HYBRID LOCALIZATION TECHNIQUES FOR GSM-WCDMA CELLULAR RADIO SYSTEM

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Abstract

Location Based Services (LBS) is an important features in the cellular radio network such as Global System for Mobile Communications (GSM), Wideband Code Division Multiple Access (WCDMA) and Long Term Evolution (LTE). The accuracy of positioning or localization in such single layer network network depend on the Location Determination Technique or Technology (LDT) implemented; the Enhanced Observed Time Difference (E-OTD) in GSM and Observed Time Difference Of Arrival (OTDOA) for WCDMA but subjected to signal hearability from at least three Base Station (BSs) or NodeBs. This paper present hybrid localization techniques for a multilayer or heterogeneous GSM-WCDMA network when a single layer network experience low signal hearability. This can be resolve by gathering at least three signal hearability from multilayer network infrastructure or using previous location information to reduce LDT error. The proposed method has been implemented and evaluated using simulation under various mobility models. Simulation shown that the LDT error for hybrid technique can been improved as compared to E-OTD and OTDOA and met E911 requirement.

Keywords : Positioning, localization, hearability, LDT, heterogeneous.

I. INTRODUCTION

The development of telecommunications system especially from fixed to wireless network has big impact in our daily life. Wireless communication generation evolved from the first generation (1G) analogue such as AMPS and ETACS to the second generation (2G) digital system such as GSM and then to the third generation (3G) system such as WCDMA. Nowadays, the fourth generation (4G) system known as the Long Term Evaluation (LTE) also already had been deployed. The system migration took place very rapidly to support user demand in term of higher data rate and throughput besides new services that require device location information.

GSM became very well known quickly because it provides better speech quality and has gone through a uniform international standard that has made it possible to use a single telephone number and mobile unit around the world. A GSM system consist of mobile station (MS), the base station subsystem (BSS) and the network subsystem and operated at 900 MHz (GSM900), 1800 MHz (GSM1800) and 1900 MHz (GSM1900) [2][3]. GSM can provide location information using different types positioning systems including network positioning (the system itself) or through the use of global positioning system - GPS Information that is provided from mobile devices. GSM services include commercial services, internal location services, emergency location services, and lawful intercept services.

Further more, WCDMA technology operated at 2000 MHz has emerged as the most widely adopted 3G air interface. 3G is designed for multimedia communication . It provides with high quality images, video, and access to information and services that enhanced by the higher data rates and new flexible communication capabilities. A WCDMA system consist of User Equipment (UE), UMTS Terrestrial Radio Access Network (UTRAN), Core Network (CN) and External Network [1][2].

II. LOCALIZATION DETERMINATION TECHNIQUE

Besides LDT using Global Positioning System (GPS) using satellite, several other LDT techniques for cellular system are available using handset/terminal based and network based techniques. The techniques also vary for various network interfaces, thus different positioning accuracy is expected since different cell size and coverage requirement exist.

LDT performances usually benchmark based on the location accuracy/error. Accuracy of a location is a measure that defines how close the location measurements are to the actual location of the mobile station being located. The location accuracy depends on the LDT adopted.

LDT performance also subjected to the signal hearability that can be defined as the ability of a MS/UE to be assigned and receive signals from multiple BS/NodeB. Hearability can be measured by the number of BS/NodeB that can be heard by a MS/UE [3]. The hearability is better as long as the number of heard base stations is higher. Low hearability occurs when the number of heard BS/NodeB is less than three and this leads to localization failure and fair localization accuracy although assisted by network information.

Under low hearability condition, localization depends on predicted information history and optimization method. Low hearability in single network can be resolve by gathering at least three strongest signal receptions from multilayer network infrastructure such as GSM/WCDMA for localization purpose to reduce LDT error.

So far, there is no clear information about which technique works better on specific heterogeneous network. However, two terms have been used to measure the LDT performance; accuracy and precision. Accuracy describes how much the measured value differs from the true value while precision is the degree of repeatability under unchanged conditions that show the same results. For E911 service, the service provider must be able to locate a caller within an accuracy of 100 m and a precision of 67% or within 300 m and a precision of 95%. Table 1 shows the LDT accuracy and precision in rural, sub-urban and urban areas [4].

Table 1: LDT Accuracy and Precession in Various Areas

LDT	Rural		Sub-Urban		Urban	
	Acc. (m)	Prec (%)	Acc. (m)	Prec (%)	Acc. (m)	Prec (%)
Cell ID	1746	95	1870	95	526	95
TDOA	8609	95	1956	95	624	-
OTDOA	27	95	-	-	97	67
E-OTD	80-110	-	80-120	-	80-110	-
GPS	5	-	5-15	-	5-30	-
A-GPS	10-15	-	10-15	-	15-100	-

Note: Prec – Precision, Acc. - Accuracies

In this study, the accuracy and precision of hybrid algorithm in multilayer network will be compared against E-OTD and OTDOA in a single network.

III. HYBRID LDT CONCEPT

The basic idea of the hybridisation is to combine the position methods in such a way so as to fully exploit their strong points, compensate for the weaknesses, and provide the most appropriate and economical position solution according to the requirements set by the applications [5]. The hybrid concept can be best describes by Table 2 and Figure 1 considering a multilayer network consisting of GSM900, GSM1800 and WCDMA infrastructure [6]. In Table 2, there are 27 possible Point of Attachment (POA) from single, double or three network interfaces. E-OTD algorithm is used when the signal heard come from GSM network only either GSM900 or GSM1800 or combinations, for example at locations A and B (POA5, POA18). OTDOA algorithm is executed when only WCDMA network heard by the MS/UE. Moreover, hybrid algorithm will be triggered when the three signal hearability gathered from both network (GSM/WCDMA) is used, for example at point C (POA 20). When the signal heard is less than three, MS/UE will be in the low hearability condition, thus previous location information can be used but lead to substantial localization error. In some cases, optimization techniques such as Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) can be exploited to predict the best possible POA using previous POA and forecast POA in accordance to mobility prediction.

Table 2 Possible POA and hybrid LDT algorithm for three signal hearability

POA	Serving BS	1st Adjacent station	2nd adjacent station	LDT algorithm
POA1	GSM900	WCDMA	WCDMA	Hybrid
POA2	GSM900	WCDMA	GSM900	Hybrid
POA3	GSM900	WCDMA	GSM1800	Hybrid
POA4	GSM900	GSM1800	WCDMA	Hybrid
POA5	GSM900	GSM1800	GSM1800	EOTD
POA6	GSM900	GSM1800	GSM900	EOTD
POA7	GSM900	GSM900	WCDMA	Hybrid
POA8	GSM900	GSM900	GSM1800	EOTD
POA9	GSM900	GSM900	GSM900	EOTD
POA10	GSM1800	WCDMA	WCDMA	Hybrid
POA11	GSM1800	WCDMA	GSM1800	Hybrid
POA12	GSM1800	WCDMA	GSM900	Hybrid
POA13	GSM1800	GSM1800	WCDMA	Hybrid
POA14	GSM1800	GSM1800	GSM1800	EOTD
POA15	GSM1800	GSM1800	GSM900	Hybrid
POA16	GSM1800	GSM900	WCDMA	Hybrid
POA17	GSM1800	GSM900	GSM1800	EOTD
POA18	GSM1800	GSM900	GSM900	EOTD
POA19	WCDMA	WCDMA	WCDMA	OTDOA
POA20	WCDMA	WCDMA	GSM1800	Hybrid
POA21	WCDMA	WCDMA	GSM900	Hybrid
POA22	WCDMA	GSM1800	WCDMA	Hybrid
POA23	WCDMA	GSM1800	GSM1800	Hybrid
POA24	WCDMA	GSM1800	GSM900	Hybrid
POA25	WCDMA	GSM900	WCDMA	Hybrid
POA26	WCDMA	GSM900	GSM1800	Hybrid
POA27	WCDMA	GSM900	GSM900	Hybrid

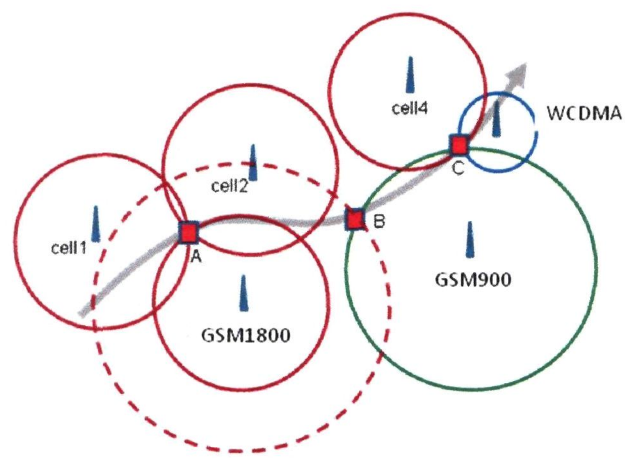

Figure 1 Point-of-Attachement and LDT algorithm scenario

IV. SIMULATION AND VALIDATION

To evaluate the proposed hybrid technique generality, these algorithms has be simulated and validated using MATLAB following work done in [7] but for heterogeneous network consisting GSM, WCDMA and WiMAX networks. The simulation environment consist of a multilayer network i.e. GSM900, GSM1800, and WCDMA. Figure 2 shows a snapshot of the simulation for a MS/UE moving in random manners but in forward directed path. The position is evaluated by triangulation using distance from three GSM900 heard by the MS/UE. Table 3 summarizes the important parameters used in the simulation set-up.

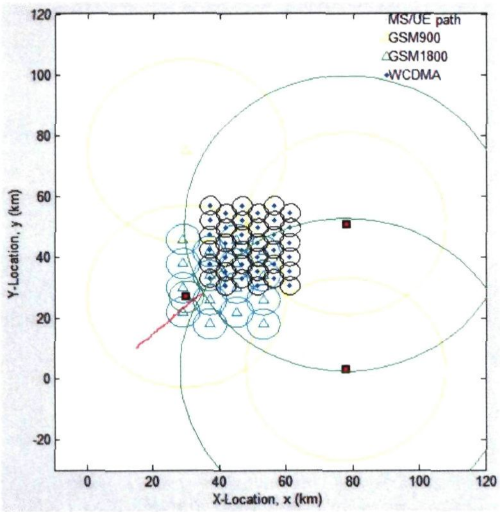

Figure 2 Simulation Scenario Snapshot

Table 2: Simulation Parameter Setting

Parameters	Value
Simulation area	100 x 100 km^2
No. Layers	3 layers
No. of BS (GSM900)	4 cells
No. of BS (GSM1800)	16 cells
No. OF BS (WCDMA)	36 cells
Cell radius (GSM900)	30 km
Cell radius (GSM1800)	10 km
Cell radius (WCDMA)	5 km
No. of MS	1
Speed of MS	60 to 120 km/hr

The overall simulation flowchart is shown in Figure 3. The program starts with initialization of network topology and MS/UE initial position. The MS/UE is update as the clock timer is updated according to random MS/UE movement in North, East or North East. The POA in each single layer network is set according to the MS/UE closest distance from BS/NodeB. The three heard signal will determine the choice of LDT technique (E-OTD, OTDOA or hybrid) been adopted. However, the LDT for low hearability not been extensively evaluated and MS/UE position is estimated according the previous location. Finally, positioning RMS error is determine and compared for various LDT techniques.

Figure 4 shows signal hearability in GSM900, GSM1800, WCDMA network and total hearability. Then, LDT algorithm will be determined according to the preferred POA and from the figure; it is shown that E-OTD is the LDT selected.

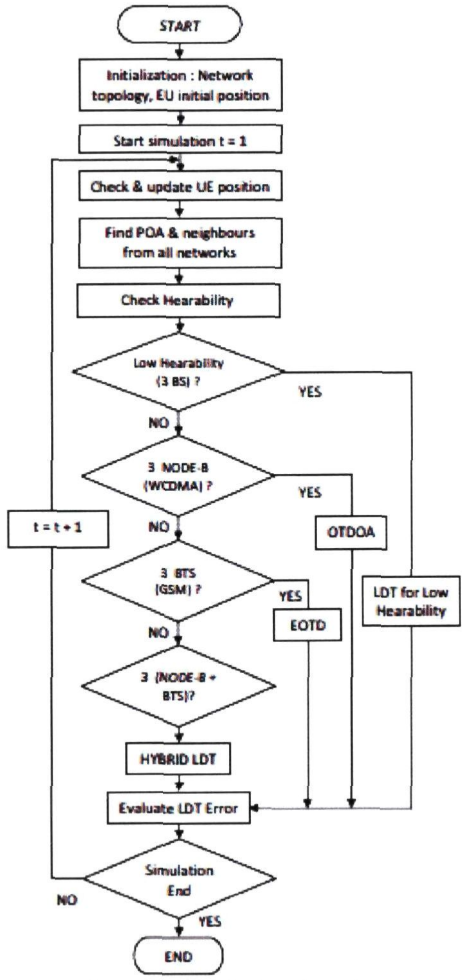

Figure 3 Simulation flowchart

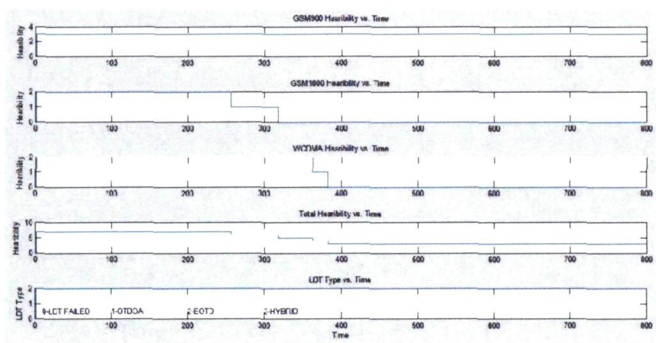
Figure 4 POA and LDT selection versus time

The simulation done includes analyzing LDT error for various MS/UE speeds, and LDT accuracy comparison between E-OTD, OTDOA and hybrid techniques.

V. RESULTS

Figure 5 shows the Cumulative Density Function (CDF) of E-OTD LDT error under different mobility models. It is shown that the LDT error increases as the MS/UE speed is faster from 20 to 100 meters.

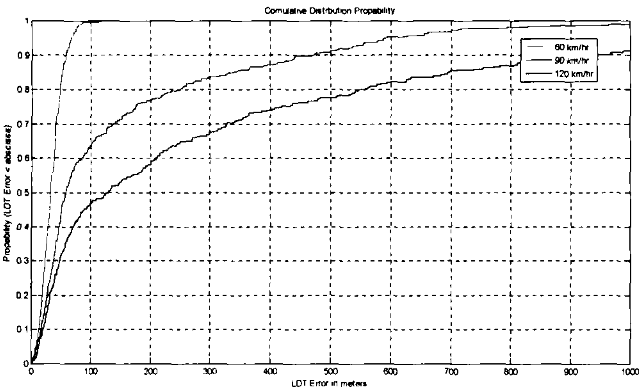

Figure 5 LDT error for various MS/UE speeds

Figure 6 shows the Cumulative Density Function of LDT error for Hybrid LDT, OTDOA, and E-OTD. It shows that the median value of the hybrid LDT location errors were recorded with 42 meters accuracy at the time that OTDOA and E-OTD obtained 40 meters and 45 meters respectively.

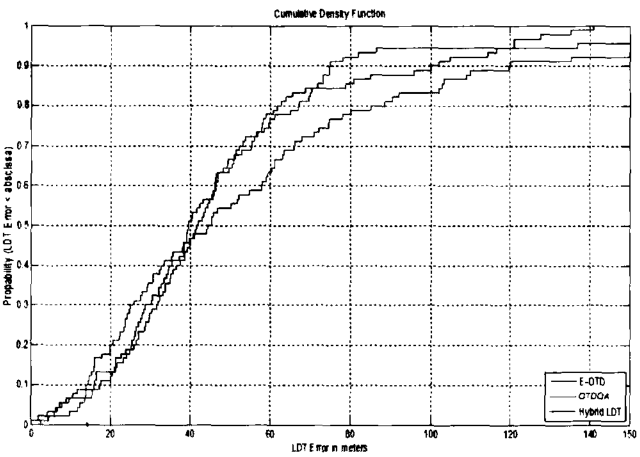

Figure 6 LDT errors for Hybrid, OTDOA, and E-OTD

Table 3 summarizes various accuracies attained by different technologies from the simulation and compared to E911 requirements.

Table 3: LDT accuracies for different LDT technology.

LDT	LDT accuracy in meters		
	50%	67%	95%
E-ODT	45	**63**	175
Hybrid LDT	43	**50**	**120**
OTDOA	40	**51**	**140**
E-911	-	100	300

VI. CONCLUSION

Hybrid localization techniques make use other BS/NodeB information heard by the MS/UE to enable successful triangulation to determine MS/UE position, thus improving LDT accuracy. The proposed method has been evaluated using simulation under various mobility models and then been compared with LDT error for E-OTD and OTDOA techniques. It is shown that the LDT error for hybrid technique improved and meet E911 requirement.

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