Intelligent Displaying and Alerting System Based on an Integrated Communications Infrastructure and Low-Power Technology

Marius Vochin(✉), Alexandru Vulpe, George Suciu, and Laurentiu Boicescu

University POLITEHNICA of Bucharest - UPB Bucharest, Bucharest, Romania
{marius.vochin,laurentiu.boicescu}@elcom.pub.ro,
{alex.vulpe,george.suciu}@radio.pub.ro

Abstract. The paper proposes an intelligent displaying and alerting system, based on a scalable integrated communication infrastructure. The system is envisioned to offer dynamic display capabilities using the ePaper technology, as well as to enable indoor location-based services such as visitor guidance and alerting using iBeacon-compatible mobile devices. The system will include a central display management console, as well as automated procedures for automatically displaying different types of notifications. 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 will be implemented, as well as multiple levels of access, from guests to system administrators.

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 following 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.

However, because these technologies are still relatively new, their use requires extensive computer programming skills to access and manage displayed information. As we stand, the current level of technology relies on the user either micro-managing individual

Á. Rocha et al. (eds.), *Recent Advances in Information Systems and Technologies*,
Advances in Intelligent Systems and Computing 570, DOI 10.1007/978-3-319-56538-5_14

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
- Communication infrastructure, which can be based on WiFi, 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.

The paper proposes an intelligent displaying and alerting system (SICIAD) that relies on wireless ePaper and iBeacon technologies [1] to create custom displays for both static and dynamic information, as well as to ease the indoor orientation of guests.

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 centres, 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 some background on ePaper and iBeacon technologies, while Sect. 3 details the envisioned architecture and use cases of the SICIAD project. Some preliminary results are given in Sect. 4, while Sect. 5 draws the conclusions.

2 Wireless ePaper and iBeacon

2.1 iBeacon

The iBeacon standard [2] is a communication protocol developed by Apple based on Bluetooth Smart technology. It represents a technology that can facilitate the development of location-based applications. A device that uses iBeacon sends radio signals to alert smartphones of its presence. When a mobile device detects a signal from the beacon, it uses the signal to estimate the proximity to the beacon and also the accuracy of the proximity estimation. This process of measuring the proximity to a device is known as "ranging" and it is based on common usage scenarios that rely on the accuracy of the assumption and the measured distance. The estimation is indicated by one of the four proximity states: immediate, near, far and unknown.

To broadcast signals, iBeacon devices use Bluetooth Low Energy (BLE) which is based on the 2.4 GHz frequency. BLE is designed for low energy consumption and uses the wireless personal area network (PAN) technology to transmit data over a short distance. The difference between the iBeacon and other location-based technologies is that the beacon is only a one-way transmitter for the receiving device and requires a specific application to be installed on the device so that the user can manage beacons reception.

The deployment of an iBeacon consists of the fact that this device can transmit its own unique identification number to the local area. Receiving devices can also connect to the iBeacon and retrieve data from the iBeacon's service. Location based services using beacons address three types of audience: application developers, people who deploy devices using the iBeacon technology and people who create devices using the iBeacon technology.

2.2 Wireless ePaper

The electronic paper can be considered as a portable storage and display medium which can be electronically written and refreshed multiple times in order to display new content. Such devices can display content which is downloaded from various sources or created with a mechanical or electrostatic tool such as an electronic pencil (stylus). Therefore, the concept of ePaper can be defined as a display technology that simulates the appearance of text written on a traditional physical paper [3]. To make the content more comfortable to be read, electronic paper provides a wider viewing angle than light-emitting displays and perfect readability in ambient light. Applications of electronic visual displays include electronic shelf labels, digital signage, time schedules for public transportation, billboards, portable signs, electronic newspapers and e-readers.

The wireless ePaper solution is based on an innovative radio technology that lowers the power consumption due to the fact that it only requires power when the displayed content is changed. The solution provides a wide variety of functionalities and options for displaying information that allow the user to set up very own customized use case, for example for radio-controlled signage at universities [4]. One key functionality consists of the fact that the users can remotely upgrade the displayed content in real time. To allow a highly flexible use, the wireless ePaper displays eliminate the need for an external power supply or a physical network connection due to the fact that the devices are battery powered and radio controlled. Furthermore, the data transmission process can be protected by a 128-bit key, allowing secure encryption and authentication standards for eduroam [5, 6].

3 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.

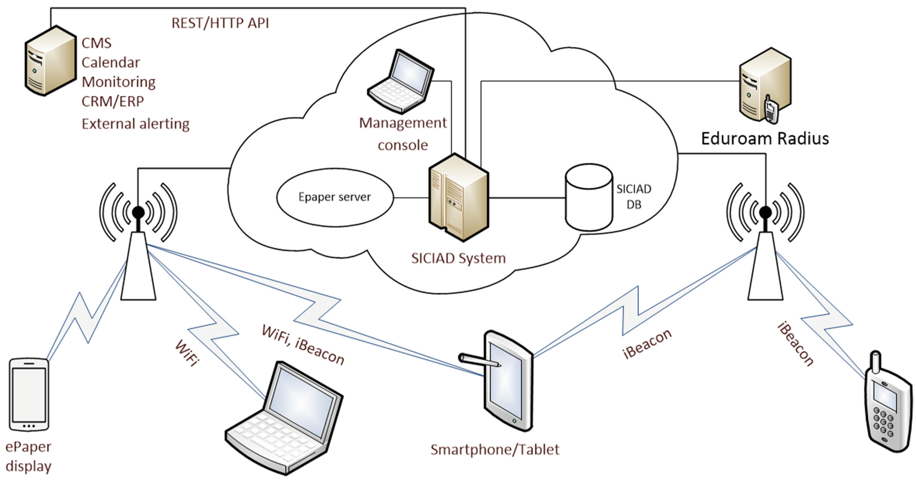

Fig. 1. High-level SICIAD architecture

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 will 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 analyse data from IoT sensors (temperature, CO2, 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.

3.1 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. The following 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. **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.
3. **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 expo.
4. **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.
5. **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.
6. **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.

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 [7]. 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.

4 Preliminary Evaluation of Wireless ePaper and iBeacon

Several tests have been performed in order to determine the delays that occur when updating the information on the ePaper displays from the wireless ePaper server. To that end, the L-151E access point was used together with a WDG-1 7.4″ ePaper display, controlled through an ePaper Server installed on a Windows Server 2013.

In the first experimental test scenario the delay of changing ePaper content was determined for simple operations, such as image delete, change, rotate and show id. The results are summarized in Table 1.

Table 1. Common operations and corresponding delays.

Operation	Details	Delay [s]
Delete	Delete image	330–473
Change	Change image 480 × 800 (7.4″)	27
Rotate	Image rotation	2
Show ID	Show label display ID	14

In the second test scenario, measurements of three different iBeacon power levels have been made on the same access point and a commodity hardware with BLE receiver such as SM-G361F smartphone.

Lancom iBeacon has been calibrated to provide three power levels at a distance of 1 m: –52, –58, –75 – broadcasted with the beacon message, in order to allow an approximation of the distance between the BLE receiver and the beacon. The measurements at reception indicate –40, –46, –62 dBm, at a distance of several cm of the antenna.

5 Conclusion and Future Work

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 indoor location-based services such as visitor guidance and alerting using iBeacon-compatible mobile devices.

Measurements taken in the evaluation phase show that the ePaper display’s response times are relatively short, being suitable to proposed use cases. Tests show that the largest delays are obtained in the case of deleting images. However, further study will be needed to guarantee rapid response times in case of emergencies.

The batteries provided by the manufacturer for the ePaper displays are sufficient for most of the use cases, whilst being easy to replace for indoor applications. For outdoor applications, ePaper systems can be recharged via solar cells and, due to their low power consumption, may function entire seasons without sunlight, offering a long-term solution for displaying information in remote areas.

Being based on the BLE standard, iBeacon technology can potentially operate with almost all smart mobile terminals, providing a cost-effective solution for an indoor positioning system. In combination with a smartphone application and a wireless communication system, BLE can enable the distribution of location-based content.

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.

Acknowledgments. 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 by University Politehnica of Bucharest, through the "Excellence Research Grants" Program, UPB – GEX. Identifier: UPB–EXCELENȚĂ–2016 Research project Intelligent Navigation Assistance System, Contract number 101/26.09.2016 (acronym: SIAN).

References

1. Suciu, G., Vochin, M., Diaconu, C., Suciu, V., Butca, C.: Convergence of software defined radio: WiFi, ibeacon and epaper, In: IEEE 15th RoEduNet Conference: Networking in Education and Research, pp. 1–5 (2016)
2. Sykes, E.R., Pentland, S., Nardi, S.: Context-aware mobile apps using iBeacons: towards smarter interactions. In: Proceedings of the 25th Annual International Conference on Computer Science and Software Engineering, pp. 120–129 (2015)
3. The technology behind LANCOM wireless ePaper displays. https://www.lancom-systems.com/fileadmin/download/reference_story/PDF/Wireless_ePaper_Solution_at_a_private_college,_Germany__EN.pdf
4. Wireless ePaper solution at a private college, Germany. https://www.lancom.de/fileadmin/download/reference_story/PDF/Wireless_ePaper_Solution_at_a_private_college,_Germany__EN.pdf
5. University of Belgrade implements eduroam. https://www.lancom.de/fileadmin/download/reference_story/PDF/University_of_Belgrade_EN.pdf
6. Winter, S., Wolniewicz, T., Thomson, I.: Deliverable DJ3.1.1: RadSec standardisation and definition of eduroam extensions, GN3 JRA3, GEANT3 (2009)
7. Lancom wireless ePaper displays specification sheet. https://www.lancom-systems.com/fileadmin/produkte/lc_wireless_epaper_displays/LANCOM-Wireless-ePaper-Displays-EN.pdf