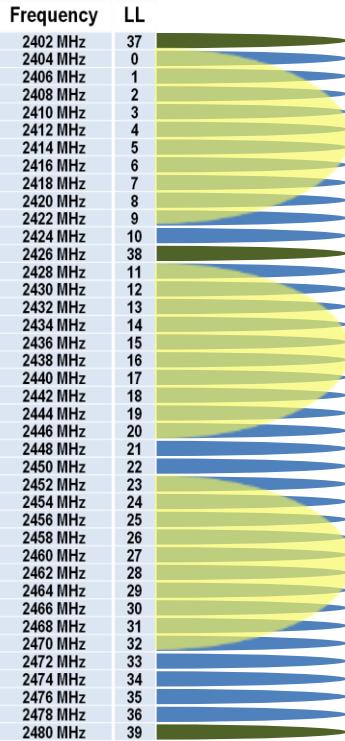
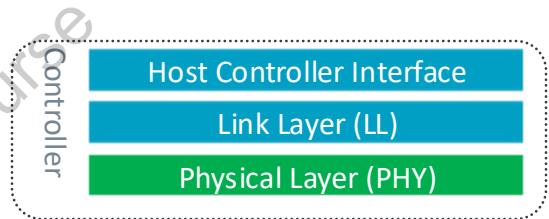
# Bluetooth LE Architecture

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

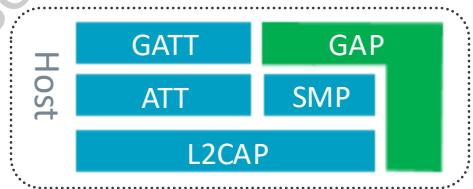
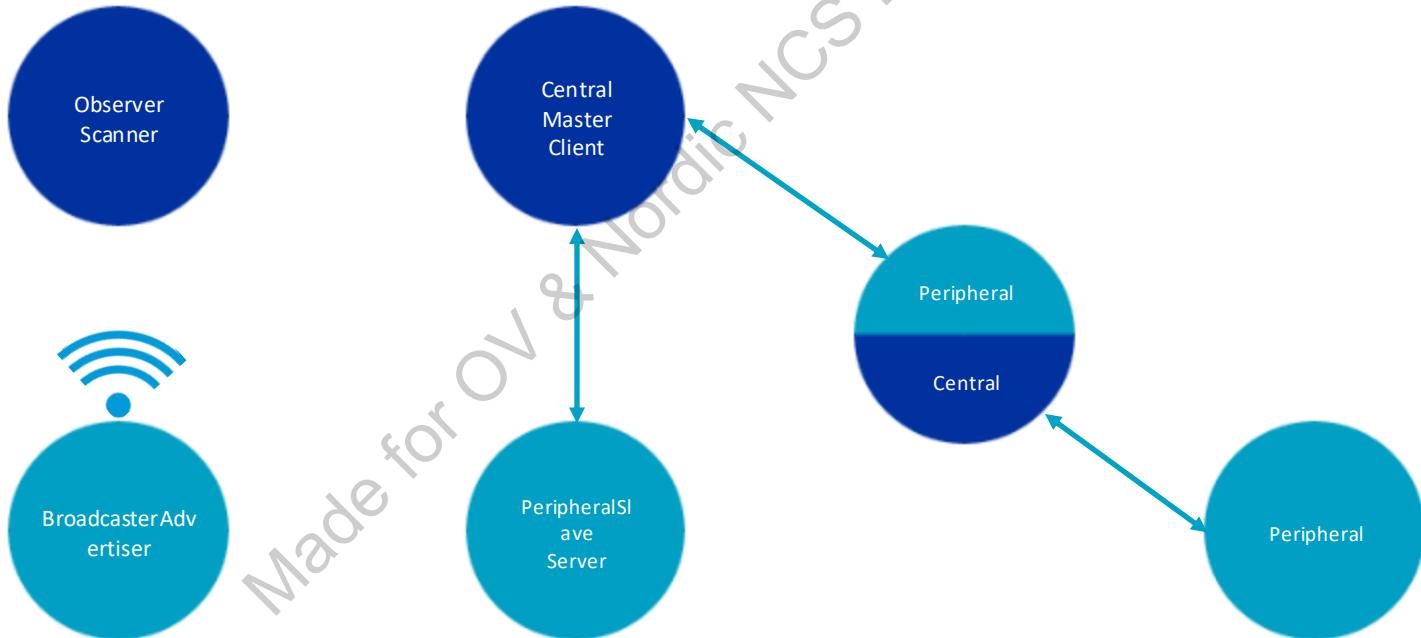


# Physical Layer(PHY)

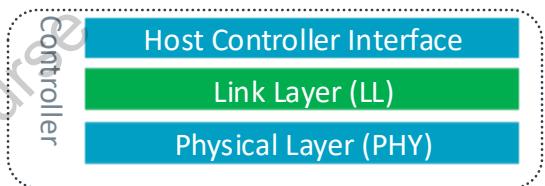


- 2.4 GHz ISM band
- Divided into 40 channels from 2.400GHz to 2.4835GHz
- Frequency Hopping Spread Spectrum(FHSS)
- Channel 37, 38 and 39 are used for advertising
- Remaining channels used during connections

# Network topology

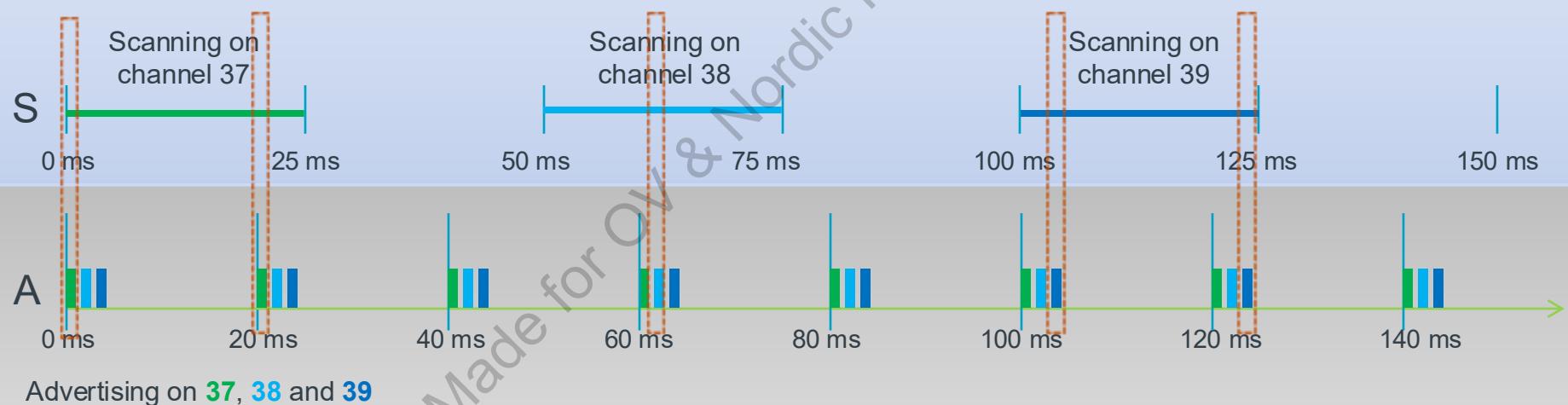


# Advertising & Scanning



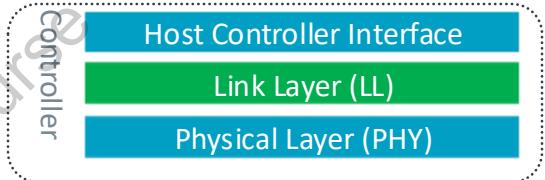
Scanner scan interval = 50 ms

Scanner scan window = 25 ms



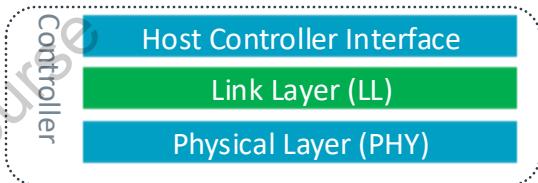
Advertiser advertising, interval = 20 ms

# Connection Establishment

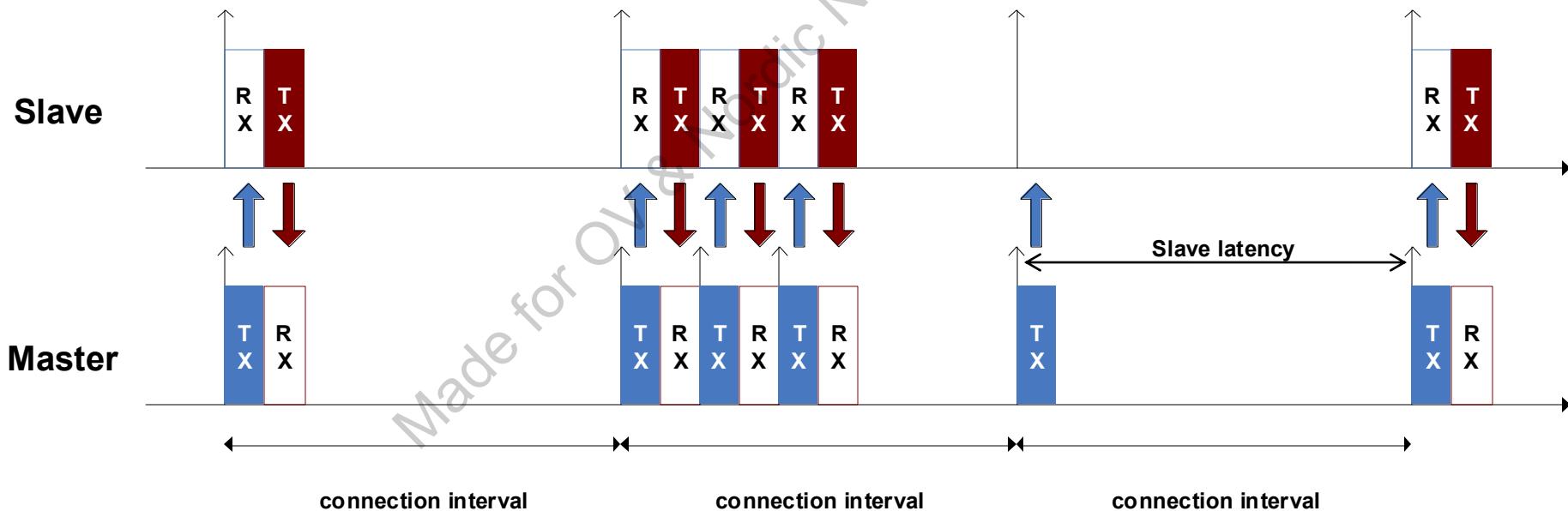


- Master starts scanning for advertising devices that are connectable
- Master initiates the connection process based on data in advertisement packet
- When a suitable advertising device is found, the master sends a connection request packet containing the following:
  - **Frequency hop increment:** *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

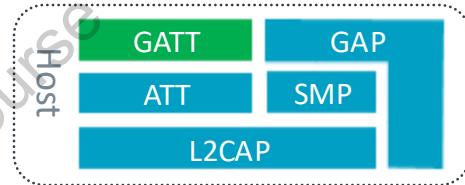


- Master sends first, slave responds
- Multiple data packets can be sent per connection event occurring at each connection interval
- Connection interval can be from 7.5 ms to 4 seconds



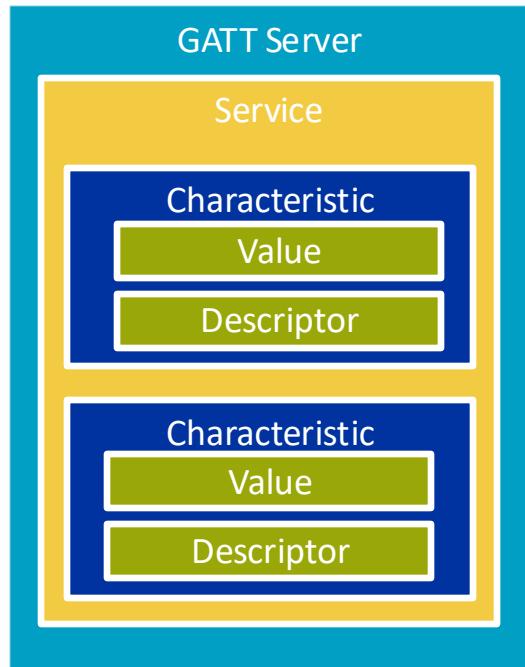
# Bluetooth Low Energy – Data Exchange

## Services, Characteristics and Descriptors



Services, characteristics and descriptors all have an UUID

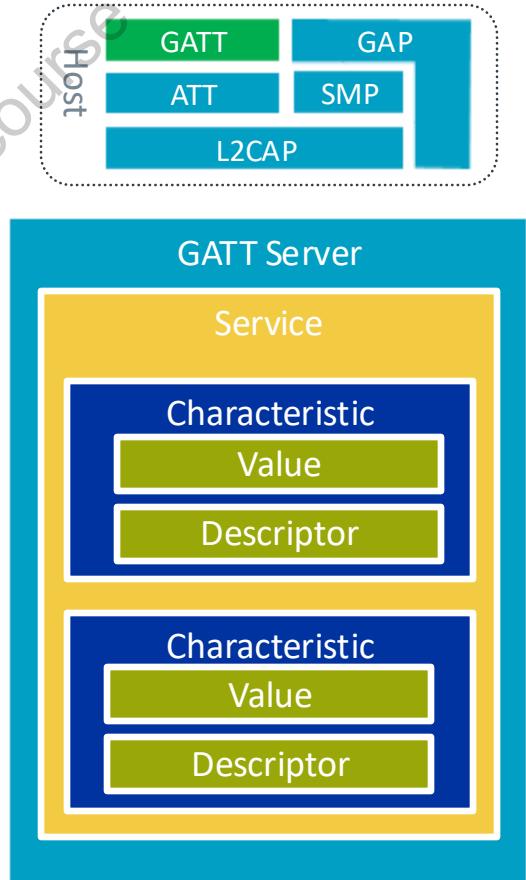
- UUID – Universal Unique Identifier
  - 16-bit short UUID using Bluetooth Base  
0000XXXX-0000-1000-8000-00805F9B34FB
  - 128-bit UUID  
XXXXXXXX-XXXX-XXXX-XXXX-XXXXXXXXXXXX
- In addition, Characteristics have:
  - Descriptor – Read/write permissions, metadata.
  - Value – Data that can be read/written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



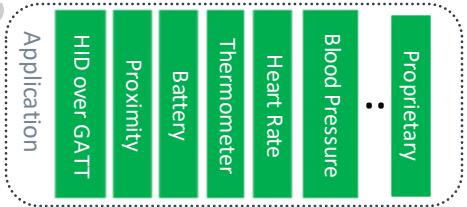
# Bluetooth Low Energy

## Services, Characteristics and Descriptors

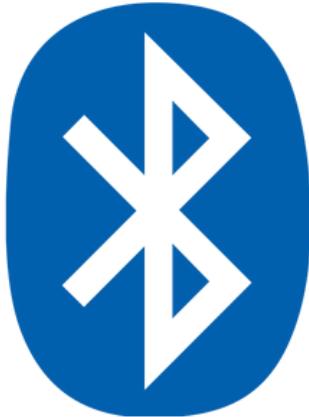
- Services
  - Group of Characteristics
- Characteristics
  - Data containers, e.g. temperature, battery voltage
- Descriptors
  - Additional meta-data of the characteristic, e.g. notifications and indications



# 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



Bluetooth™

# Bluetooth Low Energy

Crash course in the Bluetooth Low Energy protocol

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