A Visible Light Communication based positioning system for intuitive advertising in supermarkets

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Abstract

Over the years, smart advertising has become a key marketing tool for brands to communicate with their potential customers in a place where a large number of people live. For that, supermarkets are ideal advertising spaces since hundreds of consumers visit them every day and are receptive to the advertising that is offered to them. In this paper, we propose a new system that can smartly transmit advertising to contains ubiquitously customers of a supermarket using a LED lighting system embedding the VLC technology. This system aims to offer a solution to help brands to study the relevance of the deployed advertising campaign through a low-cost implementation.

1 Introduction

For people or moving objects outdoor positioning, the Global Positioning System (GPS) (Misra, P. et al. *Global Positioning System: Signals, Measurements and Performance*, 2006) on its cost and global coverage is undoubtedly the best alternative for this purpose. Nevertheless, if the GPS works perfectly in unobscured areas, it is not the case for indoors environments, highly dense metropolitan areas with buildings, and underground or submerged environments where the line of sight of satellites is blocked. To address these situations, solutions as WiFi, Bluetooth, radio frequency identification (RFID), Near Field Communication (NFC) and camera-based positioning were developed as a complement to boost the reception of GPS. however, the high cost of these complementarities, the positioning errors and the complexity of installation and synchronization does not promote their widespread in confined areas.

With the exponential demand of applications and wireless services, The Radio Frequency (RF) spectrum is becoming increasingly scarce resource due to the increase of the global data traffic related to the proliferation of connected mobile devices (smartphones, tablets…), but also those related to the

advent of internet of things that accentuate this fact. Hence, considering the upper portions of the electromagnetic spectrum (ie, the optical band) for wireless communications is the only recourse. Fig. 1 depicts the EM spectrum along with the wavelength band of various waves which include radio wave, microwave, infrared, ultra violet, X-ray and gamma ray.

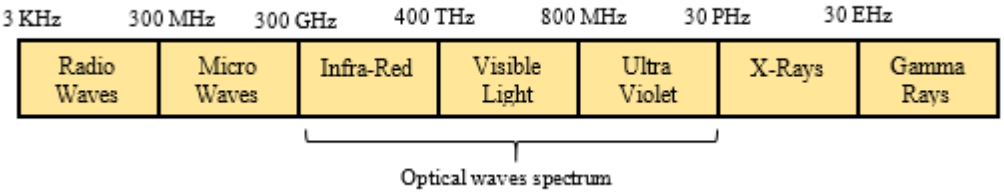

Figure 1: The electromagnetic spectrum.

Wireless communication by optical permits the use of electromagnetic waves at very high frequency bands in the ultraviolet (UV), visible, and infrared. However, the adverse effects of infrared and ultraviolet on the health of human beings, are not in favor of the aforementioned frequencies bands for large scale use. Only the visible band is suitable for use.

The first use of visible light for communication purpose comes from Alexander Graham Bell, who in 1880 developed a photophone which transmitted voice data over 200 m using beams of sunlight (A. G. Bell, and al, J. Soc. Telegraph Eng., 1880) Nowadays, the scientific community acclaim this technology named Visible Light Communication (VLC) to become the wireless communication standard in the 21st century. Moreover, since Light Emitting Diodes (LEDs) also serve as lighting devices and might be installed everywhere, it unfolds the potential of utilizing VLC as a pervasive positioning system (Do and al, *Sensors* 2016).

This paper investigates of the applicability and the implementation of an intuitive advertising system for supermarkets using VLC. The rest of this paper is organized as follows, Section II discloses fundamentals of Visible Light Communication. Section III presents and discuss VLC based positioning Algorithms. In Section IV, we present our proposed system. Implementation and the experimental results are described in Section V. The limitations of using VLC in our context are presented in Section IV, and some solutions are proposed to overcome the situation. Finally, Section VII concludes the paper.

2 Fundamentals of Visible Light Communication based positioning

VLC based positioning systems include using the visible light signal to determine the position of a mobile device. For this, LEDs whose original function is to shed light are here used as VLC transmitters for their ability to switch quickly enough to transfer data, on the other side, photodiodes or a camera are used to receive the VLC signal containing the ID, the geographical position of the LEDs or other information to locate the mobile device. Note that the key difference between VLC based positioning and vision based positioning is the manner in which the mobile device obtains positioning information. While in vision based positioning the information are obtained by processing images of landmarks in the environment, VLC based positioning that uses a camera obtains information by receiving VLC

signals transmitted by the LED base station (Do and al, *Sensors* 2016). Figure 2 describes a typical VLC based indoor positioning system.

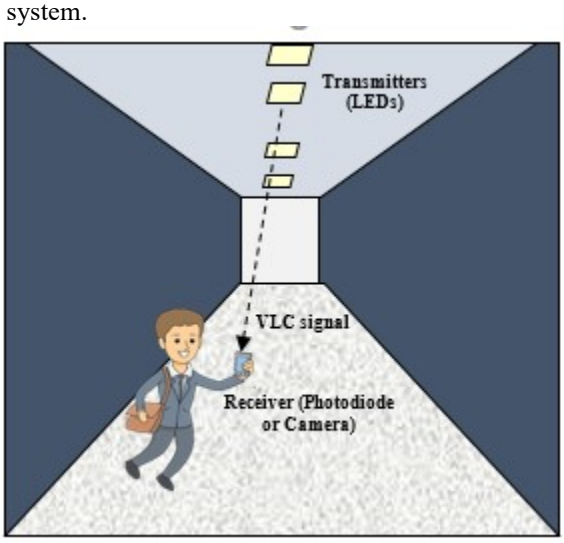

Figure 2: VLC based indoor positioning system

3 VLC based positioning algorithms

In literature, many survey have been published about VLC based positioning (Wang, C, *Commun. China* 2015). Each of them categorize those algorithms into different classifications. The most accurate and complete classification divide them in 5 main groups: proximity, fingerprinting, triangulation, vision analysis, and dead reckoning each with its strengths and weaknesses.

The proximity and fingerprinting are the simplest methods in terms of implementation, triangulation, vision analysis and dead reckoning approaches outperform them in terms of localization accuracy. Nevertheless, despite the many advantages of vision analysis and dead reckoning, these approaches have a latency that can be probabilistic for some applications, moreover, the need to have a camera that is much more expensive than a photodiode. Triangulation shows itself as the best candidate for indoor positioning in terms of simplicity, high accuracy, precision and cost. The latest use two derivations: lateration and angulation. Lateration techniques, which involve the time of arrival (TOA), the time difference of arrival (TDOA), and the received signal strength (RSS), estimate the position based on the measured distances from the mobile device to multiple LEDs base stations. Angulation, map or angle of arrival (AOA) (Do and al, *Sensors* 2016). According to many papers (Yamaguchi and al, In Proceedings of the IEEE Fifth International Conference on Communications and Electronics (ICCE), 2014), we can say that AOA yield the highest accuracy but has the disadvantage of being expensive compared to other. However, as our goal is the location of people in particular environments and for particular purpose, simplicity and reliability of the algorithm are more important than accuracy down to 10 centimeters.

4 Proposed System

In this section, we highlight the context and describe our proposed positioning system.

4.1 Context

An ad campaign is the best way for brands to communicate with their potential customers. It plays a very important role in launching or developing a product or service. It contributes to the increase in the turnover of providers by increasing their visibility in order to encourage consumers to try the product, but the most important is that it helps companies to identify and monitor their evolution compared to their competitors. As for the second party, advertising plays as important role for providers because people need to be informed about the existence of a new product on the market and need help to find the best products.

Advertising success depends primarily on the ability of a brand to reach specific customers in a place where a large number of people coexist for a fairly long time. Supermarkets are in this context ideal advertising spaces: hundreds of consumers visiting them every day. These people are ready to buy, usually in a good mood and, moreover, receptive to the advertisement that is offered to them. Pubs therefore gain in relevance and value. Moreover, if the customer is informed of the possibility of receiving promotional codes, he will be ever more receptive, especially in a difficult economic time which has exacerbated the search for tips.

4.2 System description

As mentioned earlier, VLC has a significant potential in indoor location of persons. The main motivation of the implementation of the proposed system is based on the use of a VLC based positioning system to contribute to the study and optimization of the relevance of advertising campaigns in supermarkets.

The process consists of delimiting the zones in which the owner of the supermarket wishes to deploy his advertising campaign through the positions of the LEDs suspended from the ceiling. The light signal emitted by the LEDs positioned in the area of the campaign will be interpreted directly by the smartphones of the customers, without the need to add additional hardware modules. Thus, information (pubs, promo code, video, etc.) transported by the light is directly picked up by a light sensor located on the front face of the camera and which interacts interactively with an application installed on the camera which will have the task of interpreting the information received.

To operate, the smartphone must be held horizontally, so that its camera has an optimal angle with respect to the luminaires. A study conducted by the company Philips ensures that 68% of customers declare to use their smartphone to search for information about the products while they are shopping, which eventually ease the applicability of VLC in supermarkets.

5 Implementation and experimental results

In order to study the relevance of the advertising campaigns of a supermarket, we implemented a prototype of a system that tends to approach the maximum of the reality. First, we generate the model of the store as a square of 100m length and 100m width and define 6 zones of 20m x 30m. Then, we assign different number of items to each zone labeled respectively by: 1 to 50, 51 to 60 ,61 to 210, 211 to 270, 271 to 275 and 276 to 375.

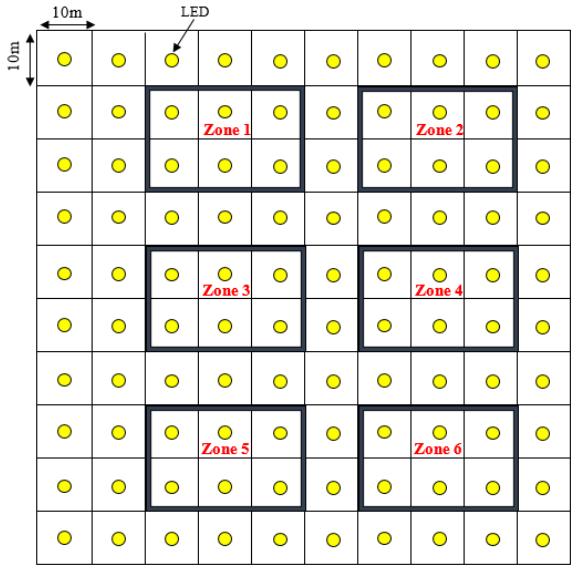

Figure 3: The model of the store.

After that, we create a random mobility model in order to simulate the mobility model of customers in a shopping mall. In our study, we took an example with 20 clients. With this model, customers can move in all direction over the entire surface of the store, with a speed varying from 0.2 to 2.2 m / s with a running time varying between 2 s and 6 s and a stopping time varying between 0 s and 1 s, the duration of the simulation is 500s of simulation time.

The next step was to define the lists of preferred products of each customer. For this we use a normal distribution with an average of 5 articles and a variance of 2, in order to model the number of items of each customer.

Once the parameters have been set, we have generated the mobility model and then created a counter that we denoted 'counters of sent advertisements' that increments each time a customer enters an area where an ad campaign is triggered. This operation allows us to study the scope of an advertisement.

A second counter denoted counter of purchased products was created which allows to count the number of products purchased once the advertisement has been received.

In order to demonstrate the robustness of our system, several random processes were generated by considering all the aforementioned parameters, the results of 4 random processes are represented in figure 4 and figure 5. In order to verify the accuracy of our system, we generated a visual animation of the mobility model and the zones, this enabled us to judge visually the relevance of the proposed system.

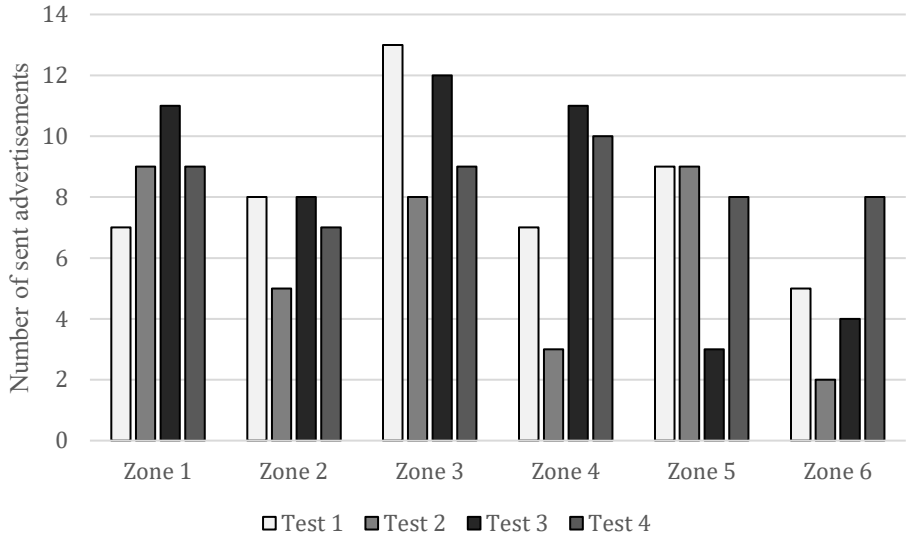

Figure 4: Number of sent advertisements by areas.

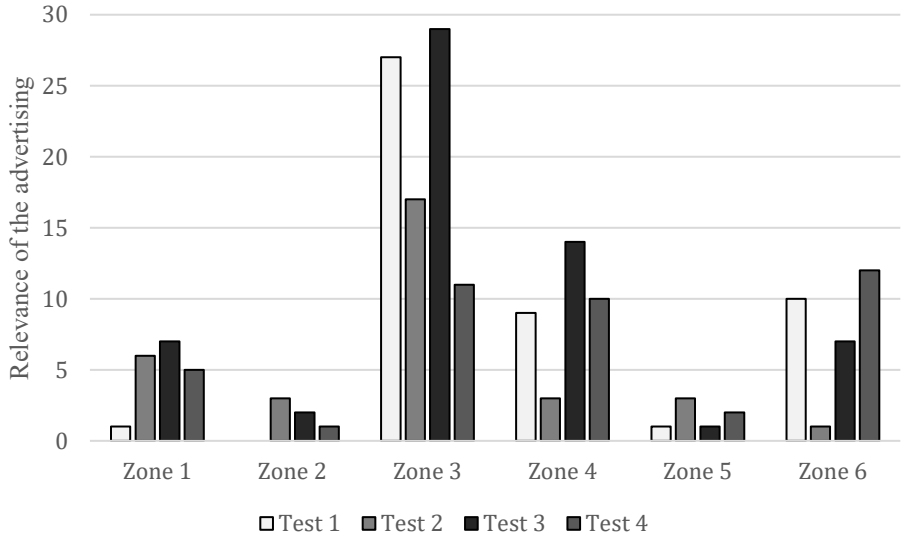

Figure 5: Relevance of the advertising by areas.

6 Discussion

several basic system level issues can be identified which require attention. In this section, we quote:

Synchronization

As mentioned before, synchronization between transmitters and receivers is difficult to obtain. Many factors govern this synchronization: Propagation time, sending time and receiving time of the signal. Those parameters are needed to compute clock offset and clock drift. Synchronization algorithms must be applied to overcome these situations.

Shadowing

As mentioned in many research papers, VLC positioning systems are built for line of sight links. If receivers have not unobscured line of sight with LEDs it might create shadowing issues. However, shadowing can be minimized by distributing lighting sources (MIMO techniques) to maintain a high SNR and to optimize the coverage.

Ambient Light Noise

One of the biggest issues of positioning using VLC is the ambient light noise. Cause the luminance of a LED is much lower than natural light and in some case, other artificial light and will create interference. Those interferences if high enough can saturate the receiver and make it blind. Many solutions are proposed in the literature to overcome this situation like using optical filters. However, these approaches are not effective solution for this problem since the sensor have to receive light signal from different directions. So far there is no effective solution to this problem.

In this work, we considered random the probability that a customer receives an advertisement correctly. But in the future, we will try to find a more accurate model.

VLC vs Wifi or Bluetooth

It might seem simpler and more efficient to use Wifi or Bluetooth for the presented application, however, the advantage of the VLC is that it does not require the use of information on the smartphone of the customer unlike Wifi or Bluetooth. On the other hand, the security breaches of the last put in peril the personal information of the client which may be solicited without his consent. Also, VLC requires a direct line of sight between the LED and the smartphone.

7 Conclusion

We have proposed in this paper to use VLC as a positioning system to deploy advertisement system in a supermarket that can transmit advertising to the customers of a supermarket across the LED lighting system embedding the VLC technology. The proposed system also makes it possible to judge the relevance of the deployed advertising campaign through a simple algorithm which measures the intersection between the proposed items in the area of the campaign and the list of preferred products of the customer. The effectiveness of the proposed scheme was tested through experiments with an actual low-cost implementation example, showing promising results. As a perspective, we attempt to apply this system to a more critical scenario, where conditions will be much less suitable for light communications to test the limits of this technology.

References

[1] Misra, P.; Enge, P. *Global Positioning System: Signals, Measurements and Performance*, 2nd ed; Ganga-Jamuna Press: Lincoln, MA, USA, 2006.

[2] A. G. Bell, W. G. Adams, Tyndall, and W. H. Preece, "Discussion on the photophone and the conversion of radiant energy into sound," J. Soc. Telegraph Eng., vol. 9, no. 34, pp. 375–383, 1880.

[3] Do, T.-H.; Yoo, M. An In-Depth Survey of Visible Light Communication Based Positioning Systems. *Sensors* **2016**, *16*, 678.

[4] Wang, C.; Wang, L.; Chi, X.; Liu, S.; Shi, W.; Deng, J. The research of indoor positioning based on visible light communication. *Commun. China* **2015**, *12*, 85–92.

[5] Yamaguchi, S.; Mai, V.V.; Thang, T.C.; Pham, A.T. Design and performance evaluation of VLC indoor positioning system using optical orthogonal codes. In Proceedings of the IEEE Fifth International Conference on Communications and Electronics (ICCE), Da Nang, Vietnam, 30 July–1 August 2014; pp. 54–59