Location-Based Services for Smart Living in Urban Areas

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1 Introduction

The dramatic growth in wireless communication technologies and mobile platform along with the increasing demand of the mobile subscribers to access various location-related information, services and also applications anywhere anytime has led to the development of a new genre of mobile services that would be able to provide useful information and services based on the current location of the mobile subscribers. This set of mobile services is called location-Based Services (LBSs). Example of such services include 911 emergency services [1], services for locating the nearest object of interest like Automatic Teller Machine (ATM), petrol pump, medical centre etc., in urban areas, mobile tour guides, vehicle tracking system and so on. Apart from these, several other applications such as Dark Sky used for obtaining accurate down-to-minute weather forecast for the present location of user, Uber ride app enabling a user to book some cab and obtain pick up service from his/her current location, Gas Buddy app helping to find out real-time fuel prices at the nearby gas stations and so on have significant usage in urban people's daily life. The wide applicability of the LBSs in several aspects of modern-day living which include transport, healthcare, leisure activities, business etc., is the main driving force behind drawing significant attention from not only the researchers but also the mobile network operators as well as the service providers in designing such services for smart living in the urban areas. Since LBSs require the knowledge of position information of the users to provide them appropriate information and

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services, localization or positioning technology is an integral part of the systems that provide such services. Apart from the positioning technology, LBS infrastructures also incorporate several other components such as mobile devices including any commercial smart phone, communication network as well as the application and content providers. On the other hand, the very poor signal strength of the global positioning system (GPS) and also the cellular network within the buildings (that constitutes indoor areas) necessitates for designing alternative positioning techniques or localization systems to provide accurate position information in such areas [2]. Thus, various promising solutions to provide accurate position information in the indoor areas based on wireless technologies like Wireless Fidelity (Wi-Fi), Bluetooth, Zigbee, Radio Frequency Identification (RFID) etc., have been proposed in literature over the past few decades [2]. Thus, the precise positioning of the user is the most important criteria for designing the LBS systems. Apart from the positioning or localization technologies, other components of an LBS system or infrastructure are the mobile devices, communication network and the services as well as content providers. This chapter, at first, provides a detailed ***definition of the LBSs*** and also states ***its importance in today's World.*** Then, it provides a ***state-of-the-art review of the various LBS Infrastructures and systems*** proposed in the literature since its origin in 1996. A brief description about the ***architecture of an LBS infrastructure*** and the data flow among its components is subsequently given in this chapter. Finally, it outlines some **important research issues** in the **provisioning of LBSs** in the urban environments.

2 Location Based Services and Its Importance

Location-Based Services (LBSs) are designed to provide useful information and services based on the current location of the user. Several other definitions of LBSs that are available in the literature and the one made by the Global System for Mobile (GSM) [3] association, are presented below.

- "Information services accessible with mobile devices through the mobile network and utilizing the ability to make use of the location of the mobile device" (Virrantaus et al., 2001 [4]).
- "The provision of geographically orientated data and information services to users across mobile telecommunication networks" (Shiode et al., 2004 [5]).
- According to the GSM Association, LBSs aim to add value to the services based on the current location of the target by filtering out unnecessary data.

Examples of such services include providing a list of nearby point of interest such as Automatic Teller Machine (ATM), Medical Centre and so on, showing the position of some target on a map, or automatic activation of the service when the target enters or leaves certain predefined region.

Based on the aforementioned definitions, most of the LBSs can be realized nowadays as data or messaging services that can be provided via the *wireless* *application protocol* (WAP) [6], *general packet radio service* (GPRS) [7] or *short message service* (SMS). LBSs can also be applied in the area of location based routing or selective routing, which determines the route of telephone calls or data based on the current location of the user. Thus, the geographical position of mobile devices must be determined accurately and consistently to support LBSs. From the perspective of research, LBSs have been generally considered a special subset of context-aware services. Context-aware services enable automatic provisioning of information and services according to the current context of the user. The context of the user typically consists of a set of user-specific parameters including his/her location, the characteristics of the access device and interface, the interest of the user and so on. Thus, the location being a part of the context information, LBSs are a part of the context-aware services.

The commercial LBSs are typically revenue-generating services that offer value to a mobile subscriber based on their current location. A certain type of commercial LBSs consist of finder service that, on request, delivers to users a list of nearby points of interest, such as restaurant or gas station [8]. Another type of commercial LBSs are generally based around a "push" model, in which selected data is presented to the mobile subscriber [8]. For example, the user can receive a special offer provided by a shop inside a market complex when he/she approaches its vicinity. Another very obvious and reasonable application of LBSs is the provisioning of emergency services, which require estimating the location of an emergency caller accurately if the call is received from a mobile subscriber [9]. In addition to commercial LBSs and emergency services, various other applications of LBSs include location-sensitive billing, pedestrian navigation, asset tracking, fleet management, smart transportation systems and so on.

3 State-of-the-Art Review of LBS Infrastructures and Systems

This section provides a brief review of various LBS infrastructures and systems proposed in the literature for provisioning of LBSs in the ubiquitous environment. At first, the existing LBS infrastructures are reviewed briefly in Sect. 3.1. Then Sect. 3.2 briefly discusses the existing LBS systems proposed providing services in ubiquitous environment.

3.1 LBS Infrastructures Proposed in Literature

Several infrastructures for delivering LBSs proposed in the literature over the past few decades are studied in this subsection. Their usefulness and limitations are also presented. Authors in [10] present an architecture based on open source technologies for the development of Location-Based Services (LBSs). Their proposed architecture SAGESS (Spatial Application Generic Environment System Standards) enables LBS developers to offer services for heterogeneous portable devices utilizing a wide category of developing environments based on different technologies. The authors also describe a methodology, Spatial Application Generic Environment (SAGE), for developing LBS applications that are OS independent. The SAGESS architecture and the SAGE development methodology offer considerable advantages to LBS application developer and content provider by providing the facilities with higher contents compared to any other existing LBS application and by reducing the LBS development cost. However, the authors present only a study on how to deploy a prototype LBS application on SAGESS architecture. No real implementation using the toolkit for SAGE development has been provided in [10]. In [11], the authors have discussed several technical issues associated with the provisioning of LBSs through the existing wireless network architecture. For providing services through a secure and reliable wireless network, the authors have proposed some modifications to the current wireless network infrastructure. Their proposed architecture contains a Geo-location Server (GLS) that gathers information required to estimate the location of the user and contains a Geo-Location Database (GLDB) for storing the geo-related information concerning geographic objects, which enables users to visualize geographic information based on their location. The authors have also presented several application scenarios based on emergency situations, context-awareness and also the user's navigation to demonstrate the feasibility of their proposed architecture. They have also shown that such an LBS infrastructure could enable the user to access the location-dependent information rapidly in a changing environment. However, their proposed infrastructure cannot provide solution to some real-world implementation related problems like lack of scalability in dynamic data collection and also the standardization of interfaces between additional equipment. Moreover, their proposed LBS Infrastructure does not take into account the location estimation and service provisioning via wireless access networks like Bluetooth or Wi-Fi-based network applicable in indoor areas.

The researchers in [12] have presented a classification of Location-Based Services based on whether the user is willing to invoke the services and data objects are mobile or stationary. They have also described the potentially useful services belonging to each category of LBS as specified by them, emphasizing on the requirements of query-processing needed to implement that service. Although some of the services illustrated by the authors can be realized by existing commercial DBMS and GIS, the implementation of other services presented in the paper requires special data structure and query-processing algorithms. The authors in [12] have also pointed out several issues associated with query-processing as these are not supported by existing DBMS. Moreover, the introduction of a new data type, namely, the trajectory in [12] imposes new functional requirements on GIS and DBMS in terms of memory, indexing and query-processing time. The authors in [13] have initially studied the feasibility of the current wireless network infrastructure to support LBSs that deliver the location-sensitive real time message to the mobiles in a target region based on the assumption that each mobile is equipped with self-geolocation capability. In order to offer a service that enables geographically targeted message delivery called geocasting, the wireless network has to provide geolocation information of the mobile devices to an application service provider (ASP) through which the service is offered. Here the main challenge to the wireless network and ASP is keeping track of the location information of the devices for maintaining a certain quality of service (QoS) for the LBSs as the QoS depends on the geolocation update frequency. The authors in [13] have presented several geolocation updating schemes to minimize the frequency of updating while satisfying the QoS of the application services since the geolocation update made by the mobile user consumes battery power, radio resources and increases signaling overhead in the network. The authors have presented two LBSs, namely location-based traffic report service (LBS-TR) and location-based navigation service (LBS-NS) with a description of how to adjust the operational parameters such as geolocation update frequency, resolution of geolocation to satisfy the QoS of abovementioned LBSs while reducing the signaling overhead. A metadata-based infrastructure needed for providing semantics aware LBSs in the smart environments is proposed by the researcher in [14]. This semantic-aware LBS infrastructure incorporates both ontological spatial and geometric representation. It also uses graph-based and knowledge-based navigation algorithms for delivering the services.

In our earlier works [15–18], we have proposed an LBS infrastructure that is able to provide services to heterogeneous mobile devices in ubiquitous environment using either wireless communication technologies like Bluetooth, Wi-Fi or the Internet connection. Our proposed LBS infrastructure comprises several base stations (BS) each of which is Bluetooth-enabled as well as Wi-Fi-enabled and one (central BS) among these BSs have global IP in order to make the services available anywhere over the Internet connection. Moreover, LBS-Middleware is deployed on each BS in order to advertise the services to the mobile users as well as enable the devices with limited resources (like computing capability, memory etc.) to consume the services in a secured fashion [16–18]. Our proposed LBS-Middleware acquires the features of generalized middleware such as interoperability, portability, scalability and so on. It can also dynamically deploy the client application onto the devices in order to reduce the memory consumption and make devices adaptable to new services it discovers whenever it reaches a new location as described in [19]. Apart from GPS-based positioning, a time-of arrival (ToA) based localization scheme, modified geometry-assisted location estimation (MGALE) proposed in our earlier work [20], can be integrated into our proposed LBS infrastructure to address the technical challenges associated with the replacement of all existing cellular handsets with GPS-equipped handsets as well as the problem of limited availability of signals in dense urban areas. Furthermore, a hybrid mobility management scheme based on integrating mobile IP and session initiation protocol (SIP) has been proposed in our earlier work [21] to address the user mobility issues and to enable the users to invoke the services in an uninterrupted fashion through our proposed LBS infrastructure.

3.2 Provisioning of LBSs in Ubiquitous Environment

Many approaches for delivering LBS to mobile users in a ubiquitous environment have been proposed by the researchers over the past few decades. From the literature survey, it has been noted that almost half of the LBS systems rely on GPS for providing services outdoor while the majority of them utilize wireless technologies like WLAN, Infrared, Radio-frequency identification (RFID), Bluetooth, Zigbee etc., for providing services indoor. Due to variations in indoor and outdoor positioning techniques used in the urban environments, various LBSs provisioning systems proposed in the literature for such environments can be divided into three categories. These are (1) indoor location-based services and tracking systems, (2) outdoor location-based services and navigation system and (3) Integrated indoor and outdoor location-based services. In the following sections, these three categories are discussed.

3.2.1 Indoor LBS and Location Tracking System

In this section, some existing systems and approaches that can provide LBSs and navigation services in indoor environments like shopping mall, airports and university department buildings are reviewed along with their advantages and limitations. To explicitly determine a user's position in an indoor environment, wireless technologies such as Infrared, RFID, WLAN, Bluetooth, Zigbee are exploited. Active Badge developed by researchers in [22] uses infrared technology for indoor localization. They encounter two major problems created by lack of line-of sight and short-range signal transmission.

SpotON proposed in [23] attempts to determine three-dimensional location of an object by using RFID based signal strength measurements. In this system, several object location tags were built and their locations were determined by homogeneous sensor nodes without having any central control. Several other LBS systems presented in [24, 25] rely on RFID technology, whereas the researchers in [26] utilize Zigbee for indoor localization. However, most of the mobile devices do not come with technologies like RFID and Zigbee.

Authors in [27] propose an approach that uses triangulation methods on the nodes in a local wireless network, e.g., a network formed by Wi-Fi or Bluetooth, to provide sufficiently accurate location estimation in an indoor area. However, this approach consumes large amount of power and also requires high network bandwidth, which are not always readily available. The LBS systems proposed in [28–30] uses Wi-Fi technology for location estimation and provisioning of services to the user. However, accurate position estimation of the devices using WLAN or Wi-Fi technology, mandates the use of some sophisticated positioning algorithms like fingerprint techniques or some model-based techniques that find out the relation between the measured signal strength at some receiving point from a transmitter and the separating distance between them [31]. On the other hand, the experimental results provided in [32], shows that the Bluetooth-based personal area networks (PANs) can maintain almost equal bandwidth and also a fixed level of energy efficiency while those for the IEEE 802.11-based PANs decrease sharply with an increasing number of PANs. The wireless technology Wi-Fi is mainly compliant with IEEE 802.11b whereas, Bluetooth is low-cost as it operates in the license-free domain, consumes less power compared to other wireless technologies and comes with almost every mobile device. Thus, in the remaining part of this section, Bluetooth-based indoor localization and the navigation systems have mainly been focused.

The authors in [33, 34] present Bluetooth based system providing LBSs in indoor environment. In [33], authors demonstrate a context-aware system developed using Java for the purpose of providing appropriate information about every art to the museum visitors while they come near to that art to view it. Their proposed system consists of three types of software entities: (1) mobile application that runs on a Bluetooth-enabled device, (2) Museum Information Point (MIP) that provides information about the arts over Bluetooth connectivity upon a request from a mobile client and (3) central data server that stores information about various arts located within the museum in its database and provides those art related information to the MIPs. The major limitation of this LBS provisioning system is that only those devices having support for Java API for Bluetooth Wireless Technology (JABWT) [35] can communicate with the MIPs via the preinstalled client application running on those devices to access art related information.

On the other hand, the authors in [34] have presented a Bluetooth based LBS system called SBIL, to determine the position of the mobile users in the indoor areas by using the Received Signal Strength (RSS) measurements combined with an algorithm Minimum Mean Square Error (MMSE) described in [36]. In SBIL, various location dependent services are provided from the server to the mobile users via Bluetooth beacons, which are also used to track the mobile user's location. In order to access and navigate the services in uninterrupted way, the mobile client in SBIL system need to remain connected to at least four beacons all the time. Thus, it mandates the deployment of a high density of Bluetooth beacons and also the extended battery life of the mobile devices for proper functioning of SBIL.

The researchers in [37] have presented an approach to provide location-aware web-based content to Java-enabled mobile devices where the localization system is separated from the content access mechanism. In their proposed system, the positioning system incorporates several different localization technologies like Bluetooth, GPS, and WLAN, in order to enable the mobile user to select the most suitable localization technology interface from among the various available radio localization technologies based on the environment he/she is residing in. Although the above-mentioned approach supports multiple radio localization technologies, the authors have evaluated the performance of their proposed system using Bluetooth technology only and have not provided any solution to the technical issues associated with switching between different localization techniques while the user is on the move. The researchers in [38] have proposed a Map/INS/Wi-Fi integrated system that applies the cascaded Particle/Kalman filter framework structure for delivering indoor location-based service (LBS) applications. The proposed system integrates two-dimensional indoor map information with the measurements from an inertial measurement unit (IMU) and also the received signal strength indicator (RSSI) value for estimating a location in the indoor areas.

3.2.2 Outdoor LBS and Navigation System

Most of the LBS and navigation systems that deliver location-related information and services in an outdoor environment are based on GPS-based positioning. A web-based mobility tracking and analysis system is presented in [39]. The proposed system collects and processes both cellular network-based position data such as BS id as well as GPS-based positions data to create the mobility profiles of cell phone users. However, cellular network-based position data leads to inaccurate mobility paths since the BS id always gives coarse location estimation. A GPS-based location tracking system that collects the positional co-ordinates from the integrated GPS receiver of the mobile device and determines the semantic location of the user with the help of GIS software, is proposed in [40]. However, such tracking system brings some privacy issues and security concerns as revealing location information and the possibility of editing tracked data may pose risks to an innocent person. Although in terms of accuracy, GPS is the most viable solution to positioning in an outdoor environment, the high prices of the GPS receiver along with the practical infeasibility of replacing all existing handsets with GPS-equipped handsets have deferred the researchers and telecom operators to accept it as the most viable positioning solution in an outdoor environment. Only a few LBS systems working in outdoor environments utilize the cellular ID-based positioning as the location estimation done by this positioning technique lacks accuracy. Some methods based on network-based localization technique in an outdoor environment have been investigated in detail in [41]. Lack of accuracy, loss of privacy of the user in case of cellular network-based location estimation and also the increased complexity of the Base Station (BS) in case of Angle-of-Arrival (AoA) and multipath analysis-based location estimation have primarily been cited as the main deterrents in using these approaches.

A hybrid location estimation scheme that combines the GPS-based positioning with the position estimate provided by the 3G network, has been proposed in [42]. The proposed scheme uses the signals received from the Base Stations of 3G network if the GPS receiver of the mobile device could not obtain signals from at least four satellites since four Time-of Arrival (ToA) measurements are essential for 3D position estimate of the device. The researchers in [43] have integrated GPS-based positioning with the GSM Cell-ID-based localization for providing proactive LBSs to the mobile users. The integrated positioning scheme aims to reduce the power consumption made by continuous invocation of the GPS-based location sensing and also introduce several strategies for extending the lifetime of the battery. However, the above two proposed hybrid localization schemes would not be effective to provide LBSs in dense built-up areas and metropolitan city areas as the signal strength of both GPS and cellular network like GSM and 3G/4G are very poor. On the other hand, an application of mobile mapping and LBSs for health care is proposed and developed by integrating remotely sensed satellite data with the geographical information system (GIS) and web GIS technologies [44]. The proposed application can provide the emergency medical services through web GIS technology and also provides medical facilities in a GIS environment for various mobile clients to find suitable facility using network analysis.

3.2.3 LBS Platforms Integrating Indoor Localization and Outdoor Localization

A generic integrated platform involving several positioning technologies such as GPS, WLAN etc., and allowing various types of mobile devices to access LBSs through different communication protocols like HTTP, WAP and SMS in both indoor as well as outdoor environments, has been proposed in [45]. The researchers in [45], have discussed about the prototype implementation of proposed LBS platform, but no experimental results in order to evaluate its performances are given there. In [46], the authors have presented mobile location-aware information system that is capable of delivering location-dependent information to the mobile users while they are roaming around. Their proposed system provides support for administration of the content, navigation of the user as well as runtime management of the user sessions. In addition to these, their proposed system behaves like a large-scale system having large number of simultaneous user-sessions. However, the authors have not provided any experimental result to demonstrate its effectiveness in offering services to the users simultaneously at the scale of hundred as claimed by the authors. Moreover, the architecture of their proposed system lacks the communication interface between the integrated platform proposed by them and the mobile device willing to invoke the LBSs.

On the other hand, the researchers in [47–49] have proposed LBS systems to enable the users to invoke the services in ubiquitous environment. These systems combine GPS-based positioning with other indoor positioning technologies such as RFID, Wi-Fi etc., for determining the user's location anywhere as well as to provide him/her location aware information and services accordingly. However, these LBS systems do not have service-advertising facility and cannot manage the user mobility. A distributed architecture to provide the LBSs available on the local web server via some local access point (AP) is presented in [50]. However, the proposed system remains silent about how the connections between the local AP and various types of mobile terminals are set up and also how the invocation of services by the user continues when the mobile terminal goes out of the communication range of the local AP. The LBS Infrastructure proposed in [51] integrates the WLAN environment with 3G network to provide services anywhere. But the LBSs provided by such system can be consumed by only those devices that have proper API support for processing the messages compliant with XML-based Simple Object Access Protocol (SOAP) [52]. A similar drawback, i.e., the devices that do not have proper API support for processing of SOAP messages are unable to consume services, is found in the work done in [53]. In [54], the authors have presented an LBS-middleware named as Middleware for Location Cost Optimization (MILCO) that attempts to reduce the consumption of network resources needed to carry out location requests. This Middleware uses most suitable localization technique for each location request to meet desired quality of service (QoS) as demanded by the user while minimizing the use of network resources. Although MILCO reduces the consumption of network resources as compared to the observed time difference-of arrival (OTDOA) and assisted GPS (A-GPS)/OTDOA coupling as shown by the experimental results, it lacks the advertising facility of location-based information services and cannot facilitate the users to consume those services in an optimal way.

The authors in [55] have investigated suitable sensors and location techniques that can be utilized in the pedestrian navigation system for continuous position determination of pedestrians. They have presented the design of a pedestrian navigation system, which integrates several suitable location sensors and incorporates different location methods in order to enable a continuous positioning of the pedestrian. However, their proposed system lacks appropriate mechanism for seamless transition between positioning in indoor area and outdoor area.

A seamless indoor/outdoor positioning scheme, which integrates GPS-based localization for outdoor environment with Wi-Fi based localization for indoor areas, is proposed in [56]. The proposed technique uses received signal strength (RSS) based fingerprint technique for indoor localization [69, 70] and also adopts some method to carry out seamless handoff between Wi-Fi-based positioning and GPS-based positioning. However, this integrated positioning scheme consumes significant battery power due to the continuous searches for available Wi-Fi APs as well as GPS signal in a continuous fashion. In [57], the researchers have presented a prototype implementation of a LBS infrastructure that have the service advertising facility and also helps the heterogeneous mobile devices to access the services. Although the proposed LBS infrastructure can deliver customable user interfaces (UIs) required to consume the services on the heterogeneous mobile platforms, but only those devices having proper compiler support to run the UIs can invoke the services effectively. A reasonable way to address the above-mentioned issue is the dynamic deployment of appropriate platform independent client application required to consume a certain LBS and also runnable on the heterogeneous mobile platforms onto the mobile device willing to invoke that service, as demonstrated by the LBS middleware proposed in our earlier work [19]. Moreover, our proposed middleware based LBS system integrating Bluetooth, Wi-Fi and GPS based positioning, can provide services anywhere over the Bluetooth, Wi-Fi or Internet connection [16–18].

Apart from the above mentioned LBS systems, several other existing LBS applications in various domains like social networks, fitness monitoring and healthcare, transport, assistive technology etc., are briefly reviewed in [58]. The authors in [59] aims to identify the public bus stops in urban areas and also to characterize their waiting time which is of much significance to the public transportation system, by analyzing the GPS-based position traces of the public bus. An LBS-based dilemma zone warning system to assist the drivers to take appropriate action during yellow interval at the signalized intersections to ensure road safety, has been proposed in [60]. Moreover, location-based real-time application to avoid collisions for on-road vehicles and to locate some suitable nearest parking spot in urban areas have been proposed in [61] and [62] respectively. An application of location-based social network to detect the functional regions in urban areas based on the co-occurrence patterns of point of interest (POI) types, is presented in [63]. Another set of LBS applications designed for remote health monitoring have been proposed in the literature to support the dementia patients and their caregivers in wandering event [64] and also in detecting emergency situation along with reporting of fall detection [65].

4 Basic Architecture of an LBS Infrastructure

The LBS Infrastructure is a compounded system consisting of four components, viz., mobile devices, communication network, service and content providers and positioning technologies as shown in Fig. 1. The intersection among these four components of LBS system is also shown in Fig. 1.

On the other hand, Fig. 2 illustrates the data flow between the different components of the LBS Infrastructure where a user can invoke services provided

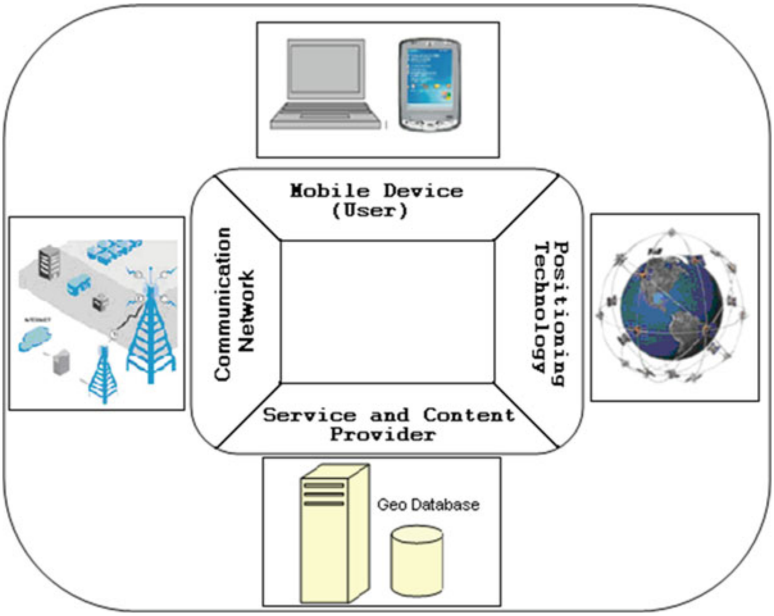

Fig. 1 Basic components of an LBS infrastructure and intersection among these components

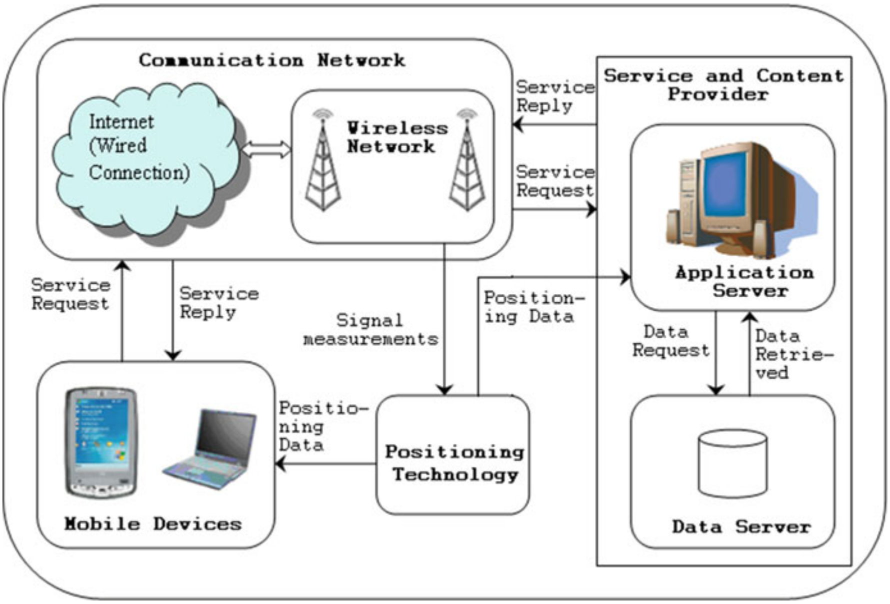

Fig. 2 Data flow between the different components of an LBS infrastructure

by the service provider from his/her mobile device having optional positioning technology through the communication network. In general, mobile user needs to send the service request to the application server where LBSs are deployed through the communication network based on wireless technologies like Bluetooth, Wi-Fi or 3G/4G. The position of the device can be estimated via terminal-based positioning if the device itself has either built-in positioning technology like GPS or the capability to calculate its position using signals received from the base stations.

(BSs); otherwise, the position of the device is estimated by invoking the location service that utilizes some network-based localization technique and the signal measurement from the network BSs. Based on the position of the device, the application server retrieves the required information from geographic information system (GIS) or geo database and sends back the service result to the user through the communication network.

5 Open Research Issues in Provisioning of LBSs

Since determining the user's position is mandatory for providing LBSs, thus location estimation or positioning is an aspect of research in provisioning of LBSs. Apart from positioning, other important aspects of LBS research are data modelling, preserving location privacy, enabling advertisement of services and their discovery by the users and also addressing device heterogeneity, the constraint of resources within the devices as well as the mobility of user. These open research issues in provisioning of LBSs are pointed out below.

- Positioning—although GPS-based positioning can provide accurate location information in outdoor areas, replacing all existing devices with the GPS-enabled devices increases their cost and size. Even though various indoor positioning systems have been devised and proposed in the literature over the past few decades to overcome the limitations of the GPS-based positioning in such areas, *switching between the indoor and outdoor positioning schemes in an uninterrupted way* is essential for provisioning of the LBSs in urban areas. On the other hand, the accuracy of 5G-based positioning is expected to be less than 1 m in the urban as well as indoor areas and the same for suburban areas is expected to be less than 2 m [66, 67]. But there are several technical challenges to 5G-based positioning. Among these, major issues are the optimal combination of the cmWave based positioning with mmWave based positioning in 5G technology, designing some low-cost highly accurate algorithm through data fusion of multiple sources like inertial sensors, cameras, Bluetooth etc., through cooperative positioning, mitigating the effect of multipath reflections/NLoS propagation [68]. Thus, *designing a positioning solution to provide accurate location estimation anywhere in the urban environments* still remains a major research issue.
- Data Modelling—the effective modelling of the LBS data such as location data as well as other context information of the users is an important requirement in the field of LBS research. The research on this aspect aims to provide some solution on how to represent, use and store this type of LBS data.
- Privacy and Security—preserving the location privacy of the LBS user, i.e., not revealing the user's location to any third party is a crucial requirement from the user's perspective. On the other hand, enabling the user to consume the services in a secured fashion in order to reduce the consumption of network bandwidth and other resources is another important requirement from the perspective of the service provider. Thus, privacy and security are two major issues in the field of LBS research.
- Service advertisement and discovery—the advertisement of the services by the LBS system to the users as well as their discovery by the client application running at the user's devices are also two important research issues in this area.
- Device heterogeneity—the continuous evolution of mobile platforms and wireless communication technologies has created the proliferation of heterogeneous mobile devices into the market. Thus, providing LBSs to the heterogeneous devices is another important consideration.
- Constraint of resources—as majority of the mobile devices have limited resources like computing capability, memory, screen size and so on, the deployment of any computationally intensive LBS application onto such resource constraint devices is a significant research issue.
- User mobility—The user mobility hinders the uninterrupted flow of information and services to the mobile users. So, it creates uncertainty in the area of providing

LBSs. The convergence of different wireless communication technologies such as Bluetooth, Wi-Fi, 4G/5G cellular and so on has enabled the mobile users to select some appropriate wireless interface to invoke a specific LBS from his/her device when roaming around the public places like airport, shopping mall, university campus etc. In this regard, the major challenge is how to provide services in the uninterrupted way to the mobile users while they are switching between different networks through either single or multiple wireless interfaces available on their devices.

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