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# A Symbolic GeoPositioning System To Allow E-Health Enhanced Usages

Nel Samama<sup>1</sup> and Alexandre Patarot<sup>2</sup>

<sup>1</sup> Telecom SudParis, Institut Polytechnique de Paris, Palaiseau, France

<sup>2</sup> SNPA SAS, Saint-Junien, France  
nel.samama@telecom-sudparis.eu

**Abstract.** Indoor positioning has had a bright future for many years. However, the deployment of such systems is struggling to develop rapidly. We propose here, within the framework of e-health, a particularly simple system to implement based on a so-called "symbolic" approach which no longer seeks to provide precise positioning, but which strives to provide very high reliability. The principle of the approach is described. Then the practical implementation as well as the results obtained both in the home of an elderly person (in order to analyze their daily behavior ) and in a hospital (for the monitoring and analysis of stretcher movements) are discussed.

We show in particular that it is then very simple, in real time if necessary, to trigger an alarm in case of detection of an anomaly at home (unusual "geographical" behavior) or to estimate, after the analysis of many trips by Machine Learning techniques for example, the moment when stretchers will be available at the emergency service.

We also propose other types of uses at the end of the article in slightly broader environments, objectives and user targets.

**Keywords:** Geo data, Symbolic positioning, Hospital, Stretcher.

## 1 Introduction – Basic principle of the symbolic positioning approach

The symbolic approach proposed here is a new look at positioning. The need to have a position in the form of coordinates, a principle derived from GPS, gives the false impression that it is always possible to characterize the accuracy of positioning. The reality often appears different, especially with systems based on the use of radio signals in environments constrained in terms of propagation and signal attenuation. Buildings are very characteristic in this sense: multiple reflections on structures, attenuation when crossing walls, ceilings or floors, presence of equipment or people in places that are sometimes small, etc. Thus, many daily realities strongly influence the reliability of the result. Our main contribution is to try to open the debate on the possible utility of a new vision, complementary to the current one. This proposal is then based on the description of the symbolic approach as well as on the practical implementation of the latter in order to present some results.

The main objective of this article is to show that it is possible to realize an efficient and reliable indoor positioning system without trying to obtain a metric precision. This is done through the concept of "symbolic positioning" providing an area of very high probability of presence rather than proceeding to a calculation by triangulation or by distance measurements. This is guided by a very simple observation: the propagation of signals, radio in this case but the remark applies to many techniques, is particularly unpredictable in an uncontrolled environment. The case of the interior of buildings is a perfect illustration. Thus, rather than seeking at all costs to obtain good quality measurements (i.e. low noise and repetitive), we will take into account the variability of the latter by "expanding" the uncertainty of measurements. This leads to the determination not of a point but of a zone. When we "widen" sufficiently, we increase the reliability of the area provided but we potentially degrade the accuracy of positioning. We have clearly chosen to reduce the accuracy in order to reach a very high reliability. Many applications seem to us to require such a reliability (i.e. a probability of presence in the provided area close to 1) even before the accuracy. Note that the high variability of indoor radio measurements is due in particular to the very changing environment due to the presence of moving people, furniture, open or closed doors, surrounding radio activity (networks, electronic devices, etc.).

The symbolic positioning is therefore based on the provision of a more or less large area depending on the signals received. In particular, the approach still works with very little signal, both in quantity and quality. Of course, it is then the size of the area that will increase with the reduction in the number and quality of signals. This concept is particularly simple and fully corresponds to "real life".

Note however that we add an important specificity in order not to fall into the opposite excess of the permanent search for precision (and to reach provided zones of too large size): we couple the measurements with the mapping of the places. The latter thus becomes an important element of the position calculation. However, we will not dwell here on the cartographic aspect in order to concentrate on the implementations and on the results obtained.

Following this introduction, the paper is organized as follows: Chapter 2 gives a brief state of the art of some positioning systems and details our contribution. Chapter 3 describes the theory of the proposed symbolic approach while chapter 4 gives the implementation details of the network and hardware aspects. The next two chapters describe respectively the available data (chapter 5) and the results obtained (chapter 6) in specific cases of real deployments. A conclusion including directions for future work is given in the last chapter.

## 2 Quick state of the art of positioning systems

An overview of the main radio technologies is available in reference [1]. This is devoted to indoor positioning and it deals with WiFi, Bluetooth Low Energy (BLE), Zigbee, RFID (Radio Frequency Identification) and UWB (Ultra Wide Band). The interesting aspect of this reference is that main advantages and disadvantages of all these methods are described, and specifically the influence of the environment on the performance. As usual, authors focus on obtaining a "precision" in "meters" or "centimeters" and in Cartesian coordinates, i.e. in  $(x,y,z)$ . Most recent AI techniques have been of course also investigated, as in [2] where data science approach using recurrent neural networks (RNN) allows to improve positioning results compared to other data processing methods except to the one of the most classical methods, such as  $k$  nearest neighbors. Reference [3] addresses the specific case of BLE, applying a particle filter to improve the accuracy to 3 meters in 74% of the tested situations. The low cost of the solution is emphasized. The current technological developments of BLE beacons allow measurements of both the angle of arrival (AOA) and the angle of departure (AOD) of radio signals. These capabilities are advantageously used for positioning [4], in addition to the more traditional time of flight (TOA) approaches. When very precise measurements are needed, probably the most advanced technique is based on TOA measurements and called UWB, as in [5], which achieves an average accuracy of about 15 cm. Such a positioning paves the way for accurate human tracking for instance. In reference [6], it is shown that radio based technologies are not unique in this field. In [6] angle detection is improved through the use of image processing. However, image based positioning is sometimes limited by presence of obstacles, even if the need for infrastructure is removed.

In the specific case of hospitals, in [7] for example, simulations are performed on a BLE system deployed in order to detect unauthorized patient exiting as soon as possible. In such a case, the delay between the exit and the alarm should be reduced. In [8] a similar idea is proposed but for mental pathologies patients. They are using a Zigbee network in this specific case. Sensors network can be used to reach very good positioning accuracy (in the range of a few centimeters), as in [9], at the cost of high deployment and low distance coverage. This is interesting but clearly is restricted to very specific applications.

A very nice concept is currently developing: the "smart hospital". Geographical data generation tools are thus required. Positioning is a must for providing useful usages and [10] proposes the introduction of fuzzy logic in order to cope efficiently with measurement variability. An accuracy of 2 meters is stated, taking into account obstacles and possible displacements of the handheld device. WiFi signals are once again used, as it is often available for communication purposes on the premises. In general IoT (Internet of Things) devices are likely to provide more than just the location of patients, but also a set of connected sensors for their continuous medical monitoring, as in [11]. To broaden the subject but with a reduced impact on real implementations today, we have to mention communication and positioning systems using light modulation through light emitting diodes (LEDs) [12].

The goal of a complete virtual hospital is the one followed indeed. The actual foreseen form of it is a "digital twin" [13], which will be able to analyze and predict the complete functioning of the hospital, the objective being in turn to be able to

optimize its global operation. Towards this goal, the positioning of people and equipment is probably a key issue.

Our contribution can be summarized in two aspects: the description of a symbolic approach to positioning that is more than the classical "geofencing" and the results obtained in real deployments. The determination of a reception area (geofence) is the classical approach of many geo-marketing systems. It allows to trigger a promotion or to call a person when approaching a catchment area [14]. Classically, positioning systems using Bluetooth signals are based on a two-step principle: the first step is to characterize the environment through measurements (the so-called calibration phase), and the second step is for the user to take measurements and compare them with those obtained during the calibration in order to determine a position. In a classical way, initiated by the GPS (Global Positioning System), this position is obtained in the form of coordinates  $(x,y)$  in any reference frame (or even  $(x,y,z)$  when the altitude is also available). The symbolic positioning proposed here is based on the observation that the indoor propagation of Bluetooth signals is complex and that disturbances due to obstacles or unfavorable orientation of the transmitter can generate significant errors. Thus, the reliability of these approaches is difficult to certify. In the case of symbolic positioning, the idea is to simplify the propagation problem and to use thresholds of received power levels in order to determine zones of higher probability of presence. The choice of these thresholds is important and it is from this choice that the reliability of the approach will be determined. Three points are fundamental to achieve a high reliability: the thresholds, the fact that the zones are included in each other and the consideration of the mapping of the building.

### 3 Details of the symbolic approach

As already stated, symbolic positioning is simple in its principle: it consists of a strong coupling between cartography and radio measurements. The map is defined in the form of structures associated with attributes. This is a fundamental aspect, where for example, a room is not a traffic zone but only a destination. This is of the greatest importance when we want to propose navigation to a user. Currently, the radio transmitters are Bluetooth Low Energy (BLE) ones from IoT (Internet of Things) domain, such as tags or smartphones. They can be installed on anything, people or equipment, like on a stretcher, on a medical instrument or even be worn by a patient or staff. It can also be used to estimate the activity of an elderly people at home.

The main components of the system are:

1. BLE tags, called "*Tags*" in the rest of the paper.
2. A network of modules including a BLE receiver and a WiFi transmitter/receiver, called "*Modules*", which is deployed in the considered building.
3. The map.

A specific point of our approach is the fact that the Modules are indeed plugs directly connected to the electrical installation of the building. So, there is no need for power management due to the presence of batteries. In addition, the stability of the operation is largely increased which in turn reduces the noise due to the modification of the voltage with age. Moreover, the installation is particularly simple. The other specificity is of course the way the positioning is achieved, i.e. the symbolic approach resulting in an area with a very high reliability but whose size will depend on the quality of signals.

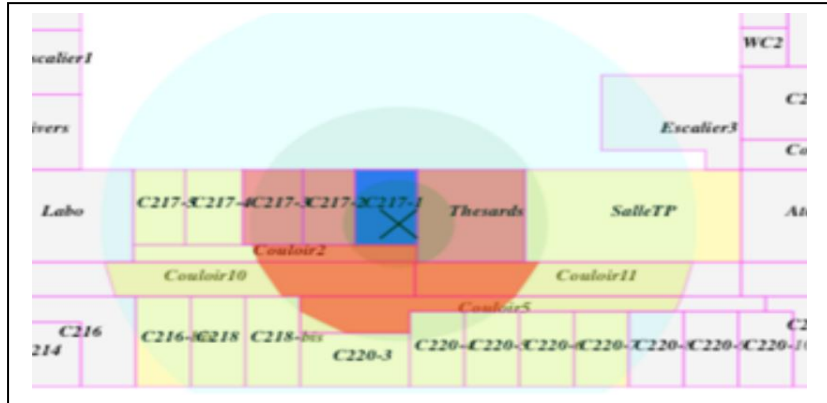
The basic principle of a typical deployment is as follows:

1. The "object-oriented" mapping (each component has associated attributes). This is at least as important as the received signals in the calculation of the position.
2. A set of Modules. It is not compulsory to have a high density of such Modules since the building architecture (walls, open spaces, electromagnetic characteristics of the partitions, etc.) has the most impact on the positioning. However, this density remains a parameter of concern.
3. The allocation of the Tags to equipments or people.

### *The localization engine*

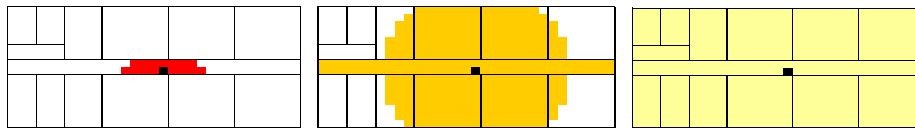
Classical approaches to BLE/WiFi positioning are based on calibrations of the building specific propagation of radio signals. They give quite satisfactory results but are dependant of people movement, electrical activities or modifications of the furniture locations. Thus, theoretical performances are not so simple to reach in real deployments. We believe another way is possible, no longer in the (x,y,z) form. It is very efficient when dealing with the most used measurements, namely RSS (Received Signal Strength). This is of course completely different in the case of good quality time-of-flight measurements such as with UWB (Ultra Wide Band) [15].

The basic idea is to define covering zones with respect to BLE reception levels. There is indeed one and only one real rule: "a high received power means the Tag is close to the Module". It is important understand that "a low received power does not mean that the Tag is necessarily far away from the Module". This second assertion is fundamental and constitutes the basis of the approach: the various zones must not be exclusive. Thus, the "symbolic" approach can be represented in Fig. 1. The determination of the real size and shape of a zone (in Fig.1, we consider three zones associated with two reception level thresholds) depends on the size and shape of the spaces where the modules are deployed. It appears from Fig. 1 that zone 1 (the blue one) occupies the entire room where the Module is plugged, while zone 2 (in orange) has a shape that depends on the layout of the building (hence the importance of the mapping step). The same applies to all the zones. Of course, one could decide to implement as many zones she/he wants, but our experience shows that three is the good number for achieving the searched for reliability.



**Fig. 1.** Philosophy of the symbolic positioning

When considering three zones, we need to set two reception thresholds: typical values are  $-45\text{dBm}$  for the “close level” and  $-69\text{dBm}$  for the second one. Once again, remember that zone 2 must include zone 1, otherwise the algorithm will lose the “reliable” part of it, the one we consider as being the most important one. This is illustrated by Fig. 2 which defines in a typical case the shape of zone 1 and zone 2, respectively in a simple architecture with a corridor and offices on each part of it.



**Fig. 2.** Zone 1 (in red, left), Zone 2 (middle orange) and Zone 3 (right yellow) for the module in black, located in the middle of the corridor.

As a summary, an automatic algorithm for the definition of zones could be the following one:

- Zone 1 is the room of the Modules.
- In case this room is large (a corridor for example), Zone 1 is a circle of limited radius (hence the shape of Zone 1 in Fig. 2).
- Zone 2 goes through the walls with a radius depending on the number of crossed walls. The resulting Zone 2 can thus have a complex shape.
- Zone 3 is the entire reception area of the Bluetooth Tag.

## 4 Network deployment and hardware aspects

### 4.1 Tags and Modules hardware

In order to have an efficient positioning, the locations of the Modules must be included in the cartography. This is this coupling between power level measurements from the Tag, knowledge of the map of the building and knowledge of the location of the Modules that leads to an efficient (thus reliable) position estimation. A lot of

algorithmic approaches can then be implemented: the one used in our current implementations is based on the two following steps:

1. defining, for each receiving Module, the shape of the corresponding zone,
2. carrying out the intersection of all the zones obtained in step one applied to all the Modules which receive signal from the Tag

Such an example, together with the resulting positioning area, is provided in Fig. 3 below.



**Fig. 3.** The coupling principle between the cartography and the localization: the green surface is the resulting localization and requires no calibration or model design. On the left hand side the picture of what the smartphone "sees" and on the right hand side the restitution of the proposed system

### *The possible Tags*

BLE transmitters are quite a standard and there exist many different size and shapes. Thus possibility covers a wide range of devices, from pins to smartphones, or to any specific devices. In medical facilities such as EPHAD or hospitals, these are mainly bracelets, necklaces, watch, pendant or pins provided to patients/residents. In case one needs to "visualize" a route or just a position, a watch or a smartphone could be preferred. Fig.4 shows a few of these possible devices.



**Fig. 4.** A possible wearable for hospitals: a wristband (left), a simple tag for the stratcher (middle), and a guiding watch (right).



In our experiments at home, our partner, Edward, did not like to have to wear a wristband and preferred to have a necklace, as the one shown in Fig. 5. In addition, in Fig.5 too, the BLE Tags are fixed on the structure of the stretcher with simple plastic collars. Note that the antenna is then oriented towards the ground in order to optimize the propagation, the stretchers being all made with metallic plates.

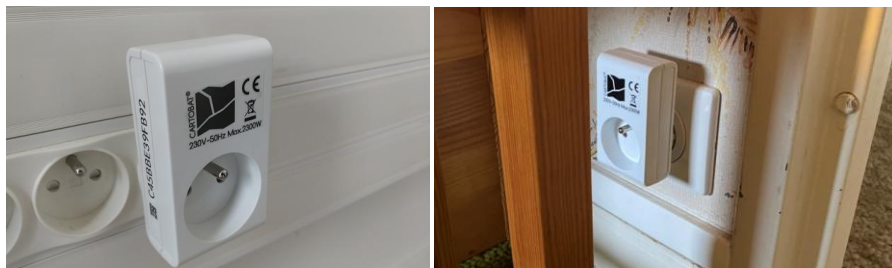


**Fig. 5.** The necklace worn by Edward at home (left) and typical tag mounted on a stretcher (left)

The technical specifications of the tags currently in use are as follows: 5x5 cm<sup>2</sup>, 1cm thick, BLE, emission power between -20 and +4dBm, transmission every 100ms (10Hz), 2 years battery life (tested in real conditions).

### The Modules

A module has two tasks to carry out: it should measure the power level received from the different Tags It receives, and also transmit them, through its WiFi transmitter, to an access point or directly to the local building's network in order to reach servers. At home, the Modules are directly connected to a WiFi/4G router and in the hospital, they were connected to a specific channel of the hospital's wireless LAN. Such Modules are visible in Fig. 6. Note that the Modules are identical for all the deployment, leading to a real simple set up in all the environments.



**Fig. 6.** A Module plugged in the hospital (left) and at home (right).

### 4.2 Details of the deployment at home

As briefly explained above, the home architecture of the network deployed could be made with several connection modes to dedicated servers (4G, VDSL, etc.). In the present case, we used the Internet Box of the house (see Fig. 7). Of course, since the

data is "sensitive", such as health data, it is also at least anonymized or even encrypted if needed.

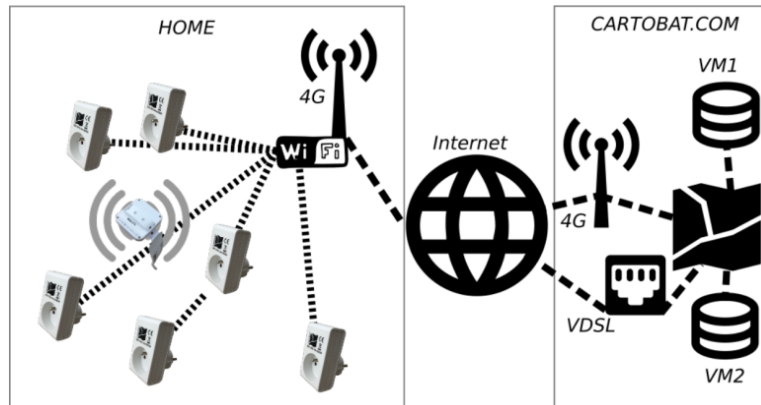
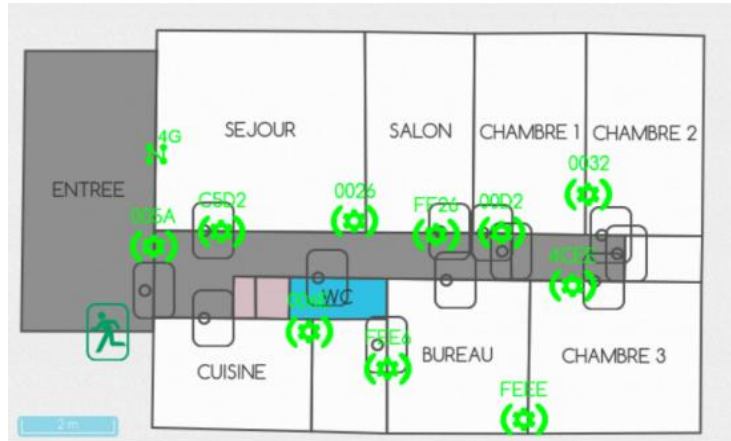


Fig. 7. Network architecture of the system

At Edward's home, the modules deployed are inserted in sockets. The latter remain usable because the modules are "staggered" (Fig. 6 right). The Modules can be seen as BLE sensors of signals transmitted by the wear worn by Edward (see Fig.5 left).

The distribution of the Modules in the house is shown in Figure 8. It is a classic house in the countryside of France with a living room, a dining room, three bedrooms, an office, a bathroom and a kitchen for a total of about 80 square meters. The green pictograms in Fig. 8 represent the location of the Modules in order to locate, in real time, Edward. Some Tags were also associated to objects such as car and house key chains, as well as in the jacket and coat usually used by the person. This set-up allows for cross correlation observations in order to strengthen hypothesis concerning Edward. For example, in case we have detected at the same time the non visibility of both Edward's Tag and the one of the car, it is probable he has gone away for a while ...

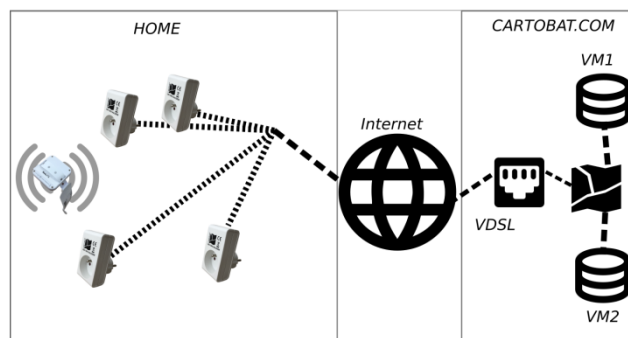


**Fig. 8.** The localization deployed socket of the house.

### 4.3 Details of the deployment at the hospital

In this case, the architecture of the network of Modules and link to the server is a little bit different since a specific wireless LAN channel was allocated to the system by the hospital network service. The corresponding network architecture is then the one visible on Fig. 9 below.

In the case of the hospital, the deployment was not continuous in that sense that the complete buildings were much too large for this first demonstration of feasibility end evaluation of performance. Thus, only a few set of services were equipped with Modules. Fig. 10 shows only those deployed at the emergency service. The other services concerned were imaging ones, namely IRM, Scanner or radio. Such a "non contiguous" deployment is absolutely not a problem with our symbolic approach. The only associated constraint is that when a Tag is physically no longer in the system's coverage area, it is then not located and defined as "out of area". A certain misleading could then happen in case the Tag is indeed no longer working ...



**Fig. 9.** Architecture used in the hospital



**Fig. 10.** Localization of the radio modules in the emergency department.

Stretchers were equipped with Tags attached to their underside in such a way that it is both inconspicuous and safe for the nominal operation of the stretcher (Fig. 5 right). The grey zones in Fig. 10 are thus typical circulation routes of the stretchers. The distribution of the Modules has been thought of in order to be able to “follow” the stretchers efficiently.

## 5 Typical data available

### 5.1 Typical “raw” data available

Our goal was to design a system to produce geo-location data and to demonstrate a simple approach can provide valuable usages. The processing of these data is not our specialty but we propose here some tracks.

In order to monitor the wireless transmissions (both WiFi and Bluetooth) for the Tags and the Modules, we implemented a specific screen allowing for the visualization in real time of all the data of the system (simplified version shown in figure 11): date and time of the last detection of the Tag, state of its battery, estimated position, quality of the received signal, etc. This allows also to manage the network aspects of the system and the follow-up of the Tags (in the case of Edward, he was alone in this case).

Site: SilverLab | CartoWear: 399F

Module	Last Wifi Update (s)	RSSI Wifi (dBm)	Last Wear Update (s)	RSSI Wear (dBm)
AC67B27700D2	9	-65	3	-79
AC67B276FF26	9	-54	9	-75
AC67B277006E	54	-65	11	-70
AC67B277005A	4	-55	110	-48
AC67B275CSD2	21	-52	6	-74
AC67B276FEE6	2	-64	1	-73
AC67B2770026	17	-52	1	-74
AC67B2770032	28	-71	5322	-72
AC67B2754CEE	124	-84	460	-79

**Fig. 11.** Screenshot of one of the monitoring system interface.

A first quite easy result consists of visualizing (possible in real time) the position of the Tag on the map of the building (Fig. 12 left). It is important to note that this is the Tag which is “followed”, and not the person, i.e. confidentiality can be preserved and no personal data have to be stored in the server, but only identifying numbers of the Tags, eventually encrypted. In the figure, a pictogram of Edward can be seen. In the case of the emergency service of the hospital (Fig.12 right), stretchers are identified by location signs and are associated with a color indicator giving, in addition to their location, an idea of the time the last update has been achieved : green for less than one second, orange when less than 10 seconds and red otherwise.

Since only a part of the hospital has been equipped with Modules (only where the stretchers are likely to go), a few stretchers will probably be outside the radio coverage of the Modules and thus will not be located. The graphical interface has thus been adapted with an additional indicator providing the hospital with the number of stretchers which are outside the zone.



**Fig. 12.** Left: the localization of Edward in real time. Right: the localization of stretchers in real time within the emergency department.

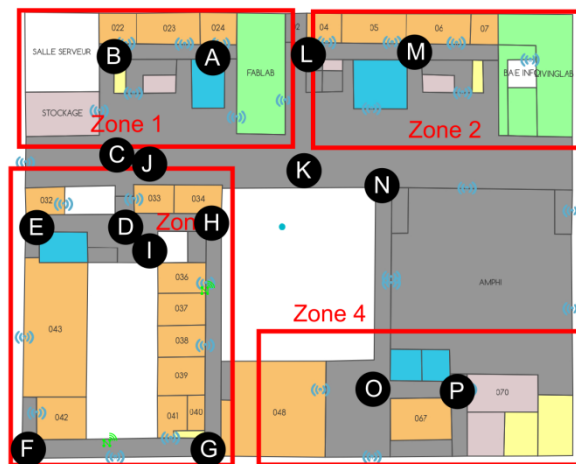
## 5.2 Typical data issued in the case of the hospital

One need of the hospital's emergency department was to have an accurate idea of the travel times to and from the various imaging departments the stretchers are bound to go. Here, the main goal is to be able to estimate the potentiality of a shortage of

stretchers with respect to the affluence and thus to be able to predict the availability of stretchers. Thus we carried out a few experiments in order to estimate which accuracy our geo-positioning system could reach towards the determination of such travel times. Since the emergency service is in charge of about a hundred stretchers, the approach was quite simple: once the network of Modules deployed in the service ans in a few imaging services, we just had to associate to each stretcher a transmitter (the Tag), and to follow them. All the data being of course time stamped, the determination of travel times is easy as long as we have the locations of the stretchers in real time.

In the symbolic approach, the positioning is based on a pre-determination of the names of all the covered areas of the hospital. An example is provided in Fig. 13 (for confidentiality reasons, the map is not the one of the hospital). Our system provides raw data but also higher level ones, such as zone names for instance. Hence, when the Tag enters “Zone 1”, the systems output the corresponding time and zone. The time is synchronized to the classical network time and the zone is the one estimated by the algorithm (and sometimes this is not the right one, or it is detected not exactly at the time on real entrance in the zone).

Also shown in Fig. 13, in order to be able to compare the “ground truth” of a route and the one given by the geo positioning system, we decided to define a route by a succession of points (from A to P in the figure). Then the experiment consisted in following this pre-defined route and to note the exact time we actually reached the each point. Analysis of the data is then possible and comparisons were carried out on more than 80 routes.



**Fig. 13.** Definition of a “path” from “A” to “P” in this case

A typical example of the data we dealt with is provided in Fig. 14 below. It shows that in addition to the time of detection, a calculation is also achieved which gives the positioning of the stretcher in the GPS (Global Positioning System) longitude and latitude coordinates (in case one wants to mix ...). The interesting data for us at this point are the last two columns: zone name (determined by the symbolic positioning algorithm according to power levels of the Tag measured by the Modules) and a

“fiabilite” (which means “reliability”) indicator. This latter could be used in order to add consistency to the system.

timestampUTC	mac	layer	latitude	longitude	zoneName	fiabilite
23/02/2022 8,00 55,00 3,403	8,5503403	00FAB601A1DC	78	45,482311	4,363553 -1_ENTREE_URGENCES	100
23/02/2022 8,00 55,00 13,520	8,5513520	00FAB601A1DC	78	45,48233	4,363475 -1_UHCD	50
23/02/2022 8,00 55,00 23,705	8,5523705	00FAB601A1DC	78	45,48233	4,363475 -1_ENTREE_URGENCES	50
23/02/2022 8,00 55,00 33,345	8,5533345	00FAB601A1DC	78	45,48233	4,363475 -1_ENTREE_URGENCES	50
23/02/2022 8,00 55,00 43,311	8,5543311	00FAB601A1DC	78	45,48233	4,363475 -1_ENTREE_URGENCES	50
23/02/2022 8,00 55,00 53,615	8,5553615	00FAB601A1DC	78	45,48233	4,363475 -1_ENTREE_URGENCES	50
23/02/2022 8,00 56,00 3,442	8,5603442	00FAB601A1DC	78	45,482328	4,363643 -1_ENTREE_URGENCES	50
23/02/2022 8,00 56,00 13,575	8,5613575	00FAB601A1DC	78	45,48233	4,363475 -1_UG_DROITE	50
23/02/2022 8,00 56,00 23,494	8,5623494	00FAB601A1DC	78	45,48233	4,363475 -1_UHCD	50
23/02/2022 8,00 56,00 33,470	8,5633470	00FAB601A1DC	0	0	0 horsPerimetre	50
23/02/2022 8,00 56,00 43,504	8,5643504	00FAB601A1DC	78	45,482365	4,363655 -1_UG_DROITE	50
23/02/2022 8,00 56,00 53,530	8,5653530	00FAB601A1DC	0	0	0 horsPerimetre	50
23/02/2022 8,00 57,00 3,582	8,5703582	00FAB601A1DC	78	45,482365	4,363655 -1_UHCD	50
23/02/2022 8,00 57,00 13,342	8,5713342	00FAB601A1DC	78	45,482311	4,363553 -1_ENTREE_URGENCES	100
23/02/2022 8,00 57,00 23,470	8,5723470	00FAB601A1DC	78	45,48233	4,363475 -1_ENTREE_URGENCES	50
23/02/2022 8,00 57,00 33,300	8,5733300	00FAB601A1DC	78	45,48233	4,363475 -1_UHCD	50
23/02/2022 8,00 57,00 43,232	8,5743232	00FAB601A1DC	78	45,482414	4,363619 -1_UG_DROITE	100
23/02/2022 8,00 57,00 53,515	8,5753515	00FAB601A1DC	78	45,482337	4,363646 -1_ATTENTE_BRANCARD_GAUCHE	50
23/02/2022 8,00 58,00 3,530	8,5803530	00FAB601A1DC	78	45,482337	4,363646 -1_ATTENTE_BRANCARD_GAUCHE	50
23/02/2022 8,00 58,00 13,482	8,5813482	00FAB601A1DC	78	45,48233	4,363475 -1_UHCD	50
23/02/2022 8,00 58,00 23,722	8,5823722	00FAB601A1DC	78	45,482323	4,363428 -1_UG_DROITE	100

Fig. 14. Detail of the available data

## 6 Example of possible processing and results

### 6.1 Example of processes data in the case of home deployment

A possible plot is the daily “geo activity” of the person at home (or weekly or monthly). It gives the percentage of time spent in the different rooms of the house (Fig. 15). An analysis of the long term evolution of, for example, the daily geo-activity (carried out by current Artificial Intelligence – Machine Learning techniques) could lead to derive habits or on the contrary to generate alarms in case of anomalies. Fig. 15 gives a typical example of a Wednesday in May 2021.

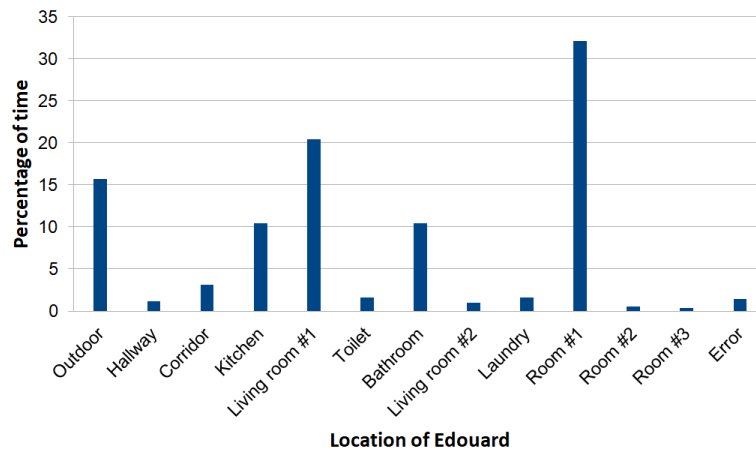


Fig. 15. A typical daily activity

Note that the data are available for any real time analysis too. Thus, an unusual long time spent in the bathroom, or even an unusual absence of time spent in the bathroom

could easily generate an immediate alarm. Another approach consists in defining periods when the Tag is not detected: Edward is then either out, in the garden, a little far from the house, or to go shopping!

The other analyses which could be thought of are for example:

- determination of periods of physical inactivity
- evaluation of the daily distance travelled
- coupling of activity data with location and duration
- analysis of the stationarity of car and house keys and correlation with the person's activity

A coupling could also be envisaged with some home automation installations such as the automatic shutdown of equipment when the person leaves the kitchen for example, unless specific action is taken by the person.

## 6.2 Travel time estimation at the hospital

In order to evaluate the accuracy of the travel times for all the routes, we applied a specific procedure, as follows:

- departure time is the moment when the system detects the exit from the initial area (that of point A),
- arrival time corresponds to the first detection of the destination zone.

Figure 16 is a screenshot of the calculation page obtained for a given route. Note that both direct and return routes were considered since patients are bound to be, or not, on the stretcher for one of the travels and this could influence the duration of the route. Table 1 is a summary of the results for all the tested routes. One can see that the typical accuracy of the proposed system is in the range of 10 to 15 seconds for travel times of 2 to 3 minutes.

Points	Time	Real location	Travel time
			00FAB601A146
A	09:57:50	-1_ATTENTE_BRANCARD_GAUCHE	Real forward travel
B	09:58:42	-1_TRAJET_MILIEU	00:02:24
C	09:59:07	-1_TRAJET_MILIEU	Measured forward travel
D	09:59:22	-1_TRAJET_MILIEU	00:02:20
E	09:59:48	-1_TRAJET_HAUT_DROITE	Error
F	10:00:14	-1_IRM	00:00:04
G	10:00:40	-1_IRM	
H	10:01:04	-1_IRM	
I	10:01:28	-1_IRM	
J	10:02:08	-1_IRM	Real return travel
K	10:02:31	-1_TRAJET_HAUT_DROITE	00:02:24
L	10:02:57	-1_TRAJET_MILIEU	Measeured return travel
M	10:03:28	-1_TRAJET_MILIEU	00:02:30
N	10:03:55	-1_TRAJET_MILIEU	Error
O	10:04:32	-1_ATTENTE_BRANCARD_GAUCHE	00:00:06

**Fig. 16.** The travel time comparison for a given imaging service



Table 1. Travel time accuracy

Nb of tracks	20			
	<i>Forward travel</i>		<i>Return travel</i>	
Real travel	Min	00:01:50	Min	00:02:06
	Max	00:03:23	Max	00:02:42
	Average	00:02:42	Average	00:02:26
Measured travel	Min	00:01:40	Min	00:01:50
	Max	00:03:00	Max	00:03:00
	Average	00:02:29	Average	00:02:22
Mean error	00:00:15		00:00:13	

It is thus possible to propose a simple positioning system quite "reliable". We show in these results that there is a way other than the absolute search for positioning accuracy (which remains a relevant solution, of course) to obtain useful geo-localized data. The typical uses for the hospital are:

- estimating the number of stretchers out of area,
- determining the average time spent in a service, from the reception to all the specialized services,
- following a particular stretcher in its medical course,
- estimating the average waiting time,
- optimizing the routes,
- etc.

### 6.3 Other possible use cases

Other uses are possible for such a simple and reliable positioning data system. First of all, it is very easy to visualize the positions of the various tags on the map of the place considered (see Fig. 17). This can be done for a company, a warehouse or a hospital. In the case of a company, it would also be easy to hide confidential parts of the cartography, for example, or to check that a participant is not in a restricted area. In the case of the hospital, this can apply to various categories of people or equipment. For example, specific tags could be provided to medical staff, others to outside workers and still others to patients' families. Of course, all this can be associated with a navigation tool. In the case of symbolic positioning, the latter must involve the user in order to be effective.

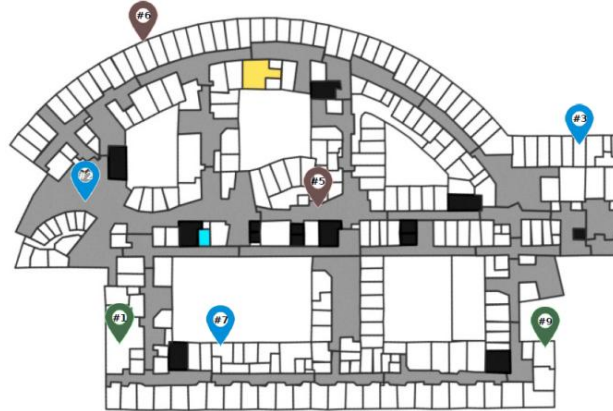


Fig. 17. Geo identification of people within a building

Another possibility, while remaining in a hospital environment, is to manage the ambulatory pathway of patients. Two objectives are envisaged, using the same geo-localized data: to allow a location in time and space of the various appointments and examinations for the patient himself, but also a tool for the post hoc analysis of the differences between the predicted pathway and the pathway actually realized by the patient (see Fig. 18). This analysis should allow the optimization of the pathways by highlighting recurrent difficulties encountered by patients or physicians.

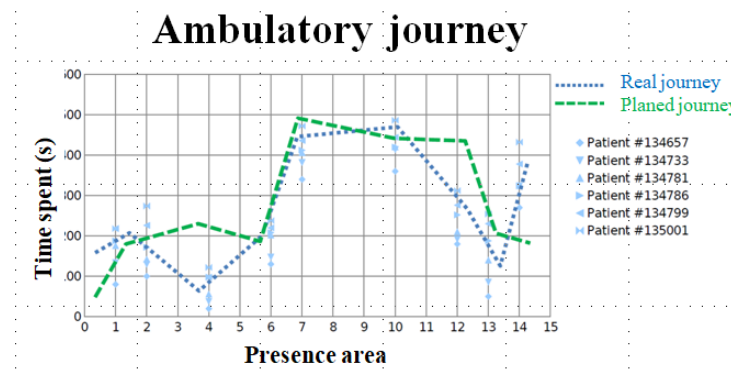


Fig. 18. Ambulatory journey scheduling evaluation

## 7 Our goal was to design a system to produce geo-location data and to demonstrate a Conclusion and perspectives

The symbolic approach proposed in this paper has been implemented practically in several environments. Reliability of positioning was sought, more than accuracy. A reliability of 90% of correctly determined zones was obtained, which is not satisfactory (the typical reliability sought is rather 98 or 99%). The main reason for this relative poor performance lies in the non-optimal deployment of the modules.

Modules that are too close together, or even worse, "stacked" at the same locations on different floors, generate conflicts in the algorithms that the latter cannot handle in the current version.

We aimed to show that there are geo-location solutions that can be implemented simply and efficiently in many useful use cases. The search for accuracy may not be the ultimate goal (complex to achieve) without detracting from the contribution of the available data. We believe that if we managed to slightly modify the perception of geolocation (it is not necessarily an "Indoor GPS") in environments where GNSS is not available (typically inside buildings), the field of possibilities opens widely, and in particular in the field of health (medical institutions, hospitals, home, ...) or "digital twins" where the "location" data is probably one of the most fundamental as soon as it is reliable. The symbolic positioning approaches was described by showing on implementations in hospitals and medical facilities how it is possible to use a very reliable but not always accurate geo-location. The measurements made, the associated treatments (with a critical view) as well as the achievable performances (and limitations) are exposed.

Such systems are also possible in much more classical cases of "navigation" of people, but this is not the objective of this presentation, which is more based on the advanced uses of geo-localized data. Offering more freedom in medical facilities while ensuring the safety of residents, ensuring the optimization and planning of emergency services or improving the management of ambulatory activities in hospitals are quantified with the help of experimental results in real conditions carried out in the services. It is shown, for example, that planning the movement of a stretcher is feasible with a reasonable deployment of means and greatly relieves the burden of logistics management.

Future work is mainly oriented towards the determination of deployment rules allowing to avoid the conflicts described above in order to allow the symbolic approach to reach the desired level of reliability. This step is essential in order to open the debate on the interest of such an approach in the context of indoor positioning, as a reliability of 98% can be seen as satisfactory for many uses. The deployments described in this paper will serve as a basis to validate the reliability improvement. Other use cases are also sought in other domains such as the tertiary sector or education.

Finally, the proposed approach has an important advantage in its ability to adapt to different environments and needs. It is very easy to extend the coverage of the system, to reduce or increase its accuracy. It is also possible to choose to cover only parts of buildings, partially or completely. The approach is in fact very versatile. Complex implementations are thus possible, for example in very large structures where the need is not uniformly distributed. However, some limitations exist for the current system, especially when it comes to leaving the buildings: the current hardware is

only Bluetooth and does not allow for outdoor tracking. The availability of plans is also an important point, which requires validation from the site manager.

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