Location Aware Tracking with Beacons

Gary Mansell, Kevin Curran

School of Computing and Intelligent Systems
University of Ulster, Derry, Northern Ireland

Abstract

Adding location awareness to a service can have great benefits in a wide range of sectors. Of particular note is the retail sector, which can benefit from location specific advertising material or innovative customer analytics. This paper outlines a location aware retail application (LARA) which could be used to improve existing loyalty reward programs using an accurate, reliable and affordable technology. Despite the availability of GPS, Wi-Fi and RFID, modern indoor location aware services are hampered by the lack of a standard technology from which accurate and reliable indoor positions can be determined. The introduction of Bluetooth low energy in version 4.0 of the Bluetooth core specification could pave the way for a successful and ubiquitous indoor positioning technology based on Bluetooth and dedicated beacon devices using an innovative packet format called Eddystone. Our system uses Bluetooth low energy beacons with the innovative Eddystone frame format and rewards customers with loyalty points based on the amount of time they spend within proximity of a particular store position (i.e. a beacon).

1. Introduction

A location aware services (LAS) is a special context aware application which recommends services to a user based on their current location. LAS have many potential applications and can benefit a wide range of sectors such as tourism, travel and retail (Chan and Sohn, 2012). Example applications include, tourists checking into a hotel where receptionists have already been notified of their arrival and travellers using a LAS to navigate transportation hubs or receive travel updates such as an airport boarding gate being opened. The retail sector in particular, can have huge benefits from a successful LAS implementation. The ability for a business to offer tailored, location specific advertising material, such as coupon codes to entice nearby prospective customer can be very beneficial. Positioning technologies can also be used in a wide range of areas such as tracking warehouse goods, providing travel directions and finding the best place for a group meeting. As mentioned, one of the sectors which could benefit most from this new technology is the retail sector (Lionel et al., 2004). Many modern retail outlets have some form of loyalty reward program which frequently offer rewards based on the number of individual transactions or accumulated expenditure. By implementing a good LAS using BLE beacon technology and recently developed practices, such as Google's Eddystone format (Young, 2015), a great number of customers can be reached and an enhanced loyalty programs, which rewards customers not only on expenditure but also time spent browsing instore, could be developed. Adding any incentive for a customer to initially enter a store, and to remain there for as long as possible, is very attractive to businesses since it is likely to result in higher sales and a higher turnover. Additionally, a good LAS facilitates innovative customer analytics which can be just as desirable. This paper outlines a location aware retail application (LARA) which includes a form of loyalty reward program. The system comprises of a mobile application which can determine when a customer is in store, a web application which will allow the management of users and beacons, and a database which will store all data collected.

2. Bluetooth Low Energy (BLE)

In June 2010 the Bluetooth 4.0 specification was released by the Bluetooth special interest group (SIG) and with it the introduction of Bluetooth low energy (BLE) or 'Bluetooth smart.' (Schilit and Theimer, 1994). BLE is a variation of classic Bluetooth with the primary aim of this new standard to provide "an efficient technology for monitoring and control applications where data amounts are typically very low." BLE power consumption is significantly reduced to 50-99% of classic Bluetooth power consumption. In theory, the lifetime of a BLE device powered with a single coin cell battery ranges from 2 days to 14.1 years, (Gomez et al., 2012). This extremely low power consumption is perfect for devices which need to run off tiny batteries for long periods. The real 'magic' of Bluetooth smart is its ability to communicate with the billions of existing Bluetooth devices already on the market, (Bluetooth SIG A, 2015; Bluetooth SIG B, 2010). Using Bluetooth for location determination is mainly achieved using trilateration with known fixed location devices, (Barahim et al., 2007). RSSI and propagation time are used to calculate precise distances. In theory any BLE compatible device, such as a smartphone, is able to take on the role of a beacon however the term beacon usually refers to a piece of single purpose dedicated hardware designed to be cheap, with a long lifetime and which transmits data in the form of Bluetooth beacon frames (Zanchi, 2015). Beacons are broadcast-only, non-connectable devices however they may become connectable (by switching the GAP from the broadcaster role to the peripheral role) to allow the beacon to be updated or configured over the air, (Texas Instruments, 2015). On top of the BLE protocol stack there are a number of standardised protocols which specify beacon packet payload formats. These protocols specify beacon frames-types and enable standardisation of how beacons can communicate with a receiver device. A number of protocols exists which may be propriety or open source. The first beacon format to gain popularity was the iBeacon format developed by Apple. Since iBeacon was closed source a number of open source protocols, such as AltBeacon were developed to allow greater protocol flexibility. AltBeacon was developed because "there is no open and interoperable specification for proximity beacons," (AltBeacon, 2015). It is in essence, identical to the iBeacon format differing only in that it is open source allowing it to be tailored as needed, (Allan, 2015). AltBeacon, which was the standard for non-iOS devices, has largely been superseded by the Eddystone protocol. The Eddystone format has gained a lot of attention since its release in July 2015 as it includes the ability to broadcast a URL rather than a unique beacon id. There are also a range of closed proprietary systems which have been developed for use by particular companies such as Estimote's Nearable protocol, (Borowicz, 2015). The dominant protocols are Apple's iBeacon and Google's Eddystone.

3. Location Aware Retail System

We use Kontakt smart beacons which support the Eddystone frame format and can broadcast Eddystone-UID will be used. This beacon is high performance beacon which supports many features such as simultaneous multi-frame format broadcasting and has an excellent battery life (Thota & Kulick, 2015). Kontakt also have an excellent development kit and an active development community with support forums where help can be obtained if required. A system architecture diagram is shown in Figure 1 displaying a number of users which possess mobile devices and can communicate with a beacon device. Based on this communication the mobile device can then communicate with an application/database server which allows the devices location to be determined.

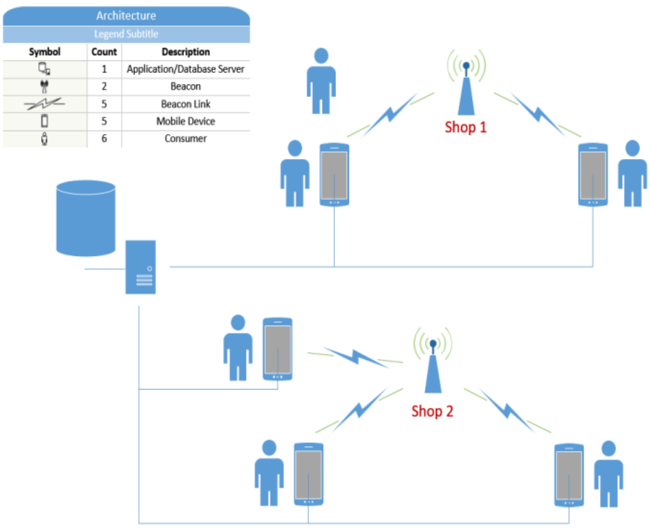


Figure 1: Overall system architecture

A total of nine beacons were acquired for use during this project. Each beacon used by the system has to be configured with advertising intervals, TX power and Eddystone-UIDs. In order to configure the beacons, the Kontakt and Estimote mobile applications were used for each type of beacon (three Kontakt beacons and six Estimote beacons). Figure 2 and Figure 3 show screenshots of the management interface these apps provide. The transmission power of beacons was set at low settings allowing the beacons to last for very long periods of time which the apps estimate at 38+ months. The advertising intervals have been set at 100ms to ensure that beacons are read successfully by the mobile application and distances calculated are as accurate as possible.

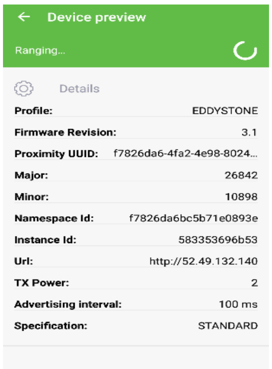


Figure 2: Kontakt config

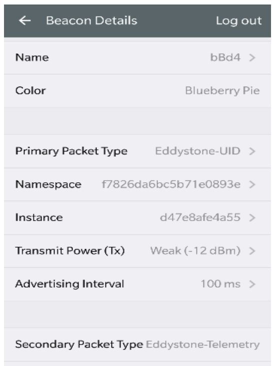


Figure 3: beacon config

The manage user accounts page displays all information relating to existing user accounts such as usernames, user account types, full names etc. From this page an administrative user can create, update or delete user accounts and may also modify a normal user's reward points.

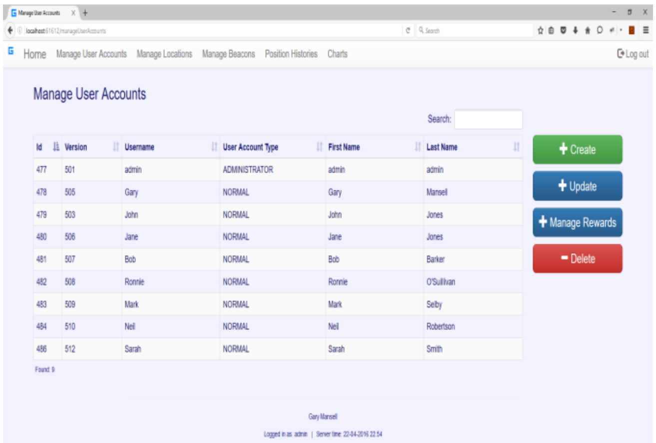


Figure 4: Manage user accounts page

In order to assign beacons to positions there must be locations which the positons are associated with. The manage locations page allows administrative users to manage locations including the ability to create, update and delete location data. Deleting a location also deletes any positions which are assigned to that location, with the user made aware of this while confirming deletion.

Figure 5: Manage locations page

Viewing charts allows an admin user to see various statistics about the system including the most popular locations by total linger time, most visited positions for a location by location linger time, average linger time for a location, and the overall top system users by reward points. Linger time and session times are calculated based on the amount of continuous time each user spends at a position, referred to as a position history session. All position history sessions are first determined in order to produce the chart data displayed on this page. This page also has auto refresh functionality which can be enabled or disabled to view a snapshot or real time statistics for the system whereby all chart data automatically updates every few seconds. An admin user can hover over each chart which will display additional detail about the targeted data in a grey popup. The view charts page is shown in Figure 6.

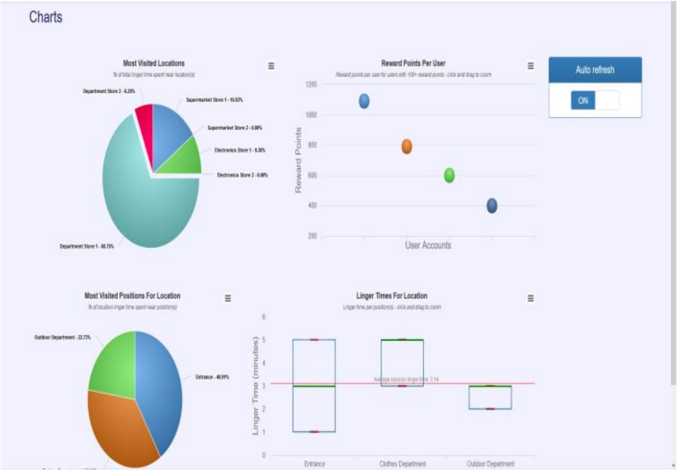


Figure 6: View charts page

The top left pie chart of Figure 6 shows which locations are the most visited (i.e. have the most time spent within proximity of them) overall. A user can select locations on this chart which will update the other charts with data specifically for the chosen location. The mobile app is used by most of the users of the system and the initial start page of the mobile application allows users to login with the username/password combination they already have or allows new users to navigate to the registration page to create a new account. New users must enter a username (which must be unique), a first and last name as well as a suitably complex password with at least four alphanumeric characters. The new password must be re-entered to confirm it is what the user expected. Users can opt to cancel and return to the previous page or use the back button (available on all pages). Informative feedback messages are displayed to the user after successfully creating an account or duplicate username errors. Input validation errors result in similar icons to those shown on the login page.

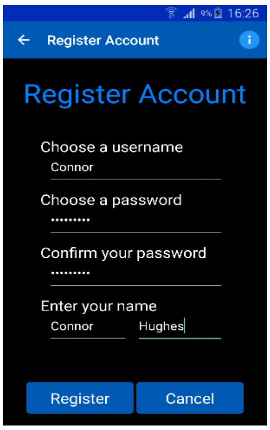


Figure 7: Successful account creation dialog

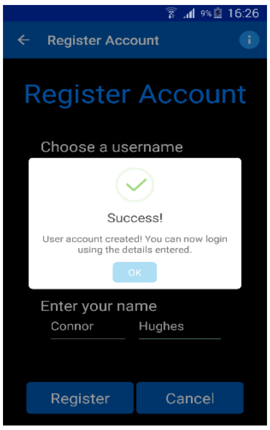


Figure 8: Username created

4. Evaluation

The web application was deployed on Amazon Elastic Compute Cloud (EC2) web services with the database also being deployed on a separate server with Amazon Relational Database Server (RDS). As the application has been deployed network latencies become a much bigger factor however the system should remain fully functional. Beacons were deployed in various locations (which were actually rooms but will be referred to as shops) with each shop having multiple fictional positions (e.g. entrance, electronics section, vegetable section etc.) each assigned with a beacon. A beacon which was stored but not assigned to any position was also included in testing. Figure 9 shows how the beacons were setup in reality with their positions and points awarded also labelled.

Figure 9: OAT beacon setup

The admin user is able to login to the deployed application and configure all beacon data including assigning beacons to specific positions with points awarded for visiting each position. When a user gets within range (0.5m for testing) of a beacon they are awarded reward points and position histories should be saved. The reward points displayed after visiting all positions should reflect a combination of the amount of time the user spent at each position and the points awarded for each position. The user's reward point display updated at each stage indicating that position histories were successfully being saved (see Figure 10 and Figure 11).

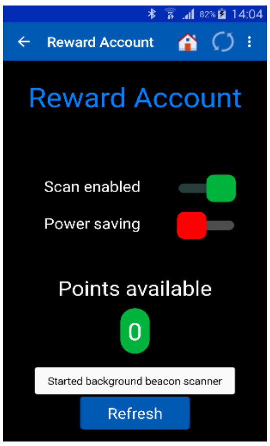


Figure 10: Initial reward account page when activating the beacon

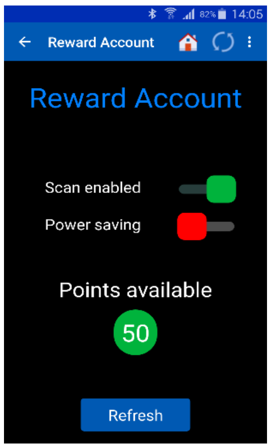
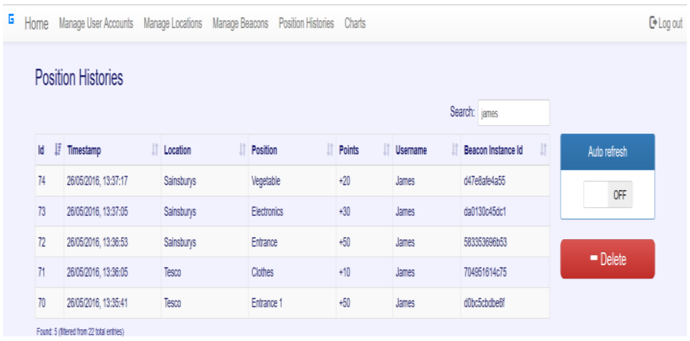


Figure 11: Reward account display at step 1

All position histories can also be viewed from the position history page. Filtered position histories which were saved for username 'James' are shown in Figure 12.



Id	Timestamp	Location	Position	Points	Username	Beacon Instance Id
74	26/05/2016, 13:37:17	Sainsburys	Vegetable	+20	James	d47e8afe4a55
73	26/05/2016, 13:37:05	Sainsburys	Electronics	+30	James	da0130c45dc1
72	26/05/2016, 13:36:53	Sainsburys	Entrance	+50	James	583353696b53
71	26/05/2016, 13:36:05	Tesco	Clothes	+10	James	704951614c75
70	26/05/2016, 13:35:41	Tesco	Entrance 1	+50	James	d0bc5cbdbe6f

Figure 12: Position histories for user 'James' (filtered using search) after completing all steps

During this test, a position history was not saved for step 3 resulting in the reward point total not being correct (off by 60 points). There are a number of possible reasons for this position history not being saved, some of which are network latency or failure to hold the mobile device close enough for the full 15 seconds - ranging distance set at 0.5m and this beacon was on a raised platform (above a door). Expected data can be calculated and compared with the charts that are displayed on the charts page. The most visited location by overall linger time is Sainsbury's with 51.282% (from 20/39*100) of the total linger time while Tesco has 48.719% (from 19/39*100) which mirrors what is actually displayed by the system in Figure 13.

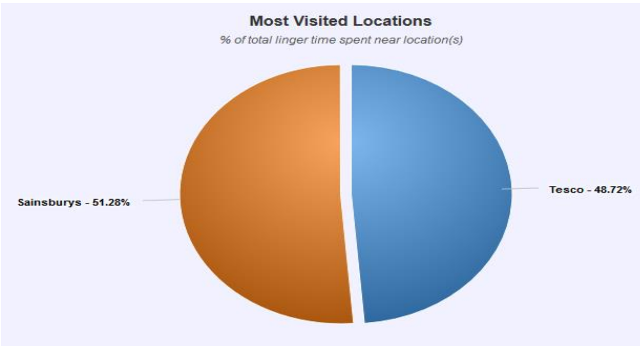


Figure 13: Most visited locations by linger time

The top users can be determined. The points calculated for each user are shown on the charts page (Figure 14).

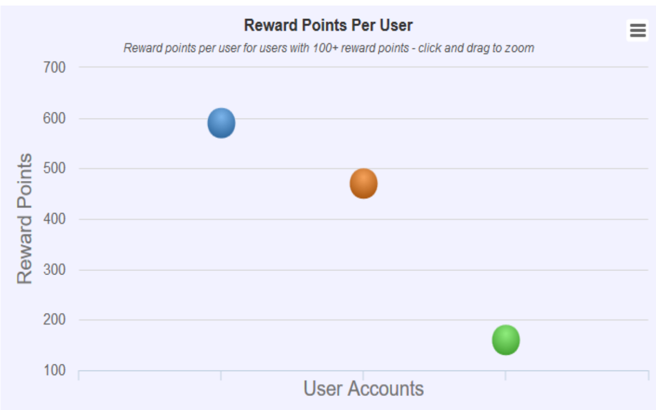


Figure 14: Overall top system users

5. Conclusion

Bluetooth low energy beacons, which have high accuracy, precision, low complexity and native support by the majority of mobile devices, seem like an obvious candidate for locating a person indoors. We have shown BLE as a viable means of accurately locating an individual indoors. The accuracy (within 0.5 metres) achieved and the reliability of position histories being saved each minute (or with a 10 second margin for new positions) is comparably better than that currently offered by other technologies given there are no major downsides to BLE. The only possible drawback with BLE beacons is the necessity to setup and configure beacons beforehand. Furthermore, should beacons become widespread in the future it is possible that a centralised body would establish a network of beacons which could be used to determine location. Together with the low cost of the hardware, BLE beacons are certainly a realistic and practical means of locating an individual in a retail environment or indeed any indoor setting.

References

Allan, A. (2015) Google Introduces the Eddystone Beacon. Available at: http://makezine.com/2015/07/20/google-introduces-eddystone-beacon/

AltBeacon AltBeacon (2015) The Open and Interoperable Proximity Beacon Specification. Available at: http://altbeacon.org/

Barahim, M.Z., Doomun, M.R. and Joomun, N. (2007) Low-Cost Bluetooth Mobile Positioning for Location-based Application. pp. 1.

Bluetooth SIG A (2015) Bluetooth Smart Technology: Powering the Internet of Things. http://www.bluetooth.com/Pages/Bluetooth-Smart.aspx

Bluetooth SIG B (2010) Adopted Bluetooth Core Specifications - Core Version 4.0. Available at: https://www.bluetooth.org/en-us/specification/adopted-specifications

Borowicz, W. (2015) What are nearables? What is Nearable protocol? https://community.estimote.com/hc/en-us/articles/206409488-What-are-nearables-What-is-Nearable-protocol-

Chan, S. and Sohn, G. (2012) Indoor localization using Wi-Fi based fingerprinting and trilateration techniques for LBS applications. . 16 May 2012 through 17 May 2012. International Society for Photogrammetry and Remote Sensing, pp. 1.

Lionel, M.N., Liu, Y., Lau, Y.C. and Patil, A.P. (2004) LANDMARC: Indoor location sensing using active RFID, Wireless Networks, 10(6), pp. 701-710. doi: 10.1023/B:WINE.0000044029.06344.dd.

Schilit, B.N. and Theimer, M.M. (1994) Disseminating active map information to mobile hosts, Network, IEEE, 8(5), pp. 22-32. doi: 10.1109/65.313011.

Thota, C. and Kulick, M. (2015) Lighting the way with BLE beacons. Available at: http://googledevelopers.blogspot.co.uk/2015/07/lighting-way-with-ble-beacons.html

Young, D.G. (2015) Introducing Eddystone, The New Beacon Format From Google. http://developer.radiusnetworks.com/2015/07/14/introducing-eddystone.html

Zanchi, M.G. (2012) Bluetooth Low Energy. http://www.litepoint.com/wp-content/uploads/2014/02/Bluetooth-Low-Energy_WhitePaper.pdf