Lumpoint, an electronic device that can be located through BLE, GPS and LoRa

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Abstract— *This paper describes the firsts steps of Lumpoint, a hardware device that solves the common location problem – tracking and finding lost animals, people or objects - focusing on the technology side. From scratch to the proof-of-concept, this paper presents the analysis of the components, the interfaces which the peripherals are connected to, the Bill of Material, the implementation of the chosen development kits, and finally, the next steps to make Lumpoint a reality in the market. Lumpoint obtained a positive opinion from the jury of the first edition of UAB STARTUP LAB, and participated on UB Emprén too.*

Index Terms — *Lumpoint · BLE · GPS · LoRa · location solutions · hardware startup · Bluetooth Low Energy · IoT*

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1 *INTRODUCTION*

While the most advanced technology exists in the present, the problem of locating something still persists. With the great impact of IoT, and the increased possibilities to make cheaply connected devices at long range with low power consumption, we decided to bring for any non-connected object the feature to be located on anywhere.

Today there is one product that has had moderate success in the market: Tile, but its product value is focused on short range, and if the object which is attached is lost, it needs other users with Tile to locate it.

On the other hand, exists Hidnseek, which is focused on long range, but today, it has not had any significant impact on the market.

Lumpoint was born to help the user to locate the object at any range, with a user-friendly app, and only with one payment without need a subscription.

This paper is organized chronologically how a hardware startup needs to be made (detailed description, analysis of the components, implementation of the chosen development boards, and test the system with an Android application in this case).

The main goals are (1) making a proof-of-concept of an electronic device which solves a problem from scratch, (2) choose the necessary technologies to allow the device to communicate externally, (3) and design a PCB layout to send for manufacturing.

2 DETAILED DESCRIPTION

2.1 Functional and benefits

One of our principal goals is making an electronic device which solves a location problem. This means that the electronic device needs to be located by itself, and notifies to the user its location.
We will differ two different types of location: the location of the device when is nearby from him, and the location of the device around the globe.

Lumpoint emits a sound when the user is nearby and he wants to locate it, and persists the geolocation coordinates so that map can be shown to him.

The via communication between the user and the device is through a phone application. We need to test the complete system with an app.

Regarding the benefits requirements that Lumpoint needs to be successfully, are the must-have of today IoT devices: low power consumption, data transmission reliability, a physical footprint small dimensions because it needs to be attached to an any object, and the no excessive cost for the user.

2.2 Technologies

Lumpoint has the opportunity of bringing all the best IoT technologies on a single device. About the requirements, Lumpoint needs low-power technology, for long and short range, and we could difference the technology on two sections.

The best dominating technology in the short-range world, is, clearly, Bluetooth. With Bluetooth, and its new developments, it brings Lumpoint the protocol to share information between two devices, in our case, a mobile phone and Lumpoint, with a low-power consumption and reliability.

On the other hand, we need to study the different alternatives on long range, that could bring the opportunity to connect the device to Internet, and how can it take GPS coordinates. We discard Wi-Fi protocol for its large consumption in a battery-powered device. With that discarded, another two technologies which highlight the far communications, are LoRa and SIGFOX.

We choose LoRa to avoid the SIGFOX subscription, and its open-source philosophy that we consider that in the future, it would have a good impact. Although, today SIGFOX has got important advances covering all the globe, and the two technologies are expanding.

Last, and not least, Lumpoint is going to take the absolute position on the globe with an GPS, with the help of three satellites and these very precisely clock, which going to communicate with the microcontroller.

In short, BLE technology will be the solution for the user when it loses a near object, and LoRa and GPS will work together to notify the user the absolute position of the device when it is lost. The functionality of LoRa will be the bridge between GPS and Internet, where the user could locate his device through an history.

2.3 Work cycle and energy consumption

Lumpoint will work in one of two main methods mentioned, long and short ranges.

On the short range, the Bluetooth Low Energy is the only that is activated, and for long range, LoRa and GPS will work together periodically to determinate the position of the object.

The work cycle defined for Lumpoint, is that following: when user wants to know its position, he could connect to it while Lumpoint is emitting beacons. Then, Lumpoint can check the authenticity via its paired list, and then emit the sound. Lumpoint activates the LoRa and GPS peripherals to notify the user its lost periodically each hour.

We could define another work cycle, using the pairing mechanism, but it is finally not implemented because we think it could consume amount of power, to reconnect and check if the device is lost or not. The algorithm activates LoRa and GPS when a previous paired device loses the connection.

On the next section, we are going to talk about the consumption for each component, but we can say in advance that, if the device has lost three times and maintains active the radio three minutes for each of them (to activate the buzzer), in a day the short range is going to consume 1.386mA.

On the other hand, if we want to locate the device twice, and tracking the device for 10 minutes, the module GPS would consume 33.25mAh to send the position through LoRa, totally would consume around 100mAh.

3 Analysis of the components

Once we know which technologies we using for Lumpoint, it is time to choose the best components that are available in the market. We considered the price, the consumption, the communication interface, and the good confidence of the company seller.

We decided to look for a system-on-chip that contains the BLE stack to minimize the area, the process unit, and looking for two independent integrated circuits that have the interface to communicate with it for GPS and LoRa.

In the case of SoC/BLE, we have chosen the nRF52832 IC from Nordic Semiconductor, for the next reasons: the documentation that offers on the webpage is useful, it has an UART interface, and its low-power consumption.

Furthermore, we have chosen this IC, because in the future, (concretely, on Q4 2017), Nordic Semiconductor is going to sell the nRF52840 IC, which reduces a lot in power consumption, and brings the possibility to connect directly two UART peripherals, which could communicate with GPS and LoRa without needing extra IC (unless the GPIO available pins emulate the UART functionality, which complicates the implementation).

As for GPS, we have chosen an easily installable module, that contains an integrated antenna. For that, we have analyzed the products from two companies that offers GPS, GSM and similar solutions: Quectel and U-BLOX. We finally chose Quectel – L86 GPS Module - for its affordable price.

Finally, for LoRa, the RN2483 module from Microchip has been chosen for its relevance in the market. It was the first LoRa module that passed LoRa Alliance Testing, and its RX Current consumption is considered well acceptable inside LoRa space (14.2mA) [3].

For the BLE/SoC we analyzed the following components:

CONSUMPTION	TX (0dBm)	RX	IDLE	OFF
nRF51822	8.0mA	9.7mA	2.6uA	1.2uA
CC2640	6.1mA	5.9mA	550uA	1.0uA
nRF52832	7.1mA	6.5mA	1.5uA	1.0uA

We present the BoM of this proof-of-concept on following. Notice that we do not present the BoM for manufacturing, only the proof-of-concept.

	Price/unit	Development kit
LoRa	13.75 €	64.70€
GPS	13.11 €	67.98€
SoC	6.61 €	34.70€

4 Brief Considerations of the Chosen Technologies

Before continuing, we should explain the deeper ideas behind each technology, so it can be better understood how to use them separately.

Briefly, LoRa is a device and gateway network that can interact with each other. LoRa works mainly on the ISM band, @413MHz and @868MHz, and due to that, it has restrictions. As it is designed to send small packets through a long range, LoRa works on a small-spectrum window.

Lumpoint uses a LoRa [5] class A device, which means that it can only start a communication by sending a packet to the gateway. The device can do it into two forms, Over-The-Air Activation (OTAA), where the secure keys are negotiated with the gateway, and Activation by Personalization (ABP), which needs to introduce the secure keys into the device via configuration commands.

A Lumpoint device never starts a communication with a received packet, and will do it with OTAA negotiation.

Once a packet is received on the gateway, it is connected to Internet and can spread it to the world thanks to different coverage-services. Lumpoint, as today, it works with the The Things Network, which is focused to increase in increasing the actual coverage with the open-community philosophy.

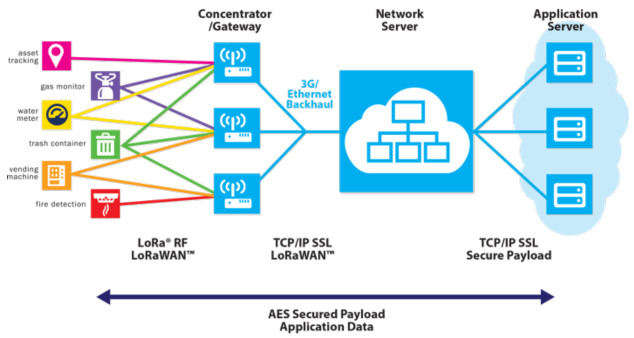

Figure 1: LoRa network: how devices, gateway and server participated on it.

All the tests for this project were used with the LoRa gateway installed in Escola d'Enginyeria, by the CEPHIS department.

GPS is the best choice to determine the device position, but it does not work inside buildings, which is a big problem of today.

GPS determinates the position with satellites via longitude and latitude, and can express it into two forms, via *Decimal Degree(DD)* or *Degrees Minutes and Seconds (DMS)*.

Our chosen module, express the position in Decimal Degree.

The process when GPS is looking for the satellites, is called acquisition time Once are located, these send to the module a very precisely clock and it obtains its position via triangulation. GPS can continue tracking avoiding to looking again the satellites. This continuity is called tracking time

The time which the GPS receiver needs to determinate its position, is called Time To First Fix (TTFF), and it varies depending on the three scenarios: hot, warm and cold.

Bluetooth Low Energy covers a lot of applications, and is prepared to customize its configuration, with Generic Access Profile (GATT) and GAP (Generic Attribute Profile). GATT configures how the devices is connected (Server or Client), and GAP is the responsible to define the device one of the four following roles, *broadcaster*, *observer*, *peripheral* and *central*.

Lumpoint would work with two roles, as a broadcaster or peripheral.

The strategy implemented in Lumpoint, is emitting always beacons, and check if the connected device is in the paired list or not. Then, it sends a signal to the buzzer, like we can see on the diagram of the Figure 2.

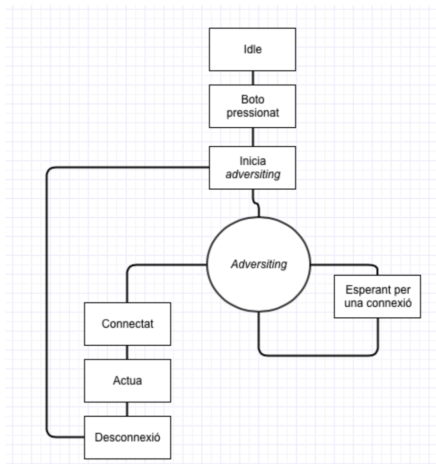

Figure 2: Flux diagram of the BLE implemented

Periodically, Lumpoint sends the position to the TTN servers through an eight bytes' payload, which is indicated the latitude on the four most significant bytes, and longitude on the less. Lumpoint uses GPS and LoRa, and the user receives the position through his mobile phone. The SoC/BLE is the responsible to control the periodic time, via RTC, which interrupts the system each hour.

5 Hardware architecture implemented

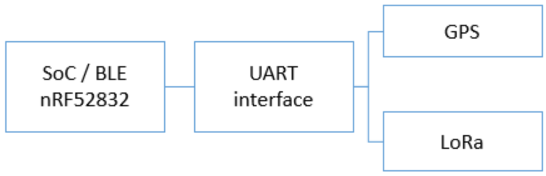

Figure 3: Block diagram of the Hardware Architecture

As we can see on the previous block diagram, the SoC BLE is the responsible to manage the system through UART interface. LoRa and GPS communicates with each other sharing the same UART interface.

5.2 Development Kits

Three development kit have been acquired, one for each chosen technology, and one Preview Development Kit for nRF52840 that Nordic Semiconductor.

LoRa RN2483 Mote from Microchip is controlled in two different ways, either via USB CDC Commands, which is controlled by serial port through USB cable, and battery-mode, which can control LoRa via UART pins or buttons. It consists of a LCD screen, a temperature sensor and two push button to interact with it. Finally, it is important to remark that the framework can be installed on its webpage, to familiarize with the LoRa concepts and the order of the commands, because it is programmed with a state-machine paradigm.

The nRF52832 DK contains a NFC sensor, BLE stack, and four push buttons to interact with it. The Nordic Semiconductor webpage offers a lot of examples to program it, a template to getting started to Android application example.

Finally, the Evaluation Board L80 from Quectel, contains of one push-button, one switch, an RS-232 interface, and USB interface. Through the switch, we can choose if we want to receive packets indefinitely without needed the configuration, or control it via AT-Commands.

5.3 LoRa: technical restrictions

LoRa, is an expanding technology in nowadays, which works on a ISM band (@868MHz), as we said on previous sections.

Although LoRa is working in that band, there are some restrictions for the users, that we must to comply to avoid saturating the channel. It is recommended that the payload weight no more than 12 bytes [1], and the transmission/reception bandwidth of 400 bytes per hour.

Users of LoRa can accomplish that by configuring the channels parameters which are available on the LoRa device.

Duty cycle is the relationship of square signal between the time equals 1, and the time equals 0, as a percentage. In other words, it open and closes the channel as we defined on duty.

On the proof-of-concept, the duty cycled configured is smaller to not saturate the channel (0 in our case), which is a regulated by the government, and to make sure to not receive the no_free_channels message [12]. This is the 10%:

```
mac set ch dcycle 0 9
mac set ch status 0 on
```

Another important issue we need to consider, is the components and the baud rate communication between the SoC, LoRa and GPS via UART.

The RN2483 by default, works at 57600 bauds per second, and GPS 9600 bauds per second instead.

We want to homogenize all the speeds, and for that, we changed the baud rate of RN2483 to 9600, sending a 0x00 “command” into old baud rate, delay few milliseconds, and then sending 0x55 into the new baud rate.

6 Software architecture implemented

6.1 System-on-Chip · Bluetooth Low Energy

The SoC nRF52832 [6] is the component that we chose to bring the BLE features to Lumpoint, as we said on previous sections. The component from Nordic Semiconductor works with the 13.0.0 version of the SDK, which uses the BLE stack (then, for Nordic Semiconductor, it is a SoftDevice). We program it using Keil uVision 5 IDE, and we used nRF Studio to erase the flash and install the SoftDevice API.

This SDK can work following two implementation philosophies, interruption events or via scheduling. We implemented the proof-of-concept of Lumpoint using interruption events.

The RTC [13] is configured and initialized to send a petition each hour to get the position through GPS and LoRa via UART [14] when the intent to reconnect of the paired device is failed.

We implemented the necessary handlers like `pm_evt_handler` (to control the Peer Manager about paired devices), `timer_timeout_handler` (to control time each hour).

However, we have no time to learn about `nrf_drv_uart_txt` (to send packets via UART), and connect BLE/SoC to Arduino Mega.

6.2 Global Positioning System

Quectel L80/L86 is one of the easiest installable GPS peripherals available on the market, with its patch-antenna integrated and interaction facility. Quectel L80/L86 communicates to the SoC via UART through AT-commands to obtain the absolute position.

The L80 Development kit which we chose brings the opportunity to always receive information from the GPS module via UART, because it is programmed by microcontroller from the kit.

This means that we do not need to configure it to obtain the proof-of-concept, that is one of our objectives, make it easily to connect with the other two peripherals.

The AT-commands of GPS follow a typical format called NMEA, which consist a preamble (which is a one byte character, '$'), TakerID, PacketID,DataField, an asterisk character ('*'), the checksum and two bytes to identify the end of the packet. For example:

```
$GNRMC,090430.000,A,4157.9906,N,00244.2688
,E,0.00,188.18,210517,,,D*74
```

We can see in the datasheet, that is expressed in Decimal Degree form, and $GNRMC indicates the latitude and longitude on the fourth-seventh substrings, following the ddmm.mmmm for latitude and dddmm.mmmm regular expressions which 'd' is the degree and 'm' the minutes.

On the example, 4157.9906 and 00244.2688 indicate that the device is located on (41.579906, 2.442688).

Due to mentioned technical restrictions in LoRa, is recommended to express the information in a compact way [13] that can be sent into a single packet of 8 bytes.

For that, we need to express the values of the $GNRMC packet to correct latitude-longitude values. Once we do that, and to send it via LoRa, we need to avoid commas, and express each value to a 4 bytes' payload, that are concatenated each other to send all the position in a single packet of 8 bytes.

For example, we can send 0x027A7582002545C0 payload, which indicates the previously mentioned example.

6.3 LoRa · The Things Network

We can interact with the LoRa devices through commands. First, we need to register our device to the TTN platform, to obtain the necessary information to connect our device to the gateway via OTAA, the Device EUI, the Application EUI, and the App Key. With that information, we can now configure the LoRa module through mac commands [2]:

```
mac set appkey <appkey from TTN>
mac set appeui <appeui from TTN>
mac set deveui <deveui from TTN>
mac save
```

With the command mac save, it saves the information on the EEPROM. With that, we don't need to put the information again, even if the module is reset.

Once the information obtained by the platform and the dutty are configured, we can join to the nearest network with `mac join otaa`, which responses to us with an "ok" and "accepted or denied".

If the message response is accepted, we can send information to the gateway (and consequently, to Internet) with `mac tx cnf 3 50`, where 3 is the port number (from 1 to 223), and 50 is the data in hexadecimal.

The Things Network service, offers to us a LoRa platform that collects the data which devices have sent. We can configure a payload to adequate it with our needs, via Payload Functions. With Encode and Decode configured, TTN sends a JSON with two more fields.


```
{
    "app_id":"lumpoint_marcelvilalta_com",
    "dev_id":"id_lumpoint_marcelvilalta_com",
    "hardware_serial":"00DC1E9D7218832B",
    "port":3,"counter":0,
    "confirmed":true,
    "is_retry":true,
    "payload_raw":"AnYwTwAfigs=",
    "payload_fields":{"lumpoint_latitude":41.300047,"lumpoint_longitude":2.066955},
    "metadata":{
            "time":"2017-06-25T12:21:59.20664563Z",
            "frequency":867.3,
            "modulation":"LORA",
            "data_rate":"SF12BW125",
            "coding_rate":"4/5",
            "gateways":
                [{"gtw_id":"eui-00800000a0000666",
                "timestamp":502448668,
                "time":"2017-06-25T12:21:58.920354Z",
                "channel":4,
                "rssi":-111,
                "snr":-0.8,
                "latitude":41.500526,
                "longitude":2.111343}]
        }
}
```


Figure 4: JSON packet received on the mobile application

The Things Network published an Android SDK through GitHub repository, which can be modified for Lumpoint. We have eliminated the temperature plot, and modify the Payload and Packet classes to decode the payload to obtain latitude and longitude, and show the results to the View List.

The result of the Android App is shown on the Figure 5:

Figure 5: User Interface of the Lumpoint Sample app

6.4 Arduino Mega as UART interface

We chose Arduino Mega, for the facility of use, to emulate the specific microcontroller which will interconnect all the others peripherals. We implemented three different input styles, which can differ what peripheral we want to send/receive from it.

When we type "get" from the command monitor of Arduino, it obtains the position of the GPS, and sends it to TTN Servers via LoRa.

If the first character is '$' (to emulate that is a NMEA format-command), it obtains the GPS position, and otherwise, LoRa responses with the result of the command.

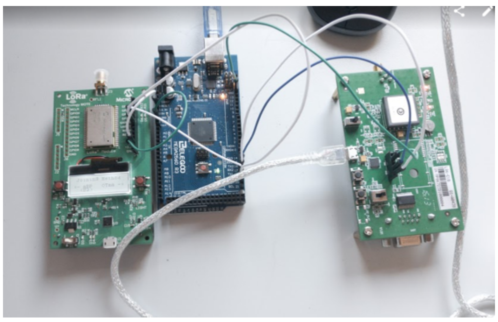

Figure 6: LoRa, Arduino Mega and GPS connected each other

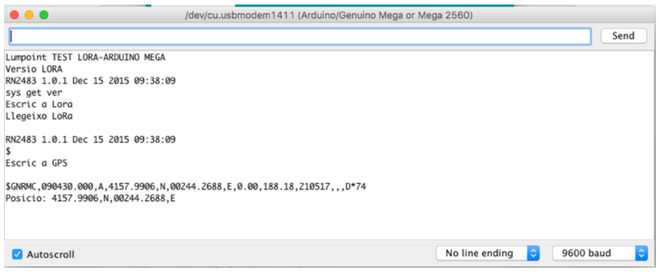

Figure 7: Output example of the Arduino Monitor

7 Next steps

Once we proved the viability of Lumpoint with the proof-of-concept presented on this paper, the next steps to be successfully as a hardware device are the design of the printed-circuit board layout, thinking about the product design, making a user-friendly application for mobile platforms.

The first next step above was one of the goals stated on this paper, which has not been accomplished. This happened because during the project, the focus turned from into making a decent proof-of-concept. The schematic will be done with the open examples of the components and the development kits.

Finally, for the layout, we will follow the rules imposed by the manufacture industry (the diameter of the via, the width of the path...), and the datasheet's recommendations of the layout-design (like the antenna design, the number of layers...).

We are going to use Altium Designer, because it is the well-known professional software for the PCB design.

Once it is designed, it will be sent to manufacturing the printed circuit board, with the possibility to indicate the components that we want to install.

8 Conclusions

We accomplished making the required functionality and the technical viability of Lumpoint has been validated. However, UART interface for BLE/SoC has not been implemented, but it is necessary to encapsulate all the systems into one.

For the Bluetooth Low Energy part, the connectivity was only implemented (flux diagram of the Figure 2), and it was only tested via the Bluetooth Settings of a mobile device.

In the nearby future, we are going to integrate the Bluetooth functionality and the LoRa/GPS on a single application for Android.

Finally, I want to empathize that, one of my most important changes of this project, was changing the initial planning, which was more focused in the hardware design.

Now, with this proof-of-concept presented, we will only need to do minimum changes to make a minimum viable product and validate the market to try to find product / market fit.

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