Using Beacons for Creating Comprehensive Virtual Profiles

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Abstract. The number of Internet of Things systems in which the general population is involved keeps increasing. At the same time, the configuration and adaptation of these systems to their users' preferences are still mostly manual. To achieve a better personalization of these systems comprehensive virtual profiles of their users, including as much information as possible, is needed. One of the most relevant information of a user virtual profile is his location. With the rise of the bluetooth low energy protocol and the appearance of the beacon technology, indoor positioning of smartphone owners can be added to these virtual profiles. However, the lack of a beacon standard and the low level information provided by these devices is hindering its adoption. To solve this, this paper presents a Beacon Management System that abstracts applications developers from the low level details of the different beacons protocols and allows the management of unregistered beacons. The proposed system has been integrated into the People as a Service computation model and in the commercial platform nimBees to improve the creation of virtual profiles in IoT applications.

Keywords: Internet of Things · People as a Service · Beacons · Bluetooth low energy

1 Introduction

The current ubiquitous Internet presence has led to the creation and deployment of all kinds of devices equipped with a network interface. Connecting those and other everyday physical objects to the Internet is getting ever easier. This has enhanced the popularity of the Internet of Things (IoT). However, the current integration between humans and IoT technologies still leaves much room for improvement [7,17]. Currently, final users must manually configure most of the devices, indicating what are their preferences and how they should behave. In a foreseeable situation in which millions of devices will be connected [27], their

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configuration and reconfiguration when users' preferences change will entail a great effort and will difficult obtaining the full benefits proposed by this technology.

In a desirable IoT scenario, technology would take the context of its users into account, learning from it, and taking proactive actions according to their needs and expectations, avoiding user intervention as much as possible. The users' contextual information plays a key role in achieving this scenario. This information can be used to infer complex data and create virtual profiles of the users [9,28]. This representation can then be used to control the IoT systems without direct human interaction. Currently, there are different approaches for creating these virtual profiles [15,23,26]. In particular, the authors of this paper proposed the People as a Service (PeaaS) computing model. This model uses the smartphones as the key element for gathering all the needed information to construct a virtual profile of their owners [18].

One of the core elements of these profiles is the user location. Currently, the precise location of a smartphone is calculated using its GPS sensor. However, its precision decreases drastically when the user is inside a building. Other techniques, such as Wi-Fi or 4G networks, could be used indoors. Nevertheless, these techniques do not have a great precision. So that, they have a limited use when a person should be located with an error range of less than a meter [20].

To improve indoor location, several companies, including Apple and Google, had recently developed new protocols and sensors typically called *Beacons*. These beacons are Bluetooth Low Energy based devices that broadcast information to nearby devices in order to allow them to trigger location-based actions or to get a fine-grained indoor position.

By integrating the information provided by these devices into the users virtual profile the indoor location problem would be solved. However, this integration has some issues: on the one hand, there is a lack of standardization of the protocols used by these devices. Different companies have defined proprietary formats for the data packets transmitted by using them [5,6,14]. This leads to some problems for mobile applications developers, since they have to specifically implement the required decoders and listeners for each protocol, and vendor lock-in problems for clients, hampering the change from one manufacturer to another.

On the other hand, beacons do not send the location of a user. They send specific information that have to be processed by the final application. For that, this application should have registered all beacons from which to receive information. This hinder the generic approaches building the users' virtual profile to make use of any detected beacon to infer the indoor location of the user. They are normally limited to infer this information only from the registered beacons. To build a more complete virtual profile, ideally, these proposals should be able to get and interpret the information transmitted by any of these devices.

This paper presents a Beacon Management System. This system, first, abstracts applications developers from the low level details of the different beacon protocols. Secondly, it allows the management of unregistered beacons. For that, if a beacon is not registered in the system, when it is detected, the system searches it in different public databases, like Wikibeacon [1], in order to get information on how to interpret the information transmitted and, thus, to know the indoor location of the user. Therefore, this system allows the developer to focus further on modelling the users' virtual profile with higher quality and precision, as they can forget about beacon specifications. In addition, it has been integrated into the PeaaS computation model and in the commercial platform supporting it, nimBees [13], so that it can create more comprehensive virtual profiles.

To present the Beacon Management System the rest of the paper is organized as follows. Section 2 details the background of this work. In Sect. 3 the Beacon Management System is presented focusing on its architecture. In Sect. 4 the integration of the Beacon Management System with nimBees is described. Section 5 lists the most relevant related work. And finally, in Sect. 6 the conclusions of this work are detailed.

2 Background

As was indicated by Dey and Abowd in [3], if we can fully understand context in a given environment, we would be better able to include context-aware behaviour in our applications.

Many research efforts have been dedicated to gather this contextual information in order to create more complete virtual profiles of the users. In [21], Liang and Cao review the most relevant context middleware tools for collecting sociological information from the user. They focus on the information acquisition through multiple sources, including users smartphones and other sensors, and providing it to different software solutions.

The authors of this paper have also been working on the PeaaS and the Internet of People (IoP) approaches. PeaaS [18] is a mobile-centric computing model to infer the context of smartphones' owners and generate their virtual profiles. IoP [24] propose an infrastructure and a manifesto for IoT systems that support proactive adaptations of the systems to the users' profile. This manifesto indicates that the interactions between things and people must *be social*, must *be personalized* with the users' profile and context, must *be predictable* from the users' context, and must *be proactive* and automatically triggered depending on the context.

These two approaches have been implemented in a commercial platform called nimBees [13]. This platform, between other elements that will be explained further, defines a library that can be imported by almost any mobile application. This library is responsible for reading the different information gathered from the smartphone sensors in order to create the users' virtual profile. One of the basic data that it has into account is the users' location.

As a running example, we are going to consider a supermarket mobile application. The nimBees library could be incorporated to the supermarket app in order to send users ads adapted to their profile. For example, if a user is taking a walk nearby one of the supermarket establishments, the system would send him an ad with the discounts of the day and, thus, encourage him to go inside.

While these approaches simplify the complexity of obtaining and processing the contextual information, there is still an open challenge regarding the user location data in indoor areas [21]. The GPS sensor loses precision inside buildings. However, the indoor location of users is very valuable for constructing more complete virtual profiles [29]. In the running example, the supermarket would also be interested in knowing if a user is inside its establishment and what sections he visits. This information would be very valuable to better know the users' preferences and to send ads suited to them, leading into a higher human-ambient interaction. Counting with such detailed data, would permit to create a new business model, opening a wide horizon of new marketing strategies. In addition, it would make the client feel as if the supermarket is adapting to himself, creating a personalized experience and reinforcing his trust in that particular establishment.

As detailed above, currently beacons can be used to obtain this fine-grained location of users in indoor places. These devices are based on one of the protocols defined by large companies, such as iBeacon [6], Eddystone [14] or AltBeacon [5]. These protocols define the format of the transmitted information. This implies that the final mobile applications should implement specific decoders for the protocols used by the beacons with which will interact. This is a burden for developers, but also difficult clients to change the type of beacons deployed in their establishment.

Therefore, to use beacons in contextual-aware inference systems, it would be necessary to register the different beacons from which receive information and how to interpret it. This is suitable for final applications in order to identify if a user is in specific locations, but it is not valid to obtain location information of a user regardless of whether the beacon is registered or not. This functionality would be quite interesting for the supermarket running example, since the application would be able to detect if a user is in a certain section of a rival supermarket and, thus, sends him an ad indicating that its prices are more competitive.

Currently, there are public beacons databases, like Wikibeacon [1], containing information on their location and the transmitted data. These databases could be used to interpret the data of unknown beacons.

In order to explain the details of the Beacon Management System deeply, the next section states its main features. This system abstracts developers and clients from specific beacon protocols and, by means of public databases, can manage unknown devices.

3 Beacon Management System

As stated above, the use of beacons would enrich the contextual information that can be gathered from IoT users by including accurate indoor positioning information to their virtual profiles. However, the lack of a standard beacon protocol, the low abstraction level of the beacon packets and the ad-hoc way in which beacons are included in most applications hinder their adoption.

To improve this situation, in this work we present a Beacon Management System that abstracts application developers from the low level details of working with these beacons and that can be used to enrich the contextual information of the users of IoT systems. Figure 1 shows the architecture of the proposed system.

All beacons protocols are based on the Bluetooth Low Energy (BLE) technology [16]. This technology provides a low-power solution for controlling and monitoring applications. In the case of beacons, it can be summarized as advertising devices that broadcast connectionless data and scanning devices listening from advertisers [22]. Once a scanning device found an advertising device a connection can be established. Advertising devices regularly transmit packets of data.

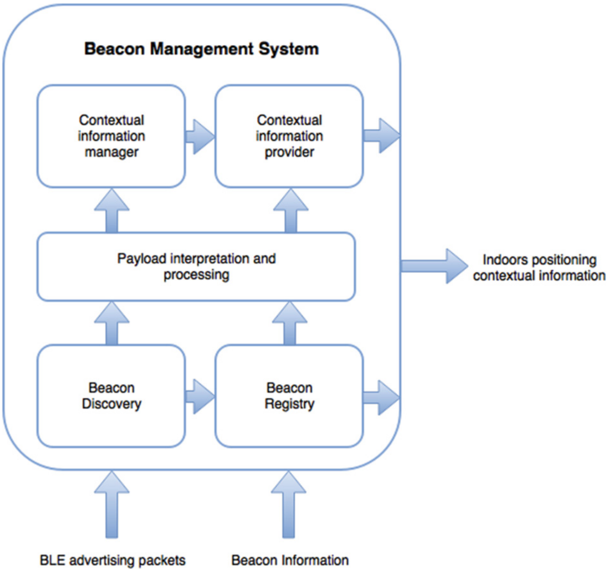

Fig. 1. Architecture of the Beacon management system.

The Beacon Management System acts as a scanning device as defined in the BLE protocol. Most current beacons applications are configured to scan only in search of specific set of beacons that are associated with the application. The Beacon Discovery module (integrated in the management system), however, listens to any advertising packet sent from any BLE device.

Once an advertising packet is received, the information of the beacon which sent it, regardless if it is an iBeacon or an Eddystone device, is sent to the Beacon Registry module of the architecture. This module contains the information of any beacon that has been found by the system. Additionally, the Beacon Registry contains information about how the beacon payload should be processed. This information defines the specific geographical position of each beacon, so accurate indoor positioning can be calculated, and if the emitting device is an iBeacon device or an Eddystone one. This information can be provided to the system as Beacon Information. By using this module and providing the specific information about the corresponding beacons, the Beacon Management System can replicate the behaviour of the supermarket application example. Moreover, when a beacon with no specific information is detected, its basic data is stored in the Beacon Registry and a default behaviour is applied to this information.

The payload of the advertising packet and the specific information about the emitting beacon contained in the Beacon Registry is then transferred to the Payload Interpretation and Processing module of the system. This module extracts the raw fields from the different types of beacons, as detailed in Sect. 2, and process them. Then, the processed information is provided to the rest of the system. This module makes the rest of the system independent of the different types of beacons, namely iBeacon and Eddystone, and allows application developers to work at a higher abstraction level.

Then the processed information received from the beacons is treated by the Contextual Information Manager, responsible for storing the indoor positioning of the system in an organized way.

Finally, the Contextual Information Provider module of the system is responsible for communicating the indoor positioning information to the user or other interested systems. This module allows the integration of the Beacon Management System with other systems gathering contextual information of the user, so richer virtual profiles can be collected.

By using the Beacon Management System in our supermarket example, an application could be used to detect other supermarkets where the user has been and then use this richer information to help the user achieve his goals. For example, the Beacon Management System can have information of a user going to the same section of three different supermarkets. The information of the beacons of these supermarkets could be added to the registry by the application owner or be automatically gathered from an external beacons database. Once the user enters a fourth supermarket, the system could use the richer contextual information to directly guide the user to the appropriate section.

3.1 Case Studies

To assess the viability and performance of the Beacon Management System it was deployed in two cases studies. Next, these are detailed.

European Researchers' Night. The first case study was designed to be part of the 2015 European Researcher's Night. The European Researchers' Night is an annual event promoted by the European Commission dedicated to popular science and fun learning [11].

For this event, an activity revolving around a mobile application was designed using the Beacon Management System. The purpose of the activity was to familiarize participants with beacon technology and indoor location. To achieve that several beacons were placed in different parts of the university buildings and participants had to locate them in a specific order.

The model of beacons used in this activity were ibks 105 beacons following the iBeacon protocol. These beacons are based on the chipset Nordic Semiconductors nrf51822 and use a CR2477 coin cell battery. More information about these specific beacons can be found on [4]

The Beacon Management System was used to develop an Android application. Participants of the activity installed this application on their mobile devices and used it to locate the beacons placed in different buildings of the university. To do that, the application received the packets emitted by the beacons and showed the users the distance in meters to the next beacon they had to find. By the variations in distance to the beacon as they moved around, the participants were able to find the beacons. Once a user was close enough to a beacon, less than 2 meters, the app marked it as found and started guiding the users to the next beacon in the activity.

By developing this case study we evaluated the viability of the Beacon Management System to perform as a traditional beacon application. In this case all the beacons in the activity were known beforehand and their information was provided to the system by the developers. Nowadays, most beacon applications work in this way and the system presented in this work was able to replicate their behaviour.

Beacons Monitoring App. The second case study focus on a more general usage of the Beacon Management System. In this case, the case study consists of an Android application to monitor any beacon.

Unlike the previous case study, and most modern beacon applications, this application process advertising packets emitted by any BLE device. The purpose of the application is very simple, to process and show the user the information provided by any nearby beacon.

Figure 2 shows a screenshot of the beacons monitoring app. In the figure, the information of three different BLE advertising devices, near which the user has passed, is shown. This information can be used by the user to know the devices that are deployed on a specific place. This application can be downloaded, and more information about it can be found, on [12].

By developing this case study and using the information obtained by its use for external users, we evaluated the viability of the Bluetooth Beacon management system in a more general situation than in the first case study. In this case, information provided by unknown beacons, both following the iBeacon and Eddystone protocols, were processed. The application has been downloaded by more than 100 users which has allowed us to test the Beacon Management System in a wide variety of situations.

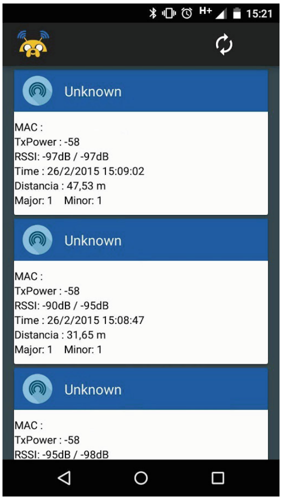

Fig. 2. Screenshot of the Beacons monitoring app.

4 Indoor Positioning as Part of a Complex Virtual Profile

Both case studies presented in the previous section allowed us to asses the viability and performance of the Beacon Management System by itself. However, the system is designed to be used as a part of a greater system in which the indoor positioning information could be used to enrich other contextual information about the users.

To verify its benefits it has been integrated with nimBees [13,25], a commercial push notification system based on the PeaaS paradigm [18]. nimBees, is an API that can be incorporated to any mobile application to provide the capabilities of creating virtual profiles of their users. These profiles are then used to send them segmented push notifications. Currently, nimBees is being used in more than 100 apps, and more than 560.000 notifications have been sent from it.

The nimBees architecture is divided into two main components, the nimBees Server and the nimBees Mobile Application. Figure 3 shows the nimBees architecture and how the Beacon Management System has been integrated with it.

The integration of the proposed system with nimBees has taken place in the nimBees Mobile Application. Once its API is integrated in an application it manages the reception of segmented push notifications. Again, by following the PeaaS paradigm the contextual information used to perform this segmentation is kept on the users devices.

With the integration of the Beacon Management System new information is added to the virtual profile of nimBees users. In particular BLE advertising packets are received by the devices and delegated to the Beacon Management System. This system provides two types of information to nimBees virtual profiles. First, the raw information received from the beacons. This information

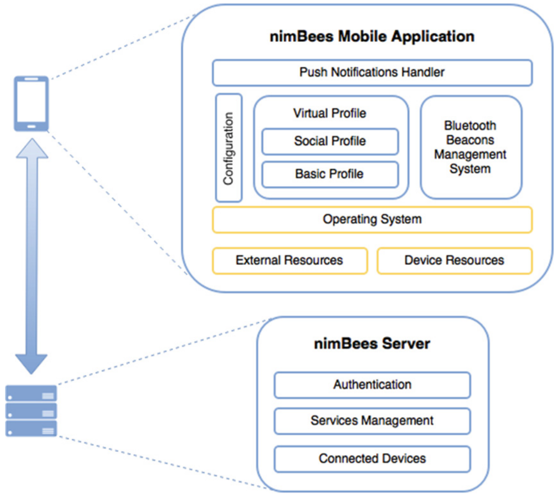

Fig. 3. Integration of the Bluetooth Beacons management system with nimBees.

is then stored in the Basic profile of the users which is later used to perform basic segmentation and to infer more complex social information. Secondly, the processed information of the beacons is provided. This information is integrated into the Social profile of the user in a timeline that contains all the complex information that has been obtained from the raw data gathered by the device.

How the data is gathered and stored in the virtual profile and how is treated can be defined at development time as usual, but it can also be modified on run-time through the nimBees server or by specific configuration push notifications which allows a more flexible management of beacons.

Finally, when a push notification is received the Push Notification Handler decides, based on the users' virtual profile, if the notification is directed to the device owner or if it should be ignored. With the inclusion of the Beacon management system new segmentation capabilities have been added to the notification handler, in particular those related to the indoor positioning of the users. For example, coming back to the supermarket scenario, an application would be able to know the indoor positioning of the user being able to recommend the user different products in relation with his profile, like a gift for his mother if his profile indicates he is going to visit her later, and directly guide him to them through the supermarket.

Since its integration, the beacons capabilities of nimBees have attracted the attention of several important customers including a Spanish supermarket chain who is piloting the use of BLE beacons in some of its more relevant supermarkets.

5 Related Works

Gathering information about the users positioning in different situations has been a topic of interest for researchers for a long time [19]. The need for precise location information has even led to the creation of an international competition to evaluate, on equal terms, different location-based solutions [8].

Beacons technology has been specifically designed to improve the indoor positioning information. In this area works like [30] proposes the use of beacons to improve previously existing location-based methods. The authors propose to transform the mobile devices of consenting users into beacons so other users could benefit from the improved location information.

In [2], the authors propose the use of contextual information, indoor positioning data, to create a system that encourages social interactions among strangers. This proposal, as the one presented here, makes use of the indoor location to improve the quality of contextual information gathered. However, unlike the work presented here, the system is designed for a particular use and it is not prepared to be used in other contextual information based systems.

Finally, in [10] the authors propose the use of beacons to improve the recognition of daily activities performed by users of ambient-assisted living systems. In this work a combination of the user's smartphone plus other wearable devices and the information emitted from a set of beacons, allow the researchers to identify more daily activities than previous works in the area. The inclusion of the indoor positioning provided by the beacons helped to improve the performance of the proposal, as in many of the previous ones. However, again the beacon inclusion was developed ad-hoc and is not transferable to other systems.

Summarizing, the use of contextual information is relevant in many systems and research areas. Also, these systems benefit from having richer contextual information. At the same time, the use of beacons allows contextual information based systems to improve the indoor positioning of users using pervasive devices such as mobile phones. However, as far as the authors know, there are no works proposing a generic solution to include the indoor positioning information provided by beacons to other contextual information based systems.

6 Conclusions

Current IoT applications can be implemented to have a specific behaviour depending on the preferences and the context of the user. This adaptation is limited to the contextual information that can be gathered from the users. The rise of the beacon technology has simplified the inclusion of indoor positioning data to the contextual information of users.

In this paper, we present a Beacon Management System which purpose is to be included in IoT systems, gathering contextual information from their users. The proposed system allows the use of beacons under different protocols, namely iBeacon and Eddystone, and allows applications developers to work at a higher abstraction level without having to deal with the technical details of the BLE protocol. The presented system has been integrated into two case studies whose success lead to its integration in a commercial push notification platform.

The next steps on this system focus on the inclusion of alternative beacons protocols to increment the number of devices supported and on provisioning higher level contextual information based on the indoor positioning provided by the beacons.

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