Expert user guide

Customer Approval

Company Name	Represented by	Date	Sign
Neuronytics	PB		

Modification history:

Revision	Date	Author(s)	Approved by	Description
V00	2019-04-28	TM	TM	1st Version
V01	2019-08-30	TM	TM	Keyboard keys pattern updated
V02	2020-06-15	TM	TM	Keyboard keys pattern updated
V03	2021-03-18	TM	TM	Serial profile replaced HID
V04	2021-11-26	TM	TM	State machine and LED behavior

PROJECT INFORMATION

Customer: Neuronytics – Internal

Product Designation: Egg V01

Project Number: Neuronytics-0XX

Customer Specification reference:

Project Manager: TM

Contents

Terms and abbreviations

Terms	Definition
LM	Link manager
GAP	Generic access profile
GATT	Generic attribute services
HID	Human interaction device
HRS	Heart rate service
HRP	Heart rate profile
PDU	Protocol data unit
LMP	Link manager protocol
DFU	Device firmware update
OTA	Over the air

REFERENCES

[1] – Bluetooth Core specs– Version 2.6.4 (2015-12-17) (link)

[2] – Advertising example by TI: Link

[3] – HID over GATT example: Link

[4] – GATT services specs: Link

[5] – DFU mode specs: Link

[6] – Bluetooth LE stack specs by Renesas: link

1. BLUETOOTH PROFILE FAMILY TABLE FOR EGG V01 DEVICE

Reference	Product	Bluetooth profiles
Egg V01	Egg, game controller, heart rate sensor	Serial Profile 0X1101 Battery service 0X180F

Product Description:

Fig 1: Egg

Key features:

  ➢ Bluetooth 0X180F and 0X1812 profiles supported, including OTA firmware update
  ➢ Can bond with up to 4 devices simultaneously
  ➢ Works for 1 week on a full single charge or 10 playcycles
  ➢ Collects PPG heart signals with a sampling frequency of 1 KHz

2. EGG V01 USE

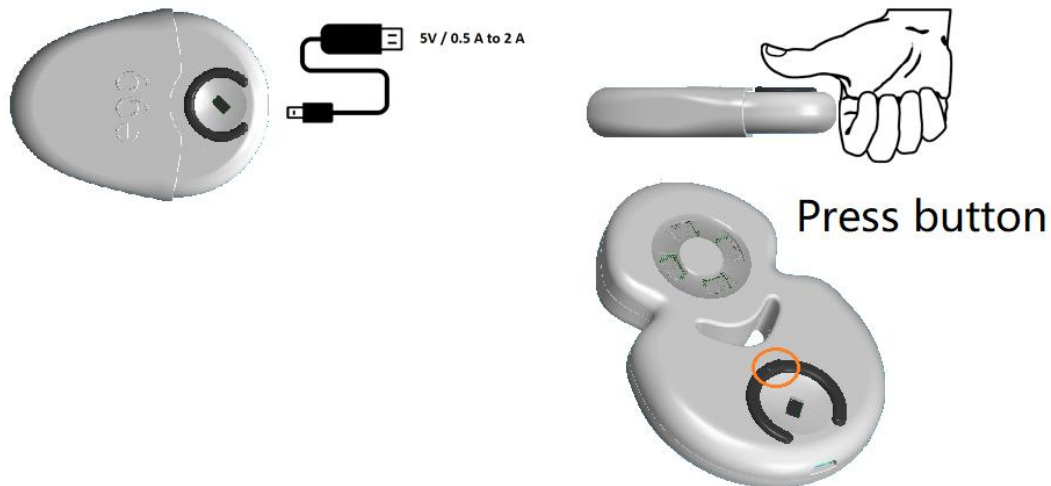*2.1. Power ON*

2.1.1. Set-Up

Fig 2: Egg power and turn ON

Make sure the battery is charged, then press the button for at least 2 seconds will turn ON the device.

2.1.2. Led Behavior

A LED color will always be displayed when the device is ON, the color and behavior will be different depending on which mode the device is in. further details about the LED behavior will be explained at relevant sections.

2.2. Button actions

2.2.1. Buttons:

The product has one tactile button (tactile does not mean touch sensor but rather a light button triggered by small forces), which can make several actions depending on how long the button is pressed, and how many times it was pressed.

Button Action	Device Actions
Single Press	**Nothing**
	Nothing
Long Press	**Device is OFF:** Device turns ON
	Device is ON: Device turns OFF
Double Press	**Nothing**
	Nothing
Triple Press	**Product in Normal mode :** Enter into OTA mode
Quintuple press	**Product in Normal mode :** LED starts glowing "*ORANGE*". Enters CW mode (next version)

2.2.2. State machine

Egg state machine
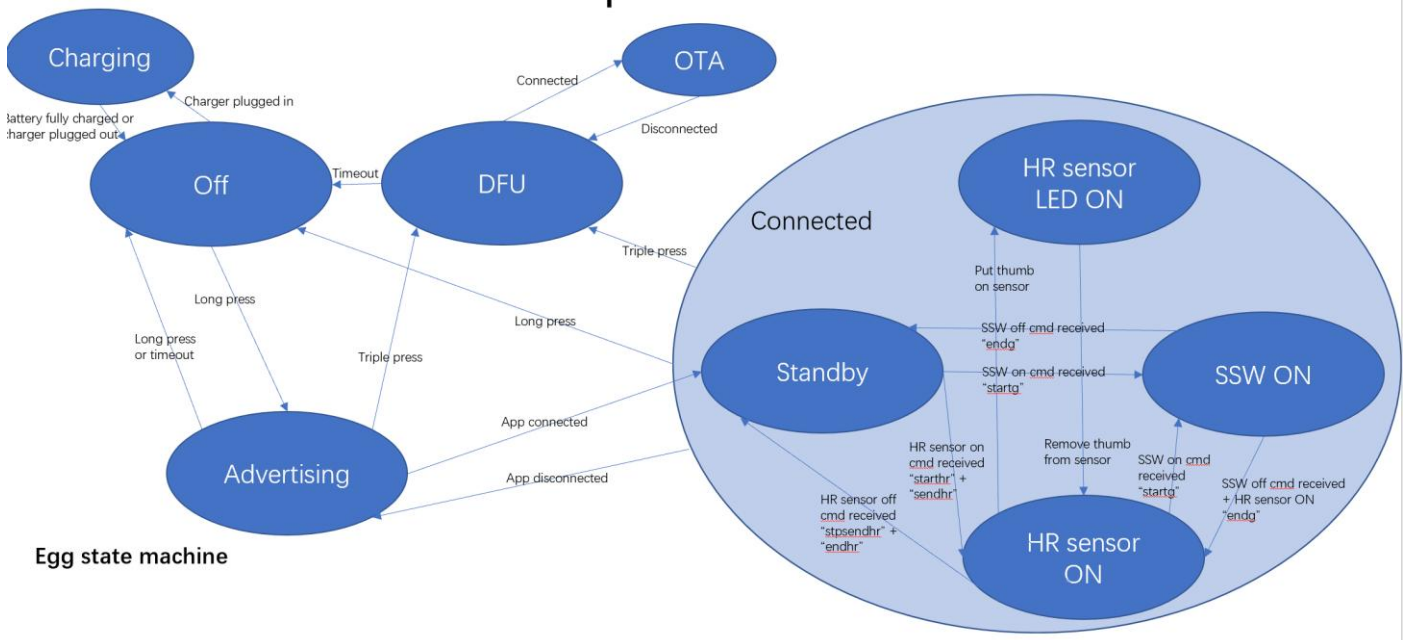
2.3. LED behavior

	Off	Advertising	Standby	HR sensor ON	SSW ON	HR sensor LED ON	DFU	Charging	OTA
LED	Off	Glowing Blue	Battery state of charge	Battery state of charge	Battery state of charge	Battery state of charge	Blink Blue	RED	Purple
RED sensor LED	Off	Off	Off	Off	On/Off	On	Off	Off	Off
IR sensor LED	Off	Off	Off	On	On/Off	On	Off	Off	Off

Battery state of charge means: Green when fully charged, Yellow when half charged, RED when battery needs to be re-charged

Egg LEDs behavior

2.4. Advertising Mode

2.4.1. Description

In this mode, the Egg is discoverable by Bluetooth 4.x supported phones and computers. Those devices can then request to connect to the Egg.

"*Advertising Mode*" timeout after 15 seconds.

2.4.2. Bond creation

In "*Advertising Mode*", when triggered the product will start accepting pairing queries, if a pairing is successful, bonding keys are exchanged between devices and the bond is created.

2.4.3. Led Behavior during "Learning Mode"

"Advertising *Mode*" status	Led behavior
Enter into "Advertising *Mode*"	Start Led glowing "BLUE"

3. DEVICES COMPATIBLE WITH EGG

The product is compatible with Bluetooth 4.x enabled phones and computer with support to GATT services. Example of oldest supported phones :

Year	Device Name	OS
2014	Samsung galaxy S5	Android kitkat
2015	Samsung galaxy S6	Android Lollipop/Marshmallow
2014	Iphone 6/6+	IOS 8
2015	Huawei Mate 8	Android Marshmallow

4. PAIRING EGG WITH AN ANDROID PHONE

4.1. Description

With Android phones from 2015 or newest running Android Marshmallow chances are the Egg is most likely supported and pairing the Egg with the phone is as simple as running any NeurodigitX APP.

4.2. Payload

The payload sent by the Egg in advertising mode is the following:

TBD

Header (16 bits)						Payload					
PDU type (4 bits)	RFU (2 bits)	TxAdd (1 bit)	RxAdd (1 bit)	Length (6 bits)	RFU (2 bits)	MAC address (6 Bytes)	Flags (3 Bytes)	UUID Serial profile (4 Bytes)	UUID Battery service (4 Bytes)	UUID Device information service (4 Bytes)	Device Name (Name length + 2 Bytes)

Field Index	Length in bits	Field Name	Description
0	4	PDU type	This value is set to ADV_IND (0000) indicating that Egg requests connection to any central device (i.e., not directed at a particular central device)
1	2	RFU	Reserved (00)
2	1	TxAdd	Set to 0, means public address
3	1	RxAdd	Set to 0, means public address
4	6	Length	Advertising payload length (Maximum 37 bytes) in our case 27 bytes
5	48	MAC address	This is the MAC address of the Egg, 6 Bytes long
6	24	Flags	These flags are set to indicate to the host device how it should manage the connection with the Egg, it is set to: 0x020106, which indicates that the Egg is in LE general discoverable mode and BR/EDR not supported (more details in Bluetooth LE core specs)
7	32	UUID (SERIAL)	This indicates that the device is a GATT SERIAL device
9	32	UUID (Battery	This indicates that the device supports battery service (TBD), Value is set to 0X03030F18 (LSB first again)

		service)	
10	32	UUID (Device information service)	This indicates that the device supports device information service (TBD), Value is set to 0X03030A18 (LSB first again)
11	16	Device name	This field specifies the Egg Name: is set to: 0X20 HEXOF(NEURONYTICS_EGG_XXXXXXXXXXXX), where 0x20 is the length of the name which is always 32 and ends by the MAC address of the Egg

Check Bluetooth core specs for full Bluetooth packets specs and further details.

NEURODIGITX

5. EGG GAT SERIAL PROFILE DESCRIPTION

5.1. Input Characteristics

Serial over GATT has the following characteristics, not all of them are used:

Characteristic	Description
Egg mode	Indicates the Protocol Mode, 1 for SSW and controls and 0 for HR
SSW command	The Report characteristic is used to exchange data between the Device and the Host. this field will contain the command codes array for game, Egg and DApp control
New Heart rate sample	When the Egg sends this characteristic, it means a new sample will start
Heart Rate sample size	This characteristic specifies the size of the incoming sample array
Heart rate sample index	Sends the index of the incoming sample
Heart Signal MSB	Heart signal most significant bit array value
Heart Signal LSB	Heart signal least significant bit array value
Heart rate signal over	Alerts that the sample array was sent

5.2. Commands actions and codes -> SSW mode

Action	CMD code
Sensawaft: Up	0x01
Sensawaft: Right	0x02
Sensawaft: Down	0x04
Sensawaft: Left	0x08
Sensawaft: No signal	0x00

The Sensawaft sent commands are emitted in continuous mode and finally when the signal is over a No signal cmd is sent.

Thumb commands are single shot actions, a command is sent once

5.3. SERIAL Output CHARACTERISTIC -> SSW mode

Eggs support also receiving data streams from host devices, which means a phone app or game can interact with the Egg by sending output chars enabling or disabling Sensawaft and heart rate sensor.
Another important feature enabled by received output chars is the generation of keys for platform authentication.

Output char command	Value	Description
ENABLE_SSW	0xDD	Enables the Sensawaft module, which means the Egg is able to send Sensawaft commands
DISABLE_SSW	0xEE	Disables the Sensawaft: a No signal is sent then no new sensawaft command is sent even when blowing on the sensawaft
ENABLE_HRS	0x33	Heart rate sensor red LED turns ON and PPG signals starts to be buffered and sent to host
DISABLE_HRS	0x55	PPG signal is not recorded anymore and sensor's red LED turns OFF
ENABLE_ALL	0x77	ENABLE_SSW + ENABLE_HRS
DISABALE_ALL	0x99	DISABLE_SSW + DISABLE_HRS
NEW_KEY	0xBB	Egg generates and stores locally a pair of private/public keys and stores them locally on the flash
SEND_KEY	0xF1	Egg sends the locally stored pair of key
PUT_IN_DFU	0xF2	Puts Egg in DFU mode for OTA firmware update

5.4. Output Characteristics -> HR mode

Characteristic	Description
Start sending	Notify the Egg to start sending data
Re-Send index	Notify the Egg to resend the following index
Index to re-send	Data sample index to be re-sent
Suspend sending	Pause sending to resume later

Stop sending	Sending is stopped and aborted
End sending	Sending is over, Notify the Egg of its status

5.5. Interaction with host devices
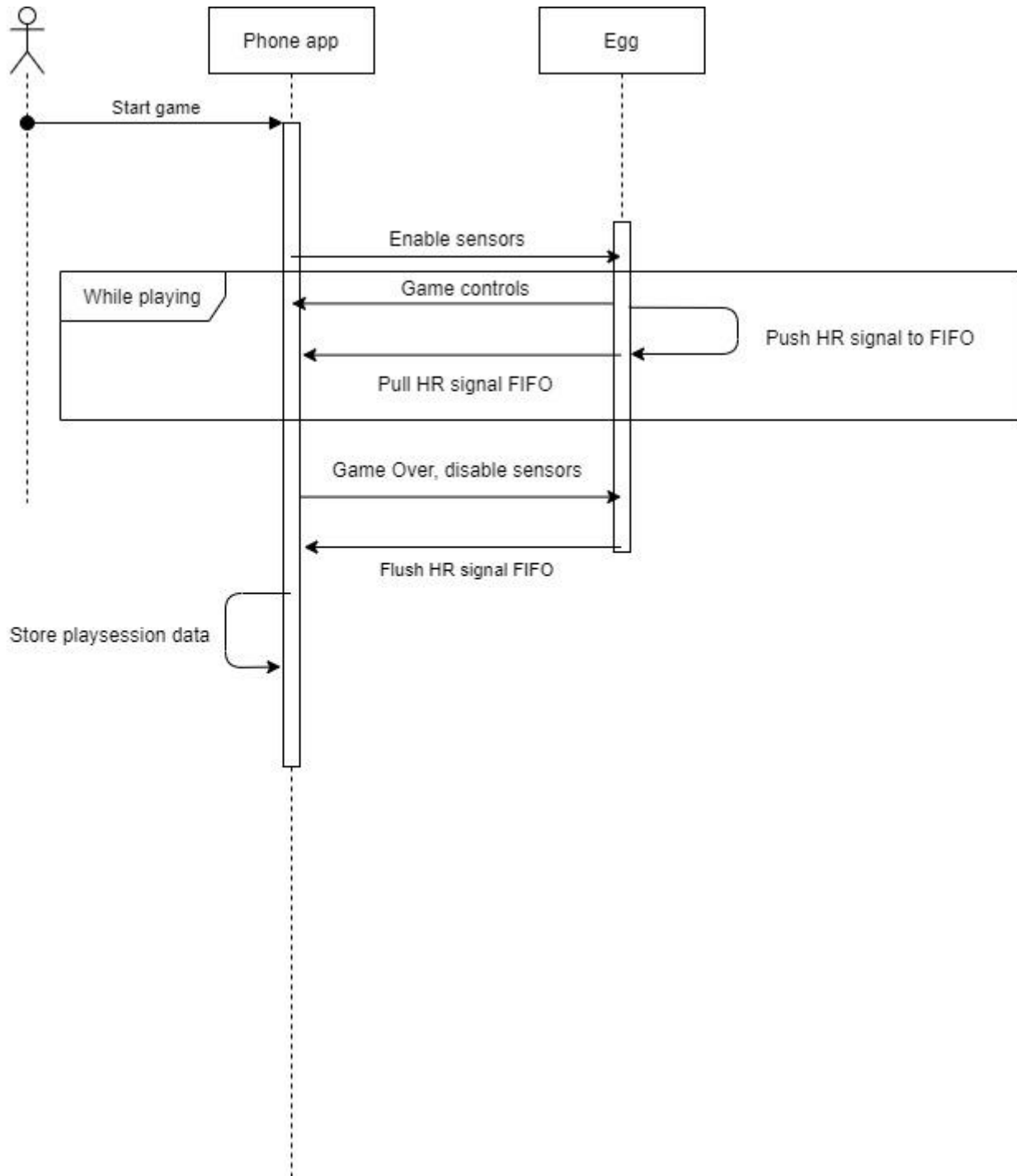
Fig 3: Heart rate and HRV reading sequence

Neuronytics Confidential. 12/14/21

6. EGG DEVICE INFORMATION SERVICE 0X180A PROFILE DESCRIPTION

6.1. Characteristics

Characteristic	Description
Manufacturer name string	This characteristic represents the name of the manufacturer of the device, in our case "Neuronytics LLC"
Model number string	This characteristic represents the model number that is assigned by the device vendor. Examples could be WD01 or WDV01 …
Serial number string	This characteristic represents the serial number for a particular instance of the device. Each production bluk has its own serial number
Hardware revision string	This characteristic represents the hardware revision for the hardware within the device.
Firmware revision string	This characteristic represents the firmware revision for the firmware within the device.
Software revision string	This characteristic represents the firmware revision for the software within the device. The same to firmware if the SDK and Softdevice are the same, but different when one of them changes
System ID	This characteristic represents a structure containing an Organizationally Unique Identifier (OUI) followed by a manufacturer-defined identifier and is unique for each individual instance of the product.
IEEE 11073-20601 Regulatory Certification Data List	This characteristic represents regulatory and certification information for the product in a list defined in IEEE 11073-20601.
PnP ID	The PnP_ID characteristic is a set of values used to create a device ID value that is unique for this device. In simpler words this is the unique ID of each Egg

These informations are shared with the host after pairing, and are then used by the host to authenticate the device or to identify it. The following sequence diagram to be reviewed according to correct pairing Bluetooth sequence
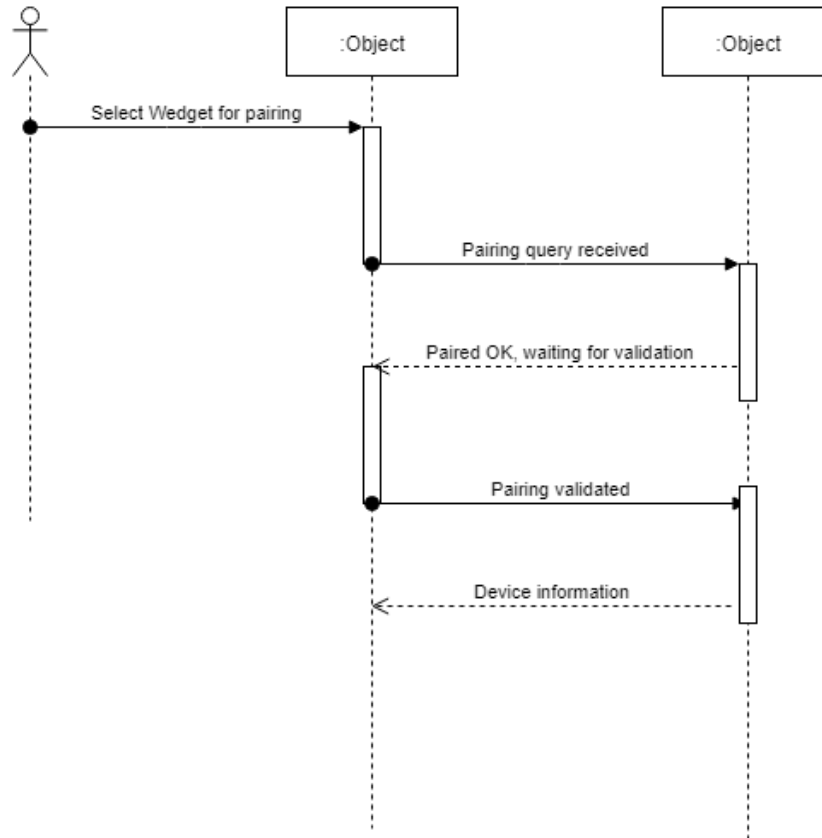
Fig 4: Device information get sequence

7. EGG BATTERY SERVICE 0X180F PROFILE DESCRIPTION

7.1. Characteristics

Characteristic	Description
Battery level	The Battery Level characteristic is read using the GATT Read Characteristic Value sub-procedure and returns the current battery charge level as a percentage from 0% to 100%

Battery sampling is managed by a timer triggered:

→ 30 seconds after each Egg turns ON when battery charge is bigger than 50%
→ Each 1 min when battery charge is between 50% and 20%
→ Each 10 seconds when battery charge is less than 20%

8. OTA FIRMWARE UPDATES
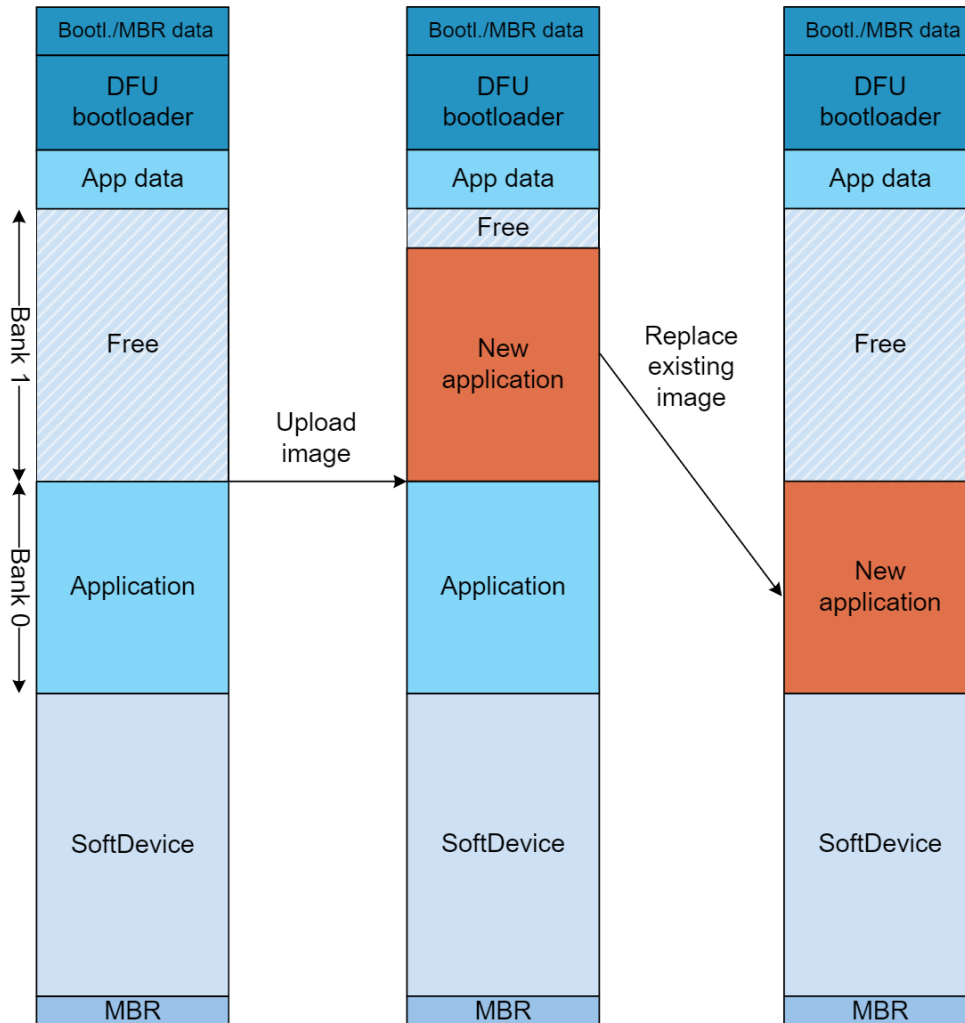
8.1. Memory management

Fig 5: Egg flash memory managment for DFU

The OTA firmware update uses a safe process where there is no risk of permanently damaging the Egg system. The new firmware is always stored in Free memory space and verified to be authentic before being copied in the main firmware space. And even if this later operation is unsuccessful, the DFU bootloader remains untouched, which means the user would have to restart the firmware update process at worst case.

The default behavior of Nordic semi DFU does not implement the notion of default factory firmware, which means, factory reset is practically impossible using only the DFU feature of Nordic semi and should be implemented separately.

8.2. Process

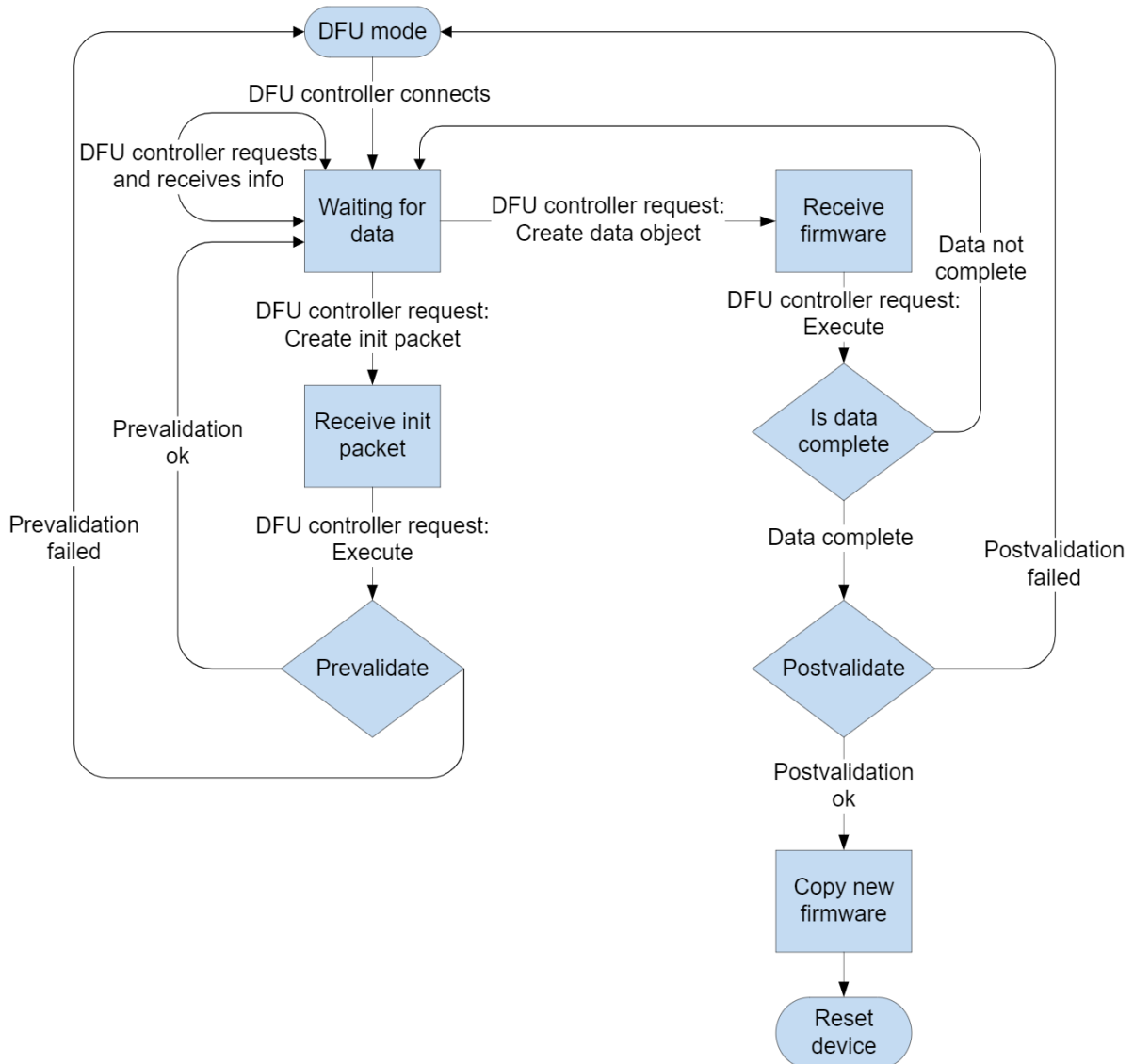*Fig 6: Egg DFU mode process flow*

The Egg enters in DFU mode in two cases:

1) No valid firmware was found

2) Egg receives from host the PUT_IN_DFU command either by a triple press or via Bluetooth

When device is in DFU mode the LED is blinking in Blue, when the device is connected to a valid DFU master the LED is purple.

8.3. Create new firmware package

In order for any new firmware to be uploadable to Egg devices using the OTA feature, the new firmware binaries should be packaged inside a special format package. Details about how to create such package could be found on: Link

Once the package is created it can be uploaded to firmware cloud repository where Neuronytics apps can retrieve it and notify the user of its availability. The user should then launch the firmware update manually in order for the process to start.

9. BOND CREATION AND MANAGEMENT

Once the Egg is in advertising mode, compatible phones and computer can detect it as a Keyboard (may be as a heart rate sensor also ?) Such devices can then send a "CONNECT_REQ" to connect to the Egg, the Egg then accepts the connection and initiate the pairing process (pairing = bonding) where Egg and host device exchange security keys for an encrypted communication between the two and authenticate each other.

This process is managed at the GAP layer by the two devices (Host: Initiating link manager, Egg: link manager) and runs as follow:
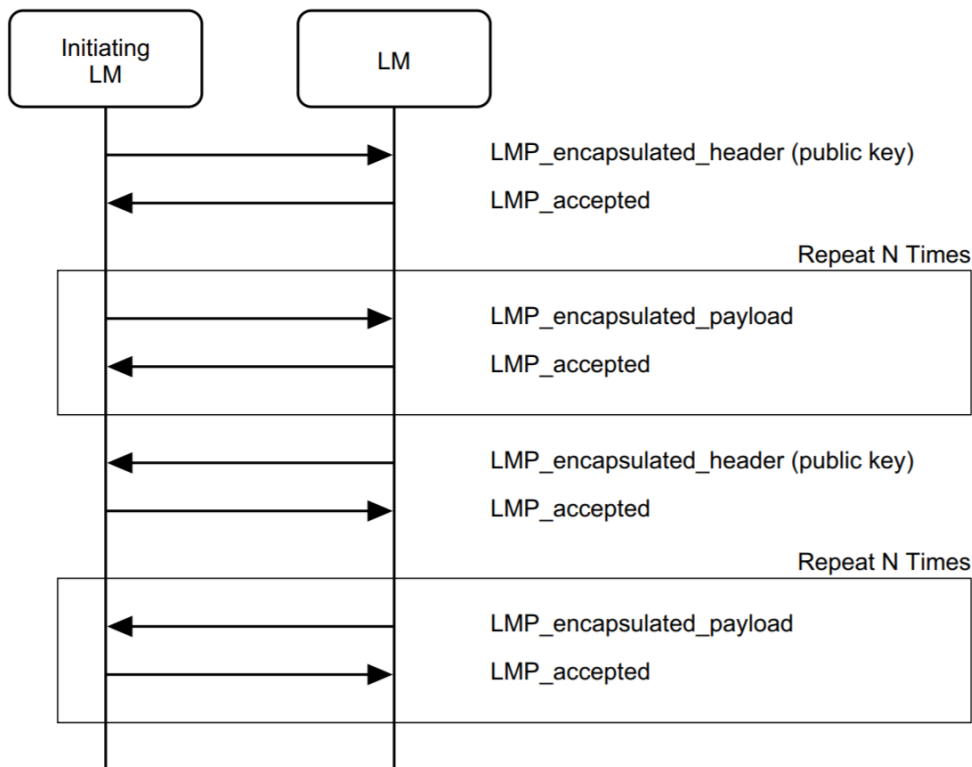

Fig 7: Egg, pairing: keys exchange for encryption

Once keys are exchanged, the authentication process is still to be run. The Egg will implement a "Simple Secure pairing " process:
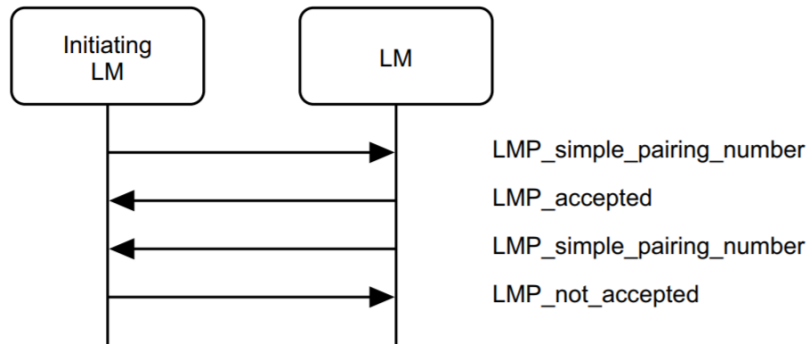

Fig 8: Egg, pairing: authentication using simple secure pairing

Also note that these sequence diagrams are simplified process descriptions, for actual process please check Bluetooth core specs Vol2, part C, section 4 (link)

CONCLUSION:

More features can be added down the road or some features removed, the most important feature to define and explore further is the ability to add a heart rate profile mode to which the Egg can switch by pressing a certain combination of key presses. In this mode the device acts as a normal Bluetooth heart rate monitor.

FCC Statement

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

 • Reorient or relocate the receiving antenna.
 • Increase the separation between the equipment and receiver.
 • Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
 • Consult the dealer or an experienced radio/TV technician for help.

Caution: Any changes or modifications to this device not explicitly approved by manufacturer could void your authority to operate this equipment.

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

 RF Exposure Information

 The device has been evaluated to meet general RF exposure requirement. The device can be used in portable exposure condition without restriction.