

Repositório ISCTE-IUL

Deposited in *Repositório ISCTE-IUL*:

2022-10-07

Deposited version:

Submitted Version

Peer-review status of attached file:

Unreviewed

Citation for published item:

Garrido, N., Serrão, C. & Coitos, B. (2021). An interactive visiting system using BLE devices. In Fausto Pedro García Márquez, Benjamin Lev (Ed.), *Internet of things: cases and studies*. (pp. 135-153).: Springer.

Further information on publisher's website:

[10.1007/978-3-030-70478-0_8](https://doi.org/10.1007/978-3-030-70478-0_8)

Publisher's copyright statement:

This is the peer reviewed version of the following article: Garrido, N., Serrão, C. & Coitos, B. (2021). An interactive visiting system using BLE devices. In Fausto Pedro García Márquez, Benjamin Lev (Ed.), *Internet of things: cases and studies*. (pp. 135-153).: Springer., which has been published in final form at https://dx.doi.org/10.1007/978-3-030-70478-0_8. This article may be used for non-commercial purposes in accordance with the Publisher's Terms and Conditions for self-archiving.

Use policy

Creative Commons CC BY 4.0

The full-text may be used and/or reproduced, and given to third parties in any format or medium, without prior permission or charge, for personal research or study, educational, or not-for-profit purposes provided that:

- a full bibliographic reference is made to the original source
- a link is made to the metadata record in the Repository
- the full-text is not changed in any way

The full-text must not be sold in any format or medium without the formal permission of the copyright holders.

An interactive visiting system using BLE devices

Nuno Garrido¹, Carlos Serrão² and Bruno Coitos³

¹ Instituto de Telecomunicações (IT-IUL)

² Information Sciences, Technologies and Architecture Research Center (ISTAR-IUL)

³ Instituto Universitário de Lisboa (ISCTE-IUL)

{nuno.garrido, carlos.serrao, bmfcc}@iscte-iul.pt

Abstract This chapter presents a use-case based on the development of an interactive, integrated and adaptable visiting system for complex buildings and surrounding grounds (smart places). The system features a mobile application that allows the user to access information from several smart places in a single application, and an Indoor Location and Tracking System that infers the user location during the smart place visit. The system calculates the tracking and location of the user based on the positioning of neighbouring BLE devices sensed via Bluetooth on the user's mobile device. The approximate location, behaviour and interests, and hence the visiting profile of each user, can be inferred by the signals from multiple beacons installed on the building at specific pre-defined positions. The system also integrates a backend content management system to allow the creation and management of smart places information and supports information import from BIM tools.

Keywords: Indoor Location System, Smart Places, BLE, Beacon, BIM.

Introduction

To satisfy the needs of an increasing number of people living or working in most cities there is a growing urge for sizeable and more complex buildings, such as hospitals, shopping malls, museums, sports facilities, amongst others [1]. This need creates a challenge for the managers of these buildings or sites since it is necessary to provide relevant information to the users/visitors. Frequently this is done by putting guiding plates, which are a minimal way to realise this task. When considering larger and complex buildings such as hospitals or museums, it is common for users to get lost or have trouble finding their way around and requiring additional information in multiple formats and languages.

Mobile devices have become ubiquitous to everyone transforming themselves into interaction gateways between the digital and the real world [2]. Therefore, mobile devices can be the right approach for this quest and an excellent way to display information about multiple buildings or sites. Furthermore, this can be achieved in a single application, removing the need for multiple applications with different

layouts and behaviours to be installed on the end-user's mobile device reducing discomfort and usability problems to the user.

Recently, there has been an increase on the number of available low-cost devices (both sensors and actuators) that have the capability to communicate through several networks and with each other. These devices, commonly known as IoT, are taking advantages of multiple protocols such as WiFi, LoRA, Bluetooth and others to increase their communication and integration. Therefore, IoT has found multiple application domains, that range from industrial automation, smart home development, health management, smart city control and management and many more. The potential for the application of IoT keeps growing.

Taking this into consideration, it was decided to propose and develop an integrated system consisting of two different components: (a) a smart and interactive mobile guiding application (named MOG – My Own Guide), that uses an Indoor Location System (ILS) based on information provided by Bluetooth Low Energy (BLE) beacons and (b) a Content Management System (CMS) module, which gives the building managers a tool to manage the information displayed to the users efficiently. Users using a specific mobile application on their devices help gather valuable information about its interaction with the building or site.

Considering that the referred buildings or spaces, can each have several zones and points of interest, loading all this data into the prototype using only a CMS is not feasible since it is hugely time-consuming. Therefore, it was an opportunity to coordinate our prototype with a tool that could have this information or parts of it, already configured. Currently, most modern buildings go through a Building Information Modelling (BIM) process, where a 3D model of the building or site is created with valuable information about the building, spaces of the building, such as rooms, and other information. Therefore, it was decided to provide an efficient and fast way for the Smart Place staff to upload files extracted from the BIM tools. This mechanism can speed up the data creation process since by using the BIM model, the building model can include and define the information needed by our prototype, such as the interest zones, groups of interest points and interest points, as well as the location of the beacons in the building, and then upload the files to the CMS which in turn can map this information to the objects defined in the data model.

Related Work

In the course of our research, the focus was on approaches that aimed at the guidance of users inside complex buildings, especially shopping malls and museums and preferably those featuring BIM. One approach where BIM models are used is [3], here a BIM tool is used to define emergency paths of buildings that can be extracted and then imported into a firefighter's guidance system. This system includes a mobile application in coordination with an ILS that combines the use of RFID, UWB and WLAN technologies, which allows support to guiding them during emergencies, whenever the intervention of firefighters is required, through the

emergency paths defined in the BIM tool. The system also contains a back-office tool, where firefighters outside the building can also see their location in real-time inside the building.

In [4], the authors developed a guiding system for museum visitors. In this system, the visitors install a mobile application and answer a couple of questions for profiling purposes that generate a QR code. When the visitor arrives at the museum, museum workers scan the QR code generated by the application and assign visitors a wearable device that must remain with the visitor throughout the visit. This wearable device captures what the visitor is seeing and combines this information with the location of the visitor, that is inferred through the sensing of BLE devices signals, allowing the system to identify the piece of art being observed, so that the mobile application can provide additional relevant information for that art piece. This approach is expensive since the museums must guarantee the maintenance and availability of the wearable devices for each visitor, which is hardly practical and affordable.

Another approach focused on enhancing museum visits is [5], where the authors propose the combined use of BLE devices and Wi-Fi areas. In this solution, the museum workers have a web-based tool to manage the information about each piece of art. When the visitor is at the museum, his position is inferred using BLE's signals and then processed taking advantage of Wi-Fi areas data. The disadvantage of this system is that it only supports the Italian language.

As mentioned in the previous section, it is more comfortable and preferable for the users to have information about several buildings or sites in a single mobile application. In this work [6], the authors have not developed the proposed system, but the concept is to combine information from a group of museums that belongs to the same district, namely Jongno district in South Korea since the authors believe this approach could contribute to the attraction of more visitors to the museums.

Another approach found is [7] where the authors developed a system used to track and guide users on a university campus. BIM was used to define the position of each BLE device and set other additional information about the building (e.g. closest stairs). This information is loaded into the system and read by an algorithm used in the mobile application to calculate the shortest path between two points. Initially, the user selects the desired destination. The mobile application calculates the nearest path inside the building and updates it as long as the user is moving, this is done taking into consideration the BLE signals intercepted to infer his current location in the building.

Several other studies [8]–[10] were addressed in the context of smart places for large buildings and sites, e.g. offices, zoos and museums, where similar solutions were studied some including the use of BLE devices or a content management system.

From related works [3]–[6] it was considered the advantages and disadvantages of each approach during the design and evaluation of the proposed prototype. The main focuses of our design were BLE sensing and a simple and intelligent information management system for building managers.

Prototype Architecture

Considering the different requirements identified for indoor intelligent guidance systems and the review on the state-of-the-art systems it was possible to detect the need for a more open and generic system that could be easily adapted to multiple different indoor guidance scenarios, at a lower cost. The proposed solution offers an end-to-end framework, for smart building managers, to create and distribute specific content to visitors, tailor visiting experiences, customise the “in-building” navigation and parametrise the end-user’s smartphone application.

The prototype architecture depicted in Fig. 1 was designed and developed to give smart building managers a fast and effective way to provide information to the building users without the need to install a specific application for each building, bring a more practical and comfortable solution that allows access to information about several buildings in a single mobile application. The system is composed of several distributed components that are described individually: two databases that interact with a content management system, a mobile application and a set of BLE physical devices.

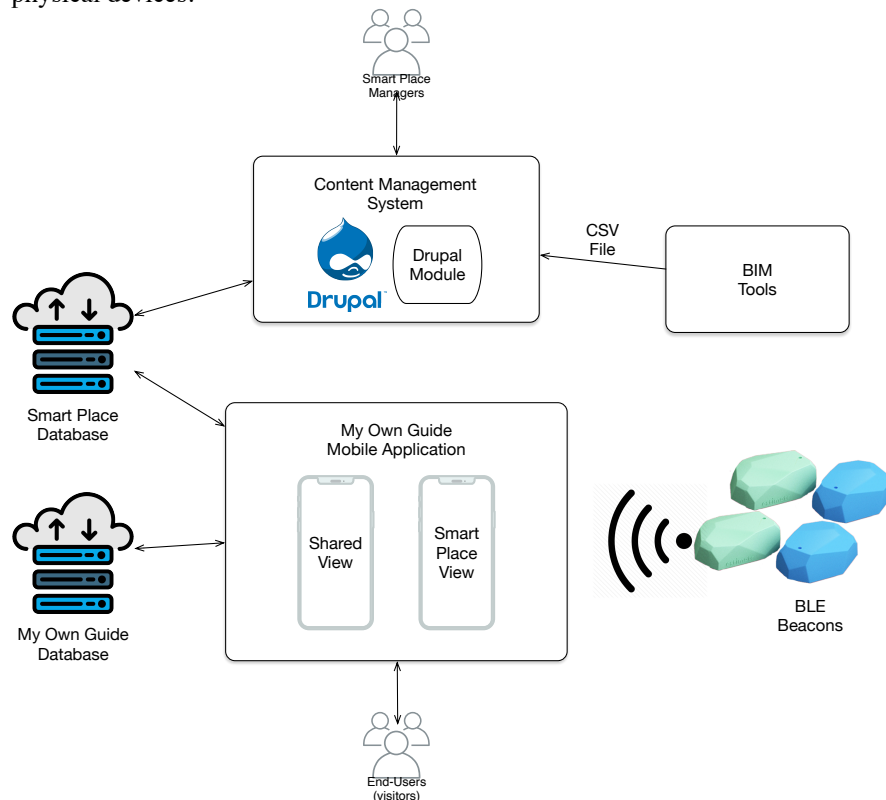


Fig. 1. Prototype Architecture

The implementation of the described prototype required the usage of a server to host the Content Management System. This server was deployed on a Linux machine (Intel Core i3 processor, 16 GB RAM, 1TB HDD), running the latest version of Ubuntu Server 18.04, with an installation of the Apache HTTP Server 2.4, the MariaDB 10.4.x database management server and the PHP 7.x development stack. All of these components are open-source software.

The mobile application was developed as an Android native Java-based application, running on all Android devices that supports at least API level 23 (Android 6.0 Marshmallow). For the development of the application it was used the Android Studio IDE. The backend of the prototype was implemented on Firebase using free accounts.

The following sections of the chapter present the different components of the developed system prototype. We start by describing the databases that are used by the system followed by an overview of the BIM component that might be used to import building indoor location information to the system. After this, the content management system used to manage the smart place content is presented. Finally, the end-users mobile application is presented.

Databases

To support all the information on the system prototype, it was defined one central database that is the MOG Database (MD) and also a database for each Smart Place that was named Smart Place Database (SPD). This design choice was made to provide smart place managers with total control over their database and of the contents that will be presented to the visiting users. The MD contains general information about a new smart place existence on the global system (pointing the system to the specific SPD whenever a smart place is selected), while the SPD contains information about one specific smart place. The smart place managers entirely manage the SPD while the MOG system administrators manage the MD.

Having into consideration the agility of the prototype development, Firebase [11] was the platform selected to hold the online databases. Firebase allows fast development since it provides all the needed services and a simple way to connect to different databases. Moreover, Firebase allows easy system scalability and adaptability, through the usage of non-relational databases where JSON-formatted documents and collections are used to represent and manage the data. Although the selection made for the prototype development, the system can quickly adapt to support other types of databases or external data-related special-purpose APIs.

MD is used to store general-purpose, high-level information about the featured smart places but most importantly, to store information about each smart place database in order to establish an interactive connection to them as depicted in Fig. 2.

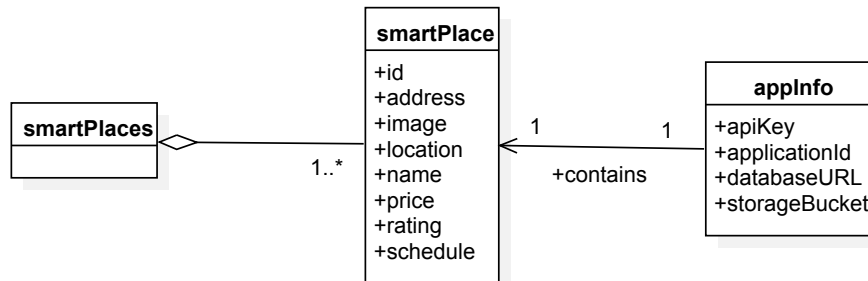
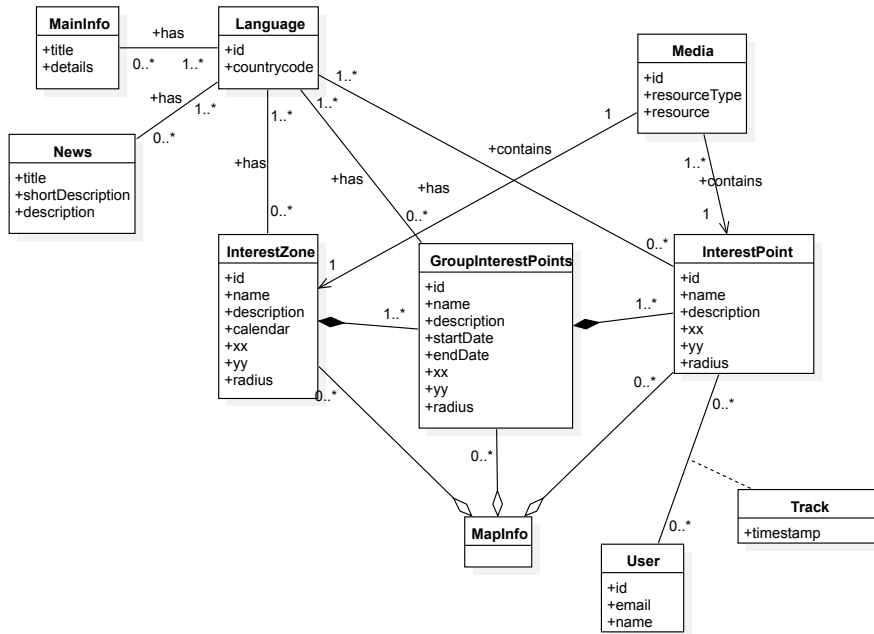


Fig. 2. MOG database model (MD)

For SPD it was implemented an internationalisation mechanism in the database. In order to achieve that it was created a specific “Language” object that allows each smart place manager to define the different content languages that are available to the mobile application end-users. For each of the supported languages, the smart place managers will need to provide the appropriate content in the different identified languages. The process is specific of the smart place managers because some smart places may have content in multiple languages while others have just a unique language.

Although each SPD is managed separately and independently, it must be compliant with the global data model, and the data model must be flexible to be easily adapted to the different needs of each Smart Place. This global data model is composed of the following three different object types to identify different spaces: “Interest Zones”, “Groups of Interest Points”, and “Interest Points” as depicted in Fig. 3.



Error! Reference source not found.Fig. 3

Fig. 3. Smart Place data model (SPD)

Hence, three possible ways for smart places to represent their spaces were created in order to have a more flexible prototype. These spaces can be represented through Interest Zones, Groups of Interest Points and Interest Points. Those represent the most relevant information for the smartphone application users and can be displayed in a set of languages defined by each Smart Place. These spaces are made available in the Map screen of the application. Each of these spaces must contain information about its location inside the building. Smart place managers must fill the mapping information (“MapInfo”) for that specific space, detailing the pixel coordinates and radius which will be used to draw the point of interest on the map as depicted in Fig. 3**Error! Reference source not found.** This information about the indoor location of each space can be either manually specified or imported into our prototype database using the information extracted from the BIM tools.

The “MainInfo” object contains the information that is displayed on the main screen of the application, and the “News” object is presented as a list with a title and short description with the possibility to view the entire news content as shown in Fig. 3.

The SPD model also includes a “Track” object. The purpose of this object is to record the different “InterestPoints”, “GroupInterestPoints” or “InterestZones” visited by the “User”. This object records the timestamp (date and time) of the visit of the user. The goal is to allow smart place managers to be able to learn and understand how visitors interact with the different interest points during their visit.

The Mobile Application section presents more details about the mobile application user interface that corresponds to each of the objects that are displayed to the end-user.

Building Information Modelling (BIM)

Building Information Modelling (BIM) is a collaborative process that consists of creating a 3D model of a building providing better building project management since it allows to have a “*document management, coordination and simulation during the entire lifecycle of a project*” [12]. In this process, it is possible to complement the model with additional information about the building, spaces of the building, such as rooms, and any other information.

The system provided to the building managers the possibility to load information extracted from a BIM tool directly into our prototype, since this modelling process is growing, and most modern buildings construction is based on it. This functionality results in a reduction of the time spent creating information about each interest zone, group of interest points and points of interest, since it is also necessary to define, for each of them, the position in the map for the prototype making it possible to the mobile users to see their location. In order to achieve these objectives, it is necessary to define the following information:

- `spaceId` – Identifier of the space.
- `name` – Name of the space, that will appear in the mobile application
- `centerCoordinates` – The coordinates allowing to draw in the map the visited spaces. This information must have the structure – (xx, yy, radius).
- `datamodelObject` – Identifies which object of the data model is. The allowed values are “*interestZone*”, “*interestGroup*” and “*interestPoint*”.
- `childObjects` – List of child objects taking into consideration the hierarchy defined in the data model.

In Fig. 4, an example of information that can be extracted from a BIM tool in a CSV file, is presented.

```
spaceId,name,centerCoordinates,datamodelObject,childObjects
dolphins,Dolphin Presentation,(231;307;127),interestZone,
mammals,Mammals,,interestGroup,[africanElephant,commonSeal]
africanElephant,African Elephant,(111;327;50),interestPoint,
commonSeal,Common Seal,(367;440;20),interestPoint,
```

Fig. 4. Extracted information from BIM tool

Hence, using this model it is possible to define each prototype object information, its building location and also extract the building images, that can, in turn, be used in the mobile application on the Map screen.

Content Management System (CMS)

The primary purpose of the developed solution was to offer a simple and open framework for smart place managers to create and manage digital content in multiple formats and languages to offer to smart place visitors with geo-referenced context. Therefore, in order to offer an end-to-end solution to accomplish this goal, the framework involved the development of a content management system (CMS) component. The CMS that was developed for this prototype has the objective of providing smart place managers with a way to easily access and manipulate the data that is stored in their database.

The CMS also guarantees that all the data stored in the database has the correct format and structure to feed the mobile application. In order to ensure the prototype openness and affordability, the latest version of the Drupal (version 8) open-source CMS was selected, due to its customizability and adaptability to multiple scenarios as well as a large number of functionalities and broad community support. Selecting Drupal as our CMS, a specific Drupal module was developed that can be installed in any existing compatible Drupal web application. This module will create a new menu entry on the web application that will allow the staff to import the data from BIM solutions, configure the available languages, manage general information of the Smart Place, create and manage zones of interest, groups of interest points and each of the interest points and also manage the relevant news to be sent to the user.

For these kinds of smart places, one of the most important information is how the users are interacting, and it is here, in the CMS, that is possible to visualise some statistical information about this interaction, such as the number of users that entered a zone of interest, the most visited zones and points of interest, the total number of users that entered the Smart Place, and much other detailed information.

Therefore, using the CMS, the entity responsible for the management of the content, in the new tab of the site, has access to a webpage where several options are displayed. One of them is “Manage Application Contents” that allows the manager to select the object and language of the desired information. Moreover, in turn, a displayed list of objects taking into account the options selected - Fig. 5 shows a list of Interest Points with English as the default selected language.

Manage Application Contents

Showing list of "Interest Points" object.

ID	Name	Operation
elefante_africano	Elefante-Africano	• View
foca_comum	Common Seal	• View

[Back](#)

Fig. 5. List of Interest Points

This provides a quick and easy way to access each object of the list. Simply clicking on the "View" operation on the list will open a new webpage with more details about the specific point of interest where "Edit" and "Delete" options are also available (as depicted on Fig. 6), and therefore the CMS contents can be easily accessed, edited and updated.

Info

ID
elefante_africano

Name
Elefante-Africano

Audio File
elefante_africano.ogg

Image File Name
elefante_africano.png

Description
The African elephant (*Loxodonta*) is a genus of the elephantidae family. The genus is composed of two existing species of elephant: the savannah elephant (*Loxodonta africana*) and the forest elephant (*Loxodonta cyclotis*). The male of one of the species of *Loxodonta*, the savannah elephant, reaches an average of 3.2 meters in height and weighs 6 tons, which makes it the largest terrestrial animal. The largest specimen ever recorded was about 12.3 tonnes. Compared to the elephant elephant of the *Elephas* genus, it is distinguished by the larger ears (an adaptation to the higher temperatures)

[Back](#) [Edit](#) [Delete](#)

Fig. 6. Interest Point Info

The CMS part of the prototype allows a reasonably natural manner for the smart place managers to continuously upgrade and update the data on the system that will be presented to the smart place visitors. The solution will help reduce the burden and cost of smart place data maintenance.

Mobile Application

The smart places visitors access the contextual information provided about the place using a mobile smartphone application. The mobile application scans for existing

nearby BLE devices signals in order to guarantee that the users will always have access to relevant information based on their location within the Smart Place. In order for this system to work, each user must grant the appropriate permissions and enable access to the device via Bluetooth connection and to Location information on their mobile device. This will enable the application to be able to read the BLE signals, issue notifications, and access the Smart Place information, obtained remotely from the CMS. In order to facilitate access to a more significant number of users, it was developed the MOG mobile application for the Android system.

The system is designed so that it allows the visitor to access information about a set of smart places in a single mobile application. The mobile application is split into two different views: Shared View, that displays information managed in the MOG database, and the Smart Place View, that is managed by the staff of each of the existing smart places. The users can access the Shared View without the need of being in the smart place, allowing the users to list the available smart places on the application and to preview the content of a specific smart place before its visit.

The mobile application welcome screen (Fig. 7.) displays the Shared View and is connected to the MOG database (MD). It has the general information about each Smart Place that is available in the system, and the option to see a full list of the available smart places or the user's past visits. The mobile application offers the possibility for the user to select one available smart place from the list or automatically, based on the user location (if available), present contextual information about the smart place where the user is located.

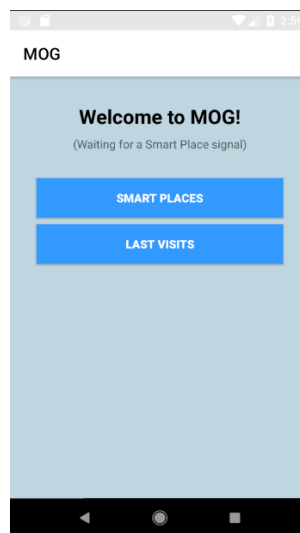


Fig. 7. Welcome Screen

If the user selects the “Smart Places” option, the mobile application shows a list of available smart places in the system with their schedule and street address that

can be used to plan his route (from its current geolocation). Fig. 8 shows a list of two example smart places used to demonstrate this prototype: one is the national natural history museum (MUNHAC), and the other is the city zoo (Jardim Zoológico de Lisboa).

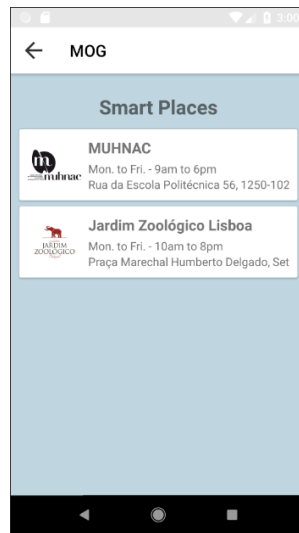


Fig. 8. Smart Places List

When a specific smart place is selected, the application displays more information about the site, namely the price (if any), schedule, address, public rating in the system and the personal rating that the user gave to this place, as depicted on Fig. 9. This screen includes the option to “See Location” that directs the visitor to the street address using Google Maps. Another option is to select the “App” button that directs the application to the Smart Place View (the specific app for the selected smart place).

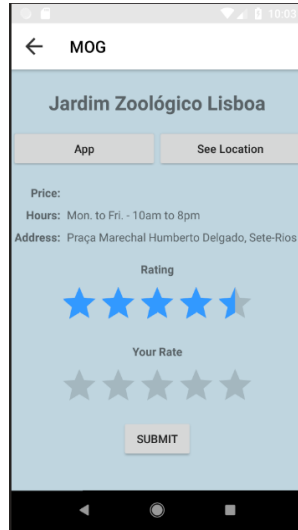


Fig. 9. Smart Place Info

The Smart Place View allows the user to access the smart place database of the chosen smart place. In this view, the user has access to all the information provided by the smart place managers through the CMS.

When a user enters for the first time in this view for a specific smart place, he will be redirected to a screen where he can choose from one of the available languages in that smart place (by default, the application will use the base language of the mobile user device). After the user defines the language, the application displays the primary information of that smart place, that can be the history, some facts or any other information as shown in Fig. 10. .

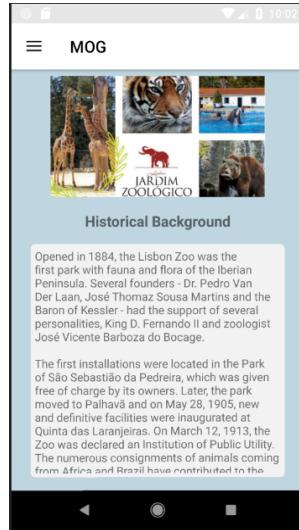


Fig. 10. Smart Place main info

In this view, the user can also check the smart place map and the news about the smart place as depicted in Fig. 11. . The news is listed containing the title and a short description, but if the user wishes to get more details, he can select specific news on the list and all the detailed information will be displayed.

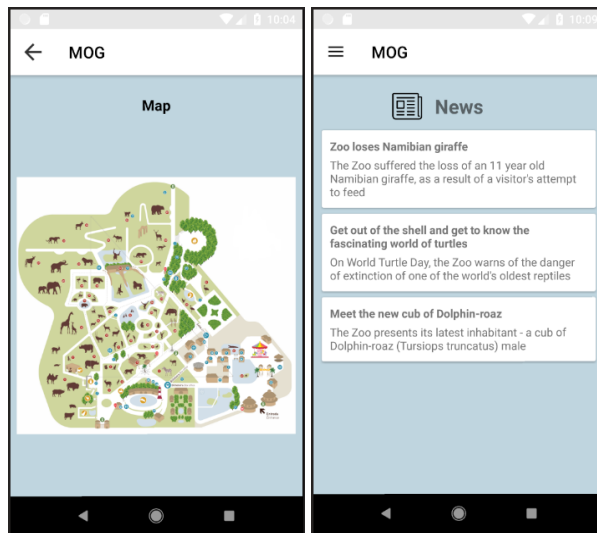


Fig. 11. Smart Place map and news

The remaining information, such as the interest points, group of interest points and interest zones will only be available when the user intercepts a BLE signal. When this occurs, the user receives a notification, after clicking on it, it will open the mobile application in a screen showing the desired information as shown in Fig. 12. .

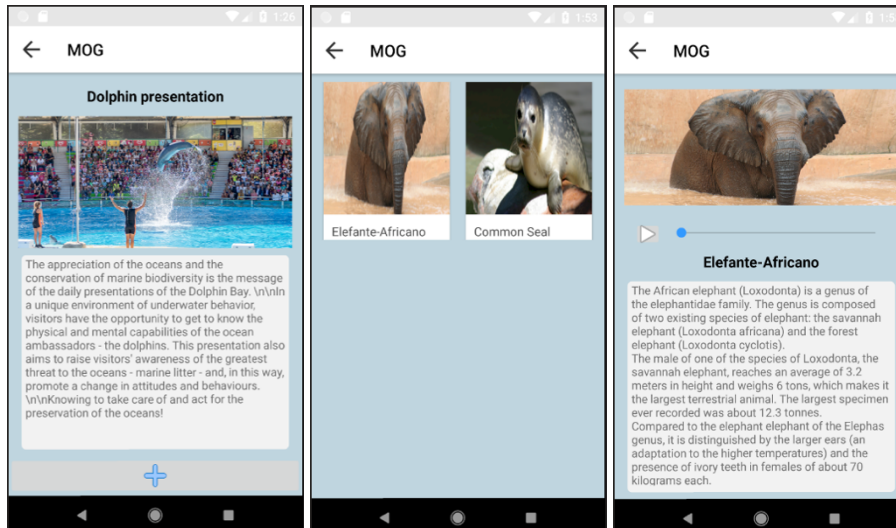


Fig. 12. Interest Zone, Group of Interest Points and Interest Point screens

While using the MOG application to interact with the different Interest Points, information about this interaction is recorded by the system. This action enables the collection of data from the user about the different visited InterestPoints and InterestZones as well as some additional information, such as the date and time of the visit, the visit duration, and, in some cases also the user opinion about the visited object or areas as well. The collected data is presented in an integrated and anonymised way to the smart place managers as well as some analytical information, such as smart place heatmaps (indicating the most visited areas) and the most common routes the users follow inside the smart place.

This tracking information is useful for smart place managers to have a better understanding of the user's interaction with the smart place, identify potential problems and opportunities to improve their smart places management.

BLE Devices

Bluetooth Low Energy (BLE) devices [13] on the system will allow the users to receive push notifications and be redirected in the mobile application to the screen

with relevant information considering his indoor location. This mechanism allows the creation of a more interactive and immersive environment that will enhance the visiting experience for the user.

The BLE devices used in this prototype are Proximity Beacons from Estimote [14]. These beacons take advantage of their own Proximity SDK [15] for the development of the mobile application. The Proximity Beacon supports Bluetooth 5.0, has a 5-year battery maximum time duration, a range of 100 meters and supports multiple programming languages such as Java or Swift. There are other multiple options for BLE beacons, but for this specific prototype, this specific beacon supplier was selected. The Proximity SDK allows the definition of multiple beacon attachments, which are represented in a “key-value” pairs format, allowing us to get the values in the mobile application when an event is triggered. Besides that, the SDK provides an “onEnter” event that is triggered when the mobile device enters in range of a beacon signal, that we opted on using in order to provide relevant information based on the space that the end-user is entering.

As it was previously mentioned, in order to have a flexible system three possible spaces were created: the Interest Zones, Group of Interest Points and Interest Points. Therefore, each BLE device must have an attachment to identify how it is used by our prototype, thus avoiding reading information from other beacon networks that may already exist in the same space. Fig. 13 depicts a set of multiple beacons in a Smart Place with several triggering actions.

Key	Value	
beacon_to	MyOwnGuide	Remove
smartPlace_id	lisbon_zoo	Remove
interestZone_id		Remove
groupInterestPoints_id		Remove
interestPoint_id	elefante_africano	Remove


 Add Attachment

Fig. 13. Beacon attachments

The beacon signals are captured by the mobile application that accesses the MOG database and, based on the smart place identifier, gets the information needed to connect to the corresponding Smart Place database (SPD). After that, the mobile application uses it to connect and get the information of the specific location that the BLE device represents in order to display the relevant information to the user.

In the context of other types of smart places like museums, such as the natural history museum, the beacons should be distributed amongst the facilities according

to the interest areas or interest points. In this case, the beacons can identify one specific part of an exhibition, a showroom, or one interesting item.

Fig. 14 shows an example of the indoor placement of beacons that allows the visitor to receive and click in notifications when entering rooms, or simply see a list of items that are close to him.

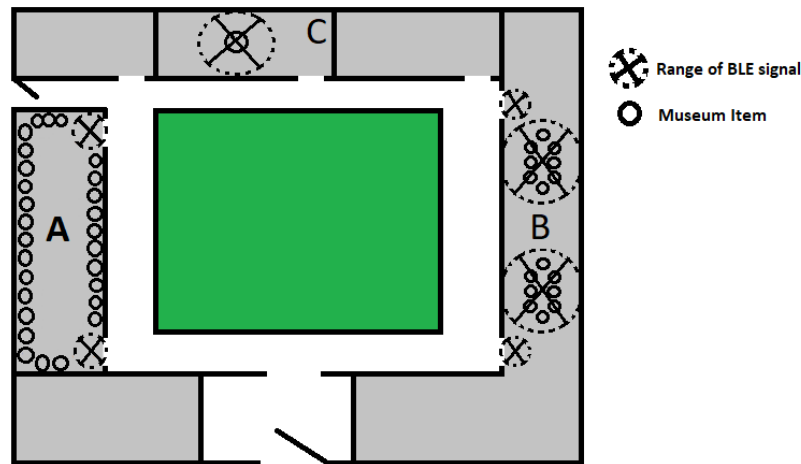


Fig. 14. Beacon placement example

System comparison and discussion

As mentioned, previously, it was possible to find some relevant approaches to respond to the needs of complex buildings, namely those related to guidance and contextualised information for their users/visitors.

In this section, it is provided a comparison between some of these available approaches and the prototype described and implemented. First, in the related work section, we mentioned solution [3] that uses BIM to define emergency paths of a building and then this information can be imported to a system and feed a mobile application that can be used by firefighters in rescue missions. This approach is not aimed at enhancing the guidance of building visitors or users, but the result is similar, this means, the resulting system has a mobile application that can guide users, based on BLE devices signal, taking in account information defined in a BIM.

The second and third works mentioned as [4] and [5], are both aimed at enhancing the visiting experience of museum visitors. In [4], the approach has some functionalities, like communication to social networks in order to share their experience, that our approach does not. However, this solution is complex and can be too

expensive for most museums, while our system was designed and developed aimed at being affordable and straightforward. The solution proposed in [5] is simpler, but the users can only see the information in Italian which is a disadvantage, especially if the sites or buildings have foreign, non-native language speaking, visitors.

One of the main differences of our prototype is the use of a single centralized mobile application for different smart places, that can be sites, buildings or any other space. It is our understanding that this approach brings further benefits to the final users since they can plan and make the most of their visits without the need to install multiple different applications (one per smart place visited). This concept of centralisation was already mentioned in [6], but in this case, the authors proposed the development of a centralised system limited to a geographical area, which was not developed, and hence makes a comparison between the technologies impossible.

Table 1. Comparison between the different proposed solutions

	MOG	[3]	[4]	[5]	[6]
Centralised App	✓	-	-	-	✓
Multi-Language	✓	-	-	-	?
Simple and Cheap	✓	✓	-	✓	?
Indoor Location System	✓	✓	✓	✓	?

In terms of costs, the proposed approach presents, at its core, serious cost reductions. First of all, it is mostly centred on open-source software, both in terms of the support infrastructure and also the developed components (the CMS is based on Drupal). The mobile application is developed in Android, and all of its configuration is made through the CMS. The backend database for the prototype is currently based on Firebase, which is not free. However, there are two options: either support the payment of the Firebase account (after the free account expires) or use the internal API, that is currently being developed as an alternative to Firebase. The BLE beacons that we are using in our prototype are the Estimote Proximity Beacons that costs 99 USD per 4 beacons. Although, these beacons are used in our prototype, other less expensive beacons may be selected as well (currently there are other options that cost as low as 6 USD per beacon).

Conclusions and future work

Throughout this chapter, it was presented the design and development of an intelligent visiting system prototype that combines components from BIM systems with a Content Management System and a mobile application. All of those components are complemented with BLE devices to provide smart and interactive information to mobile application users, based on their location and visiting context. The system

also provides valuable management information to the smart place managers allowing them to understand better and improve the users visiting experience.

This prototype is designed to offer complex buildings staff an appealing and interactive tool to provide information to their users/visitors while keeping it affordable and straightforward. Since different buildings have different needs, the prototype database has been designed to meet diverse requirements and to be easily adapted to each building or user profile.

The CMS based on a special purposed developed Drupal module that can be installed in any Drupal web application allows the building staff to manage the data displayed to the users with the option to upload data extracted from a BIM tool. This module also provides vital analytical information about the interaction of the users with the smart place.

The prototype architecture was designed aimed to allow mobile application users to access information, in a standard interface for several buildings without the need to install multiple applications. The tracking capabilities of the system allow smart place managers to comprehend the way the visitors navigate through their spaces and capture relevant analytical data about visitor routes and most visited areas. This analytical data is absolutely crucial for better management decisions and space location improvements.

In order to test the developed system prototype, it was considered two specific use cases (the city zoo and a museum) that have different characteristics. The first one is a broader space, with a mix of open and closed spaces, while the second one has a smaller dimension and is entirely composed of indoor spaces. The heterogeneity of the selected use-cases helped proof the openness and adaptability capabilities of the developed system.

The team is continuously working to improve the prototype and its functionalities. An area of improvement refers to the analysis of the user tracking information and the design of information dashboards that are presented to the smart place managers through the CMS. Another vital area of improvement is on the personalisation of the MOG smartphone app, that will need to allow better specific customisation (mostly in terms of design) according to the smart place specificities.

References

- [1] “68% of the world population projected to live in urban areas by 2050, says UN | UN DESA | United Nations Department of Economic and Social Affairs.” <https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html> (accessed Jun. 12, 2020).
- [2] “Mobile devices a necessity in today’s business world - TrackVia blog.” <https://trackvia.com/blog/infographics/mobile-devices-are-a-necessity-in-todays-business-world/> (accessed Jun. 12, 2020).

- [3] U. Rueppel and K. M. Stuebbe, "BIM-Based Indoor-Emergency-Navigation-System for Complex Buildings," *Tsinghua Science and Technology*, vol. 13, no. SUPPL. 1, pp. 362–367, Oct. 2008, doi: 10.1016/S1007-0214(08)70175-5.
- [4] S. Alletto *et al.*, "An Indoor Location-Aware System for an IoT-Based Smart Museum," *IEEE Internet of Things Journal*, vol. 3, no. 2, pp. 244–253, Apr. 2016, doi: 10.1109/JIOT.2015.2506258.
- [5] A. Chianese and F. Piccialli, "Designing a smart museum: When cultural heritage joins IoT," in *Proceedings - 2014 8th International Conference on Next Generation Mobile Applications, Services and Technologies, NGMAST 2014*, Dec. 2014, pp. 300–306, doi: 10.1109/NGMAST.2014.21.
- [6] E. S. Bae, D. U. Im, and S. Y. Lee, "Smart museum based on regional unified app," *International Journal of Software Engineering and Its Applications*, vol. 7, no. 4, pp. 157–166, 2013.
- [7] J. Ferreira, R. Resende, and S. Martinho, "Beacons and BIM Models for Indoor Guidance and Location," *Sensors*, vol. 18, no. 12, p. 4374, Dec. 2018, doi: 10.3390/s18124374.
- [8] M. Choi, W. K. Park, and I. Lee, "Smart office energy management system using bluetooth low energy based beacons and a mobile app," in *2015 IEEE International Conference on Consumer Electronics, ICCE 2015*, Mar. 2015, pp. 501–502, doi: 10.1109/ICCE.2015.7066499.
- [9] A. Corna, L. Fontana, A. A. Nacci, and D. Sciuto, "Occupancy detection via iBeacon on Android devices for smart building management," in *Proceedings -Design, Automation and Test in Europe, DATE*, Apr. 2015, vol. 2015-April, pp. 629–632, doi: 10.7873/date.2015.0753.
- [10] T. Ishida, Y. Shinotsuka, M. Iyobe, N. Uchida, K. Sugita, and Y. Shibata, "Development of a Zoo Walk Navigation System using the Positional Measurement Technology and the Wireless Communication Technology.," *J. Internet Serv. Inf. Secur.*, vol. 6, no. 4, pp. 65–84, 2016.
- [11] "Firebase." <https://firebase.google.com/> (accessed Jun. 12, 2020).
- [12] "Benefits of BIM | Building Information Modeling | Autodesk." <https://www.autodesk.com/solutions/bim/benefits-of-bim> (accessed Jun. 12, 2020).
- [13] "What are beacons? - Kontakt.ioKontakt.io." <https://kontakt.io/beacon-basics/what-is-a-beacon/> (accessed Jun. 12, 2020).
- [14] "Estimote – experts in location and proximity solutions." <https://estimote.com/> (accessed Jun. 12, 2020).
- [15] "Why should I use Proximity SDK? What are the benefits? – Estimote Community Portal." <https://community.estimote.com/hc/en-us/articles/204100866-Why-should-I-use-Proximity-SDK-What-are-the-benefits-> (accessed Jun. 12, 2020).