ECEN 5823-001
Internet of Things Embedded Firmware

Lecture #20

01 November 2018

Be Boulder.

University of Colorado Boulder

Agenda

- Class Announcements
- Quiz 8 review

Class Announcements

- Quiz 9 due on Sunday, November 4th, at 11:59pm
- Course Project Proposal due Sunday, November 11th, at 11:59pm

Sensor Dev Kit update

Rain sensor:

MOD-000HL83 Qty: 2

https://www.gearbest.com/other-accessories/pp_1802002.html?wid=1433363&currency=USD&vip=4444999&gclid=EAIaIQobChMIyv32rK2q3gIV1rjACh1mMwmpEAQYAiABEgKoQ_D_BwE

UV sesor:

VEML6075 Sparkfun Qty: 1

Quiz 8 review

Match the application to the best suited memory technology

Data logging with limited power	[Choose]
Flash technology that is good for fast random access	[Choose]
Non-volatile program memory for micro controllers	[Choose]
Non-volatile program memories for DSPs and Microprocessors	[Choose]
Flash memory that requires ECC	[Choose]

Quiz 8 review

If a NAND memory that has a maximum number of 9,000 erase cycles per page and has a total of 10 pages configured as follows:

4 program pages

2 data pages

4 empty pages

What is the maximum number of erase cycles could this NAND memory typically experience if there is no wear leveling?

Quiz 8 review

Match the application to the best suited memory technology

Data Security	[Choose]
Lowest average power	[Choose]
Low cost non-volatile byte writeable memory to augment FLASH program memory	[Choose]
Program memory for a Processor or DSP	[Choose]
Over the air updates with very limited power	[Choose]
Non-volatile memory for data loggers that require a significant amount of memory	[Choose]

Quiz 8 review

In Bluetooth Mesh, the [Select] is used to exchange data from a Bluetooth Mesh node to a Bluetooth Smart device.

Quiz 8 review

FLASH single big data retentions failures are erroneous 1s?

- True
- False

Quiz 8 review

What user process results in a logical 0 in a NAND memory?

Quiz 8 review

In a Bluetooth Mesh network, select the Bluetooth Mesh feature with the phrase that it is associated with.

All Bluetooth Mesh messages are encrypted and authenticate	[Choose]
A Bluetooth Mesh network an be divided into subnets, each cryptographically distinct and secure from the others	[Choose]
Nodes can be removed from the network securely	[Choose]
Bluetooth Mesh security protects the network from a device using a previous message to gain access to the network	[Choose]

Quiz 8 review

The philosophy of Bluetooth Mesh security is concerned with [Select] while in Bluetooth Smart, the security philosophy is concerned with [Select] .

Quiz 8 review

What can be written as a single bit, byte, or words to a NAND flash memory cell? (Select all that apply)

- [ ] 0s
- [ ] 1s
- [ ] Neither 0s or 1s

Quiz 8 review

A Bluetooth Smart clients writes to the Bluetooth Mesh proxy using the [Select] to the Bluetooth Mesh proxy [Select] .

Quiz 8 review

Order the below non-volatile memory technologies from the least expensive per bit to the most expensive.

NAND	[Choose]
NOR	[Choose]
FRAM	[Choose]

Quiz 8 review

Match the application to the best suited memory technology

Aerospace application where alpha particle disturbances occur and high reliability is a requirement	[Choose]
Write performance is highest priority	[Choose]
Data logging, but cost is important as well	[Choose]
Low cost micro controller	[Choose]
Energy Harvesting	[Choose]

What is Persistent Data?

- **Persistent Data** denotes information that is infrequently accessed and not likely to be modified. The opposite of this is dynamic **data** (also known as transactional **data**) where information is asynchronously changed as further updates to the information become available. (Wikipedia)
- Our definition is that the data is not modified frequently, and is non-volatile

Why do you require Persistent Data?

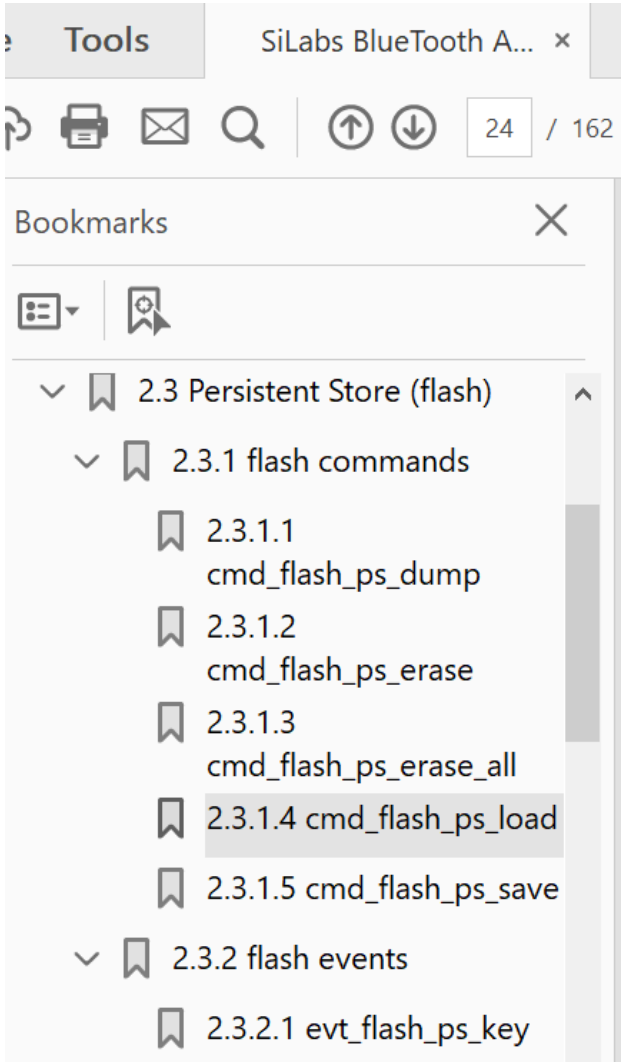
- Remove the need to reconfigure a device upon power loss and reboot
- Examples:
  - Temperature settings on a thermostat
  - Turn on and turn off times of a smart light
  - Critical set points of a sensor alarm
    - Setting the minimum temperature alarm
- Can you protect yourself from a power loss and not require non-volatile memory?
- When could you have loss of power?
  - When the battery is changed

What do I need to consider?

- I have just changed my program to use persistent data
- What happens the first time I boot up and try to read the persistent data?
  - It is not initialized
  - You must be able to recognized that it is not initialized and handle this case
    - Load some default initial value
- What event should you use to initialize your variables from persistent data?
  - gecko_evt_system_boot_id

What is required to program the BG Persistent Memory?

- Go to the Bluetooth API document
- Persistent Store commands can be used to manage the user data in the flash memory of the Bluetooth device
- User data stored in PS keys within the flash memory is persistent across reset and power cycling of the device
- The maximum user data size associated to a PS key is 56 bytes



Dynamic Memory (DDR3, DDR3L, LPDDR3

- DDRx – often referred to as (JEDEC) standard or commodity DRAM or just DRAM (DDR, DDR2, DDR3. etc.) JEDEC standard JESD79E, etc
- LPDDRx – Referred to as low power, mobile or wireless DRAM (LPDDR, LPDDR2, LPDDR3). Also defined by JEDEC standard JESD209A, etc
- In most system, the type of DRAM will be limited by the micro processor, DSP, or FPGA memory controller, thus the DRAM should be included in the decision of these devices.
- Most common DRAM in today's mobile devices will be DDR2 or DDR3

DDR3 comparisons

- LPDDR3
  - Core voltage: 1.2v (1.8v WL required)
  - I/O voltage: 1.2v
  - Max Data rate: DDR1600
  - Pin Cofig: 16x, 32x
  - Partial Array Self-Refresh: individual bank and segment masking for partial-bank modes
  - Deep Power Down Mode: Yes
- DDR3
  - Core voltage: 1.5v
  - I/O voltage: 1.5v
  - Max data rate: DDR2100
  - Pin Conf: 4x, 8x, 16x
  - Partial Array Self-Refresh: Optional
  - Deep Power Down Mode: No
- DDR3L
  - Core voltage: 1.3v
  - I/O voltage: 1.3v
  - Max data rate: DDR2100
  - Pin Conf: 4x, 8x, 16x
  - Partial Array Self-Refresh: Optional
  - Deep Power Down Mode: No

SDxx memory cards provide:

- SPI bus to interface to micro controllers
- Card Security
  - Commands to disable writes
  - Write-protect notch
  - Card password
  - DRM copy-protection
- Real World Performance Issues:
  - Write Amplification
  - File Fragmentation

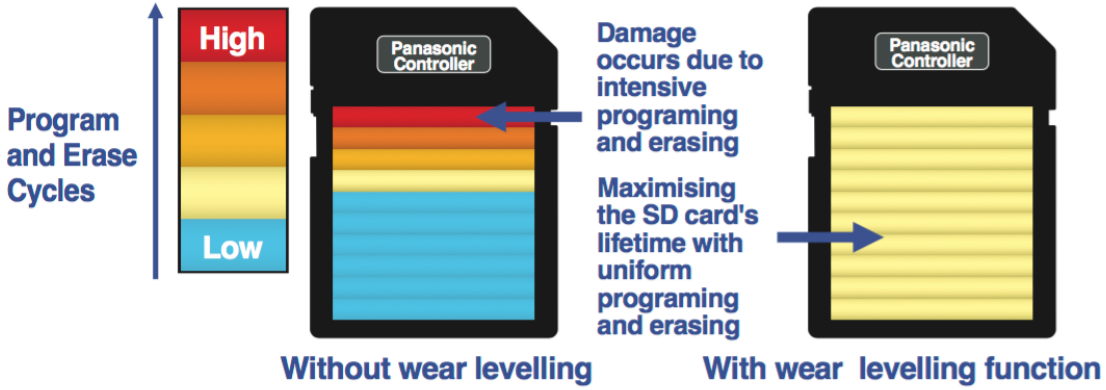
Example of Industrial SD memory card

Data Programming and Erase Endurance

Wear Levelling

● **Maximising SD Memory Life**

Static wear levelling controls written data, including fixed data. Various use cases eliminate intensive data writing and maximise the lifetime of the SD card.



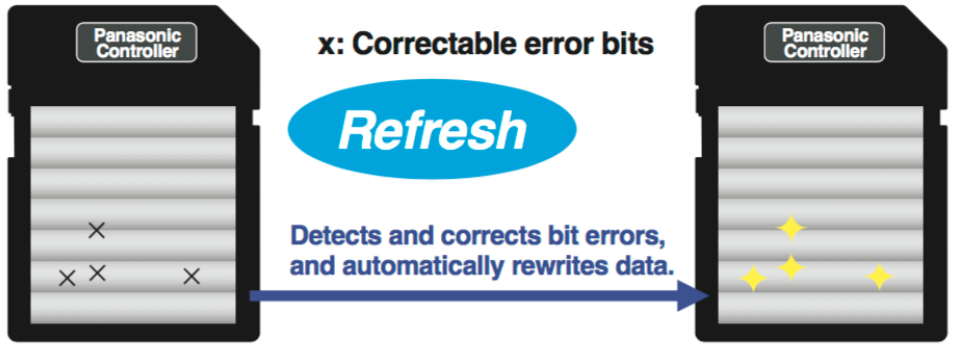
Secure Storage

Bit Error Auto Refresh

● **Withstanding Repeated Reading Operations**

Automatically refreshes the bit errors that accumulate over time, before they exceed the threshold. (Accumulated bit errors are detected from read data.)

* This function does not guarantee permanent data retention.



Example of Industrial SD memory card (Cont.)

Intelligent Data Writing

● **Dispersion of Writing Stress to NAND Flash Memory**

Intelligent data writing disperses the writing stress to NAND flash memory, to reduce program disturbances.

Recovery

● **Protects saved data and device**

Unique Panasonic algorithms minimise data damage in the event of a power interruption. Even in the event that an error is generated, the controller recovers the data, restoring it to the condition prior to the error, and preventing errors from reaching the entire SD memory area.

* Power Fail Robustness Mode firmware also available for more robust MLC system

Example of Industrial SD memory card (cont.)

Panasonic SD memory features high endurance against static electricity, magnetism, and X-rays.

Temperature Resistance

Operation is assured even under harsh temperature conditions.

A usable temperature range of -40 ˚C to 85 ˚C maintains stable performance everywhere, from extremely cold to intensely hot climates.

Electrostatic Resistance

ICE 61000-4-2 compliance: Clears Electrostatic Discharge Immunity Tests of 150-pF energy storage capacitance, 15-kV aerial discharge, and 330-Ω discharge resistance.

Impact Resistance

High endurance against bending and twisting.

Bending load resistance	20 N (Newton) min. (SD standard: 10 N)
Twisting torque resistance	0.3 N•m (Newton meter) min. (SD standard: 0.15 N•m)

Magnetic Resistance

Minimal damage from magnetic forces.

Operable after being set onto a 1,000-gauss DC magnetic field for approx. 1 minute.

X-Ray Resistance

Data is protected from X-rays.

ISO 7816-1 compliance: Operable after 0.1 Gy (gray) of X-ray irradiation.

Water Resistance

JIS IPX7 compliance: Operable after submerging the product in water (tap water, 1-m depth) for 30 minutes.

* micro SD – Excluding SD adaptor use.
* Card only.

Built-in Fuse

The internal card fuse protects against excess current and abnormal heating.

Even if excess current or abnormal heating were to occur due to internal card damage caused by the device being used or the environment, the built-in fuse will operate to prevent the SD Memory Card from overheating or igniting.

What comprises a verification plan?

- What each line item should include?
  - What is being verified
  - Definition of passing
  - Date test performed
  - Who completed the test
  - Measured result
  - Did it pass

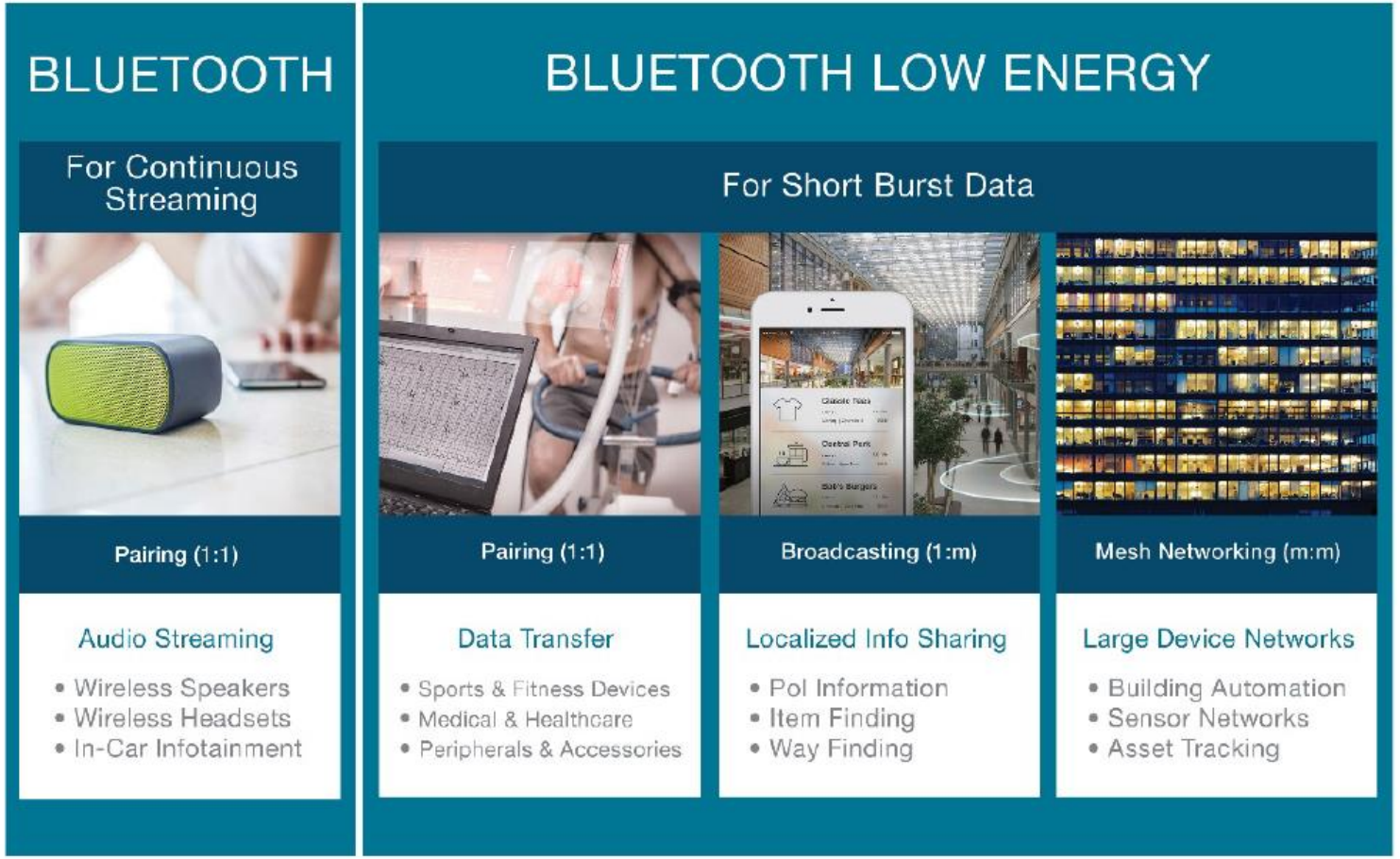
To be verified	Definition of passing	Date test performed	Tested by	Measured result	Passed?
Digital Vdd does not drop below minimum system specification	Minimum voltage during 3uA to 4mA step at minimum batttery voltage (2.4v) above 2.0v				
Digital Vdd does not go above system specification	Maximum voltage during 4mA to 3uA step at maximum battery voltage (3.2v) below 3.6v				

What comprises a verification plan?

- What are the line items that need to be included?
  - Each BLE or Mesh Service or Client profile / model
  - Secure OTA update
  - Persistent Memory functionality
  - LCD driver
  - Any other drivers
  - Include BLE or Mesh security features
  - Bluetooth Mesh node software (Proxy, rely, friend, low power)
  - Complete scheduler
  - Etc.


1:02 / 1:26
CC

Bluetooth Mesh



Development of Bluetooth standard from Bluetooth BR/EDR (left) to LE and Bluetooth mesh (right)

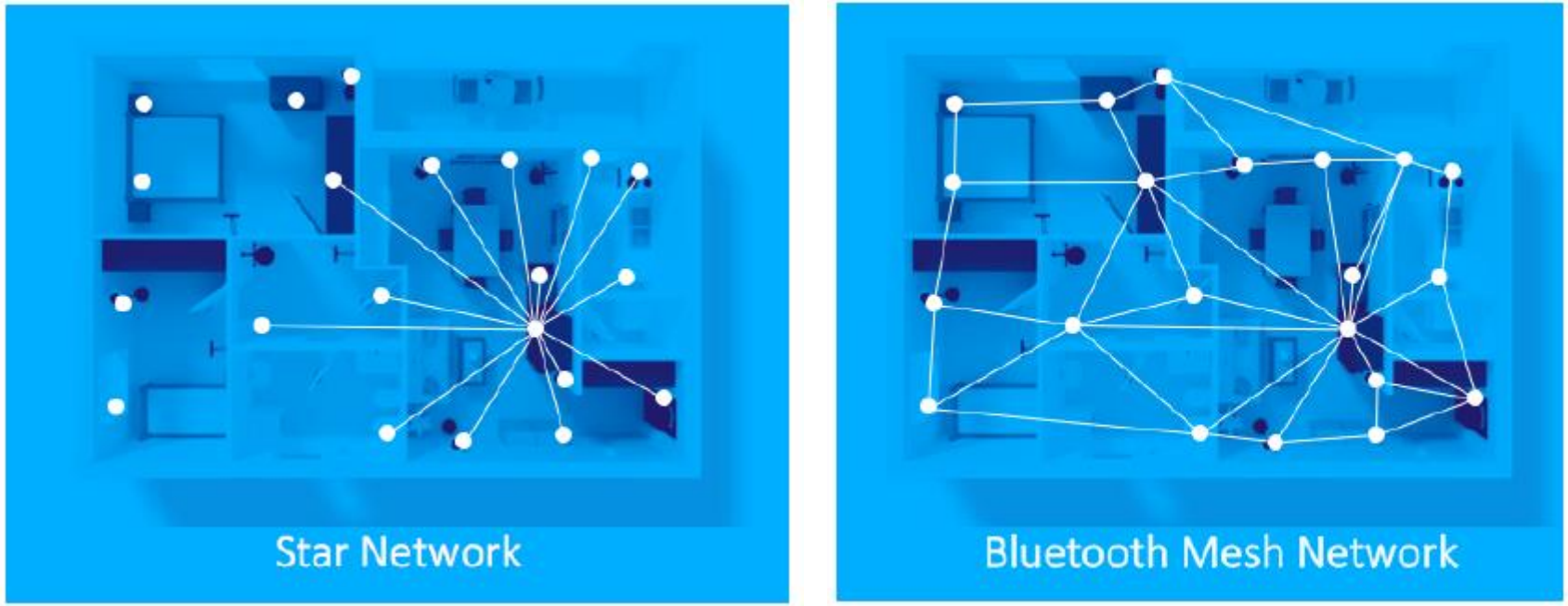
Bluetooth Technology Summary

- Bluetooth Classic BR/EDR
  - de facto wireless technology for voice and audio streaming and use cases like wireless speakers, headphones and in-car infotainment
  - not optimized for low power applications IoT devices
- Bluetooth Low Energy
  - short burst wireless connections and data broadcast for the wearable devices, sports and fitness sensors and beacon applications
  - Limited range and number of connections

Bluetooth Technology Summary

- Why Bluetooth Mesh or what are its advantages over Bluetooth Smart?
- Bluetooth Mesh
  - Addresses the needs of the quickly growing IoT market
  - Increased connectivity
  - Increased reach – mesh network
  - Increase functionality – publish-subscribe

Bluetooth Mesh



- Bluetooth mesh nodes can also support existing Bluetooth LE topologies and use cases such as point-to-point connectivity and Bluetooth beaconing

How does Bluetooth Mesh Route?

- What type of mesh networking and how does it work?
- Flooding type meshing:
  - Broadcast channels are used to transmit messages from nodes
  - As messages are received they are relayed further making it possible to extend the range by adding more nodes
  - If the density of the mesh nodes is sufficient that any node can send messages to any other node directly it is full mesh
  - or first to nodes close-by after which the nodes relay the messages onward to further nodes it is partial mesh
- Flooding-based mesh networks are considered easier to implement and more resilient if compared with routing-based mesh networks
- But, routing-based networks have better scalability

Bluetooth Mesh – Managed Flooding

Feature	Description
Heartbeats	• *Nodes send heartbeat messages periodically to indicate activity.* • *Heartbeat messages contain data to allow receiving nodes to determine the number of hops between the nodes which can be taken into account using the Time to Live (TTL) parameter (see below).*
Time to Live (TTL)	• *All Bluetooth mesh PDU's contain this field.* • *Controls maximum number of hops.*
Network Message Cache	• *Compulsory for each node.* • *All recently received messages are stored in the cache.* • *If the received message is already in the cache it is an indication that the message has been processed already and is therefore discarded immediately.*
Friendship	• *Used in combination with Low Power nodes.* • *Friendship node receives and buffers addressed to the configured Low Power node and forwards buffered messages to the Low Power node when it becomes active after waking up.*

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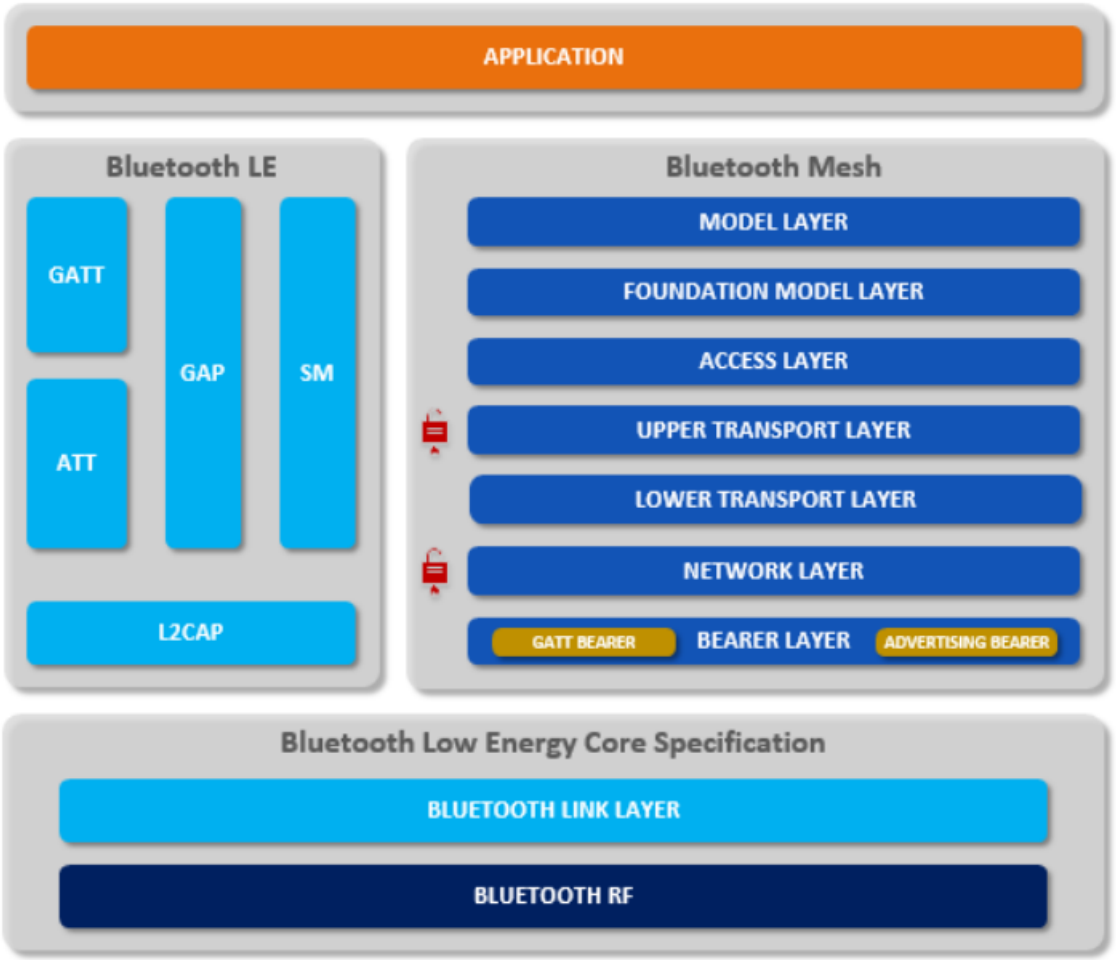
Bluetooth Mesh – Managed Flooding

Feature	Description
Pre-emptive "filtering"	• *Received messages are passed up the stack and various checks are performed by the Network Layer to decide whether to discard the message or pass further to higher layers.* • *PDU Network ID field is used to decide if the NetKey used to encrypt the message is recognized or not. If the NetKey is not known the PDU is discarded.* • *If the Message Integrity Check (MIC) check fails when using the NetKey corresponding to the PDU's Network ID the message is discarded.* • *Optimizes filtering of messages not addressed to the node.* • *AppKey of message is used in Upper Transport Layer with the help of Application Identifier.* • *If the Application ID is not recognized the PDU is discarded by the Upper Transport Layer.* • *If the transport Message Integrity Check (MIC) is not succesful the message is discarded.*

Bluetooth Mesh Software Architecture

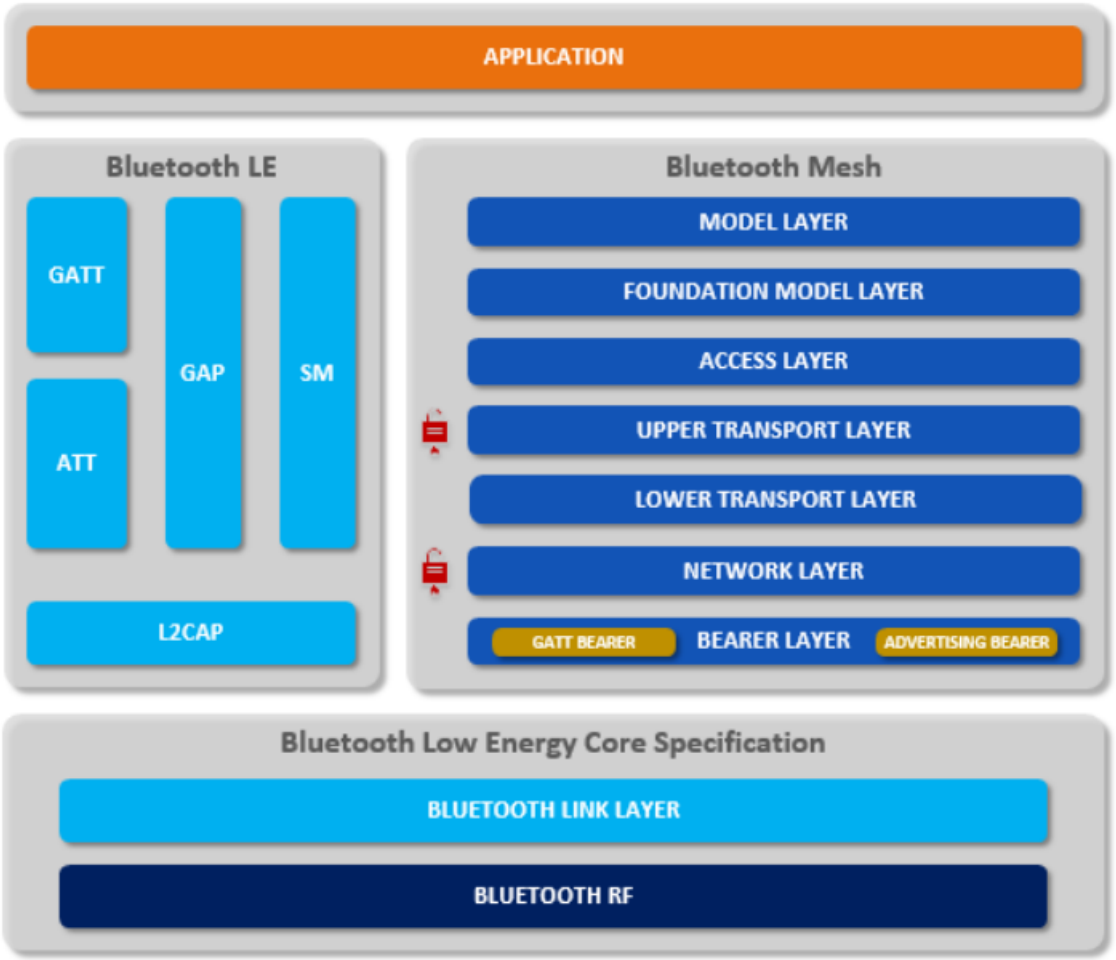
- Seven software layers on top of the Bluetooth Low Energy Core Specifications
- The Model Layer defines models which standardize typical user scenario operations as defined in the Bluetooth Mesh Model specification



Bluetooth mesh architecture (right) with Bluetooth LE architecture (left)

Bluetooth Mesh Software Architecture

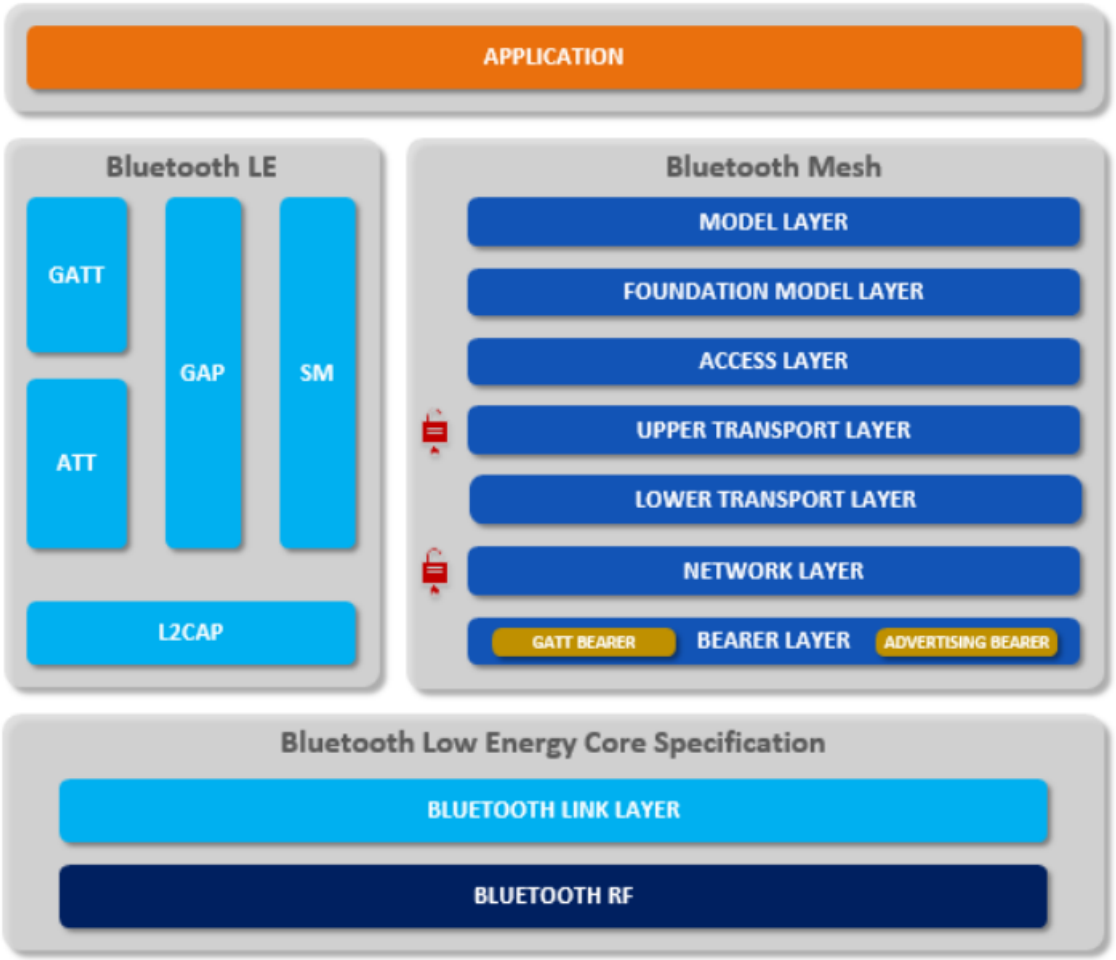
- The Foundation Model Layer defines the states, messages and models needed for configuring and managing a Bluetooth mesh network
- Higher Layer application usage of the Upper Transport Layer is defined in the Access Layer



Bluetooth mesh architecture (right) with Bluetooth LE architecture (left)

Bluetooth Mesh Software Architecture

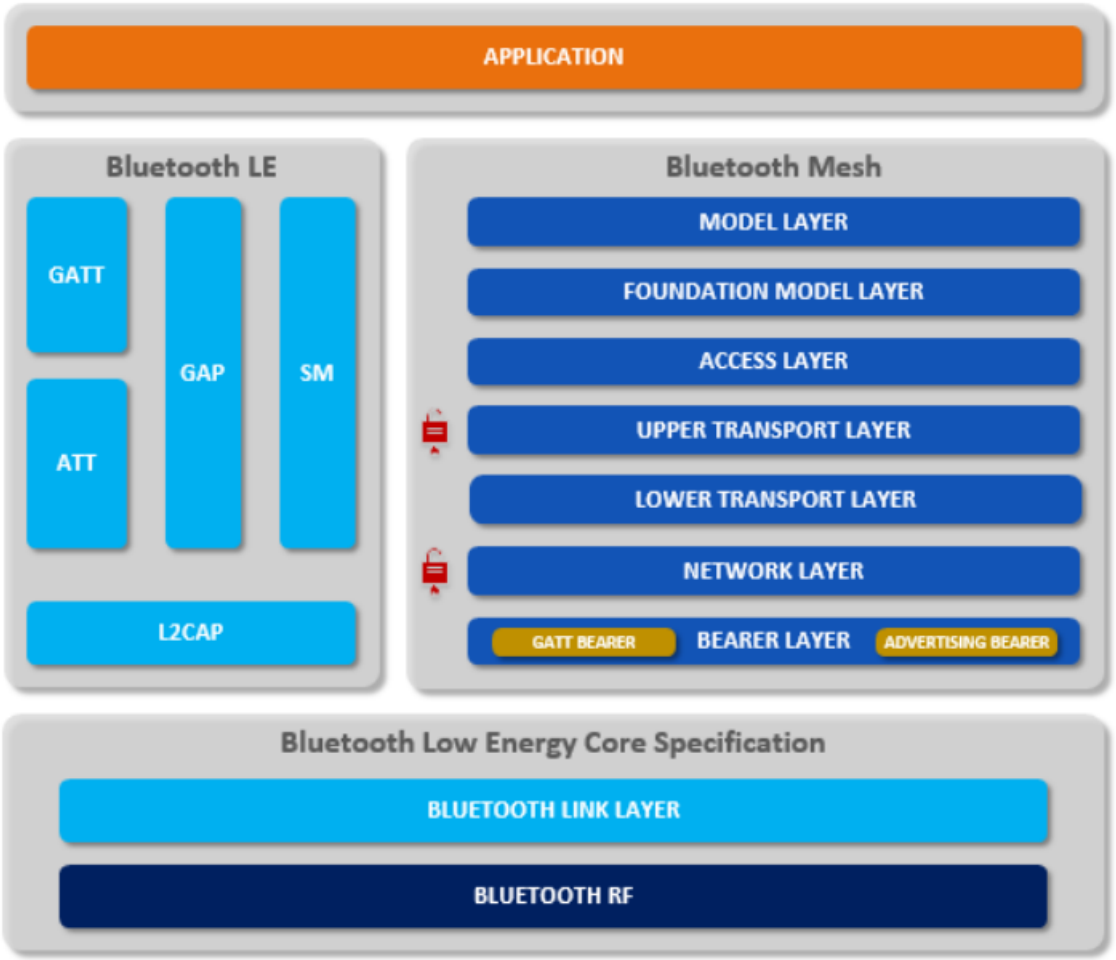
- Upper Transport Layer guarantees confidentiality of access messages through encryption, decryption and authentication as well as defines the way transport control messages are used for managing the Upper Transport Layer between nodes, also for the Friend feature



Bluetooth mesh architecture (right) with Bluetooth LE architecture (left)

Bluetooth Mesh Software Architecture

- Rejection of messages, decision to relay messages or to further process the messages instead of rejecting them is managed by the Network layer
- Bearer Layer defines the transportation of network messages between nodes
- An important point is the inclusion of two different bearers, one for Advertising and one for GATT



Bluetooth mesh architecture (right) with Bluetooth LE architecture (left)

Bluetooth Mesh - Nodes

- Relay: Receive and retransmit mesh messages by using the Advertising Bearer to enable larger networks
- Proxy: Receive and retransmit mesh messages between GATT and Advertisement Bearers
- Low Power: Operation at significantly reduced receiver duty cycle in conjunction with a node supporting the Friend feature
- Friend: Enables helping a node supporting the Low Power feature by storing messages on its behalf
- Gateway: Used between a Bluetooth mesh and a non-Bluetooth wireless network to allow data sharing based on protocol conversion