The Development of Simulation Model and Location Accuracy for Observed Time Difference of Arrival (OTDOA) Positioning Technique in WCDMA and LTE System

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Abstract— **Obtaining and delivering user location in Long term Evolution (LTE) technology are various methods that help Communication Service Providers (CSPs) monetize and optimize their networks. It is very important in case of user makes an emergency call and service provider need to locate the geographical position of the user. In this paper, the goal with this work is to analyse the Location Determination Technique (LDT) based on Observed Time Difference of Arrival (OTDOA) in positioning technique in WCDMA and LTE system. This kind of positioning method were chosen as the user equipment (UEs) need to "hear" the signal from the nearest three base stations (Bs). Data from the driven test of Received Signal Code Power (RSCP) Node Bs will be used to simulate by using the OTDOA simulation model with fixed input parameters. Drive test has been made in urban areas in Kuala Lumpur and Shah Alam as the LTE system is in trial version in Malaysia when this paper is written. Then we proceed with analyse the data to gain the accuracy of the location by using OTDOA method. The accuracy will be evaluated by the standard of accepted location approximation error that has been state in WDCMA and LTE network in many studies. The analysis shows that the location errors in WCDMA and LTE system by using OTDOA method were least and have the most accuracy.**

Keywords— **LTE; LDT; OTDOA; hearability**

I. Introduction

Localization is the important application that has been offered in user equipment, especially for smart phone to give services base on location and location awareness. This service is highly important to mobile user especially in the location estimation with high accuracy is needed and when emergency situations happen.

According to E-911 that has been released, the regulatory in emergency positioning is required in typical region to determine the location of an emergency call in wireless system. US Federal Communication Commission had released the regulatory of emergency positioning (FCC E911). It states that in the terminal based positioning the location of emergency calls must be delivered to an emergency call centre with an accuracy of 50m (67%), 150m (95%),whereas 100m (67%) and 300m (95%) in the network based positioning [1].

Many issues specific to the radio access technology need to be drawn attention to make the positioning service meets the requirements. For example; signals that relevant for positioning measurements, hearability of the signals from the base stations, bandwidth span, etc, therefore, the impact of positioning techniques in real environments with the WCDMA and LTE system is highly important to understand [2].

The next section of this paper is organized as follows. Section II and III review the relevant positioning technology in WCDMA and LTE on OTDOA technique. We proposed the model of the positioning approximation in Section IV. The analysis that has been done to evaluate the accuracy and the error positioning was discussed in Section V. Lastly, in Section VI this paper ends with conclusion.

II. LDT in WCDMA and LTE

LTE [3] is an evolution of Universal Mobile Telecommunications System that is standardized for radio access network technology in 3GPP. Developing the positioning service is the focus of 3GPP ongoing Positioning Working. The mainly focus is terminal-assisted variant where it is on the OTDOA method.

There are several methods in LDT for LTE and WCDMA networks system used to determine the UE's location. For example, Cell-Identity (Cell ID), Angle of Arrival (AOA), Extended Observed Time Difference (EOTD), OTDOA, and Assisted Global Positioning System (AGPS).

Hearability is the existing issue with the currently standardized physical signals that is received from terminal or based stations, for example cell-specific reference signals (CRS). It will reveal the need of measurements quality for improving positioning by means of new positioning signals or interference coordination [4].

III. OTDOA METHOD

The OTDOA positioning method measures the comparison transmission delay between several base stations that is synchronized while the UEs are not. In order to measure the position, there are three parameters that must be solved. There are coordinates x, y; and also offset of unknown delay, τ_{off}. From this measurement, the time difference of arrivals may be expressed as distance differences [5] and we can get two Reference Signal Time Difference (RSTDs) [6]. At least three base stations separated are needed to get two dimensional coordinates of the UEs (User Equipment) as in Fig. 1.

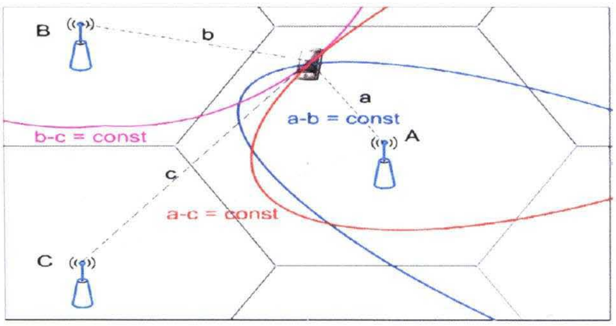

Figure 1: OTDOA method

The time difference is converted to a constant difference to two BSs and we can get the hyperbolic equation so that it often referred as hyperbolic method. The intersection of two equations of hyperbolic is the possible location of an user [7] as shown in Fig. 2.

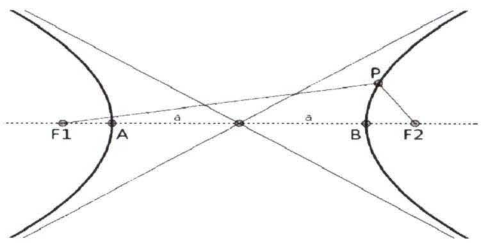

Figure 2: Hyperbola principle

Nowadays, people always keep moving from place to another place as technology moving forward. Fig. 3 shows the scenario of OTDOA technique applies in positioning UEs.

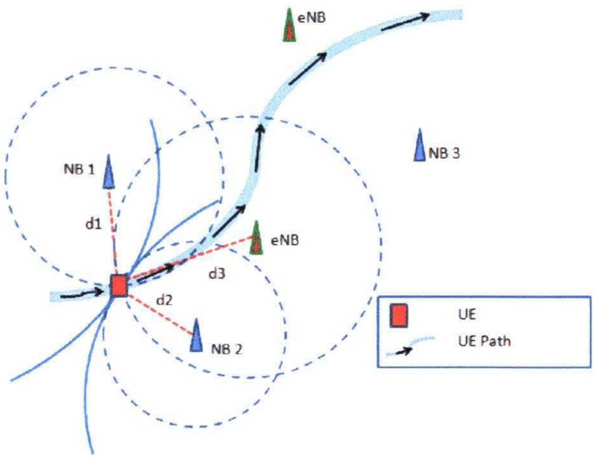

Figure 3: Scenario of LDT in OTDOA method

As mention earlier, by using this method it needs at least three base stations to estimate the position of UEs[8]. For example, user will moves by using transport in a highway as the arrow directions. Along the highway (UE path) there are many base stations labelled as Node B (NB) and eNode B (eNB) located in certain coordinates. UE will receive RSCP from NB1, NB2 and eNB. The distance from UE to each base station marked as d1, d2 and d3 respectively. The positioning of the user will be estimate by using the hyperbola principle that is intersection of the two distances. Then UE will continue moving to the next point at point of time and it will receive another three signals from the nearest base stations.

IV. RESEARCH METHODOLOGY

This research started with analysing several LDT's that are being used for WCDMA and LTE system to identify the most accurate technique. For this research, OTDOA methods were selected to determine the position of UEs.

Then the availability of 3G and LTE base station was investigate in real location in study area. It is important to know to analyse the accuracy of the positioning method that has been chosen.

The third activity in this research is to design software that can be used to simulate some data to estimate the user position. The radius of the identified base station will plotted in the software base on signal strength. Then, analysing and approximating the accuracy of LDT using simulation model that will be developed based on OTDOA. The summary of the methodology illustrated in figure 4.

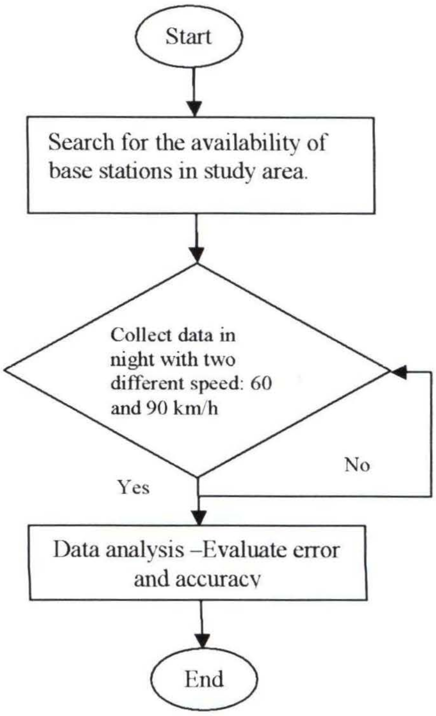

Figure 4: Summary of methodology

In this research, the LDT technique based on OTDOA needs at least three base stations or Node Bs. By using this method, it based on triangular ties principle with reference to the Time of Arrival (TOA).

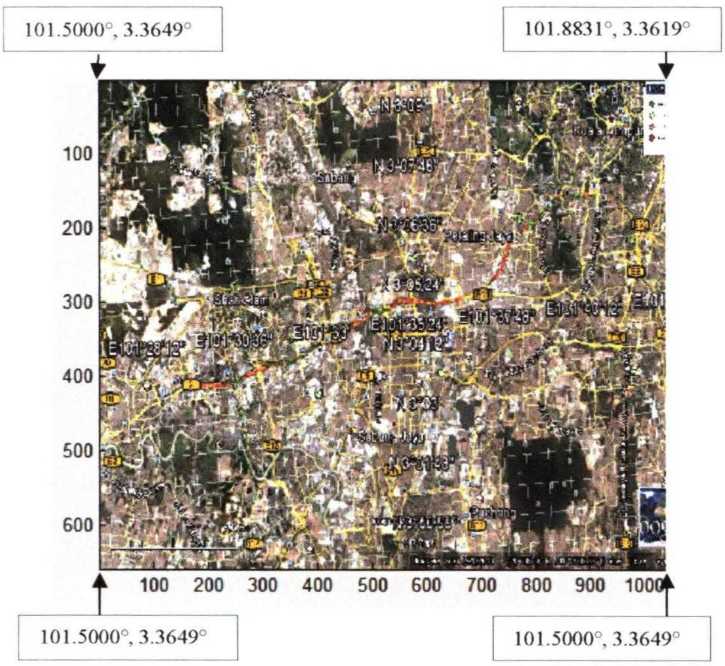

Figure 5: Sample of research area

The location of user is defined in coordinate's format as shown in Fig. 5. RSCP is the power received by UE from Node B denoted as P_r. Equation below (J.H. Yap et al 2002) has been used to determine the power received by Node B:

$$Pr = P_t + G_t + G_r - L_p(d) - u(\sigma_{sha}) \text{ (db)} \quad (1)$$

Where the distance between UE and Node B, d that has been changed caused by path loss is $L_p(d)$. G_r is the antenna gain at mobile user, while G_t is antenna gain from Node B and P_t is the transmitted power at Node B. Shadow fading, $u(\sigma_{sha})$ varies the random lognormal distribution with σ_{sha}, that is variance.

From equation (1), we can determine the path loss:

$$L_p(d) = P_t + G_t + G_r - Pr - u(\sigma_{sha}) \quad (2)$$

and then we get:

$$d = 10^{(L_p(d) - \beta)/10*\alpha} \text{ (meter)} \quad (3)$$

RD_1 and RD_2 are relative distances between UE and Node B1 and Node B2 respectively.

$$RD_1 = d_1 - d_2 = c \times GTD_1 \text{ and} \quad (4)$$

$$RD_2 = d_1 - d_3 = c \times GTD_2 \quad (5)$$

The intersection point can be find by using hyperbolic equations:

$$d_1 - d_2 = \sqrt{(x - x_1)^2 + (y - y_1)^2)} - \sqrt{(x - x_2)^2 + (y - y_2)^2} = RD_1 \quad (6)$$

$$d_1 - d_3 = \sqrt{(x - x_1)^2 + (y - y_1)^2)} - \sqrt{(x - x_3)^2 + (y - y_3)^2} = RD_2 \quad (7)$$

The flow chart of the user location determination was illustrated in Figure 6.

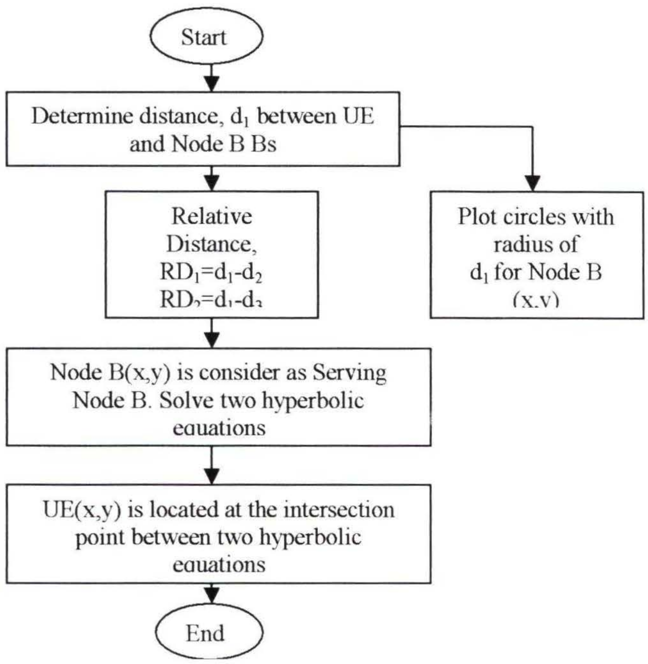

Figure 6: Flow chart to determine the location of UE

V. RESULT AND DISCUSSION

A. Drive Test

Figure 7 shows the result recorded by NEMO Outdoor from the drive test. NEMO Outdoor colours the route that indicates the route taken from UITM Shah Alam to the Mid Valley Kuala Lumpur along Federal Highways.

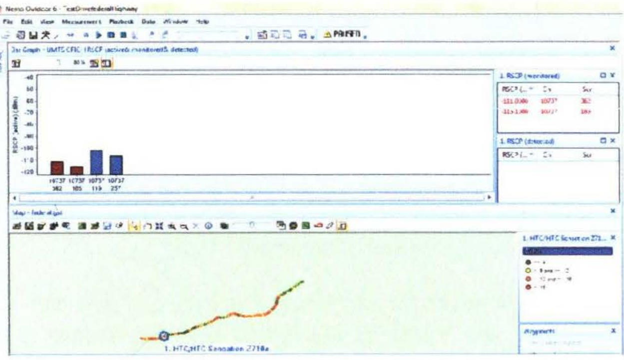

Figure 7: NEMO Outdoor view in laptop

Before starts the drive test, the availability of the network at selected area must be confirmed first. The extracted of the RSCP results into excel will get from the NEMO analyser as shown in Figure 8.

Longitude	Latitude	1. HTC/HTC Sensation Z710e : RSCP (active)
101.491203	3.06355	-96.1
101.491501	3.063667	-98.6
101.492516	3.063483	-95.6
101.493149	3.063333	-78.7000, -78.7000
101.493149	3.063333	-81.3000, -81.3000
101.493301	3.0633	-80.3000, -80.3000
101.493301	3.0633	-88.3
101.493446	3.063267	-89.8
101.493568	3.06325	-91.7
101.493568	3.06325	-93.6000, -93.6000
101.493698	3.063233	-88.8000, -88.8000
101.493698	3.063233	-88.2000, -88.2000

Figure 8: Data extracted from NEMO analyser

During the drive test, the NEMO was log to RSCP. Besides, the other parameter was longitude and latitude of the user can be found in the same table. HTC/HC Sensation Z710e refers to user, or mobile that has been used in this study when collecting data.

B. SIMULATION MATLAB

The data from the drive test were used in the simulation Matlab software. The locations of the base station in longitude and latitude format were used as the input. Then the simulation model will find the three nearest base stations every time the user moves [4].

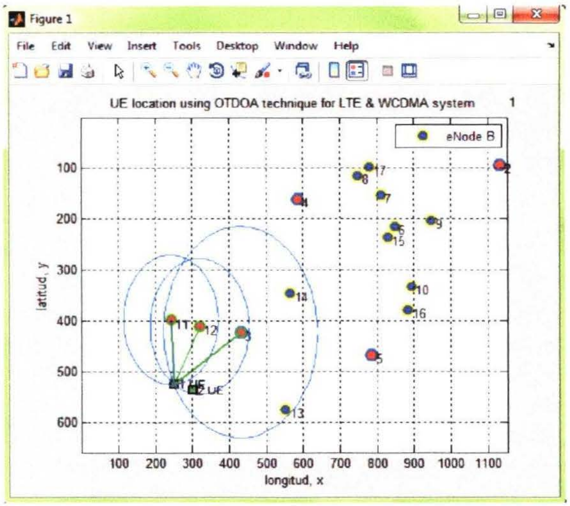

Figure 9: Location of base stations

Figure 9 shows the location of base stations plotted on the grid. The base station consists of eNode B and Node B. eNodeB is a base station for LTE network marked as blue color while Node B is for WDCMA network marked as red color. Suppose with this method, the user can searched the nearest three base stations, even though it comes from different networks especially for LTE and WCDMA.

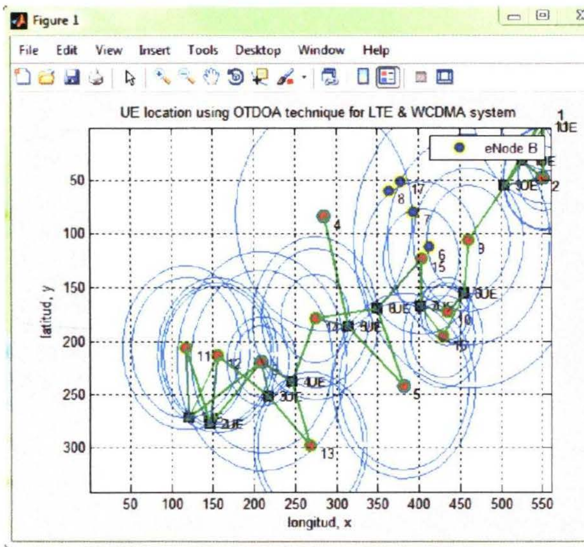

Figure 10: User moves through several points

When user moves from one point to another point, it always searched the three nearest base stations as shown in Figure 10. From the simulation, it will calculate the distance between user and the base stations.

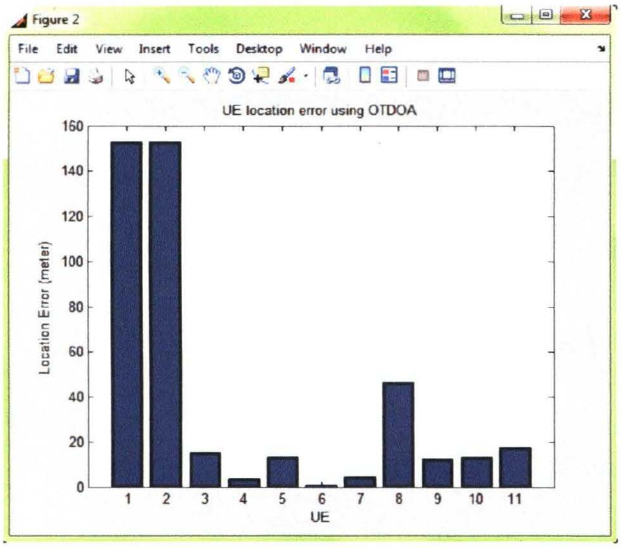

Figure 11: Accuracy of user location

Bar chart in Figure 8 shows the accuracy location of user. The simulation was calculated in meter unit. For this study, eleven users were selected to be simulated in this method. The selection of user movement based on the Bs locations in that study area.

Cumulative Density Function (CDF) was used to identify the percentage of location error (m) using OTDOA method. Figure 9 shows the location error using OTDOA simulation model. The graft shows at 67% the error location was almost 20m, while at 95% the error location occur almost 150m. Thus, localization in that study area is possible and can be determined.

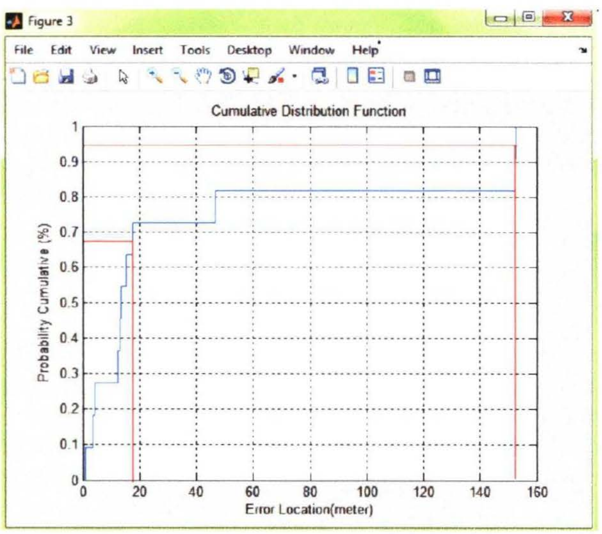

Figure 12: CDF of location error

Table 1 show that comparison between different speeds of user. With the same procedure as the first data with the speed of 60 km/h, the second data was collected along the same path with the speed of 90km/h. It shows that the speed of user affected the error localization.

Speed of user	Percentage of location error (m)	
	67%	95%
60 km/h	19.02	152.63
90 km/h	19.04	152.87

Table 1: Location Error for OTDOA Technique Simulation Model

VI. CONCLUSIONS

In this study, the location determination simulation model was developed base on OTDOA method. From the simulation, the real location of mobile users, UE which can be determined with a minimum of location error at the stage of 95% percentile is approximately 150m. The result of this simulation is still not very stable since he location error depends on data value of RSCP (db) received by UE from all node Bs. In this paper, the accuracy performance of different speed also compared. To optimize the accuracy of the location determination, further analysis need to be done.

REFERENCES

[1] FCC 99-245, *"Revision of the Commission's Rules to Ensure Compatibility with 911 Emergency Calling Systems"* , FCC, October 1999.

[2] Andreas Schmidt-Dannert, "Positioning Technologies and Mechanisms for Mobile Devices", Seminar Master Module SNET2, TU-Berlin.

[3] E. Dahlman, S. Parkvall, J. Skold, and P. Berming , 3G Evolution: HSPA and LTE for Mobile Broadband, 2nd ed., Academic Press, 2008.

[4] 3GPP TSG RAN WG1, DL OTDOA framework, R1-092010, May 2009.

[5] Jonas Medbo, Iana Siomina, Ari Kangas, Johan Furuskog, "Propogation Channel Impact on LTE Positioning Accuracy", Ericson Research, Ericson AB, Stockholm, Sweden, 2009.

[6] Tao Zhang, Dengkun Xiao, Jie Cui, Xinlong Luo, "A Novel OTDOA Positioning Scheme In Heterogeneous LTE-Advance Systems", IEEE,2012.

[7] Evolved Universal Terrestrial Radio Access (E-UTRA); "Stage 2 functional specification of User Equipment (UE) positioning in E-UTRAN", 3GPP TS 36.305.

[8] Keeratpal Singh, Mahamod Ismail, 2005. OTDOA Location Determining Technology for Universal Intelligent Positioning Sysem (UIPS) Implementation in Malaysia. IEEE: 1057-1061