CHAPTER 1

INTRODUCTION to CONTEXT AWARE SYSTEMS

1.1. Overview on Context Aware Location Based Systems

Pervasive computing is an emerging area being effectively employed in diversified fields. Steady growth of information access and communication elements allows everyone to access the information and it could virtually exist everywhere at all times. Pervasive computing is an extended form of mobile computing in which user employs many different mobiles, stationary and embedded computers over the course of the day. In this model, computation does not occur at a single location in a single context, as in desktop computing, but rather spans a multitude of situation and location covering the office, meeting room, home, airport, hotel, classroom, market, bus station etc. Users might access their computing resources from wireless portable devices and also through stationary devices and computers connected to local area networks. This collection of mobile and stationary computing devices that are communicating and cooperating on the user’s behalf form a mobile distributed computing environment. This form of computing is broader than mobile computing because it concerns people who are mobile and not just mobile computers. This system aims to provide ubiquitous access to information, communication and computation. One significant aspect of this computing is its constantly changing environment. Similarly, the user may move from one location to another, joining and leaving groups of people and frequently interacting with computers with reference to changing social situations. This results in a new class of applications that are aware of the context in which they are administered. A context-aware application requires contextual information that must be gathered from various sources, such as sensors that are embedded in the environment, devices that are worn by end users, repositories of historical data tracking use of the application, and information contained in user profiles. Systems that are aware of the context are called Context-Aware Systems.
(CASs) [1]. CASs adapt according to the location of use, the collection of nearby people, hosts and accessible devices as well as to changes to such things over time. These systems have the capability to examine the computing environment and also react to environmental changes [2]. In context – aware computing, the application adapts not only to changes in the availability of computing and communication resources but also to the presence of contextual information, such as who is in the vicinity, the time of the day, where the system currently resides, the emotional state of the user, the action the user is performing and the intention with which that action is being performed. Different types of context are available [3]. Location context is the most prolifically used type of context for developing context-aware applications. It could provide the information about where the user currently resides. This information can be raw location information such as, the latitude and longitude of the user or it can be obtained at a higher level, such as the number of the room in which the system is currently operating.

Location awareness services (LASs) are becoming more popular with the advancement in the next generation wireless networks and broadband multimedia wireless technologies. To provide location awareness services, fixing accurately the position of a user is important. Positioning forms a key component for mobile computing and pervasive computing technologies. The term ‘Pervasive’ was first introduced by Weiser [4]. Pervasive computing technology is an advanced computing model that would appear anytime and anywhere. Services offered by the system based on the location are called as Location Services (LSs) or LASs or Location Based Services (LBSs). It generally plays a vital role in people’s daily life due to the development of mobile devices, Internet and other wireless networks. In particular, LASs find application in various fields. During periods of emergency like gas explosions, aircraft crashes, earth quakes, tsunamis and train accidents, there is a dire need to identify the presence of human beings within the disaster zone. LASs are also used to
provide accurate positioning and personal identification of human concealed/buried under debris. In hospitals, it is used to keep track of the patients who need care, to track the doctors or nurses and even locate expensive medical equipment and accessories. In museums and exhibition halls, LBSs are used to guide the visitors/tourists through exhibition halls based on the location. In library, they are used to guide the reader to choose the book of their choice through archives. In university, LBSs are used to track the visitors and guide them to their destination. They are also used to keep track of the teaching staff so that the students can easily find them. They find their use at home to keep track of the children and also give guidance to the elderly people. Also they provide navigation aids to visually or differently abled people to move inside a familiar or an unfamiliar building.

Greater use of mobile devices and Personal Digital Assistants (PDAs) enables the persons to access the Internet anywhere, anytime. Through Internet, people can obtain the relevant information about the events (parties, concerts) and places (cities, museums, hospitals) by search results. Let us consider a simple example that one wants to take dinner in a restaurant, they can make a search about a restaurant in the Internet. One of the useful approaches to prevent the search results about restaurant list on the world, people could restrict search by adding further search criteria. An easy solution is to identify the place (city) where the mobile user is (position), the time or specific type of restaurant (Indian or Chinese). In such a situation, LBSs have to provide the services with respect to position and time. Thus, one of the definitions of LBS is information services accessible with mobile devices through a mobile network and utilizing the ability to make use of the location of the mobile device [5, 6, 7]. Even though Geographic Information Systems (GISs) and LBSs have some common similarities, they have different origins and user groups. GIS is based on professional geographic data applications, whereas the idea of LBSs was introduced recently due to evolution of wireless networks. Also GIS require extensive computing resources,
whereas LBSs operates well within the restrictions of mobile computing environment like low power, small displays or the restricted battery run time of the mobile devices. If the user wants to use LBSs different infrastructure elements are required. In essence, LBSs are services that are using the potential and capabilities of modern mobile devices, positioning technologies and mobile networks to deliver to the user value added information or service based on his location. The main value of LBSs for users is that they do not have to enter location information manually, but it is automatically collected (with positioning technologies) and used to generate personalized information. LBSs are often to be a part of the integral Context Aware Services (CASs).

Generally, context refers to what surrounds the centre of interest, provides additional sources of information “Where, Who & What” and increases understanding. Definition of context and its types used by an application are discussed in [8, 9, 10, 11]. From an Engineering perspective, many definitions have been proposed. According to Dey [11], Context is any information that can be used to characterize the situation of an entity. An entity is a person or object that is considered relevant to the interaction between a user and an application, including the user and the application themselves. The use of context is growing increasingly important for applications, where the user’s context is changing rapidly [12, 13]. Systems adapt according to the location of use, the collection of nearby people, host, and accessible device as well as to changes to such things overtimes are called CASs. General architecture of a Context Aware System is shown in Fig.1.1
Various definitions of a context and context-awareness have been discussed in [14, 15]. Context-aware applications for pervasive computing offers flexible and adaptable services to users and are totally conscious of the user, what surrounds him, his environment or anything that might be useful for the end user.

1.2. Motivation

Normally, people find it very difficult to locate a particular place, person or object in an unfamiliar or complex environment like airports, exhibitions, corporate premises, school campuses, hospitals, museums, shopping malls, railway stations and urban areas. These examples motivate a person towards the need for a suitable device that would guide the user in real time, through a sequence of steps in enabling him to reach the desired destination. Navigation aid is not only useful for guiding users through unfamiliar places but also has applications in navigating autonomous robots and guiding the visually impaired or differently abled people through safe path within an environment.
1.3. Literature Review

In human to human communication, the use of implicit contexts (information pertaining to situation) improves the correctness and integrity of conversation. However, this use of implicit information to convey ideas does not work well with human-computer communication. Interactive computers employ an improvised mechanism for providing input into their systems. This was realized by improving the computer’s access to context and thereby improving the richness in human-computer communication. Such context aware computers were widely used in handheld and ubiquitous computing [16]. Useful research in context aware computing was started in the early 1990’s at Xerox Palo Alto Research Centre (PARC) Laboratory and Olivetti Research Ltd. The first context aware systems are Active Badge System [17] and Parc Tab System [18] which are used to determine the user’s present position and communicate this information through a phone call to the nearest telephone unit to another user. Similar environment and application is described in [19]. In intelligent residential environment, such context aware system helps to monitor the elderly, differently abled people and also children. Then, it produces an alarm if anything goes wrong [20, 21, 22, 23, 24]. The CAS described in [25] has an application in emergency environment such as fire accidents. The other environment where this system has an application is in the development of tourist guide [26, 27]. Context information uses several parameters reflecting the context of the user’s task. These parameters may be subdivided into personal, technical, spatial, social, and physical contexts. The major problem linked with CASs is modelling those parameters in a quantifiable and computable way. The spatio-temporal information about the user is one of few parameters that is straightforward and fairly easy to measure and use. If a system uses context to provide useful information and/or services to the user, where relevancy depends on the user’s task, it is termed a Context Aware System [28, 29]. Location context is the most prolifically used type of context for developing context aware applications [30].
Related work on finding location context was started in 1996 due to the growth of different wireless positioning technologies (such as Internet, GISs, Global Positioning Systems (GPS) and Wireless Networks). Federal Communication Commission (FCC) released an order requiring wireless operator to provide Wireless Emergency Services (WESs) to their customers [31]. The appearance of these technologies leads to a new type of information technology called Location Based Services (LBSs). Attraction of LBSs increases significantly due to its capability of achieving range of highly personalized and context aware services. They have the ability to locate a mobile user geographically and to provide services to the user, based on his location. The important fact behind LBSs is that it does not enter positioning manually but it is automatically collected using various positioning technologies and useful to provide personalized information. It exists from short range to long range wireless communication networks. Several research works are in progress related to LBSs. In [31] the authors describe three different types of services and the major research challenges in LBSs.

Generally, there are three different environments to find the location of the mobile user namely indoors, outdoors and mixed (region between indoor and outdoor) combination. Hence, positioning system can be classified as: (i) Indoor positioning, (ii) Outdoor positioning and (iii) positioning in Mixed Environment. Positioning of the mobile user in these environments has been achieved by several ways [31].

In an outdoor environment, satellite based system such as GPS [32, 33, 34] performs far better to find the location of the mobile target (user or object). But, GPS signal is unable to travel inside the buildings (indoors), urban area, any type of closed environment and underground. Hence, location awareness becomes a more difficult issue in the indoor environments (like airports, corporate and school campuses, exhibitions, hospitals, museums, shopping malls, and railway stations).
Indoor Positioning System (IPS) has to provide accurate positioning of the object/person (stationary or non stationary). The major challenging issues in IPS are area of the deployment and its cost, hardware and computational cost, obstacles inside the room (like walls, fans, furniture, doors and other building materials) causing the signals to get attenuated and reflected, resulting in multipath effect. In order to achieve high accuracy, the IPS must able to handle these problems effectively.

Localization is a method of estimating the physical position of the mobile target (a person or object). General classification of localization is based on area of deployment, type of wireless technology and measured parameters, Lookup table method, Estimation technique, localization entity and privacy issues [35].

The present study mainly focuses on wireless technology, measured parameters and estimation techniques. Wireless technology plays an important role in positioning. Higher the operating frequency smaller will be the time and hence high time resolution is achieved. High accuracy in positioning requires higher frequencies, but it would cover only shorter range. The physical area that the wireless network must cover is called coverage region. Based on the wireless technologies used, localization can be classified as Ultra Sound (US), Infra Red (IR) and Radio Frequency (RF) Systems.

In [36] the author has developed a location support system using Time Of Arrival (TOA) based positioning using ultrasound signal. Also, Receiving Signal Strength Indicator (RSSI) based localization is analyzed in [37, 38]. Ultrasound signals have the following limitation such that they are not able to penetrate walls and other indoor obstacles. Its gets reflected from most of the indoor obstacles. Also, the speed of ultrasound signal is 106 times slower than the RF signal. In acoustics propagation, 1ms corresponds to 0.3m while in the case of RF, 1ns corresponds to 0.3m. An ideal radio wave has high speed, uses little energy and travels long distances. It can penetrate through obstacles like building walls and human
bodies easily. Hence the radio waves has the ability to transfer information in a very short time covering large area with less hardware compared to other systems.

Most of the earlier mobile devices utilized Infrared (IR) for positioning the mobile target. It requires clear Line Of Sight (LOS) between the transmitter and the receiver [39, 40]. The major limitation in this type of positioning is that it can cover only shorter distances, interferences due to sunlight and other light sources, requiring expensive hardware and maintenance cost [41].

This is the main reason why current IPS is based on RF technology. The advantages of this technology are RF signal can travel larger distance and cover more area with less hardware. It can penetrate obstacles such as building materials, doors, furniture and other indoor materials as well. Generally, RF based IPS are classified into narrow band (RFID, Bluetooth, Wi-Fi, and FM) and Ultra Wide Band (UWB) technologies. This system is to locate the mobile user by measuring the radio signal travelling between the Mobile Node (MN) and a set of fixed stations. Depending on the distance between the transmitter and a set of receivers, distance measurement by this system is categorized into Network and client based Positioning System (PS). The first RF based technique for location determination and user tracking was RADAR [42] by Microsoft Research. Radio Frequency Identification Device (RFID) enables a one-way wireless communication using a noncontact and advanced automatic identification technology that uses radio signals that put an RFID tag on people or objects, for the purpose of automatic identification, tracking and management. Tracking the movements of objects in RFID is done through a network of radio enabled scanning devices over a distance of several metres. RFID technology is used in a wide range of applications including people, automobile assembly industry, warehouse management, supply chain network, and assets without the need of line of sight contact [43]. Bluetooth is a wireless standard for wireless personal area networks (WPANs). Almost every Wi-Fi enabled mobile
device, such as mobile phone or computer, also has an embedded Bluetooth module. Bluetooth operates in the 2.4GHz ISM band. The benefit of using Bluetooth for exchanging information between devices is that this technology has the advantage of high security, low cost, low power, and small size. Each Bluetooth tag has a unique ID, which can be used for locating the Bluetooth tag. There are several recent research works dedicated to Bluetooth based localization systems [44, 45, 46]. The drawback of using Bluetooth technology in localization is that it cannot penetrate walls and Bluetooth device has latency unsuitable for real time positioning applications. The FM radio-based system is widely used in most households and in cars. It uses the Frequency Division Multiple Access (FDMA) approach which splits the band into a number of separate frequency channels that are used by stations. There are only a few limited works dedicated to FM radio based positioning. Recently Popleteev et.al. and Moghtadaiee et.al. presented their research work on indoor positioning using FM radio signals [47, 48]. Applications that require low-power consumption but do not require large data throughput utilize ZigBee technology. It is an emerging wireless technology standard which provides solution for short and medium range communications as a result of its numerous benefits [49]. Ad Hoc ZigBee network described by Fernandez [50] provides improved position determination based on the power levels.

Radio technology for short range, high-bandwidth communication having the properties of strong multipath resistance is Ultra Wide Band (UWB). Widespread use of UWB has been made in a variety of localization applications requiring higher accuracy than achievable through conventional wireless technologies like RFID and Wireless Local Area Network (WLAN).

Recently positioning systems attract significant attention of the researchers to combine several different positioning technologies [51] in determining the location of a mobile target. Many location technologies are used to estimate the position of mobile user
based on some mathematical models. The local positioning systems fail to work outdoors; whereas GPS based positioning systems do not work accurately inside buildings due to the absence of the line of sight to the satellites. So, there is a need for positioning systems that can work both indoors and outdoors, and hence, the concepts of combined indoor-outdoor positioning systems are used [52]. Several such positioning systems are currently being developed and used in services from Combain Mobile, Navizon, Xtify, PlaceEngine, SkyHook, Devicescape, Google Maps for Mobile, and sopenBmap for applications in smartphones.

Based on measured parameter, RF Position Location (PL) systems can be classified into two broad categories: (a) Direction Finding (DF) and (b) Distance or Range Based systems.

Direction finding systems is to locate the position of a source/target by estimating the Direction-of-Arrival (DOA) or Angle-of-Arrival (AOA) of the signal coming from the source and it is received at multiple fixed receivers [53]. The DOA measurement restricts the location of the source along a line in the estimated DOA. When multiple DOA measurements from multiple receivers are used in a triangulation configuration, the location estimate of the source is obtained at the intersection of these lines. The performance of this position system depends on propagation environment. Scatter near and around the source and the receiver affects the measured AOA. It would cause multiple signals to appear at the receivers from the source and vice versa. Absence of LOS signal component and also even with LOS, multipath would still interfere with AOA measurements. Hence, the accuracy of AOA method decreases with increasing distance between the source and the receivers [54].

Position determination based on distance measurements is commonly referred to as *lateration* or *trilateration* or *multilateration*. Trilateration determines the position of the target by measuring its distance from multiple reference points. Thus, it is also called *range
measurement technique. In it, the “tri” says that at least three fixed points are necessary to determine a position. Various localization schemes use different parameters. Techniques based on the measurement of the propagation-time system e.g Time Of Arrival (TOA), Round Trip Time Of Flight (RTOF), and Time Difference Of Arrival (TDOA) and Received Signal Strength (RSS) based and received signal phase methods are called lateration techniques [55, 56, 57].

Range-based PL systems can be categorized as ranging, range-sum or range-difference PL system. The type of measurement used in each of these systems defines a unique geometry or configuration of the position location solution [57]. Ranging systems are also known as TOA or spherical Position Location (PL) system. They are used to locate the target by measuring the absolute distance between a source (target) and the receiver (known position of the fixed wireless nodes). Accurate measurement of TOA requires a high resolution clock. This would limit the distance resolution to 300 m for RF transmission or 343m for ultrasound. Hence, due to the cost of high resolution clock, ultrasound based TOA techniques [36, 58, 59, 60] are preferred to RF based TOA techniques [61, 62, 63]. TOA based positioning needs accurate time synchronization between the transmitter (target whose position is to be determined) and receiver (fixed known position of the wireless node). But, this is eliminated in RTOF. In RTOF the receiver retransmits the signal back to the transmitter. This method of positioning is affected by the latency in the receiver response depending on processing the queue at it. Another time based positioning technique is Time Difference Of Arrival (TDOA). It considers the difference in time of the signal received at different receivers [35, 53]. In RSSI based positioning, Received Signal Strength (RSS) is defined as the voltage measured by a receiver’s Received Signal Strength indicator (RSSI) circuit. In practical environments, Signal Strength (SS) varies inversely with distance‘d’ [64] and hence, this scheme is preferred for low cost simple localization and is frequently used in
Local Area Localization (LAL) [35]. In [42, 65, 66, 67, 68] authors described the positioning of the target using RSSI based scheme. The main challenge in RSSI positioning is to overcome the error due to clutter and multipath indoor environment.

Once the position of the moving person at a given time is obtained based on localization method, then the real time tracking of the target is possible by employing deterministic and probabilistic estimation techniques. Most commonly used deterministic technique is multilateration [42, 61]. Multilateration also utilizes Least Square Estimation (LSE) [69]. Hatami and Pahlavan proposed a variation of LSE scheme such as Prioritize Maximum Power [70]. Probabilistic techniques have also been used to improve localization estimate, track users and avoid aliasing [71]. Youssef and Agrawala, Castro et al., Ladd et al., Madigan et al., described localization techniques based on Probabilistic estimation [66, 67, 68]. Aliasing in localization occurs when two largely separated locations have similar parameter distribution or statistics (such as mean SS). This results in erroneous location estimation. Haeberlen et al., Castro et al. introduced hidden Markov model for modelling a mobile target and showed considerable improvement in localization accuracy, thereby avoiding any sudden change in current location estimate that may be caused due to aliasing or other errors [66, 72]. This present study follows the probabilistic approach namely Kalman filter for real time position estimation of the mobile user.

Based on the literature work reviewed, the broad scope of the research problem undertaken is outlined in the next section.

1.4. Scope of the Research Problem
1.4.1. Formulation of the Research Problem

The emergence of network-enabled devices and the promise of ubiquitous network connectivity have made the development of pervasive computing environments an attractive research goal. A compelling set of applications enabled by these technology trends are context-aware, location-dependent ones, which adapt their behavior and user interface to the
current location in space, for which they need to know their physical location with some degree of accuracy. While much research has been focused on developing services architectures for location-aware systems \[73\], less attention has been paid to the fundamental and challenging problem of locating and tracking mobile targets, especially within in-building environments.

The few efforts that have addressed earlier localization systems in the context of IR wireless network resulted in Active Badge system \[17, 74\]. This system provides significant contribution to the field of location-aware systems. A badge worn by a person emits a unique IR signal every 10s. Sensors placed at known locations within a building pick up signals from the unique identifiers and relay these to the location manager software which determines the user location. Accuracy in positioning information is better for limited coverage area (no scalability). The problem in this system is that it involves significant installation and maintenance costs. Also system performance is limited by the presence of direct sunlight.

Another system that utilizes the combination effect of RF and ultrasound technologies to provide a location-support service to users and applications is Cricket and Bat \[36, 58\]. Major design goal of Cricket includes user privacy, decentralized administration, network heterogeneity and low cost. Rather than explicitly tracking user location, it helps devices to learn where they are and let them decide whom to advertise this information to; it does not rely on any centralized management or control and there is no explicit coordination between beacons. Cricket mainly emphasizes location-support system, rather than a conventional location-tracking system. The differences in design goals between Bat and Cricket are due to radical differences in architecture. But major drawback of these systems is that ultrasonic interference at the receiver can lead to incorrect distance measurements.

Another ultrasound based localization scheme for wireless Ad Hoc sensor networks is described in \[59, 61\]. It uses TDOA method for fine grained localization scheme. It should
operate in a distributed fashion unlike Cricket and Bat. In an Ad Hoc setting, there is no fixed reference node for ranging. The performance of Ad Hoc based positioning depends on the Ad Hoc network topology changes.

SpotON [75] is a flexible alternative to infrastructure centric location systems. It is a system of Ad Hoc networking tags which uses received radio signal strength information to estimate inter-tag distance. SpotON combines ideas from object localization and Ad Hoc networking. Ad Hoc location systems can provide relative and absolute location data and can support both infrastructure-centric and wearable application models. Ad Hoc location sensing considers only three qualities such as location, homogeneity and socialistic information. RSSI based measurement variances are sometimes more than what is needed to estimate the target positioning. This could be overcome by using time based (TOA and TDOA) techniques.

DV-Hop [76] presents an algorithm that exploits the characteristics of Ad Hoc wireless sensor networks to determine the position information without radio capability. The algorithm exploits two principles: (1) the communication hopping between two sensors can give an easily obtainable and reasonably accurate distance estimate and (2) using imperfect distance estimates from many sources can minimize the position error. Additional sensors are needed to overcome failure in terms of accuracy by coordinate system. Next similar scheme is APIT [77] for localization and tracking the target. Basically APIT is area based range-free localization scheme. Localization error affects a variety of location dependent applications. Accuracy provided by the range-free schemes is sufficient to support various applications in sensor networks with only slight performance degradation.

Simple hybrid TOA/AOA algorithm based on least squares solution of lines of position is proposed in [78]. This system utilizes the TOA or range measurements at two or more BSs and the AOA at the serving BS to locate the MS. Effect of NLOS errors is minimized by nonlinear constrained optimization and lines of position (LOP) technique. The performance
of the system is improved if it knows a prior knowledge of the distance between the servicing BS and the nearest obstacle along the AOA direction.

Horus is a non centralized client based RF location determination system and it is currently implemented in the context of 802.11 wireless LANs [67]. Low computational requirement is one of the design goals of this system. This requirement is achieved by location clustering techniques. But accuracy of this system highly depends on threshold parameter. If this threshold value increases more access points are consulted to reach a decision. As the number of access points increases, the number of operations (multiplications) per location estimate increases and so does the accuracy.

RF networks offer a significant advantage over IR and Ultrasound networks in terms of range, scalability, deployment and maintenance. One of the RF based systems RADAR [42], uses Signal Strength information gathered at multiple receiver location to triangulate the user’s coordinates with help from offline phase and real time phase. Large scale variation in the RF signal propagation environment causes the error distance for tracking the mobile user to be only slightly worse than that for locating a stationary user. The accuracy of the position system is improved with the help of the base station based environmental profiling.

The existing positioning systems have the following limitations:

1. In terms of wireless technologies used, most of the earlier PL systems were Ultrasound and IR based. These systems provide better accuracy in positioning a target but, the performance of these systems is affected by coverage range and scalability of the wireless link. In positioning systems based on combination of Ultrasound and RF technologies, the system performance is limited by ultrasonic interference.
2. Non-centralized Ad Hoc sensor network based positioning systems do not use fixed reference node (receiver) for ranging. The accuracy of such systems depends on changes in Ad Hoc network topology.

3. There are only few research papers on RF based positioning system for localization and tracking. Accuracy of range free systems is affected by position dependent parameters. The performance of the range based PL system using signal strength information is limited by multipath reflection faced by RF signal. This motivates the need for time positioning schemes (such as TOA, TDOA) for indoor localization.

4. RF based indoor positioning systems use least square estimation and hidden markov model to track the mobile target. Large variation in indoor propagation environment introduces error distance for tracking the mobile user. It requires all the past values to predict the target’s future estimates. This motivates the need for better tracking methods.

To overcome the aforementioned limitations in the performance of the existing positioning system, indoor environment is considered and the objectives are presented in the subsequent section as a contribution of the research work.

1.4.2. Objectives

The objective of this study is to locate the indoor target by RF based schemes and to track the mobile target using linear predictive filter. This work differs from the other methods in terms of estimation techniques employed and the choice of wireless technology deployed.

- TOA based PL system is used to locate indoor target and the user is tracked by linear predictive method using UWB technology.
- TDOA based indoor positioning is employed to locate the user and tracking is obtained using Kalman Filter by establishment of UWB radio link between the receivers and transmitter.
Hybrid RF based scheme is deployed to locate the indoor target and estimated position of the user is optimized with unconstraint nonlinear optimization technique using UWB wireless platform.

For outdoor environment satellite based positioning system, using GPS receiver kit (GPS-04) is used to estimates the location of the user.

In the regions in between indoor and outdoor boundaries, both UWB and GPS have to provide the position information of the user, based on the assumption that UWB access points are close to this region and two of the active satellites have to be used by outdoor GPS.

1.5. Organization of the Dissertation Report

- **Chapter 1** introduces the research dissertation that commences with a broad overview followed by an introduction to the subject-matter details and expresses the major factors motivating the author to undertake this research investigation. This chapter presents the literature survey undertaken followed by the scope of the research dissertation, research problem formulation and presents the important findings of the thesis. The chapter terminates with the organization of the thesis dissertation.

- **Chapters 2** outlines the various range based position location schemes and demonstrate the mathematical modeling and general architecture for representation of the mobile target in three dimensional (3D) spaces. The first module of the chapter deals with target positioning based on conventional TOA scheme. The last two modules cover the direct and the objective methods, using UWB platform. Kalman Filter is utilized to provide the real time estimation of the mobile node.

- **Chapter 3** analysis is undertaken on the effect of TDOA for indoor positioning of the UWB node. The chapter explains the mathematical modeling of the three different methods of determining user TDOA and the succinct effect of Generalized Cross
Correlation (GCC) method for indoor positioning of the mobile target. The last module deals with localization of the wireless nodes, using centralized technique called Multidimensional Scaling (MDS).

- **Chapter 4** portrays the importance of the Hybrid based positioning using UWB technology. The chapter demonstrates the mathematical modeling of the RSSI-TOA based scheme for locating a wireless node. Then, the position of the node is optimized by Unconstraint nonlinear optimization approach.

- **Chapter 5** outlines a model for combined indoor and outdoor positioning using UWB and GPS technologies. The first module of this chapter explains the application of GPS for positioning a node in outdoor environment in terms of various windows, using NMEA message. Demonstration of various blocks present in GPS trainer and explanation of the positioning of the target in the transition region, using combined effect of UWB and GPS technologies are illustrated in Appendices A and B.

- **Chapter 6** consolidates the results and conclusion drawn from the previous chapters. It further substantiates the novelty of the research work undertaken and concludes with a brief note on the scope for future work.