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Performance evaluation of monitoring IoT systems using LoRaWan

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Abstract

The proliferation of smart devices, or even better, IoT devices, has led to the widespread development of applications that take advantage of these devices. Of particular interest is the precise localization of such a device. However, these use cases become extremely difficult when connectivity to end-devices is required even in areas where the signal is too low or different technologies co-exist for the transmission of the data. In this research work, we study LoRaWan and Wi-Fi as two possible candidates for data transmission. We are particularly focused on the study of the above technologies in terms of performance as well as application development that can be used as rescue monitoring systems. For this reason, we start by describing LoRa as an ideal low power and long-distance communication protocol on the IoT devices compared to the Wi-Fi network. We perform various simulations in terms of time on air transmission, bit error rate by changing important metrics to study the behavior of the whole mechanism. Based on our simulations, the main findings highlight that the contribution of a spreading factor and bandwidth optimizations can be applied to real hardware for real search and rescue (SAR) cases giving improved results in case of coverage and battery extension applications. As a continuation of our research, we developed a monitor application that collects and visualizes data from end-nodes (wearables). These data are processed gateway and network server to The Things Network (TTN) for further analysis. The proposed solution can be used in different rescue monitor scenarios such as identifying and find individuals of vulnerable groups or those belonging to group of people with a high probability of being lost. The purpose of the above solution is to overcome monitor problems on SAR cases, compare with WiFi and suggest a module supporting both technologies in order to be used in real experiments.

Keywords Internet of Things · LoRaWan · Wi-Fi · Monitor · TTN

1 Introduction

It is a fact that the Internet of Things industry is facing some issues regardless of the recognition they have received from the university community and companies that develop software and hardware for these devices. Especially today, the development of the IoT has led to a wide connectivity of home appliances (such as bulbs, smart thermostats) and electric devices remotely connected through various wireless networks. All these smart devices communicate through various protocols, for example, Bluetooth, ZigBee, Z-Wave as well as WLAN and HiperLAN. The need for good connectivity that can give a strong connection over long distances can lead to more requirements in terms of power consumption and data rates. The above need for low-power-wide area networks promising high efficiency both in terms of energy distance coverage up to 15 km in Line-Of-Sight (LOS) lead companies, institutes and network providers in search for larger networks designed exclusively for these small size devices using simple batteries for their power. High demand of coverage as well as real time data push is a portion of the basic characteristics of multiple IoT applications.

In recent years, there has been an effort by organizations and research centers on IoT device connectivity to achieve the best quality of service based on the available wireless networks. The above need is being introduced by many LoRaWan projects such as smart systems able to be

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used as monitor systems for people in need or emergency applications. Following the high demand for user specific applications and the way that LoRaWan has not yet pulled in comparable dimensions of consideration from the exploration network and mechanical organizations, we present an IoT solution based on LoRaWan that permits things interconnect with their surroundings and gather required data with low power utilization, exploiting LoRaWan capacities for monitor needs.

Our goal in this study is to provide a solution for vulnerable groups and individuals belonging to these groups to be able to be tracked by their familiars in terms of location estimation. The above example could be part of a SAR scenario. In order to achieve the above, first stage is the study and development of simulations in order to study the LoRaWan technology and protocol and then to extract results and integrate them into real experiments with physical hardware at a location near the area of University of Patras. In the above simulations, we run different scenarios by changing the Spreading Factors' values as well as the transmission bandwidth. The simulation results after the required analysis will help us to optimize SF and BW values which can be used in a real IoT network testbed. Along these lines; we look at SF values of LoRaWan produced for a transmission of various bandwidth values, running multiple test cases and analyze the results.

The battery life of IoT modules is an important issue for smart devices, due to the fact that most of them need extra battery capabilities or even charging. For this reason the system must consume the least power and adopt as well energy harvesting. So, we present a comparative evaluation of LoRa network for monitor applications against to the traditional Wi-Fi networks in order to compare both technologies if can apply to SAR scenario based on the experiments. By using low power IoT modules, we introduce the details of LoRa network, the parameters in the physical layer and some basic issues related to the rescue monitor needs. We then describe a SAR use case the architecture and implementation of the platform that could be used as a rescue monitoring system. The above ecosystem consists of IoT modules that collect info for user position and sensor values, a central gateway that interconnects these devices with the cloud and forwards captured data to webservers. This is not only for personal use, as it can be integrated at smart bikes, vehicles, animals or individuals moving inside a production line of a factory or workspace acting like smart labels.

The remaining part is described below: In Sect. 2 we analyze the related work. Section 3 contains an overview of LoRaWan approach and describes the motivation behind our work and the theoretical background. In Sect. 4. we make some experiments at LoRaWan simulation testbed for IoT concepts together with the simulation results. After that the a SAR use case scenario together with the device configuration, software for both scenarios (Wi-Fi and LoRaWan) and real experiments are being featured in Sect. 5. Section 6 included the conclusions of our study; while in Sect. 7 some ideas for future research activity are listed.

2 Related work

In the first section, a few publications in the IoT monitoring are studied. The accessible distribution of IoT devices has introduced industries, organizations and individuals to the development of significant worth including IoT applications in section of rescue monitoring. It's a fact that IoT can certainly help in developing better solutions and real time added value to IoT devices and applications suitable to improve our lives and operational processes. In rescue and general healthcare area, there are several occasions such as rescue monitoring and tracking where sensors can play an important role.

The high integration of IoT for social insurance is an important topic which has been proposed in a few publications. In [1], a thorough research of social insurance has been introduced. It gives the primary parts of activities for IoT human rescue services. A reliable rescue monitor system respecting the lifespan of the IoT battery is proposed in [2]. In this work, the authors have focused on the security and vitality utilization parts of IoT based social insurance framework. In [3], a sensor network based on body has been proposed for observing a few sensor parameters. Security perspectives have additionally been considered which proposes safety efforts for IoT services. A contiguous approach has been proposed in [4], which is related to rescue monitoring. This is achieved through a set of sensors connected to visualize people's characteristics for further consideration. In [5], a sensor structure technique for low power technologies has been proposed for portable based rescue services applications. This study introduces an indoor overview on real time tracking applications of IoT. In [6], an IoT-based architecture that is based on software, communication protocols that have been described to enable real-time monitoring and management of solar photovoltaic systems at large scales. The above systems allow control and monitor in a remote way the photovoltaic systems various environmental factors that affect its performance. The above architecture seems useful in our research as it offers tips in designing and implementing the general architecture of a monitor IoT system. In [7] a rescue monitor approach is being described. The above ecosystem offers an inter connection of all resources for quality of life improvement. The collected data as captured from sensors is transmitted to a Raspberry pi which process and analyze the data.

Also in [8], authors propose an Access Control Four States (AC4E) trust model that can be used to isolate the influence of "malicious" nodes and reduce the energy loss of the system.

In our approach as we are examine SAR systems and real hardware we would like to adopt LoRa capabilities in order to reduce the total energy of the system. For this case we run simulations examining changes on SF and BW in order to improve our Quality of Service.

In [9], authors show through results that the multi-attribute decision making based on Software-Defined Network (SDN) and Network Function Virtualization (NFV) can select the appropriate Mobile Edge Computing (MEC) center. Moreover, the mechanism further reduces the server response time and improve the quality of user service experience. However, in our study we considered parameters such as topology, user mobility, gateway coverage in order to adapt the changes on a SAR system and communicate with its available GW.

In [10] a research study about pain monitoring is being described based on a wearable device that acts as a wireless sensor node and transmit sensor data through Wi-Fi to central servers for further operations. Large area coverage and monitoring with modules consuming low power is the main goal of this IoT research work. Embedded IoT devices are deployed in networks to monitor patient parameters, for example, users' position, current physical status and alarms in the event of emergency conditions. This wearable framework isn't just constrained to individual use, as it can likewise be introduced on a vehicle, animals or employees who move inside a factory or an open space or work area.

There are many studies referred to WiFi and LoRa, such as [11], where authors suggest and design a multi interface communication module between supporting WiFi and LoRa technology. In this research work, an IoT composition is suggested in order to offer various services. The requirement in this study is, devices that support WiFi and LoRa. Having this in mind we tried to integrate LoRa as a candidate for SAR systems by using a common module for both technologies. This convenience was brought to us by the Pycom module which introduces the possibility of communication with both technologies based on each technology availability. This was very important when comparing the 2 technologies in real experiments focused on monitor the location of end-devices.

To conclude our literature review, we should mention that to best of our knowledge no LoRa monitor solutions have been developed for SAR systems, supporting SF and BW changes adaptation to user mobility or coverage of GWs. To this direction, out work exploits the properties of LoRa and its capabilities in terms of coverage and energy consumption requirements for SAR systems. More analytical, we introduce the details of LoRa network, its physical parameters, the essential standardization issues, and the coordinating attributes with the rescue monitor needs. We depict our design and implementation environment stage for rescue monitoring as a proof of concept. In order to strengthen our research, we also carried out comparison with of the already known WiFi against LoRa in order to come to conclusions and see if the benefits of LoRa are really strong so that it can be considered a strong candidate. This was confirmed by the results of both simulations and the real experiments as well.

3 LoRaWan approach

3.1 Motivation

The motivation of this study is the development of a rescue monitor system for position notification exploiting LoRa technology.

The system will provide basic communication with base stations that can be located many kilometers away from the device location using LoRa technology. The end-device will use low energy consumption communication and long reach protocols such as LoRa. The transmission rate of the broadcasted data packets will adjust to the special conditions of application, so that battery life can last for days or even weeks. The above monitor system is considered to be best suited for use in many scenarios such as:

- *People with autism spectrum disorders* The 50% of people with this condition has been reported that they have get lost or been at risk due to a tendency to flee at least once since the age of 4.
- *People suffering from dementia* People with dementia have at least 60% possibility to get lost in open areas.
- *Infants and Children* When exposed to large open locations, infants and children are likely to get lost. They are also extremely vulnerable to malevolent attacks and they are often unable to defend themselves.

Applications that control and monitor end-devices for example wearables through LoRa connectivity allows us to know the exact location, and status through sensor capture for vulnerable group of people [12, 13]. The objectives of the next section are the simulation, the development of the above system as well as successful evaluation in real time conditions after the required simulation study [14].

3.2 Architecture

LoraWan refers to the protocol and architecture of the general communication, while LoRa refers to the physical layer. A LoRaWan topology consists of end-nodes and Gateways (GWs). Each GW is responsible to transmit the received packet through the channel to the cloud server via a backhaul connection either Wi-Fi or cellular, based on the availability. LoraWan uses a mechanism to filter multiple copies of the same packets from the available GWs. This is done in order to ensure that each packet exist only once. The above operation can be done by using Acknowledgements (ACKs) in the whole communication between GWs and Application servers. Devices which are close to a GW, without keep attention on interferences, allow having less redundancy and gaining speed. Orthogonal separation is being given through spread spectrum achieving a higher data rate ratio. The equation beneath refers to the mathematical relation of symbol and data rate:

$$R_b = SF * \frac{1}{\left[\frac{2^{SF}}{BW}\right]} bits/s \tag{1}$$

where SF refers to the used spreading factor and variable BW to the bandwidth in Hz.

The SF values used in our scenarios are used to adapt the radio signal speed having in mind the range between the GWs and the end-nodes (adjusting data rate). BW remains one of the most significant metric of the LoRa study. The chirp rate value in LoRa is close related to the BW value. This is very important mainly in multiple IoT environments where low power is needed; such as IoT devices with small battery life capabilities. The selection of the SF value can also affect the whole communication range between a GW and the end-node. Bit Error Rate (BER) in comparison to Energy per bit to Noise density ratio is being studied in this section. Starting from a theoretical point of view the mathematical relation is given below:

$$E_b/N_0(dB) = SNR(dB) + 10\log\frac{BW}{R_b}(dB) \tag{2}$$

LoraWan a low power technology used by multiple organizations as a long range protocol from 1 km^2 to few km^2. The above technology use BW values between 125 and 500 kHz and an unlicensed spectrum [15]. The table below includes the basic testbed parameters.

LoRaWan exploits ALOHA protocol as it allows embedded devices to rest as they are in idle state. As Table 1 shows, we came to the conclusion that applications that are not require continuous data transmission, are suitable for LoRa protocol use [16]. The total network setup and configuration cost differs from 100$ per GW. Next step is the evaluation through performance the time on air data transmission of a low power IoT device to a central GW. We can imagine LoRa as a Multiple Frequency Shift Keying (MFSK) modulation over a CSS type. It uses SF values from 7 to 12 not giving attention to extra interferences. This allows us to change the modulation rate and the power of transmission of each unique end-node. As SF is being increased the data packet size decreased, giving a greater power value on GW channel even on bigger distance [16].

Table 1 Physical metrics on LoRaWan

Metric	LoRaWan
Spectrum	Un-licensed
Modulation	Chirp spread spectrum (CSS)
BW	From 125 to 500 kHz
Energy efficiency	$<$10 years of battery capabilities
Device capacity	GW configured
Peak and sleep current	32 mA to 1 mA
Installation cost	Under 1000$

Table 2 Testbed simulation metrics

Parameter	LoRaWan
SF	From 7 to 12
BW	From 125 to 500 kHz
Code rate (CR)	4/5
Bits during Transmission	25,000
Frequency	125 k

4 Experiments

4.1 Description of testbed

As we already referred, LoRa is capable to be used on low power IoT devices in long range communications. The selection of the ideal SF affects the whole communication protocol and system performance. Table 2 refers our metrics being used in our simulation. A LoRaWan network makes use of SF to set the data transfer rate relative to the distance. Spread Spectrum in case of LoRaWan is insensitive to multipath propagation, interference, and fading as well. For the general encode, chirps have been used on the Tx side, while inverse chirps are used on the Rx side for signal decoding. The above SFs show us how many chirps are used, and define the bit rates per symbol radiated power, and distance range.

LoRa' physical layer has 2 synchronization symbols and 8 preamble symbols. Due to the fact that LoRa uses the above range of spreading factors, in the current study we take consideration on Frequency and Time study for the above factors [17].The above parameters must follow the standards of a IoT network which are:

- Large battery capabilities: at least few years' life existence for transmission of small packets.
- IoT modules in low prices.
- Low cost of deployment, through new hardware set up.
- Full range coverage (indoor and outdoor).

Based on the above requirements for a successful IoT ecosystem we summarize the system parameters for the two

Table 3 LoRaWan and Wi-Fi system parameters comparison

Name of standard	IEEE 802.11/Wi-Fi	LoRaWan
Frequency band	2.4 or 5 GHz	868 MHz ISM
Channel	1–16 MHz	EU: 8 × 125 kHz
Range	35–70 m (Indoor) 140–250 m (outdoor)	2–5 km (Urban) 15 km (Rural)
End node transmit power	1 mW–1 W	EU:< + 14 dBm
Data rate	11–72 Mbit/s	0.3–50 kbit/s
Governing body	IEEE 801.11	LoRa Alliance

technologies used in our scenarios in Table 3. These parameters are used in the simulations and in real experiments.

From a theoretical perspective, no winner exists in IoT concepts. As a result of there is no trivial method to assess in what way the various solutions will deal with an increasingly high number of nodes with regards to the service parameters such as latency, battery capabilities as well as throughput. However, once we consider the above study from a market perspective, we conclude that the LoRaWan has low cost modules that make it directly a tempting candidate. The Wi-Fi solution appears not to work in IoT wearable concepts because of the restriction of battery life just as the relative little scope of up to 200 m network coverage. As a consequence, we have to see how these networks scale by changing node topology and limit power consumption issues so as, to have a clear overview of our ecosystem [18, 19]. For the above reason we start out research by simulating a LoRaWan network that will be discussed and analyzed. Then the generated results will be used as input in our real experiments.

4.2 Experiments results

LoRa utilizes three distinctive BW values 125 kHz, 250 kHz and 500 kHz. First use case is usage of 125kHZ BW and SF alteration from 7 to 12. Figure 1 demonstrates distinction on over-the-air transmission time and data rate in case of 125 kHz BW. By studying the Fig. 1, we can see that as spreading factors changes on the testbed values from 7 to 12 respectively, the over-the-air time tends to increase significantly. Generated result can be seen since, as the quantity of SF expands, the outline appears to extend.

By modifying the bandwidth value from 125 to 250 kHZ and 500 kHZ individually, we would like to view the behavior of our mechanism in transmission time and data rate metrics. As figures below shows, as the BW changes, the data rate seems to expand. On the other hand, transmission time is being decreased on about the half in every cycle. About the physical importance of generated experiments, once an IoT device forwards a data packet to the central GW, additional gain is accomplished because of the capacity (Fig. 2).

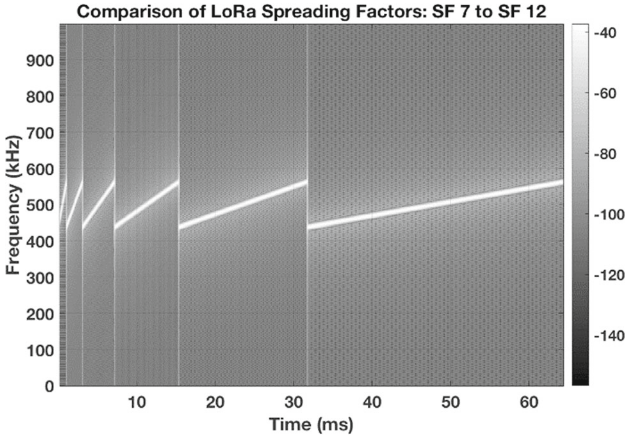

Fig. 1 SF generation using 125 kHz BW

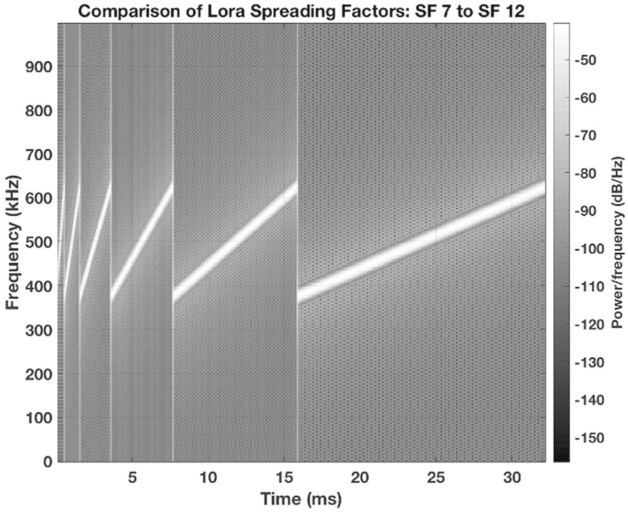

Fig. 2 SF generation using 250 kHz BW

In sensor networks, IoT devices acting as end-nodes have to forward multiple data packets with the GW by transmitting in time intervals (for example each two hours or even after some days). The simulation analysis broadens the pre-constructed simulations of Sakshama Ghoslya[1] from the point of view of the Internet of Things. According to Table 2, the SF varies from SF7 to SF12, and the BW from 125 to 500 kHZ. The case of 250 kHZ BW in terms of SF results are displayed in Fig. 1, whereas a change of BW to 500 kHZ is being depicted in Fig. 3.

Following our simulation above, we extract the behavior of bit error rate as the spreading factors vary from 7 to 12 all through the 25.000 bits transmission by improving the Signal-to-Noise-Ratio (SNR) value. The SF7 gives us—23 dB SNR and for SF12 a SNR of 6 dB. SF9, is approximately 4 times slower than SF7 in terms of bit rates. LoRa protocol is able to compose the transmission power and

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[1] http://www.sghoslya.com/.

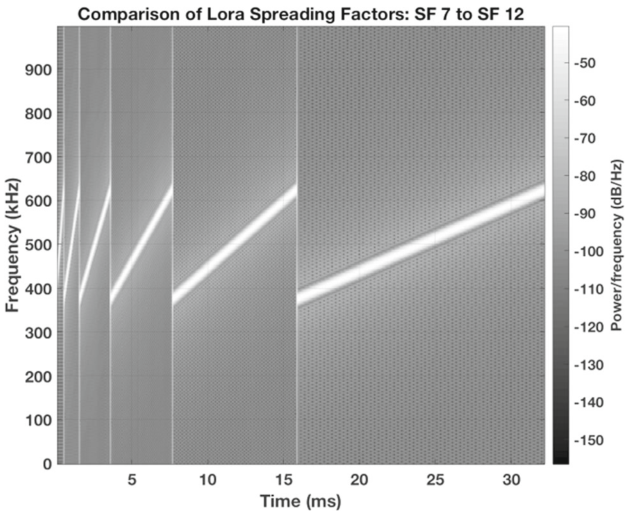


Fig. 3 SF generation using 500 kHz BW

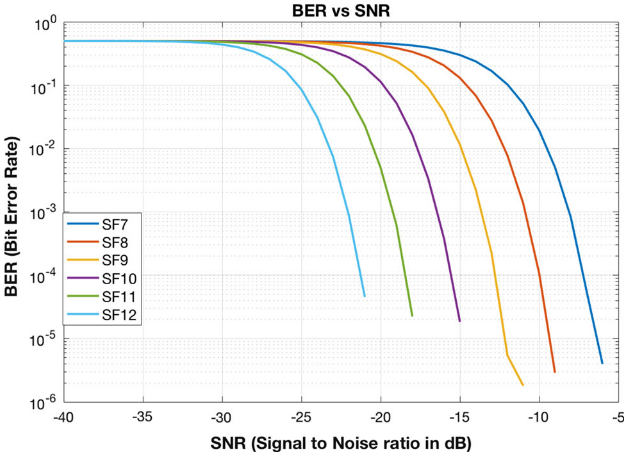


Fig. 4 BER vs SNR for different SF values

Table 4 LoRa SF for 125 kHz BW

SF	SNR (dB)	Bitrate (bit/s)
7	− 6	5372
8	− 9.2	3120
9	− 12	1757
10	− 14	977
11	− 17	534
12	− 21	284

modulation rate in each node of the topology independently as the scalability of LoRaWan is achieved by SFs. All in all, a chirp encodes one symbol of data. In the event that the SF is expanded, the data packet will be reduced, giving a higher power on the channel and a longer transmission range. Table 4 presents the LoRa spreading factors for 125 kHz BW (Fig. 4).

The results could be even better if our topology had more end-nodes. GW modules can use at the same time 8 distinct channels communications [20]. In conclusion we would say that the energy increases as the coverage distance increases and decreases bit rate. The investigation of instances of 250 kHz and 500 kHz of BW did not have any apparent impact as the quantity of bit error rate decreases close to 0 at a comparable rate in all spreading factor different cases. The above results indicate that applications that need low data rate can benefit from extra range capabilities of LoRa making it an ideal candidate for new IoT applications.

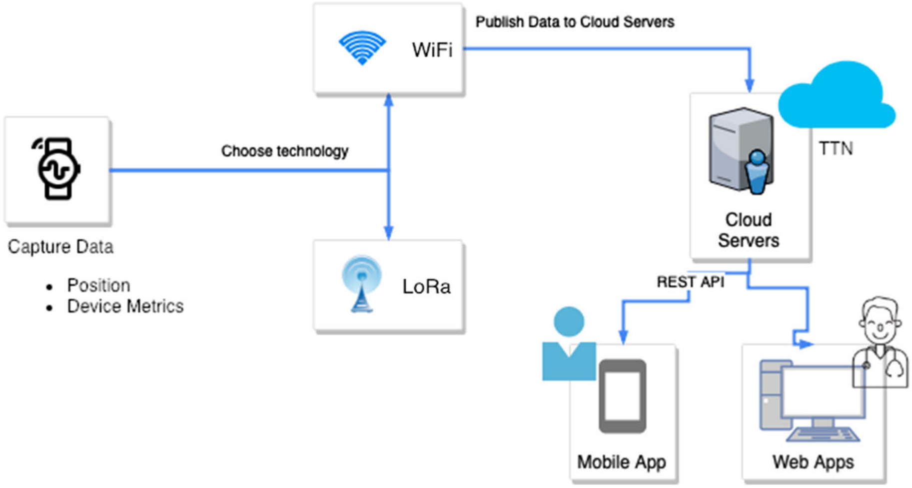
5 SAR use case

5.1 Architecture

The real experiments in our study in case of LoRaWan network done in urban environments with 2–5 km distance between end-nodes and gateway. For the general device configuration and experiments setup the results from the above simulation study was required in terms of bandwidth and spreading factors' alteration. The above results for spreading factors' and bandwidth values were used in our device configuration on the code that runs on the embedded devices. As we concluded through the above simulation, SF7 value together with the configured bandwidth on 125 KW give us smaller time-on-air and satisfactory results on system performance and power consumption by extending the battery duration to some days. By following this configuration in the embedded devices, we start by designing our general architecture and device setup. The general architecture is being described in Fig. 5.

This model monitors the present position just as the Received Signal Strength Indication (RSSI) end-device signal from the gateway in order to recognize how far is the end-device located from the Gateway. The collected data are visible and optimized through cloud to any web or mobile application. For the general communication protocol two predetermine technologies have been utilized for the end-device communication. The first is the known Wi-Fi availability in which the end-device connects to an open Wi-Fi Router and distributes its position to TTN. The second one permits associating a wearable gadget (LoPy) to a LoRaWan system, for example, TTN utilizing a nano-gateway. The second example uses settings explicitly to associate with The Things Network inside the 868 MHz area. For the parameters selection the simulation analysis results from our study used as well. As we can extract from Fig. 5 the wearable constitutes an IoT module that integrates all the required sensors (e.g. temperature, position). Based on the availability of the network the module selects the network with the strongest signal and connects for the data transmission. For simplicity reasons in our experiments below, we start by study both network cases WiFi and LoRa so as to have a clear overview of the behavior of the ecosystem in both cases.

Fig. 5 System architecture of our ecosystem



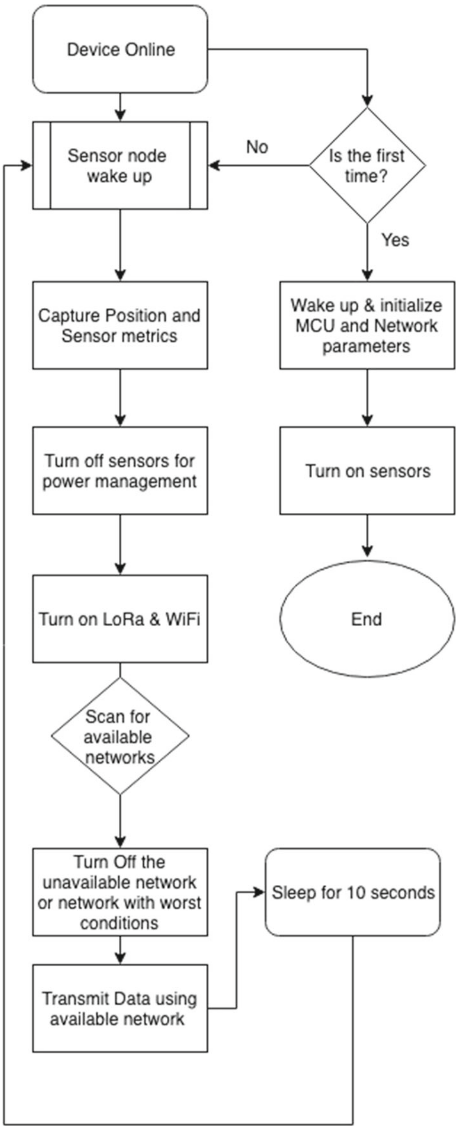


Fig. 6 Wearable node's software algorithm

5.2 Mechanism

For the implementation of our system we chose modules of the company Pycom.[2] The reason we chose the above modules is the fact that in addition to being economical (less than 20€ per node) they offer all the features of the LoRa network and NarrowBand IoT (NB-IoT) such as the ability to transmit over long distances as well as relatively low power consumption. The FiPy development board integrates LoRaWan and Wi-Fi into a compact module. Its architecture is based on the Espressif ESP32, with 512 KB RAM and 4 MB flash which even includes 8 × 12-bit ADC channels. It is very popular due to its support for development via MicroPython[3] [21]. MicroPython was the first Open Source scripting language ported to ESP32. It is a perfect board for building large-scale IoT projects where connectivity requirements are different. Also it can be used just as an independent cellular or Wi-Fi node pushing data to cloud or LoRa Wide Area Network as well. For the calculation of the current position a Pytrack[4] sensor shield which can be used with any of the Pycom multi-network modules is installed. Some of the Pytrack features are the accurate Global Navigation Satellite Systems (GNSS) Glonass GPS integrated on the shield which can calculate the exact location of the module, as well as the low power operation (1uA). For the temperature calculation a DS18B20[5] temperature (digital) sensor using 1-wire protocol has been installed. The above module together with its peripherals gathers the data from various inputs and pushes them using our Application Programming Interface (API) to TTN using 2 gateways strategy Wi-Fi and LoRa based on availability of the network. In the first case, using Wi-Fi, the FiPy acts like an end-device sending via web request

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[2] https://docs.pycom.io/.

[3] https://docs.micropython.org/en/latest/esp32/quickref.html.

[4] https://docs.pycom.io/datasheets/boards/pytrack.html.

[5] https://datasheets.maximintegrated.com/en/ds/DS18B20.pdf.

the collected data (in JSON format) to the UdiBots central web-server where the data are used in a web page. The data transmission process for the module is presented in Fig. 6.

In order to obtain measurements each module must be connected to a central gateway. Based on the availability of networks (LoRaWan and Wi-Fi) our mechanism has the ability to switch between the two transmission based on the availability and strength of the network. This is very important as in urban or inaccessible or remote areas it is necessary to ensure that the measurements which captured from the IoT module will not be lost as well as will be sent safely based on network availability. For this reason our mechanism scans in time intervals the available networks in LoRa and Wi-Fi network so as to be ready to switch in the next available network. However, time intervals in terms of seconds give us energy that cannot be managed from IoT devices. Hence, the intervals initiate up to 30 min for our study [22].

The algorithm for the case of WiFi transmission is being analyzed below.

Algorithm 1: Pseudo code of the End-Node connected with Wi-Fi

```
% UdiBots token, SSID, PASS and connection_timeout
% Connect to WLAN using the provided data
wlan. connect(SSID, auth=(WLAN.WPA2, PASS, connection_timeout)
% Start LoRaWAN nano-gateway
LoRa(mode, frequency, bandwidth, coding_rate)
% UDP socket creation
s=socket . socket ( socket. AF_LORA, socket. SOCK_RAW)
if events &LoRa.RX_PACKET_EVENT:% LoRa radio events callback handler
rx_ data = self. lora_sock.recv (256)
packet= make_ packet (ex_ data, rx_ timestamp,  rssi,  snr)
push_data(packet)% Data are available for optimization through TTN Network Cloud
```

For the LoRa case we used two FiPy Pycom[6] modules, the first one which acts as a nano-gateway and the other one as a wearable end-device transmitting its position in time intervals to the above nano-gateway [23].

Algorithm 2: Pseudo code of the End-Device connected with LoRaWan

```
% Pick the region that matches the device location (Europe in our experiments)
lora = LoRa (mode=LoRa. LORAWAN, region=LoRa. EU868)
% OTAA for the Device Unique ID (DEV_EUI), Application Unique ID (APP_EUI ), Application Unique ID (APP_KEY
) in which the data from the end-node will be associated in the TTN
dev_eui = ('DEV_EUI')
app_eui = (' APP_EUI')
app_key = ('APP_KEY')
% Join LoRa Over the Air Authentication
lora. join (activ=LoRa. OTAA, auth= (dev_eui, app_eui, app_key), connec_timeout = 0)
% Sleep until has joined the network
while not lora.has_joined():
time. sleep(3)
s = socket. socket ( socket. AF_LORA, socket.  SOCK_RAW) % Create a UDP socket
% Capture current position and start adding data to the connected socket stream
payload = {'lat' : get_curr_lat(),  'lot': get_curr_lot()}
% Input DS18B20 library data line connected to pin 10
ow =  OneWire(Pin('P10'))
temp = DS18X20(ow)
payload = {' temp temp}
s.send(payload) % Wait for the ACK after the successful data transmission and poll for network availability
```

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[6] https://github.com/pycom/aws-pycom.

LoRaWan specifies a number of unique keys such as NwkSKey, AppSKey and AppKey. These keys have a minimum size of of 128 bits. The Network Session Key is used for contacting the end-device and the Network Server, used to check the authority of the messages. This extra validation is used to match a non-unique device address to an AppEUI and DevEUI. To support low-power mode in LoRa scenario, we used the power sleep, and it is configured to wake up in time intervals for network availability discovery. For simplicity reasons we set up some basic LoRa parameters such as spreading factor, BW and code rate to exploit network' capabilities on low-power.

Algorithm 3: Pseudo code of the LoRA Nano-Gateway

```
% GW parameters (Cloud Token, SSID, WPS, Frequency and connected Server)
Network_initialization(gw_ssid , gw_password , gateway , ntp = 'pool.ntporg', period)
%  TTN cloud server connection in order to post data after a successful device receive
ntp_ sync (ntp _ server, update_period = ntp_period)

% Start LoRaWAN nano-gateway
LoRa(mode, frequency, bandwidth, coding_rate)
% UDP socket creation
s=socket . socket ( socket. AF_LORA, socket. SOCK_RAW)
if events &LoRa.RX_PACKET_EVENT:% LoRa radio events callback handler
rx_ data = self. lora_sock.recv (256)
packet= make_ packet (ex_ data, rx_ timestamp,  rssi,  snr)
push_data(packet)% Data are available for optimization through TTN Network Cloud
```

5.3 Experiments with real hardware

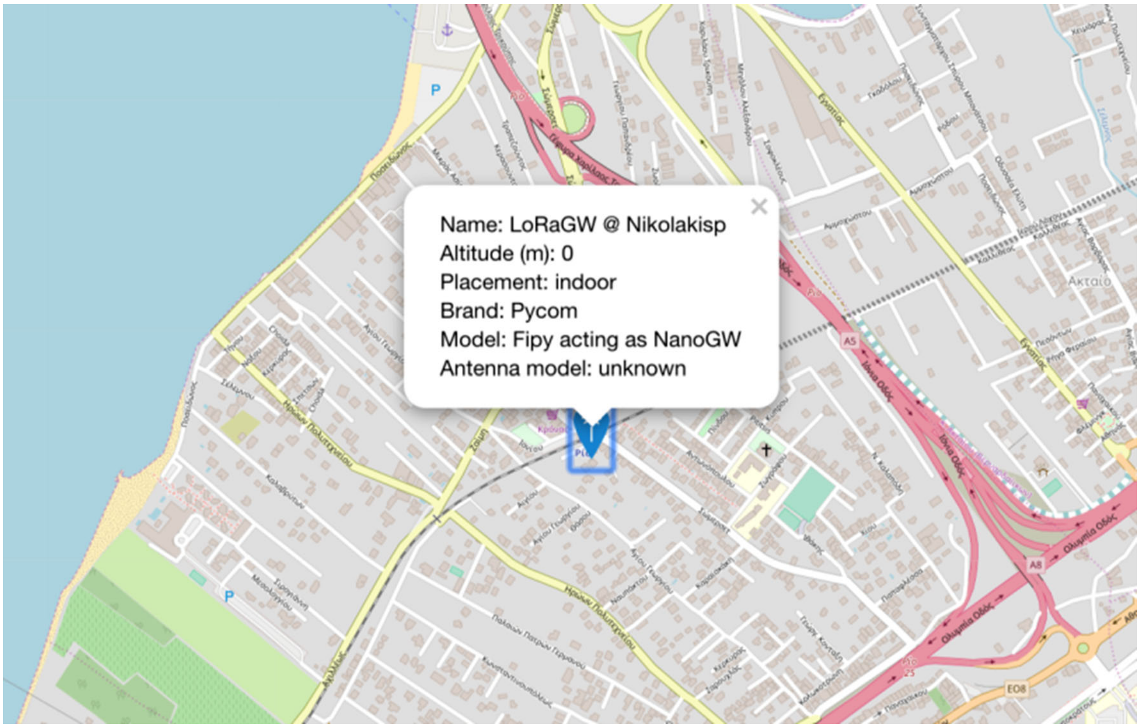
5.3.1 End-node connected to LoRaWan nano-gateway

This scenario is executed utilizing 2 FiPy boards for nano-gateway and end-node also. The two devices are powered through USB links for research scopes of this work because battery capability will be object of our next work. For the implementation of the first experiment we use the pseudo codes presented in Algorithm 2 and Algorithm 3 of paragraph 5.2 for both end-node and LoRa nano-gateway. After the successful commitment we start our real experiments by activating the LoRaWan nano-gateway. In the above assessment, the end-device, connects to the LoRa nano-gateway, captures the present position and post it through User Datagram Protocol (UDP) socket to the associated stream in time intervals.

The gateway denigrates and merges the gathered information from the UDP socket and pushes the collected sensor values to TTN cloud server for further processing.

Figure 7 shows the current position of the LoRa gateway in our case. For the study purposes, we test our equipment near the area of University of Patras at distances of a few kilometers (2–5 km) due to the topology of the area (not urban but with some buildings) andblocking LoS direct communication. Table 5 shows an example from the received payload from Gateway side on the TTN platform where the algorithm is also attached. In Europe, LoRaWan operates in the 863–870 MHz frequency band. This is the Regional ISM band (Industrial, Scientific and Medical) assigned for Europe only. The exact frequency value in our scenario is 868.1 MHz where code rate has constant value of 4/5 using spreading factor 7 and BW 125 W. The data rate should be as fast as possible so as to minimize the airtime (56.6 ms). SF7BW125 that represents spreading factor 7 with 125 W BW used in our scenario is a good place for research study as it consumes the least power and airtime. The payload and packet size remains constant through the communication.

The received packet from the nano-gateway is decoded in JSON format where an example is given below.



Name: LoRaGW @ Nikolakisp
Altitude (m): 0
Placement: indoor
Brand: Pycom
Model: Fipy acting as NanoGW
Antenna model: unknown

Fig. 7 Setup of the LoRa nano-gateway

Table 5 LoRa gateway traffic

Time	Frequency	Modulation	Code Rate	Data rate	Airtime (ms)
19:50:00	868.1	LoRa	4/5	SW7/BW 125	56.6
19:49:50	868.1	LoRa	4/5	SW7/BW 125	56.6
19:49:40	868.1	LoRa	4/5	SW7/BW 125	56.6

JSON Decoded Data

```
{
  "freq": 868.1,
  "mod": " LORA ",
  "drate": " SF7 BW 125 ",
  "crate": " 4/5 ",
  "longitude":  24.7327,
  "latitude":  37.9567,
  "temperature": 35.2,
  "format": Celsius,
  "gws": [ {
"gtwid": "eui-30jgjfj4fffe78f320",
"timestamp "{
     "time": "2019-12-15T16:35:01.409984Z"
}
"rssi": -111
   } ]
}
```

Table 6 Example of the visualized data as captured in the TTN platform

Time	Counter	Port	Payload
18:35:51	5	2	4E 69 6B 6F 6C 61 73
18:35:41	4	2	4E 69 6B 6C 6A 54 62
18:35:31	3	2	4E 69 6B 6F 6C 64 75

Every packet sent to TTN would then be able to be pictured and utilized by the API for further process [24, 25]. A case of the posted data can be found in Table 6 where we can see that the end-node transmits data every 10 s to the nano-gateway just as the payload in bytes structure.

5.3.2 End-node connected to WiFi access point

This scenario is executed utilizing 1 SiPy board with Wi-Fi, Bluetooth and SigFox network availability. The evaluation figures present the position of the end-device and distribute longitude and latitude values to the UdiBots Server (Fig. 8). We utilized UdiBots, as a server since it gives a User friendly Interface utilizing straightforward dashboards dependent on the captured information made by client. Following Algorithm 1 described in paragraph 5.2 we start our real experiments based on parameters in Sect. 4.1.

After the successful Wi-Fi association, our end-device captures current position and creates the JSON data that will be sending through http request to the UdiBots educational platform. The above end-device measures position, temperature of user and RSSI Signal through the installed sensors. This embedded device, transfers sensor data to cloud through the gateway while an example we can see in the figure below.

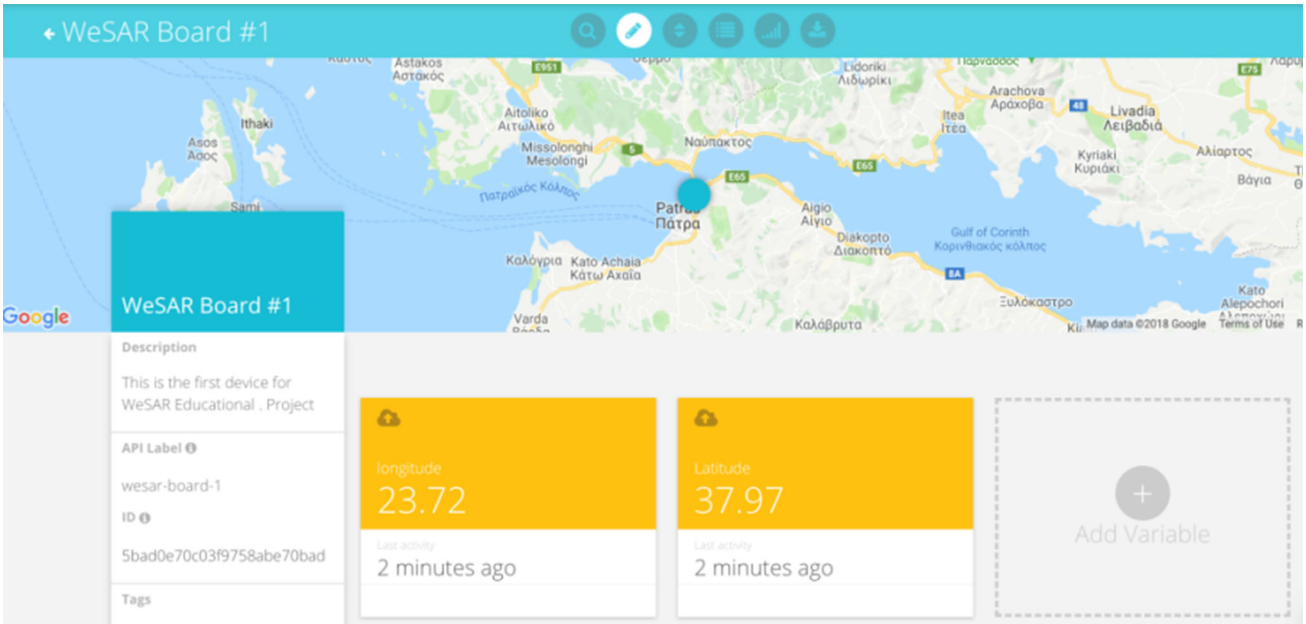
Figures 8 and 9 demonstrate the position through time of the end-device as captured and sent to the Udibots cloud server. The above graph refreshes in 10 s time interval, and visualizes the gathered data on the platform. A built-in API can be utilized for further analysis of the gathered information [26]. It is realized that Wi-Fi is restricted in range as the end-node must be in a distance up to 200 m so as to have the capacity to transmit information to an associated Wi-Fi Access Point based also in our theoretical study. In human scenarios' where the particularly vulnerable groups might be a few kilometers from the gateway, a long range communication is required. The LoRa technology seems to be a perfect candidate for this reason as it utilizes very little battery, perceived as a low power utilization protocol. Moreover, LoRaWan is a long range, speed protocol for low power applications. It is also an open specification, allowing the implementation of the protocol on real hardware equipment.

6 Conclusions

Local Area Networks have well established standards such as Wi-Fi, Bluetooth 4.0, Zigbee and Z-Wave. However the biggest problem is the battery consumption as well as the transmit coverage. In this paper, LoRaWan and traditional Wi-Fi technology were studied as network candidates for IoT monitor applications. Both technologies appear to be encouraging solutions for IoT monitor applications. First of all LoRaWan is perfect for modules with sensors that randomly send a value for instance the position of an end-device at regular intervals. It is likewise a decent choice for following and monitoring vulnerable group of individuals with a LoRa-empowered wearable. LoRaWan is perfect for long range (roughly 5–15 km) utilizing low power yet additionally BW (51 bytes/message) communication. This network is developed to work only with IoT devices which need best in class battery life. In the above study, we initially performed a simulation experimenting with different values of spreading factors, BW and code-rate in order to study the behavior of our communication protocol. More specifically, we extract that the values of SF, BW and CR affect the time-on-air and the sensitivity affecting the transmission distance. Then using the IoT modules and real experiments using the values of the simulations for SF, BW and CR we run the real experiments. If we are not interested in time on air/power consumption, we can set the BW to minimum value and SF to maximum. This will lead to incredible link budget with a LoS of 100 km or more based on simulations. From the restricting perspective, Wi-Fi works in situations where has limited range based on the available Wi-Fi Access Point. It additionally, utilizes power, so it isn't ideal candidate for battery IoT module like wearables. The goal of our study is the integration of a switching mechanism between the two technologies in Wi-Fi and LoRa respectively into rescue concepts. Concluding, it's important to make sure that IoT modules are able to capture metrics from various sensors, able to switch networks based on the strength of the central gateway and RSSI signal and power safe.

7 Future work

Our future research work, should concentrate on approaches to diminish the power utilization of the IoT modules. This should be possible by picking the accessible technology (LoRa or Wi-Fi) just as to limit the power utilization of the device during the transmission with the least power consumption values. Our next goal is the integration of hardware used in IoT industry e.g. development kits as (e.g. Smart-



WeSAR Board #1

Description

This is the first device for WeSAR Educational . Project

API Label

wesar-board-1

ID

5bad0e70c03f9758abe70bad

Tags

longitude 23.72

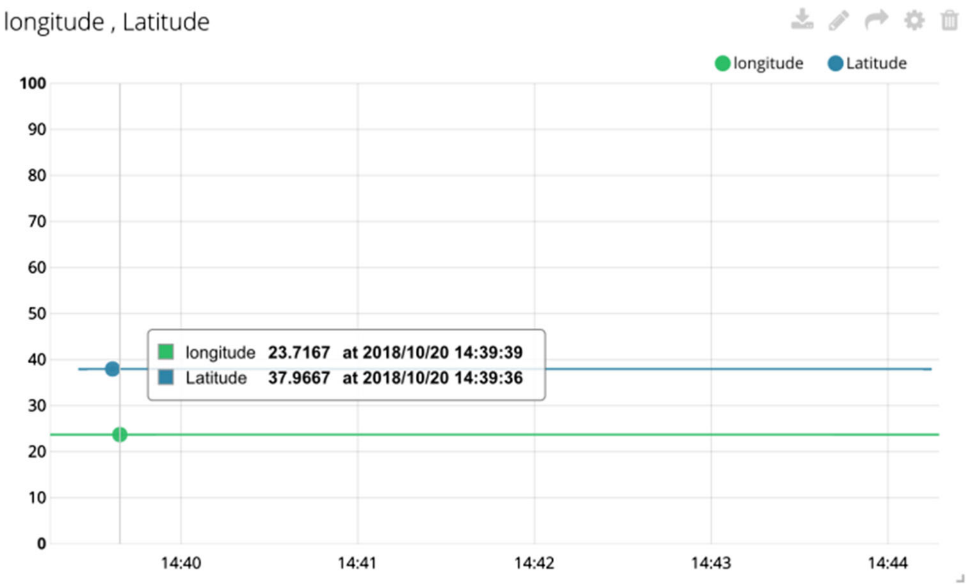
Last activity 2 minutes ago

Latitude 37.97

Last activity 2 minutes ago

Fig. 8 Wearable position based on the collected sensor values

Fig. 9 Calculated position of the wearable through time



Bond™ DA14681 Wearable Development Kit[7]) in order to develop and build our solution into different kits, to confirm our speculation and apply as wearable device in real SAR scenarios. The choice of this development kit is beyond its wearable substance, its easy programming the ability to add LoRa communication module as well as the already existing built-in rescue-related sensors. The above IoT wearable device could be used with real data information from people in long distances with different available networks to have clear overview in our measurements. It's very important to focus on power consumption of these devices, to ensure their existence even some days. So, we will try to test intelligent algorithms so that data transmission through the wearable above occurs when the device consumes the lowest power consumption. This facilitates the process as the necessary calibration has been performed before the measurements start. Our goal is not so much the validity of the values as the confirmation and proper operation of the network switching mechanism, the reduction of energy consumption. An additional issue that needs to be addressed is the security of the

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[7] https://www.dialog-semiconductor.com/products/connectivity/bluetooth-low-energy/smartbond-da14680-and-da14681.

data we send within the network. In addition to the functionality provided by the TTN using keys between end-devices and GWs, next goal is to use encryption algorithms (AES with 128 bit key) in order to encrypt and decrypt the collected data and secure the communication under each gateway.

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