A Glimpse into the Research Space of Location Based Services

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Abstract—**Location Based Services are becoming an integral part of the wider telecommunication scenario. However, the approaches to provide Location Based Services and the research issues in this area are diverse and broad. In this paper, the present state of the Location Based Service systems has been analyzed. The analysis confirmed the heterogeneity of the research problems associated with Location Based Services as well as the array of solutions to address these problems. On one hand, the study carried out will enable one to get some idea about essential features for the implementation of a Location Based Service system. On the other hand, it is strongly believed that this study will assist researchers and the industry to get a sense of the multidimensional research space of Location Based Services which will be helpful for later exploration of this field.**

Index Terms—**Location Based Services, Location Based Services research issues, Location Based Services survey.**

I. INTRODUCTION

Location Based Service (LBS) has become the next goldmine which is being excavated by the researchers all over the world. As this exploration continues, new problems are identified, new solutions are proposed and new developments are taking shape. The ultimate goal of most of the proposed techniques is to have a user centered design through which the user is able to retrieve location related information in the easiest way. However, the design of an application that puts the user at the focal point of the Human-Computer Interaction paradigm in the context of LBS is easier said than done. The complexities of designing interactive applications are obviously higher than simple ones. These systems need to take into consideration the factors related to the context of the users. The context is not merely the geographic co-ordinates. It encompasses the preferences of the user, the service layer agreements (SLAs), the features of the environment in which the user resides, the ability, skill or disability of the user and even the history of user behavior. Furthermore, there is another side of the coin. It comprises of the technical contexts (for example device capabilities, bandwidth constraints, etc).

From the above discussion, a rough and general sense of the design considerations for realizing LBS systems can be obtained. This study has been done as part of a preliminary investigation on implementing a campus information system. Campus information system is not an entirely new concept. It has been realized in some other campuses around the world some of which will be analyzed in later part of the paper. However, the uniqueness of the campuses may impose varying demands on these systems. Campus information systems can be considered a part of LBS systems. But their scopes are limited by the geographical boundary of the campus.

This study has helped to identify the broad spectrum of problems faced by researchers. In fact, the solutions to these problems should be included in any LBS system. Some common trends which exist related to the conceptualization and implementation of the system architectures for providing location related information are marked out. On the other hand, diversities of the research issues as well as the approaches applied to address those issues are remarkable. This paper is designed to represent the diversity of the approaches taken to solve the most common problems related to LBS. Rest of the paper is structured as follows: Section II briefly describes the main components of LBS, Sections III-V provide sequential analysis of the recent research articles, Section-VI presents the results of this analysis. Finally, Section VII provides the conclusion.

II. LBS SYSTEMS AT A GLANCE

A brief overview of LBS Systems will be provided in this section before continuing the in-depth study of LBS research arena.

There are some essential parts of Location Based Service Systems: 1. Geospatial Database, 2. Positioning mechanisms for indoor/outdoor localization, 3. Location and context related contents which are delivered to the users depending on their context and position, 4. Graphical User Interfaces (GUIs) so that the users are able to communicate with the location aware application interactively and efficiently. According to this definition, main components of a system that provides location related information are depicted in Figure-1:

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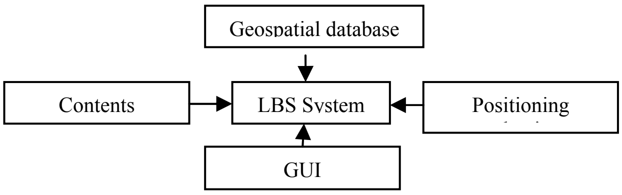

Figure 1. Components of a LBS System

The first step to build a LBS System is to create a geospatial database of the region for which location based services are delivered. There are various ways to build a geospatial database. This is related to Geographical Information System (GIS). Geographical Information System (GIS) is a computer system capable of capturing, storing, analyzing and displaying geographically referenced information. Location and context related contents need to be stored in the database. These contents may include map of different parts of the region of interest, pictures, video or audio files associated with each part, etc. The databases can be built, maintained and queried with the aid of software like Quantum GIS, ArcGIS, SQL, etc.

Positioning of the user is an essential part of LBS architecture because this is the feature that co-relates the geographical entities of interest to the contents. These contents provide the user essential information about the geographic features (for example highways, restaurants, supermarkets) in his/her proximity. It is especially significant for mobile users who are always on the move. Accuracy of positioning should be high because the delivery of the relevant information is depending on the position of the user. There are a few methods for positioning in indoor/outdoor environment. Different methods of positioning (for example triangulation, trilateration, etc) for indoor and outdoor localization of a mobile user are described in [1-6]. For providing location related information effectively, the positioning system should be able to operate in a variety of environments. For example, outdoor open spaces, sub-urban areas, urban environments with high-rise buildings or even underground subway stations. One type of positioning is unable to keep up with such changing environments and deliver the geographic position of the user. Therefore, combinations of positioning systems with the provision of switching between individual positioning techniques are envisaged by the researchers.

The usefulness of location related information will ultimately be depending on how the system conveys information to the end users. Therefore the designers must come up with interactive and user-friendly graphical user interfaces so that the user would be able to understand the instructions and information provided by the system. The interaction of the system with the user should be two way communications. For example, the users should not only be able to receive location related information in their preferred manner but also they should have the facility to provide their location based feedbacks in an easy way. For example, a hotel guest may want to provide his feedback about a particular hotel. Incorporating or relating such feedbacks or comments with the geographical location of interest will serve as a useful tool to guide future users of a LBS system. In addition, such information will enrich the contents related to that particular place of interest.

In the following sections, a sequential analysis of LBS research topics will be carried out. We will also try to classify and group the wide aspects of LBS research. On the other hand, there are some research problems which cannot be clearly classified under a certain category. However, one can consider the research results included in this analysis as a sample from the research space of Location Based Services and even an abstract classification is often useful for analysis. The papers investigated might not completely represent the research arena, but this study will be able to give the readers some idea about the present trends in LBS research.

III. ARCHITECTURAL AND DESIGN ISSUES IN LBS

It is reasonable to start the analysis with the structural aspects of LBS systems. For many systems, other problems and research issues arise after some kind of architecture is implemented. This is no different for LBS systems. Hence we analyze the studies related to the design and architectural issues first.

A. LBS content management and delivery: LBS depend on a structured content management and content delivery system. In [7] the authors identified the significance of a structured content management system. There are tradeoffs between the flexibility to modify the content database and the stability of the database. The authors tried to harmonize these two sometimes contrasting facts. A notable advantage of the proposed architecture is that it can deliver LBS to the users within the framework of existing Wireless Local Area Network (WLAN) infrastructure. Some software upgrades and a client server model for delivering location specific contents will be enough if the proposed approach is implemented. The proposed system works for handheld devices and laptops. The involvement of the users as content providers is a key feature of the proposed content management and delivery architecture. This ensures dynamism of the database in providing relevant information which is space and time specific. In fact, by analyzing the implementation section, one can realize that the procedure for addition or modification of contents requires minimal computing skills. This ensures flexibility for maintaining the contents. The implementation section demonstrates the ease of use of the system for both the content provider and the content recipient. Locations which could be of interest to the user are shown in an interactive manner. The option of turning "off" and "on" specific types of layers on the map ensures that the users are not overwhelmed by excessive information.

Delivery of the right content to the right user at the right time depends on accurate estimation of the user's position. Harsha Tummala et al. [7] mentioned the use of Tiger data sets to calculate the latitude or longitude of the user. Since the Tiger data sets are only defined for regions of United States of America, the extensibility of this type of location estimation technique is questionable for other regions of the world. Another shortcoming of the proposed architecture is that, it's usability was not assessed by the end users. After all, location based services are aimed to make navigation and information services readily available to the recipients. Therefore the evaluation of any such system remains incomplete without the opinion of end users.

A GIS database is one of the major elements of the LBS system. It stores the information about geographical features, spatial characteristics and attributes. Connection to the GIS database is established to retrieve location related information. The loading time associated with the retrieval of such information is significant. Wen-Zhong Shi et al. [8] have come up with a mechanism of dynamic database creation. In general, such databases are created dynamically by applying the spatial, temporal and attribute constraints associated with the user query. For example, the district name and time constraints identified from the user query are used to filter a GIS database that stores ten thousands of records. In this way, a dynamic database which holds only three thousand records can be created. The client software on the user terminal would just compare it's query with this dynamic database to find a match. It was shown that, the response time for retrieval of location information from dynamic database is lower compared to retrieval of such information from the original GIS database. Two more benefits of using such dynamic databases are: accuracy of relevant information extraction is increased and dynamic databases provide a way to reflect the changing environment of Mobile GIS. The drawback of this mechanism might be the cost of processing due to the creation of dynamic database each time a query is invoked. No actual analysis on this has been presented in this paper. The number of simultaneous queries from different clients may also affect the performance of this system.

The relevance of location related information is indeed an important aspect to be considered. A user at a particular geographic location might not be interested to receive notifications about sales discount in a mall few miles away. Therefore, Allan Brimicombe [9] et al. have suggested to create a space time envelop to limit the area of relevance for the user. This envelop is built using current position, direction of travel and some parameters defined by the user. Therefore the amount and type of location related data that the users receive are influenced by the shape of the space time envelope. The authors have also presented a pseudo code for implementing the space time envelope. If the space time envelope is able to manipulate the information about user preferences, profiles and the history of user requests for location information, it can be very useful for the LBS system.

B. LBS Architectures and Platforms: Leandro Krug Wives et al. [10] described the necessities for providing information services in a campus environment. A notable characteristic is that the system can provide the information in Wireless Application Protocol (WAP) specified standards. This means the system can provide services to a wider range of users. The authors have discussed a component based architecture where different components are responsible for different functions. These components interact to detect the users, to estimate their location, to authenticate them and to provide them location related data. Such a design based on modular architecture gives some useful insight into how complex campus information systems can be managed in an easy way. The authors of this paper have also described how guests or visitors can receive information regarding the surrounding environment. This is important since visitors may visit campus for conferences, seminars and other purposes. Authors have also proposed that, users should be able to receive relevant information regarding the surrounding environment by using VoiceXML. VoiceXML or VXML technology allows a user to interact with the Internet through voice-recognition technology. Instead of a traditional browser that relies on a combination of HTML, keyboard and mouse input, VXML relies on a voice browser and/or the telephone. Using VXML, the user interacts with voice browser by listening to audio output that is either pre-recorded or computer-synthesized. They can provide audio input through voice or through a keypad, such as that of mobile phones. This provides an easier way for the users to query the system for information. Moreover this system will incorporate even a wider community of users receiving LBS because the user does not need a smart phone to get these services. A low cost mobile phone would be enough. However VXML on the other hand will require some other associated functions and components like accurate speech recognition and VXML platform. The delay and bandwidth requirements for VXML applications are also major issues to be investigated. The communication component which is discussed in this paper offers flexibility in terms of communication with the user because it takes into account the context of the user and activates the appropriate communication subsystem, for example: vocal interaction or alert. The authors defined a range of commands which helps them locate and identify the characteristics of their items of interest. Privileged users can in fact modify the attribute of some resources (for example teachers can change class schedules) stored in the system. The "Alert" component described in the article provides a personalized service to the users for managing schedules and meetings. The analysis of this paper shows that the authors have been able to identify the main components and their functions of a comprehensive information system for providing location based services in a campus setting. The nature of human computer interaction within the framework of the campus information system has been identified too. However, the authors have not presented any implementation or proof of concept demonstration to verify their idea.

As the technology is heading towards Fourth Generation (4G) Communication Networks, the delivery of LBS in 4G scenario becomes an interesting topic of research. This area has been investigated by Zhang Yun et al. in [11]. In the paper the authors have proposed an agent based system to deliver location related content to the user. According to the framework provided by the authors, different access networks and servers are connected by an IP core network. In this architecture the servers provide the basis for delivering LBS. Location based services may involve contents such as media files. The delivery of such contents may consume a lot of bandwidth. Therefore the authors have proposed data compression to speed up the process. The suggestion that, high capacity caches should be built for 4G mobile terminals to reduce the need for frequent transmission also seems to be reasonable. This is because transmitting data every now and then involves wasteful use of bandwidth. The authors however did not explore one important aspect of location based services in 4G network. In a 4G environment the users will have multi interface mobile devices based on the Software Defined Radio (SDR) technology. The users are likely to shift from one radio access technology to another even in the middle of a data transfer session. In such a scenario the positioning technology will have to deal with the shifts in transmission modes. For example, the current position can be sent to the new access network by detecting some triggers prior to handover. If the accurate position information of the user is sent seamlessly to the access network to which the session is handed over, LBS can be delivered even when the 4G network user is changing his/her mode of access.

Arpan Roy et al. [12] proposed a web based architecture for LBS that has several advantages. The most obvious one is the flexibility of adapting the delivered information depending on the capability of the mobile device. The users can receive information related to their location in either textual mode or graphical/animated mode depending on their device capability. The authors have mentioned the usability of their system in providing location information to new comers to a particular location so that they can find the places of their interest. The location information is provided to the users in response to their requests. This is referred to as “Pull Mode” data transfer. “Pull Mode” data transfer enables delivery of only the relevant, precise and desired information to the user. User is not overwhelmed with excessive location information. The tracking application would store user requests and later will use those requests to estimate the location of the user. This ensures that, the tracking application does not need to start a completely new process to find the location of the user, thus reducing the tracking time. Intuitively this storage mechanism of user requests may help the system to identify the frequent users and their usage pattern. A closer look at the paper also reveals some drawbacks. The delivery of information relative to present location (for example the nearest medical centre) is dependent on the accurate retrieval of latitude/longitude of the receiver. Thus, GPS enabled hand phones are required. Therefore the system would work fine for hand phones having GPS positioning capabilities. The authors have also kept provision for delivering location services in WAP enabled hand phones operating in GPRS networks. However, if those phones do not have GPS positioning ability, the accurate latitude/longitude information cannot be obtained from these types of phones. Therefore delivery of location based services cannot be implemented for these types of devices. Also, the proposed system requires a new comer to an area provide his/her credit card number to receive information of his interest. A traveler who plans to stay in the area for a short period of time might be skeptical to provide such data. Finally, in the result section authors have acknowledged the fact that the path tracing application can sometimes yield slow response.

One of the major challenges faced by the industry related to efficient delivery of location based information is the tight coupling of the GIS functionalities with the telecommunication service provider’s infrastructure. Interoperability with other systems and services reduces due to lack of standardized procedures and protocols in such an environment. A solution to this problem is suggested by Zanuldin Ahmad et al. [13]. They have illustrated an architecture whereby the GIS functionality and processing is separated from the domain of the telecommunication service provider. Two servers namely the GIS Web Services Server and Content Web Services Servers are introduced. These servers provide GIS functionalities and other information such as weather reports and traffic patterns by means of web services. Since the interaction among the LBS system, GIS Web Server and the Content Web Server takes place through standardized protocols like HTTP (Hyper Text Transfer Protocol), SOAP (Simple Object Access Protocol) and XML (Extensible Markup Language), the interoperability of LBS systems with different telecommunication providers can be ensured. Therefore, the main contribution of the proposed framework is that, it reduces the load of GIS processing for telecommunication service providers. Also, it enables standardized service provisioning by the use of standardized web services and protocols between the GIS components and the LBS systems. It also gives the GIS solution developers a chance to develop applications without focusing too much on the constraints of the telecommunication service providers. One more advantage is notable from the implementation section. The architecture provides a flexible and non static way of representing location information and map images. However, one potential weakness of the proposed system could be the delay associated with the interaction among the GIS components, content web services server and the LBS system of the telecommunication service provider since these components are decoupled. Sometimes, the users of LBS are in need of quick delivery of relevant information and they will be dissatisfied if this information is not delivered to them in time. Therefore analysis of the delay between the service request and delivery of the location related information would have been useful for evaluating the proposed architecture. But, such analysis was not presented.

An architecture for Mobile GIS Technology is described by Feixiang Chen et al [14]. Mobile GIS based LBS have been described as a client server system by the authors. They have divided the whole system into two subsystems: the terminal subsystem and the service centre subsystem. They have also kept the provision for adapting the nature of LBS based on the terminal capability. Each of the subsystems is further divided into modules (for example spatial data visualization module, GPS location module, etc).Such a modular architecture helps the developers to identify the functions of each module clearly and implement the modules in an optimal way. However, in a modular structure the interfaces through which these modules interact should also be clearly defined. The lack of clarity in describing the inter-relation, interaction and interfaces of the modules is a weakness of the architecture depicted. Also, the implementation of the paper reported that, compression rate and speed of data transmission are high. However, without numerical and concrete data such claims are hard to verify.

Another LBS architecture called AROUND [15] uses identifiers to distinguish the association between services and the locations. This is achieved by defining scopes of the location related services as the set of location contexts in which these services are available. In simple terms location contexts within the described framework are just the representations of physical spaces (for example, campus). The location services are distributed among servers called AROUND Servers. A process called contextualization determines the user context and the service point (for example an access point) through which the user is accessing the network. Finally, a process called Name Service helps to identify the Around Server from which the user can conveniently receive location information. The authors have presented a client program which requests location dependent services based on the above concepts.

In [16] the authors have described a LBS system that makes use of WIBRO (Wireless Broadband) network for delivering location related data. The authors tested their implementation in a campus environment. They described the system's potential applicability for unmanned helicopters which can be used during natural calamities.

In [17] the authors have briefly described some features of Android platform for developing location aware applications. The authors have argued that, since Android is an open source platform, it can provide certain amount of flexibility for designing location based applications.

A web based GIS/LBS System has been described in [18]. This is also a modular architecture with provisions for extensions. The location information is provided through web applications. The authors have stressed the need for dynamic map generation for providing interactive location related mapping services. They have implemented these services using Java Server Page (JSP) and MapBeans, a JavaBean component. Finally the significance of dynamic map generation as part of LBS is demonstrated by using these maps to model the traffic situation in an area of Cluj-Napoca, Romania.

A distributed architecture might be used to reduce the network congestion caused by LBS. In [19] the authors have proposed a layered spatial service architecture where the geographical databases are deployed over a distributed network. This decreases the excessive load on a central server for handling geospatial processing. The use of Peer to Peer (P2P) multimedia data sharing can be helpful in reducing the server load.

A LBS Server might have to deal with too many requests from users requesting text, map or multimedia associated with their present geographical location. Ching-Sheng Wang et al [20] have also suggested a P2P data sharing mechanism to provide location related data. These data are used in conjunction with a virtual navigation system that takes the position of the user in a real environment and shows the position in a virtual model of the same environment. Groups of users are formed based on their location and interests to optimize the P2P file sharing. The implementation of the mechanism shows that, P2P system significantly reduces time for downloading navigation data compared to server only system.

IV. Interaction of LBS System with the User

This section aims to discuss the nature of interaction of the user with LBS system. The research problems related to such interactions and a few solutions addressing these problems will be analyzed.

A. Semantic capabilities, natural language and query processing: A key enabler technology to provide effective location information through web is to add semantic capabilities to the description of those services. Incorporating such capabilities make the task of discovering location related information easier for software agents. Such a framework for providing LBS on the web have been described by Jun Shen et al. [21]. Initially, the authors have built a Geographical Markup Language (GML) and Web Ontology Language (OWL) based geographic Ontology. Secondly, they have built a Web Ontology Language (OWL) Service profile related to the Geographical Ontology of the corresponding service. A module named OWL Service matchmaker is used to compare the request of the client for a location service and the web services offered. The authors have provided an algorithm that selects the nearest peer having the least distance to provide a requested service.

LBS can be provided on the basis of user queries as well. In fact incorporating such capability into an LBS system introduces flexibility in the sense that it gives the user a chance to make their questions in natural language. A technique for such query processing has been described in [22]. Defining the context free grammar and syntax of queries is the key to enable human-machine interaction for the LBS system. The authors have described some examples illustrating how a predefined context free grammar allows the machine to understand human queries in natural language. To summarize, the paper describes a framework for understanding the LBS queries of users by making use of natural language processing.

Of course, defining such a framework for natural language processing is a huge task because of the fact that, the sentences used by the users will vary widely in terms of their structure. Nevertheless, the success of search engines like Google is a sign that such an approach to provide location based services is quite reasonable.

Tongqiang Guo et al. have described architecture for providing information services to tourists [23]. It makes use of Global Linear Quadtree to encode the regions of the world. This spatial encoding serves as the location identifier of the region. The present location of the user is revealed by using path matching, point matching and region matching algorithm. The global linear quadtree defined previously is traversed to find the location of the user, exploiting and understanding the semantic relations among a variety of data. To make this possible, authors have proposed a framework for cross media data management.

As a LBS system has to deal with a large number of queries, it is of utmost importance that these queries are handled efficiently and are responded quickly. At the same time the processing cost related to the query processing should be minimized. These issues have been investigated in depth by Mohamed F. Mokbel et al. [24] as part of the PLACE project in Purdue University. In this paper the authors have clearly explained the nature of the Spatio-Temporal queries. The characteristics of different Spatio-Temporal queries have been identified. Although, on the surface it seems that only the queries related to the present state of a user is relevant, a deeper look reveals that users of LBS might be interested in obtaining information about past events. For example, a visitor to a tourist destination may be interested to know the number of tourists who have visited that destination during the previous month. Therefore the nature of queries to a LBS system will have a broad range and variety. For example, the authors have described queries such as: moving queries on moving objects, stationary queries on moving objects, etc. However, it might be possible to group queries based on some common attributes of the queries. The authors have shown how the concept of sharing can be applied to Spatio-Temporal queries. To do this, they have suggested some mechanisms which identify the shared elements of multiple queries. Consequently, the processing of the query and cost for retrieving the information corresponding to the query can be reduced.

Location is the first entity that comes into our vision when we are talking about LBS. An in depth analysis of the meaning of physical and geographic location has been presented in [25]. The authors have argued that understanding the semantics beneath the physical location is important so that the LBS providers can deliver adaptive context aware location related information to the users. Therefore they have described the concept of semantic location. In fact, semantic location provides a useful way to model geographic locations or objects because it not only expresses the location's relations with other locations but also an ontological expression of the semantic location enables computers and devices understand the rules associated with the location. For example, a mobile phone goes into silent mode in a meeting room. This can be realized by embedding the ontological description mentioned above into the location aware system which makes the mobile phone understand the context of the user.

B. Enhancing user experience with augmented and user requirement based LBS: Some ways of enhancing user experiences while providing LBS are investigated by researchers. Multimedia services as part of location based services offer one such opportunity. In [26] the authors proposed a LBS system that incorporates multimedia features (for example, video, audio and images).These multimedia files are associated with each unique site of a region. When the user reaches a particular site, the corresponding multimedia files are played or displayed. Therefore, the users can receive informative feedback in an interactive way for the sites. The authors have proposed a framework by which these multimedia data can be compressed and stored. These compressed data can be downloaded by mobile terminals through wireless link. Compressing such data prevents wasteful use of memory on the server and reduces bandwidth consumption. On the terminal side, the multimedia and other data can be decompressed by using a Dynamic Link Library (DLL). In this paper, the key enabler for providing LBS is the use of unique site ID for each site in an area. Configuration files are created for each site which stores the relevant tourist information as well as the multimedia files associated with the site. Later, when a tourist traverses the region, the ID of the site is retrieved through GPS positioning. Once the ID is found the files associated with this unique ID are invoked, thus enabling delivery of location information through multimedia files and other data. The authors rely entirely on GPS positioning to extract the position of the tourist. Since the GPS signals are not available indoors most of the time, the system proposed may not work indoors.

LBS can be coupled with personalized information services in order to provide an enhanced user experience. Such system need to keep a track record of user's activities, preference, interests, professions, etc. One such system architecture based on modular components is explained in [27].

The usability of LBS depends on the proper understanding of the instructions delivered by the LBS system to the user. Therefore the nature of interaction among the components of a LBS system with the users should be explored. This point is emphasized in [28]. In this paper, Virtual Reality (VR) based model of a region is developed. Then, participants are asked to take tours in the virtual environment. They were asked to find locations of churches, pubs, etc in the virtual tours. As they took the tour they would ask for location information using their handheld PDA. They can choose to get this information through texts, voice instructions or maps through a web browser interface. The interactions of the users with the environment and the LBS system are recorded using software. Other methods like questionnaires were also used for data collection on user preferences and actions. Thus the ability of the system to meet user demand can be studied. Though VR offers a controlled environment to conduct the experiment on LBS, sometimes it differs significantly from the ground truth. The obstacles faced by a LBS system in reality could not be modeled completely by Virtual Reality. Nevertheless, the use of virtual reality might offer a useful platform to make some preliminary assessment of newly developed LBS Systems.

The need for a user centric LBS system design has been reemphasized in [29]. In this paper, the authors have described details of the first phase of their research on a Mobile LBS system. This phase first defined a target group selected from Australian citizens. This group was considered the representative population of leisure travelers. The individuals who were willing to participate in the research were given a set of questionnaires. The answers to these questionnaires helped to identify the user characteristics, context and preferences. Later, using the knowledge obtained from the user interactions, a number of 'Personas' were considered. In simple terms, Personas are generalized models of the users. Finally, the interactions of the personas in different scenarios were considered. Consequently, the nature and characteristics of location information required by users at different scenarios were identified. Some of the requirements that an LBS system should meet were also found by analyzing the results of the research. For example, a Mobile LBS system should focus on 'on trip support'; it should support user preferences on map orientation and directions, etc.

Delivery of Personalized, Adaptive and Ubiquitous Location related information is a major goal of LBS systems. Alexander Zipf and Matthias Joest [30] have stressed the need of defining Ontology to realize such systems. In their paper, they have depicted some schemas in order to illustrate the Ontology. These structures have the provision of employing 'user models' which may help in providing personalized geographical or other location related information. Context in simple terms is the present situation of a user. Context awareness is also a vital factor for LBS systems. Therefore, authors have suggested an integration of user and context models.

In [31] a walking guide application is described. This is built on an Ontology called LAIR which models the geographical relations and functions of spaces. The distinctive feature of this walking guide is that it can generate written instructions to help the user move from one point to another. The instructions are accompanied by a map which shows the position and surroundings of the user. These types of instructions are helpful in increasing the interactivity of LBS. An interactive simulator designed in conjunction with the model has the ability to describe the features and functions of the place in which the user is in, proximity of a place from the user's current position, etc. The application has been evaluated by a number of volunteers and the results demonstrated the effectiveness of the application.

The issue of interaction between LBS system and the users has been investigated in detail by Weining Yue et al. [32]. First, authors have tried to explore the psychological issues related with these types of interactions. By analyzing these issues a framework for proficient communication between users and the LBS application is proposed and implemented. The authors have identified the technological requirements for the realization of such a system. The major requirements are: 1. a multimodal and easy to use user interface for communicating with LBS, 2. context awareness on the part of the LBS system. The authors have implemented an interface which is able to turn itself depending on the movement of the user and the way the handheld device is held. One more remarkable feature is the use of semi transparent popup menus for displaying suggested locations on the foreground of the map to show the user's current position. The authors have carried out detailed evaluation of the system through potential end users to justify the validity of the concept. The users were told to interact and receive location related data using different modes of interaction.

The delivery of appropriate information to the user has been investigated in [33] too. The authors have provided an intuitive way to classify location information. By using the Naïve Bayes classification approach the application is able to learn about the interests of particular users. So the system with such a classifier is able to judge whether new location related information falls in the category of data which is of interest to a particular user. If it does not fall in this class, the system does not push this location related information to the user.

Moodlog [34] is a tourist information system that emphasizes a deeper understanding of a place by making the scope of LBS wider than just traditional "Way Finding" instructions. It enables the tourists to experience the feelings of previous visitors to the place. With this application in operation, a visitor to a place can express his/her mood by taking and uploading photos, music, videos, etc. These data become part of the mood of the place itself. The tourists who come subsequently are able to experience these contents. This is done by determining the position of the user and retrieving the associated contents from a database. The database stores the feelings of prior tourists in the shape of photos, music, videos and colors.

C. Displaying location related information and user interface design: Displaying maps on the mobile devices is an essential part of LBS. However, displaying pixel based graphics on the mobile devices may result in excessive bandwidth consumption during transmission through wireless links. One way to reduce this bandwidth consumption is to use Scalable Vector Graphics (SVG) to display the maps [35].Scalable Vector Graphics is based on vector graphics. Vector graphics represent the map images with lines, polygons, curves, etc by using mathematical equations instead of pixel based bitmap images. In this paper, a client side Active X component is incorporated with SVG. There is a map database on the server side which stores the geographic features by using lines, polygons, etc. When the client requests information about maps of a particular area, Structured Query Language (SQL) is used to retrieve the relevant information from the map server. The map stored in XML format is converted into SVG format. The authors also suggested reducing the number of characters in the SVG document in order to decrease the file size and use less resource on wireless links. The Graphical User Interfaces for connecting with mobile map server and a simplistic map are shown based on the concepts described in the paper. From the display output observed, some basic functional icons for customizing the view of the map are shown. However, the geographical features are not annotated on the map shown on the mobile terminal.

In [36] authors have proposed a system to support the panoramic view of different places using wireless devices. The system stores images of landmarks, routes and objects. These images are hyperlinked so that the users can view related images as they traverse through a location. For example, a user in a particular location can find corresponding snapshots of that location by clicking on the map. Moreover, the user interface provides a number of hyperlinks associated with a particular location. Clicking on these links will take the user to the images of places, streets and objects surrounding the place of interest. This gives the user a chance to judge his current location by comparing the virtual and the real environment. Two more distinctive feature of the application are: 1. it allows the users to have different viewpoints of the same location and 2. the system is able to provide sufficient detail for resolving exact address of the destination. The system uses a 2D imaged based representation to compound a collection of discrete images. However with this approach it might be difficult to determine the number and the viewpoint of images which will ensure a precise depiction of a location.

Amel Bouzeghoub et al. [37] have envisaged an interface which first highlights the objects or locations of interest to the user on the display. The system would decide highlighting such information by comparing the present context with the user profile, location and interests of the user. If the user is willing to know more about the highlighted object, he/she can click on the object icon. Therefore the user does not have to filter out unnecessary data manually. An Ontological framework to realize this concept is also described in the paper.

Rahat Iqbal et al. [38] proposed a system that allows the on road monitoring of an individual by their family members or friends. The location of the driver is tracked and showed on a smart home display. The display is smart in the sense that: 1. it is unobtrusive and 2. it becomes prominent only if there is some updated information to show. The application uses Google Maps to show the location of the drivers. Several drivers can be tracked at the same time. The application also supports transfer of messages between the driver and the individual who is tracking. A standout characteristic of the application is: it provides a personalized tracking system where a person is able to choose the people who are able to monitor him.

V. MISCELLANEOUS ISSUES RELATED TO LBS

Some other research issues cannot be grouped in the manner which is being followed in the previous sections. Therefore, this section tries to shed some light on these issues.

A. Privacy issues: The delivery of location related data without exposing the identity of the user is a research challenge. There are many users who are reluctant to reveal their identity in exchange for receiving LBS. Toby Xu and Ying Cai [39] have suggested a mechanism to hide the identity of the users of LBS. This mechanism gives the user an opportunity to specify the locations for which he is willing to reveal his position. Otherwise the positions of the actual user of LBS cannot be resolved by malicious parties because this information is hidden among a group of similar information corresponding to the locations of surrounding users. The authors have explained a mathematical model for realizing this vision. They have also implemented it and evaluated the performance by using three different approaches. An analysis of CPU utilization, memory and storage requirements for the application is presented to justify the use of this approach to secure privacy while providing location related information. The probable abusive use of GIS and LBS has been described in detail by J.E. Dobson et al. [40].

B. Power consumption of the user terminal and LBS: A research area in LBS which has been explored less commonly is the power consumption for providing location related information. In a mobile environment a user should not be forced to recharge the battery of his/her mobile every now and then. Mikkel Baun Kjaergaard [41] has analyzed this issue in considerable detail. The power consumptions of different location based services have been depicted. They have also investigated the power consumption of features (for example, Bluetooth, Processor, etc) of a Nokia N95 mobile phone. Based on the analysis of the power consumption, authors have discussed some techniques for minimizing power consumptions. Two possible strategies recommended for reducing power consumption are: 1. decreasing the frequency of position estimations by using error models to estimate the position and 2. Use of caching to avoid frequent transmission of LBS related data.

C. Care support systems and LBS: Care support systems can be considered an essential part of location services. These systems are specifically developed with the aim of monitoring children and elderly people. One such system named uEyes has been implemented in [42]. There are some outstanding features of the developed system. It describes agent based architecture to realize the vision of ubiquitous context awareness. Most of the other LBS systems have taken into account only the context of the user while contexts related to device capabilities, network capacity, bandwidth constraints have remained largely unnoticed. To take into consideration these contexts the authors have implemented user agents, software agents, network agents, etc. These agents co operate with each other to provide a comprehensive context aware care support system. The authors have shown the operation of the system where an individual is able to monitor his father's health remotely through context aware video streaming. The streaming can be transferred to different devices depending on the contexts of the watched and watching users, device capabilities, display requirements and bandwidth constraints.

D. Campus information systems and LBS: Efficient delivery of location related information may also be affected by some factors which are not so obvious. Sandra Sendera et al. [43] have described a technique to study the mobility behavior of people in a campus setting. Since most university campuses are covered by WLAN access points the association of MAC addresses with those access points can be used to analyze the movement of people in the campus. In general, the dynamism of the movement of people is reflected by the changing association of MAC addresses with different access points in different buildings or locations of the campus. This information allows identification of most visited places in the campus as well as the detection of buildings which have the highest roaming correlation. Consequently, mode of delivery of location related information can be adapted depending on the network traffic associated with particular buildings.

An information system named eyeJOT [44] has been implemented by Bashar Al Takrouri et al. to provide personalized information to individuals in a campus environment. The system uses Bluetooth for device level communication. On the other hand, MySQL, PHP, Macromedia Flash and .NET framework are used to realize the software platform for the eyeJOT system. An example of the interaction of the eyeJOT system is explained where a new university student comes to eyeJOT's display and sees information about his invitations, classes and schedules automatically on the display. The eyeJOT system recognizes the presence of the ID of the student's PDA (Personal Digital Assistant) and therefore displays the above mentioned information. The system is also able to sense the proximity of the student and adapt the level of information details depending on the proximity. Therefore, a user has to come at least a minimum distance near the eyeJOT display to retrieve information. Otherwise she/he'll be considered out of range. Although the authors did mention the system's ability to convey personalized information to the out of range users within the campus through SMS, they have not shown exact mechanism of how this can be done. A similar system that implements campus wide digital notice boards is described in [45]. These notice boards are connected and are able to provide public notices, private or group specific messages to individuals in a campus. It is a matter of debate whether these are part of LBS but according to our reasoning these systems use the proximity of a user and deliver information to the user based on his/her proximity, so these information systems could be related with LBS systems. Another campus information system for providing class schedules, detailed information about faculties, map services has been described by Jose Almeida et al. [46]. The system uses three tier architecture to provide information services through web applications. A mobile navigation system for people with visual impairments has been described too.

E. Tourism, navigation and tracking: Since tourism is the primary source of income for several countries, providing information about the surroundings of a tourist site to the tourists is a major goal of LBS architectures. Delivering this type of information to tourists has been described in [47]. The system uses ARCGIS 9, GEOGENIUS, TRIMBLE and SKIPRO software to build and process a GIS map of some popular tourist destinations in Jordan. To do this, the GPS co-ordinates of the sites are determined and the satellite images of the sites are captured. These images are digitized and converted into a layered GIS map. This layered GIS map represents the different geographic features (for example, hotels, hospitals, mosques, churches) by using annotated shapes on a map. Different layers represent different geographic features. All the layers can be combined to show all geographic features in one single layer. In addition, a geo-spatial database is built to store the names, locations and attributes of the geographic features. If the user clicks on a feature the attribute value of the feature is shown. For example, the rank of a hotel can be seen by just clicking on the name of the hotel on the map. The proposed system has kept the provision for finding the information about a feature and viewing pictures of the features by the use of hyperlinked data. Moreover, more complex queries such as finding a feature within a certain distance from another feature can be answered. The authors have mentioned a website which aims to provide the relevant location related information mentioned above. However, they have not made available the URL of the website in their paper. Also, the system transfers data to the tourists in "Pull Mode". This does not autonomously detect the user position and transfer the location information related to his present position. The tourist himself has to go to the website and retrieve the information.

LBS are closely related to the positioning of the user and the GIS database. This relationship is identified in [48]. The major areas for LBS applications are also highlighted in this paper. Certain measures need to be taken in order to improve the delivery of location related information. The main suggestions provided by the authors are: regular update of GIS data and maps, interoperability between co- ordinates specified by Global Navigation Satellite (GNSS) system and the local co-ordinate systems. GNSS co-ordinate systems are characterized by Latitude, Longitude and Altitude. Examples of local co-ordinate system are street addresses to uniquely identify a house or an apartment block. There has to be an accurate and efficient mechanism for converting the position of a geographic feature from the GNSS co-ordinate system to the local co-ordinate system and vice versa. The authors have implemented an Automatic Vehicle Location System for the public transportation company operating in Amman, Jordan. According to the authors, the developed web tracking software will serve as a competent tool for monitoring the movement of vehicles on the road, thus enabling better fleet management. It should also help the authority to take prior actions to solve possible problems by analyzing web data. Another information system developed by the authors is the Police Traffic Information System. This system reports the location of accidents to the police stations. The area of the accident is shown by graphical means. Additionally, the system reports the name of the driver, number of vehicle, state of weather associated with each accident. Nonetheless, the numerical results obtained by the web tracking software were not shown. Additionally, there was no concrete example of how the tracking software and the Police Information System enabled the authorities to tackle problems related to traffic congestion, management and accidents.

In [49] an experiment is discussed whereby the movement of an individual has been tracked over a period of two weeks using a GPS device. The result shows useful information about the daily activity of a person, his locations at different periods and even the pattern of his social activity. This type of user tracking might help the telecommunication service provider to classify user behaviors and preferences. Consequently, appropriate LBS can be delivered to the users by using this information intelligently. Some issues related to the accuracy of GPS tracking have also been outlined by the authors. Also the GPS signal is not always available and dropouts in GPS signals have been observed. The telecommunication service providers themselves can benefit from the use of LBS. While most of the existing literature discusses different ways to provide LBS to the users, the usefulness of location related information to the telecommunication service providers is rarely mentioned.

Proper maintenance and troubleshooting of the telecommunication infrastructure can be possible with the help of location based information services [50]. In this paper, a mobile GIS system is discussed. While part of this system monitors and detects the faults of Base Stations, Base Station Centers and cable networks, the other component does troubleshooting and maintains the dispatching system for repairing the faults. These two components interact using the GIS system that stores the records of base station subsystem and cable network locations. When a fault occurs in the base station subsystem, the location of the faulty system is determined by the use of positioning technologies. Then the GIS map shows and highlights the determined location. Therefore, the vehicles used for troubleshooting can be deployed to fix the problem. The location of these vehicles can be observed through the map too. Again, a GSM based Short Messages Service (SMS) is used to maintain communication between the vehicles and the dispatch centre. Hybrid positioning technology is used to locate elements of the system to ensure retrieval of location information under different conditions. Finally, the authors have proposed an algorithm to locate faulty points which makes use of the longitude and latitude stored in the GIS database of the telecommunication system infrastructure. The implementation of the algorithm described is not explained clearly though.

Todd Simcock et al. [51] described a tour guide system which uses Compaq Aero augmented with a GPS receiver unit. The users have focused on designing a simple user interface. The tourist guide application can be operated in three modes: map mode, guide mode and attraction mode. These modes show the position of the user on the map, highlight the attractions and provide sites, sounds and attractions of the corresponding points of interests. New tours can be loaded into the system. The authors have also shown that the use of differential GPS (DGPS) increases the accuracy of the system. However, authors have mentioned the system's inability to provide in depth and detail information such as complete street addresses and building names. Therefore, the requests of tourists in need of detailed information might not be served. Another, drawback is the separate GPS receiver used to find the location of the user.

Sometimes a Mobile LBS application can be used by more than one person. A typical scenario would be the collaborative use of a "Way Finding" application by two friends visiting a new place. Such scenarios have been investigated in detail by Derek Reilly et al. [52]. Authors have set up an experiment where pairs are given typical "Way Finding" tasks. The user actions during the Way Finding" tasks are documented by observations, voice recordings, etc. These observations revealed the impact of user interface of LBS applications on the interaction and collaboration between the individuals in a pair. Such analysis gives the designers of LBS system useful hints for implementing applications which might be used for collaborative navigation.

In [53] an application that uses photographs of street segments or landmarks for navigation has been described. An experiment was set up where two groups of users were given navigation instructions through two modes. One mode involved the use of map and delivery of textual routing information. The other mode involved delivery of photographs surrounding the user's destination or current location. It was found that the users having the provision to use photographs in addition to map and textual instructions completed the navigation tasks earlier. In addition, authors have mentioned the ability of GPS enabled devices to automatically determine the co-ordinate of a photograph taken at a specific place as a key enabler for photograph based navigation. However, the photographs must satisfy some conditions in following scenario: 1. the photographs should be updated and should reflect the present state of the place, 2. the photographs should be linked with the corresponding photographs of the same place taken at different seasons and different times of day or night.

Alternatively, a simulation application can be applied to a photograph of a place to express the effects of changing weather and lighting conditions. Another work similar to [53] is described in [54]. A photo or landmark based navigation application is explained. The salient characteristic of the designed navigation client is the use of an image selection algorithm. This algorithm selects the photographs of landmarks along a path which will be best for navigational guidance. Another special feature is the use of arrows overlaid on landmark photos to indicate directions. This application was also subject to a quantitative evaluation by the end users. In general, the responses of the users were positive on the landmark based navigation client.

A "Way Finding" application named Photomap [55] aims to integrate commonly found 'you are here maps' with the Internet based maps. The 'You Are Here' maps are the local maps found at universities, small natural parks that help people to navigate within those locations. The common Internet maps found often do not provide details for small local regions. For example, a Google map shows the campus of Universiti Sains Malaysia (USM) but the level of detail it provides is not sufficient: it does not show the exact locations of USM bus stops, restaurants, academic buildings, hostels, etc. Therefore this coarse grained map will be of little help to a newcomer in the university. The authors have highlighted this issue and provided a mechanism for integrating the local maps with large scale Internet maps. The described mechanism allows an individual with a camera phone to take a picture of the local 'You Are Here' map, align this map with the internet maps and geo-reference this photo in order to support "Way Finding" and navigation in a small localized region. One of the most important parts of LBS is to help the user find the nearest place of interest. For example, a user might be interested to find the nearest chain shop, theatre or park. Retrieving such information is a demanding task and requires implementation of some mathematical models. A mechanism that may help the user receive such information is described in [56]. This paper uses aggregated nearest neighbor queries to model the problem and find nearest point of interest in large scale road networks. The implementation and incorporation of such mechanisms within the framework of an LBS system might reduce the navigational workloads of a user.

VI. LBS RESEARCH TRENDS- SUMMARY AND IMPLICATIONS

As a result of the detailed analysis presented above, some patterns of the present LBS research space can be revealed. Due to the broadness of the field no survey or analysis would be able to cover every aspect of LBS research. But revealing the general direction of LBS research is important since this gives the potential researchers an idea about the aspects which have not been investigated thoroughly. The summary from the above analysis is listed in Table-II, Table-III and Figure-2. The abbreviations to be used in Table-2 are explained in Table-I. From the tables and the Figure-2, a clear

Table I. Abbreviation of Research issues in LBS

Research Issues according to the sequencing in Section III-V	**Abbreviation of Research Issues to be followed in Table-2**
III-A. LBS Content management and delivery	III-A. **LBSContent**
III-B.LBS Architectures and Platforms	III-B. **LBSArchitecture**
IV-A. Semantic capabilities, natural language and query processing	IV-A**. LBSSemantics**
IV-B. Enhancing user experience with augmented and user requirement based LBS	IV-B**. LBSEnhanced**
IV-C. Displaying location related information and user interface design	IV-C**. LBSDisplay**
V-A. Privacy issues	V-A**. LBSPrivacy**
V-B. Power consumption of the user terminal and LBS	V-B**. LBSPower**
V-C. Care support systems and LBS	V-C**. LBSCare**
V-D. Campus information systems and LBS	V-D**. LBSCampus**
V-E. Tourism, navigation and tracking	V-E**. LBSTour**

depiction of the distribution of LBS research issues within the scope of analysis can be seen. A total of 50 papers on Location Based Services have been analyzed. Most (11) of the papers are on LBS architecture and platforms. It constitutes a percentage of 22%. This is understandable since the deployment and commercial use of LBS are still on the preliminary stage in many countries of the world. Therefore, the architecture and platforms are the main subjects explored by researchers. LBS research and development is also fueled by the continuous information needs of tourists as well as navigational and tracking applications. This is also reflected from Figure-1. It shows that papers related to these matters make up 20% of the total papers investigated in this survey. User requirement based LBS studies which aim to take into account user satisfaction and tries to provide users with augmented services on top of basic location based services have also received a lot of attention from the researchers. On the other hand, LBS in campus environments design of interactive display of location related information have also received noteworthy concentration from the researchers. Only two papers which emphasize on privacy of users in the context of LBS have been identified. Battery power consumption related to use of LBS also received minimal attention from the research community. The reason behind this is not too hard to identify. These are the matters which will come up as people start using location based services more frequently. For example, the topics related to security on the Internet really came up when use of internet became widespread. Surprisingly though, only 1 paper among the 50 papers examined has discussed about care support systems. However, the potential of LBS systems as part of care support systems is enormous which can be realized from the illustration presented in the mentioned paper.

Table II. Distribution of LBS research issues

LBS Research Topics	Number of Papers	Percentage of total papers analyzed in this survey (%)
III-A. **LBSContent**	3	6
III-B. **LBSArchitecture**	11	22
IV-A. **LBSSemantics**	5	10
IV-B. **LBSEnhanced**	9	18
IV-C. **LBSDisplay**	4	8
V-A. **LBSPrivacy**	2	4
V-B. **LBSPower**	1	2
V-C. **LBSCare**	1	2
V-D. **LBSCampus**	4	8
V-E. **LBSTour**	10	20
Total	50	100

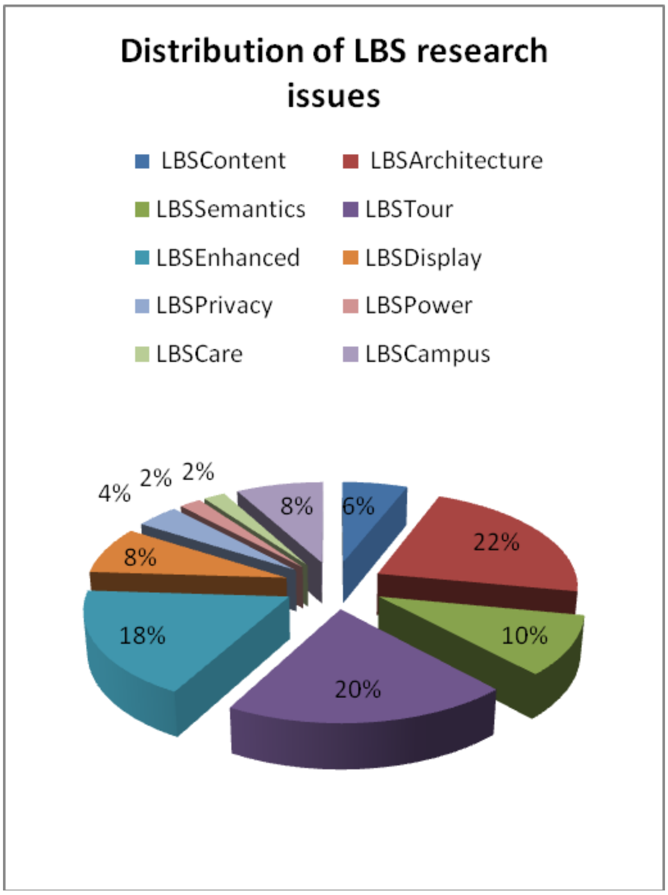

Figure 2. Distribution of LBS research issues

Therefore these systems are expected to receive more attention from the researchers in future.

Table III. Main features of the papers analyzed in sections III-V

LBS Research issues	Main features of some of the respective papers
III-A. **LBSContent**	1. Participation of users as content providers [7]. 2. Dynamic Database creation [8]. 3. Creation of Space-Time envelops to limit the area of interest for Location Based Services [9].
III-B. **LBSArchitecture**	1. Use of VoiceXML [10]. 2. LBS in 4G scenario [11]. 3. Decoupling of GIS functionality from Telecommunication service provider [13]. 4. Modular architecture for GIS [14], 18. 5. P2P architecture for LBS.
IV-A. **LBSSemantics**	1. GML and OWL for LBS [21]. 2. Context free grammar for LBS query in natural language [22]. 3. The nature of Spatio-Temporal LBS queries [24]. 4. Semantic Location [25].
IV-B. **LBSEnhanced**	1. Associating Multimedia with location [26], [34]. 2. Personalized LBS [27], [30]. 3. Virtual Reality for LBS modeling [28]. 4. Interactive LBS [32].
IV-C. **LBSDisplay**	1. Displaying SVG Maps [35]. 2. Hyperlinked Panoramic views for LBS [36]. 3. Smart home display [38].
V-A. **LBSPrivacy**	1. Hiding position information of the user [39]. 2. Monitoring and exerting control by manipulating location information [40].
V-B. **LBSPower**	1. Battery power consumption related to LBS [41].
V-C. **LBSCare**	1. Care support system using agent based architecture [42].
V-D. **LBSCampus**	1. Digital Notice boards [44]-[46].
V-E. **LBSTour**	1. Automatic Vehicle Location System [48]. 2. LBS for maintenance of Telecommunication networks [50]. 3. Tour guides [51]-[52]. 4. Photo or Landmark based navigation [53]-[54]. 5. Integrating local maps with Internet Maps [55].

In table-3 a summary of section-III-V is presented. Not all the papers analyzed in the respective sections are mentioned in the table. However, the main features have been highlighted. The interested reader should be able to get a comprehensive summary of the subjects of this paper by having a look at this section.

VII. CONCLUSION

In order to identify the desired features of a LBS system, a thorough study of the research problems related to LBS is required. In this investigation, the fundamental features of such a system have been identified through an in-depth study of the existing implementations. Sections III and IV are intended to make a logical grouping of related research topics in LBS. The analysis in these sections discusses the characteristics, strengths and weaknesses of the solutions developed by the researchers. In addition, some suggestions are included to enhance the performance of these systems. Section V on the other hand provides a similar discussion of issues which can not be grouped in a pre-specified way.

However, the major contributions and key findings of this paper are highlighted in section-VI. The analytical study carried out in this paper was able to reveal the direction of LBS research. It established the fact that, the architectural issues still remain the main area explored by the researchers. In addition, tourism, navigation related applications together with interactive transfer of location related information have received considerable interest from the research community. This investigation has also discovered the research areas which are explored less frequently by the academia and industry. Therefore, through the glimpse at the research arena of LBS, one would be able to reveal the pattern of inclination that exists in the LBS research space towards specific topics. It is believed that, this paper will be able to give the LBS industry and research community a general idea about the present trends in LBS research and it will also help the potential researchers to make choice of their research topic for Location Based Services.

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