Fast and Accurate Practical Positioning Method using Enhanced-Lateration Technique and Adaptive Propagation Model in GSM Mode : Case Study Using Android Smart Phone in Egypt Roads

Mohamed Abdel Meniem[1], Eman Shaaban[1], Ahmed Hamad[2]
[1]Ain Shams University, Egypt
[2]British University in Cairo, Egypt
mohammed.hussein@cis.asu.edu.eg

ABSTRACT: *In this paper, we consider problem of positioning of mobile phones, different approaches were produced for these targets using GPS, WiFi, GSM, UMTS and other sensors, which exist in today smart phone sensors. Location awareness in general is emerging a tremendous interest in different fields and scopes. Position is the key element of context awareness. However GPS produces an accurate position, it requires open sky and does not work indoors. We produce an innovative robust technique for positioning which could be applied on terminal-based or network-based architecture. It depends only on Received Signal Strength (RSS) and location of Base Transceiver Station (BTS). This work has been completely tested and analyzed in Egypt roads using realistic data and commercial android smart phone. In general, all performance evaluation results were good. Mean positioning error was about 120 m in urban and 394 m in rural.*

Keywords: Cell-ID, BTS, GDOP, GPS, GSM, ITS, MCC, MNC, RSS, UMTS, WiFi

Received: 11 October 2013, Revised 18 November 2013, Accepted 27 November 2013

1. Introduction

Cellular phones and smart phones are being used by more people in modern life. Several applications are used; contextaware applications gain more interest. Positioning plays the main role in context aware applications. Positioning is a process to obtain the spatial position of a target [1]. There are various methods to do so. In general, positioning is determined by:

- A positioning method for position calculation.
- A descriptive or spatial reference system.
- An infrastructure and protocols for positioning process.

It is obvious that GPS [2] provides most accurate positions, it is commonly used with navigation applications and some of emergency applications. Also some of traffic analysis applications use GPS-enables smart phones as probes for traffic data collection like [3] [4]. Since GPS requires line of sight to the satellite and not all phones equipped with GPS, more attention has been gone to alternatives like WiFi. It is commonly used in urban and sub-urban areas, hot spots are everywhere. WiFi has been used for localization in many researches [5] [6] [7] and also commercial applications [7] [17] [43] .

However, WiFi-based localization techniques addressed several challenges, not all cellular phones are equipped with WiFi too.

Also, WiFi raised privacy concerns especially at "*War-Driving*" [16] . Therefore, GSM-based localization techniques appeared again. According to [9], GSM represents about 85% of today's cell phones. GSM consumes minimal energy compared to WiFi and GPS as in [42]. Several meth-odologies and approaches produce efficient GSM based localization techniques. For example, using Cell-ID [10] [11]. Time Advance (TA) is also used in combination with Cell-ID, as in [13]. Other techniques are used also like Angle Of Arrival (AOA), Enhanced-Observed Time of Difference (E-OTD) and Time Difference of Arrival (TDoA) as in [1] [14]. Almost all of these techniques have been produced for academic purposes.

After the revolution of smart phones and mobile applications development some approaches have been implemented specially those who use accessible parameters from operating systems and do not require modification on software or hardware layer. Most of these approaches use parameters like RSS and TA, some systems use the famous Centroid algorithm [19], which was first used in wireless sensors networks. Then it has been used in cellular environment with different implementations [20] [21]. It is clearly known that some approaches require transform RSS into distance. In order to achieve these transformations, radio propagation models are used. In a default scenario, any GSM phone sends Network Measurements Report (NMR) every 480 ms in active mode. These reports contain information about signal strength of serving base station and cells marked as neighbours for serving base station. Thus, core network can simply calculate position of any active subscriber. In idle mode, some paging techniques could be used to receive the same NMR as in [1] .

This research provides detailed implementation for *E-Lateration* technique with adaptive propagation model. The rest of paper is organized as follows. Section 2 gives an insight to propagation models and other RSS-based localization techniques in cellular environment. Section 3 and 4 present detailed methodologies proposed and evaluated by authors, followed by trial results in Section 5. Finally, Section 6 provides a conclusion and suggests possible directions for future research.

2. Background

2.1 Positioning Methods

According to [1], positioning methods can be classified into proximity sensing, pattern matching and hybrid methods. Proximity sensing includes lateration, AOA and dead reckoning. Pattern matching includes fingerprinting-based techniques [6] [7] and Database Correlation Methods (DCM). Among the existing methods of positioning we are interested in the circular lateration method. If the positioning is based on range, the fixed position can be calculated by means of a circular lateration, determining the intersection of the circles formed by the radii of the target in relation to nearby base stations. The ranges of a target in relation to *n* base station are obtained by measurements. As a prerequisite, the method of circular triangulation requires that the ranges r_i between the target and a number of base stations $i = 1,..., n$ are known in advance. It is necessary to enable the application of the method. Knowing the range between a terminal and a single base station limits the target position to a circle around the base station, with the range given by the circle radius, as shown in Figure 1 (a). If we add the range of another base sta-tion, then the target position can be reduced to the two points in which both circles intersect Figure 1 (b). The range of a third base station leads, finally, to an unambiguous target position Figure 1 (c).

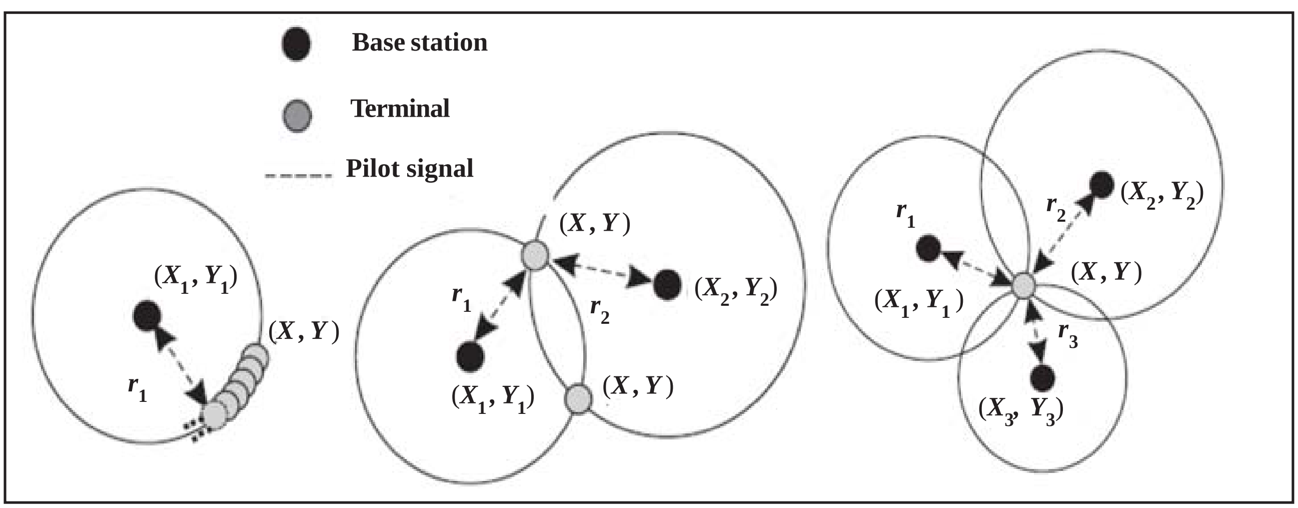


Figure 1. Circular Triangulation

The calculation of target position is based on the *Pythagorean* theorem [25]. If (X_i ,Y_i) are the well-known coordinates of the *i-th* base station in the Cartesian coordinate system, and if (*x*, *y*) are the unknown coordinates of the target to be calculated, then range r_i between the *i-th* base station and the target can be expressed by Equation 1.

$$r_i^2 = (X_i - x)^2 + (Y_i - y)^2 \quad (1)$$

Then, the geographical position of the target could be estimated. If the coordinates of the base-stations are given by latitude and longitude, or if the target position must be expressed in latitude and longitude, the ellipsoidal coordinates can be transferred to Cartesian coordinates and vice versa, in order to apply the equation. Other positioning techniques like Google's MyLocation [30], it does not use RSS explicitly, but rather estimate the cell phone location as the location of the cell tower the phone is currently associated with. *Jie Yang* in [33] proved that using estimating position based on cell tower with Max RSS has better accuracy than normal Cell-ID technique. Positioning in wireless sensor networks is hot topic. Several coarse grained localization techniques are proposed like the famous centroid [19]. The algorithm which can be performed on each unknown uses the location information of all beacons in its own range to calculate its position as the centroid as shown in Equation 2. In this formula, *P*(*x, y*) indicates the position of unknown node given by its two dimensional coordinates.

The known position of antenna *j* is given by *Bj* (*x*, *y*). The number of beacons which are within the communication range of the unknown node is indicated by *m*.

$$P\,(x, y) = \frac{1}{m} \sum_{j=1}^{m} B_j\,(x, y) \quad (2)$$

J. Blumenthal in [31] proposed the featured Weighted Centroid Localization (WCL), which quantify each beacons position with a quantification function that uses the distance from an unknown node towards each beacon in range. The quantifier is described as shown in Equations 3, 4.

$$p_i\,(x, y) = \frac{\sum_{j=1}^{n} \left(w_{ij} \cdot B_j\,(x, y) \right)}{\sum_{j=1}^{n} w_{ij}} \quad (3)$$

$$w_{ij} = \frac{1}{(d_{ij})^{g}} \quad (4)$$

Where w_{ij} describes the quantification for beacon *j* used by node *i*. The distance between beacon *j* and node *i* is given by d_{ij} and *g* symbols is a controllable parameter, which ensures that remote beacons still impact the position determination. Choosing best value of *g* in cellular environment is completely different from wireless sensor networks. It always ranges between 0.5 and 3. Some of recent researchers [32] proposed a correction function to WCL, however it is difficult to generalize its case in practical especially in dense urban ar-eas where different sources of attenuation affect the signal.

2.2 Propagation Models

To transform RSS into valid range it is important to utilize the path loss or attenuation a pilot signal experiences when travelling from the sender to the receiver. Signals on different media behave in different ways, depending on the physical properties of the respective medium. They are always subject to attenuation and different types of noise, which basically appear on all media but with different degrees. The attenuation is a function not only of the range between sender and receiver, but also of the wavelength and the path loss gradient. The path loss is determined by more or less complex mathematical models that have been tailored according to the special circumstances of the environment under consideration, for example, indoor versus outdoor and degree of obstacles. The simplest of these models is obviously the *Friis* free space equation [26] , which allows for considering environmental parameters only in the form of the path loss gradient. A number of dedicated and more accurate models have been proposed for positioning purposes, for example, the famous COST231 [27] and *Hata* model [23] which considers environment either urban, suburban or rural and many other parame-ters like antenna height frequency, distance, base station height, mobile height, street width, angle between the street and the propagation direction, buildings average height and separation.

In general, propagation models could be categorized into three main groups empirical models, semi-deterministic models and deterministic models which is site specific and require enormous number of geometry information about the cite, very important computational effort and accurate.

3. Enhanced Lateration Approach

In this section, we describe *E-Lateration* system for GSM phones localization. We start by introduction about KML language followed by Haversine formulas and finally circle intersections and position calculation.

3.1 Keyhole Markup Language (KML)

Google submitted KML to the OGC to be evolved within the OGC consensus process. KML Version 3.0 will be an adopted OpenGIS implementation specification that will have been harmonized with relevant OpenGIS specifications that comprise the OGC standards baseline. We used KML [28] to visualize *E-Lateration* and clearly illustrate intersection points. Also, compare our approach results with other positioning techniques. Some of experiment results will be illustrated in Section 5.

3.2 Great - Circle Functions

It is important to distinguish between Euclidean distance and great circle distance or Haversine distance. The first is well known and applied for planar system, however almost all of positioning system applies it to evaluate their results. Ecludian distance cannot be used due to the curvature of the Earth's surface. Haversine distance gives the great circle distance between two points on a sphere from their longitudes and latitudes. We used implementation of greatcircle functions by *Ed Williams* in [29]. For example, calculation of mid-point lat_m, lon_m for two points (lat_1, $long_1$) and (lat_2, $long_2$) is expressed in Equation 5.

$$Bx = cos\,(lat_2).cos\,(long_2 - long_1)$$
$$By = cos\,(lat_2).sin\,(long_2 - long_1)$$

$$lat_m = atan\,2\,(\sin\,(lat_1) + \sin\,(lat_2), \sqrt{((cos\,(lat_1) + Bx)^2 + By^2))}$$
$$lon_m = lon_1 + atan\,2\,(By\,,\,cos\,(lat_1) + Bx \tag{5}$$

To find destination point lat_d, $long_d$ given an initial point lat_1, lon_1, degree θ and distance d. Formula in Equation 6 was used.

$$lat_d = \operatorname{asin}\left(sin\,(lat_1) * cos\left(\frac{d}{R}\right) + \cos\,(lat_1) * sin\left(\frac{d}{R}\right) * cos\,(\theta)\right)$$

$$lon_d = lon_1 - \operatorname{asin}\left(\sin(\theta) * \frac{sin\,(\frac{d}{R})}{\cos\,(lat_1)}\right. \tag{6}$$

Where R is Earth radius, d in Km and θ in radian. There is a special case if $cos\,(lat_d) = 0$, then $lon_d = lon_1$. Other functions like calculating bearing between two points and distance between two points could be found in [29].

2.3 Circles Intersections and Position Calculation

However calculating intersection points appears easily through one of famous circle intersection algorithms like [34], Practical implementation of *E-Lateration* technique is quite different. First, we define formula for normal circle intersection, as shown in Figure 2. We did not transform (x, y) from cartesian to geodetic coordinates (lat, $long$) since transformation error is very small and could be neglected. This assumption is valid in small distances only.

Calculate the distance d between the centres of the circles P_1 and P_0.

$d = |P_1 - P_0|$ for $d < r_0 + r_1$ and $Pn = x_n, y_n$ Calculate a, b as in equations 7, 8

$$a = \frac{(r_o^2 - r_1^2 + d^2)}{2d} \tag{7}$$

$$b = \sqrt{r_o^2 - a^2} \tag{8}$$

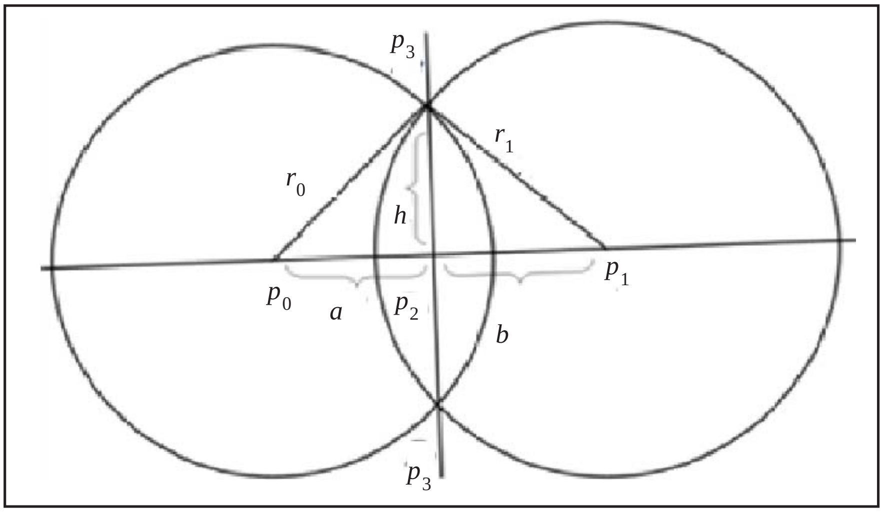


Figure 2. Intersection of two circles

Then, P_3 (x_3, y_3) could be calculated as shown in Equation 9.

$$x_3 = x_2 \pm \frac{h\,(y_1 - y_0)}{d},\; y_3 = y_2 \mp \frac{h\,(x_1 - x_0)}{d} \tag{9}$$

After practical tests, we found that sometimes $d > r_0 + r_1$. (Circles are far away) at this case, midpoint of two antennas is calculated using formulas in Equation 5. Also, sometimes $d < | r_0 - r_1 |$ which means that one circle contains the other. Figure 3 shows practical implementation with real dimensions. At this case we calculated midpoint of nearest-contours *P*mc. In order to calculate P_{mc}, we calculated bearing θ between the two antennas P_0, P_1 starting with circle with greater radius (P_1 at our case). From equation 6, we can get destination point P_{c0} with knowing each of P_0 as starting point, θ as bearing and d as radius of circle (RSS transformed into range using propa-gation model). By the same method P_{c1} could be calculated. Finally, we can easily calculate P_{mc} as geometric center be-tween P_{c0} and P_{c1}.

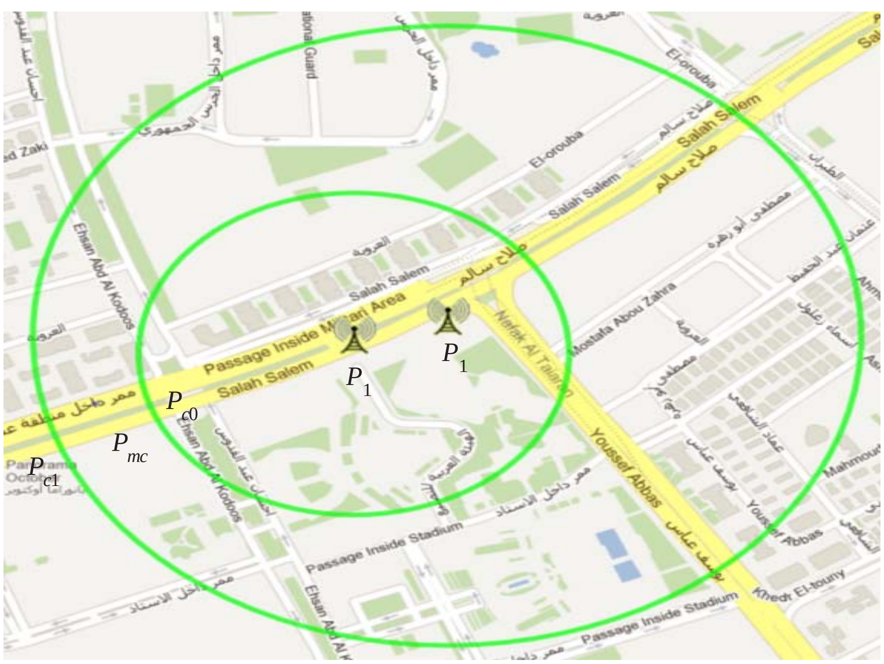


Figure 3. Special case of circle intersections

For more than two (Base Transceiver Station) BTS, we calculate the geometric center of all intersection points using Equation 5, as shown in Figure 4.

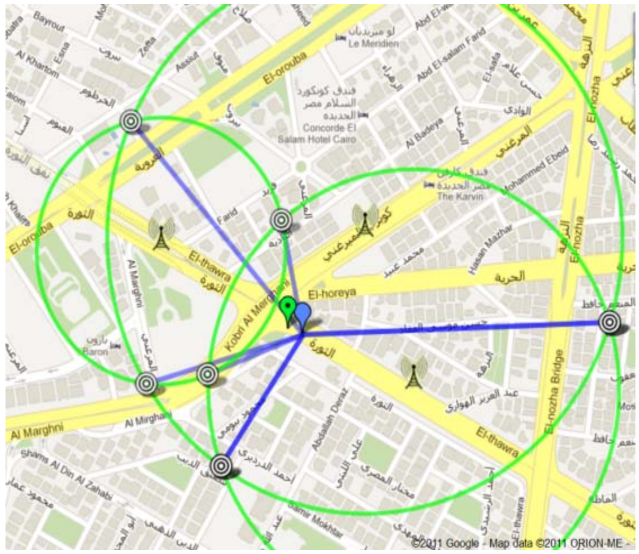


Figure 4. Circle Intersection, Real Case Urban (3 BTS), dotted green is ground truth, solid blue is calculated position

4. Adaptive Propagation Model

As we mentioned before, lateration technique does not provide a method to transform RSS into range. As part of EgTNS framework, it was important to provide practical independent technique able to transform RSS into accurate distance in meters using minimum number of parameters. Especially applying *Hata* [23] model requires information about antenna height, mobile height and obstacles height which are not available in practical case. That's why we build our simplified propagation model based on direct empirical approach.

The main purpose is to find a direct formula to transform RSS into distance in meters. In order to achieve that, we collected more than 6500 sample in different areas with different speeds to decrease fast fading and doppler effect. Then, we calculated best curve fit using Least Mean Square (LMS) [44] for both linear and polynomial. We used Root Mean Squared Error (RMSE) [37] to evaluate both curve fitting degrees as show in Equation 7.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (\acute{y} - y)^2}{n}} \qquad (10)$$

Where y is predicted range and y is actual range. We have found that RMSE for the polynomial was 113, while error for linear fitting was 141. Figure 5 shows relation between RSS and distance in both urban and rural area.

5. Performance Evaluation

First of all, it is important to mention that BTS positions were derived from Google DB and OpenCellID [36]. Positioning error was measured using *Haversine* formula [29].

5.1 Experiment & Data Collection

We collected data for two areas: Urban 524 samples (Inside Eastern Cairo), and Rural (Cairo El-Suez Road) 124 samples. Data was collected using Motorola *Milestone* [38] smartphone running on android 2.1 with 700 MHz processor, equipped with GPS. We used free app called "*Antennas*" [39] from android market to collect data (Cell-ID, MNC, MCC, GPS, timestamp, and RSS for both serving cell and neighbour cells too).

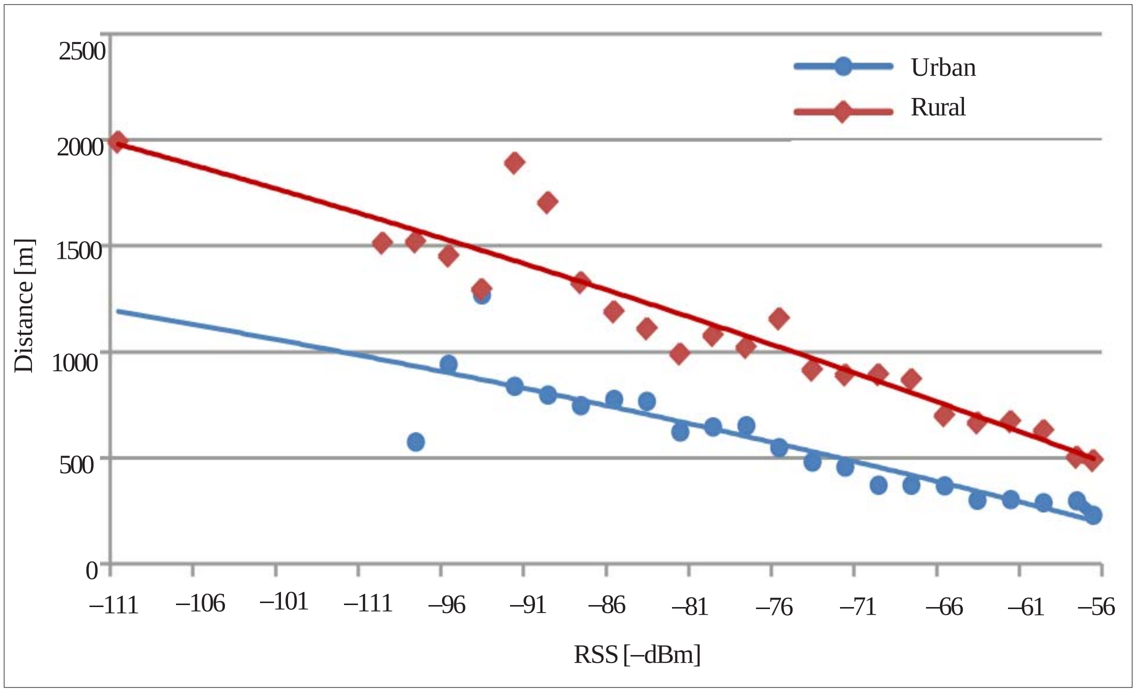


Figure 5. Relation between RSS and Distance, Empirical Adaptive Propagation Model for Urban and Rural Areas

5.2 Comparison with Other Techniques

E-Lateration technique and adaptive propagation model have been implemented on normal performance server with Intel Core 2 Duo 2.5 GHz, 6 Mb cache with 4 Gb RAM and 64-bit OS. We have implemented also each of:

1) *Cell-ID* [1]: Which assumes location of mobile is location of serving cell.

2) *Max RSS* [33]: Supposing serving cell has the max RSS is not always right assumption, our practical experiments proved that Max RSS technique has better accuracy than Cell-ID at least in urban areas.

3) *Centroid localization* [33]: Using Equation 2.

4) *Weighted Centroid Localization Technique WCL* [32]: Using Equations 3 and 4. We performed our own analysis to choose best *g* for both urban and rural which adapts with our test environments. As shown in Figure 6, best value for g was 3 in urban and 1 in rural.

We considered *d* is the distance in meters which derived from RSS using our adaptive propagation Model. WCL mean positioning error was 152 m for urban areas and 428 m for rural. All results of tested localization techniques are shown in Table 1 and Cumulative Distribution Function (CDF) of distance error illustrated in Figure 7. *E-Lateration's* accuracy is better than other techniques by at least 27% in urban and 9% in rural. Average running time depends on several factors like number of detected cells and rounding level. At our experiment average number of valid detected cells was 3 and rounding level was 6. Average running time appears slightly long, 6.5 msec per sample.

3.3 Error Sources

To understand positioning accuracy, it is important to figure out error sources. First of these errors is GPS (Ground Truth), GPS accuracy should be evaluated using GDOP [2] value. We used free live-crowdsourced website *Cellumap* [40] to illustrate GPS accuracy of our smart phone. Although, GPS accuracy should be within 5 ~ 20 m, it reached 50 m in dense urban areas. Also, bad geometrical of antennas [1], i.e. when all antennas converging at one direction (east, west, etc). As we mentioned before BTS coordinates were derived from online DB which have margin of error. Also, rounding and calculation errors reduce the accuracy especially at implementation of Haversine functions and circle intersection algorithms.

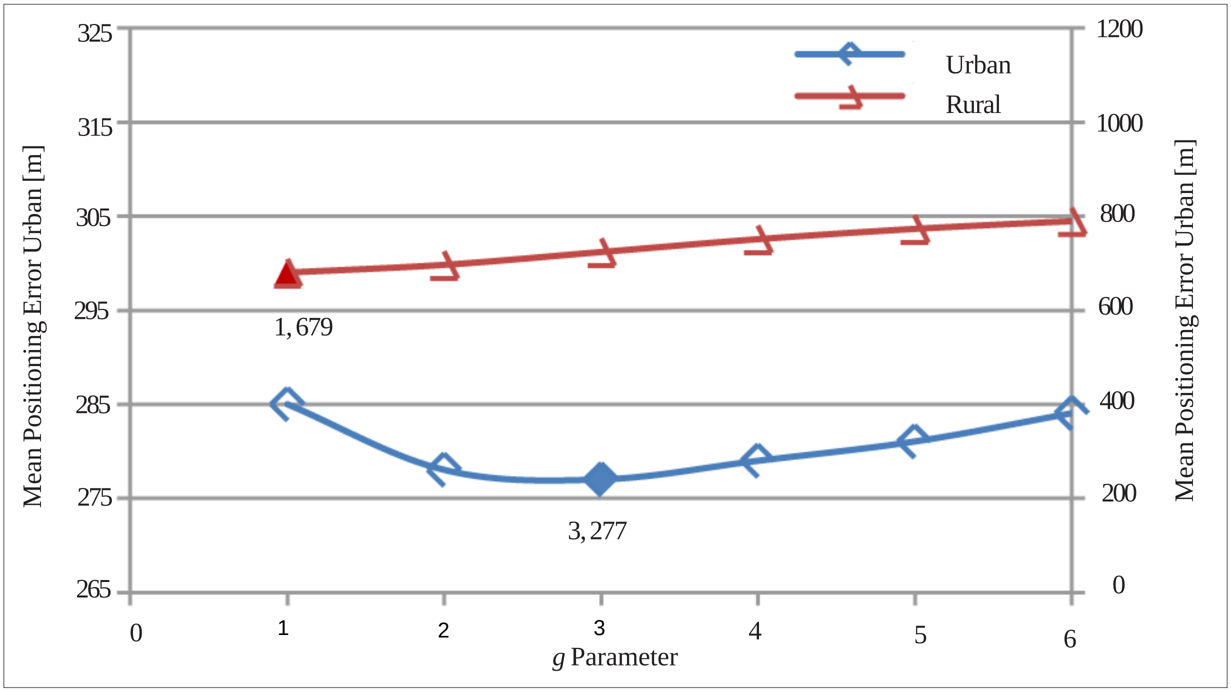


Figure 6. Relation between *g* Parameter and Mean Positioning Error

Algorithms	**Cell-ID**		**Max RSS**		**Centroid**		**WCL**		**E-Lateration**	
	Urban	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
Mean Error [m]	220 (83%)	637 (61%)	151 (74%)	634 (61%)	174 (45%)	435 (10%)	152 7%)	428 (9%)	120	394
Median Error [m]	156	446	123	331	171	404	126	440	121	441
67th Percentile [m]	211	627	160	454	203	514	152	549	145	511
95th Percentile [m]	526	1617	343	914	367	799	296	902	193	660
Run Time [msec]	1		1		< 3		< 3		6.5	

Table 1. Comparison between Different Positioning Techniques. Numbers Between Parentheses Represent Percentage Degradation Compared to *E-lateraion*

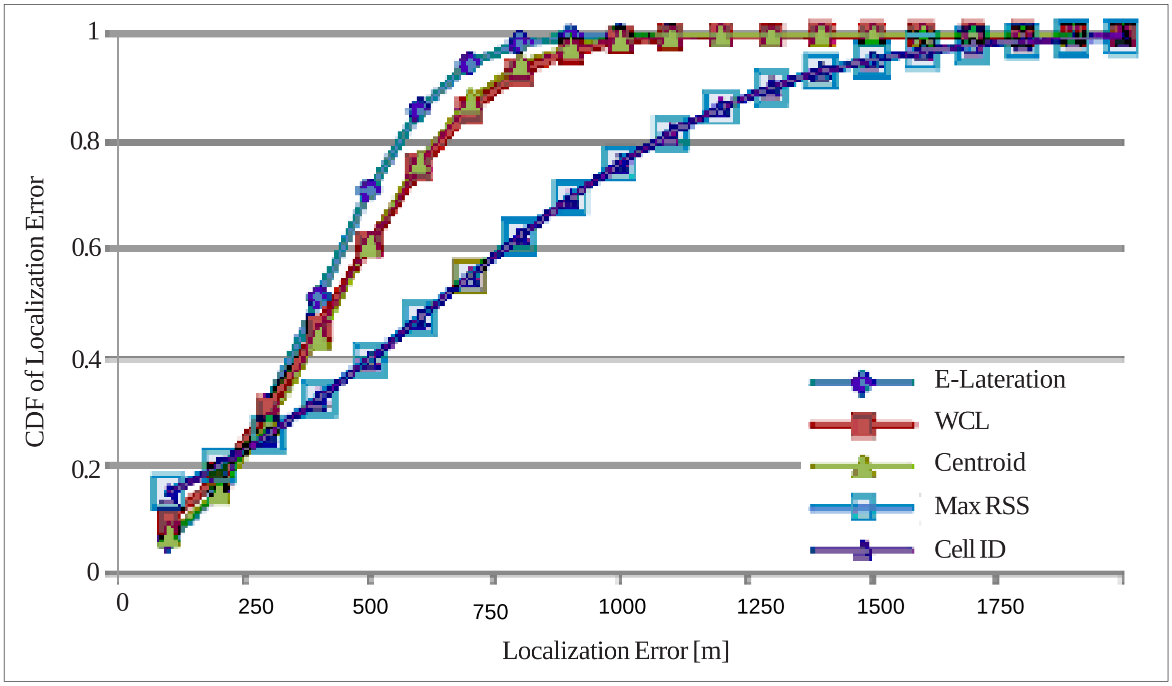
4. Conclusions

We proposed *E-Lateration*, a ranging positioning approach for GSM phones. We proposed also adaptive propagation model which requires minimum number of parameters. All details, tools and implementation notes have been proposed. Complete study case was produced using Android smart phones, OGC tools and KML. Tests and experiments have been done in Egypt roads on both rural and urban areas. Results have been compared to most recent ranging positioning techniques, and proved it has better accuracy in urban and slight improvement in rural.

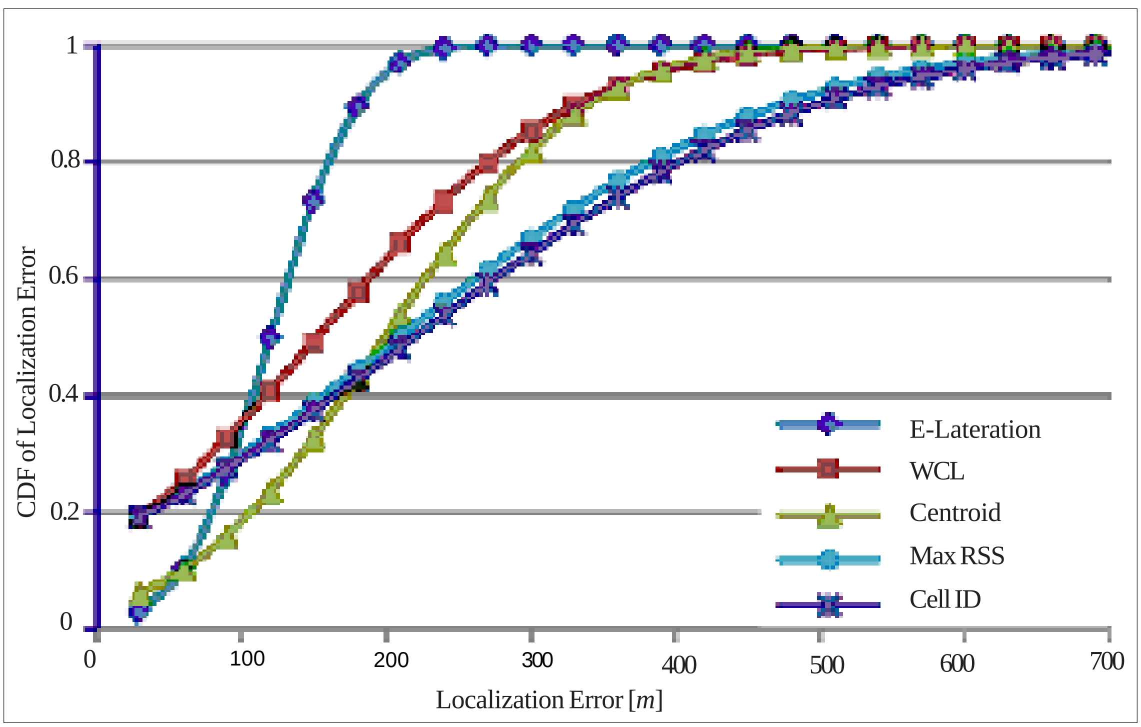
Currently, we are working on optimize the calculations and decrease running time, testing on larger set, combining multiple NMR in spatiotemporal manner, study the effect of dynamic *g* in WCL. As a part of EgTNS, *E-Lateraion* will be combined with traffic estimation approaches and map matching algorithms. Also, apply *E-Lateration* on Cell tower localization. We believe that these studies should be tested using external GPS unit or high sensitive GPS devices.

5. Acknowledgment

We would like to thank Prof. Moustafa Youssef, Dr. Tarek Attia, Abeer A. Ghandar, Haytham A. AbuelFutuh and R&D department in Vodafone Egypt.



(a) Urban



(b) Rural

Figure 7. CDF's of Positioning error for Different Algorithms

References

[1] Küpper, A. (2005). *Location-based services*: Wiley Online Library.

[2] El-Rabbany, A. (2002). *Introduction to GPS: the global positioning system*: Artech House Publishers.

[3] Herrera, J. C., Work, D. B., Herring, R., Ban, X. J., Jacobson, Q., Bayen, A. M. (2010). Evaluation of traffic data obtained via GPS-enabled mobile phones: The Mobile Century field experiment, *Transportation Re-search Part C: Emerging Technologies*, 18, p. 568-583.

[4] Thianniwet,T., Phosaard, S., Pattara-Atikom,W. (2009). Classification of Road Traffic Congestion Levels from GPS Data using a Decision Tree Algorithm and Sliding Windows.

[5] Cheng, Y. C., Chawathe, Y., LaMarca, A., Krumm, J. (2005). Accuracy characterization for metropolitan-scale Wi-Fi localization, in *Mo-biSys* '05: Proceedings of the 3rd international conference on Mobile systems, applications, and services. NY, USA: ACM.

[6] LaMarca, A., Chawathe, Y., Consolvo, S., Hightower, J., Smith, I., Scott, J ., Sohn, T., Howard, J., Hughes, J., Potter, F. (2005) . Place lab: Device positioning using radio beacons in the wild, *Pervasive Computing*, p. 301-306.

[7] Chen, Q., Lee, D. L., Lee,W. C. (2008). Rule-based WiFi localization methods, *In*: Proceeding of Embedded and Ubiquitous Computing, EUC '08, p. 252-258.

[8] Skyhook. WIRELESS. INC: SKYHOOK Wireless. (2008). URL http://www.skyhookwireless.com.

[9] Wikipedia contributors. (18 October 2011). *Comparison of Mobile Phone Standards*. Available: http://en.wikipedia.org/w/index.php?title=Comparison_of_mobile_phone_standards&oldid=449546220.

[10] Dufková, K., Ficek, M., Kencl, L., Novak, J., Kouba, J., Gregor, I., Danihelka, J. (2008). Active GSM cell-id tracking: Where Did You Disap-pear?, p. 7-12.

[11] Varshavsky, A., Chen, M., de Lara, E., Froehlich, J., Haehnel, D., High-tower, J., LaMarca, A., Potter, F., Sohn,T., Tang, K., Are GSM Phones THE Solution for Localization?, p. 34-42.

[12] Laitinen, H., Lahteenmaki, J., Nordstrom, T. (2001). Database correlation method for GSM location, 4, p. 2504-2508.

[13] Borenovic, M. N., Simic, M. I., Neskovic, A. M., Petrovic, M. M. (2005). Enhanced Cell-ID+ TA GSM positioning technique, p. 1176-1179.

[14] Wang, S., Min, J., Yi, B.K. (2008). Location based services for mobiles: Technologies and standards.

[15] Kjærgaard, M. (2007). A taxonomy for radio location fingerprinting, *Loca-tion and Context-Awareness*, p. 139-156.

[16] Sathu, H. (2006). Wardriving dilemmas, 19th Annual Conference of the National Advisory.

[17] Pahlavan, K., Akgul, F., Ye, Y., Morgan, T., Alizadeh, F., Shabdiz, M. H., Steger, C. (2010). Taking Positioning Indoors—Wi-Fi Localization and GNSS, *InsideGNSS, May* .

[18] Lakmali, B., Dias, D. (2009). Database Correlation for GSM Location in Outdoor & Indoor Environments, p. 42-47.

[19] Bulusu, N., Heidemann, J., Estrin, D. (2000). GPS-less low-cost outdoor localization for very small devices, *Personal Communications, IEEE*, 7, p. 28-34.

[20] Schuhmann, S., Herrmann, K., Rothermel, K., Blumenthal, J., Timmermann, D. (2008). Improved Weighted Centroid Localization in Smart Ubiquitous Environments, *Ubiquitous Intelligence and Computing*, p. 20-34.

[21] Behnke, R., Timmermann, D. (2008). AWCL: Adaptive Weighted Cen-troid Localization as an efficient improvement of coarse grained localization, p. 243-250.

[22] Belloni, F. (2004). Physical Layer Methods in Wireless Communication Systems, *Fading models course, Helsinki University of Technology, November.*

[23] Hata, M. (1980). Empirical formula for propagation loss in land mobile radio services, IEEE Transaction on Vehicular Technology, *VT-29*, p. 317-325.

[24] Bellini, A., Cirilo, C. E., Araujo, G., Duque, J. L., Annibal, L. P., Durelli, R. S., Marcondes, C. (2010). A low cost positioning and visualization system using smartphones for emergency ambulance service, pre-sented at the Proceedings of the 2010 ICSE Workshop on Software En-gineering in Health Care, Cape Town, South Africa.

[25] Farouki, R. T., Sakkalis, T. (1990). Pythagorean hodographs, *IBM Jour-nal of Research and Development*, 34, p. 736-752.

[26] Friis, H. T., (1946). A note on a simple transmission formula, *proc. IRE*, 34, p. 254-256.

[27] Damosso, E. (1999). Digital mobile radio towards future generation systems: COST action 231: European Commission.

[28] Reed, C. (2007). KML 2.1 Reference–An OGC Best Practice, *Open Geospa-tial Consortium. Available online: http://portal.opengeospatial.org/files.*

[29] Williams, E. Aviation Formulary V1. 42, *Aviation*, 1, p. 42.

[30] G. Inc. *Google Maps for Mobile*. Available: http://maps.google.com.

[31] Blumenthal, J., Grossmann, R., Golatowski, F., Timmermann, D. (2007). Weighted centroid localization in Zigbee-based sensor networks, in *Intelligent Signal Processing*, p. 1-6.

[32] Li, R. Z., Luo, X. L., Lin, J. R. Weighted Centroid Correction Lo-calization in Cellular Systems, *American Journal of Engineering and Applied Sciences*, 4, p. 37-41.

[33] Yang, J., Varshavsky, A., Liu, H., Chen, Y., Gruteser, M. (2010). Accuracy characterization of cell tower localization, *In*: Proceedings of the 12th ACM international conference on Ubiquitous computing, Copenhagen, Denmark, p. 223-226.

[34] Fewell, M. (2006). Area of common overlap of three circles, DTIC Document.

[35] EgTNS. (2011). *Egypt Traffic and Navigation System* Available: http://www.egtns.com/.

[36] OpenCellID. (2011). *Open source project aiming to create a complete database of CellID worldwide and assigning them to geographic loca-tions*. Available: http://www.opencellid.com/.

[37] Wikipedia contributors. (2011). *Root mean square deviation* Available: http://en.wikipedia.org/w/index.php?title=Root_mean_square_devia-tion&oldid=453935951.

[38] GSMArena. (2010). *Motorola Milestone Smartphone Specs* Available: http://www.gsmarena.com/motorola_milestone-3001.php.

[39] Michael Polymenakos. (2010) *Antennas*, Available: https://market.android.com/details?id=com.technolatry.antennas&hl=en.

[40] Cellumap. (2010). *Cellular Coverage Map*. Available: http://www.cellumap.com

[41] Ahmed M. Hamad, Mohamed , Abdel Meniem H.,and Medhat, R. To-wards a Complete Navigation/Traffic integrated System Adapted to Egypt Roads, *In*: *Proceedings of International Navigation Conference, Melaha*, Egypt.

[42] Lin, K., Kansal,A., Lymberopoulos, D., Zhao, F., (2010). Energy-accuracy trade-off for continuous mobile device location, in 8th international conference on Mobile systems, applications, and services. MobiSys, p. 285-298.

[43] Thiagarajan, A., Ravindranath, L., LaCurts, K., Madden, S., Bala-krishnan, H., Toledo, S., Eriksson, J. (2009). VTrack: accurate, energy-aware road traffic delay estimation using mobile phones, *In*: Proceedings of the 7th ACM Conference on Embedded Networked Sensor Systems, p. 85-98.

[44] Björck, A. (1996). *Numerical methods for least squares problems*: Society for Industrial Mathematics.