DEVELOPMENT OF SIMULATION MODEL & ESTIMATED ACCURACY FOR LOCATION DETERMINATION TECHNOLOGY (LDT) USING ENHANCED OBSERVED TIME DIFFERENCE (E-OTD)

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Abstract— ***Location Based Services (LBS) has become an important area of research, for emergency as well as for commercial services during the past few years. There are several mobile station positioning determination techniques for LBS). However, the focus of this dissertation is d on two methods of Location Determination Technologies (LDT) which are using E-OTD and TOA as comparison. The analysis for the TOA and E-OTD techniques was simulated using MATLAB 7.0. The development simulation model is purposely to estimate the accuracy of E-OTD based on error performance using a sample of channel model. Estimated accuracy using error magnitude of $1x10^{-6}$ s at 70% for TOA is at 330.3 metre and 257.7 metre for E-OTD. Therefore, simulation shows that the accuracy of E-OTD is higher than TOA technique.***

Keywords— Location Determination, Positioning, Enhanced-Observed Time Difference

I. INTRODUCTION

Location Based Services, *(LBS)* is a service that allow a mobile user to use the services personally. Location Based Services provide certain information about a location. LBS can guide the user to the place that the user desired, provide current infomation such as traffic condition and weather or provide the user with information about their route and journey.

When a user is in a new location, LBS can provide interactive information and a map along with the correct and accurate direction.

Amenity that being provided by this location base service will not be meaningful if the supplier are not able to identify the location of the user accurately. This is where the existance of Location Determination Technology, *(LDT)* that can determine the location of the user or mobile station, *(MS)* acurrately become important. There are several technology that had being introduced to determine the location of a MS until today such as (*Cell-ID*), *Angle of Arrival* (AOA), *Time of Arrival* (TOA), *Observed-Time Difference of Arrival* (OTDOA), *Enhanced-Observed Time Difference* (E-OTD), and *Global Positioning Services* (GPS).

It is particularly interesting to evaluate the precision of *Enhanced observed time difference* (E-OTD). The E-OTD positioning method generally relies upon measuring the time at which signals from the Base Transceiver Station (BTS) arrive at two geographically dispersed locations – the mobile phone/station (MS) itself and a fixed measuring point known as the Location Measurement Unit (LMU) whose location is known. The position of the MS is determined by comparing the time differences between the two sets of timing measurements. Because of the great demand for additional hardware, such as LMUs, the introduction of E-OTD will require significant investments.

(II) METHODOLOGY

To implement this study, we need to use the programming language to get the result like we experiment it close to the real world or actual situation. It is important to make sure the result that we get in this simulation can be used as reference and as a guide for us before we apply the services in the real world.

To represent the actual situation, we use objected-oriented software engineering such as MATLAB to run the simulation part. By using this software, we can design the location, calculate the situation based on our study and make the analysis about the result. We can change the design and readjust the simulation if the result that we get is not like we supposed to get in the real world.

We use this software to implement this application for several reasons, including the fact that this is an object-oriented language. Besides that, this software is familiar to us and we already use this software before. It is easy to learn and have a good tool to help new user to create graphical interfaces and others

(III) LOCATION POSITIONING USING E-OTD

The Enhanced Observed Time Difference (E-OTD) positioning method is specified as one of the positioning mechanisms in the GSM standard for Location Services.

In synchronized networks, the target MS measures relative time of arrival of same signals from several neighbor BTSs as well as from its serving BTS. These measurements are called ***Observed Time Difference*** (OTD). In unsynchronized networks, a type of measurement units with known locations, named Location Measurement Unit (LMU), are used to calculate the ***Real Time Difference*** (RTD) to compensate the errors introduced by unsynchronized clocks at different BTSs. MS and LMU send their measurement results, OTD and RTD, back to

PCF, which in turns calculates the position of the target MS by deducing the geometrical components of the time delays to an MS from the BTSs. To obtain an accurate triangulation, OTD measurements (and for non-synchronized BTSs, RTD measurements) are needed from at least three geographically distinct BTSs. If measurements from more BTSs are available, the estimated location area can be further narrowed down. The calculation can be done either in the network or in the MS itself if all needed information is available in MS.

i. *Observed Time Difference*, OTD
ii. *Real Time Difference*, RTD
iii. *Geometric Time Difference*, GTD

The OTD is time interval observed by the MS between the reception of burst from reference and neighbour BTS. For example, signal from BTS_1 is receive at t_{RX1}, and signal from neighbour BTS_i is receive at t_{RXi}.

Hence, the value for OTD is [2]:

$$OTD_i = t_{RX1} - t_{RXi} \quad (1)$$

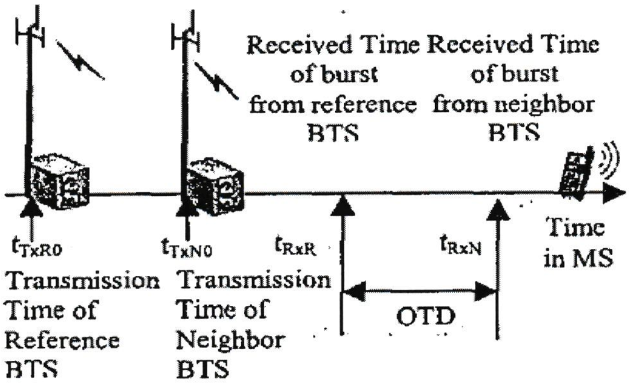


Figure 1: Observed Time Difference [7]

If the two signal been received at the same time, so the value of OTD = 0.

RTD calculate the difference between propagation delay of signals tranmitted from reference and neighbour BTS. RTD is measured by LMU that exist in the network. For example BTS_1 (Reference BTS) send signals at t_{TX1}, and neighbour BTS_i send signal at t_{TXi}. For this reason, the value of RTD is [2]:

$$RTD_i = t_{TX1} - t_{TXi} \quad (2)$$

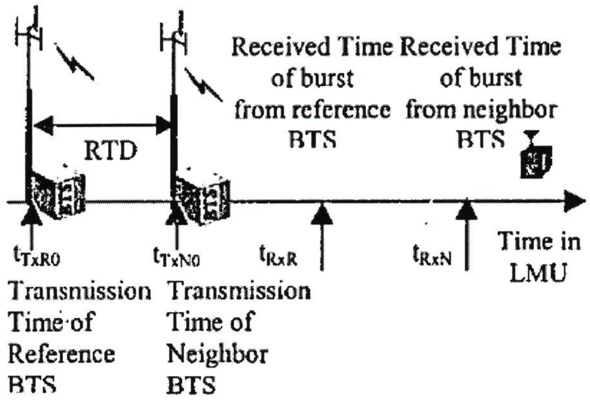


Figure 2: Real Time Difference line in GSM [7]

If the network had sent signals at the same time, it means that the network is parallel, so RTD =0. In this research, the value of RTD had been set to 0 to make the calculation easier. However in real situation, this parametre should also be considered.

The GTD is based on a hyperbola between reference and neighbour BTS, the actual quantity involving information about the location of the MS. Let the length of propagation path between the MS and and reference BTS be d_1 and the length of propagation path between the MS and the neighbour BTS be d_i with c as the speed of ligh ($3x10^8$ ms^{-1}).

If both BTSs are equally far from the MS, GTD = 0, as shown in figure 3,the GTD value is defined as

$$\begin{aligned} GTD_i &= (t_{RX1} - t_{TX1}) - (t_{RXi} - t_{TXi}) \\ &= (d_1 - d_i)/c \\ &= RD/c \end{aligned} \quad (4)$$

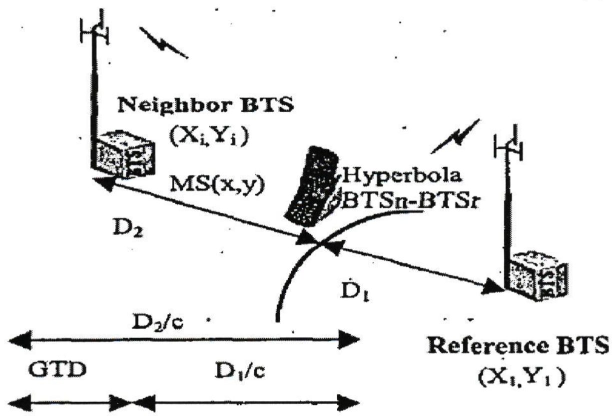


Figure 3: Geometric Time Difference [7]

(IV) E-OTD ESTIMATION ALGORITHM

If the coordinate for BTS_1 and two other neighbour BTS (BTS_2 and BTS_3) are known, the MS location (on x,y) can be determined by solving the simultaneous equation as follow [Jonsson and Olavesen, 2002]:

$$c*GTD_{1,2} = \sqrt{(x_1 - x)^2 + (y_1 - y)^2} - \sqrt{(x_2 - x)^2 + (y_2 - y)^2} \quad (5)$$

$$c*GTD_{1,3} = \sqrt{(x_1 - x)^2 + (y_1 - y)^2} - \sqrt{(x_3 - x)^2 + (y_3 - y)^2} \quad (6)$$

MS location can be located from the intersection point between both equations (5) and (6). The Enhanced Observed Time Difference (E-OTD) method is based on the measured Observed Time Difference (OTD) between arrivals of bursts from serving and other BTSs as shown in Figure 3.

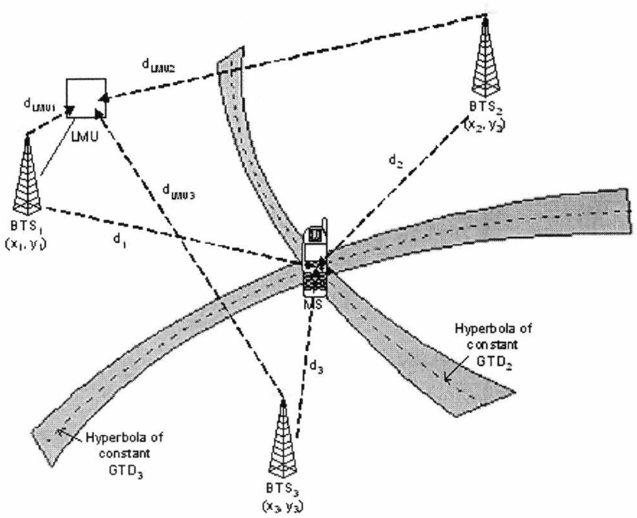


Figure 3: Principle of the Enhanced-Observed Time Difference method

With d_1, d_2 and d_3 are the passage length from each BTS to MS. Meanwhile d_{LMU1}, d_{LMU2}, d_{LMU3} are the passage length from each BTS to LMU.

(V) CHANNEL MODEL

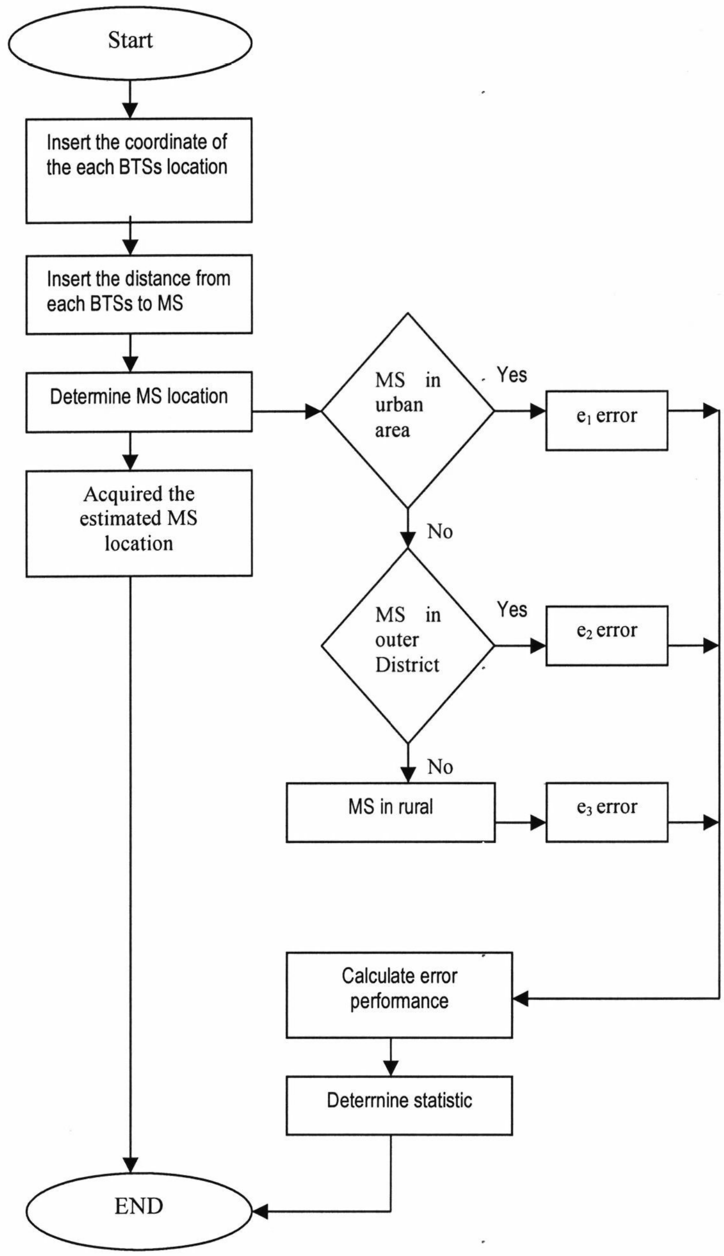
In order to analyses test of the E-OTD technique. Error magnitude have to be applied into the simulation model. Error magnitude that will be used is referred from the calculation of Jonsson and Olavesev [2]. Table 1 shows the error magnitude for three different main environment, urban, outer districts and rural environment.

Table 1 : Error magnitude in different environment [2]

Area	Error magnitude (s)
Urban	$e_1 = 1x10^{-6}$
Outer Districts	$e_2 = 1x10^{-7}$
Rural	$e_3 = 1x10^{-8}$

The developement of channel model is the main part in this research. By applying the error magnitude for different environment, the performance of the channel model can be evaluated.

A. Simulation Model Flow Chart



(VI) RESULTS

The error performance for E-OTD technique is been compared with the error performance for TOA technique to determine which technique is more accurate and precise.

A. Error Performance E-OTD Technique Compared With TOA Technique

Error performance for TOA and E-OTD technique for urban, outer districts and rural area are plot into cumulative distribution function to get a better display and clearer. For the three area, CDF percentile value are display at 30%, 50%, 70%, 90% and 95% can be tabulated into Table 2 and Table 3.

Table 2 shows the percentiles for the estimated location of the cumulative distribution function by using TOA method in the mention environment as above.

Table 2. Error percentile using TOA (3 BTS)[9]

	Error percentile (m)				
Environment	**30%**	**50%**	**70%**	**90%**	**95%**
Urban	299.8	311.5	330.3	392.9	449.3
Outer Districts	34.7	37.0	43.5	67.4	94.2
Rural	3.5	3.8	4.2	7.7	12.4

Table 3 shows the percentiles for the estimated location of the cumulative distribution function by using E-OTD method in the mention environment as above.

Table 3. Error percentile using E-OTD (3BTS)

	Error percentile (m)				
Environment	**30%**	**50%**	**70%**	**90%**	**95%**
Urban	227.9	242.3	257.7	318.4	344.3
Outer Districts	23.9	26.2	28.3	30.2	32.1
Rural	2.3	2.7	2.5	3.0	3.2

From the table, E-OTD technique gives smaller error compare to the TOA technique. From Table 2 and Table 3, error location difference that given using TOA and E-OTD technique in the urban area, shows a difference from 72 to 105 metre. This reading is quite high for that environment. For outer districts environment, the error difference between both techniques are between 11 to 62 metre. For rural area also, the location error difference for TOA and E-OTD is small, in between range of 1 to 9.2 metre only.

(VII) ESTIMATED ACCURACY

Estimated accuracy for channel model location determination that been construct is done based on the error performance outcome for both technique TOA and E-OTD.

A. Estimated Accuracy Using TOA

Accuracy percentile are acquire from the channel model for TOA tenchnique is estimated referred on Table 2. Based on Table 2, estimated accuracy for TOA technique simulation at the stage of 70% will be at 330.3 metre in urban environment (error magnitude $1x10^{-6}$s), 43.5 metre in outer districts environment (error magnitud $1x10^{-7}$s) and 4.2 metre in rural environment (error magnitud $1x10^{-8}$s).

From Table 2 also, the TOA technique accuracy is estimated between 34 until 94 metre specifically when being simulated using error magnitude of $1x10^{-7}$ (in research considered as outer districts).

B. Estimated Accuracy Using E-OTD

Based on Table 3, estimated accuracy for E-OTD technique at the stage of 70% is at 257.7 metre in urban environment, 28.3 metre in outer districts environment and 2.5 metre in urban environment.

Other than that, simulation model accuracy for E-OTD technique also being compared with the accuracy acquire from Jonsson and Jorgen [2] and Soontorn and Suthicai [7]. Accuracy comparison at level of 70% and 90% using E-OTD technique is shown in Table 4. As an addition, based on the theory, E-OTD technique accuracy at 70% is at 125 metre[5]. But in this theory, accuracy that is obtain from the theory did not state the error magnitude that was used in his research. From Table 4 it can be observed that all three simulation model using E-OTD technique that have been construct are very different.

Table 4. Comparison of E-OTD estimated accuracy method between different equations

	Jonsson & Olavesen		**Soontorn & Suthicai**	
	70%	**90%**	**70%**	**90%**
Urban	257.7	318.4	104	173
Outer Districts	28.3	30.2	68	118
Rural	2.5	3.0	64	101

C. Analysis of Estimated Accuracy

Estimated accuracy for location determination simulation model using TOA and E-OTD technique is been simplified into Table 5 based on the error location performance for cumulative distribution at 70%. I choosed 70% because from the output graf start to shows a real difference when the circular error reach around 70% of the error percentile.

Table 5. Estimated accuracy from simulation results at 70%

Environment	Error at 70% (m)	
	TOA (3 BTS)	E-OTD (3 BTS)
Urban	330.3	257.7
Outer Districts	43.5	28.3
Rural	4.2	2.5

From Table 5, it is found that circular error for locations that is determined using E-OTD technique is much smaller compared to the TOA technique. Hence, from this simulation it can be summarised that E-OTD technique accuracy is higher compare to the accuracy for TOA technique.

The accuracy for TOA and E-OTD technique from simulation maybe differ from the accuracy stated in the theory and also that been done by other canvasser. It occur maybe because the difference in assumptions that is done in processing the simulation such as the use of different error magnitude, differences in channel model that been used and also the difference in density and BTS topology. .

(VIII) CONCLUSION

This research has shown an overview of mobile station location based service (LBS) and the location detection technology in the GSM network. The E-OTD method has been explained in detail, simulated by MATLAB.

The accuracy of the E-OTD method is quite good, which makes it a promising location method. The outcome from this simulation shows that accuracy estimated using error mgnitude for $1x10^{-6}$ s at the level of 70% TOA is 321.3 metres meanwhile for E-OTD is 255.4 metres. Because of that, simulation proved that the accuracy for E-OTD technique is higher compare to TOA technique.

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FUTURE DEVELOPMENT

Future development for this thesis is to make research on other type of technique in Location Determination Technology (LDT), such as cell-id technique which is been widely use in today's technology. Thus, determining the most suitable technique to be used in determine the MS location.

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