# UNIVERSITY<sup>OF</sup> BIRMINGHAM

An Overview of Internet of Things (IoT) for Study Space Monitoring

## 1. Purpose

Finding a seat in some of the study spaces around the university has become an important issue for students. A survey from Bilyard & Johnson (2017) has found that finding a seat in the library is classified as a major issue or very major issue for 69% of students at the University of Birmingham. The need for a study spaces monitoring system has become essential. This kind of system will have a twofold benefit: for the students, it will help them to easily find a seat in the library; whereas for the staff at the university, it can be used to monitor the room occupancy and improve student satisfaction. However, developing a real-time room occupancy system is challenging. Accuracy, reliability, cost, and efficiency are key factors in choosing the right system. In this document, we present several *Internet of Things* (IoT) technologies that can be used as a tool to monitor the study spaces throughout the university. We also outline the pros and cons for each system, and give recommendations for the best system. Finally, A SWOT analysis and an evaluation matrix score are also carried out to give an overview score of this system.

# 2. IoT for Occupancy Monitoring

### 2.1 Bluetooth Low Energy (BLE)

Bluetooth Low Energy (BLE) is one of the most exciting new technologies that offers indoor location detection and can be used as a tool to monitor room occupancy, including the availability of study spaces around the university. BLE has a higher accuracy and consumes less energy for an indoor positioning system, compared to Wi-Fi or GPS.

BLE technology is available for two major mobile operating systems: Android and iOS. BLE uses a small device to advertise its unique ID called *Universally Unique Identifier* (UUID). The mobile phones will use this ID to identify the BLE beacons around. This UUID allows any devices within the proximity of the beacons to recognise each beacon with a high level accuracy. A study from Corna et. al. (2015) found that a room occupancy detection using BLE beacons has 80%-90% of accuracy in detection.

To preserve the energy, BLE beacons only advertise the UUID without doing much work on its own. Signal processing and any other actions are done within a mobile device that detect the beacon. With regard to the signal strength, BLE beacons have a range of up to 200 meters. However, in a real world, this range might vary due to the interference, for example: physical objects, human body, wall, etc. The signal strength of beacons is configurable to suit the needs.

In terms of the interaction with the other devices, BLE beacon has two different mechanisms: *region monitoring* and *ranging*. In the first mechanism, an action will be triggered whenever a device is entering/exiting the beacon's region. A mobile app using this mechanism will work both on background and foreground, additionally, the app will keep working even it has been killed. Whereas the latter mechanism works based on the proximity of the app to the beacon and it only works on the foreground.



Figure 1. Architecture model of BLE system

The architecture model for the study space monitoring system using BLE beacons can be seen in the Figure 1. The beacons will advertise signal and data that can be captured by the mobile app. The app will identify the beacons with a smart algorithm to determine the

Ref: Internet of Things for Study Spaces Monitoring Overview 28/09/2017 Adhi Wicaksono (ITIC Intern, CS Phd) <u>Axw412@cs.bham.ac.uk</u> location within the study space and its occupancy status. Then, the app will transfer the data into server for further analysis. The other students can get a real-time update about the room occupancy status by accessing the data server via a mobile app. For the staffs at the university, they can also access the data in the server to get a real-time status about the room capacity and they can inform the students if some study spaces still have plenty of empty seats.

One of the leading companies in BLE beacon is Estimote (<u>estimote.com</u>). Estimote has provided a full-fledged support to implement a beacon-enabled detection system, including the hardware (BLE beacons) and also the software (Software Development Kit for Android and iOS). The availability of the SDK will help the developers in creating a project that leverage the power of BLE beacons and ensure that the app developed is fully compatible with the beacons.

The weakness of this approach is the necessity of the students to install a mobile app to detect the BLE beacons. Additionally, the approach requires students to turn on the Bluetooth on their phone. This makes the implementation not viable because it requires a lot of effort from the students and too obtrusive. Moreover, the accuracy of this approach for a room occupancy system is low because it cannot detect how many students are in the room unless all of them install the app.

#### 2.2 Pressure Sensor

The other technology for room occupancy monitoring system is using pressure sensors. This approach uses a sensor attached to the chair. As the name implies, the sensor will detect any force/pressure when someone is sitting on the chair.



Figure 2. Pressure sensor architecture (Jacobson & Johnson, 2014)

Using pressure sensor has a higher accuracy in term of occupancy detection because it monitors per chair, compared to abstract detection in BLE. The pressure sensor is also cheaper than BLE. However, in terms of practicality, installing the pressure sensor on each chair can be complicated because each sensor requires a processing system to transfer the data (usually using Arduino). Until now, there is no company who provides a room occupancy monitoring system using pressure sensors.

The approach of using pressure sensor is still limited in the stage of research and development. Jacobson & Johnson (2014) designed a prototype for a room monitoring system using pressure sensor. The installation of the system required a pressure sensor connected to Bluno (an Arduino board with bluetooth connectivity). The pressure sensor circuit also had an Atmega 328 microprocessor and a resistor. To power the circuit, they used 9V wall wart, although in the final design they use solar cells as the power source for the pressure sensor circuit. Due to manual installation, using pressure sensors for study space monitoring in the university would require a lot of efforts because we need to manually install the circuits for all of the chairs. The other disadvantage of this approach is the reliability of the system. If a person leaves his bag on the chair, the sensor will read is as occupied. Therefore, it needs more effort to design the algorithm for the occupancy detection.

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#### 2.3 Passive Infrared Sensor

The other technology for room occupancy sensing that has been widely used by the commercial companies is passive infrared (PIR). This technology uses infrared to monitor heat and movement from its surrounding. A PIR sensor is usually attached under the table to monitor the activity from a person who uses that table. The sensor is equipped with wireless transmission that transfer the data to the central wireless hub, which then upload the data to the cloud to allow real-time monitoring.



Figure 3. PIR sensor from Occupeye (www.occupeye.com)

Among the other approaches, PIR sensor is the most effective and has been developed in various companies. The accuracy and reliability are also very good. The other advantage is its easy installation. Furthermore, a lot of commercial providers already provided the tech support that will help the installation process. The installation also comes with a software bundle that is able to monitor the room occupancy in a real-time, so the client does not need to develop an additional software.

Some of the companies that provide room occupancy monitoring system are:

- Occupeye (<u>www.occupeye.com</u>)
- Enlighted (www.enlighted.com)
- Condeco (<u>www.condecosoftware.com</u>)

#### 3. SWOT Analysis

Based on the above overview of the use of the Internet of Things (IoT) for room monitoring system, we carry out with SWOT analysis as follows.

#### **OPPORTUNITIES STRENGTHS** Using passive infrared sensors is The software that comes with easy and can be deployed quickly. passive infrared sensors offers some Passive infrared sensors have a high opportunities to build other services level of accuracy in detecting on top of their existing system, such occupancy, it is very suitable to be as mobile app that uses API. used for student space monitoring There have been no study spaces monitoring system for student, system. Some companies offer a bundle of whereas the need is quite high. hardware and software, making it Open up possibilites to connect with very useful. the other services in the university. **WEAKNESSES** THREATS University has around 24,000 seats Need more piloting to test the and deploying passive infrared reliability of the system. sensors for that amount would be Developing an app on top of their challenging. system needs to comply with their > The price for such system maybe existing software architecture. expensive.

### 4. Conclusions and Recommendations

Bluetooth Low Energy (BLE), pressure sensor, and passive infrared (PIR sensor) can be used in room occupancy monitoring system, including study space finder. Whereas all of them have a good accuracy, the characteristic from each technology is different. BLE requires a mobile app to be installed from the user's side, making it too obtrusive. It also requires the Ref: Internet of Things for Study Spaces Monitoring Overview 28/09/2017 Adhi Wicaksono (ITIC Intern, CS Phd) Axw412@cs.bham.ac.uk users to turn on their bluetooth in order to detect the occupancy. Whereas pressure sensor and passive infrared do not need any effort from the user's perspective. The problem with pressure sensor is too complicated in term of installation, making it not feasible to be implemented in the university due to the amount of study spaces (24,000 spaces). This leave PIR sensor as the best alternative for room occupancy monitoring. PIR sensor has been widely used by various companies and is proven to be work and effective. It is also easy to install and comes with software to monitor the real-time occupancy. In term of the cost, we need to talk directly to each provider to compare the pricing.

Area	Scoring System	Score	Reason
Maturity	1 = Idea 5 = Mainstream Product	3	Study Place monitoring is becoming a critical issue for the organization. Commercial companies are providing off-the-shelf products.
Technology (Adoption timescales)	1 = > 3 years 5 = < 3 months	4	There are commercial products off the shelf which are ready to be adopted.
Business Process (Adoption timescales)	1 = > 3 years 5 = < 3 months	4	There will be some business process changes involved in terms of adoption of the system.
Adoption Overview	1 = v long time 5 = very short	4	Reasonable timescale if using the commercial product; some business process changes involved.
Existing Technology (Impact)	1 = v large impact 5 = very little	5	There is little or no negative impact on existing technology.
Resources Required	1 = v large impact 5 = very little	2	A large resource will be required to install the system both hardware and software, with support needed in the long run.
Scope	1=very difficult 5=very easy	2	The system is only designed for study place monitoring, which makes it quite difficult to use in other area.
Usability	1=very difficult 5=very easy	4	It is easy for user to check the availability of the seats from app or web browser.
Security	1 = very poor 5 = excellent	4	Security features is considered in the commercial product.
Innovation Value	1 = low innov. 5 = high innov.	4	It will enable the students to find study places quicker and easier, which will increase the students' satisfaction.

#### 5. Appendix I. Evaluation Matrix Scores

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Cost Effectivene ss	1=very expensive 5=very cost effective	2	The overall cost for implementing such system in the university wide is quite expensive.
Adoption Readiness Score	<20 - not ready 20-29 - emerging 30-39 - Adoptable >39 Fully Ready	30	Adopt a study space monitoring system will make it easy for students to find a study space in the campus. Although it will require a big investment and resources, it will increase students' satisfaction and benefit the university.

**Note**: Rows that have no highlight colour indicate the score value is not added to the adoption readiness total. Instead, the overview score for that area is used as part of the total score.

### 6. Reference

Bilyard, R., & Johnson, L. (2017). WhereChair. Retrieved July 13, 2017, from <a href="https://intranet.birmingham.ac.uk/it/innovation/documents/public/ETech/Wherechair.pdf">https://intranet.birmingham.ac.uk/it/innovation/documents/public/ETech/Wherechair.pdf</a>

Corna, A., Milano, P., & Nacci, A. A. (2015). Occupancy Detection via iBeacon on Android Devices for Smart Building Management. In 18th IEEE Conference on Design Automation & Test in Europe (DATE). <u>http://doi.org/10.7873/DATE.2015.0753</u>

Jacobson, Sophie., & Johnson, Brooke. (2014). Olin Library Seat Status Tracker. Washington University in St. Louis.