Intelligent Low-Power Displaying and Alerting Infrastructure for Secure Institutional Networks

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Abstract. This paper proposes an intelligent displaying and alerting system, based on a scalable low-power communication infrastructure. The system is designed to offer dynamic display capabilities using the ePaper technology, as well as to enable indoor location-based services such as visitor guidance and alerting capabilities using iBeacon-compatible mobile devices. The system is designed primarily for educational and research institutions, allowing remote authentication through eduroam-type technology performed by the user's distant institution of affiliation. As such, secure access based on locally-defined policies is to be implemented, as well as multiple levels of access, from guests to system administrators. An analysis concerning the dependency of system power consumption on the value of the advertising interval of the iBeacon frames is performed. Based on this, recommendations are made to the institution regarding the optimization of system configuration.

Keywords: ePaper · iBeacon · Alerting system · Indoor positioning
Low power display

1 Introduction

With the ever-increasing use of technology in all life aspects, a sustainable and easily managed system for digital and up-to-date room signage for offices, meeting rooms, and conferences has become the next challenge for modern office buildings. The emergence of Internet of Things (IoT) and digital interactions using electronic paper (ePaper) technology has marked a new phase of development in this direction. The new technology relies on ambient light reflection instead of a backlight, as well as a screen that only consumes a significant amount of energy during the update phase. Such digital displays offer good visibility of information in all light conditions, with the benefit of a low power consumption. The same can be said about iBeacon, which relies on the Bluetooth Low Energy (BLE) standard to create stationary constellations of low-power beacons to determine the indoor position of mobile terminals [1].

O. Fratu et al. (Eds.): FABULOUS 2017, LNICST 241, pp. 141–150, 2018.
https://doi.org/10.1007/978-3-319-92213-3_21

However, because these technologies are still relatively new, their use requires extensive computer programming skills to access and manage displayed information. The current level of technology relies on the user either micro-managing individual displays, or writing complex scripts for the dissemination of multiple information flows and dynamic update of these displays.

There are several companies that offer display and notification solutions based on wireless ePaper. All these solutions are, generally, based on three elements:

– Display, which can be either ePaper or LCD (Liquid Crystal Display);
– Communication infrastructure, which can be based on Wi-Fi, 3G or Bluetooth/ZigBee;
– Content management and publishing application.

Most solutions are focused on static content display and less on dynamic content. There are also digital signage applications which focus on complex content, both static and dynamic, but in this case, a more complex infrastructure is required, and a low power consumption or flexible infrastructure is no longer the target [2].

The paper proposes an intelligent displaying and alerting system (SICIAD) that relies on wireless ePaper and iBeacon technologies to create custom displays for both static and dynamic information, as well as to ease the indoor orientation of guests. The system is currently undergoing testing and preliminary results from real-world deployment are available in [3].

Although the system is primarily designed for public institutions like universities or government buildings, some of its applications may include public transport, exposition and commercial centers, museums and both indoor or outdoor amusement parks. Any organization may benefit from an indoor positioning and orientation system, as well as a centrally-managed display and alerting system.

The paper is organized as follows. Section 2 presents the envisioned architecture, while Sect. 3 details use cases of the SICIAD project. Some preliminary results are given in Sect. 4, while Sect. 5 draws the conclusions.

2 SICIAD Architecture

The SICIAD project was proposed in order to capitalize on existing advanced technology available at a company's premises, as described in Sect. 2. It targets the development of an intelligent system that can dynamically display information and provide notification on certain events. For this, it proposes the development of an integrated management application for the infrastructure and wireless ePaper displays, along with an interface for connecting to internet calendar, several access levels and e-mail message programming. The proposed high-level architecture is depicted in Fig. 1.

The implemented management console will enable the dynamic display of information, either on ePaper devices connected to the infrastructure and without wired power supplies, or on the users' cell phones, using beacons based on the iBeacon technology. An internet calendar interface with email entry will be created, allowing the display of event schedule, as well as an electronic notice board for announcements, commercials, etc.

An application for the operation and monitoring of the system's state parameters is to be implemented, offering the ability to send generated alerts through technologies like e-mail, GSM SMS, ePaper displays in areas of interest, or iBeacon messages.

The intelligent system will analyze data from IoT sensors (temperature, CO_2, smoke, gas) to identify threats, send alerts through its available means, or even automatically initiate emergency evacuation and facilitate the avoidance of problem areas and to provide guidance towards safe exits (including aid for the hearing impaired).

The infrastructure will be designed and implemented using the economic operator's LANCOM ePaper and iBeacon existing technologies, as well as generic open-source technologies available to the university.

The economic operator will be able to implement the system in domains like: universities, schools, conference halls, hospitals, etc.

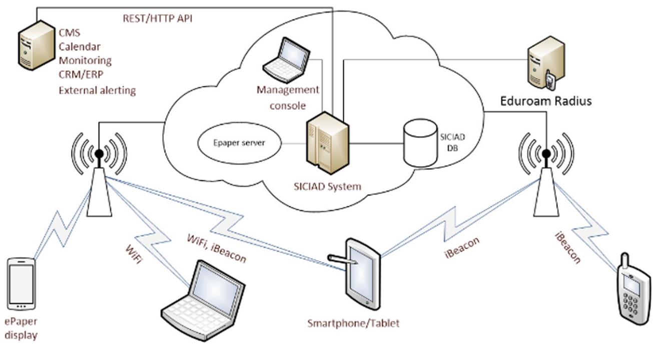

Fig. 1. High-level SICIAD architecture

The Lancom ePaper Server comes integrated with features for displaying user-provided images, as well as generating (rendering) ePaper images based on the user's specifications. All operations, including ePaper display management, display tasks, image upload and image generation, are performed through the system's XML API (Application Programming Interface).

Pre-rendered images can also be directly uploaded to the ePaper Server, also through XML API calls. For the system to function properly, the images must be encoded in BASE64 format and then sent using the API.

Finally, the API can also be used to manage the ePaper displays, remotely gain information regarding their status, or even access the system's logs: including uploaded images and performance data.

As such, the first step in the design and development of SICIAD has been to create a system capable of interacting with the API to send images and tasks for each available display. First and foremost, performance data for the ePaper Server, as well as the displays, is necessary to decide how to proceed further. Moreover, it must be determined if the low-power displays used can work within the system's constraints (specifically as an emergency alerting system).

Since the server is written in Java, for consistency purposes, it has been chosen that SICIAD will also be based on the same programming language, making it a platform-independent software as well. To simplify access to the test system, it has been implemented as a web application.

The system's initial components include:

– An HTTP client, capable of sending all API calls and capturing (and identifying) responded data, offering access to full HTTP information for analysis;
– An XML parser, used to process performance data and convert it to CSV format, for further analysis;
– An integrated database, to store complete test data;
– And a basic web interface, for sending manually-generated XML requests to the ePaper Server API.

The current version of SICIAD focuses solely on centrally managing the information displayed on the ePaper devices, leaving all management functions to the already implemented Lancom tools. In its current design phase, the system uses iBeacon devices integrated in the Lancom Access Points to provide indoor location services. However, the use of stand-alone BLE devices is also considered, to enable a more accurate location of users.

3 Use Cases

Several use cases are envisioned for the development of the SICIAD architecture, based on the project's objectives. Here, wireless ePaper devices are used to display static or dynamic information, while the iBeacon technology can enable smartphone apps to provide guidance, custom advertisements or even location-based alerts. Several use cases are proposed:

1. **Dynamic or static announcements and notifications in public transport stations.** In this scenario, the ePaper will display the schedule of public transport associated with a stop, along with a short map of the surrounding areas and the transport network, and other useful information. There will also be dynamic information such as the remaining time until a public transport vehicle arrives or temporary changes of the schedule.
2. **Dynamic display of information in educational and research institutes and visitor guidance.** Wireless ePaper displays can be used to replace traditional notice boards. As such, a hierarchical architecture could allow each room's administrator to present information regarding schedule, special events, contests and projects. Furthermore, additional information could be managed by the upper hierarchy of the institute. For large organizations, visitors could be guided using an iBeacon-based in-door positioning system.

3. **Dynamic display of alerts and emergency evacuation.** An intelligent monitoring system can determine safety threats and automatically enact predefined evacuation plans. Here, ePaper displays can be used to show the best route for evacuation, while iBeacons can be used to broadcast alerts or guide visitors towards exits through smartphone applications.
4. **Guidance for customers in large shopping areas/malls.** Here, ePaper is used along with beacons. ePaper can ensure the display of price tags, and can also dynamically modify them. For instance, based on information from beacons, it can enlarge the font if there is a senior person or with eyesight problems. Also, a loyal customer may get a lower price and notifications regarding the existence of such price.
5. **Guidance and notifications for museum visitors.** In this scenario ePaper is used for tagging exposition halls and exhibition pieces, as well as marking the visitation route. Also, beacons will enable, via a smartphone app, an interactive electronic guide of the exhibition.
6. **Tourist information and guidance in national and adventure parks.** Here, beacons are used, via a smartphone app, for providing information on tourist landmarks in the area, as well as for providing interactive audio guide.

Based on the above use cases, as well as the details presented in Sect. 2, it can be concluded that ePaper displays controlled over a wireless network can be used to fulfil SICIAD's main objectives. More important, the use of wireless technology simplifies the deployment of the system, since additional wiring or power sources will not be necessary. However, several special cases result from the use-case analysis.

First off, the ePaper displays (including the Lancom ePaper displays proposed for use in the system's architecture) are designed to work at a low level of power consumption. This means a slow refresh rate of the displayed information, when changes occur. For static information, this is not an issue: all the displays can be updated in the off hours, when no one is using them. However, an issue may arise when trying to display urgent dynamic notifications, like the emergency evacuation alert from the sixth use case. For such cases, further study is needed regarding the wireless ePaper response time.

The specifications of Lancom ePaper displays indicate a battery life time between 5 and 7 years, if the displayed information is changed four times a day [4]. For more interactive applications (like the first use case), or improving response times for emergency situations, additional power sources may be needed, which may come in the form of solar panels in outdoor deployments (when battery replacement may become an issue).

Secondly, the Lancom WiFi Access Points integrate iBeacon technology. This offers a simple means of determining whether a mobile smart device is in close range of the access point, but a larger iBeacon network is necessary for determining exact indoor position. As such, further work may relate to the integration of stand-alone iBeacon devices in the SICIAD architecture.

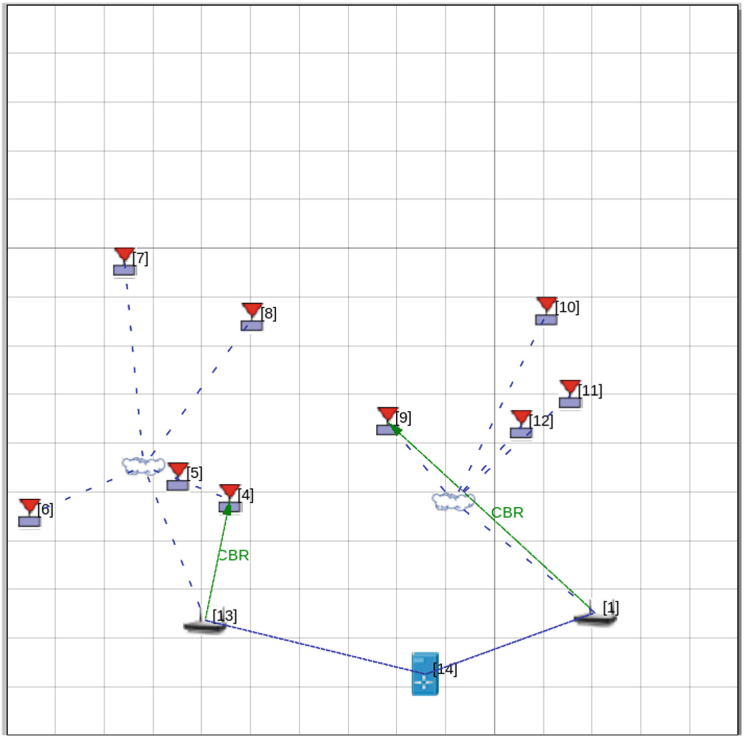

Fig. 2. Scenario topology simulated in EXata

The above use cases highlight three general use cases for the SICIAD system:

1. **Dynamic display system** - which updates the ePaper devices based on a set predefined rules, either automatically or at the user's request;
2. **Visitor guidance system** - relying on BLE iBeacon emitters to pin-point the users' locations and provide indoor navigation assistance and location based services;
3. **Dynamic alerting system** - relying on components from the previous use cases and superseding their displayed/broadcasted information. In case of an alert, the system will store the previous normal running state, proceed to alerting (or even evacuating all visitors) and, once the alert has passed, restore it.

4 Evaluation

In order to determine the battery behavior of standalone iBeacons in the SICIAD architecture, we devised a topology that resembles as closely as possible the network in the BEIA company building that would be used to implement iBeacons in the SICIAD architecture. The battery behavior is important as it will serve as a metric for deciding the advertising interval of iBeacon. A very small interval (100 ms as recommended by Apple) will likely lead to a fast discharge of the beacon battery. Whereas a high interval (larger than 1000 ms) might lead to a drop in the positioning accuracy for applications like indoor positioning.

We used EXata Network Simulator [5] in order to send iBeacon frames to receiving devices. The transmission is modeled as a Constant Bit Rate (CBR) application, as BLE (iBeacon) frames have a constant size and a constant transmission interval. Figure 2 shows the scenario topology.

The battery models available in EXata were used to capture the characteristics of real-life batteries and to enable the analysis of the discharge behavior under different system loads without resorting to time consuming and expensive prototyping.

The analysis was conducted using two battery models:

1. **Service Life Battery Model**. This model estimates the total service life of the battery and uses a model developed by Sarma and Rakhmatov [6] as an abstraction of the real battery. It can be used for different particular batteries, provided that one has the rated capacity vs. discharge current.
2. **Residual Life Battery Model**. This model estimates the remaining service life of the battery and, similar to the service life battery model above, will need a battery efficiency plot to estimate the discharge rate.

Table 1. Simulation parameters

Parameter	Value
Packet size	30 bytes
Packet transmission interval	100; 200; 350; 700; 1000 ms
Simulation length	24 s
Battery model	Service life; Residual life
Battery type	Duracell-AAA
Initial battery charge	1200 mAhr

The two battery models where used, together with varying rates of advertising interval, to see the effect of the value of the interval on the battery life. Table 1 shows the main parameters used.

Results are shown in Figs. 3, 4 and 5. From Fig. 3 we can notice that the consumed energy does not decrease linearly. We see that the rate of decrease is higher at lower transmission intervals (which was of course to be expected) but we see that going from 700 towards 1000 ms, the rate of energy consumption has a very small value. If we look at Fig. 4, we can make the same observation. The residual battery capacity tends to increase as the transmission interval decreases. This means that the battery of the beacon will last longer when having a higher

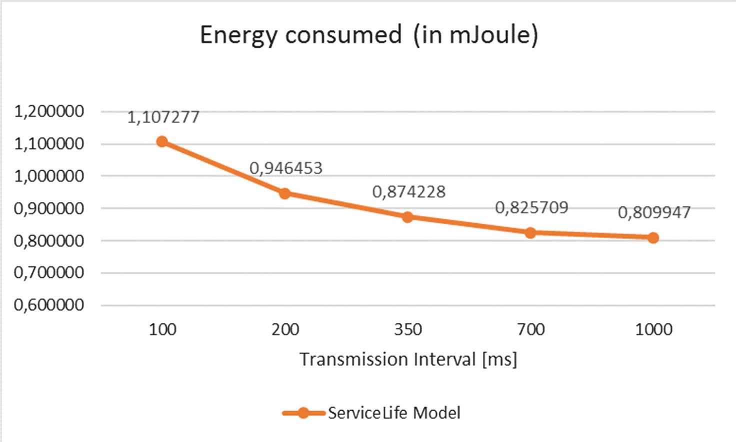

Fig. 3. Energy consumed

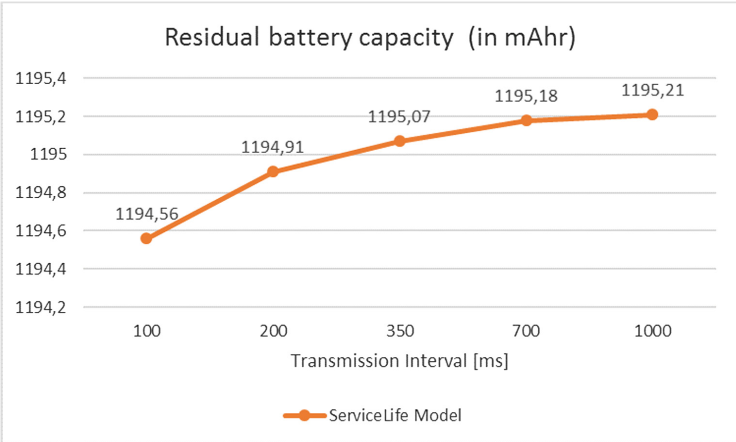

Fig. 4. Residual battery capacity [Service Life model]

transmission interval (which only makes sense, as one needs to transmit once every second, and not 10 times per second).

We analysed the same parameter using the Residual Life Model (Fig. 5). Although the curve is similar, we can see that the values predicted are more optimistic than the Service Life model. We also notice that, in terms of absolute values, the Service Life model estimates a higher discharge rate for the beacon battery. Several conclusions now can be drawn by putting the results together. It is plain to see that by using the recommended transmission interval (100 ms) the battery would deplete in a very short time. However, increasing the transmission interval ten-fold (to 1000 ms) does not lead to a 10-fold drop in the discharge rate. The battery life will last between 13 and 30% longer (depending on the battery model that was used). Taking into account the residual battery capacity together with the consumed energy curve, the recommendation for the company would be to choose and advertising interval between **350** and **600** ms as that accommodates both a good indoor positioning accuracy as well as a good battery discharge rate.

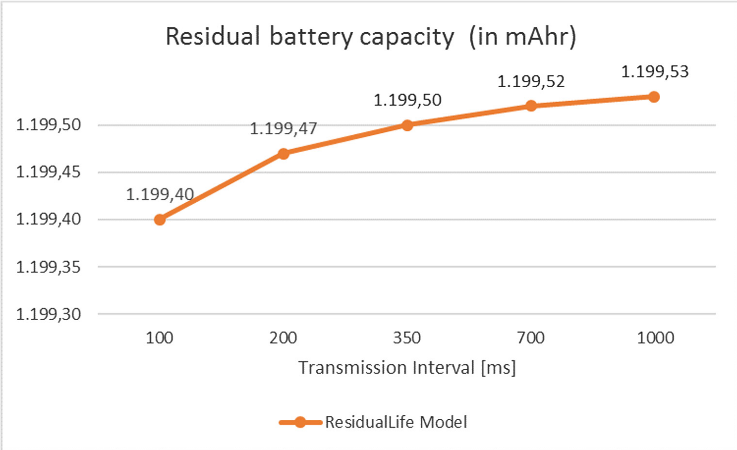

Fig. 5. Residual battery capacity [Residual Life model]

5 Conclusions

The paper presents a displaying and alerting system, based on an integrated communication infrastructure. The system offers dynamic display capabilities using the ePaper technology, as well as enables in-door location-based services such as visitor guidance and alerting using iBeacon-compatible mobile devices. While the iBeacon emitters integrated in the used Wireless access points can enable location-based services, accurately determining each users' location may require additional, battery-powered BLE beacons. Such a network (or constellation) of beacons could provide a more elegant indoor guidance system, due to its effectiveness at a range of several meters (compared to several centimeters for NFC tags). Moreover, although the investment in Beacon devices may be significant, the already widespread use of compatible smart devices may reduce the necessity of other hand-held devices. Future work with the project will include the development of the system's management console, along with the further investigation of ePaper response times and iBeacon functional range, as well as the proposed architecture's scalability, performance and security.

Acknowledgement. This work has been funded by UEFISCDI Romania under grant no. 60BG/2016 "Intelligent communications system based on integrated infrastructure, with dynamic display and alerting - SICIAD" and partially funded University

Politehnica of Bucharest, through the "Excellence Research Grants" Program, UPB - GEX. Identifier: UPB - EXCELENTA - 2016 project Research projects "Intelligent Navigation Assistance System", contract number 101/2016 (SIAN) and "Platform for Studying Security in IoT", contract number 96/2016 (PaSS-IoT).

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