Does implementation of BLE technology affect synchronous communication in an office space?

Bachelor of Science Thesis in Software Engineering and Management

ANITA POURFERDOSI
PUSHPENDRA UPADHAYAYA

Does implementation of BLE technology affect synchronous communication in an office space?

This study examines communication in a co-located context, emphasising on the role of location-awareness through the introduction of Bluetooth Low Energy (BLE) technology in an office environment. An investigation into the relationship between location-awareness and face-to-face communication is conducted at the offices of Sigma ITC. How much privacy is traded by the employees in favour of localisation via BLE, and its effect on communication practices is inspected here. The methodology consists of developing a mobile application acting as a localisation artefact in combination with BLE iBeacons placed at the case company. A privacy-related questionnaire and, a series of interviews with the employees form the data collection process. Evaluation of collected responses through emergent coding identifies the prominent themes later highlighted as answers to the proposed research questions. Synchronous communication is found to remain unaffected by location- awareness on the study. The employees are found willing to sacrifice some aspects of privacy in favour of localisation, albeit with certain reservations about time and choice. No discernible effect is seen in terms of communication frequency thus, the overall effect of BLE on communication is said to remain inconclusive from this study.

Supervisor: {MIROSLAW. OCHODEK}
Examiner: {MICHAL. PALKA}

University of Gothenburg
Chalmers University of Technology
Department of Computer Science and Engineering
SE-412 96 Göteborg
Sweden
Telephone + 46 (0)31-772 1000

[Cover: Estimote iBeacons, Nearables]

Does implementation of BLE technology affect synchronous communication in an office space?

A Case Study

Anita Pourferdosi
Software Engineering & Management 2015 -18,
Dept. of CS&E, Göteborgs Universitet
Göteborg, Sweden
gusanipo@student.gu.se

Pushpendra Upadhayaya
Software Engineering & Management 2015 -18,
Dept. of CS&E, Göteborgs Universitet
Göteborg, Sweden
gusupapu@student.gu.se

***Abstract**: This study examines communication in a co-located context, emphasising on the role of location-awareness through the introduction of Bluetooth Low Energy (BLE) technology in an office environment. An investigation into the relationship between location-awareness and face-to-face communication is conducted at the offices of Sigma ITC. How much privacy is traded by the employees in favour of localisation via BLE, and its effect on communication practices is inspected here. The methodology consists of developing a mobile application acting as a localisation artefact in combination with BLE iBeacons placed at the case company. A privacy-related questionnaire and, a series of interviews with the employees form the data collection process. Evaluation of collected responses through emergent coding identifies the prominent themes later highlighted as answers to the proposed research questions. Synchronous communication is found to remain unaffected by location-awareness on the study. The employees are found willing to sacrifice some aspects of privacy in favour of localisation, albeit with certain reservations about time and choice. No discernible effect is seen in terms of communication frequency thus, the overall effect of BLE on communication is said to remain inconclusive from this study.*

Keywords: BLE, indoor localisation, synchronous communication, iBeacons, face-to-face discussions, privacy v/s location-awareness

I. INTRODUCTION

Direct verbal communication and face-to-face discussions are an integral part of development in agile projects [1]. These are also the quickest, most efficient methods of information exchange between developers working at the same location [10]. Additionally, informal and ad-hoc communication between developers working in agile teams is often considered equally relevant as formal communication [2]. Unscheduled, synchronous communication helps align perspectives and, bridges the gaps between subjective interpretations of requirements thus, reducing chances of logical misgivings and misunderstandings while developing a software product [3, 4].

To have such unscheduled in-person talks, teammates must be able to locate each other which can be challenging in large office buildings, especially when people are spread far out and unbound to a schedule or a particular office space.

Multiple solutions are currently employed to facilitate communication between teams within the industry, with research suggesting that teams working at the same location communicate more efficiently and make use of co-located office spaces, whiteboards, status boards and, informal communication means such as face-to-face conversations and discussions for synchronous communication [5, 6]. Asynchronous communication is mostly handled via emails and online resources for collaboration such as desktop sharing and instant messaging [8, 9]. Remote collaboration, between teams separated over large distances, is mostly handled over the phone or through other synchronous means such as video-calls and, planned meetings with everyone involved travelling to a common location.

This research study expands further on the work in this area and examines communication in a co-located context, where it emphasises on the role of location-awareness through the introduction of Bluetooth Low Energy (BLE) technology in an office environment.

BLE[1] is a fairly modern enhancement on existing Bluetooth framework of technologies and has the advantage of granting associated devices with long lasting life-cycles. Implements of this technology include small devices such as fitness trackers and, advertisement beacons capable of broadcasting an identifier and small packets of information which can then be detected by nearby BLE-capable devices such as smartphones. A type of these beacons (iBeacons) are used in this study to register users when in proximity to a beacon thus, helping with indoor-localisation at the office spaces of the case company.

The main research question considered in this study is:

---

[1]https://blog.bluetooth.com/bluetooth-low-energy-it-starts-with-advertising

Q) Does implementation of BLE technology for indoor localisation *affect* synchronous communication within agile development?

The effect would be investigated by answering the two related sub-questions as follows:
  1) Is the frequency of unplanned synchronous communication affected by being aware of where people are in an office space?
  2) To what extent are employees willing to trade privacy for location awareness in the office space?

In this study, we evaluate the application of new indoor localisation technologies and how they could influence communication among software development agile teams. In addition, we developed a software application prototype using BLE and iBeacons for indoor localisation which is used by the developers at the case company (Sigma ITC).

This document is organised as follows: Section II provides the relevant work in literature within this area. Section III describes the research methodology followed on the study along with the evaluation criteria for collected data. Results from the data and a detailed description of the artefact developed during the study are provided on Section IV. An analysis and discussion surrounding the obtained results, attempting to answer the identified research questions are presented on Section V. An appendix providing all the collected data, questionnaires and interview questions used during the study can be found at the end of the document.

II. RELATED WORK

Literature is abundant with studies discussing communication; most discuss communication in distributed environments and, the effect that differences in culture, work practices, language may have on communication between developers or; examine the various technologies used for remote communication to bridge these inherent differences in distributed projects. Quite a lot of research focuses on the effect of environmental variables such as open-plan layouts, organisation into cubicles, noise levels and number of gathering places in an office space. Only a few studies exist about communication in co-located environments, and even less so from a technological perspective. Some of this relevant research and associated findings are presented in this section.

A. The Problem Domain

Hummel et al. [1] conducted an extensive systematic literature review examining the role of communication in agile software development. The review attempted to identify research gaps within the communication process in software development by scrutinising 333 research documents. From their analysis, 155 studies were related to communication and team-distribution where in co-located environments factors such as spatial layouts, barriers, noise levels and their impact on communication, its frequency and, usefulness were investigated. Informal face-to-face communication is discussed in detail from a number of studies, with the summary of the findings quoted on the review as follows:

"Informal face-to-face communication as the primary device for knowledge sharing has proven most effective, and it is suggested to utilize it as often as possible because it involves little filtering and distortion (Korkala et al. 2006; Mishra et al. 2012). Developers are also reported to strongly prefer face-to-face communication because immediate feedback is possible and misinterpretations can be easily avoided (LaToza et al. 2006). Specifically, it has been observed that fewer mistakes are made and less rework has to be done when important information is continuously shared through informal communication (Petersen and Wohlin 2009)."

The subset of studies examining the role of informal communication relate to our thesis work, which would attempt to verify these results at Sigma ITC and comment on the frequency and usefulness of informal communication in a co-located environment connected via BLE technology.

B. Potential Solution Approaches

Layman et al. [2] describe how globally-distributed software development teams collaborate on projects using methodologies relying on informal communication and face-to-face conversation. Conclusions from this study suggested asynchronous methods such as emails as an option for communication between geographically distributed teams, however; contradictory results were cited from studies on co-located teams by Layman[15, 16, 17], where the introduction of XP increased informal exchanges between developers and, helped improve overall quality of releases compared to traditional practices involving less informal interaction. Pikkarainen et al. [7] conducted a case study comparing between communications strategies used within agile projects. Their findings suggested that agile practices markedly improved both informal and formal communication between development teams and; a number of communication mechanisms, formal and informal, needed to exist to ensure coordination on projects.

The subject of "Privacy vs Location Awareness" is discussed at length by Sami Levijoki [11], highlighting important concepts and vulnerabilities about the intrusiveness of various location awareness technologies such as infrared, GPS and RFIDs. How intrusive can these be to one's privacy and, the overarching legislation applicable to the use of such technologies in different environments is also discussed in the study (Levijoki's). It concludes describing the trade-offs between being location aware and maintaining privacy; ultimately considering permission from an informed user to be the deciding factor for the use of any location aware technology.

C. Indoor Localisation Studies

The performance of indoor localisation systems using BLE [12], and a mixture of BLE and Wi-Fi are evaluated in [13]. However, no research has directly addressed the role of awareness in terms of co-location and its impact on synchronous communication; something we attempt to do on this study.

III. RESEARCH METHODOLOGY

Since this research aims to investigate synchronous communication between developers in a real-life context [14], a case-study at the software firm Sigma ITC was chosen as a suitable research approach. Most employees here work in small, co-located teams and are accessible to each other at their respective workstations for the most part. Communication at Sigma ITC flows through multiple channels where employees are requested to use status messages over Skype or Slack to indicate whether they are at work, busy, or available at any given moment. However, response to this system of communication and digital presence registration had been underwhelming thus far, with employees expressing disinterest at regularly updating their statuses online and having to use multiple tools to stay informed about others. None of the communication tools used provided support for indoor localisation and a further problem of non-uniformity through the use of multiple communication platforms seemed to occur here.

Therefore, the first phase of this case study involved developing an artefact to introduce indoor localisation within this office environment and, provide an efficient manner of discovery, detection and, localisation for all employees working in the same locale. The developed software artefact was made accessible in the form of an Android mobile application and communicated with low energy Bluetooth devices such as iBeacons integrated into the office environment. The application would poll for user location indoors through judging user proximity to these beacons and then make this data available for retrieval by other users of the application thus, providing a means for increased location awareness among users of the app working at the case company. The beacons were strategically placed throughout the workplace after asking the employees' opinions regarding which locations in the office would they like to be informed about and, which spots did they think most appropriate for location awareness purposes without feeling distracted or, being invasive in terms of privacy and freedom of movement at the workplace.

Data collection during the study took place in three phases and mainly focussed on answering the research questions from a qualitative perspective by taking into account the employees' experiences before and after the deployment of said artefact at the workplace. A short questionnaire (see Appendix) was used during the first phase of data collection and it collected responses about privacy concerns and issues regarding location tracking and awareness. It included questions asking people about how often they wished to be tracked, which locations in the office they would consider appropriate for tracking and, which method of interaction (email, instant messaging, face-to-face meetings etc.) they preferred. Further questions about how intrusive they found a location tracking application such as ours to be, how concerned were they in general about privacy issues in a connected workspace and, would they be willing to sacrifice privacy in favour of being more location-aware; were asked on this questionnaire. Responses accumulated during this phase helped us gain an understanding about the employees' privacy concerns in the workplace at Sigma ITC and enabled us to determine an answer for the research sub-question addressing this issue (Sub-question 2). The questionnaire also helped determine some of the implementation and interaction details on the artefact.

The second and third phases of data collection took place after completion of artefact development and were conducted through a series of semi-structured interviews. The first set of interviews (see Appendix) were conducted before artefact deployment and focused on determining a baseline regarding communication preferences, practices used at the case company. Questions such as how did the developers communicate on projects, where most discussions took place, and how often; were asked on these interviews. To determine the extent and, role of location awareness; additional questions regarding how often was there a need to locate a certain person in the office space and, how long did it take to locate said person; were also asked on these interviews and helped collect relevant data for later comparisons, after deployment of the developed artefact.

The application was then made available for use to the participants on these interviews with the beacons deployed around the office. The participants were briefed beforehand about the application's functions and capabilities, with simple instructions provided to ensure ease-of-use and least possible learnability issues. This allowed for a perceived best case scenario in terms of gathering data pertaining to user experiences for the next round of interviews. The employees were then given a week to experience this new office environment and use the application, after which interviews conducted again asking the users to summarise their experience. The two sets of responses from the interviews were then compared and; qualitatively analysed to determine the effect of location awareness in office space and whether it made any difference to the communication practices.

Evaluation was mainly based on the difference in user responses before and after the implementation of BLE in the office. Questions pertaining to the reported time estimates to locate someone, usage of the application and, frequency of usage constituted the most important aspects of evaluation

here. Data analysis was carried out manually by reviewing the interview-transcripts and through the process of coding [18]. Common themes on the responses were identified through emergent coding and the most frequently occurring ones (themes) were considered as the overall response for the questions. This related to the main research question on the study and also helped determine an answer to the first sub-question. The second sub-question was answered exclusively through results gathered from the privacy questionnaire and the analysis based on majority between the options picked i.e. the most frequent choices as answers for each question determines the collective response for it on the questionnaire.

Validity Threats to our study may include the observer effect i.e. people behaving differently than usual knowing they are part of a study. Technical limitations of the equipment used on the study such as low accuracy of localisation, or irregular performance issues from any number of the beacons used could be another performance-based threat, which we hoped to eliminate through rigorous testing of all hardware before deployment. Moreover, learnability issues could be encountered by users due to the relatively short time-frame between exposure, data collection and, evaluation of the implemented solution however; attempts to reduce such issues were made by providing clear usage instructions and guidelines to the participants beforehand. Similarly, skewed results may be observed due to this relative short time frame as factors such as eagerness to use a new technology, or a short-term hype without being aware of the problems, or the opposite - being afraid of new technology to experience its benefits; might affect people's perceptions and thus, influence the frequency of usage for the artefact and affect the results gathered on the study. The sample size used for data collection is rather small and presents a threat to any generalisations made from the results of this study.

IV. RESULTS

A. BLE Scanner & Localisation app

The developed artefact was a mobile application running on Android smartphones capable of BLE detection. It was written in C#, using Visual Studio[2] and Xamarin Android[3] Development Tools. Estimote Proximity SDK[4] and CrossBluetoothLE[5] were the plugins used for detection of BLE devices. The application was then paired with a Mobile Service created using Microsoft Azure[6], providing an intermediate layer for communication with a Node.js database configured using Azure SQL[7]. The application consisted of an interface for the users to register themselves and be uniquely identified on the application. It provided capabilities to scan

for BLE devices in the vicinity before determining their order of proximity, and assigned the closest device detected as the location for an instance of the app. Since we were only interested in monitoring and registering certain chosen areas of the office as locations, the scanning had to be filtered to only identify the pre-assigned beacons placed by us in these locations. The beacons are identified by their 16-byte unique identifier UUID defined in the iBeacon[8] protocol developed by Apple. The beacons were placed around the office and configured to advertise small packets of data containing their location. Beacons used on this study were part of the beacon development kit manufactured by Estimote[9] and were configured using Estimote's portal for interface with iBeacons to broadcast the necessary information. The proximity of beacons to the users; was determined using the received signal strength indicator (RSSI) metric. The RSSI metric (defined in units of decibels (dB) or decibels per miliwatt (dBm)) is a measure of the intensity of received signals from each of the beacons to the app. The closer the RSSI value is to 0, the stronger the signal and the closer the beacon. The farther the source of a signal, the RSSI value becomes increasingly negative and has an upper threshold of -90db beyond which the distance to the source becomes too great and can no longer be detected. The mobile application was then configured to work with a mobile service provided by Microsoft Azure and communicated with a cloud-based database to store usernames and their perceived locations as determined by the app. This stored data, pooled from multiple users could then be accessed on the application and would indicate a user's location in the building/ offices at Sigma ITC. In order to respect people's privacy and always have explicit permission for tracking, the users were notified by the app when coming within the proximity threshold of a beacon after which they could choose whether or not to register their presence i.e. send over the location data to the server at that particular location, making this information available for viewing to other instances of the app within the office building.

Development of this artefact required approximately 21 days and constituted an important part of this study. A simple representation of its architecture is provided in the Appendix (see Appendix, Figure 7).

B. Questionnaire

To better understand the privacy concerns and implications of indoor-localisation, a survey using a questionnaire was conducted. The questionnaire was created using Google Forms and shared via email with all the employees working at Sigma ITC, Lindholmspiren 9. We gathered 19 responses from this pool of employees in total and, all of the respondents were software developers in some capacity but with differing roles such as a Project Manager, Tester, Front-end developers etc.

---

[2] https://www.visualstudio.com/
[3] https://www.visualstudio.com/xamarin/
[4] https://developer.estimote.com/proximity/android-tutorial/
[5] https://github.com/xabre/xamarin-bluetooth-le
[6] https://azure.microsoft.com
[7] https://azure.microsoft.com/sv-se/services/sql-database/

[8] https://developer.apple.com/ibeacon/
[9] https://estimote.com/

A total of 8 questions were asked on this questionnaire; Question 1 aimed at understanding the prevalence of commonly used methods for synchronous communication at the case company. Question 2 narrowed the scope further and focused on a single type of synchronous communication, 'face-to-face', attempting to identify the most commonly used areas at the office for such communication. These questions helped determine the frequency and, role of synchronous communication, especially 'face-to-face' communication within the employees' routines at the workplace. Questions 3 & 4; introduce the concept of location awareness via beacons and helped determine the willingness among the participants for tracking themselves and their co-workers via the developed artefact (Q3). Responses collected on Q4 identified the most appropriate areas for placing the iBeacons. Questions 5 & 6 were aimed at assessing intrusiveness to one's privacy, helping determine the extent till which the users found location tracking through the mobile app acceptable. The assessment comprised of a time component and, an interaction component with users being asked to answer how often did they wished to be tracked (Q5) and, then about their preferred mechanism/ approach to localisation (Q6). Provided responses on both these questions ranged from the 'most intrusive, least private' to the 'least intrusive, most private' approaches, with the results later helping decide the mechanism used on the app during the study. Questions 7 & 8 addressed privacy concerns in a more direct manner; responses to these questions provided an indication of the general attitudes towards privacy; if the participants' appeared too concerned about being localised or in terms of their privacy – they may not use the app at all thus, having an influence on later results during interviews after deployment and, suggesting an answer to the privacy quotient on the study.

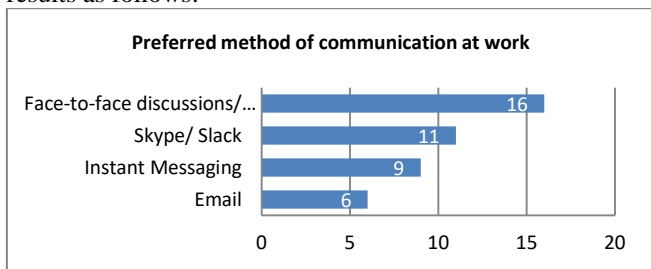A total of 19 respondents answered the questionnaire, with the results as follows:

Figure 1: Results (Q1) Communication preferences at the workplace

Majority of the responses indicated 'Face-to-Face discussions' as being the preferred option for synchronous communication. 16 of the 19 (84%) respondents chose it as one of their preferred options (see Figure 1) thus, indicating a significant role for this type of communication within the context of their duties and routines at the workplace.
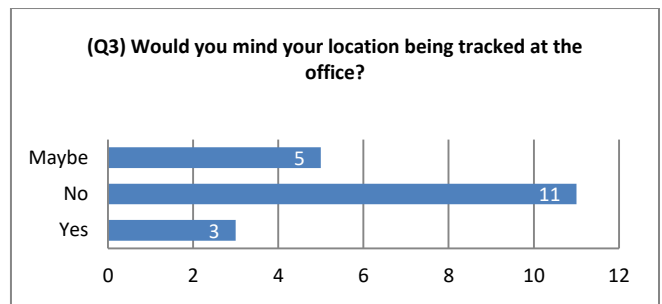

Figure 2: Results (Q3) Aversion/ agreeableness to location tracking for indoor localisation

Results from Q3 indicated that majority (58 %) of the participants did not mind being tracked by the application at the workplace (see Figure 2). Tracking, in this context, referred to their locations with respect to the beacons and worked only in specified spots where iBeacons were placed.
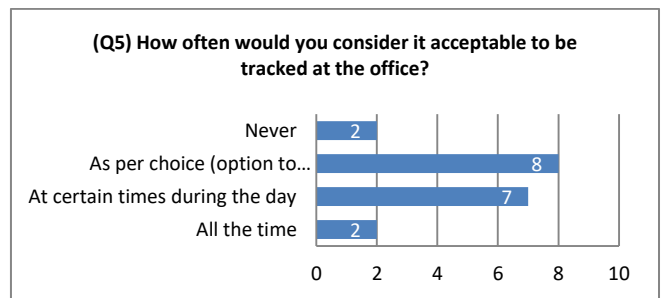
Figure 3: Results (Q5) Frequency of Tracking

As for the time component of intrusiveness, majority of the results indicated users preferring to have the choice of when to be tracked (see Figure 3). This was presented as the 'least intrusive, most private' option among the available answers to this question; granting users the most control with regards to location tracking on the application thus, signaling towards certain privacy concerns and reservations in terms of an acceptable frequency of location tracking at the office space via the app. An almost equal split was seen among the results, with a number of responses (7/19) choosing the slightly 'less private, more intrusive' option of allowing the application to automatically track user locations at certain times during the day (see Figure 3). Both these approaches to tracking were then implemented on the app, with an option to explicitly scan for beacons and register user location in the foreground and, through an automated background service doing the same every hour when turned on by a user.

Figure 4: (Q6) Acceptable approaches to localization and interaction

Figure 5: (Q7) Respondent's level of perceived intrusiveness to privacy through use of a location awareness app
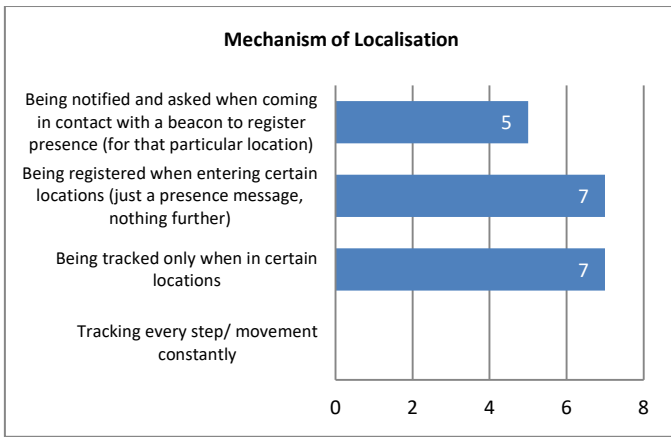

Figure 6: (Q8) What is your general level of concern regarding privacy issues in a digitally-connected work space?

For the interaction component of intrusiveness (to privacy), the participants were asked to choose between various methods for indoor tracking and localization. All methods were considered intrusive to differing extents, with "constant and automatic tracking" considered as the 'most intrusive, least private' option and, "being notified and asked to register/ broadcast one's location when encountering a beacon" considered as the 'least intrusive, most private' response to the question. A considerable proportion (5/19, 26 %) of the responses seemed to prefer the option offering the most privacy thus, indicating some concern regarding privacy among the respondents in terms of the approach used towards localization. An even split (7/19) was observed between the other two relatively 'more intrusive, less private' options and, none of the respondents seemed to prefer the most intrusive and least private option among the available answers (see Figure 4). Keeping these results in mind, two approaches to interaction regarding mechanism of localization were implemented on the app, with an option to be notified on detection (of a beacon) and then having the choice to broadcast this as your current location -- representing the most private option or, allowing the background service to notify and register user location automatically on detection (of a beacon), broadcasting this information for other users to see; being the relatively 'less private, more intrusive' option to localisation. Since 100 % of the collected responses seem to indicate some level of concern regarding privacy, it can be inferred that the employees were agreeable to losing some privacy in favour of location awareness but, none of them were agreeable to losing all privacy in favour of indoor localization, without being able to explicitly grant permission on the application to do so. This also reinforces Sami Levijoki's conclusions on the subject of "Privacy vs Location Awareness" [11] where explicit permission from an informed user is considered to be the deciding factor for location-awareness services and all its associated trade-offs.
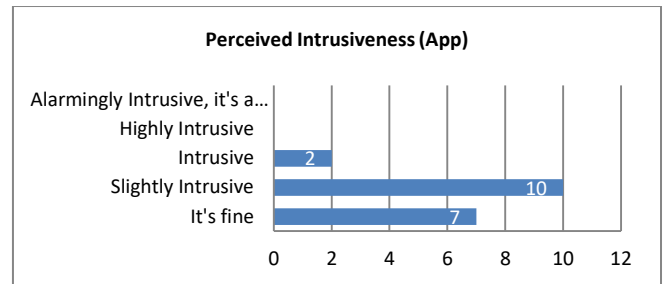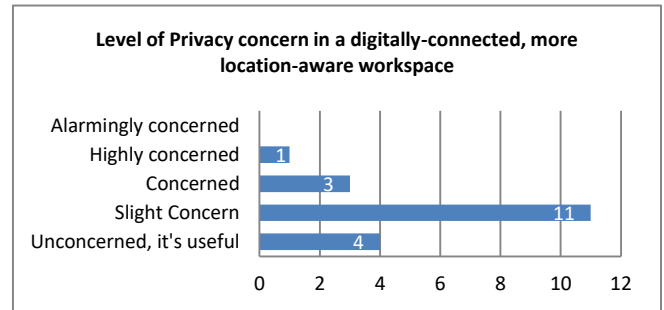
Responses gathered on Q7 and Q8 provide some insight about the employees' general attitudes towards privacy and, the level of concern regarding location tracking via a location awareness application. The results show majority of the employees choosing moderate responses on these questions (see Figure 5, 6) thus, indicating slight concern regarding the premise and functionality of the application, however; some apprehension on introduction of a new system was always to be expected and, the overall level of concern was considered insufficient to affect the usage of the application by the participants.

C. Interviews

The study involved carrying out two interviews with the same set of participants before and after the deployment of the beacons and the app. A total of 6 participants were involved on these interviews. The participants were selected from the respondents on the earlier questionnaire and based on their availability, ensuring their participation at least twice and avoiding time or, scheduling constraints. The interviews were conducted face-to-face and all questions had to be answered. Admittedly, the sample size was quite small but varied enough in terms of the duties and roles carried out by the participants.

C.1: Pre-interviews

As mentioned previously (Section III), results from the first set of interviews (pre-interviews) focussed on determining the frequency, need for localisation and, the possible difficulties (to locate someone) as faced by the participants, given the

practices used for communication and indoor localisation before the app.

The major points of analysis were how often was there a need to locate someone, how difficult was it to locate them, which were the preferred methods for communication and how prominent was face-to-face communication in the employees' daily work routines. Common themes were then elicited from the gathered responses and used as emergent codes (see Appendix-II, Table 1 & 2) to tally the responses. The most frequently occurring codes were the used as the cumulative answer for aforementioned points of interest.

Results from the pre-interviews (see Appendix-II, Table 1 & 3) suggested that direct communication and face-to-face interaction were often the preferred method for communication between the employees and represented an integral part of their overall communication and work routines at the office. Most responses from the participants suggested that the need to locate someone specific in the office did arise, however; the frequency for this was different for different roles. For instance, Project Managers needed to locate people more often than Developers. Methods used for localisation by the participants mainly involved going around to the other person's work space and checking if they were available (see Appendix-II, Table 3, Q6). The participants' described this method as adequate for its purpose, however; they were aware of its drawbacks including having to go elsewhere simply to know if someone was present or not, which could become annoying when located at opposite ends of the office or far away from one another. On being asked whether they (the participants) would consider an app aiding location awareness in the office space to be useful - majority of the respondents expressed a positive interest in such a solution (see Appendix–II, Table 3, Q8) and stated that it could be helpful and time-saving to know where people were at different times in the day thus, avoiding unnecessary trips searching for someone around the office.

The cumulative response gathered from the pre-interviews suggested that face-to-face communication and localisation were frequent needs in the roles carried out by the participants. This, in addition to the difficulties (in localisation) as pointed out by the employees indicated a scenario where a location awareness app, could be deployed in a supportive environment where we could be reasonably sure about it being used by the employees.

C.2: Post-Interviews

The post-interview sessions were conducted with the same set of participants (6) as earlier, after they had the opportunity to use the BLE-localisation app at the office for a week. Questions asked during this interview focussed on determining the usefulness of the app (from frequency of usage), its effect on localisation and, its effect on communication. A similar approach to analysis as before, through emergent coding

identifying common themes and tallying their frequencies, was applied here as well.

From the gathered results (see Appendix-II, Table 4 & 5), all six participants claimed to have used the application within the week. The reported frequency of usage among the participants showed little variation according to the roles occupied by the participants at the office, with most of the developers (Participants 1, 4 & 6) reporting a lower frequency of usage than participants in more communication intensive roles such as the Project Manager (Participant 3) claiming to have used the app 'often'.

On being asked whether the BLE-app made it easier to locate people, all participants agreed that it did make indoor-localisation easier (see Appendix-II, Table 5). As for the time it took to localise someone, all but one of the participants had a positive response, with all of them acknowledging the instant nature of localisation through the app thus, being quicker in terms of information exchange than the previously used approach for localisation i.e. having to walk over to someone's workstation (see Appendix-II, Table 5). The sole, remaining response from Participant 6 was a bit more ambiguous to decode as the subject did not have a particular need for localisation during the week and could not provide a definitive response of their experience of the time it took for localisation with the app.

The application's effect on communication was judged based on frequency – whether or not did people communicate more often being aware of where others were in the office space? Majority of the participants' responses to this question seemed to suggest that the frequency of communication for them remained the same even with the app (see Appendix-II, Table 5). The reasoning for this as given by several (3/6) of the participants was because, communication with others only took place when needed thus, having a localisation app made little difference as to how often the need to communicate arose, leaving no effect on communication frequency for these participants. Two of the six participants, however; did claim to communicate more often knowing when someone was in the vicinity regarding the other person as more approachable when nearby and open to consult on small matters that would not be part of an official discourse otherwise.

Nearly all of the participants seemed unconcerned about indoor-localisation through the application and could not suggest any issues or, problems in the time they had using the app (see Appendix-II, Table 5). One potential concern about privacy was raised by a participant where they did not wish for others to know their location at all times in the office, however; this was already taken care of in the app where the automatic service can be switched off by the user granting them total control of when and where to share information about their location. The testing period for the application was relatively short during this study thus; the possibility of potential drawbacks, over an extended period of usage, remains.

V. DISCUSSION

Frequency of communication was found to largely have been unaffected by the introduction of BLE localisation. The artefact acted its purpose and replaced the need to travel around the office to find someone to have a discussion thus, making localisation faster and easier. Majority of the interviewees (4 out of 6) on Phase-3 (post-interviews) stated that it had made no difference as to how often they communicated even after being location aware at the office. The reason for this might be that indoor localisation had no influence over how often people needed to communicate. A third of the interviewees however, did find communication to be more frequent under a more location-aware environment. Therefore, at this moment in time, from the data collected it is unclear whether BLE induced localisation had any effect on communication frequency. **Since, majority of the interviewees claimed that it made no difference, for now we conclude that frequency of communication remains unaffected by location-awareness.**

The employees were willing to trade privacy for more location awareness in the office, however; with some reservations about being tracked all the time and, being tracked in certain locations such as WCs around the office. To determine the extent of privacy traded, we can compare in terms of the accepted frequency of tracking and, places deemed appropriate for tracking by the employees on the questionnaire. Among the answers, majority of respondents avoided the response with the most frequent tracking i.e. 'all the time' thus, suggesting that there were times in the day when they (the employees) did not wish to be bothered or have their location known to others in the office. In terms of the places to be tracked or localised at; eight of the suggested nine areas for placing the iBeacons were considered acceptable by the employees, indicating their willingness towards location-awareness and little resistance through arising concerns related to privacy. Based on this data and reasoning, we can theorise that the participants (on the questionnaire) were willing to concede nearly all privacy with respect to where they could be tracked but, were less willing to give up on privacy regarding when they could be tracked.

The element of choice or, explicit permission was another factor considered when discussing privacy. To have localisation run automatically or, to explicitly grant the permission on the application to do the same; were the choices made available on the questionnaire. Majority of the answers avoided taking control away from the user thus, suggesting that the users wished to remain informed about when and where they were tracked. **From all this, we gather that overall the participants had no qualms about the introduction of BLE-localisation and were willing to trade privacy to the extent where they remained aware of being tracked, could choose the times they were tracked and, had the option to turn off the localisation service as per their wishes.**

We can speculate about the implications of this case study for the case company which already includes the provision of a faster and easier approach to localisation via the developed BLE application. The employees can choose to remain location-aware and perhaps, interact more often outside of planned spaces such as meeting rooms and group rooms. The number of users may increase in the near future as more employees become interested; the study only involved 6 for this test case. More use-cases for beacon-related functionality might be possible such as digital sticky notes or, location-tagged reminders; the company can choose to personalise the application to fit their demands better if necessary.

Limitations

The study was conducted in a very limited time frame; results may differ over an extended period of time. The participants had only a week to use the artefact and report their experiences, making it quite possible that familiarising oneself with the artefact and its usage might have played a role, effectively reducing this time even further. Since indoor localisation through BLE had just been introduced at the case company as part of this study, there may have been some curiosity/apprehension among the participants involved and may have influenced how often the application was used during this period. A very small sample of data is collected and used on the study thus; results may differ when repeated with a larger data set.

VI. CONCLUSION

Localisation can be viewed as an important precursor to synchronous communication and becomes an inevitable task when considering face-to-face discussions. The study set out to understand if there was any relation between being location-aware about one's colleagues and, communication in the workplace. We approached this issue with a purpose to ease indoor-localisation in terms of time and effort in large office environments.

Localisation capabilities implemented through BLE using iBeacons communicating with a mobile application; were tested as part of determining if any relation did exist, between communication and a more location-aware environment. Frequency and extent of privacy conceded were the two quotients identified to study the effect on communication.

Communication frequency was found to remain the same in majority of the observed cases. An increase (in communication frequency) was reported by a third of the participants knowing where someone, whom they wished to talk with, was. It is possible that such technology might ease communication; however, this cannot be confirmed from the limited evidence and small data sample used on the study. Any perceived effect on communication in terms of its frequency

can be considered inconclusive at best from the findings of this study.

The extent of privacy traded in favour of localisation was found to concern the times and places at which people could be localised and, control of the explicit choice between being traceable or not. Subjects on the study were found willing to trade privacy to the extent where they remained aware of being tracked, could choose between the times they were tracked and, had the option to turn off the localisation service.

The overall effect of BLE-induced indoor localisation on communication therefore, remains inconclusive from this case study.

Future Research

More data, in an expanded setting, possibly over a longer period of time could be collected to verify the presence/absence of an effect. Modifications could be made on the study, such as focussing on being more effective in solving problems that require communication -- comparing between the solutions arrived at using different communication methods in different environments, possibly adding a quantitative element to the analysis.

REFERENCES

[1]   Hummel, M., Rosenkranz, C. & Holten, R. Bus Inf Syst Eng (2013) 5: 343. https://doi.org/10.1007/s12599-013-0282-4

[2] L. Layman, L. Williams, D. Damian and H. Bures, "Essential communication practices for Extreme Programming in a global software development team," Information and Software Technology, vol. Volume 48, pp. 781-794, 2006.

[3] Melnik G, Maurer F (2004) "Direct verbal communication as a catalyst of agile knowledge sharing" In: AGILE 2004, Los Alamitos. IEEE Press, New York, pp 21–31

[4] Vidgen R, Wang X (2009) Coevolving systems and the organization of agile software development. Inf Syst Res 20(3):355–376

[5] Fruhling A, de Vreede G-J (2006) "Field experiences with extreme programming: developing an emergency response system". J Manag Inf Syst 22(4):39–68

[6] Mishra D, Mishra A, Ostrovska S (2012) Impact of physical ambiance on communication, collaboration and coordination in agile software development: an empirical evaluation. Inf Software Technology 54(10):1067– 1078

[7] Pikkarainen, M., Haikara, J., Salo, O. et al. Empir Software Eng (2008) 13: 303. https://doi.org/10.1007/s10664-008-9065-9

[8] Korkala M, Pikkarainen M, Conboy K (2009) "Distributed agile development: a case study of customer communication challenges". In: Abrahamsson P, Marchesi M, Maurer F (eds) Agile processes in software engineering and extreme programming (XP 2009). Springer, Heidelberg, pp 161–167

[9] Estler HC, Nordio M, Furia CA, Meyer B, Schneider J (2012) Agile vs. structured distributed software development: a case study. In: International conference on global software engineering. IEEE Press, New York, pp 11–20

[10] Korkala M, Abrahamsson P, Kyllonen P (2006) "A case study on the impact of customer communication on defects in agile software development. In: Chao J, Cohn M, Maurer F, Sharp H, Shore J (eds) AGILE 2006,Minneapolis. IEEE Press, New York, pp 76–88

[11] Sami Levjoki, "Privacy vs Location Awareness", Dept. of Computer Science, Helsinki University of Technology

[12] Hyunwook Park, Jaewon Noh, Sunghyun Cho, "Three-dimensional positioning system using Bluetooth low-energy beacons", International Journal of Distributed Sensor Networks, Published: Oct 4, 2016

[13] Pavel Kriz, Filip Maly, and Tomas Kozel, "Improving Indoor Localization Using Bluetooth Low Energy Beacons," Mobile Information Systems, vol. 2016, Article ID 2083094, 11 pages, 2016. doi:10.1155/2016/2083094

[14] Yin RK (2003) Case study research: design and methods, Saga, Thousand Oaks, CA

[15] L. Layman, L. Williams, L. Cunningham, Exploring Extreme Programming in Context: An Industrial Case Study, presented at 2nd IEEE Agile Development Conference, Salt Lake City, UT, 2004.

[16] L. Layman, L. Williams, L. Cunningham, Motivations and Measurements in an Agile Case Study, presented at Proceedings of the Workshop on Quantitative Techniques for Agile Processes (QUTE-SWAP '04), Newport Beach, CA, 2004

[17] L. Williams, W. Krebs, L. Layman, A. Anto´n, Toward a Framework for Evaluating Extreme Programming, presented at Eighth International Conference on Empirical Assessment in Software Engineering (EASE 04), 2004.

[18] Per Runeson, Martin Höst, Guidelines for conducting and reporting case study research in software engineering, Empir Software Engineering – 2009, Published online: 19 Dec 2008

APPENDIX

Privacy Questionnaire:
https://docs.google.com/forms/d/e/1FAIpQLScea7PDJnJHzsN3OloIbPM7lxRge-PJDW147XGpC0FgJselXg/viewform

Pre-Interview Questions:

Background (Job descriptions, Roles, Experience etc.)
1)   How long have you been working in this particular office space (Sigma ITC, Lindholmspiren 9)?
2)   Describe your role at the office. How important is communication towards fulfilling it?

Communication practices
3)   Describe the practices currently followed by you/ your team to communicate in the workplace.
4)   Which method of communication do you prefer? Why?
5)   How often is there a need to communicate things in-person/ face-to-face?

Localisation
6)   Is there often a need to locate someone specific in the office? If so, how do you do it?
7)   When necessary, how easy/ difficult is it to locate people? Are people mostly available at their workstations or, moving about through the office at different times of the day?
8)   Would it be useful to have an app aiding location-awareness at the office?

Post- Interview Questions:

Q1. Did you use the application? If yes, how often – once/day, few times/ day, several times/ day, often, constant?

Q2. Was it easier to locate people given the application?

Q3. Did it make any difference in terms of the time it took to locate someone in the office?

Q4. Do you think communication was more frequent, being more location aware via the app about others working at the office?

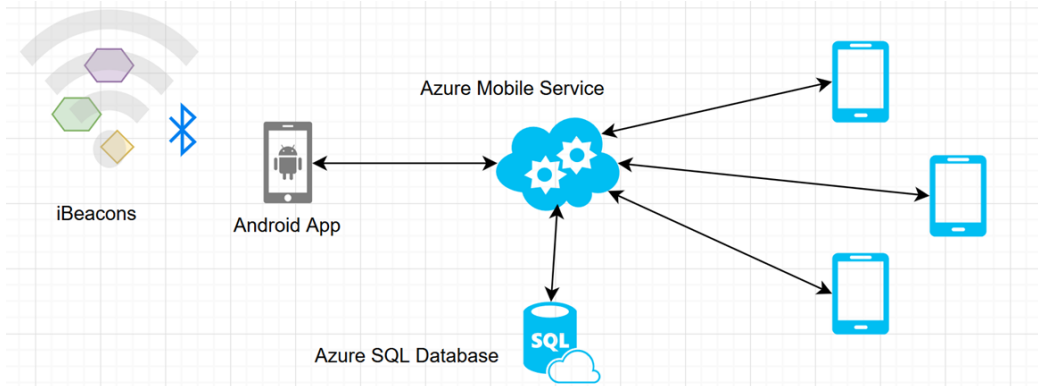Q5. In your opinion/ experience, were there any drawbacks to using a location awareness application?

Figure 7: The Artefact (Components + Interactions)

Table 1: Pre-interview Results

How long have you been working in this particular office space (Sigma ITC, Lindholmspiren 9)?	Describe your role at the office. How important is communication towards fulfilling it?	Describe the practices currently followed by you/ your team to communicate in the workplace.	Which method of communication do you prefer? Why?	How often is there a need to communicate things in-person/ face-to-face?	Is there often a need to locate someone specific in the office? If so, how do you do it?	When necessary, how easy/ difficult is it to locate people? Are people mostly available at their workstations or, moving about through the office at different times of the day?	Would it be useful to have an app aiding location-awareness at the office?
3 years	I'm working as a front end developer mainly with JavaScript and web development. Communication plays a big role in my daily work routine, I have to communicate about my ongoing projects with my back end teammates and	Most of our communication is face to face since we are working in same office space. Communication with clients is usually handled online or via phone. Group meetings are held weekly to synchronize tasks on the project and update the project manager/product	I prefer group meetings since there is a chance to discuss things and listen to different point of views about something. It also is simple and avoids confusion.	Very often	Sometimes. I usually do it by going to a person's desk and checking if they are available or not.	Most times it is not difficult and people can be found at their desks.	Yes it would be good to have, it will make it easier to find people without having to go and check at their desks.

	the project manager to know what to implement or how should something look like on the interface	owner before receiving the next set of instructions.					
4 months	I'm a backend developer, working with databases and testing. Communication is quite important to my role as any modifications to a database or schema need to be discussed and confirmed before implementing.	Most times, it's communication with the back-end team who work in the same area so, communication is most often in-person and direct.	Direct, face-to-face communication is most preferable as it is quicker and easier.	Quite often but not as much since, once a database is created, most work is to do with maintenance tasks which don't require much communication.	Not usually for me personally since, everyone working with me have their workstations close by.	Not difficult at all. Usually people are where they are supposed to be and most communication is scheduled beforehand so, not often a need for locating individuals.	It might be useful sometimes, is worth testing, can't say for certain before that.
4 years	I'm a project manager. A big part of my job is communication and making sure that the team has a shared understanding of the projects.	We use Kanban boards to organise tasks, weekly meetings to update each other on the progress and daily stand-up meetings between team members to discuss daily tasks and implemented user stories from time-to-time.	Among the team members, I prefer to communicate face-to-face; I find it simpler to explain things or take in information that way. With the clients, again direct communication is preferable but, we like to ensure some form of documentation through emails and other means to keep a trail of all discussions.	Very often, as any completed task prompts the need for a discussion before moving on to the next ones.	Yes, there is often a need to locate project members at the office. For now, we just go and check for people at their workstations or otherwise, call them up if it's something urgent and someone can't be found.	It is quite simple during most times in the day but, can be difficult during lunch hours or when someone has stepped out for a coffee etc. No one is really bound by a strict schedule for these occasions so, can be found moving around the office sometimes.	Yes, it would be quite useful especially during hours around lunch and evenings.
7 years	Back-end developer, I'm working in Java development. It's important to communicate with other colleagues to ask for help or update them with recent work done or talk about projects we are doing in common and talk with project managers to know about divided tasks and deadlines or being updated by them about customer needs.	I work some days at office and other days at home so I contact my team through chat or skype if is needed and meet them face to face when I'm at office.	I'm not very comfortable communicating face to face so I prefer chat but face to face communication is necessary when doing projects within a team so I can't avoid it.	Sometimes. Most things can be handled by texting or email.	Yes sometimes, when I work at office I will need to find a certain colleague for example.	Mostly can find people at their desks but sometimes takes time to find people like times they are in meetings or sitting in different rooms at office.	Yes, whatever makes locating people easier and faster would be useful.I would like to try it anyways.

1 year	Tester. Communication is necessary for my role to determine and stick to the acceptance criteria while testing.	It is mostly talking directly with the developers about the features to test, and the expected outcome for a certain implementation etc.	Direct communication is preferable. Much easier to understand and for reference while testing.	Often, if there are failed tests. When everything goes as planned, it isn't needed.	Sometimes, when there is need to find the developer responsible for a particular feature which fails the test.	It is easy. Usually, can find the person at their desk or, just leave a message instead and they contact you later. If it's something urgent, then we contact the project manager who can decide the next course of action.	Yes, it can be useful. Will save me some trips across the office perhaps.
2 years	I'm a full stack developer currently working with app development across devices. Communication between the customer and the project manager is usually important for me to do my job. Between developers, it's important as well but is mostly informal once the scope and tasks for the project are decided.	Group meetings with everyone involved on the project present there. With the customers, it's mostly through Skype or sometimes, we schedule a meeting in-person.	I prefer group meetings since, they are quicker and everyone can be updated at the same time.	It happens often but, isn't necessary really as most things can be discussed during the scheduled sprint meetings anyways.	Not very often for me personally, as all my team members and I work in the same section and can see each other always.	It is easy for the most part. Only issue could be when someone is absent and haven't informed you about it.	It sounds good, maybe can be useful when we need to find someone from other section of the office.

Table 2: Emergent Codes from Pre-interview responses

How long have you been working in this particular office space (Sigma ITC, Lindholmspiren 9)?	Describe your role at the office. How important is communication towards fulfilling it?	Describe the practices currently followed by you/ your team to communicate in the workplace.	Which method of communication do you prefer? Why?	How often is there a need to communicate things in-person/ face-to-face?	Is there often a need to locate someone specific in the office? If so, how do you do it?	When necessary, how easy/ difficult is it to locate people? Are people mostly available at their workstations or, moving about through the office at different times of the day?	Would it be useful to have an app aiding location-awareness at the office?
3 years	Role: Front-end Developer Communication plays an important role	Most communication is face-to-face, Online, Group Meetings	Prefer group meetings	Very Often	Sometimes Usually by going to a person's desk and checking if they are available	It's not difficult Most times people can be found at their desks, workstations	Yes Takes away the need for going around people's desks and check for them
4 months	Role: Back-end Developer Communication is	Most communication in person and Direct	Face-to-face communication	Often	Not usually Most people I work with	Not difficult Most communication	It could be useful

	quite important				have their workstations nearby	can be scheduled	
4 years	Role: Project Manager Communication is a big part of my role	Weekly meetings, Daily stand-up meetings between teams	Face-to-face communication	Very Often	Yes, often	It is simple Most times people can be found at their desks, workstations Can call them up otherwise	Yes
7 years	Role: Back-end developer Communication is important	Face-to-face meetings Through Skype when not at the office	Prefer instant messages	Sometimes	Yes, sometimes	Not difficult Most times people can be found at their desks, workstations	Yes
1 year	Role: Tester Communication is important	Direct communication (face-to-face)	Direct communication (face-to-face)	Often	Sometimes	It is easy Most times people can be found at their desks, workstations	Yes
2 years	Role: Full stack developer Communication is important	Group meetings Skype	Prefer group meetings	Often	Not very often Most people I work with have their workstations nearby	It is easy	Yes

Table 3: Pre-Interview Coding Results (Questions/ Points of comparison in Green, Themes identified in White, Frequency of occurrence in Yellow)

Questions	Coded Responses					
How long have you been working in this particular office space (Sigma ITC, Lindholmspiren 9)?	3 years	4 months	4 years	7 years	1 year	2 years
Frequency	1	1	1	1	1	1
Role at the office (Q2)	Developer		Project Manager		Tester	
Frequency	4		1		1	
Role of communication (Q2)	Communication plays an important role		Communication is a necessity and plays an important role in my job		Communication has a smaller role and is not a necessity	
Frequency	4		1		1	
Current communication practices (Q3)	Group Meetings	Face-to-face/ Direct communication	Daily Stand-up meetings	Scheduled meetings	Skype/ Online	Emails
Frequency	2	4	1	1	2	1
Preferred method of communication (Q4)	Group Meetings		Face-to-face/ Direct communication		Instant Messaging/ Online tools	
Frequency	2		3		1	
Frequency of face-to-face communication (Q5)	Very Often		Often		Sometimes	
Frequency	2		3		1	
Is there often a need to locate someone specific in the office? (Q6)	Yes, but not often		Yes, sometimes	Yes, often		No, it isn't needed
Frequency	2		3	1		0
Method of Localisation (Q6)	Most people I work with have their workstations nearby so, can see them at all times		By going to a person's desk and checking if they are available	Calling the person		Leaving a note at their desk if unavailable

Frequency	2	3	1	1
When necessary, how easy/ difficult is it to locate people? (Q7)	It is easy	Not difficult	Difficult	
Frequency	3	3	0	
Would an app aiding location awareness be useful? (Q8)	Yes, it would be useful		No, it would be unnecessary	
Frequency	6		0	

Table 4: Post-Interview Results

	Did you make use of the application? If yes, how often?	*Was it easier to locate people given the application?*	*Did it make any difference in terms of the time it took to locate someone in the office?*	*Do you think communication was more frequent, being more location aware via the app about others working at the office?*	*In your opinion/ experience, were there any drawbacks to using a location awareness application?*
Participant 1	Yes, maybe twice-thrice a day.	Yes, it was handy	Yes, you could know instantly where someone was instead of going and checking in person	It was about the same frequency and the only thing that changed could be just checking the app for where someone was when you needed to talk to them.	No, it was quite useful
Participant 2	Yes, several times a day	Yes it was easier to know if someone was in the building or not	Yes, it was quicker than checking at someone's desk and you could have this information while sitting at your own desk	Yes it was more often that if someone was nearby as shown on the app, I could go and discuss few things with that person which I wouldn't have done otherwise	No
Participant 3	Yes, used it quite often	Yes it was easier and more convenient	Yes it was much quicker	It wasn't more frequent since I only used the app when it was necessary to communicate and I would have to do it anyways regardless of the app or not.	No drawbacks
Participant 4	Yes, once or twice the days that I was at the office	Yes, It was easier if someone was at the other side of the building but I mostly work with people situated around me so can see them anyways	It is quicker to know, takes the same amount of time to travel however	No it wasn't for me, It made no difference.	Not that I could think of any but I did not use the app as much.
Participant 5	Yes, several times per day	Yes, you could know without moving if someone was there or not	Yes it was faster	Yes it was more frequent because if I knew a developer was nearby I could easily approach them and discuss about the tests if needed.	No, I didn't experience any
Participant 6	Yes, few times a day	I didn't have much need for it but it should make it easier and quicker than before	Again, I didn't have much need for it and I work with my team in same section of the office so it didn't make a difference for me	It was the same	I'm bit concerned about others knowing where I may be at all times but otherwise no

Table 5: Post-Interview Coding Results (Questions/ Points of comparison in Green, Themes identified in White, Frequency of occurrence in Yellow)

Questions	Coded Responses			
Did you make use of the application? If yes, how often?	Yes, few times/ day	Yes, several times a day	Yes, quite often	No, didn't use it
Frequency	3	2	1	0
Was it easier to locate people given the application?	Yes, it was easier		No, it made no difference	
Frequency	6		0	
Did it make any difference in terms of the time it took to locate someone in the office?	Yes, it was quicker to find someone		No, it didn't make any difference	
Frequency	5		1	
Do you think communication was more frequent, being more location aware via the app about others	It was the same		Yes, communication was more frequent	
Frequency	4		2	
In your opinion/ experience, were there any drawbacks to using a location awareness application?	No, there were no drawbacks		Concerned about privacy	
Frequency	5		1	

Table 6: Questionnaire Results

What method of communication do you prefer while at work? (select all that apply)	Email		Instant Messaging	Skype/ Slack	Face-to-face discussions/ Stand-up meetings		Others (Please specify)
	6		9	11	16		0

When communicating face-to-face, which areas of the office do you usually use? (select all that apply)	Meeting rooms	Near the coffee machine	Lunchrum	Skrivare	Personal workstations/ Offices	Gaming Lounge	Office corridors/ lobby/ open spaces etc.
	12	4	6	0	15	7	16

*Would you mind your location being tracked at the office? (Tracking, in this context, works only in specified spots where iBeacons are placed) *	Yes			No		Maybe	
	3			11		5	

*Which parts of the office would you like to be location aware of i.e. which areas would you prefer the beacons placed in? *	Meeting rooms	Near the coffee machine	Lunchrum	Skrivare	Personal workstations/ offices	Gaming Lounge	Office corridors/ lobby/ open spaces etc.	WCs	Övrigt
	12	10	9	4	14	12	17	0	4

*How often would you like to be tracked at the office? *	All the time		At certain times during the day		As per choice (option to deactivate the service)		Never	
	2		7		8		2	

There are several methods of indoor tracking and localisation, all intrusive to various extents, however; which of the following methods do you find the most acceptable: *	Tracking every step/ movement constantly	Being tracked only when in certain locations	Being registered when entering certain locations (just a presence message, nothing further)	Being notified and asked when coming in contact with a beacon to register presence (for that particular location)
	0	7	7	5

Do you feel if a location-awareness application, such as the one suggested here, intrudes on your privacy?	It's fine	Slightly Intrusive	Intrusive	Highly Intrusive	Alarming
	4	10	5	0	0

What is your general level of concern regarding privacy issues in a digitally-connected work space ?	Unconcerned	Slightly Concerned	Concerned	Highly Concerned	Alarmed
	4	11	3	1	0