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New Technique for Mobile User's Location Detection, Future Prediction and their Applications

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Abstract:-Positioning of mobile users has received growing attention and has potential for applications and services to enhance both Location Based Services (LBS) and cellular network performance. So, several researches are carried out to develop methods and algorithms which enhances the positioning accuracy and execution time [1]-[7]. This paper presents a new technique for current location detection with high accuracy and accepted execution time [8]. Combination of cellular network and Global Positioning System (GPS) positioning techniques provide a higher accuracy of mobile location than positions based on a standalone GPS or mobile network platform. The proposed hybrid Uplink Time Difference of Arrival and Assisted GPS technique (UTDOA-AGPS) for mobile user's location detection utilizes Universal Mobile Telecommunication System (UMTS) network, Mobile Station (MS) and GPS positioning characteristics. Due to flexibility of the proposed technique, many positioning sub-techniques are chosen according to positioning parameters. As a result, the required number of GPS satellites is reduced and many drawbacks are overcome. The paper also presents a novel algorithm for future location prediction of mobile subscriber over mobile network platform [9] which results in great enhancement in LBS applications and mobile network performance. In the proposed algorithm, Intra Cell Movement Prediction (ICMP), for mobile user's future location prediction is carried out to benefit from both intra and inter cell based techniques to enhance both network and services. The proposed ICMP algorithm depends on map based intra-cell prediction and utilizes the network database and hybrid (UTDoA-AGPS) positioning technique in extracting user trajectories and movement rules to predict the next movement of mobile user. The performance of the proposed algorithm is evaluated through computer simulation and compared with that of [10] and [11]. The simulation results indicate that the proposed ICMP algorithm shows a comparable precession, accuracy, execution time and it can be adapted according to the needed application characteristics and the surrounding environment. Many public and commercial location applications are regenerated based on the proposed current location detection and future location prediction techniques.

I. INTRODUCTION

LBS and their applications are regarded as the most growing services applied on communication systems. According to the great enhancement in mobile network architecture and its related database servers, we are not only able to develop LBS applications but also to enhance the performance of mobile networks. Many applications are based on users' current location, but sometimes this is not enough [13]-[14]. LBS are services for providing information that has been created, compiled, selected, or filtered taking into consideration the current or future locations of the users or those of other persons or mobile objects. The prediction of users' next location would allow providing services related not only to their current location, but also to their future destinations. The attractiveness of LBSs results from the fact that their participants do not have to enter location information manually, but that they are automatically pinpointed and tracked. The accuracy of location detection plays an important role in services and applications' quality and usage. The better the accuracy of location detection process the more reliability of mobile based applications and services. So, one of the most accurate positioning systems is carried out in this paper based on Hybrid Uplink Time Difference of Arrival and Assisted GPS technique. This technique shows high accuracy, less time of execution than other positioning systems and can be adapted according to application type, mobile equipment' features and surrounding environment. Many applications are generated according to the new proposed system utilizing both high position accuracy of hybrid uplink time difference of arrival with assisted GPS technique and ICMP algorithm for future location prediction of mobile user as presented in [12]. The proposed applications are categorized into commercial applications and public applications. The public applications include emergency applications, and Muslims' applications. Whereas, mobile marketing and finding places of services are the commercial ones. From the other hand, many applications related directly to future location prediction such traffic management and people tracking applications are considered. This paper is organized as follows. Section 2 presents the proposed hybrid positioning technique based on uplink time difference of arrival and assisted GPS technique. Study of Time to First Fix (TTFF). Network elements and number of satellites which are needed to achieve the proposed system is also introduced. Also, a modified mobile station receiver design is implemented. Finally, the position of mobile user is calculated and recognized. Section 3 begins with an overview of future location prediction of mobile subscriber over mobile network platform. Then the problem definition is discussed with proposed parameters and assumptions for ICMP algorithm. After that, the process of predicting future location of mobile user is created. Section 4 presents a system that is used to generate services and applications based on mobile user's location detection and future location prediction. It also presents the architecture and database of the proposed system. After that, emergency applications and Muslims application including Qibla's direction are introduced. Mobile marketing applications, and places locations are described according to the proposed system as a commercial type of LBS. Finally, traffic management applications and people tracking applications which based mainly on future location prediction are generated. Section 5 summarizes the main conclusions and future directions.

II. HYBRID UPLINK-TIME DIFFERENCE OF ARRIVAL AND ASSISTED-GPS POSITIONING TECHNIQUE

Assisted GPS A-GPS technology follows the principle of Differential GPS D-GPS with additional assistance data from cellular network which is used to reduce acquisition time, enhance positioning accuracy and provide communication facilities. By integrating GPS into cellular networks, the GPS positioning is supported by additional D-GPS reference stations as integral part of the cellular infrastructure and by additional signaling procedures between network and terminal. The resulting positioning method is commonly known as A-GPS [14]. U-TDOA technology locates wireless phones by comparing the time it takes a mobile station's radio signal to reach several Location Measurement Units (LMUs) installed at an operator's base stations, as shown in Figure 1. U-TDOA approach is used to enable location-based services such as emergency location, and mobile concierge services. Uplink TDOA location method has proven highly accurate for location of wireless subscribers in CDMA based systems.

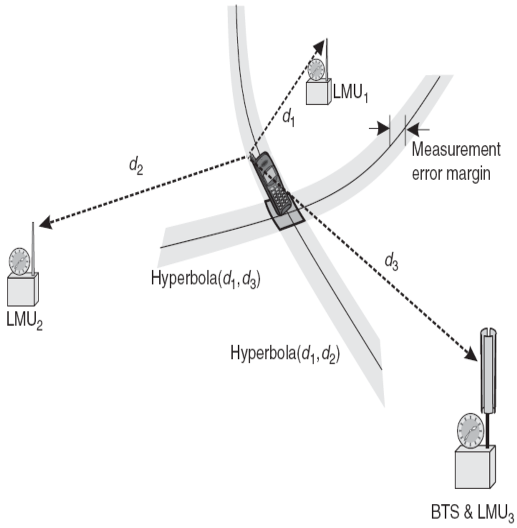

Fig (1) U-TDOA Network Configuration.

2.1 Advantages of U-TDOA and A-GPS hybrid positioning technique

Hybrid positioning technique is based on integration between GPS data and cellular network infrastructure based on U-TDOA assisted data to achieve accurate position of mobile user and to overcome short comes of both techniques while being used individually. It is observed that GPS is the most accurate positioning technique with position accuracy (5-30m). U-TDOA is the most accurate positioning technique depending upon cellular based networks with approximately less than 50 m accuracy. So, integration between the two methods will produce highly accurate positioning technique valid for most environments and with a higher performance than that used by each technique in standalone mode.

2.1.1 Decreasing Latency in Time to First Fix Using Hybrid Positioning Technique.

Conventional GPS consumes more than one minute to get first reading of mobile user location. Although each GPS satellite transmits at the same frequency, the signals are not observed at the same frequency because of the Doppler shift caused by the satellite motion, the receiver motion and any frequency offset in the receiver reference oscillator. Receiver would scan all possible frequencies till reach the accurate frequency. Also, GPS receivers find a correct code delay for the correlators to generate a correlation peak within about more than thirty seconds. This delay is named frequency/code delay search space [15]. Network assisted data is necessary to have at least a rough a priori position and a priori time and satellite orbits. The expected Doppler frequencies can then be computed then frequency delay search space is reduced. The correlation peak varies with frequency as a sinc function:

$$Sinc(\frac{FTc}{2}) = \frac{1}{2}Sin(\pi FTc)/(\pi FTc)^{1/2}$$

(1)

Where F is the frequency error and T_C is the coherent integration time, as shown in [14]. Also, the Doppler Effect results from receiver speed is

L1·S· Cos (q /c) (2)

Where, L1 is the GPS L1 frequency (1,575.42 MHz), **S** is the receiver speed and q is the angle between the receiver velocity direction and the direction from the receiver to the satellite. The frequency offset caused by the reference oscillator is typically large. There will be an additional 1.575 kHz of unknown frequency offset for each 1 ppm of unknown receiver oscillator offset. A-GPS is mainly used to reduce the frequency and code-delay search space. To reduce the frequency search space it is necessary to have at least a rough a priori position and a priori time and satellite orbits. The expected Doppler frequencies can then be computed. Similarly, to reduce the code-delay search space, it is necessary to have a good a priori position and a priori time. Where, the a priori time must be known to better than 1 ms which is known as fine-time assistance else it is a coarse-time assistance. By these means of frequency/ code search space reduction, TTFF will be reduced significantly.

2.1.2 Decreasing number of satellites and network elements

Four satellites are needed at least to determine the three dimensions of the mobile equipment position in conventional GPS. Four satellites are used to determine the following position parameters (x_i , y_i , z_i , t) where x, y and z are the three dimensional Cartesian location coordinates, i indicates the satellite number and t is the synchronization time error. Each

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satellite has its position detection sphere which introduces one position equation. By solving such four equations, the four mentioned unknowns can be determined and mobile equipment position is detected. By suggesting distance between the ith satellite and the receiver position as Ri, satellite position (xi , yi , zi) and receiver position (X,Y,Z) and receiver time clock error t, equations (3) represent the four satellites equations adopted for position determination. By solving these equations, the four unknowns X, Y, Z and t can be determined.

$$\left.\begin{aligned} R_1 &= (X-x_1)^2 + (Y-y_1)^2 + (Z-z_1)^2 + t^2 \\ R_2 &= (X-x_2)^2 + (Y-y_2)^2 + (Z-z_2)^2 + t^2 \\ R_3 &= (X-x_3)^2 + (Y-y_3)^2 + (Z-z_3)^2 + t^2 \\ R_4 &= (X-x_4)^2 + (Y-y_4)^2 + (Z-z_4)^2 + t^2 \end{aligned}\right\} \quad (3)$$

In the proposed hybrid positioning technique already has network GPS receivers either these are included in NodeB or separated, which are synchronized with satellites. Time delay data (t) are calculated using mobile network so we need only three satellites for mobile position determination instead of four satellites had used in conventional GPS. The accuracy of position determination depends upon the code used in calculations. In case of neglecting Z-coordinate "altitude of the mobile receiver", we will need only three satellites to get (X,Y,t) unknowns of the receiver position in conventional GPS positioning. Whereas, only two satellites are sufficient to detect two-dimensional receiver's position in hybrid positioning.

2.1.3 Choice of the Most Accurate GPS Satellites

There are about 31 satellites catering to the worldwide GPS systems. In proposed hybrid technique as we need only three GPS satellites to determine mobile user position in 3-D or two satellites in 2-D, the best satellites should be chosen. GPS signal strength is the main factor which is used to choose the best satellites needed for measuring process.
There are several methods to measure GPS signal strength. The most common method used by civilians is the ones related to telecommunications, including the Received Signal Strength Indication (RSSI) based on the IEEE802.11 protocol. On the other hand, many GPS manufacturers build their own GPS algorithm to create code for calculating GPS signal strength. Received signal strength is used to select the most accurate NodeBs/LMUs required in location determination process. The higher the RSSI number, less negative, the stronger the received signal.

2.2 Hybrid Positioning Technique's Parameters

Each of the already existed positioning technique has its advantages and drawbacks. Positioning techniques are classified according to main parameters which are presented in Table (1) these parameters are: 1) Accuracy; 2) Latency; 3) Call state; 4) Environment; 5) System loading.

Table (1) illustrates the used suitable positioning technique according to the main positioning parameters. Suit-able positioning technique such as A-GPS, stand alone GPS or U-TDOA, is selected according to the location based service application needed. For Examples, Mobile tracking applications: The major property of these applications is latency sensitive, so stand alone GPS isn't a suitable positioning technique. Accuracy is the second parameter in these applications so, if application need accuracy less than fifty meter, then hybrid technique is being used. Otherwise U-TDOA will be the most suitable technique here.

Emergency applications: These applications require high accuracy without time delay. Then, hybrid method is selected in outdoor applications whereas U- TDOA will be more precise in indoor applications. Commercial advertisements and general information applications: Most information like weather, traffic, advertisements are highly used in city center and crowded regions. So, system loading is the most positioning parameter that should be taken into consideration. So, U-TDOA is the most suitable positioning technique for heavy sys- tem loading.

2.3 Secure User Plane Location Protocol

In order to decrease system loading problem especially in crowded locations and city centers secure user plane location protocol is used instead of Radio Resource Control (RRC) protocol which is used by UMTS mobile network as discussed in [16]. Secure User Plane Location Protocol (SUPL) is a network layer based on IP technology that was developed to support Location-Based Services (LBS) for wireless communications. SUPL employs available user plane data bearers for transferring location information, GPS assistance data, and for carrying positioning technology related protocols between a SUPL Enabled Terminal (SET) and the mobile network. This developed protocol permits hybrid developed technology to be used in heavy loaded networks' systems. SUPL provides low cost and complexity in network implementation than conventional RRC protocol which is based on control plane.

2.4 Network Elements and Positioning Sequence

Network equipments used in mobile location determination using hybrid technique is called Position Determination Equipment (PDE). PDE is mainly consists of Location Gateway (LG), Serving Mobile Location Center (SMLC), Location Measurement Unit (LMU) and NodeB [17]. As shown in Figure (2), plenty of network elements are needed within hybrid positioning technique. For more arrangement and decrease among network components the following actions are taken into consideration.

a) Integrate each LMU into corresponding NodeB with common processor, as shown in Figure (3). Processors are mainly responsible for network management and provide a centralized pool of digital signal processing resources used in location calculation.
b) Integrate SMLC into corresponding RNC/BSC.

The procedure of detecting mobile location using hybrid positioning technique can be logically summarized into the following steps as indicated in the flow chart of Figure (4):

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Table (1) Positioning parameters versus suitable positioning technique as in [8].

		Accuracy		Latency		Call state		Environment		System loading	
		High	Low	Sensitive	Insensitive	On-call	Idle	Indoor	Outdoor	Heavy	Light
Accuracy	High			Hybrid	Hybrid	Hybrid	Hybrid	UTDOA	Hybrid	UTDOA	Hybrid
	Low			UTDOA	GPS	UTDOA	UTDOA	UTDOA	UTDOA	UTDOA	UTDOA
Latency	Sensitive	Hybrid	UTDOA			UTDOA	Hybrid	UTDOA	Hybrid	UTDOA	Hybrid
	Insensitive	Hybrid	UTDOA			UTDOA	GPS	UTDOA	GPS	UTDOA	Hybrid
Call state	On-call	Hybrid	UTDOA	UTDOA	UTDOA			UTDOA	Hybrid	UTDOA	Hybrid
	Idle	Hybrid	Hybrid	Hybrid	GPS			UTDOA	Hybrid	UTDOA	Hybrid
Environment	Indoor	UTDOA	UTDOA	UTDOA	UTDOA	UTDOA	UTDOA			UTDOA	UTDOA
	Outdoor	Hybrid	UTDOA	Hybrid	GPS	Hybrid	Hybrid			UTDOA	Hybrid
System loading	Heavy	Hybrid	UTDOA	UTDOA	Hybrid	UTDOA	Hybrid	UTDOA	Hybrid		
	Light	Hybrid	Hybrid	Hybrid	GPS	UTDOA	Hybrid	UTDOA	Hybrid		

- MS sends request to LG including serving NodeB, cell ID, associated frequency, code, communication parameters and authentication.
- LG receives the location request from MS, check authorization and validation.
- LG sends the request to the SMLC which serve the MS and controls the entire positioning process, including allocation of resources, evaluation of timing measurements, and calculation of position fixes.
- SMLC receives the request and selects the nearest LMUs for serving MS from a list of LMUs included in SMLC database. The database contains the latest data of satellite locations and motion parameters related to each LMU.
- LMU receives GPS navigation message periodically and extract Doppler shifts, pseudo ranges and navigation messages, correction data and sends these data to SMLC.
- SMLC receives satellite data from LMU and periodically or on demand evaluates satellites' locations and updates current list of assisting satellites' IDs, Doppler shift and pseudo range domains appropriate for each LMU.
- SMLC sends the determined GPS data to LG which redistribute its location parameter to MS to be able to detect satellite rapidly and decrease TTFF.
- SMLC requests location related data from all LMUs selected to cooperate in providing measurements.
- LMUs respond to SMLC by the extracted, measured and obtained data related to the MS of interest.
- LG receives the GPS data measured by the MS GPS receiver and sends them to the SMLC.
- SMLC calculates the optimal integration of MS GPS data with the LMU measurements which represent the most accurate location of MS and send it to LG.
- LG receives location determination from SMLC and sends it to the MS as a response of original location request.

Positioning requests by external applications can be done using the same steps from Step 4 to step 11. Then, the calculated position is sent from LG to the requester such as application server. Figure (5) shows the flow chart of the main functions their procedure of the hybrid UTDOA and A-GPS technique.

2.5 Modified MS Receiver Architecture

Mobile station main components are shown in Figure (5). Bidirectional antenna 1 is adapted to receive both UMTS and GPS signals. Duplexer 2 allows bidirectional communication, transmit and receive, into single channel. Electrical switch 3 is implemented to switch between GPS signal and 3G signal. Low noise amplifier 4, first band pass filter 6, first mixer 10 and second band pass filter 14 are the first part of receiver of UMTS signal which are used to down convert the RF signal into inter-mediate frequency band. The IF band signal represents the first step to get the base band source signal. By the same way, the path contains 5, 7, 11 and 15 circuits is used to down convert GPS radio signal into intermediate frequency band. Dual phase locked loop PLL 9 controls the local oscillators 12 and 13 at specific reference frequencies to down convert both UMTS and GPS radio signals. Clock generator 8 extracts clock from UMTS signal, as LMU sends it via Node B to MS thus GPS, Node B, LMU and MS will be synchronized. IF Demodulator 16 is the first part of the Application Specific Integrated Circuit (ASIC). This provides the second stage of IF to base band down conversion, sampling and A/D conversion

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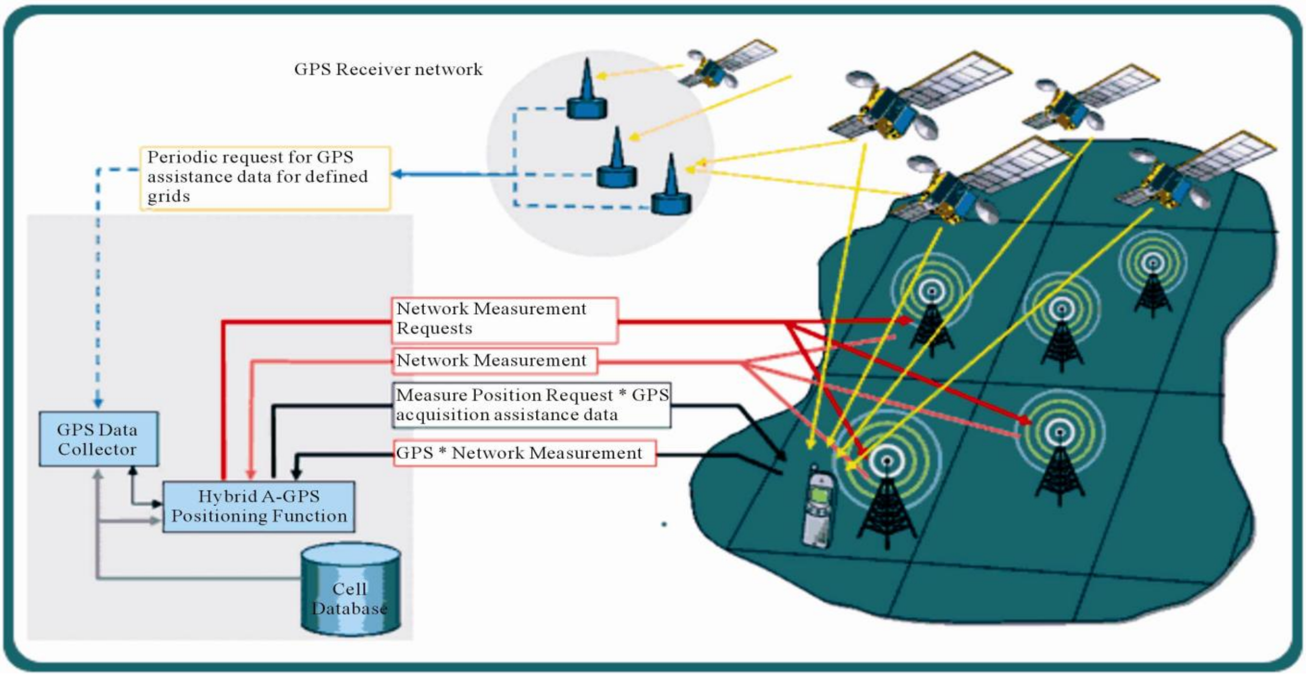

Fig (2) Hybrid GPS_UTDOA network platform.

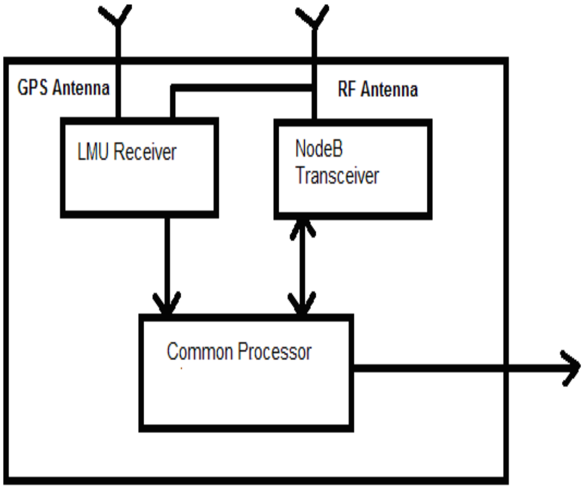

Fig (3) Common processor LMU and Nu odeB.

Second switch 17 is analogues to switch 3 and they controlled by the same controller unit to separate CDMA and GPS received signals at radio and intermediate frequency bands. LMU provides GPS data to MS via Node Bs. So, this data will be extracted by MS using Decoder 18 to extract almanac, Doppler shift, etc. for each of GPS satellites. The Doppler frequency Fd that is recognized by decoder 18 is added to local oscillator Fif to control the GPS mixer 19. This mixer is used to convert IF signal to base band signal as the last stage of base band signal down conversion in GPS received path. The output of automatic gain control AGC 21 circuit is fed to analog to digital converter A/D 22. The output of the A/D consists of the (I,Q) in phase and quadrature components as a first and second output digital streams respectively. The digital streams are fed to the digital signal processor DSP 24 to produce the required pseudo measurements. Buffer 23 is used to store data streams in case of the rate of flow of data is faster than that of DSP rate of processing. Pseudo ranges are sent via MS transmitter to LMUs to calculate the user position accurately.

2.6 Position Calculation

Location determination and measurements using hybrid technique are classified into two main measurements.

2.6.1 Position Calculation Using U-TDOA Technique

This type of measurement is one of distance related measures where distance is calculated through mobile network. Measurements are based mainly on the difference between two Times of Arrivals (TOA) for two distinct signal receptions at least. MS is a common transmitter for signal to the distinct and different LMUs as receiving stations positioned at locations XR1 and XR2 respectively. TDOA technique is directly related to the difference in TOA at different receivers. This leads to difference in signal propagation distances (DR1, and DR2) at receivers.

$$\left.\begin{aligned} TDOA_{21} &= TOA_2 - TOA_1 \\ &= \frac{(DR_2 - DR_1)}{c} \\ &= \frac{[X_T(TOT) - X_{R2}(TOA)) - ((X_T(TOT) - X_{R1}(TOA))]}{c} \\ &= \frac{[|X_{R1}(TOA) - X_{R2}(TOA)|]}{C} \end{aligned}\right\} \quad (4)$$

Where, c is the propagation speed of RF signal, $X_R(TOA)$ is the three dimensional vector coordinates of receiving position at time of signal arrival. Determination of transmitter location doesn't require knowledge of the TOT common epoch at which MS signal was transmitted. Then synchronization between MS and NodeB isn't necessary. From (4) we need at least two NodeBs to enable U-TDOA technique to calculate the position of mobile terminal.

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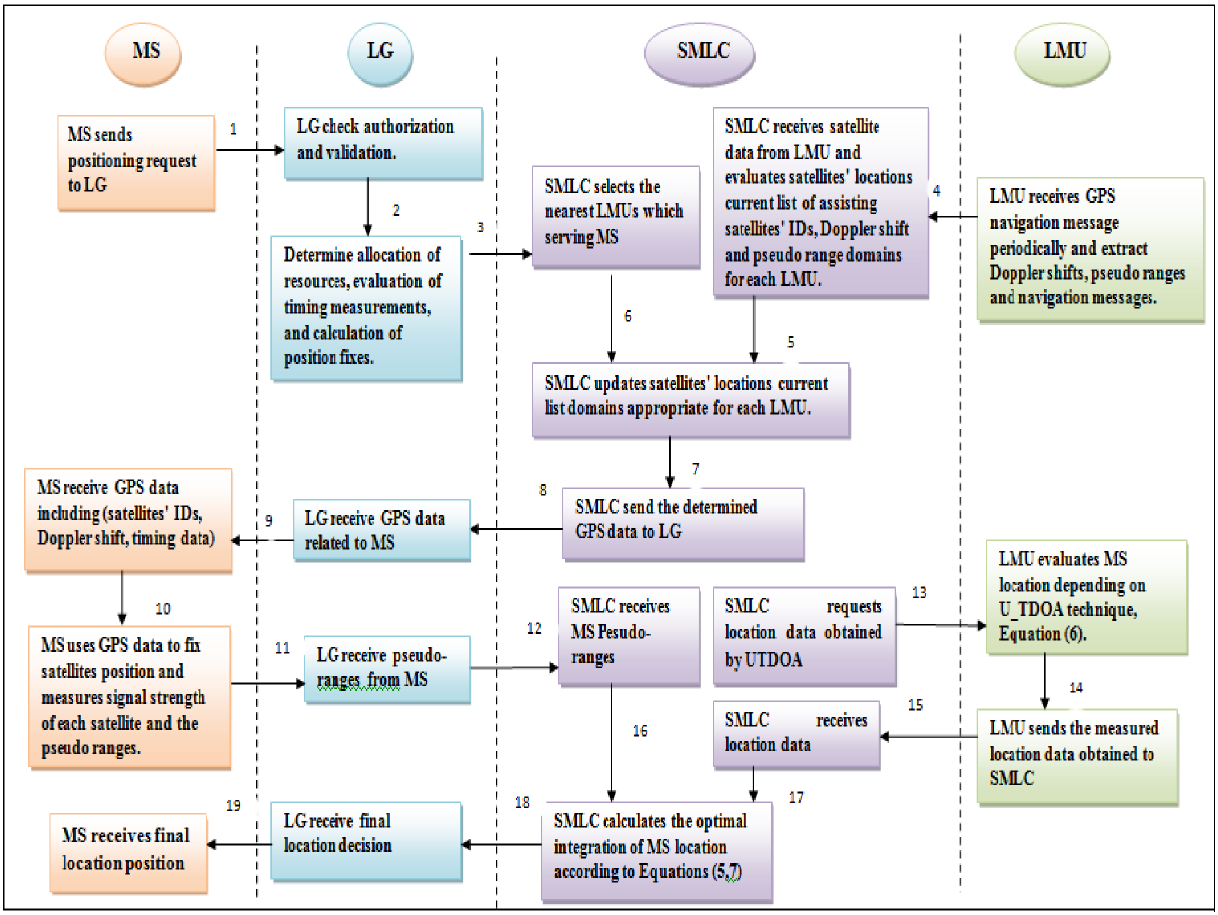

Fig (4) Flow chart of main functions and procedures of hybrid UTDOA and A-GPS technique

2.6.2 Position Calculation Using Hybrid Positioning Technique

The optimum estimation of mobile user location depends on the location-related information available which is extracted from the following sources:

1) Measurement of received signal characteristics.

2) Collateral information that indicate the relative probability of MS position.

Using Bayes probability relation the relative probability of occurrence of measurements under condition of a priori state condition is expressed as:

$$P(x/z) = [P(z/x)*P(x)]/P(z) \quad (5)$$

where *x* is the state vector of location parameters, *z* is a vector set of location measurements and P(x/z) represents the probability of the state vector components are evaluated for x under condition that the observations have the values of measurement values z. Whereas P(z/x) represents the probability that the values of vector z would be observed under condition that the state variables are of the values in *x*. *p(x)* is the marginal probability that the state values of x occurred. Whereas, is the total probability of occurrence of measured parameter values for the observation vector *z*. The jointly combined probability of independent data elements are the product of the probability of independent data sets alone [18]. Using the proposed system, the data of various types from diverse sources, satellite and mobile network, integrates statistically independent data. Then, the probability product relation is accumulated as a sum of "log likelihood". Sum of probabilities will introduce higher location probability than product formula and higher results can be obtained. This way leads to accumulation and integration between both GPS and UTDOA techniques to get higher positioning technique than obtained from standalone technique. *p(z).*

III. FUTURE LOCATION PREDICTION OF MOBILE SUBSCRIBER OVER MOBILE NETWORK USING INTRA CELL MOVEMENT PATTERN ALGORITHM

Mobile network is mainly divided into clusters which consist of cells and each cell consists of sectors. It should be noticed that User Mobility Pattern (UMP) algorithm that is based on sequential mining doesn't introduce intra cell prediction [10]. In [11], movement Rule-based Location Prediction (RLP) method has been developed using All Movement Pattern (ALLMOP) algorithm and based on Global Positioning System (GPS) network platform. However, the use of GPS network platform won't enhance the mobile network resources allocations and management and it requires GPS supported terminals. In fact, the UMP algorithm is outperformed by the RLP method. The two short comes of [10] and [11] are solved here through the utilization of both mobile network structure and ALLMOP algorithm to create map based intra cell architecture. This yields to enhancement in mobile network resources and location services.

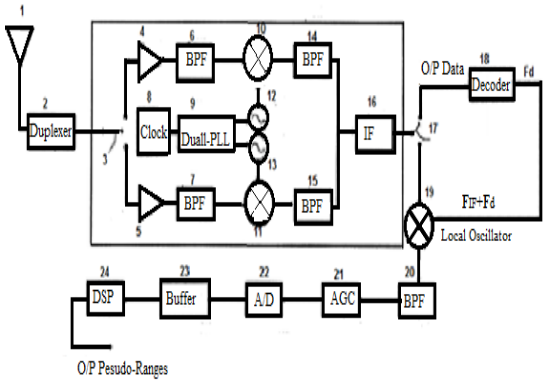

Fig (5) Block Diagram of MS Receiver

3.1 PROBLEM DEFINITION

While user moves in mobile network from one cell to another, its movement will be recorded in a database named Home Location Register (HLR). Each base station can detect the specific sector which serves the user. By applying one of location detection techniques for mobile user specially Uplink Time Difference of Arrival (UTDOA) and Assisted GPS (AGPS) technique presented in [8] or UTDOA alone in non-supported GPS phones as presented in [19] the accurate position of the subscriber is determined. The database structure is constructed from four fields [Pmn, X, Y, T] where, (Pmn) represents Cell ID (m) and sector ID (n), (X,Y) represent user coordinates (latitude and longitude respectively) and T is the time set of measurement. The proposed method is based on three levels of location detection:

1- Intra-Sector Prediction (ISP) level: fully depends on user's accurate position "longitude, latitude" within the specific sector and is used mainly to enhance LBS applications especially in urban and downtown areas.

2- Sector to Sector Prediction (SSP) level: Only knowledge of user's cell and sector leads to establish this level of prediction which is used mainly to enhance intra-cell handover and network resources in addition to LBS applications in sub-urban areas.

3- Cell to Cell Prediction (CCP) level: using clustering technique as each (n-sectors) represent one cell. Cell to cell prediction is highly effective in inter cell handover process beside LBSs applications especially in rural areas. User trajectory is generally specified as Traj. = { Pmn, x, y,Ti } (i=1:k), where k represents the trajectory's length. The determination of trajectory's length depends on the following assumptions:

a- If a mobile user stays at any point,(cell, sector or subsector), according to the used level of prediction, for more than a predefined threshold period before moving to another location. Then, we assume trajectory length ends at this point and any later movement will be considered as a start of another new trajectory. These trajectories are considered as Real Trajectories (RTJ) which looks like User Actual Path (UAP) presented in [10].

b- Moving Sequence (MS) is being defined as a list of temporally ordered cells, sectors or sub sectors. A sequence maximum lifespan [start, end] where, ($start \leq t_i \leq t_k \leq end$), for($k \leq T$)and ($1 \leq i \leq k$).

c- Sequence composed of k points is defined as k-pattern.

d- Subsequence is generated if all points in sequence (S1) is contained in sequence (S2) with the same temporally direction flow then S1 is a subsequence of S2.

Frequent patterns can be extracted when real trajectory comply with moving sequence at a timestamp. Each moving sequence contains support value corresponding to number of trajectories in the cell, sector or subsector at a specific time set. If this value is equal to or greater than the predefined minimum support value (min_supp) then, the pattern is considered as frequent one pattern. A movement rule in this work is defined using the expression $A \rightarrow B$, where A, B are moving sequences and $A \cap B = \emptyset$. The part of the rule before the arrow is the antecedent and the part after the arrow is the consequent of the rule. The confidence of a rule $A \rightarrow B$ is known as an estimate of the probability P (B|A). Namely, the probability of finding the consequent of the rule in moving sequences under the condition that these moving sequences also contain the antecedent A. Therefore, the confidence is defined as:

$$Conf.(A \rightarrow B) = \frac{Sup(AUB)}{Sup(A)} \quad (6)$$

3.2 PROCESS OF PREDICTING USER'S FUTURE LOCATION

The three levels of predictions are carried out using the following four main processes as follow:

1. Moving sequences' creation process.
2. Extraction of all frequent movement patterns.
3. Finding movement rules.
4. Prediction of user's next movement.

3.2.1 Finding moving sequences.

Creation of moving sequences from corresponding input requires definition of the following new parameters:

(Ii): Sub-sector number, the sector area is divided into sub areas to achieve intra-sector prediction level according to Significant change in (Xi-1,Xi) and (Yi-1,Yi). The number of sub-sectors is determined according to the network topology, accuracy of the required application and surrounding environment. (Di): Intra-sector Enabling parameter, indicates change in Ii values at two consecutive timestamps within the same sector (i.e. no change in m, n values). The following algorithm is developed for Moving Sequence (MS) creation regardless of used prediction type. The inputs of MS algorithm are:

- User's location point within timestamp (Pmn,Ii,Ti).
- User's real trajectory (RTJ)

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- Maximum length of points per trajectory, Max_span (Tmax).

The process of moving sequence's generation can be summarized into the following steps:

1) Initialize the set of moving sequence; (MS← Φ).
2) Extract location of Mobile user.
   where, (Pi ← (Pmn, Ii, Ti)
3) Initialize user's previous location (prev. loc.) ← 1.
4) Create moving sequence points according to prediction levels shown in Figure (6) as follow:

For (i=2 ; i= max_span points ; i++) (7)

4-1) Cell to Cell prediction (CCP)

4-1-1) Disable sector and intra-sector prediction

ni, Ii → disabled

4-1-2) Create moving sequence: when there is a change from one cell to another within two consecutive timestamps. Then, MS consists of the previous MS in addition to the current obtained real trajectory meets the previous conditions.

If mi ≠ mi-1
RTJ=RTJ U (Pmi,Ti)
MS = MS U RTJ

4-1-3) Stop moving sequence at the current cell: if the user still in the same cell from the current point Tc till reaches Tmax. Any other movement after that is a start of new movement.

If (mi = m i-1) , Tc<t < Tmax
MS ← stop

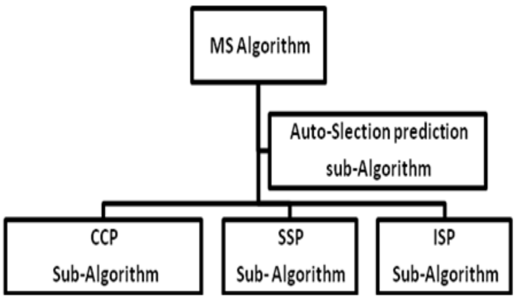

Fig (6) Chart of MS Algorithm with its sub-categories

4-2) Sector to Sector Prediction (SSP)

4-2-1) Disable intra-sector prediction

ni → enabled , Ii → disabled

4-2-2) Create moving sequence

If Pmni ≠ Pmni-1
RTJ=RTJ U (Pmni,Ti)
MS = MS U RTJ

4-2-3) Stop moving sequence at the current sector.

if Pmni = Pmn i-1, Tc<t <Tmax
MS ← stop
Return MS

4-3) Intra-Sector prediction (ISP)

4-3-1) Enable intra-sector number within prediction

ni → enabled , Ii → enabled

4-3-2) Create moving sequence: when there is a change from one sub-sector to another within two consecutive timestamps.

If (Pmni,Ii) ≠ (Pmni-1,Ii-1)
RTJ = RTJ U (Pmni , Ii , Ti)
MS = MS U *RTJ*

4-3-3) Stop moving sequence at the current sub-sector; if

(Pmni,Ii) = (Pmn i-1,Ii-1) , (tc<t <Tmax)
MS ← stop
Return MS

4-4) Auto-Selection of MS pattern

4-4-1) Enable Sub-sector prediction parameter (Di)

If Di = 1

4-4-2) change in sub-sector prediction level, So ISP level is used.

Go to (4-3) → "ISP"
Else if Di = 0

4-4-3) Check sector to sector changes: if there is movement from one sector to another within the same main cell. Then, STS prediction is used.

If ni ≠ ni-1 , while mi = mi-1
Go to (4-2) → "STS"

Else, cell to cell prediction is the proper MS algorithm
Else Go to (4-1) → "CTC"

B. Generating frequent-1 pattern.

A dataset of real trajectories are decomposed into groups of corresponding moving sequences. Then, frequent-1 patterns represent dense sectors or clusters that contain at least the minimum support points at specific timestamp. Full trajectories on Map based are shown in Figure (7). In ICMP cluster enabling Algorithm each three sectors within the same cell will be considered as one cluster. Assume that minimum support value is 2 (min_Sup≥2) then region (R1) will be considered as a frequent one pattern at timestamp T1 where R1 contains two points in time T1. Cells which contain lower points than minimum support points within specific timestamp will be considered as outliers as <R6, t3> and <R9,t5> in Figure (7). Empty cells will be discarded as cell R7. In ICMP cluster disabling algorithm, each cell, sector or sub sector contains the minimum support number of points at specific timestamp is considered frequent -1 pattern. At any prediction method, if the same trajectory hits the same region more than one time before it moves to the next region, only the first hit is taken into consideration and other hits are neglected (e.g. <(4B,t2)>) will be discarded and moving sequence of this trajectory will be [<(4B,t1)>,<(4C,t3)>, <(8A,t4)>]) as shown in Figure (7). If the user remains at the same sector till Tend, trajectory movement is terminated at this point.

C. Generation of frequent-k patterns

Frequent-2 pattern is created by joining frequent-1 pattern with another frequent-1 pattern under condition that both cells are neighbors and comply with the real trajectory while moving from one cell to another. Frequent-k pattern, where K >2 can be extracted from

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joining frequent-(k-1) pattern with frequent-1 pattern with condition that, the two patterns related to the same trajectory and achieve minimum support value. The following algorithm is developed to generate frequent-k pattern in ICMP-algorithm with clustering enabled and disabled sub-patterns. The inputs of the algorithm are:

- moving sequence (MS).
- Minimum support (min_sup).
- Prediction patterns (CCP, SSP, ISP).

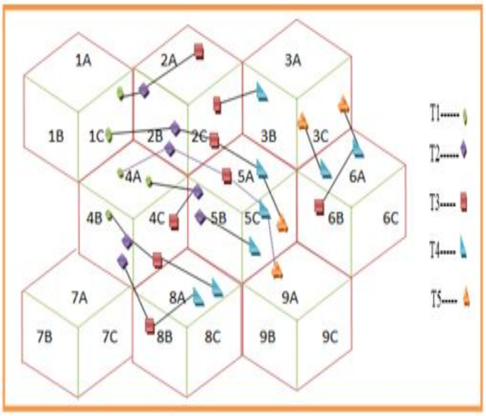

Fig (7) Full Trajectories on A Map Based on Mobile Network Architecture as in [9]

The creation process of ICMP-frequent-k pattern algorithm can be summarized into the following steps: 1- Initialize the frequent movement-1 pattern with maximal timestamp among all movement of MS.

F-1 → Φ

2- For each ti (i=1 , i<=T, i++)

2-1) For clustering enabled sub-pattern:

2-1-1) Merge three sectors into one cell

Cell (X)← sectors (XA U XB U XC)

2-1-2) Define Region (R) as a Cell (x) with minimum number of points at timestamp (ti) and discarding outliers.

Region(R) ← (Cellx,Ti) ≥ minsupport

2-1-3) Discard intra-sector level (Di ←Disabled)

2-1-4) Extract (frequent-1 pattern) within specific time (Ti). F-1←F-1 U (R,Ti) (8)

2-1-5) Initialize (Candidate-2) and (Frequent-2) patterns.

(C-2← Φ , F-2← Φ)

2-1-6) Generate (frequent-2) patterns.

∀ F1 (Ri,Ti) ∈ F1

If(Ti>Tj), Ri,Rj neighbor cells, i≠j

Then, C-2←C-2 U < (Ri,Ti),(Rj,Tj)>

If MS [Ri→Rj] ≥ Min_Sup

Then, F-2=F-2 U <(Ri,Ti),(Rj,Tj>

2-1-7) Generate infrequent list including non- frequent patterns to discard them from freq. k-patterns

Else, insert (infreq_list, Cand.)

2-1-8) Generate (frequent k-pattern), k>2, and update of in frequent list as shown in [14].

For F-1 , F-(k-1) ≠1

∀ (Pi) ∈ Fk-1 , ∀ (Pj) ∈ F-1

Cand-k ←joining (Pi,Pj) ∈ *MS*

If Cand-k ≠ Φ (9)

Then, Ck ← Ck U Cand-k

If MS[P(k-1)→Pj] ≥Min_Sup

Fk ←F(k-1) U F1

Else, update (Infreq_list ,candk)

2-1-9) Create all Frequent patterns.

ICMP_Clustering Enabled← <F1,…,Fk>

2-2) clustering disabled sub-pattern "Sector to sector prediction"[SSP]

2-2-1) Represent [sector to sector prediction] as a type of clustering disabled technique.

Region(R) ← (Pmn)

2-2-2) Discard intra sector change, then apply the same procedure from equation 3 to 4 to get all possible frequent patterns.

Di → Disabled , Go to 3:4

ICMP_SSP ← <F-1,….,F-k)

2-3) Clustering disabled sub-pattern "Intra-Sector prediction"[ISP]

2-3-1) Regions consist of intra sectors with minimum support points at timestamp after discarding outliers; Region(R) ← (Pmn,I)

2-3-2) Enable intra sector change. Then, same procedure is applied (from equation3 to 4) to get all possible frequent patterns.

Di → Disabled , Go to 3:4

ICMP_ISP ← <F-1,….,F-k>

3.3 Finding movement rules and next movement prediction

Regardless of the ICMP sub pattern, the pre obtained movement patterns are temporal joint points. For example, movement pattern [(R4,t1),(R2,t2),(R5,t3)] shown in Figure (2) is obtained from cluster enabling algorithm. This pattern represent frequent-3 pattern and has the possible movement rules: [<(R4,t1)>→<(R2,t2),(R5,t3)>]or[<(R4,t1),(R2,t2)>→(R5,t3)]. The confidence value of the two possibilities should be evaluated according to equation 1. The patterns' rules which achieve the required threshold confidence value are selected whereas other rules are discarded. The first assumption in the previous example has a confidence = [Sup((R4,t1) U(R2,t2)U(R5,t3))/Sup(R4,t1)]. Sup((R4,t1) U (R2,t2) U (R5 ,t3)) =1. Whereas, Sup (R4,t1) = 3 points. So, confidence of the first assumption = 33.33%. By the same way the second assumption has a confidence = 100%. So, if the threshold confidence value is 75% then, the second movement rule is taken into consideration whereas, other movement rule is discarded. By applying these movement rules on frequent-k patterns, next movement of mobile user will be predicted according to predefined confidence. Recursive depth fashion is used to improve the procedure of movement rules as being discussed in [2]. For a pattern [<(Ra,ta)> ,<(Rb,tb)> ,<(Rc,tc)>, <(Rd,td)>] we first get the confidence for rule[<(Ra,ta)>, <(Rb,tb)>,<(Rc,tc)> → <(Rd ,td) >] If this rule achieved the threshold confidence value, then [<(Ra,ta)>,<(Rb,tb)> → <(Rc,tc)>,<(Rd,td)>]

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shall be studied. Else, there is no need to check sub patterns of this pattern as it surely will not achieve the confidence value. ICMP rules for location prediction can be clarified within the following algorithm. The inputs of the ICMP rules are the Minimum Confidence (Min_conf.) and the Frequent movement pattern (K-pattern) , K≥1. The algorithm used in rules creation can be summarized in the following steps:

1- Initialize the value of the prediction rule **(**Rule = Φ)

2- Calculate support value of k-pattern and k-1 pattern.

P-k ∈ K Pattern, Sup(Pk) ← A

P-y ∈ K-1 Pattern, Sup(Pk) ← B

3- Calculate the confidence value of the first generated rule.

Conf.(P) = Sup(Pk) / Sup(Py) = A/B

4- Compare the calculated confidence value with minimum confidence value adjusted to meet the required accuracy of prediction..

Min_conf ← minimum Confidence

If Conf(P) ≥ Min_Conf

Then, Rule = Rule U <(Py)→ (Pk-y)>

Else , return rule

5- Apply recursive depth fashion in finding rules

For P(y-i), (1<i<y-1)

Conf(Pi) = Sup(Pk)/Sup(Py-i)

If Conf(Pi) ≥ Min_Conf

Then Rule=Rule U <P(y-i)→P(k-y+i)>

Else, return rule.

3.4 Simulation and results

The experimental results are obtained by performing the synthetic datasets and estimating the performance of our algorithm. Results are adopted according to simulation model. The adopted model is general and flexible to be matched with variety of understudy cases. Experiments are executed on C# basis with a 2.39 GHZ Intel(R) core(TM) 2 Due CPU, 1.95 GB of RAM running on Windows XP operating system.

3.4.1 Dataset generation

To simulate the movement of the mobile user, random data generator based on the used adopted algorithm is developed. Table (2) includes the used parameters in generating and processing data with default values used in this approach. The proposed simulator is designed to enable user to adjust the input parameters.

3.4.2 Evaluation of precision and recall

Precision and recall evaluation indicate system performance and prediction algorithm accuracy. Using cell to cell, sector to sector and intra-sector algorithms with 1000 trajectories in 4x3 map, minimum support =2, minimum confidence=80 and 100 trajectories per day, as shown in Figure (8)

Table (2) Summary of parameters

Symbol	Definition	Default values
TR	Total Number of trajectories per user in the proposed map	1000
Lmin	Minimum number of points per trajectory	3
Lmax	Maximum number of points per trajectory	7
TRday	Number of estimated trajectories per day	100
M	Map size = (mxn) cells , m=length , n=width	4x3
SC	System capacity : No. of last trajectories used to evaluate predictions	1000
Min_sup	Minimum support value	2
Min. conf	Percentage of Minimum Confidence	80

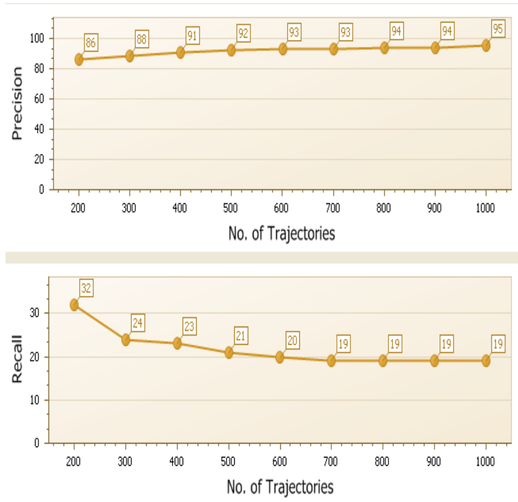

Fig (8) Precision and Recall VS Trajectories Number

3.4.3 Effect of Minimum support

Here, we study the impact of minimum support (Min sup) values on the precision and recall percentage of proposed algorithms. Figure (9) shows the decrement of precision and recall values by increasing min sup value.

3.4.4 Effect of Minimum confidence

There is a direct effect of changing the percentage of minimum confidence on the precision and recall percentages of our proposed system. By increasing the min conf value, the percentage of system precision also increased due to the increment in correct predictions compared to total number of predictions occurred. Whereas, recall percentage decreased by increasing min conf value as shown in Figure (10). The optimum min conf. value =100%.

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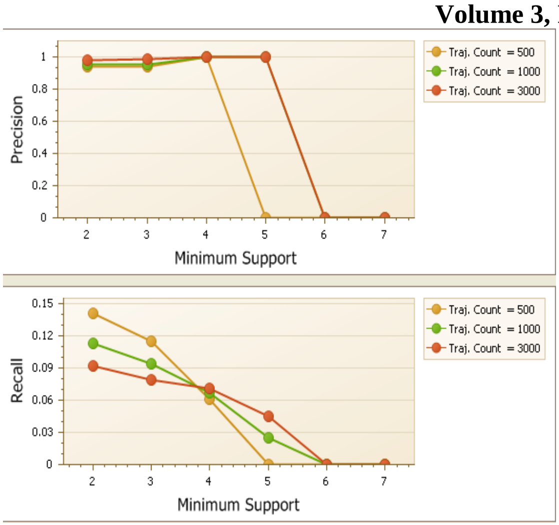

Fig (9) Precision and Recall versus Min sup Value

3.4.5 Algorithms' Execution time

In this section, we study the execution time proprieties of our proposed algorithms to estimate the performance of proposed system. Figure (11) shows execution time measured in (m sec) as a function of total number of input trajectories using CTC, STS and intra-sector algorithms. The optimum parameters and working modes can be adjusted according to the required application, user environments and flexibility of adjusting input data parameters.

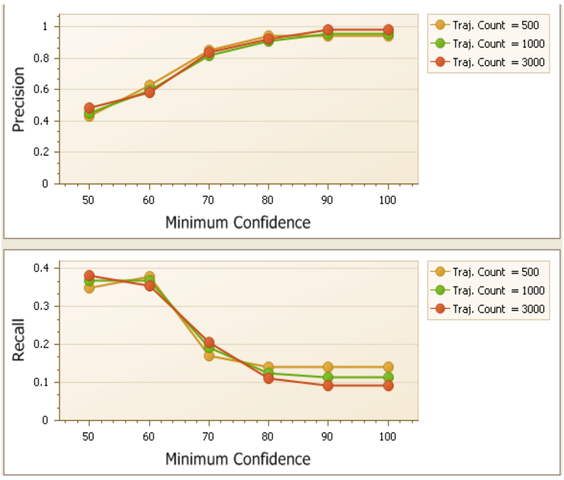

Fig (10) Precision and Recall versus Min conf. Value.

3.4.6 ICMP Algorithm Versus other algorithms

The proposed algorithm can be applied on mobile users at any environment as its parameters are adjustable according to the needed accuracy and the surrounding environment. Also, sub algorithms are adapted to suite various location based applications in addition to enhancement of mobile network allocation resources and mobility management.

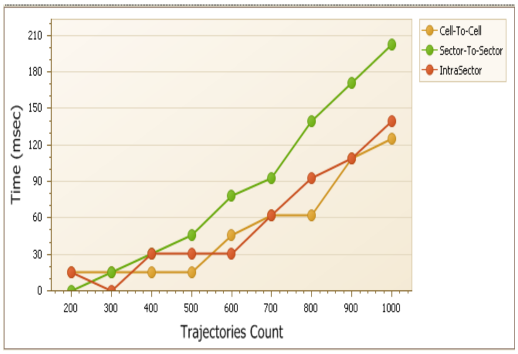

Fig (11) Execution Time in (msec) as a Function of Different Trajectories Length.

As indicated in Table 4, the precision of ICMP algorithm is compared with UMP and RLP algorithms. ICMP algorithm outperformed the two other algorithms within range of min. support values and it matched with the other two methods according to minimum confidence values. The execution time of completing algorithm and get the predicted points shows good time less than half second in comparison with RLP method. ICMP proposed algorithm benefits from U-TDOA technique to introduce sector to sector and intra sector predictions. These techniques are highly efficient in LBS applications based on mobile networks. The optimum parameters and working modes can be extracted depending on the required application, user environment and flexibility of adjusting input data parameters. The proposed algorithm not only theoretical one but it represent practical solution for future location prediction based on mobile network platform at various environments.

Table (3) Precision comparison of UMP, RLP and ICMP

	Min. Support [3% - 21%]	Min. Confidence [50 % - 100%]	Execution Time, "sec."
UMP	0.61 – 0.93	0.6 – 0.98	0.01-0.05
RLP	0.82 – 0.99	0.82 – 0.99	20-40
ICMP	0.9 - 0.99	0.5 – 0.99	0.18 – 0.22

IV. SERVICES AND APPLICATIONS BASED ON MOBILE USER'S LOCATION DETECTION AND FUTURE PREDICTION

Many location based services and applications can be regenerated according to the proposed hybrid UTDOA and assisted GPS positioning technique. Mobile location applications based on basic cellular phones depend on available network platform and there is no need for additional resources unlike smart phones which use extra resources such as WAP, WiFi and internet applications which consume more resources, time and they need additional network infrastructure. On the other hand about 28.73% of total world populations are Muslims. So, Muslims' applications are highly required to support more than quarter of world's population especially when they travel to other countries. Location based services are one of the most growing services based on mobile techniques which play an important role in many life

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branches. Emergency cases, safety issues, traffic management, Muslim's applications and public information are public type of mobile location services. Marketing, advertisement, entertainment and tracking applications are classified as commercial part of mobile based services.

4.1 Public Applications

There are a lot of vital public applications in human life as emergency, safety, traffic management, Muslims' applications and public information applications. These public applications serve peoples with common and important needed data and services. Finding places like nearest restaurant, hotel, stations, permissible food for Muslims are most required location services. In this section some applications are regenerated according to the proposed system.

4.1.1Emergency Applications

Emergency application is regarded as one of the most important applications which are based mainly on position detection. In many emergency cases, there is no time to describe your location or maybe you are in the high way and you can't describe your position accurately. So, using mobile detection system will solve this problem utilizing the proposed system. The quality of emergency applications depends on position accuracy and time response. While mobile user requests emergency service, mobile terminal automatically requests position using generated system in [8]. The estimated position will be stored in database server which will send it to emergency server in time. By this technique, time and accuracy are guaranteed in emergency applications.

4.1.2 Muslims' Applications

Due to traveling from one place to another, there are many services needed by Muslims to complete their religion activities and duties. Moreover, the numbers of Muslim travelers for work or leisure, both domestic and outbound, has increased tremendously. Qibla direction is one of the most important services needed for Muslims to pray. Prayer time which is a basic part of Muslims' life is based mainly on user location and it differs from one location to another even they are in the same country. Many researches introduce public and Muslims' applications based on internet network which need more time, resources and internet supported mobile devices to obtain the required application [19], whereas the proposed system depends on the available mobile network and the regular mobile devices without significant time delay. According to Figure (12), starting with law of cosine of spherical triangle with (a, b, c) sides of triangle and (α, β ,ɤ) are its angles we have:

$$\cos (b) = \cos (a)*\cos (c)+\sin (a)*\sin (c)*\cos (\beta) \qquad (10)$$

Where, β= lon2 - lon1, **c** = $\pi/2$ - lat1**,** a = $\pi/2$ - lat2**.**
Substituting these values in (3) leads to:

$$\cos (b)=\cos(\pi/2-lat2)*\cos(\pi/2 - lat1) + \sin(\pi/2-lat2) *\sin(\pi/2-lat1)*\cos(lon2-lon1) \qquad (11)$$

Solving for angular distance between the two points (b) yields,

$$b=\arccos\{\cos(\pi/2-lat2)*\cos(\pi/2-lat1)+\sin(\pi/2-lat2)*\sin(\pi/2-lat1)*\cos(lon2-lon1)\} \qquad (12)$$

The azimuth from (lat1, lon1) to (lat2, lon2) is calculated by the law of sines:

$$\sin(\alpha)/\sin(a)=\sin(\beta)/\sin (b)=\sin(\gamma)/\sin(c) \qquad (13)$$

Then, $\sin (\alpha) = \sin (a) * \sin (\beta) / \sin (b)$ (14)

Consequently,

$$\alpha= \arcsin\{\sin (\pi/2-lat2)*\sin(lon2-lon1)/\sin (b)\} \qquad (15)$$

As shown in Figure (12) and by solving system of equations from 10 to 15, the angle "α" represents the required azimuth between the two points. So, while user is located at point 1 and Ka'baa is located at point 2, the calculated azimuth 'α' represents the Qibla's direction.

4.2 Commercial Applications

Due to enormous use of mobile devices all over the world, there are many economic and commercial applications and services based mainly on mobile location. Many surveys predict billions of dollars in revenues for mobile advertising [21]. Mobile network operators are well positioned to take up a significant percent of this advertising revenue as they negotiate deals with content providers. Recent deals between media companies, advertising agencies and Internet/software industry also demonstrate significant optimism for future growth [22]. Mobile marketing, gaming and tracking applications represent economical part of mobile positioning services. There are many challenges that should be overcome to achieve good services. Quality of Service (QoS) can be expressed in terms of location accuracy required, response time, and reliability of operation [23].

4.2.1 Mobile Marketing Application

In order to spread commercial advertisements to specific users, mobile operators mainly use cell ID method as positioning system. This method especially in macro cells which serve big area leads to lose of time, money and network resources as services may reach to unexpected and undesired customers. Utilizing hybrid uplink time difference of arrival and A-GPS method generated in [8] the accuracy of position is refined. Using Equations from (10) to (12) the angular distance between the user and the target is determined.

$$Arc\_length = radius * angular\ distance \qquad (16)$$

So the distance (d) can be obtained from:

$$d = Earth\ Radius*\arccos\{\cos(\pi/2-lat2)*\cos(\pi/2-lat1) + \sin(\pi/2-lat2) * \sin(\pi/2-lat1) * \cos(lon2-lon1)\} \qquad (17)$$

Using Equations (16) and (17) the distance d is the actual distance between the two points. According to marketing application, server determines the critical distance “d0”. If d is less than or equal d0, the user will receive the marketing service. Otherwise, mobile user isn’t the target for this service.

4.2.2 Finding Places

One of the most useful applications used nowadays especially in travelling abroad is finding places using mobile phones. The nearest restaurant, mosque, church, cinema, university and any other place can be found using the proposed system. Data base server related to each SMLC contains the location "longitude, latitude" of places and is divided according to each base station. There are two options of finding places: find nearest place or specific place.While user requests the location of nearest place, database server check for the place within the user base station then the neighbor base stations. Location "longitude, latitude" of the place is compared to user location. The distance between user and place can be calculated according to Equations (10),(11),(12),(15) and (16). Also the direction of the target is determined according to equations (13) and (14).

4.2.3 Traffic Management Application

When there are more crowds in some streets, road administrators need to turn the way to another road or warn cars' users. By using location prediction technique, application server related to road administration will send the warning messages to users whose future locations are in the target road. The confidence threshold value is adjusted according to the required prediction accuracy. Also, for more precise applications when there is a need to inform the user by distance or direction of specific target like stop point, crowded point, etc. Equations from (10) to (17) are used. This technique achieves good quality of service due to good adjustable accuracy, less time delay and save money and resources of mobile network operators.

4.2.4 Children, Elders and Friend Tracking Applications

In this section a new and valuable application is generated. Using short message service mechanism, parents can be informed whether their children lost their path to school or didn’t reach their expected destination in predicted time. Parent phone or any other people responsible of children phone number are stored in database related to child number. By applying the proposed prediction algorithm it is possible to predict a child (x) who should reach a specific location within time (Tx). So if this prediction achieved then, short message is sent to parents’ mobile phone that user (x) already reach the predicted target. Otherwise, alarm message to parent phone is reached that child (x) didn’t reach the predicted target. By the same way older people are tracked by their healthcare persons or friends. In this application, user privacy mechanism introduced in [24] is used to control which cellular phones is accepted to track others and authentication behavior. All the above data should be stored in application server which is connected to SMLC and mobile network to achieve the tracking application properly.

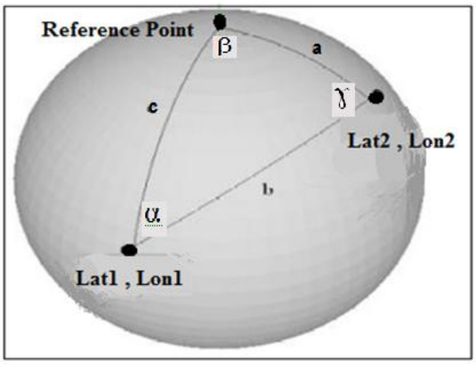

Fig (12) Circle path from point 1 to point 2 as in [12]

V. CONCLUSION AND FUTURE WORK

In this paper, hybrid UTDOA and A-GPS positioning technique in mobile network is carried out. Network elements' functions and its procedure for location determination are introduced. Advanced GPS receiver structure to achieve procedure requirements and generate the required pseudo-ranges is implemented. The developed technique theoretically achieved the following advantages:

- Reduction of TTFF by about 45% using assisted data from LMU in mobile network.
- High positioning accuracy than that obtained based on standalone GPS or UTDOA.
- Number of needed GPS satellites is less than that is needed in conventional GPS according to two or three dimension (2D/3D) applications.
- The optimal positioning technique such as GPS, U-TDOA or hybrid is obtained depending on the positioning parameters such as accuracy, latency, call state, environment and system loading.
- Problems caused by system loading can be solved using SUPL protocol between MS and mobile network.

A novel future location prediction algorithm (ICMP) is developed. ICMP algorithm is divided into three main parts cell to cell, sector to sector and intra-sector prediction levels, each prediction level is convenient with specific application within certain environment. The developed ICMP algorithm achieved the requirements of future prediction of mobile users' location which is used to enhance both LBS based on mobile network operators and mobile network allocation resources, hand over process and mobility management operations. The proposed algorithm is mainly considered as one of the most reliable and applicable algorithms which can be applied on basic mobile terminals at any environments due to its flexibility and sub algorithms which are adapted to suite various location based applications in addition to enhancement of mobile network allocation resources and mobility management. ICMP algorithm outperformed other future location prediction algorithms as proven. There are varieties of services and applications based on the detection of mobile location are regenerated according to accurate hybrid positioning technique with mobile network system including database server. Emergency applications, Qibla direction as one of the most important Muslims applications and mobile marketing are based on the proposed system. The proposed technique is applicable on basic mobile phones without any hardware addition. Future work implies developing more accurate positioning methods and future location prediction including Geographical Information System (GIS).

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