BLUETOOTH LOW ENERGY (BLE)

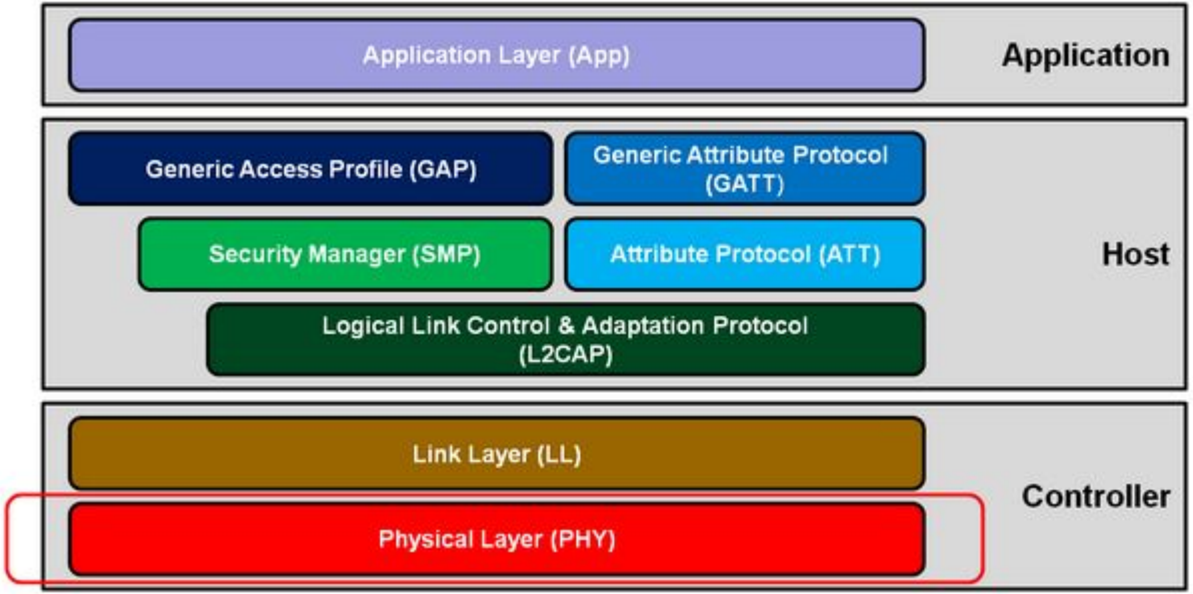
INNOVATIVE SMART SYSTEMS

INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES TOULOUSE

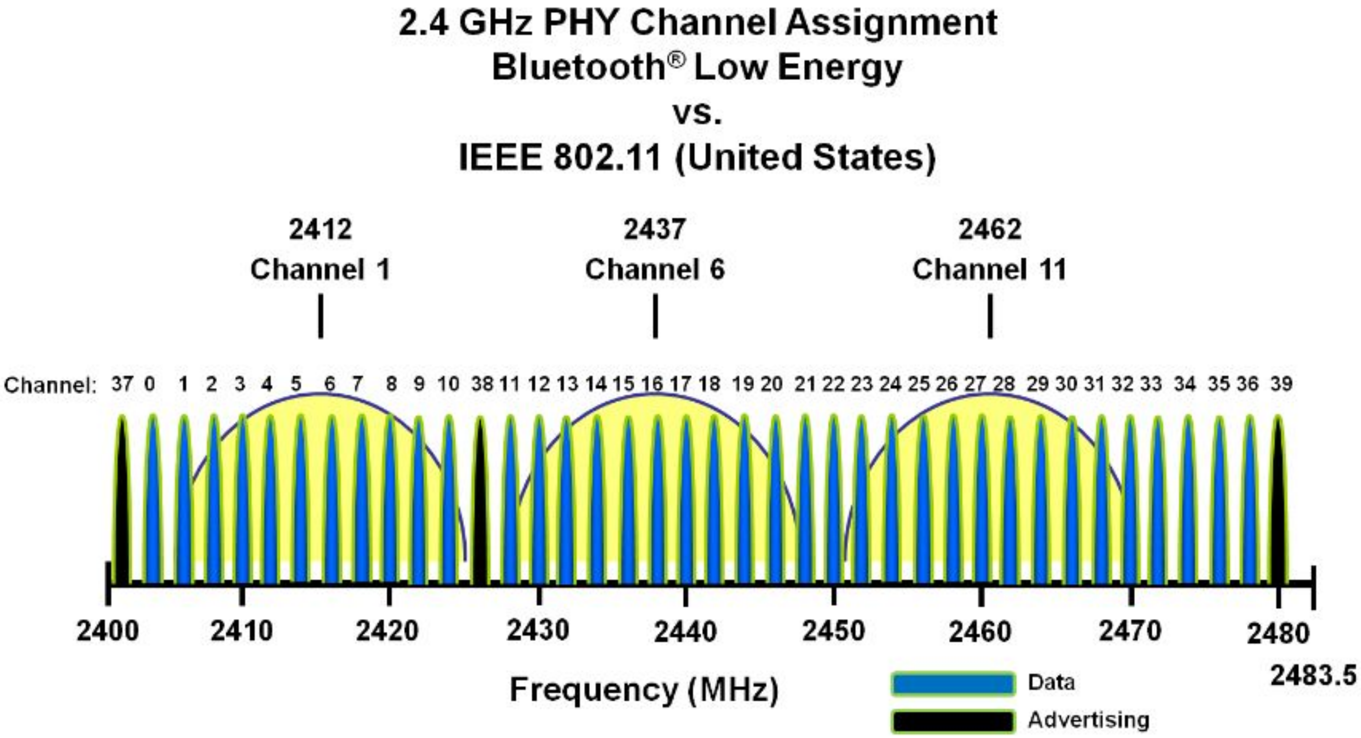
Planning

1. Physical Layer
2. MAC Layer
3. Power consumption
4. Security

Physical Layer



Physical Layer

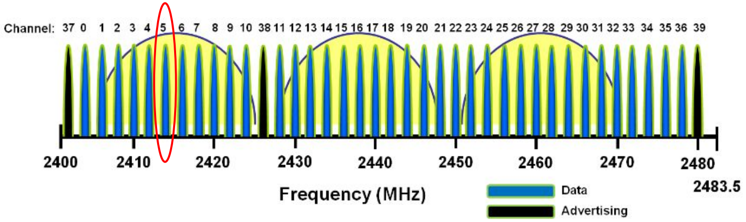


https://microchipdeveloper.com/wireless:ble-phy-layer

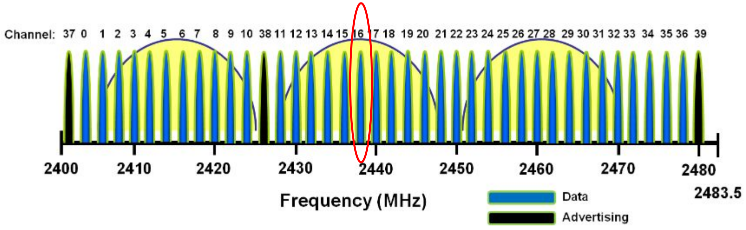
Physical Layer

Frequency Hopping Spread Spectrum (FHSS)

$$f_{n+1} = (f_n + hop)\ (mod\ 37)$$



(e.g : hop = 11)



Physical Layer

FSK

$$F_{Channel\ n} + \Delta f = 1$$

$$F_{Channel\ n} - \Delta f = 0$$

(140 kHz ≤ Δf ≤ 175 kHz)

+

Gaussian Filter

=

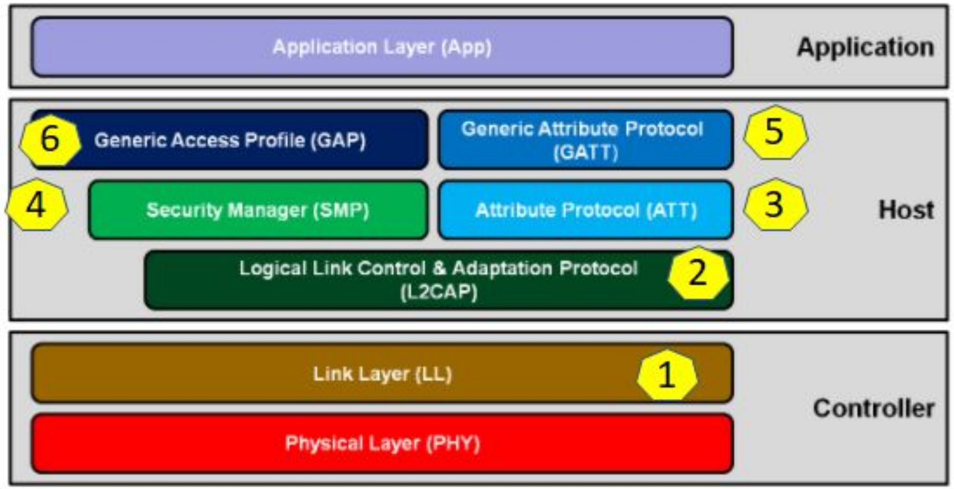
GFSK

Physical Layer

😱 1 Mb/s 😱

But...

Link Layer



FUNCTIONS

6 Definition of interaction between devices

5 Exchange of data between applications

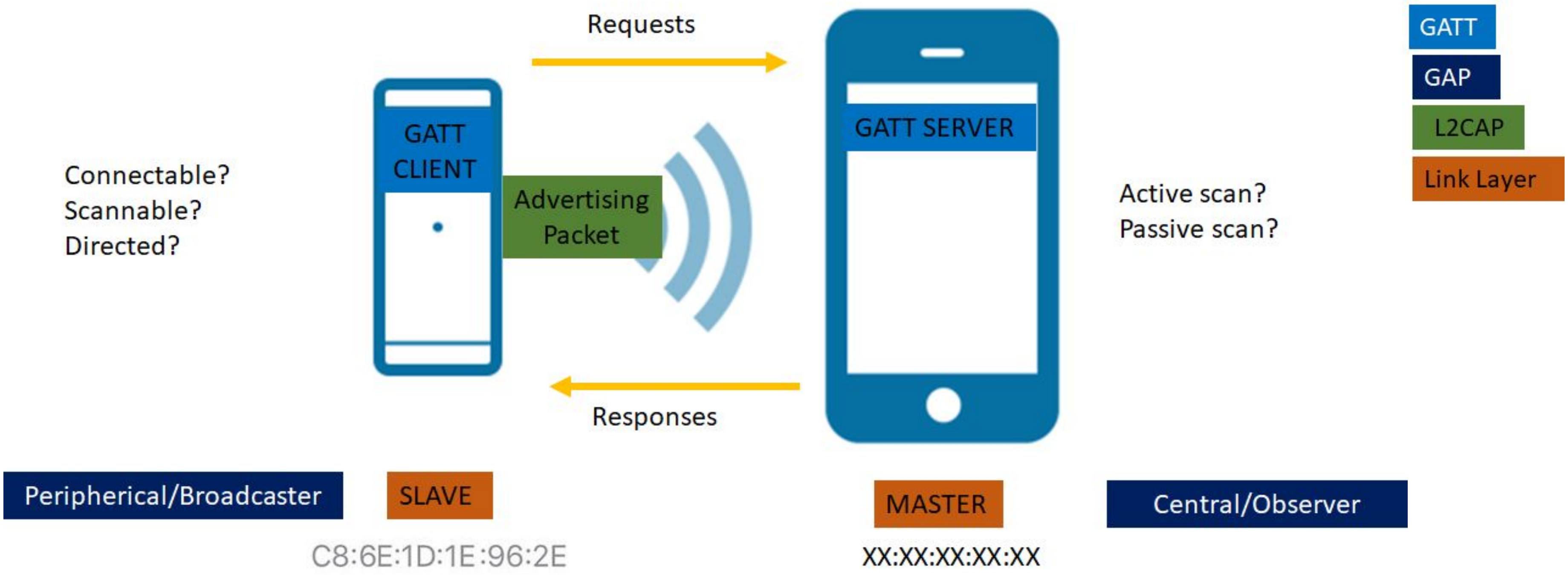
4 Generation & exchange of security keys

3 Client/server protocol based on shared attributes

2 Transport of data

1 Addressing + communication

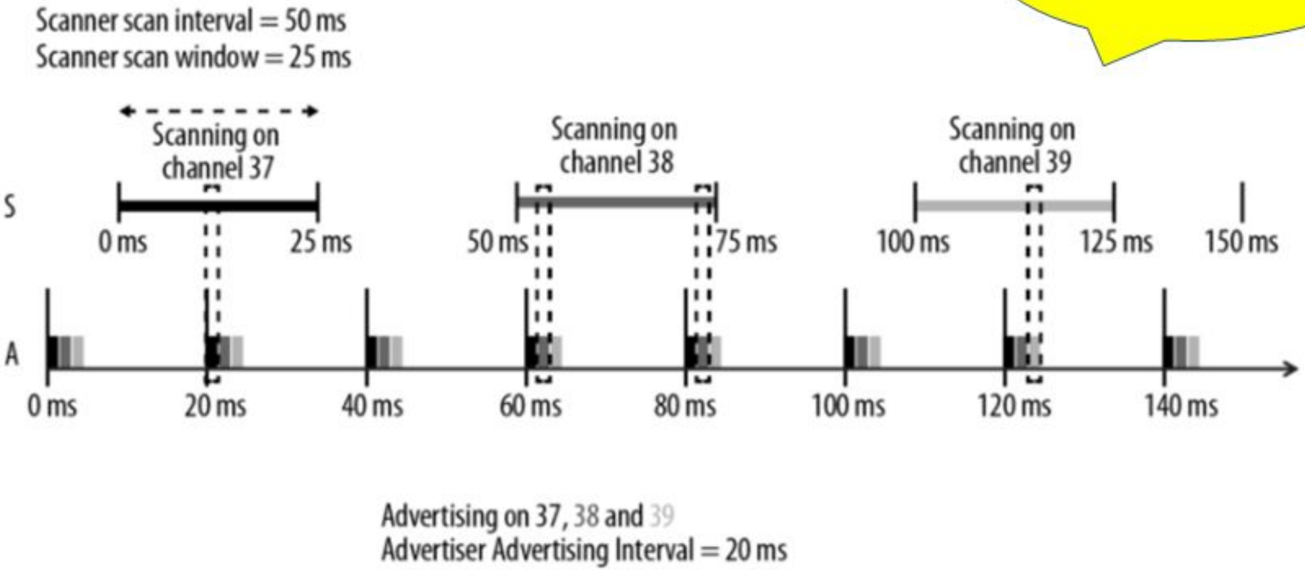
Connection



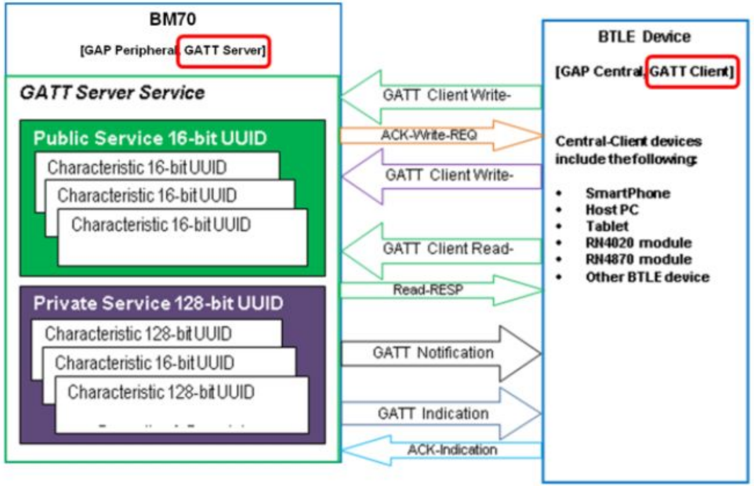
Requests
GATT CLIENT
Advertising Packet
GATT SERVER
Responses
Connectable?
Scannable?
Directed?
Active scan?
Passive scan?
GATT
GAP
L2CAP
Link Layer
Peripherical/Broadcaster
SLAVE
MASTER
Central/Observer
C8:6E:1D:1E:96:2E
XX:XX:XX:XX:XX

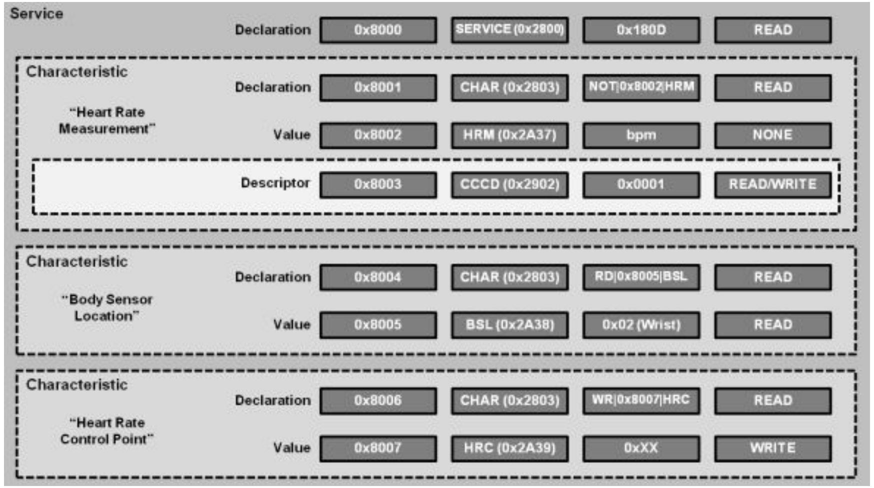
Synchronisation

No synchronisation



Generic Attributes Protocol



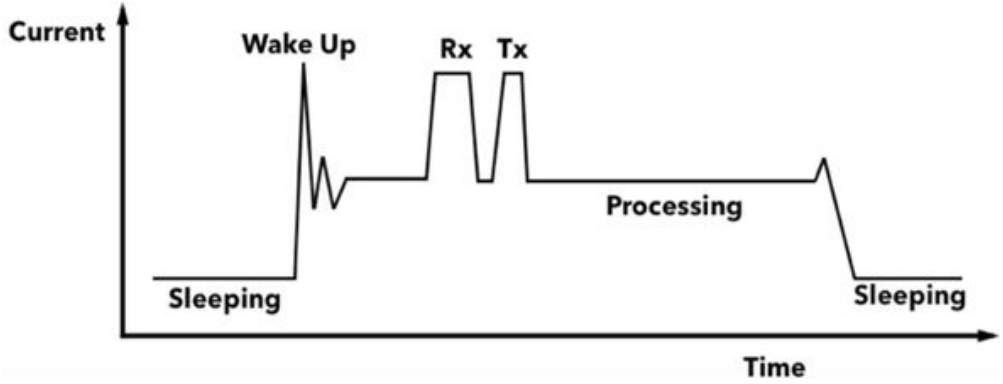


BLE Consumption

It's not straightforward to predict the exact BLE power consumption due to the several parameter depending on. BLE consumption depends on:

- Chipset/radio
- BLE Stack + version
- BLE parameters
- Firmware efficiency

<u>Current Consumption Draw during a cycle</u>



Awaking Mode Consumption

We can define the overall energy consumption during an awaking mode as the sum of each different energy consumption state: E_awake= E_wake-up+ E_rx+ E_tx+ E_processing+ E_IFS

- Wake-up energy
- RX energy (mainly depends on the data number to receive)
- IFS energy
- TX energy (mainly depends on the data to send and the transmit power used)
- Post-processing energy (mainly depends on the application running)

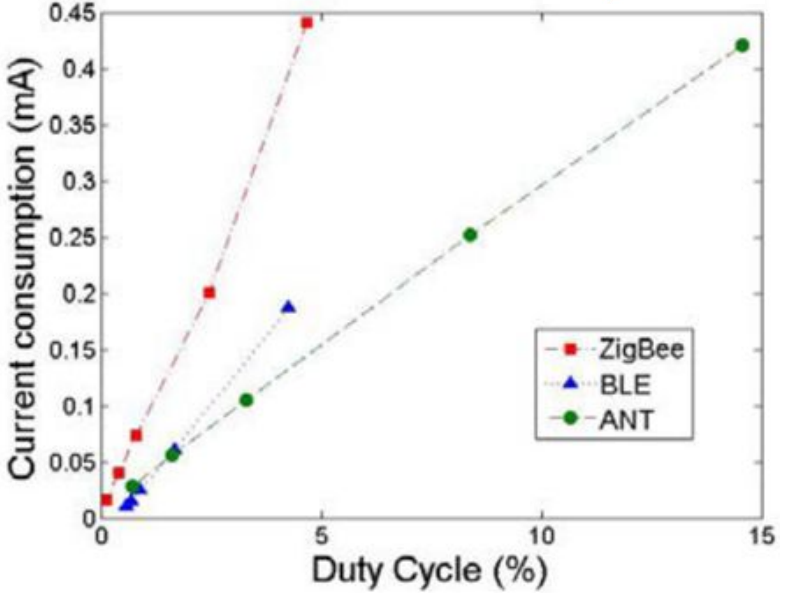
Phase	Power draw ($V_{DD} = 3V$)	Duration
1. wakeup & pre-processing	$P_{wu} = 15mW$	$D_{wu} = 1ms$
2. RX	$P_{rx} = 66mW$	$D_{rx} = 8\mu s/B$
3. IFS	$P_{ifs} = 45mW$	$D_{ifs} = 150\mu s$
4. TX	$P_{tx} = 84mW$	$D_{tx} = 8\mu s/B$
5. post-processing	$P_{mcu} = 24mW$	$D_{mcu} = 1.4ms$

Sleeping Mode Consumption

Sleeping mode is useful for saving energy when the BLE device didn't send any data. In order to save energy, consumption is very low (2 µW) in this mode, an engineer which is looking to increase a BLE device autonomy, will handle to reduce the duty cycle.

Overall BLE consumption in cycling mode:

E_ble = E_awake + E_Sleep



<u>Mean current consumption related to the duty cycle</u>

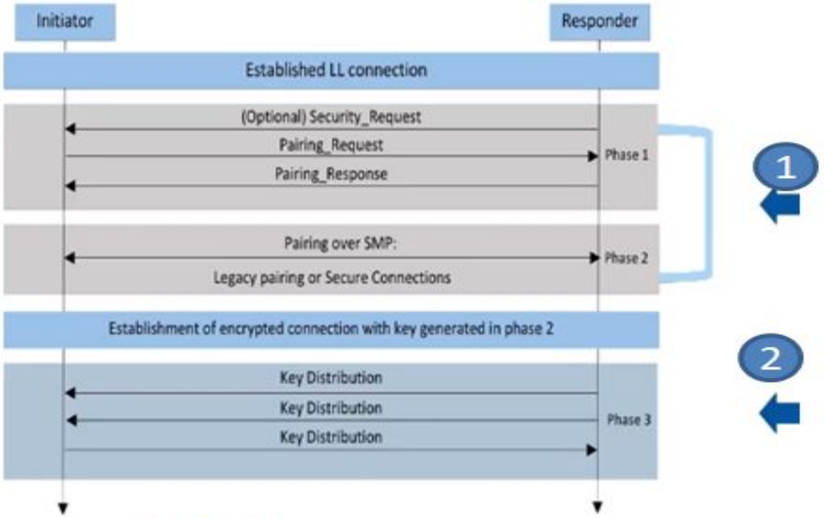
BLE modele de securité

- Pairing: 1

  Processus de création de clés partagées / sécurité temporaire / connexion cryptée .

- Bonding: 2

  Stockage de la clé créée lors du couplage pour une utilisation ultérieure .



1-Concevoir l'authentification:

Vérification des clés stockées .

2-Confidentialité :

Les données ne sont pas lisibles par d'autres utilisateurs .

3-Intégrité : Protection contre l'altération des données .

Sécurité Manager

Sécurité Manager est un module de l'achitecture BLE :

❖Protocole et algorithme .

❖Génération et échange clés .

❖128 Bit de de crypte selon [Standard Avancé de criptage (AES)]

❖Maitre initialise la sécurité .

❖Esclave peut demander la sécurité

❖**G**arantissez la confiance, l'intégrité, la confidentialité et le cryptage des données.

❖**R**esponsable de la sécurité

❖**R**esponsable de:

-Pairing

-Distribution des clés .

-Générer des clés à court terme .