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Optimizing Resource Allocation and Indoor Location Using Bluetooth Low Energy

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Abstract—The recent tendency of "Internet of Things" (IoT) has developed in the last years, causing the emergence of innovative communication methods among multiple devices. The appearance of Bluetooth Low Energy (BLE) has allowed a push to IoT in relation to smartphones. In this moment, a set of new applications related to several topics like entertainment and advertisement has begun to be developed but not much has been done till now to take advantage of the potential that these technologies can offer on many business areas and in everyday tasks. In the present work, the application of BLE technology and smartphones is proposed on some business areas related to the optimization of resource allocation in huge facilities like airports. An indoor location system has been developed through triangulation methods with the use of BLE beacons. The described system can be used to locate all employees inside the building in such a way that any task can be automatically assigned to a group of employees. It should be noted that this system cannot only be used to link needs with employees according to distances, but it also takes into account other factors like occupation level or category. In addition, it has been endowed with a security system to manage business and personnel sensitive data. The efficiency of communications is another essential characteristic that has been taken into account in this work.

Keywords—Bluetooth Low Energy, indoor location, resource assignment, smartphones.

I. Introduction

NOWADAYS, the technology is in a process of a paradigm change, leaving behind the conventional interaction between the user and the machine. In the IoT [1], there is a huge number of devices that can communicate between them and which can transmit a great diversity of contents: localization [2], publicity, meteorology, etc. Moreover, the intense use of smartphones as well as the appearance of BLE have been key factors to make IoT the center of creation of innovative applications in several sectors. From leisure to medicine, many reduced size devices which allow to produce new contents at mobile phone application have appeared. The direction being taken by the IoT has mainly been focused on the "conventional user" but it has a great potential for a variety of operations into business, i.e. it allows to expand the range of possibilities that the technology offers in the business sector.

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With the idea of providing an improvement in coordination, monitorization and assignation of human resources into business as well as the creation of secure and efficient communication systems, an application in the frame of IoT has been developed. The use of BLE beacons together with the smartphones allows an indoor location [3] effective enough to provide an added value to the application with the purpose of assigning resources.

The suggested application, called BLETasker, for the optimization of the resources is composed of three main parts: a server with the ability to process and determine the key factors to carry out a proper allocation; a set of BLE beacons located conveniently along the facility; another set of smartphones associated to the personnel. With these three elements and mathematical triangulation methods it is possible to locate an employee inside the facility, with the purpose of taking as a main variable the localization of employees and deciding the ideal group to carry out an activity. However, the location is not the only determining factor because it would be unfair to assign the task only taking account the distance. To provide impartiality to the decision, other factors like the workload or the work done are taking into account. Those employees who have worked harder will be favoured and the new tasks will be given to those who have worked less. Furthermore, as the smartphones have been used, the application has an interface that allows the employees managing fast and easy way all the activities that have been designated for their realization. Also, in order to open a new possibility in the same application, it provides the integration of the activities management with the communication between employers and employees. It should be noted the flow of information between them, the server through a web platform and the employees with the use of smartphones, so it is necessary to provide security for this new channel of transmission. Each package of information needs to be transmitted encrypted and signed to guarantee the integrity, the confidentiality and authenticity in the communication.

This paper is structured as follows: Section II describes the communication system, including its operation and the description of the security associated with this system. Also, in this section, the location system is defined and how it makes it possible to optimize the task assignment when we used both systems is explained. Section III provides a few details about the practical implementation of BLETasker including screenshots of the web platform and the mobile phone application. Finally, Section IV closes the document with some conclusions and open problems.

II. Overview of BLETasker

As mentioned above, the application is composed of more than one element and more than one system, which allow the optimization of resource allocation into huge facilities like airports. Each of the elements join in several systems but these systems can be explained in function of it functionality which it represents: the communication and the localization, therefore these aspects will be explained individually as well as together.

A. Communication System

That the communication system between business and employees is secure and efficient is essential, a better transmission of information allows a better understanding of the activities. Consequently a dual communication system in order to notify and synchronize data between the emitter and the receptor is developed for this application, as it can be seen in Fig. 1. Those involved in this system are: a server managed trough a web platform and the personnel devices with the application proposed.

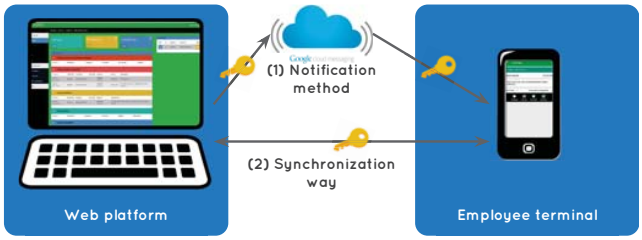

Fig. 1 Communication scheme

Firstly, an unidirectional communication able to establish the notification from the server to the employees' terminals correctly. Google Cloud Messaging (GCM) is used because of its capacity to send the message to multiple devices without the individually management of each device and because of its powerful resend policy which allows us to set up several rules with the purpose of guaranteeing the reception of the message. Moreover, GCM has been chosen because it belongs to the Android operating system, providing lesser consumption of resources as well as more efficiency when the application receives some notifications. The messages that flow over this channel are those that include the main information of each new activity, allowing that the mobile application "hears" when it needs to be synchronized. In this moment the second way of communication takes part.

Secondly, a bidirectional communication system is based on the synchronization of databases in both ends. This method has two key features: it updates mobile application's database when a new activity or message arrives and it updates the server's database whenever an employee interacts with his or her activities or messages through the application.

Finally, in both communication methods, a security mechanism is implemented in order to guarantee the integrity of the package and also the confidentiality of the origin and the authenticity at the moment of receiving this package. The used tools require that the emitter sends all messages encrypted and signed by means of a public key scheme that is shown in Fig. 2. Public key cryptography [4] is used and OpenSSL certification authority has been implemented for distributing of RSA keys. Also, RSA encryption is used for ciphering the messages and the hashing method to sign these messages is SHA-256.

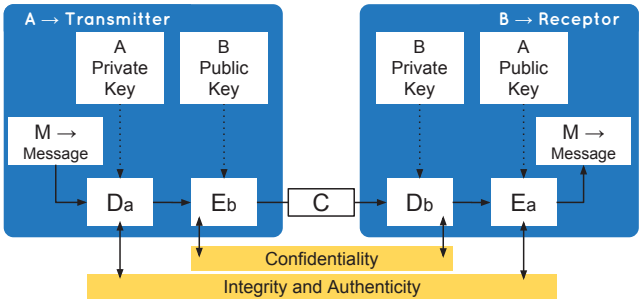

Fig. 2 Security Scheme

B. Location System

An indoor location system is not a trivial labor, on it many variables take part (architecture, people flows, signal strength of devices, receptors...) but the application has the purpose of providing a reliable system. BLE beacons are located [5]-[7] to determine the reference points, thereby the application can reference these points to locate the employees inside the installation.

To calculate the employee position in the facility is necessary to take into account several aspects:

- A receptor that is continuously registering the beacons is necessary.
- At least one beacon should be detected in each iteration, a minimum of three beacons is recommended.
- The Received Signal Strength Indicator (RSSI) must be converted to distance [8], [9] with the following formula: $D = 10^{(((A-RSSI)/K)}$.
- With the distance to each beacon, whenever is possible, the system realizes a triangulation to solve the employee position.

To perform these operations, the receptor must have installed a BLETasker application. Thus, each detected beacon can be packed and it is sent to the server to be analyzed. In the server side the number of detected beacons is taken into account to realize the most adequate operation, it carries out a conversion between RSSI and the distance, as mentioned above. In Fig. 3, the possibilities which the server need to solve to localize the personnel is shown.

In the A case, it is observed that three beacons are detected. However, more than three beacons can be detected but, in this case, the three best RSSI values are taken and with these it realizes the same operation. Thus, triangulation methods are performed for this situation, applying geometric property that declares that three intersecting circles between them only have one radical center which coincides with the employee's position. To calculate this value it is necessary to solve an equation system with the equation of circumference like base, where (x, y) is the radical center.

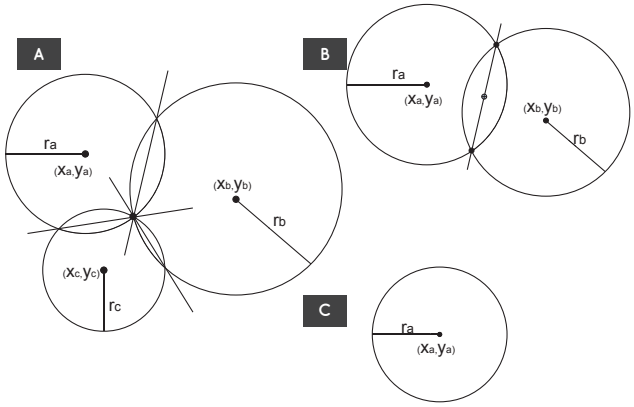

Fig. 3 Cases: Detected beacons

$$\begin{cases}(x-x_a)^2+(y-y_a)^2-r_a^2=(x-x_b)^2+(y-y_b)^2-r_b^2\\(x-x_a)^2+(y-y_a)^2-r_a^2=(x-x_c)^2+(y-y_c)^2-r_c^2\end{cases}$$

The B case represents the situation where the receptor only detects two beacons. This possibility allows the application of a similar geometric property to that of the previous case, if a circle is intersected by another one they form a radical axis with two intersections which coincide with a two possible points where the employee can be located. Since it is optimally covered installation that this case does not happen, it is a possibility, therefore, the middle point of the segment formed with two intersecting points is an approximated solution in order to provide homogeneity to subsequent calculations. So, it is necessary to use a similar equation system.

$$\begin{cases}\sqrt{(x-x_a)^2+(y-y_a)^2}=r_a\\\sqrt{(x-x_b)^2+(y-y_b)^2}=r_b\end{cases}$$

The last case is the worst if it is not considered the absence of beacons, only one beacon is detected. Logically, the geometric operations previously used to this case will give as result a infinite set of points in a r_a radius, as it is shown in Fig. 3 (c). In this particular case the probability that it occurs is less than in other cases but the employee's location is approximate to the beacon place, i.e. $(x, y) = (x_a, y_a)$.

C. Integration of Both Systems

The systems described above, as aforementioned, can be explained individually but the main aim is that they work in a coordinated way. In this section, the moment of intervention of each subsystem and the variables that it takes into account in order to a good allocation are explained. Fig. 4 shows the complete process to flow the information between all elements and events that the application performs as well as those links of communication which need to use the security system.

In the web platform, the administrators can define new activities with the set of parameters of Table I. These parameters describe the activity and it allows the system to associate a necessity to a particular point inside the facility.

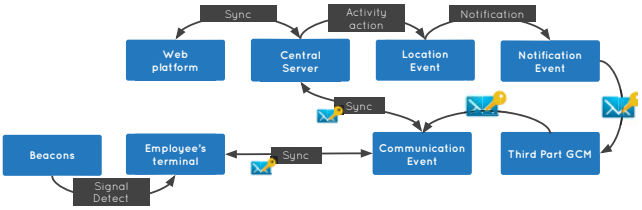

Fig. 4 Flow diagram

Also, at any moment the employees' location is registered and it is sent to the server to calculate the distance (d_T) from L_{xy} to point (x, y) of each employee around the C_l. This variable is the first influential factor when the system tries to choose one or another employee to execute the activity. Besides, all the activities have associated an estimated time and also the actions over the employees' activities are being registered continuously therefore two new parameters can be considered fundamental for the assignation: one is the time of the complete activities (t_C) and the other one is the time of the pending activities (t_P). As mentioned, other factors are taken into account in order to be fair with the assignment, the weight of each parameter has been measured over the other, the following formula represents:

$$\min\left(d_T+0.4\times\sum_{n=1}^{k_C}t_n+0.6\times\sum_{m=1}^{k_P}t_m\right),$$

$$k_C = number\ of\ complete\ activities,$$

$$k_P = number\ of\ pending\ activities$$

After the ideal group of employees to carry out the proposed activity has being chosen, the next action that the system should execute is the communication of them through GCM as a notification method. When the news reaches its destination in the employees' terminal, these employees can interact with the assigned activity. Moreover, a synchronization system keeps updating in any moment the databases of the server and the terminals without using GCM as intermediary. This is based on the updating with the comparison of a timestamps. The voice and text messages as well as the information of detected beacons are sent through this method.

TABLE I
VARIABLES TABLE

Name	Description	Identificator
Category	Category to search	C_a
Cluster	Zone of facility	C_l
Description	Information about the activity	D
Id	Identificator for the activity	Id
Location	Point of reference of the activity	L_{xy}
Priority	Priority of activity (Low, Normal, High)	P
Required	Number of employees for the activity	R
Time	Aprox. time to complete the activity	T_e

III. Implementation of BLETasker

For the implementation, several tools and technologies have been chosen, the tendency and the efficiency of each one has been considered. The agility in relation to the programming

tasks and the stability when the maintenance is needed have been taken into account.

In the server side, the unification of the programming languages has been a key point to decide to use Node.js [10], MongoDB and Express because they work in the same language. The server is the responsible of managing the work flow and the monitorization of the set of activities. For this purpose, a work space into the web platform allows the administrators to visualize the data in an ordered way like the zones with activity for each employee during the work day, as you can see in Fig. 5. The state of the activities and the employees related with their assigned tasks are other important piece of information that the web platform allows to visualize.

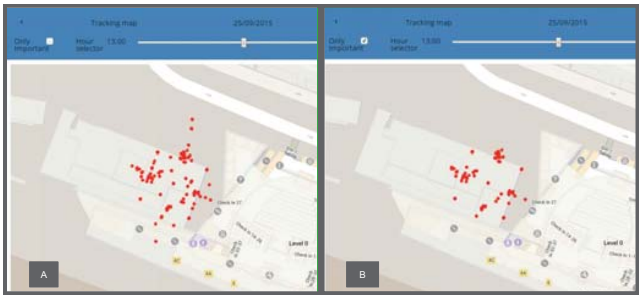

Fig. 5 Simulation of movement with (B) and without (A) of important points

In the mobile phone application, Android operating system has been chosen for developing this application, without excluding other systems that can be developed with the same philosophy. In this, the employee can manage all the activities assigned (Fig. 6 (a)), he/she can look up the full description of any activity (Fig. 6 (b)) and check the information about the location (Fig. 6 (c)) as well as he/she can know the state of the beacon monitoring service (Fig. 6 (d)).

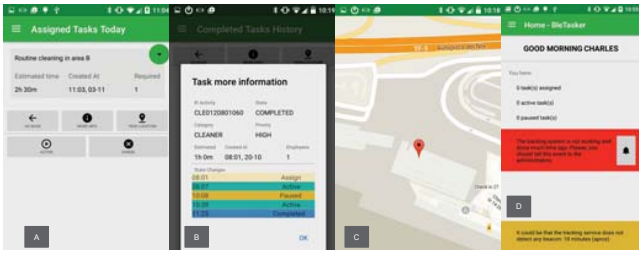

Fig. 6 Details of activity: task list and information of the state of the activity

All the transferring data from the server to the terminal or vice versa are encoded in JSON. This format is adequate for the data type that are transferred and it is a lightweight format. It is necessary to remember that absolutely any data are sent through the security system.

IV. Conclusion

This application is not only a practical platform for managing the personnel or for the communication between employers and employees. This is a powerful tool that allows to expedite these communications and to endow it with a security layer. The optimization of resources allocation can allow the increase of the efficiency in the business. Individually, it allows managing each employee but it is able to provide a global group vision of the workers like the professional categories or the activity sectors.

The advantage of the application is that it is able to register daily all of the activities and the monitorization of the employees. It allows the administrators to know the performance of the employees, the success level about the estimated time of the routines, the zones and the sectors with more flow of personnel, among other things. In addition, this is very versatile given that it is able to adapt to the several scenarios (airports, sports venues, universities...) and situations (daily control of the activities, punctual events with high number of participants...).

Regarding with the future development of this application, a set of new tasks can be observed. Firstly, a test phase in real environment is necessary, in spite of the good results obtained, the simulation of the tool has been the only way to check this until now. Secondly, the study about RSSI could solve some errors in relation the calculus of the location. Finally, the application could show the activities like a group so the employees know the progress of the mates in the same activity.

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