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Report on future directions of LBS and potential solutions

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Abstract: This document describes the future directions and potential solutions of Location Based Services

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Executive Summary

This document describes current challenges and issues of Location Based Services (LBS) markets, the available solutions to them and also potential alternatives such as upcoming technologies and new regulations that may bridge the gap between the remaining challenges and current requirements and the targeted future for the LBS markets.

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List of Acronyms and Abbreviations

Term	Description
ER	Experienced Researcher
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
ITN	Initial Training Network
LBS	Location Based Services
MultiPOS	Multi-technology Positioning Professionals
LBSN	Location Based Social Networking
IoT	Internet of Things
IVS	In-Vehicle Systems
BLE	Bluetooth Low Energy
UAV	Unmanned Aerial Vehicles

1. Introduction

This document, the deliverable D2.12, reports on the current challenges to the development of the LBS markets and the future directions of LBS and some of the potential solutions to the current challenges.

This document enumerates some of the most important challenges to the current applications and services which essentially need the location to function. Such challenges have been identified through a survey conducted by the author, reviewed research papers and market reports. This document studies the available solutions to the identified challenges and finally discuss the future directions, and upcoming/potential technologies and concepts that may have an impact on the future of LBS markets.

This document partially reports on the findings and outputs of MultiPOS (Multi-technology Positioning Professionals) research project within Marie Curie Initial Training Network (ITN). This research project, entitled “developing markets for Location Based Services (LBS)”, aims to understand the requirements of the technology for future of LBS, and assess LBS market, applications, challenges, and also to assess the market forecast and future trends. And this document is mainly a report on the second and the third objectives of the project, i.e. to assess LBS markets’ requirements and challenges, and to assess the LBS market forecast and future trends.

The market reports, literature reviews, and the results of the conducted survey shows that the most important challenges to the adoption and the development of LBS the Quality of Services (QoS) of seamless positioning services (including accuracy, continuity, availability), privacy concerns associated with location data, cost of location-enabled devices and sensors, and the availability of indoor maps. Acknowledging the technical (e.g. positional accuracy and response time) and non-technical (e.g. privacy and cost) requirements of LBS applications, the current and possible solutions are explored. They include available positioning technologies, privacy protection policies, regulations and techniques, crowd sourced mapping, new business models, and some new/upcoming technologies. This document finally evaluates the efficiency and the usability of available solutions and if there are still some the gaps and more importantly what could be suggested to bridged such gaps.
This document is structured as follows; next section identifies the challenges and the requirements of LBS. To do so, it reviews the literature and explains the results of the conducted survey. Section 3 studies available and upcoming solutions to address the identified challenges. And section 4 evaluates if they can effectively address the challenges and requirements of the LBS markets and if not what could be the potential solutions.

2. Challenges to the Development of Location Based Services Markets

This section reviews the market reports, research papers, and also explains the details of the conducted survey. And based on the literature review and the results of the survey, it identifies the current challenges and issues of the LBS markets.

Although some of the challenges and issues to the development of LBS are shared by many applications of LBS, they can be different from one application to another. For example, the availability and the quality of positioning service, e.g. accuracy, is one of the biggest challenges in front of many LBS applications as the most widely-used positioning technology for outdoors, i.e. Global Navigation Satellite System (GNSS) such as GPS, may not be available indoors. However this varies depending on the type of the applications; For instance, the accuracy of positioning services can be the major issue for tracking and navigation while even a hundred of meters positional accuracy might be enough for location based advertising and social networking. In this regard, this report first categorises the applications of LBS to be able to identify the shared issues within each category.

This document categorises LBS applications into following segments: navigation and tracking (such as pedestrian navigation, tracking), marketing and advertisements (such as in mall ad services, proximity-based voucher sharing), entertainment (such as location based social networking and fun sharing, location-based gaming), indoor-based information retrieval (such as in-gallery tours, and real-time information retrieval), and emergency and assistive services (such as ambient assisted living, E112). As it is shown in table 1, the required Quality of Service (QoS), including the positional accuracy and availability, privacy, cost, power consumption, reliability and continuity of the positioning services, and the real-time/response time, for each category is also explored. Such requirements for QoS are driven from the literature (Basiri et al. 2015b), (Ghai and Agarwal 2013), (Harle 2013), (Abbas 2015b), (Torres et al 2014), (Basiri et al. 2014), (Wirola et al. 2010).

LBS Category	Application Domain	Quality of Service Requirement
Navigation And Tracking	• Pedestrian Navigation • Path Finding And Routing • Tracking • Asset Finding	- Very high availability (seamless indoors, outdoors) - Response in real-time or few seconds (in general applications) - Accuracy of few meters or less - Very high reliability and continuity - Medium to low power consumption - Reasonable or cheap price - High privacy preserving
Indoor Marketing	• LB (Social) Marketing • Advertisement • Proximity-Based Voucher/ Offers/ Rewards • LB Social Reward Sharing • Location Based Dealing	- Medium availability - Response in few minutes - Accuracy in the order of hundreds of meters - Medium reliability and continuity - Very low power consumption - Almost free or very cheap - Medium privacy preserving

Entertainment	• LB Social Networking • LB Gaming • LB Fun Sharing • Find Your Friend • LB Chatting • LB Dating	- Medium to high availability (seamless indoors and outdoors) - Response in real-time or few seconds - Accuracy in the order of tens of meters - High reliability and continuity - Low power consumption - Reasonable or cheap price - Medium privacy preserving
Indoor Location-Based Information Retrieval	• Location-Based Q&A (Query) • Proximity Searching • Tourist Guide • Transportation Info.	- Medium availability - Response in real-time or few seconds - Accuracy from a few meters (e.g. for tourist guide and proximity search) to hundreds of meters - High reliability and continuity - Low power consumption - Reasonable or cheap price - Medium privacy preserving (depending on the application)
Safety And Security	• Emergency Services • Emergency Alert Services • Ambient Assisted Living • Security Surveillance	-Very high availability (seamless indoors and outdoors) - Response in real-time or few seconds - Accuracy of tens of meters or lower -Very high reliability and continuity - Low power consumption - Reasonable or cheap price - Medium or low privacy preserving

Table 1. LBS applications segments and clusters

In addition to the literature review, a survey was conducted targeting several groups of participants including ordinary users of LBS, application developers, and LBS component providers (including positioning hardware and mobile device manufacturers). The distribution of 130 participants and the level of expertise in LBS are shown in table 2.

As it shown in table 2, more than half (54.72%) of the participants identified themselves as "LBS users", who only use LBS applications, devices and service in daily life. Due to having the majority of the responses from this group of participants and also understanding the end-users' requirements and demands, this paper reflects the views of the ordinary users of LBS.

Participants Group	Percentage
LBS users (who only use LBS applications, devices and/or services in daily life)	54.72%
LBS application developers (who design, develop, or deploy LBS applications/services)	9.43%
LBS content providers (who provide content and/or information, such as map, points of interest and advertisements, to be delivered through LBS applications and/or services)	1.89%
LBS components company (who produce LBS components, such as antennas, receivers, transmitters)	0.00%

LBS researcher and LBS market analyst (who studies LBS and related technologies, applications, markets)	26.42%
Other	7.55%

Table 2. The types of the participants in the survey

52.63% of the users (i.e. 20 participants) have three or four devices with positioning capabilities, such as mobile phone, Satnavs, fitness devices, iWatch, iPod, iPad, in-vehicle navigation devices). 22 participants have one or two, and only 5.25% (i.e. 2 participants) have 7-8 devices and use it routinely. More than a quarter of the participants use their devices once a day and almost one-fifth (21.05%) use them 2-5 times (see figure 1).

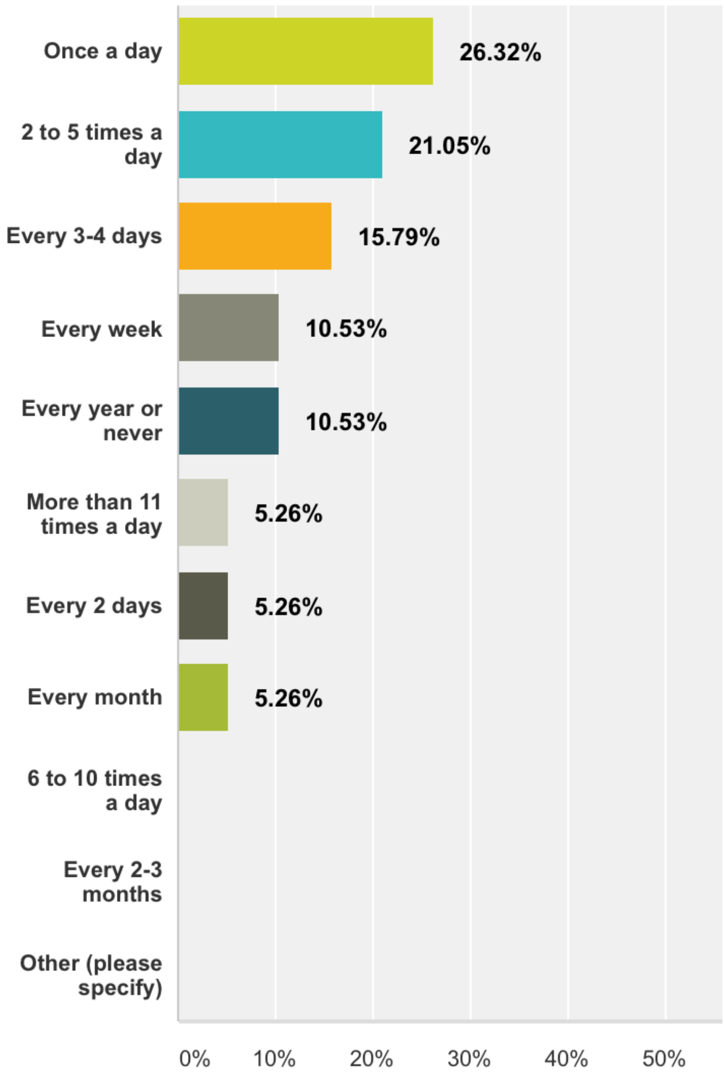

Fig. 1. The frequency of use of the location-enabled devices by the participants of the survey

When it comes to the LBS apps (rather than the device), it seems that the frequency of use is much higher; more than double percentage; i.e. 44.44% of the participants use LBS apps 2-5 times a day, see figure 2.

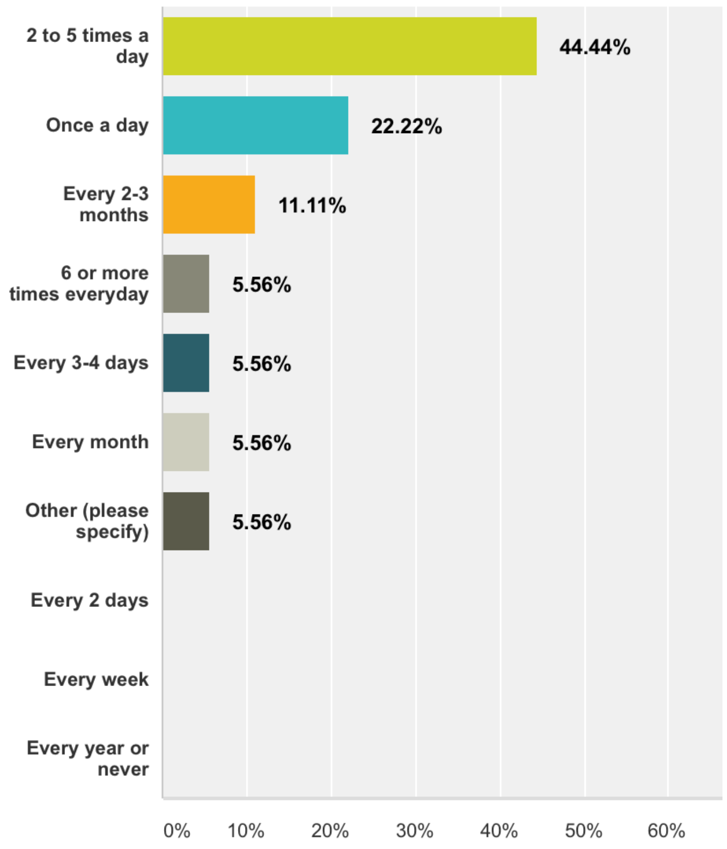

Fig. 2. The frequency of use of the LBS apps by LBS users

From LBS users perspective, the most important features of a location-enabled device, such as satnav or mobile phone, is the size of the device, cost, size of the screen, weight of the device, and user interface, which all can be considered as not-technological factors, see figure 3. There are some factors to do with the quality of the positioning services, including accuracy and continuity, but they all come after size, weight and other design-related parameters. As it is shown in figure 3, privacy and battery life are not the major concerns of the users when they buy a new device, however, these become more important when the user download and use an LBS app.

The participants were asked to rank the least to the most important features of an LBS application. The available features included power consumption, user-friendly interface, the price of the first purchase, subscription or update fee, privacy and cost of supporting technology. The results surprisingly show that the subscription fees, price of the first purchase, and the update fee, are the least important features when users decide to download or use an LBS app. While the cost of the supporting technology, such as buying a new device or modification of their mobile phone to support the app, are the most important features. This shows that users do consider financial implications; however, when it does not permanently change the hardware they are more willing to pay. Also, it might be due to the fact that amount of money to be paid for app purchases or subscription/update are relatively lower than device modification and/or purchase. The hardware purchase cost is not at an interest of this paper, and this paper only focuses on the non-technical factors of an LBS *app* rather than device or *hardware*.

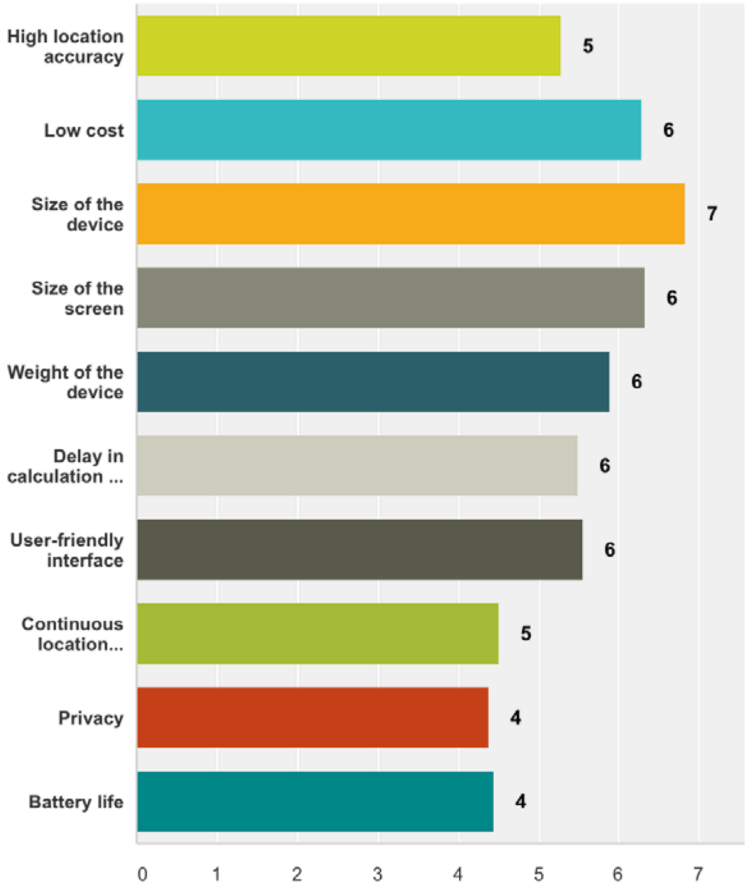

Fig. 3. The important features of location-enabled devices, such as SatNav and mobile phone, from users point of view (10 is the most important and 1 is the least)

As it is illustrated in figure 4, users prioritised the features of an app as following; privacy protection features, low power consumption, user-friendly interface, price of the first purchase and, the least importantly among others, subscription/update fee.

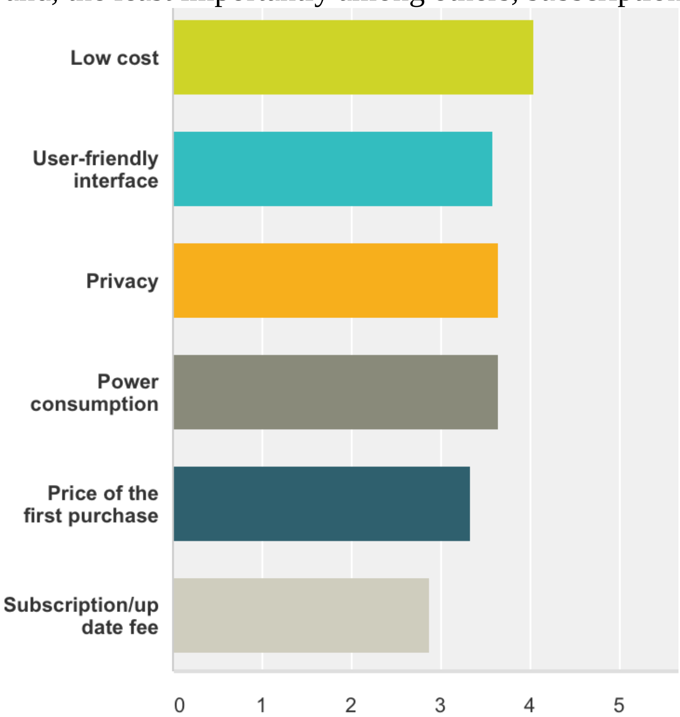

Fig. 4. The importance of LBS app features from LBS users point of view (10 is the most important and 1 is the least)

Besides some design and interface features (Such as size and weight of the device, user-interface), it seems that the most important features for the users to use either an LBS app or Location-enabled device is QoS of positioning services (including accuracy and continuity of the positioning services), privacy, cost and power consumption. Most of theses features are to do with the positioning technology, either being embedded in the device or being used by the app. They include accuracy, cost, coverage and power consumption level of the positioning technology, also the availability of the maps (which affect the continuity/reliability of the LBService) and privacy.

3. Available and Potential Solutions to the Identified Challenges

3.1 Positioning and Localisation

Availability of a seamless (indoors and outdoors), low-cost (ideally free of charge) positioning service, which can provide an acceptable level of accuracy, is one of the requirements of many applications. As it shown in table 1, each segment of LBS may require a different level of accuracy, continuity, privacy protection, power consumption and cost. Here the most widely used positioning technologies are studied to have a better understanding of what are the remaining challenges for each segment.

GNSS is the most widely used positioning technology (GSA report, 2015), however, it mainly works well in the open outdoor environment. It cannot provide the position of its users with an acceptable level of accuracy and reliability indoors. GNSS signals can be attenuated by roofs, walls and other objects, the signals can experience shadowing and multipath even in some “outdoor” areas such as urban canyons. There are other positioning technologies that can be used for indoor localisation, such as techniques based on Wireless Local Area Network (WLAN), Bluetooth Low Energy (BLE), Inertial Navigation Systems (INS), Surveillance Cameras, Ultra-Wide Band (UWB), Ultra-Sound (US), mobile networks, passive/active Radio Frequency Identification (RFID) and many other more. However considering the positional requirements of indoor LBS, including accuracy, cost, privacy, power consumption and availability of infrastructure, it seems that finding a positioning technology which can address all the positional requirements of pedestrian navigation (Basiri et al., 2015b). This subsection reviews the positioning technologies from quality of their service point of view to give a clearer picture of what is the biggest challenge in seamless (indoor and outdoor) positioning as one of the essential requirements of LBS.

In general, Localisation techniques can be categorised into three main categories; Radio-Frequency (RF) based positioning systems, Dead-Reckoning (DR) positioning systems, and finally Surveillance positioning systems. There are some technologies that can be categorised into more than one category due to the basis of measurement they make, though. Any combination of positioning technologies, from one or different category, can generate a forth group, i.e. Multisensory positioning. The measurement units (i.e. sensors) characteristics and capabilities may differ according to the physical properties that are being measured (Mautz, 2012). The challenges and a short explanation for the variety of technologies are presented in the following paragraphs. The division is made by the physical properties that the sensors measure.

i. Radio-Frequency (RF) based positioning systems

- *GNSS*

The most well-known positioning technology, which uses RF signals, is GNSS, however, the GNSS signals can be easily attenuated, reflected and/or blocked by buildings walls and roofs (Kjærgaard at al. 2010). There have been attempts to use GNSS signals inside buildings, where

GNSS signals are not available. Theses attempts have resulted in the development of pseudolites (Kuusniemi et al. 2012) and high sensitivity GNSS receivers, however, they encounter many challenges, including legislative and technical issues, as discussed below.

- *Pseudolites*

Pseudolites (PL) are ground based replacements for the satellites. Users' positions can be acquired from pseudolite systems with the same receivers as the GNSS, depending on the national policy. In some countries, e.g. the UK, users' need some modification on their GNSS receivers to get pseudolites' signals. Nevertheless, PL the infrastructure is not available in all places, thus PL is not a low-cost solution. The accuracy and power consumption of PL positioning are same as GNSS (Samama 2012), (Bonenberg at al. 2014), (Bonenberg et al. 2013), (Bonenberg at al. 2012).

- *High Sensitivity GNSS receivers*

High Sensitivity GNSS receivers are able to synchronise with heavily attenuated GPS signals. The sensitivity can reach down to -190 dBW. This enables the receiver to work (where the GNSS signal strengths are approximately -176 dBW. Building materials attenuate the GNSS signals. The reported positioning accuracy for brick buildings is approximately 10 meters. This is affected by the current satellite constellation. The receiver module cost ranges from few euros to hundred euros depending on the features the module offers (Pinchin et al. 2013).

Neither high sensitivity GNSS receivers nor pseudolites have not been successfully replaced as "indoor GNSS", despite their potentials. High sensitivity receiver can be used together with a particle filter for positioning and an accuracy of few meters was achieved inside an office building. Using pulsed pseudolites it is easier to deal with the near-far problem that arises when weaker signals cannot be detected because of the presence of a very strong signal. In addition, the interference with true satellite GNSS signals is smaller. As the Pseudolite signals imitate the original satellite system signals, the availability of these signals must be carefully planned. In the UK, same frequency bands cannot be used as for GNSS signals. Moreover, the GNSS signals indoors are so weak that it is very difficult to acquire dynamic position easily. Television broadcast and cellular signals penetrate indoors better than GNSS signals (Torres-Solis et al. 2013). The positioning accuracy that can be achieved with these signals is not accurate (>50m) (Deng et al. 2013). To enhance positioning coverage TC-OFDM systems are researched.

- *Digital Video Broadcasting — Terrestrial (DVB-T)*

DVB-T has also been considered as a positioning technology due to its signal characteristics. It relies on OFDM signals, which can provide fine information regarding the channel state. Besides that, the emitters' locations are usually known, which also offers a great advantage over the other technologies. However, one of the main challenges is the low number of emitters. Besides that, the receiver has to identify and match the incoming signal to a specific emitter. This poses a question on how accurate and reliable this can be done, increasing the risk of errors in the position estimation (Huang et al. 2013).

- *WLAN*

IEEE 802.11 is certainly one of the most popular standards for wireless local area networks (WLAN). This protocol has made its way to almost every electronic device. Due to this, it has become ubiquitous in urban environments, residential and commercial. IEEE 802.11 currently operates in two frequency bands, the 2.4 GHz unlicensed industrial, scientific and medical (ISM) band and 5 GHz unlicensed National Information Infrastructure (U-NII) band.

In a positioning context, these networks have been used mostly under fingerprinting solutions, offering a relatively good performance, 5 to 10 meters, in densely covered areas (Shrestha at al.

2013), (Nurminen et al. 2013). Since most recent IEEE 802.11 protocols rely on OFDM signals, these signals pose a new opportunity for positioning. These signals report the fine information regarding the channel state, which can be exploited in a positioning context to obtain range measurements. This metric is more reliable than the Received Signal Strength Indicator (RSSI) but it also requires accurate environment models. However, these models are difficult to build, since most channel effects are difficult to model or understand how to properly model them. Therefore a training phase could also be necessary (Xiao et al. 2013).

There are many existing WiFi access points. Signal strength and flight time are usually the wanted attributes. 802.11v consists also of positioning protocol. (Ciurana et al. 2011) assesses the 802.11v standard for ToA positioning. Furthermore (Sendra et al. 2011) compares the coverage and interference of the different protocols in the 802.11 families. In (Hao 2013) WiFi access point signal strengths were collected for fingerprinting. The strength was represented according to the WiFi AP MAC addresses. (Hejc et al. 2014) used WiFi with GPS receiver and IMU. Moving from indoor to outdoor environment is challenging, because the GPS requires time to achieve the first fix. Thus it is necessary to identify these transition region characteristics between the technologies used.

- *Ultra wideband (UWB)*

Ultra wideband (UWB) characteristics offer advantages for coping with multipath. Especially UWB impulse radio short pulses make it easier to detect the multipath components. Repeatability is a strong advantage for the ultra wideband approach. This means that the positioning result stays consistent over a time period (Meng et al. 2012). UWB tag was placed on shoe and helmet in (Zampella et al. 2012). The tag measurements on the shoe had much more outliers due to non line of sight conditions. Although high time resolution of UWB signals makes it easier to distinguish between original and multipath signals, the non line of sight condition is still a challenge.

- *Bluetooth*

Bluetooth is a wireless technology standard for exchanging data over short distances (Hossain et al. 2007). Several physical layer parameters are suitable to be considered in a positioning context, such as RSSI, Link Quality Indicator (LQ), and Transmit Power Level (TPL). However, most of these parameters are manufacturer dependent and some initial studies have reported a relatively bad positioning performance. Although interest has been increasing with the release 4.0, since the LE protocol offers a direct relationship between the RSSI and the absolute received signal power. Having an absolute received power level indicator is seen as promising for Bluetooth positioning (Bluetooth.org).

Hardware influence might be reduced by doing fingerprinting at the network nodes, instead of the mobile devices, but this raises further privacy concerns. Besides fingerprint, through the signal’s angle of arrival is possible to design systems based on high precision. However, these require dedicated hardware, raising the costs in an initial phase.

Bluegiga WT41-A evaluation kit is able to receive signal strength indicators from Bluetooth access points in the environment. It was used in (Kuusniemi et al., 2011) as one sensor in a multi-sensor setup. The new standard Bluetooth 4.0 and the LE protocol offer an additional indication of RSSI and absolute received signal power relation. In addition, the ease of deployment of the tags makes BLE a very promising and fast choice for indoor positioning.

- *RFID*

RFID system consists of RFID readers and transceivers or tags. In the active approach, the user carries the reader and scans the tags in the environment. In the passive approach, the user carries the tag and the environment has readers set up for positioning. The passive RFID detection range is very short (2m) and in practice, a stand-alone passive system would be costly to set up. Privacy is of concern especially in passive RFID tag systems where the computation capability of the tag cant supports necessary cryptographic data protection. RFID is implemented generally as a proximity positioning system (Fujimoto et al. 2011), (Seco at al. 2010), (Pateriya et al. 2011), (Hasani at al. 2015).

Table 3 summarises the achievable QoS provided by the RF-based positioning technologies.

Positioning technology	**GNSS**	**Pseudolite**	**mobile networks**	**WiFi RSS**	**WiFi ToF/AoA**
Technology Type (stand-alone or assistive)	stand-alone	stand-alone	stand-alone	stand-alone	stand-alone
Data Type (the typical form of sensor data used for position derivation	synchronisation	synchronisation	synchronisation / fingerprinting	fingerprinting	timing/Angle
Data Rate (typical sensor data output rate)	~1Hz	~1Hz	1Hz-few Hz	<1Hz/ 0.25Hz, 3Hz, 0.2Hz	1Hz/ 1-10Hz/ 1Hz/ 2Hz
Accuracy	4m – 7m	2cm – 3m/ ~7m (pulsed pseudolite)	lambda ~1m/ 4-25m/ 3m(FM)/ 10 – 23m/ >100m	2 – 4m/ 1.53m	1.7 – 10m
Measurement variance characteristics	~5m(wood)/ 10m(brick)/ 20m	cms/ few m	~10m	<10m/ multipath	multipath
Reach (typical range characteristic of the positioning signal)	outdoor/ satellite availability	~tens kms (50km)	~kms	~45m/ 10m/ 25 - 50m	~25m
Cost-user (sensor and electronic hardware/ component cost on user device)	u-blox LEA5H ~£50	Locata receiver ~£5000/ IFEN NavX	>£10(OMAP)	HP Ipaq £77	>£5
Cost, Infrastructure	>expensive	>expensive ~£100000/transmitter(CNET.com/news)	expensive	>£50 (AP Prices)/ 20£	>£50 (AP Prices)
Computational load/ Battery consumption	~500mW/ >150mW/ 1.5W	~1W transmit power	~1W(TI OMAP)	>1W/ 700mW WSN802GX/ >500mW transmit and 200mW for receiver	>1W/ 100mW
Calibration and setup complexity	demanding	demanding	demanding	demanding	demanding

Bluetooth RSS	RFID passive	RFID active	UWB RSS Proximity/ Scene Analysis	UWB ToF
stand-alone	stand-alone	stand-alone		stand-alone
pattern detection	proximity	pattern detection		timing, ToA, TDoA, AoA
0.2Hz (template matching)/ 2Hz/ 1Hz/	20Hz RI-TRP-R9TD/ 80Hz RFID reader	0.5Hz/ 0.2Hz		~25Hz/ >10Hz/ 0.75Hz (lab)/ 10Hz
~2 – 5m/ 1.88m	~15 – 50cm	~1-3m/ 2m	2.5m	15cm/ 50cm/ 2cm/ 20cm/ 30cm/ 1 – 7cm
Recognition error	Recognition error	Recognition error		multipath/ NLOS
Modifiable 1-25m/ 150m open field	~2m	30 – 100m		~5m/ 50-100m/ 175m (sounder Zetik)/ 30m(in tunnel/ 72m with los)
~£5 receiver	>£10 per tag	~£300 I-Card III interrogator/ M220 >£500 reader		expensive laboratory equipment/ £60 for ubisense tag IP63 slim)
~£10/beacon, £5	~£200 >£1000 reader	>£10 tag		expensive laboratory equipment
<50mW/ 30mW nRF51882/ 25mW	~200mW reader/ <50mW tag/ 300mW reader	~250mW		>1W/ (500mW transceiver)/ ~300mW receiver and 600mw transmitter)
simple	demanding	demanding		demanding

Table 3. The QoS for the RF-based positioning technologies

ii. Dead-Reckoning (DR) positioning systems

Inertial Navigation can be categorised into two clusters; the plain Inertial Navigation Systems and Step and Heading Systems (SHS). Tactical grade Inertial Measurement Units have a drift of few meters in a minute (Boll at al., 2011), but they are quite expensive and bulky for dead reckoning. Low cost MEMS inertial measurement units have to be constrained with an additional external feature to achieve similar accuracy as the tactical grade IMUs. Zero Velocity Updates, Map matching and external sensor aid are few possible constraints that are used (Harle 2013), (Hide et al. 2010), (Pinchin et al. 2014), (Hide et al. 2012).

In (Skog et al. 2010), Zero Velocity detectors are evaluated for foot-mounted INS. The gait style, step size estimation and attitude determination are the key parameters in Step and Heading Systems. Furthermore, the positioning of the INS is important. Mounted on a shoe the IMU signal is more easily analysed than from a mobile device located in a pocket (Skog et al. 2010), (Hide at al. 2012).

Attitude initialisation can be aided with a magnetometer (Pinchin et al. 2014), although usually in indoor environments magnetic perturbations are large. Map matching techniques like the cardinal heading aided inertial navigation that was used in (Pinchin et al. 2013), bring the low cost MEMS INS accuracy closer to LBS.

Cold atom interferometry and chip-scale atomic clocks are still under research (Groves 2014). Before more accurate inertial measurement is possible using inertial measurements will have to rely on help from external absolute positioning technologies like GNSS and Wi-Fi.

The drift of the position is the challenge in the inertial dead reckoning. Double integration of acceleration data into position information is hard to stabilise. Another challenge is the initialisation of the IMU parameters. If the starting position and heading are slightly wrong in the beginning these errors will accumulate when navigating. In (Pinchin et al. 2012) the cardinal directions of buildings and built environments were used. This map-matching technique adjusts the user track and position by aligning it with the predefined cardinal directions that are typical in buildings and built environments.

The full and detailed review of the inertial positioning systems is done by Harle (2013). In Step and Heading Systems (SHS), the step length and heading are estimated. Peak-detection, zero crossing, template matching and spectral frequency analysis are ways to detect steps. Furthermore, (Skog et al. 2010) compared four step detection algorithms. These were acceleration moving variance, magnitude, angular energy rate detection and a likelihood method that combined all the previous three. Slippery ground, shuffling and elevator are challenges for estimating the next step position. These make it difficult to detect zero velocity thresholds or zero angular velocity. Alternative and even more complex ways for getting the inertial navigation solution are for example by using learning methods like statistical model comparisons of learnt IMU records, artificial neural networks and regression forests (Nguyen et al, 2010). In summary, the inertial systems as dead reckoning systems are not accurate for indoor positioning by themselves.

iii. Surveillance positioning systems

- *Tactile*

Piezoelectric, capacitive touch surfaces, levers and buttons can be used in recognising activity at certain locations. Load cells on the floor may be used to sense the position of a user within a building. Tactile localisation is based on a sensor or probe being in a direct physical contact with a surface or an obstruction. Similarly, an odometer sensor measurement probe contact is direct and continuous (Kivimaki et al. 2014). Piezoelectric PVDF sensor LDT0-028K was used in (Middleton et al. 2009) to detect the heel strike for gait cycle and step detection.

The localisation using tactile sensors is relatively straightforward and accurate. Depending on the sensor placement the user position is the sensor position where the activity is detected. Identification of multiple users is more complex. The tactile sensor information needs additional information like the measure of weight or camera image recognition in order to deliver the correct location for the correct user. Identity in odometry, on the other hand, is usually easier to implement as the user is carrying the sensor. The accuracy of odometry, like many dead reckoning approaches, leaves much to be desired..

- *Camera*

Cameras can also be used for navigation in at least three different ways. Camera images can be compared and matched with a database of crowd sourced images. Camera pose can be resolved through analysis of multiple features and by comparing feature descriptors of known objects. In addition, using visual odometry, the location can be tracked from the image flow by comparing patterns in sequential images. Stereovision setup can be applied for more accurate camera movement estimation.

In (Basiri et al. 2015), markers/codes were placed around the landmarks. Mobile phone camera was used to detect unique markers and to solve the positions according to the acquired marker image. (Kivimaki et al. 2014) lists infrared sensor technologies. Microbolometer and Golay cell based InfraRed cameras are very expensive and are not applicable for many indoor LBS applications, such as pedestrian navigation. Thermopiles and pyroelectric sensors, although less accurate, are very affordable. These could be preferred in low lighting conditions where conventional image processing is impossible.

Image processing procedure starts with image acquisition. The second step is segmentation and feature extraction. Third is the search for matches where features are compared with pre-existing information. This step involves scale rotation and luminance analysis. The last step is to compute the camera location and pose or the target tracking information. The database collection phase is called the offline phase. The actual navigation with the help of this collected database is called the online phase. There are two ways in setting up the infrastructure. Either the camera can be carried by the user, but also a user feature or marker can be detected by a camera network that is set up in the environment (Torres-Solis et al. 2010).

- *Compressible Media*

Sound and ultrasound signals travel through a medium like air. The changing temperature and pressure conditions increase the difficulty in sound localisation systems design for specific locations. Signal strength, form recognition and travel time are the common methods used in the location derivation. (Hoflinger et al. 2014) used signal amplitude envelope detection on the received chirp-form signals. After detection, the position was acquired using TDoA. (Rishabh et al. 2012) used Time of Arrival (ToA) to calculate the position. The timing was based on detecting specific sound signals by comparing them with the reference signals at base stations. The recorded signal detection was carried out by cross-correlation with the reference signals. The sound source can be carried by the user or multiple sound sources can be located within the environment as base stations (Rishabh et al. 2012). The multipath, echoes and noise sources in the environment make the sound-based localisation system design challenging.

The ease of using barometers for measuring air pressure indoors makes it feasible to use it for detecting the change in height or altitude. The floor level was successfully detected in (Bai et al. 2013). As the weather conditions change the necessary parameters (the reference pressure, measured pressure and the temperature) correct height is challenging to compute in a real time application.

- *Magnetic*

Metallic objects or radio devices often make orientation determination very difficult with magnetometers. These and other environmental magnetic anomalies and perturbations make positioning with magnetometers difficult indoors. Magnetic north measurements indoors do not work well because of this. An alternative way to take advantage of the magnetic field measurements is described in (Zampella et al. 2012). Here the stable magnetic field during stance phase was measured. If there was any angular rate detected during the stance it was used to correct the yaw drift and gyroscope bias. Fuzzy Inference System (FIZ) was designed in (Afzal et al. 2011). This used four magnetic field parameters to detect whether the magnetic field was disturbed inside a mall (Hao at al. 2010).

Table 4 summaries the features of the above-mentioned surveillance positioning technologies.

Magnetic		Compressible media			Tactile	Physical property
magnetometer	barometer	sound	odometer	tactile environment	tactile device on user	Positioning technology **(hardware sensors and software and algorithms)**
Stand-alone with magnetic map/ otherwise assistive	assistive	stand-alone	assistive	stand-alone	assistive	Technology Type **(stand-alone or assistive)**
permanent magnet ranging/ fingerprinting	difference between reference and measured	timing/ synchronisation/ signal pattern	counter	binary/ force level	binary	Data Type (**the typical form of sensor data used for position derivation**
5Hz/ 75Hz	2Hz	1Hz-tens of Hz/ 3Hz	4 pulse per rotation	22Hz/ 60Hz	100Hz/ 50 – 500Hz	Data Rate (**typical sensor data output rate)**
1mm for permanent magnet/ 20cm for fingerprinting	33cm/ 0.2m	1cm-1m/ 9cm/ 10cm/ 5cm/ 20cm		4cm – 40cm/ 28.3cm		Accuracy
metallic objects and magnetic perturbations		multipath/ 5cm	dead reckoning	implemented resolution		Measurement variance characteristics (**variance characteristics of the derived position)**
1m/ magnetic fingerprint map		~3 – 10m/ 10m	dead reckoning	implemented structure		Reach (**typical range characteristic of the positioning signal)**
>£2/ £10	£10.00	~Few hundred £ (Neumann microphone)/ Devantech US module(£10)	low	low		Cost-user (**sensor and electronic hardware/ component cost on user device)**
>£2*n	£10.00	Devantech sonar module (£10)/ 3D-Locus £100 per node		Expensive/ £100 per 3x2m mat/ €80 per 3x0.5m mat		Cost, Infrastructure (**cost for providing citywide seamless support implementation)**
<50mW	5mW	>20mW (Devantech)/ 100mW for HC-SR04		low	150mV per control element	Computational load/ Battery consumption, user device
demanding	easy	demanding	easy	demanding		Calibration and setup complexity (**approximated effort measure for the setup of the system**
high for sensor/ low for user carrying a magnet	high	medium	high	low		Privacy (**approximated system security measure against location information hacking)**

IR Light		Light		
Image feature matching	image marker (IR marker or reflective element)	image feature matching	image marker	electromagnetic transmitter – receiver system
Stand-alone	stand-alone	stand-alone/ odometer assistive	stand-alone (continuous)/ assistive (snapshots/odometry)	stand-alone
pattern detection	pattern detection	pattern detection	pattern detection	Nfer-ranging/ Complex Image Theory Ranging
20Hz	50Hz	0,1/ 10/ 2k(Odometer)/ 3Hz/ 5 - 30Hz/ 4Hz/ 15 – 30Hz/ 30Hz/ 2Hz	5/ 15/ 30Hz	1Hz
0.2 – 0.8m	6m(Active Badges CoO)/ 10cm	~10cm/1%drift for odometer/ 20cm/ 50cm/ 15cm	1mm/ 30cm	1% of range/ 5cm (resonance coupling)/ [illegible]
AoA	(Placement)/ Recognition error	Recognition error	Recognition error	metallic objects/ 25degrees/ 1m
~6m/ 10m	(tag placement)/ ~6m	~6m/ scalable and resolution dependent	~6m/ scalable and resolution dependent	~ 50m/ 2m
~£1/ thermopile	~£1/marker and ~£10/camera	~£1 for odometer/£10and £100 for camera modules	~£10 for camera/ 500£ for CLIPS	>£1000
~£1 per thermopile/ €8000 microbolometer camera	~£1/marker and ~£10/camera	~£10 – £100 per camera	>£10 for marker amount	>£1000/ £16 per mm2 (tiletrack)/Xsens Mti
<50mW (thermopile)	<50mW for markers and 3,3V*50mA=165mW for camera(OV9625) + processing consumption	<50mW for odometer and >200mW/ >1W for cameras/ 684mW	>300mW/ ~2W/ snapshot 700mW	>1W
demanding	demanding	odometer simple, camera demanding	demanding	demanding
low(environment)/ high(user)	low(environment)/ high(user with camera)	high(odometer and user)/ low(environment	high (for user carrying camera), medium (projectors)	low

Table 4. The QoS for the surveillance positioning technologies

- **Potential Solutions**

As the practical experiments and application requirement analysis have shown that a single positioning technology cannot be an answer to the requirements of many applications of indoor LBS. Multi-sensor positioning can solve some aspects of indoor positioning for some applications. BLE and upcoming sensors also promise more opportunities as the power consumption, accuracy and cost have been distinctively moderated.

Using multi-sensors for positioning, equipment of mobile devices with more and more sensors, high sensitivity and accuracy of current sensors, upcoming technologies, including BLE, Galileo with higher signal penetration, change in policy and legislation regarding use of some technologies such as pseudolites can help to improve quality of positioning services for indoors.

When it comes to multi-sensor positioning technologies, the indoor LBS role of applications' requirement becomes more and more important to decide what combination of sensors is the best fit for each application and scenario. However based on levels of positional accuracy, cost, coverage and availability provided by different sensors, it seems that BLE and Wi-Fi are two default players in most of such multi-sensors solutions. They can be combined with other sensors including barometers, cameras, accelerometer, gyro, microphone, etc. to provide better positioning service for indoor LBS application. ABI Research (2014) forecasted the shipment of BLE to reach 500 million USD (60 million unites) by 2019. Shipment of 60 million unites BLE is promising many new LBS applications, which will work based on proximity beacons. In addition to BLE, the growth of LTE (4th generation) and Wi-Fi 5G popularity can confirm that in near future Wi-Fi and BLE are default choices for positioning, however, they cannot provide acceptable positioning service unless they are being used in a multi-sensor framework, i.e. in combination with other sensors.

3.2 Privacy concerns

The personalisation is one of the key features of LBS, welcomed by many users. The personalisation features make LBS growingly popular, however, they may require personal preferences, history of activities, and more importantly current location and (previous) trajectories of movements (Toch et al., 2012). The threats associated with the violation of the location privacy can dramatically limit the development, adoption and growth of LBS applications usage. The LBS requires the users to disclose their locations to be able to get the personalised and more relevant services. The LBS service providers can potentially store, (mis-/re-) use, and sell location data. Such potential threats can discourage the users to share their location (Chin et al., 2012). Unrestricted access to information about an individual’s location could potentially lead to many harmful encounters (Duckham, 2006).

In addition, an individual’s (sequence of) locations can potentially disclose activities, preferences, health, background and history and many other (even more) private aspects of life. In particular, if the sequence of locations is accompanied by time, i.e. trajectory of the movement, then more can be revealed about the individuals (Chen et al., 2013). (De Montjoye et al., 2013) understood that only four anonymous spatio-temporal points are enough to uniquely identify 95% of the individuals within the crowd.

In addition to such potential threats already fully understood, the lack of awareness regarding the location privacy issues among ordinary users of LBS may introduce even big threat to the LBS markets; public may overestimate the potentials as the threat can be potentially even overestimated by the users (Shokri, 2015), (Chin et al., 2012). This might be partially due to the fact that the necessary guards to protect the location privacy do not need to be the same for all the applications and services. The level of accuracy, the potentials of unauthorised access and/or inference of higher-level private information, and the impact of privacy violation in each LBS application can be different. Puttaswamy (2014) found that the location privacy concerns could be dependent on the type of applications and the level of privacy for each application category identified within the survey is illustrated in table 1.

In order to access location-based services, mobile users have to disclose their location to the service providers. However, such information can be simply reused by the same or other sectors without users’ permission. In order to protect the privacy of the LBS users, there are several approaches and mechanisms. Duckham (2006) categorised the privacy protection approaches into four categorises; regulatory, privacy policies, anonymity, and obfuscation.

The first category of privacy protection approaches is based on regulation. The regulatory approaches to privacy are to develop and define some rules to manage the privacy of individuals and public. Although the regulations and rules are being developed by the governments and legislative sectors and in general high-power, the regulatory approaches have faced several challenges.

One of the biggest challenges of the regulations and rules is the possibility of having different interpretations and implementations. In addition, due to the time-consuming and complicated process of development of rules and legislations, the number of privacy regulations is relatively small (Duckham, 2006). This becomes even longer process when it comes to Europe with 28 members of states that are supposed to reach agreements on a rule. And, of course, far bigger problem when the rules are supposed to protect the information and data being captured, used, and produced by the fast-growing technologies. The recent innovations, new technologies and applications of LBS (Basiri et al. 2015), put the development of location privacy protection rules far behind the needs and demands.

Also regulations, on their own, cannot guarantee or even prevent the invasions of privacy as they are to be used when the privacy violation occurs, i.e. the regulations and rules can only exist to ensure the accountability of the governments and enforcements in the case of privacy invasion.

While regulatory approaches target the global or group-based safeguards, the second category of privacy protection approaches, the privacy policies, are to provide more flexible and adaptive protection mechanisms to make it possible to be used for individuals (Myles et al., 2003), (Gorlach, 2004).

The location privacy policies, such as The Internet Engineering Task Force (IETF) GeoPrive, the World Wide Web Consortium (W3C)'s privacy preferences project (P3P), Personal Digital rights management (PDRM) are of the most developing protection approaches to do with LBS. However, there are several challenges in the long way of being fully established and implemented. The nature of LBS applications introduces a big challenge to the privacy policies; the rapid changing, highly innovative and fast growing ecosystem of LBS makes it difficult to update, issue, adapt the policies to protect the newly popped up applications, technologies and situations. This challenge is being shared by the regulatory approaches and this becomes even more problematic when the privacy policies need to rely on the available regulation to be practically applicable. In many cases, the privacy policies cannot practically protect the privacy and the liability relies on the supporting regulations and rules.

The next category, anonymity, provides a mechanism to minimise the traceability of the information and the individual's identification or even other associated data. The anonymity-based approaches, such as K-Anonymity (Sweeney, 2002), disassociate the location information from the users' identity or minimise the possibility of inference and tractability the users' non-identity information. Although anonymity –based approaches are technically easy to apply and implement, they can be viewed as a barrier to the personalisation features of LBS, which are becoming more and more popular and for many applications essential (Xu et al., 2011). The possible solution for this challenge can be pseudonymity-based approaches as they partially allow some levels of personalisation. Pseudonymity-based approaches keep the individuals anonymous while giving a persistent identity (a pseudonym). Therefore the privacy is protected by using an alias (pseudonym), which can be potentially linked to their actual identity under higher safeguards. Although the pseudonymity can be an answer to the personalisation problem, the sequence of pseudonymised location may lead to identification of the individual if this sequential data is being added to other non-identical data as well. (Sweeney, 2002) shows that 87% of the people can be uniquely identified using the collection of non-identity attribute, including their postcode, age and gender.

The fourth category of the privacy protection approaches is obfuscation. Obfuscation lowers the positional quality of the users' location to protect misuse and/or re-use of it (Duckham, 2006). The Obfuscation degrades the quality of location information: inaccuracy, imprecision, and vagueness to lower the associations between positional data and reality, specification in information, and play with the existence of boundary cases in data (Duckham, 2006). As it mainly deals with the quality of positional data, table 5 summarises the level of accuracy, boundary size (coverage), and other aspects of quality of the service provided by the positioning technologies used by LBS applications.

Although the obfuscation can protect privacy of the users in many scenarios, it can be viewed as a challenge to the quality of the LBS responses, requested to by the users. The quality of al service provided by the LBS applications highly depends on the input positional data quality. This correlation depends on the application type (see table1); for example, in proximity/local information retrieval the obfuscation may not affect hugely but in pedestrian navigation services, the impact would be obvious. However, there are also many situations where it is possible to expect high quality of the location-based services based on the low-quality positional information.

While anonymity hides an individual's identity and its associations with the location, the obfuscation approach degrades the spatial quality of the data, allowing the individual's identity to be revealed. Since the users' identity may be revealed, another disadvantage of this approach is the requirement for the LBS users' authentication.

Obfuscation assumes that the users are able to choose what information about their location to reveal to a service provider. Therefore it is very useful approach for professional applications of LBS.

It can be the case for many scenarios where more than one privacy protection approach would be required. Table 5 summarises the challenges and disadvantages of each four privacy protection categories.

Privacy Protection Category	Disadvantages And Challenges
Regulation-Based Approaches	• The possibility of having different interpretations and implementations of the very same rule and regulation. • The small number of rules and regulation due to the time-consuming and complicated process of development, particularly for the fast-growing, innovative and rapid changing technologies and applications, e.g. LBS. • The regulations, on their own, cannot guarantee or even prevent the invasions of privacy and they act when the privacy violation happens
Privacy Policies	• The rapid changing, highly innovative and fast growing ecosystem of LBS makes it difficult to update, issue, adapt the privacy protecting policies • The privacy policies need to rely on the available regulation to be practically applicable and the liability relies on the supporting regulations and rules.
Anonymity	• Anonymity can be viewed as a barrier to the personalisation features of LBS, which are becoming more and more popular and for many applications essential. • The sequence of (pseudo) anonymised data may lead to identification of the individual if this sequential data is being added to other non-identical data as well.

Obfuscation	• Obfuscation can compromise the quality of the LBS responses, as The quality of al service provided by the LBS applications highly depends on the input positional data quality. • It needs the LBS users' authentication. • Obfuscation assumes that the users are able to choose what information about their location to reveal to a service provider, which may not be the case for many cases.

Table 4. Privacy Protection Approaches

In addition to need for more than one approach to protect LBS users' privacy, another general challenge is deciding if (location) data worth being protected. Due to the spatial and/or temporal accuracy, there are some datasets that may not worth attacking and therefore (extra) protection may no longer be required. However, one application's public data can be considered as private data for another one and vice versa. Also, the social trends and public acceptance/reaction to the concept of privacy is changing.

The results of the survey showed yet another challenge to do with privacy; lack of mutual understanding the LBS users and the service providers. When users were asked about non-technical parameters in an LBS app, users prioritised the features of an app as following; privacy protection features, low power consumption, user-friendly interface, price of the first purchase and, the least importantly among others, subscription/update fee. When the app developers are asked what the most important feature of a successful LBS app, they privacy is ranked behind other parameters. However, its importance is appreciated by many developers and service providers as they have given a fairly high rank to the privacy (on average 7.25 from 10). Giving equally importance level to the availability of the positioning service and the privacy reflects that the developers are fully aware of the significance of privacy concerns in the success or failure of an LBS app. However due to the lack of executable, enforcing and up-to-date policies and regulations (Wernke et al., 2014), lack of technical solutions (Shokri, 2015), and lack of business models and monetisation schemes that do not push/require the developers to share the location data for advertisements purposes, the privacy of do not take as serious as it should be (Freudiger et al., 2012).

Enforcing the new and up-to-date privacy protection legislations, becoming more transparent in regards of the (im) possibility of (mis/re-) use of location data, giving clear explanation and lay reports on the level of protection and potential traceability and other threats, adjusting the level of the location requirements based on applications, publicity of the potential applications based on secondary data and reuse of location data and also open source contributory projects which requires trust of users, and having a mutual understanding of the users' concerns and the technological limitations for LBS industry can help to handle some of the challenges of privacy in LBS ecosystem.

3.3 Indoor Map Coverage

Almost all LBS apps and services require spatial data, such as maps and network of roads, to provide routing and navigation services. However availability of indoor maps is dealing with some challenges such as privacy and legal issues. In addition to availability, reliability, spatial, temporal and thematic accuracy and in general quality of indoor data cannot be easily assured. Difficulties of indoor data quality assurance are due to the limited access to indoors and legal and privacy issues of publishing and editing indoor maps.

Google seems to be one of the major players in indoor LBS. The Google product tells customers what floor they are on in a building. Google's indoor mapping partners include only 18 U.S.

airports, detailed floor plans automatically appear when the user is viewing the map and the map is zoomed to buildings where indoor map data is available. But even for this newest release of Google Maps, a lot of (indoor) areas have not been added to Google maps also the indoor mapping does not provide proper navigational instructions (e.g. between floors navigational instructions don't suggest to take stairs). Overall, indoor map coverage is not comparable with outdoors mapping coverage and resolution.

In contrast with indoor positioning challenge, the poor coverage of indoor maps is not mainly a technical issue (Lorenz et al., 2013). It is more due to privacy issues associated with personal properties and also the lack of privacy protecting policies and technical standards of indoor mappings.

One of the solutions, which has already shown its practicality and growing popularity, is crowd-source and volunteer-based mappings. Collaborative mapping and crowdsourcing are two methods of generating spatial content on the Internet, which involves contributions from a large, disparate group of individuals. These methods rely upon web applications that allow people to upload information easily and allow many others to view and react to this information. Such web applications are often considered part of Web 2.0.

There are several tools available, which allow users to create and edit web content, such as tagging tools, wiki software (Wikipedia), and web-based spatial data editors (e.g., Google Earth, Google Maps, Google Map Maker, OpenLayers). This method of map data collection and generation is based on involving citizens to participation in large-scale data collection, sometimes with the participation of companies. This crowdsourcing approach could be very suitable for indoor mapping. The popularity of VGI is growing. For example, by looking at the entire OpenStreetMap (OSM) dataset, it has been found that there was a growth of 75% in contributions to the project in 2013, and over 150% over the last two years. On average during 2013, each week over 96,000 kilometres of new roadway data are added to OSM. These approaches can be partially or completely applied by many mapping agencies and data gathering institutions.

Despite the popularity and involvement of citizens with the collection of geospatial data, there is still poor mapping coverage for indoor spaces. VGI projects, such as OSM, and geospatial mapping companies are contributing to the increasing trend of interest in indoor map generation but both approaches have still had a long way to go. Data formats, scale, metadata, privacy issues, etc. have not been fully standardised yet. In truth, having a global coverage of indoor mapping may find obstacles in the form of privacy issues and political opposition. Many of those who openly contribute to VGI projects for outdoor environments might not want to publish their home's indoor map because of security and privacy issues. In addition, if they do contribute this data to a VGI project, these maps cannot be edited by other contributors since they may not have been there in that house. This simple example highlights accuracy, reliability, and precision as some of the key criticisms regarding VGI data.

It seems that the best option to have a better coverage of indoor maps is changing policies and legislations to encourage more companies and people to contribute to crowd-sourced data. This is a big challenge as privacy concerns are still an issue. There is a high demand to have a standard and policy for preserving privacy of users, however, there are many “public” places, such as shopping malls, airports and universities which have already provided their map online but locally on their own web pages. These kinds of areas can be a good target to start or expand the indoor map network of contributors, as there are fewer privacy concerns.

Considering these prevalent issues in LBS; indoor positioning, indoor map coverage and privacy it appears that indoor LBS is quite a challenging segment of LBS. Additionally, there are some other challenges such as a need to customise current services for indoors, more need to consider context awareness and adaptability of applications with a variety of scenarios.
ABI research reports distinguish between location-based services and location enabled services. According to ABI research 2012, global revenue of LBS reaches to 8 Billion dollars and the two most widely used LBS applications are navigation and enterprise, respectively.
As it explained, there are differences in regards to LBS market segmentation, market size, number of subscribers and most appreciated applications and their revenue. It is very important for market report to clarify what they mean by location-based service, what is included and what is not. This document analyses different market reports bearing in mind the impacts of having different market boundaries. The assumptions, findings and identified trends and challenges of the reviewed market reports are summarised in the next section.

4. Future Trends and Market Drivers

Reviewing published market reports are one of most important steps in the process of market forecast. There are many market reports about LBS and related concepts, including positioning and location technologies, mobile applications, and context-aware services. This section summarises the outputs and findings of the (freely) available market reports.

The market report from ABI Research highlights the retail/shopping, ambient intelligence, hyper-local social and personal asset tracking/BLE beacon applications as emerging segments of LBS which play an important role in the next wave of location based services over the next five years, with ABI Research forecasting a four-fold increase in revenues by 2019. ABI Research believes the market is also shifting geographically (mainly in BRIC countries), technologically (particularly HTML5, indoor positioning) and vertically (e.g. tablets, cameras), creating new opportunities.

ABI believes that despite relatively stunted growth thus far, the tablet and camera markets are the next major market for location-based services and GPS penetration. ABI Research believes that ubiquitous location becomes a necessary component, which introduces a big challenge to current markets. And the camera market has huge potential, with Geo-tagging a clear driver. With more than 30 GPS-enabled cameras on the market, and the second wave of new applications emerging around tracking, maps and points of interest, and dead reckoning. As an industry, there needs to be a complete overhaul of how cameras are designed, to find a way to leverage the photography revolution occurring on smartphones. ABI Research has forecast that this will open the door to GPS, alternative location, and LBS in future. ABI expects to see a big growth at the location-based gaming (LBG) industry.
According to Berg Insight report Local search, social networking and navigation services are the top application categories in terms of a number of active users. Also, Berg Insight anticipates that beacon adoption will take off as retailers launch innovative marketing schemes and leverage the possibility to analyse how customers roam and dwell in stores and aisles. Berg Insight believes that the social networking and entertainment category is now the largest LBS segment, both, in terms of a number of users and revenues. It defines this category as a broad set of services that can be segmented into general social networking, chat and messaging apps, friend finders and location-enhanced games. Mapping and navigation are the second largest segment in terms of revenues and the third largest in terms of the number of active users. Although the number of active users of mapping and navigation services is still growing, revenues are only increasing slowly as competition from free and low cost services has intensified. More navigation service providers are now focusing on freemium apps where the

core navigation service is free and users have the option to purchase additional content and features. Local search and information services are now the second largest LBS category in terms of unique users.

On the basis of technology, MarketsandMarkets believes that among the various technologies, hybrid technology is emerging and is expected to grow tremendously in the near future. The retail, and food and beverages industries are the two major industries where LBS devices are increasingly being used to reduce the transportation costs. MarketsandMarkets expects that the increase in the number of Smartphone users will lead to further comprehensive smart alerts related to LBS. According to this report, the market for LBS technology is expected to grow due to several factors including availability of cheaper GPS enabled devices, high interest in personalizing services based on users' location information, advancements in analysis capabilities, global deployments of 3G and 4G wireless services promising ubiquitous connectivity as well as cost benefits from deploying solutions like vehicle tracking and management. MarketsandMarkets thinks the major areas of opportunities includes navigation, local search, enterprise services, mobile location-based advertisements, location specific health information, tourism, consumer tracking and location based business intelligence.

MarketsandMarkets considers concerns about privacy, cost, and government regulations as challenges in the adoption LBS. However, the general trends are wide acceptance of LBS applications across various verticals.

MicroMarketMonitor believes that the most prominent segment of LBS is tracking, it contributed the largest chunk of revenue in 2013. Tracking can be further segmented in following types: People tracking (patient, kids), inventory tracking, medical/hospital equipment tracking, vehicle tracking, freight tracking, and so on. Navigation and Mapping segment is ranked second in terms of revenue generation according to this report.

Accordingly MicroMarketMonitor, the LBS market is expected to grow further due to availability of low-cost GPS devices, high interest in user's private location information services, and deployment of 4th generation (4G) of mobile network. According to this report, the major areas of opportunities for LBS market are from the navigation, mobile advertisements, tourism, and consumer tracking.

The Juniper Research's report, "Mobile Context & Location Services: Navigation, Tracking, Social & Local Search 2014-2019", expects the value of the mobile context and location-based services (LBS) market will more than triple in the next five years. This growth rate is mainly because of the adoption of highly targeted and context-aware ad-supported apps, which will account for over two-thirds of revenues. Juniper Research believes that social apps will be the primary driver of growth in ad-supported revenues related to apps. Local search apps will come in second in terms of ad spending.

In regards of monetization schemes, Juniper Research expects that in-app purchases (IAP) to take off, growing on average more than three times as rapidly per annum as the classic pay-to-download model. According to this report in-app purchases will be particularly prevalent in Navigation, Social and Tracking apps, with consumers preferring the low- to zero-entry cost and developers leveraging Lifetime Value (LTV) rather than one-off sales and consumers are likely to prefer zero or minimal entry costs to participate.

Growing interest in mobile advertising, increase in deployments of Wi-Fi hotspots and Bluetooth low-energy beacons are some of the market drives specially in creating location-based offers targeted at mobile-device users.

The research highlighted the availability of comprehensive app-based digital maps, at little or no cost to the consumer, as a key driver. It also noted that context-awareness is now considered to be key amongst app developers in delivering a relevant user experience. According to this report, the use of location and context-driven apps on smartphones will far exceed tablet uptake. Juniper Research believes that cellular network use on tablets is not common amongst consumers, restricting the ability of these devices to take advantage of hyper-local positioning unless connected to public Wi-Fi. Nonetheless, tablets represent a proportionally higher per-app revenue stream relative to smartphones, with higher in-app spends and greater advertising revenue per session.

This report expects that privacy concerns still remain among users, with location to be shared via apps on an instantaneous, rather than continuous basis. Juniper Research believes that ad-supported apps will account for 71% of the total location and context-based service revenue. It also considers the combination of 3G and 4G and the multitude of sensors and data produced by mobile devices as the solution for greater revenue and also as LBS market drives.

A Pyramid Research's report, "Location Based Services Market Forecast 2011-2015", considers growing adoption of GPS devices as a key driver of the LBS market. This assumption (trend) is still valid. The growth rate for adoption of such devices may increase due to upcoming other GNSS systems. According to this report, growing adoption of GPS devices also helps different applications and services to grow. In addition to growth in adaption of GPS enabled devices, this report believes that success of new business models, continued growth of mobile advertising, and the wider coverage and higher speeds of mobile networks are key drivers of LBS market. According to Pyramid Research navigation is the largest LBS revenue generator while the most aggressive revenue growth rate is for Location Based Advertising (with 60%). The key driver in this segment is development of advertising-funded models and the continued growth in local search.

TechNavio's report, the Global Location-based Service (LBS) Market 2012-2016 forecasts, believes that the key factors contributing to the LBS market growth are the increasing adoption of GPS-enabled devices. However, the increasing concern associated with personal data privacy could pose a challenge to the growth of this market. TechNavio believes that technologies such as WLAN, Wi-Fi, Bluetooth, AGPS, MEMS, UWB, and other hybrid technologies that cover smaller areas can be good solutions for indoor positioning challenge. This report enumerates some of positioning requirements of indoor LBS, including high accuracy to locate the position of the object. According to this report, increased use of beacons is one of the most important market drivers while technology-related complexities is a challenge for many retail enterprises. Also, increasing concern for data privacy could pose a challenge to the growth of this market. This report considers increased adoption of location-enabled devices in APAC as a key market driver, which results in increased adoption of location-based in many sectors specifically in location-based search and advertising. However, this has encountered some challenges including lack of knowledge of LBS among consumers.

And finally, according to the Global LBS Platform Market 2014-2018, one of the emerging trends in this market is an increase in the use of LBS for public safety and national security as most government organizations and security agencies use this platform to trace the location of emergency callers. According to the report, one of the main drivers in this market is the integration of mobile advertising and LBS. Most of the businesses use location-based mobile advertising to advertise their products and to provide the right information at the right time and at the right place to consumers.

According to the Global Consumer LBS market report, the revenue generated from the following revenue streams are the biggest ones for LBS: licensing of indoor LBS software, applications, middleware, and platforms, annual sales of devices used for indoor LBS, indoor LBS maps and navigation, tracking, monitoring, emergency services, and analytics, and LBS search and advertising revenue

5. Conclusion

Indoor LBS has not got its position in mobile applications market yet as there are many challenges still remain. In order to develop markets for indoor LBS and provide solutions to bridge the gap between requirements and demands, there is a need to understand challenges and potential solutions. This paper studies indoor LBS current market conditions, and challenges and issues. Based on the reviewed papers, market reports and a survey conducted by the authors, the quality of the indoor positioning services (such as availability, accuracy, and cost), the privacy concerns associated with location data, and the availability of the indoor maps are the major challenges in many of LBS applications. The paper also studied the current solutions and identified the gaps that need to be bridged and made some suggestion in this regards. The development of multi-sensor positioning services, new technologies such as BLE, enforcement of policies and legislations, updating current policy protection approaches, and having a mutual understanding between the end-users and the service providers, and also crowd-sourced mapping are some of the potential trends and solution to address the challenges.

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