

Building the Physical Web: A Campus Tour Using Bluetooth Low Energy Beacons

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Abstract

Estimote Bluetooth Low Energy (BLE) beacons deployed throughout a university campus enabled the creation of interactive tours for prospective and accepted students at Fall and Spring open house events. By configuring their mobile devices with an app to detect the beacons' signals, participants could view webpages containing information based on their current physical locations from the web addresses pushed to their devices by nearby beacons.

Google Analytics and relational database reporting functions provided information related to the behavior of campus guests. This study presents lessons learned from deploying a Physical Web and results of analyzing user behavior based on the analytics data. The conclusions drawn from this data can be used to improve campus visits for prospective students and supplement decision making in university admissions offices. Participants in a follow-up survey shared their impressions of the Physical Web as an emerging technology. By joining in the project, participants said they learned more about the Physical Web and its application to real-life scenarios.

Keywords: Physical Web, Bluetooth, beacons, Internet of Things, mobile devices, campus admissions

1. INTRODUCTION

The Physical Web provides a platform for seamless interaction between the virtual and physical worlds. Coupled with the increasing prevalence of the Internet of Things (IoT) and mobile computing, the Physical Web allows individuals to interact with nearby physical objects through their mobile devices ("The Physical Web - Google"). Want, et. al. refer to "devices that are part of the IoT and directly accessed, monitored, or controlled by Web technologies as the Physical Web" (Want, Schilit, & Jenson, 2015, p. 28).

This emerging technology enhances the use and understanding of various locations and process-critical objects in a variety of applications. From a deployment standpoint, the Physical Web is indiscriminate, allowing any place or thing to broadcast useful data to nearby mobile devices. Bluetooth Low Energy (BLE) beacons, which are small devices that can be embedded or affixed to an object or building, often provide this broadcast capability. Case studies using beacons for Physical Web functionality include smart airports (Namiot and Sneps-Sneppe, 2015), remote tourist locations (Lodeiro-Santiago et al., 2017) and Physical Web retailing (Lazaris and Vrechopoulos, 2014). Beacons represent the

hardware component of the Physical Web, providing proximity-based access to IoT resources. Major manufacturers of BLE beacons include BlueUp, Gimbal, and Estimote. Estimote manufactured the BLE beacons, shown in Figure 1, used in this project. An Estimote Developer Kit with four proximity BLE beacons can be purchased for \$99 on estimote.com (Estimote).

This paper describes the steps involved in building a Physical Web using a collection of BLE beacons to provide a self-guided campus tour experience for visitors at Fall 2017 Prospective Students day and Spring 2018 Accepted Student's Day events at Bentley University, a business university in Massachusetts. The authors were interested in participants' first impressions of the Physical Web as an emerging technology, and after experiencing it, what applications they might imagine that could make use of the Physical Web.



Figure 1. Estimote BLE beacons.

These research questions guided this study:

- How might experiencing beacon technology inspire participants to consider potential business applications of the Physical Web?
- What will participants learn about the Physical Web after participating in a demonstration of its capabilities?
- In what ways can the Physical Web enhance a visitor's campus tour experience?

2. APPLICATIONS OF THE PHYSICAL WEB

While the Physical Web is a new technology, its foundation rests in common and widely deployed tools and technologies like Bluetooth and web addresses (URLs). This allows for seamless integration and creates numerous areas of research and experimentation, addressing the specific use of the Physical Web alongside IoT devices and existing standards. First introduced

by Google in 2014 as an improvement to existing physical-virtual interaction (i.e. QR codes), several industries have created use cases and proposed applications for the Physical Web.

Namiot et al. study an application of the Physical Web for smart cities, exploring the use of beacons for navigation and terminal information within airports (Namiot and Sneys-Sneppe, 2015, 2). In the retail industry, Lazaris and Vrechopoulos, (2014) investigate the technology as a disruption to traditional multichannel retailing, providing tailored selection and presentation of material for users' mobile devices. Lodeiro-Santiago et al. specifically harness the power of storing webpages directly on BLE beacons to present useful tourism information at remote locations without Internet access (Lodeiro-Santiago et al., 2017).

In addition to Physical Web deployments in industry, tourism, and business environments, educators have explored its applications as well. Apoorv and Mathur (2016) investigate the use of the Physical Web to enforce school attendance in India. Their research focuses on using BLE beacons attached to student ID cards, and an Android application for use on the mobile phones of school faculty. In another example, Uttarwar et al. describe an experiment with BLE beacons deployed in a library to present information regarding books and their locations within the library to proximate mobile devices (Uttarwar et al., 2017). A university library in Sweden uses BLE beacons to show information about nearby books based on the user's location among the shelves (Jergefelt, 2015).

Much of the existing literature includes the use of specific mobile applications designed to communicate with beacons. However, Google's original support for the Physical Web was based on a strictly pull-based browsing approach ("The Physical Web - Google"), where a user deliberately requests to view notifications from nearby beacons. This approach included Physical Web functionality through Google's Chrome Browser, available on both Android and iOS devices. This method contrasts with push-based notifications, implemented by Apple's iBeacon technology. Push-based notifications send messages to users' devices without their explicit request (Daradkeh and Namiot, 2015). Due to a wide array of potential abuse associated with push-based approaches, including phishing attacks, most current Physical Web platforms are pull-based.

3. BUILDING A PHYSICAL WEB ON CAMPUS

In preparation for this event, students placed 24 BLE beacons at various locations throughout campus, including academic buildings, student life centers, and athletic arenas. This section summarizes the process used to create webpages used for the open house campus tours and describes how to configure Estimote beacons to broadcast their web addresses.

Developing Campus Tour Webpages

Webpages for the Fall 2017 project were written in HTML and CSS to display static content about locations on campus, shown in Appendix 1, Figure A1. A campus web server hosted these pages.

For the Spring 2018 project, students created interactive webpages with Python and the Django web framework. Django facilitates the development of data-driven webpages. Hosted on a third-party cloud server, these dynamic pages contained short student-made videos describing each location and campus trivia questions pulled from a MySQL database. A short domain name was purchased to make webpage addresses more accessible for visitors. Examples of interactive Django pages are shown in Appendix 1, Figures A2, A3, and A4.

Configuring Beacons

Students used the Estimote app shown in Appendix 1, Figure A5 to configure each beacon with its associated address of a webpage to broadcast to nearby users' devices. Each beacon broadcast the address of a webpage using the Eddystone-URL format. Eddystone-URLs are short web addresses developed by Google, and compatible with both Android and iOS devices (Bhattacharya et al., 2016).

A Beacon-Enabled Campus Tour

At the opening programs for prospective and admitted students, an information card (shown in Appendix 1, Figure A6) placed at each seat contained instructions inviting visitors to configure their mobile devices to receive signals from BLE beacons deployed at various locations throughout campus. The University President and Director of Admissions both called attention to this project during their introductory remarks to encourage participation. Visitors used the Google Chrome mobile web browser's Physical Web feature to receive beacon signals. As an incentive, participants who, during the day, captured screenshots of any three webpages broadcast from the beacons received a free T-Shirt.

The Spring 2018 Admitted Student's Day Physical Web experience used the Phy mobile app (*The Phy Platform | We Reinvented the Universal QR Experience.*), as a replacement. Phy is a browser for the Physical Web and represents a pull-based system in which users must open the app to view nearby beacons. In Figure 2, the Library notification appears in the Phy app, shown at the left, when a visitor approaches the beacon located in the library. Tapping the Library notification card in the Phy app displays its campus tour webpage in the web browser of the visitor's mobile device, as shown in Figure 2 at the right.

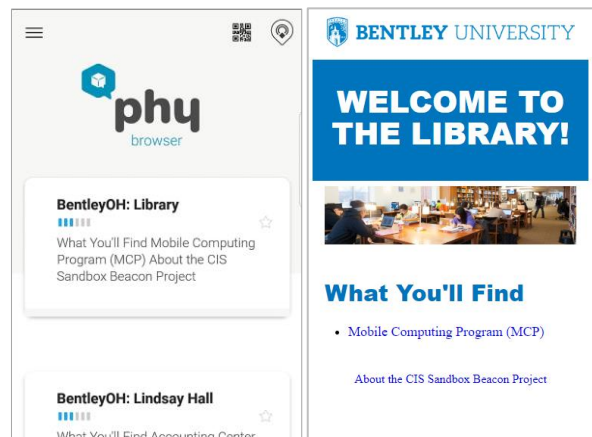


Figure 2. The Phy application running on an Android mobile device (left) and the webpage launched by tapping the link obtained from a beacon notification (right).

4. RESULTS

This section describes results of the deployment of BLE beacons at Fall 2017 Prospective Student's Day and Spring 2018 Admitted Student's Day. A limitation of this study is that a small percentage of visitors chose to participate in the activity at each open house event. Presumably, those who participated were already tech savvy, were interested in learning about the physical web, or wanted a free T-shirt. An expected outcome is that participants who claimed their T-shirts were interested in the activity and did not have difficulty setting up their mobile devices to interact with the beacons. The number of visitors who had difficulty setting up their mobile devices to receive signals from the beacons is unknown. These visitors were unable to claim their T-shirts because they could not complete the activity.

Fall 2017 Prospective Student's Day

During the Fall 2017 Open House, 700 students and their families visited campus throughout the day. Of these, 115 participants found beacons

placed at locations across campus and viewed their associated webpages. This represents a 16% participation rate among visiting families, assuming one person per family participated. The Google Analytics platform aggregated webpage activity, providing useful data points for analysis during and after the implementation. User behavior patterns, as exhibited in Appendix 1, Figure A7, provided insights into the order in which visitors encountered beacons that directed them to campus tour webpages.

This data shows that most participants started at campus locations adjacent to the welcome event (49 at Smith building and 40 at Registration) and then traveled to buildings further across campus (Smith, Quad, Library, CIS Sandbox) in their first stops. From there they went to the library, bookstore, student center, and campus center later. This is consistent with project expectations because many visitors first learned about the project during the welcome event and continued their tours at locations nearby. The 115 participants contributed to 194 unique web sessions. The data shows that 112 visitors dropped off, or closed their browser, after viewing the welcome page. From there, 36 visitors dropped off after viewing their first location's page, and 19 participants left the campus tour website after viewing the second location's page. Participants may have stopped viewing beacon pages at this point because they needed to capture only three screen shots of webpages to claim their T-Shirt prize at the end of the day.

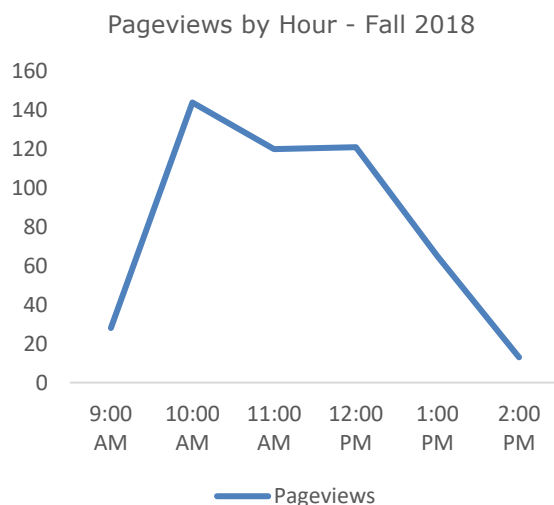


Figure 4. Pageviews by hour for Fall 2017, Prospective Student's Day.

The behavior data also provided information about page views throughout the entire open

house event. This data, summarized in Figure 4, shows that peak beacon usage occurred between 10:00 AM and 12:00 PM. This usage aligns with the introductions to the project given by the University President and Admissions Director during the opening presentation beginning at 10:00 AM.

Of the 69 visitors who received T-shirts, 33 further participated in a Physical Web survey. Among respondents were 24 students, 5 parents, and 4 other campus guests. Only 18% (6/33) of survey respondents had heard of the Physical Web before participating in the beacon project. This response shows that many end users are not aware of Physical Web technology or its uses.

Survey results regarding users' first impressions of Physical Web technology included, "It is very interesting, and I believe it has the potential to grow and become amazing" and "Useful for marketing." Survey respondents also provided several ideas for real world applications of the Physical Web including parking meters, museums and statues, real-time marketing, and directions in cities.

Spring 2018 Admitted Student's Day

During the Spring 2018 Admitted Students' Day, 800 students and their families visited campus throughout the day. The Spring 2018 Physical Web implementation had 92 participants, with a total of 268 pageviews. This interaction represents an 11.5% participation rate, a 28% decrease in participation from the Fall 2017 project. Webpage viewing patterns for the Spring 2018 deployment are shown in Figure 5 and identify the same 10:00 AM to 12:00 PM timeframe as the peak beacon usage for the event.

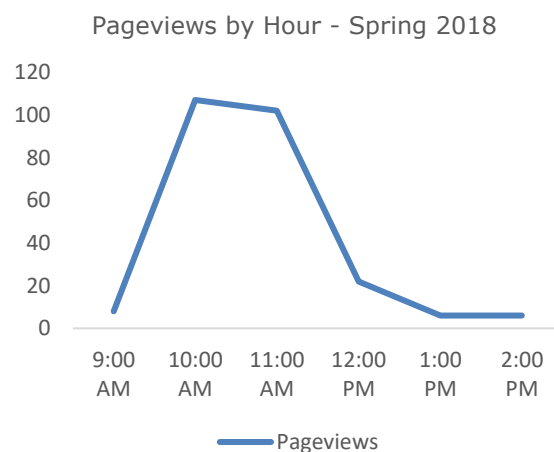


Figure 5. Pageviews by hour for Spring 2018, Admitted Student's Day.

Like the Fall 2017 project, this peak usage is correlated to the timing of the President's address and introduction to the project, as shown in Figure 4.

The Spring 2018 project featured specific paths (Academics, Campus Life, Campus Resources) to tour various university locations. Each path directed the visitor to several locations related to the path. For example, Campus Life was the most popular selection among visitors who chose a specific path. Those who followed that path visited the student center, dorms, cafeteria, and other related locations. A MySQL database connected to the tour webpages stored users' path choices. The breakdown in path choice is shown in Table 1.

Table 1. Tour path selections for Spring 2018.

Path	Number of Participants
Academics	14
Campus Life	26
Campus Resources	23
No specific path	29

Of the 92 project participants, 12 successfully completed their chosen campus tour paths and received a T-Shirt Prize. All 12 of these visitors, composed of 11 students and 1 parent, responded to a Physical Web survey for the Spring 2018 project. The survey data shows that a larger percentage had heard of the Physical Web before completing the project than had in the Fall 2017 implementation.

Attitudes and Ideas about the Physical Web

Based on the Spring 2018 event survey, 67% of respondents agree and 33% strongly agree that their participation in the beacon project enhanced their campus experience. In addition, 75% of respondents expect to use the Physical Web in their homes within five years, as shown in Figure 6. This result suggests that visitors saw the value of the Physical Web and can imagine its maturity as an emerging technology.

Survey results regarding users' first impressions of Physical Web technology included, "easily found the beacons on the phone" and "it is very useful and boosts productivity." Real world applications offered by respondents included virtual tour guides, stadiums and concerts, video games, tourism and school orientations.

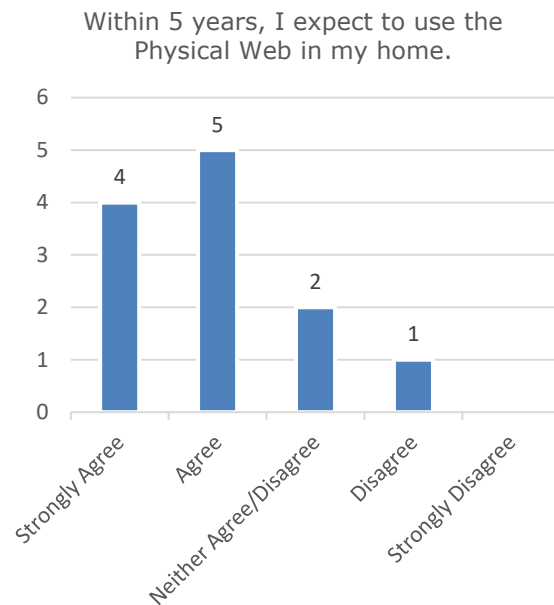


Figure 6. Participants who expect to use the Physical Web in their homes within 5 years (Spring 2018 project).

Respondents further provided feedback when asked what they learned about the Physical Web by participating in the Spring 2018 beacon project. Responses included:

- "It was my first time using it, so I learned how it can be applied to everyday events."
- "I learned about how the Physical Web network is actually set up."
- "The digital world can yield implications in the real world."

5. DISCUSSION AND CONCLUSIONS

The Physical Web was an experiment conducted by Google where beacons broadcast their web addresses to the Chrome browser. As the Physical Web evolved, its features have migrated into the Eddystone-URL protocol and were integrated to the Android platform through the Nearby and Notifications apps. As a result, Google discontinued support for the Physical Web within the Chrome mobile browser in October, 2017 (Levine).

Based on Google Analytics data and survey results, the authors compared the two Physical Web projects to answer guiding research questions and evaluate the Physical Web as an emerging technology.

The beacon-enabled campus tour inspired many creative ideas for potential business applications for the Physical Web. Survey respondents from both events suggested uses such as parking meters, real-time marketing, and virtual-physical tours, all of which are current real-world applications. Hands-on experience as end-users in a Physical Web environment successfully provided visitors with an opportunity to explore the effectiveness of this technology and to brainstorm future use cases.

The authors further considered the contexts of the two university events when analyzing the data collected at each. The Fall project was set up for Prospective Student's Day to orient students interested in attending the university. In contrast, the Spring project was designed for accepted students. Prospective students are likely to be more eager to participate in campus activities and learn as much about the campus as possible. This is a probable explanation for decreased Physical Web participation in the Spring 2018 project compared to Fall 2017. While students in the Fall were focused on academics and evaluating the university, students in the Spring had already decided Bentley was a likely fit and were more interested in campus life resources like dorms, athletic buildings, and student centers. This premise supports the "Campus Life" path being the most popular virtual tour selection among participants in the Spring 2018 project.

Using the Phy mobile application in the Spring project streamlined the participation process and is likely the reason for 0% of participants expressing difficulty setting up their devices compared to 27% in the Fall project.

Participants in the Spring 2018 project expressed several key takeaways. These included raising awareness about the Physical Web, its technology and applications; the implications of bringing together the physical and virtual worlds; and the Physical Web's application to everyday objects. Through their participation in this project, school visitors were able to learn about a new technology while also more effectively touring campus.

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Editor's Note:

This paper was selected for inclusion in the journal as an EDSIGCON 2018 Meritorious Paper. The acceptance rate is typically 15% for this category of paper based on blind reviews from six or more peers including three or more former best papers authors who did not submit a paper in 2018.

Appendix 1. Additional Figures



Figure A1. Static webpage for a campus location in Fall 2017 Prospective Student's Day.

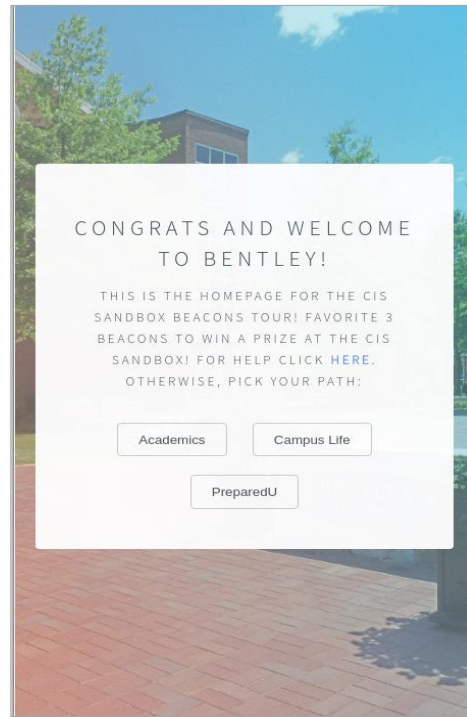


Figure A2. Path selection webpage from Spring 2018 Accepted Student's Day.

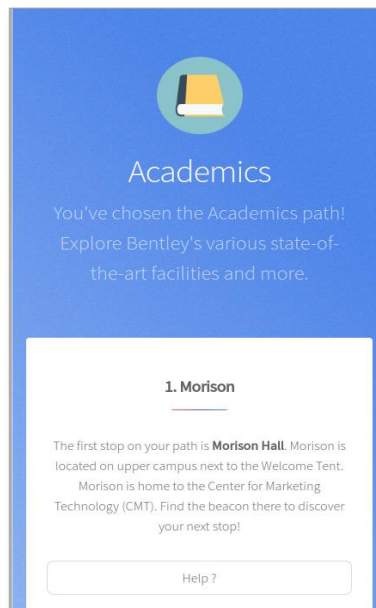


Figure A3. Sample Academics Path page. Used at Spring 2018 Accepted Student's Day.

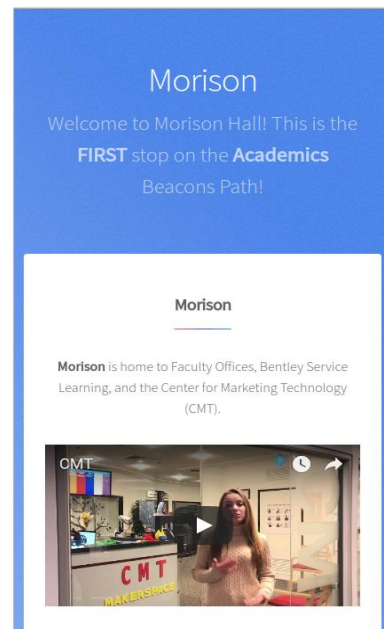


Figure A4. Sample location webpage with video. Used at Spring 2018 Accepted Student's Day.

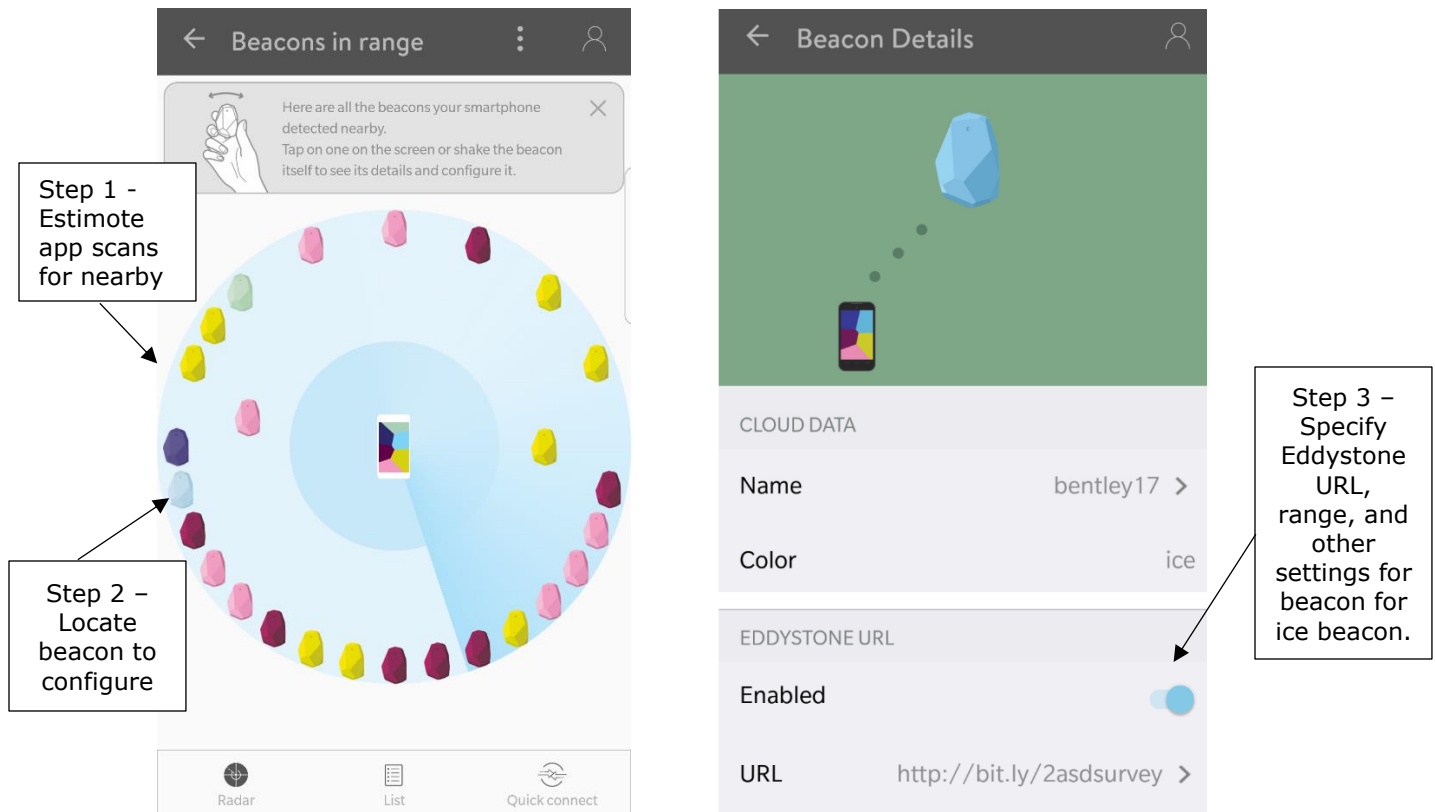


Figure A5. Configuring Beacons with the Estimote App.



Figure A6. Information card placed at each seat for Spring 2018 Admitted Student's Day, with instructions for participating in the Physical Web campus tour.

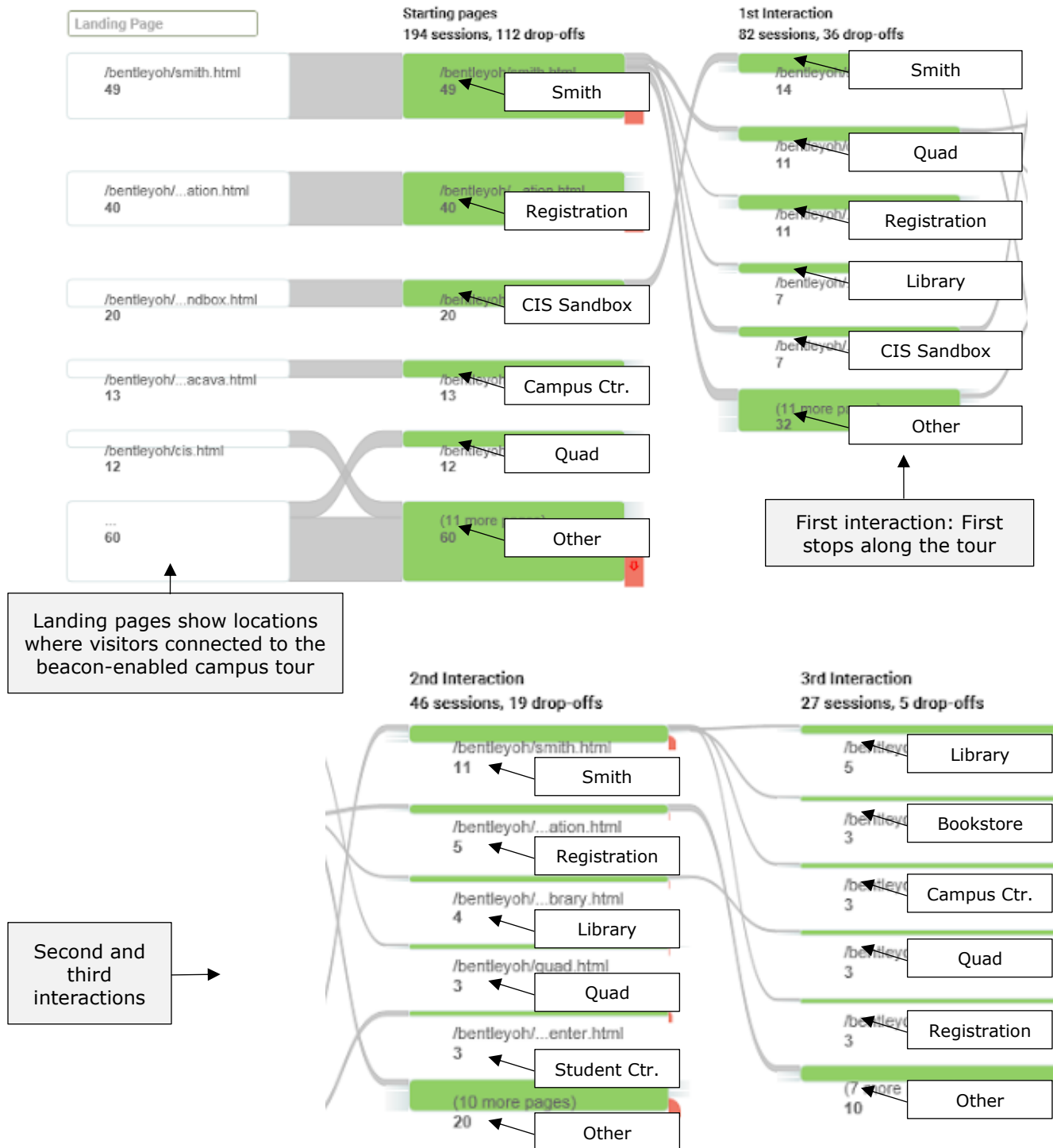


Figure A7. Google Analytics shows user behavior for the Fall 2017 Prospective Student's Day. The height of each green bar represents the number of visitors to its corresponding webpage.