Analysis of Signal Hearability for Location Determination Techniques (LDT) in UiTM GSM and UMTS Network

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***Abstract*—Localization or famously known as Location Determination Technique (LDT) is an information service, which is accessible with mobile devices through the mobile network and which uses information on the geographical position of the mobile device. LDT has recently become more popular and telecommunications providers take the advantage of this service to gain the profits. In order to ensure the LDT works accordingly at any locations, parameter so called hearability is a very important parameter to be considered. Therefore this paper presented the analysis of signal hearability along the main road inside UiTM Shah Alam. Based on data recorded by NEMO Outdoor during measurement campaign, the result shows that no low hearability signal detected in GSM network and several locations found with low hearability in UMTS network. In addition, the GPS signals are available along the main road.**

Keywords—component; Location Determination Technique: GSM; UMTS; GPS; Hearability.

I. INTRODUCTION

In few decades, the development of mobile phones is growing farther compared to the fixed line facilities. According to a research conducted by Malaysian Communication and Multimedia Commission (MCMC) in 2004, there are over 15 million of mobile phone users in Malaysia. On top of that, Malaysia telecommunication provider compete each other to provide and producing the best quality in their voice, data and value added services. One of the value added service provided is location based service (LBS).

LBS started in USA where US Federal Communication Commission (FCC) requires that the precise location of all enhanced 911 (E911) callers be automatically determined since most of the callers are coming from mobile phones [1]. The requirement from FCC was to determine the location of MS within accuracy of 100m [2]. According to this needs, LBS system has been developed in parallel with the advancement of cellular system as this technology will be beneficial to many different public and enterprise. For instance, LBS have been commercialized to fully utilize to its potential and this completely change the way the cellular industries does business. Malaysia also not left behind in the development of LBS system where Maxis has introduced the LBS system called Friend Finder in 2004 for their subscribers. Location of MS can be determined by implementing LDT with the availability of cellular network [3]. However, there were lots of techniques can be use to determine the MS position. Generally these techniques are divided into two categories such network based and terminal based. For network based approaches the network will do the measurement by collecting few parameters and use them to calculate and estimate the position of MS. Thus no changes at MS are required. Meanwhile for terminal based approaches MS will do the calculation and not depending on the network [4].

In network based positioning, there are several common LDT specified for GSM and UMTS network which Cell Identity (Cell ID), Time of Arrival (TOA), Time Difference of Arrival (TDOA), Observed Time Difference of Arrival (OTDOA), Extended Observed Time Difference (E-OTD), and Angle of Arrival (AOA). In addition, Global Positioning System (GPS) and Assisted Global Positioning System (A-GPS) can be used to determine the location of MS as well. For network based techniques, the position of MS cannot be located unless the MS able to detect signals from at least 3 Base Station (BS) and it also known as signal hearability. In UMTS network, hearability is a common issue where for some reason, MS unable to detect signal from at least 3 BS and this phenomenon known as low signal hearability [1][4].

In cellular telecommunications network, in order to reduce the interferences to other MS which reside in the same cell or adjacent cell the minimum power transmitted will be always used. Therefore the hearability for MS is getting lower when MS residing at the center or in a large cell. This issue is more critical in UMTS network where UMTS has a tight power control scheme [1]. For a higher accuracy in mobile positioning, GPS technique is the best one however this technique requires at least 4 covering satellites.

The rest of the paper is organized as follows. Section 2 explained on the research methodology and experimental setup. Results and discussion well discussed in Section 3 while conclusion is in Section 4.

II. METHODOLOGY

Field measurements started with identified the selected route for drive test in UiTM Shah Alam by referring to Google Maps and UiTM map. For this research, Celcom GSM and

UMTS network were selected for data collection. Then, data collection was carried out for three times in the morning, evening and night using NEMO Outdoor. Once data collection completed, all data were analyzed and appropriate LDT techniques was proposed at UiTM area according to the hearability condition. The summary of the methodology for this research is illustrated in Figure 1.

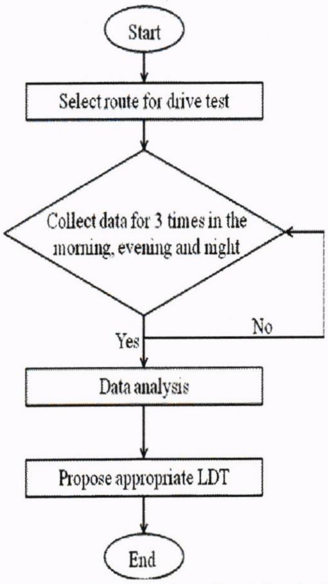

Figure 3.1: Summary of methodology

By referring to Google Maps, the drive test or data collection route has been identified as shown in Figure 2 and only main road was covered during the data collection. For data collection, GPS and two Nokia mobile phones were connected to NEMO outdoor which has been installed in laptop. The GPS was placed on vehicle roof while both Nokia phones were placed under the vehicle front screen as illustrated in Figure 3. Before the measurement campaign started, Nokia phones and GPS was connected to the laptop. Then NEMO Outdoor was initialized and the connection was checked in order to avoid any connection error during the measurement. After successful connection, UiTM map was loaded in NEMO Outdoor, and then one phone was locked in GSM band and the other one locked in UMTS band. Once NEMO outdoor was ready, measurement campaign started and NEMO outdoor is recording all the measurement campaign and saved in the log for further analysis.

The distance of measurement campaign was around 10km and average of vehicle speed is 25kmh^{-1}. During data collection, GPS monitoring application (GPS Tool Scott Presnell, Tworoads Software, and Version 1.5) has been installed in Blackberry device in order to monitor the GPS signal availability at UiTM main roads. The NEMO Outdoor and Blackberry device were carried out simultaneously during the drive test and Figure 4 illustrated how the GPS monitoring via Blackberry works.

Figure 2: Selected routes for data collection

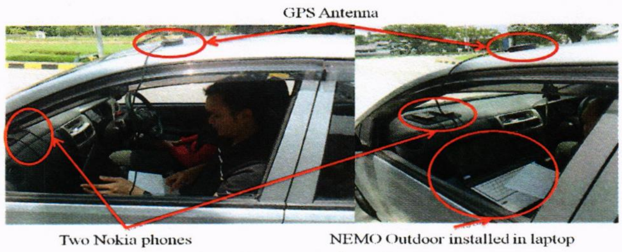

Figure 3: Data collection setup

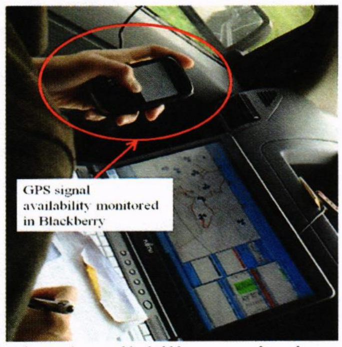

Figure 4: GPS signal availability monitoring via Blackberry device

NEMO Outdoor collects data relating to the network itself, services running on the network such as voice or data services, radio frequency scanner information and GPS information to provide location logging. Data collected for GSM network are time, site/cell name, serving cell, neighboring cell, cell ID, Rx level, channel number, location area code, latitude, longitude, distance of travelling and speed. While for UMTS network, the data collected are time, site/cell name, serving cell, neighboring cell, cell ID, RSCP, path loss, transmitter power, mobile receive power, channel number, location area code, latitude, longitude, distance of travelling and speed. Figure 3.6 shows the sample of NEMO Outdoor interface for UMTS seen in laptop where all data collected was stored in the log file and user may extract the log and analyzed in NEMO Analyzer. In addition NEMO Outdoor has playback features where user can play and watch again all data collection event.

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level, channel number, location area code, latitude, longitude, distance of travelling and speed. While for UMTS network, the data collected are time, site/cell name, serving cell, neighboring cell, cell ID, RSCP, path loss, transmitter power, mobile receive power, channel number, location area code, latitude, longitude, distance of travelling and speed. Figure 5 shows the sample of NEMO Outdoor interface for UMTS seen in laptop where all data collected was stored in the log file and user may extract the log and analyzed in NEMO Analyzer. In addition NEMO Outdoor has playback features where user can play and watch again all data collection event.

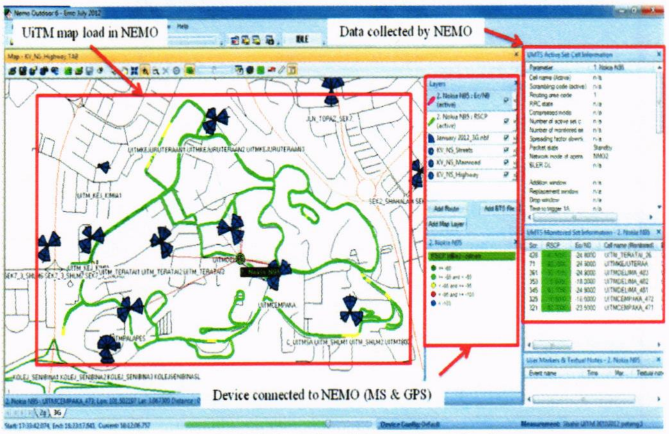

Figure 5: NEMO Outdoor view in laptop

III. RESULTS AND DISCUSSION

A. *GSM Drive Test*

Figure 6 shows the results for GSM measurement campaign recorded in NEMO Outdoor. NEMO Outdoor colored the route taken in UiTM according to standard GSM signal strength as shown in Figure 6. The Celcom standard signal strength are Good (>=-65dBm), Average (<-85 and >=-65), Fair (>=-95 and <=-85) and Poor (<-95).

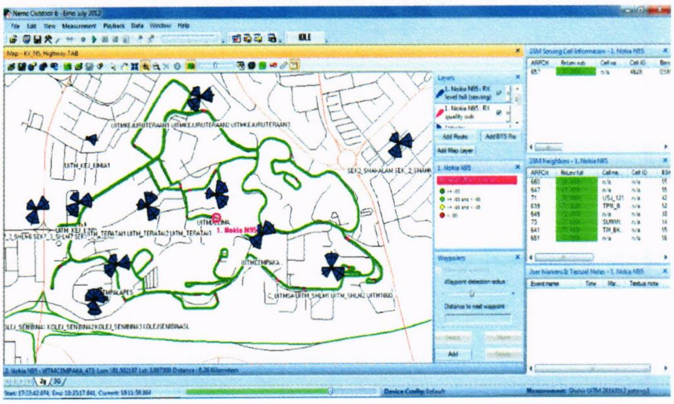

Figure 6: Route for GSM data collection in evening

From Figure 6 can be seen that GSM signal strength were in good condition and therefore no low signal strength detected around UiTM main road. Next, data from recorded GSM log was analyzed using NEMO Analyzer and extracted into Excel sheet as shown in Figure 7. Serving row is referring to the serving BS while Neighbor row is referring to the neighbor BS. Other parameters related to network info captured during measurement campaign can be found in the same table. Based on this table, MS able to get at least six neighboring BS and the maximum number of neighboring BS detected was nine neighboring BS. It shows that signal hearability in UiTM GSM is very good. Same goes to data collection for morning and night, same result was identified. Moreover, average power receives level (Rx Level) for GSM neighboring BS is -60dBm.

Time	Cell type	Site name	Cell name	RxLev full	ARFCN	BSIC	C1	C2	LAC	RAC
5:35:13 PM	Serving	UITM_KEJ_KIMIA1	UITM_KEJ_KIMIA1	-52	66	5			10901	1
5:35:13 PM	Neighbor	UITM_TERATAI1	UITM_TERATAI1	-72	670					
5:35:13 PM	Neighbor	UITM_KEJ_KIMIA1	UITM_KEJ_KIMIA3	-68	4					
5:35:13 PM	Neighbor	UITM_KEJ_KIMIA1	UITM_KEJ_KIMIA2	-81	74					
5:35:13 PM	Neighbor	KOLEJ_SENIBINA1	KOLEJ_SENIBINA1	-89	73					
5:35:13 PM	Neighbor	KOLEJ_SENIBINA1	KOLEJ_SENIBINA3	-91	2					
5:35:13 PM	Neighbor	SEK_7_SHAHALAM1	SEK_7_SHAHALAM2	-93	7					
5:35:14 PM	Serving	UITM_KEJ_KIMIA1	UITM_KEJ_KIMIA1	-52	66	5			10901	1
5:35:14 PM	Neighbor	UITM_TERATAI1	UITM_TERATAI1	-71	670					
5:35:14 PM	Neighbor	UITM_KEJ_KIMIA1	UITM_KEJ_KIMIA3	-68	4					
5:35:14 PM	Neighbor	KOLEJ_SENIBINA1	KOLEJ_SENIBINA3	-88	2					
5:35:14 PM	Neighbor	KOLEJ_SENIBINA1	KOLEJ_SENIBINA1	-89	73					
5:35:14 PM	Neighbor	SEK_7_SHAHALAM1	SEK_7_SHAHALAM2	-92	7					
5:35:14 PM	Serving	UITM_KEJ_KIMIA1	UITM_KEJ_KIMIA1	-55	66	5			10901	1
5:35:14 PM	Neighbor			-72	670	11				
5:35:14 PM	Neighbor	UITM_KEJ_KIMIA1	UITM_KEJ_KIMIA3	-71	4					
5:35:14 PM	Neighbor	C_UITMSA	UITM_SHLM3	-78	5					
5:35:14 PM	Neighbor	KOLEJ_SENIBINA1	KOLEJ_SENIBINA3	-87	2					
5:35:14 PM	Neighbor	KOLEJ_SENIBINA1	KOLEJ_SENIBINA1	-88	73					
5:35:15 PM	Serving	UITM_KEJ_KIMIA1	UITM_KEJ_KIMIA1	-53	66	5			10901	1
5:35:15 PM	Neighbor			-71	670	11				
5:35:15 PM	Neighbor			-71	4	58				
5:35:15 PM	Neighbor	C_UITMSA	UITM_SHLM3	-79	5					
5:35:15 PM	Neighbor	KOLEJ_SENIBINA1	KOLEJ_SENIBINA3	-87	2					
5:35:15 PM	Neighbor	KOLEJ_SENIBINA1	KOLEJ_SENIBINA1	-87	73					

Figure 7: Extracted GSM Data collected by NEMO

Cumulative Density Function (CDF) was used to identify the percentage of neighboring BS collected by MS at the respective time. According to morning, evening and night data, 50% of the data shows that MS was able to get eight neighboring BS as illustrated in Figure 8. As for localization technique, two neighboring cell is sufficient to calculate the MS position. Thus localization in UiTM GSM network is possible. In addition, no low hearability area detected from GSM data.

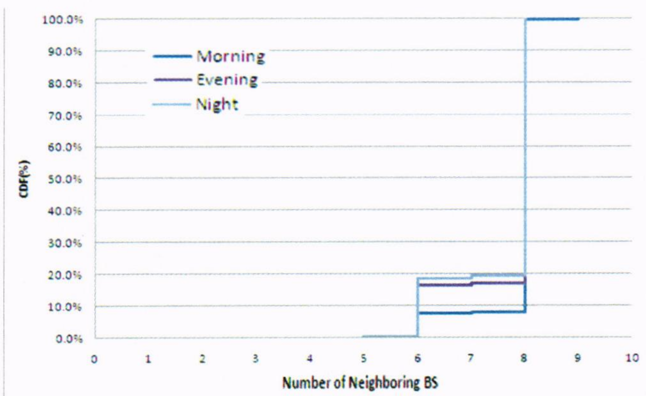

Figure 8: CDF of GSM neighboring BS

B. *UMTS Drive Test*

The results for UMTS measurement campaign recorded in NEMO Outdoor is illustrated in Figure 9. Same goes to GSM, NEMO distinguished the UMTS signal strength (RSCP,dBm) into Very Good (>=-65dBm), Good (<-85dBm and >=-65dBm), Average (<-85dBm and >=-95dBm), Poor (<-95dBm and >=-103dBm) and Very Poor (<-103dBm) as illustrated in Figure 4.8. Based on conducted drive test the UMTS signal strength in Uitm Shah Alam seems fluctuated between very good (green), good (light green) and average (yellow).

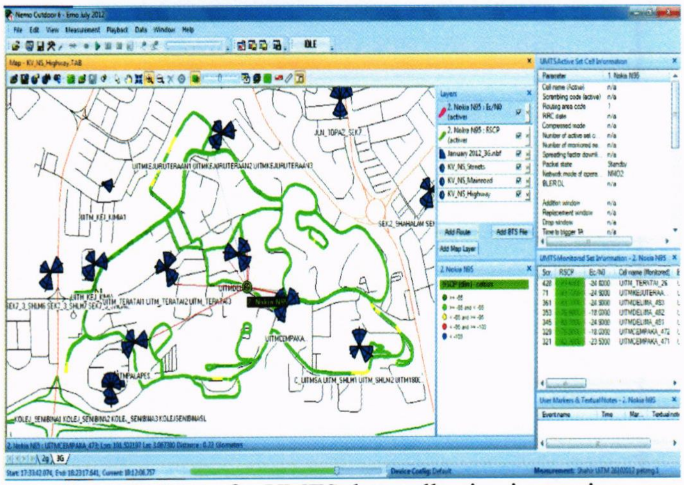

Figure 9: Route for UMTS data collection in evening

From recorded UMTS log, the data was analyzed using NEMO Analyzer and extracted into Excel sheet as shown in Figure 10. Same goes to GSM, the active row is referring to the serving BS while monitored row is referring to the neighbor BS. Other parameters related to network info captured during measurement campaign can be found in the same table as well. Based on Figure 10, the number of neighboring cell was not consistent where at some area only one neighboring cell available and another area might get from two to eight neighboring cells. Since there were areas detected with one neighboring cell only, meaning that low hearability area existed in UiTM UMTS network. Besides, average power received (RSCP) for UMTS neighboring BS is -79dBm.

Time	Cell type	Site name	Cell name	Cell ID	Ch	Scr.	Ec/N0	RSCP	Pathloss
5:59:16 PM	Monitored	UITMPALAPES	UITMPALAPES_499	10493	10762	389	-23.39999962	-92.60	
5:59:16 PM	Monitored	UITM_KEJ_KIMIA	UITM_KEJ_KIMIA_1603	11603	10762	29	-24.79999924	-94.10	
5:59:17 PM	Active	UITM_TERATAI	UITM_TERATAI_2603	12603	10762	436	-13.10000038	-82.50	
5:59:17 PM	Monitored	BDRBOTANICKLG	BDRBOTANICKLG_652	10652	10762	46	-13.60000038	-83.10	
5:59:17 PM	Monitored	UITMDELIMA	UITMDELIMA_483	10483	10762	361	-17.70000076	-87.10	
5:59:17 PM	Monitored	UITM_KEJ_KIMIA	UITM_KEJ_KIMIA_1602	11602	10762	21	-17.79999924	-87.20	
5:59:17 PM	Monitored	UITMKEJUTERAAN	UITMKEJUTERAAN_968	10962	10762	71	-18.70000076	-88.10	
5:59:17 PM	Monitored	BDRBOTANICKLG	BDRBOTANICKLG_651	10651	10762	38	-20.79999924	-90.20	
5:59:17 PM	Monitored	UITMPALAPES	UITMPALAPES_499	10493	10762	389	-22.60000038	-92.00	
5:59:17 PM	Monitored	UITM_KEJ_KIMIA	UITM_KEJ_KIMIA_1603	11603	10762	29	-24.89999962	-94.30	
5:59:18 PM	Active	UITM_TERATAI	UITM_TERATAI_2603	12603	10762	436	-12.69999981	-82.30	
5:59:18 PM	Monitored	BDRBOTANICKLG	BDRBOTANICKLG_652	10652	10762	46	-12.10000038	-81.90	
5:59:18 PM	Monitored	UITM_KEJ_KIMIA	UITM_KEJ_KIMIA_1602	11602	10762	21	-16.60000038	-86.30	
5:59:18 PM	Monitored	UITMDELIMA	UITMDELIMA_483	10483	10762	361	-18.60000038	-88.30	
5:59:18 PM	Monitored	UITMKEJUTERAAN	UITMKEJUTERAAN_968	10962	10762	71	-18.70000076	-88.40	
5:59:18 PM	Monitored	BDRBOTANICKLG	BDRBOTANICKLG_651	10651	10762	38	-19.5	-89.20	
5:59:18 PM	Monitored	UITMPALAPES	UITMPALAPES_499	10493	10762	389	-22.39999962	-92.10	
5:59:18 PM	Monitored	UITM_KEJ_KIMIA	UITM_KEJ_KIMIA_1603	11603	10762	29	-24.89999962	-94.60	
5:59:19 PM	Active	UITMPALAPES	UITMPALAPES_498	10492	10762	381	-7.099999905	-77.30	
5:59:19 PM	Monitored	BDRBOTANICKLG	BDRBOTANICKLG_652	10652	10762	46	-11.80000019	-82.00	
5:59:19 PM	Monitored	UITM_KEJ_KIMIA	UITM_KEJ_KIMIA_1602	11602	10762	21	-16.79999924	-87.00	
5:59:19 PM	Monitored	UITMDELIMA	UITMDELIMA_483	10483	10762	361	-18.60000038	-88.80	
5:59:19 PM	Monitored	BDRBOTANICKLG	BDRBOTANICKLG_651	10651	10762	38	-20	-90.10	
5:59:19 PM	Monitored	UITMPALAPES	UITMPALAPES_499	10493	10762	389	-22.60000038	-92.80	
5:59:19 PM	Monitored	UITM_KEJ_KIMIA	UITM_KEJ_KIMIA_1603	11603	10762	29	-24.79999924	-95.00	

Figure 10: Extracted UMTS Data collected by NEMO

From CDF data shown in Figure 11, 50% shows that MS was able to detect five neighboring cell during morning, evening and night. For overall, signal hearability in UMTS network still acceptable for localization although there were few area affected with low hearability signal.

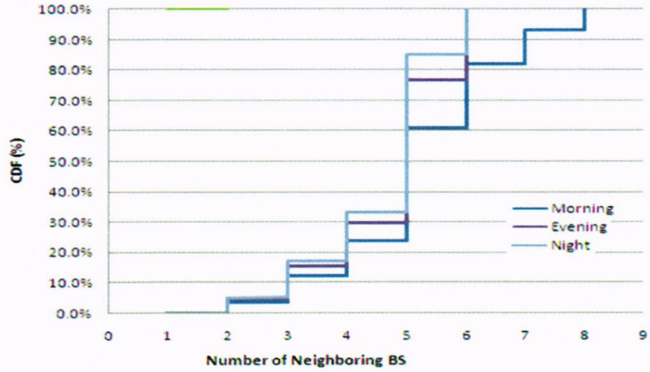

Figure 11 CDF of UMTS neighboring BS

Low signal hearability has been detected at two locations which only one neighboring BS can be heard by MS. Although the signal hearability is low at this area, localization is still possible with the assisted by GPS signal. The affected areas are UiTM swimming pool and from Faculty of Civil Engineering to Faculty of Computer and Science as shown in Figure 12.

Figure 12a: UiTM swimming pool

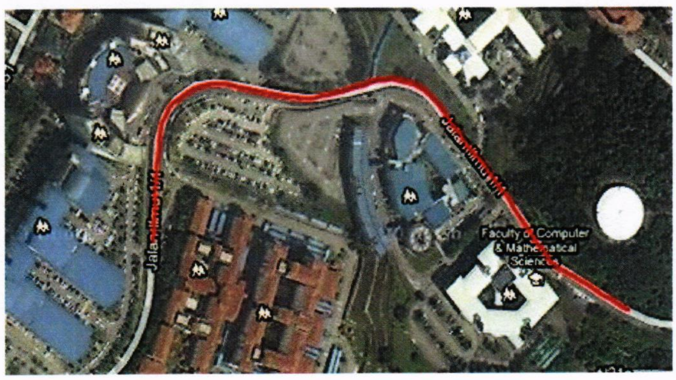

Figure 12b: From Faculty of Civil Engineering to Faculty of Computer and Science

C. Satellite Reception for GSM and UMTS

Since NEMO collected both GSM and UMTS network info at the same time, the same GPS was used to monitor the satellite reception for both GSM and UMTS positioning. By referring to Figure 13, the lowest satellite reception detected by GPS in UiTM during morning data collection is four and the highest is nine. Therefore satellite signal hearability in UiTM Shah Alam is very good and UiTM main road areas are fully covered with satellite signal. As a result, localization using GPS technique should be working at all time.

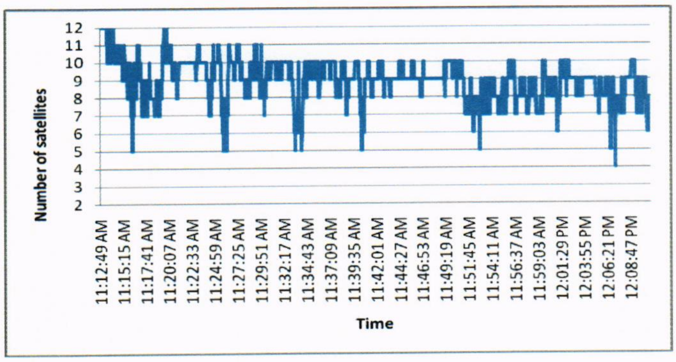

Figure 13: Number of satellite detected

Satellite CDF data illustrated in Figure 14. It shows that at 50% nine satellites has been detected throughout the data collection. Furthermore, no low hearability for satellite signals at UiTM main road during morning, evening and night. Plotted coordinates in latitude and longitude for GPS during morning, evening and night are illustrated respectively in Figure 4.15.

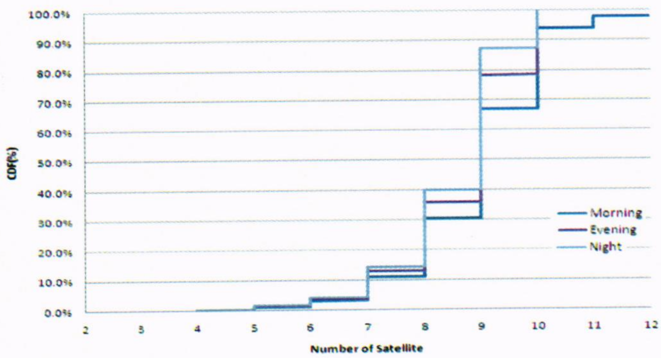

Figure 14: CDF of Satellite reception

Figure 15: Plotted coordinates for GPS during drive test

Instead of monitored the GPS hearability via NEMO, GPS application was installed in Blackberry device as well and it has been use together during the data collection. As a results there were no low GPS signal hearability been detected along the main road in UiTM. Therefore this result is tally with the GPS monitored by NEMO. The output of GPS signals monitoring by Blackberry application is illustrated in Figure 16.

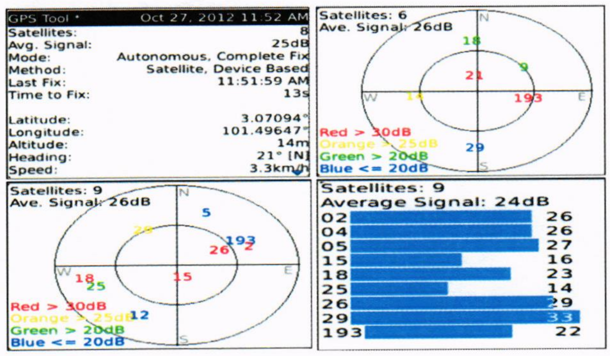

Figure 16: GPS Signal monitored by Blackberry application

For GSM network in UiTM, there should be no issue to apply the LDT as no hearability issue been detected. Therefore E-OTD method could be applied. In UiTM UMTS network, most of the areas are well covered with sufficient neighboring BS. Thus network based localization is possible by using OTDOA method. However there are several locations that unable to hear enough neighboring BS signal. In consequences, localization using network based is impossible due to low signal hearability. On the other hand, localization can be done by assistance from GPS since GPS signal is available at all main road area. Localization using GPS method can be used in order to resolve the low hearability issue at swimming pool, in front of Faculty of Computer and Multimedia and in front of Faculty of Civil Engineering. Summary of the obtained results are summarized in Table 1.

Network	GSM	UMTS
Neighbor BS	8	5
Low Hearaility	No	Yes
GPS Availability	Yes	Yes
Power Received	-60dBm	-79dBm
Proposed LDT	E-OTD & GPS	OTDOA & GPS

Table 1: Summary of Signal Hearability

Below example explained briefly on how MS location can be determined by using OTDOA method. Table 2 shows the sample of data collected for UMTS network which contains of time, serving and neighboring BS, RSCP and path loss value. By referring to path loss value for serving BS, distance between serving BS and MS can be calculated by using Okamura-Hatta path loss model.

Time	Cell type	Site name	RSCP	Pathloss
11:12:52 AM	Active	UITM_KEJ_KIMIA	-61.90	97
11:12:52 AM	Monitored	UITM_TERATAI	-72.30	
11:12:52 AM	Monitored	UITMDELIMA	-73.10	

Table 2: Data collected for UMTS network

Okamura-Hatta path loss model:

$$L_b = 28.9+33.9 \log_{10} f_c + 35.2 \log_{10} d \qquad \text{(dB)}$$

Where L is the path loss in decibels, ② is the wavelength and d is the transmitter and receiver distance. As referred to Table 2, path loss (L) is equals to 97dB, therefore d is equals to 0.3km. Then the location of MS can be calculated by using OTDOA formula as per below:

$$c \times GTD_2 = \sqrt{(x-x_1)^2+(y-y_1)^2} - \sqrt{(x-x_2)^2+(y-y_2)^2}$$

$$c \times GTD_3 = \sqrt{(x-x_1)^2+(y-y_1)^2} - \sqrt{(x-x_3)^2+(y-y_3)^2}$$

Where;

$$c \times GTD_2 = d_1 - d_2 = RD_1$$

$$c \times GTD_3 = d_1 - d_3 = RD_2$$

Then MS location can be identified as shown in Figure 17.

Figure 17: Calculated MS position

IV. CONCLUSION

In this paper signal hearability in UiTM Shah Alam GSM and UMTS network are analyzed. No low hearability detected in GSM network but few locations were detected with low hearability. Despite network based positioning can't be used at this area, GPS method is able to overcome the low hearability issue. Moreover GPS signal is available along the main road.

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