Investigation of the Most Suitable Location Finding Techniques for GSM1800 Network

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Abstract

In this work, several existing techniques, such as Cell ID, and Signal Strength methods, are applied to field measurements that were done in the real commercial GSM network in Istanbul. Then, the Database Correlation Method (DCM) and Kalman Filtering are applied to locate the subscriber. Different methods are compared. The method used in this work is not imposing any modifications in the mobile units, thus it may be implemented easily. Significant improvements in the results are obtained after post processing the measurement results.

1. Introduction

From the first day of the communication, the questions "who?" and "where?" have been important. When the mobile communication era started, the question where has been emphasized, and the positioning became more and more important. In the early days, location was important especially for security and emergency purposes [1-2]. In today's world, commercial issues are another driving factor of the wireless location finding technologies. Almost all the mobile operators would like to provide the right service, at the right time, in the right location, to their customers.

Despite the fact that there are numerous drivers for locating the mobile subscribers, there isn't any successfully deployed solution among the GSM operator in Turkey. Another factor negatively affecting the success is the presence of many methods using various techniques; however there is no one single solution applicable for all cases. In addition to that, the locating performance isn't still sufficient.

In Turkey, a new driving force for the establishment of the location finding systems among the GSM operators may appear soon due to the European Union standards and integration requirements. The Caution++ project, conducted by European Union's Information Society Technologies (IST), targets to design and develop a novel, low cost and flexible system which able to monitor the available resources from the cellular networks of the second and third generation (2G, 3G) and Wireless Fidelity (Wi-Fi) networks [3]. Enhanced 112, started in 2002 in Europe, may be another governmental driver for locating the subscribers [2-3].

2. Overview of Positioning

The positioning technologies can be divided into three main categories: Network based technologies, handset based technologies, and hybrid technologies.

Network based technologies have the advantage that they can be used with old mobile terminals. The four methods are Cell-ID (CGI) and TA, Time or Arrival (TOA) / Uplink Time of arrival (UL-TOA), Angle of Arrival (AOA), and Signal Strength (SS).

Handset based technologies have the best accuracy, but need new or upgraded mobile terminals. The Assisted GPS (A-GPS) method, use a GPS receiver in the MT to find the MT position. The satellite navigation system developed by the US military makes use of the signals from 27 satellites to calculate the position on earth, both horizontally and vertically with accuracy better than 10 meters [4]. A GPS terminal, wherever it is in the world, needs to see four or more satellites, to calculate the receiver's position.

In the hybrid technologies category, upgrades are needed both on the mobile terminals and in the network. The software in the mobile terminals must be upgraded and new elements must be deployed in the mobile network. The E-OTD method belongs to this category. 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. Both normal and dummy bursts can be used. The measured time difference between pairs of base transceiver stations, are referred to as OTD. Because the transmission of frames from the base transceiver stations are not synchronized in the GSM network, the real time differences (RTD) between pairs of base transceiver stations is measured by an LMU [4].

3. DCM and Post Processing Techniques

The Database Correlation Method is described in [5-6], as general location method, which can be applied to any cellular or WLAN network. The key idea is to create a database of reference fingerprints from the whole area of interest. The reference fingerprint is a recorded measurement sample from a certain location in the area. In addition to the location information, the reference fingerprint contains signal information from the cells that were hearable when the measurement was carried out. The positioning is conducted by comparing the signal information of the request fingerprint to signal information of the reference fingerprints and returning the location of the best matching reference fingerprint.

4. Kalman Filtering

The Kalman filter is a recursive solution of the discrete-data linear filtering problem. The word recursive means that the filter uses the information about its previous state during the estimation process of the current state. In mobile positioning, the discrete-data linear filtering problem is the approximated movement of the mobile terminal. With Kalman filtering, it is possible to track the position and speed of the MT and therefore, reduce the positioning error [7].

5. Simulation Results

In three independent sessions, around 300,000 samples are recorded during field measurements. Itinerary of each field measurement is as follow: Ümraniye-Şile, Şile to Ümraniye, Güneşli-Atatürk Airport-Eminönü-Beşiktaş-Maçka.

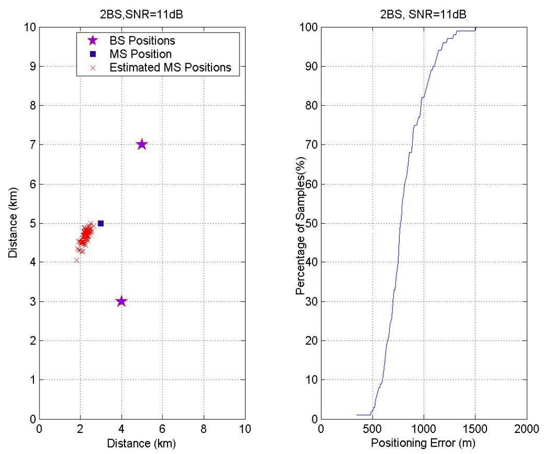

Fig. 1. Computer Simulation results for SNR=11dB and 2 BSs

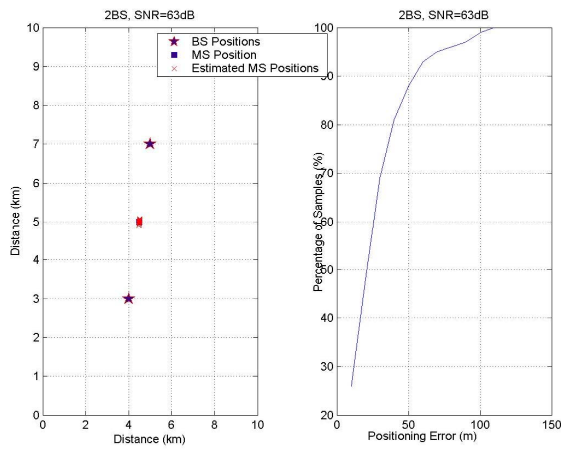

Fig. 2. Computer Simulation results for SNR=63dB and 2 BSs

Figure 3 shows the places where there are more then 3 BSs around the MS, but with low signal quality (SNR near to 11dB). The practical case can be encountered in the city centers, where the BSs serve in order to support high GSM services traffic. The accuracy is around 400 meters for 67% of the sample

Figure 4 shows the places where there is a good coverage provided at least more then 3 BSs. Although the examples depict 6 BSc, in practical cases 3 BSs yield the same accuracy level. This is the case for most of the large streets or squares in the cities. Accuracy is less then 100 meters for approximately 90% of the samples.

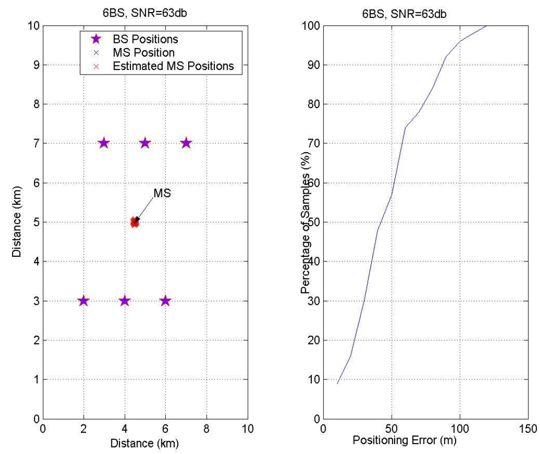

Fig. 3. Computer Simulation for SNR=11dB and 6 BSs

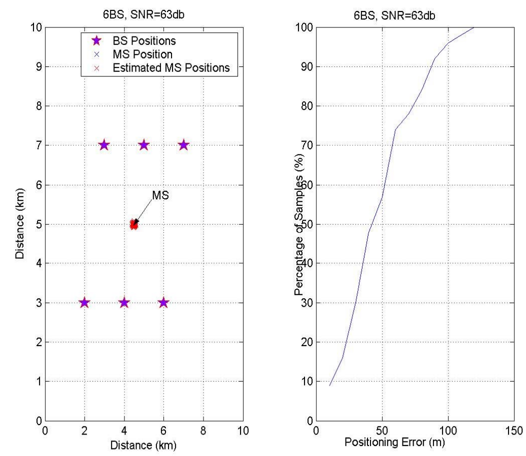

Fig. 4. Computer Simulation for SNR=63dB and 6 BSs

6. Location Estimation for Field Measurements with the Implementation of Simulated Models and Kalman Filtering

After the SS and DCM model applied and the estimations are obtained, Kalman filter is implemented to the results.

Kalman filter applied results mostly showed better accuracy than their previous states.

In Figure 5, the results are given for one serving and one neighbor BS. The existence of the two BSs is not sufficient for successful location estimation. Although the results of the Figure 5 show an accuracy ranking from 200 to 500 meters for 67% of the samples, the below results are specific for the place where MS is.

Figure 6 is a typical example of an MS going along to shoreline of Istanbul. The serving cell is not the closest one to the MS, but any other within the line of sight.

Figure 7 shows the places where there is a good coverage provided at least more then 3 BSs. Although the examples depict 6 BSc, in practical cases 3 BSs yield the same accuracy level. This is the case for most of the large streets or squares in the cities. Accuracy is less then 100 meters for approximately 90% of the samples. The below examples depict an MS in the Taksim square.

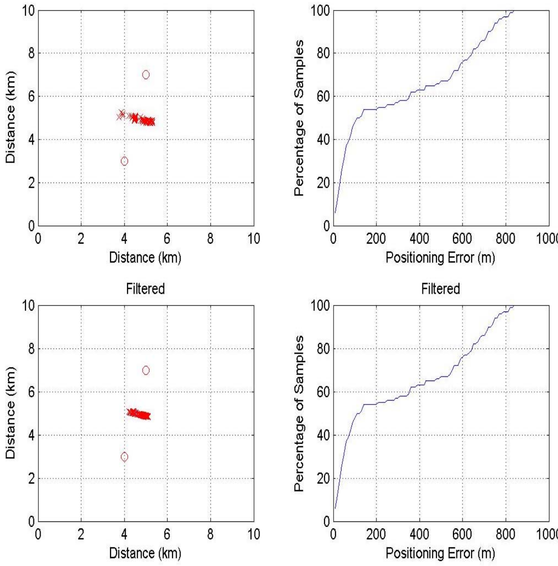

Fig. 5. Filtered and Unfiltered Location Estimation for SNR=11dB with one Serving Cell and one Neighbor Cell

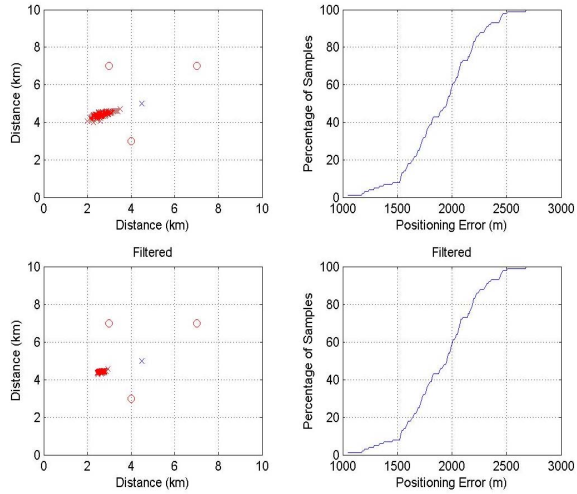

Fig. 6. Filtered and Unfiltered Location Estimation for SNR=11dB with one Serving Cell and two Neighbor Cells

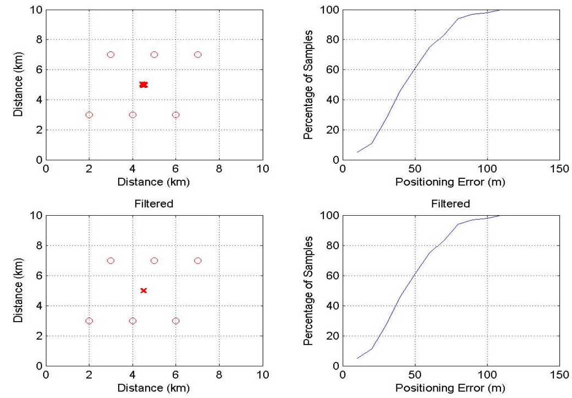

Fig. 7. Location Estimation for SNR=63dB with one Serving Cell and five Neighbor Cells

Table 1. Comparisons of the calculated results before and after the postprocessing

		Before Postprocessing		**Improvements (in meters) with Kalman Filtering only**		**After Postprocessing with Kalman Filtering**	
Base Stations (SC for Serving and NC for Neighbor Cells)	SNR (dB)	Mean (meters)	Standard Deviation (meters)	Mean (meters)	Standard Deviation (meters)	Mean (meters)	Standard Deviation (meters)
SC+2NC	11	1.908,10	324,39	-	-	1.930,90	98,26
SC+2NC	63	116,48	35,08	15,2	20,48	101,27	14,59
SC+3NC	11	325,75	199,3	192,91	119,31	132,84	79,99
SC+3NC	63	54,37	30,04	37,21	19,15	17,17	10,89
SC+5NC	11	241,79	172,33	175,78	131,95	66,01	40,38
SC+5NC	63	45,3	22,52	34,31	15,05	10,99	7,47

7. Evaluation of the Postprocessing Effect to the Accuracy Improvements

To better investigated the post processing effect for the accuracy improvements; the error values are given both before and after the postprocessing applied in Table 1. In low SNR (around 11 dB), one serving cell and two neighbor cells environment, the accuracy of the positioning is very low. In such cases, the average error is greater than 1900m. The postprocessing technique could not result any improvement in these cases.

One more neighbor cell to the same environment mentioned in the previous paragraph yields better accuracy levels. Despite of low SNR (around 11 dB), location estimations error for an environment with one serving and three neighbor cells is decreased to 325 meters. After postprocessing applied, it is decreased to 132 meters.

The number of the neighbor cells surrounding the MT contributes positively the accuracy, especially when the SNR is low. In an environment with one serving, five neighbor cells with SNR around 11 dB, before postprocessing an error of 241 meters is obtained. After the postprocessing, it is decreased to 66 meters.

As seen in Table 1, high SNR (around 63 dB) yields lower error values. With one serving and two neighbor cells the error is around 116 meters, and after postprocessing it is decreased to 101 meters. By the increase of the numbers of the neighbor cell, the error done in location estimations are decreased furthermore, accordingly the postprocessing provides extra improvements for positioning accuracy. For one SC and three NCs, the error values are 54 and 17 meters, respectively before and after postprocessing. Finally for one SC and five SCs, the error values are 45 and 10 meters, respectively before and after postprocessing.

Table 2. Positioning Accuracy results before postprocessing

Before Postprocessing		Percentage of the samples below the error level R<x meters		
Base Stations (SC for Serving and NC for Neighbor Cells)	SNR (dB)	R<50 (m)	R<100 (m)	R<200 (m)
SC+2NC	11	-	-	-
SC+2NC	63	2,0%	29,9%	91,3%
SC+3NC	11	1,4%	11,0%	31,0%
SC+3NC	63	51,7%	91,0%	99,0%
SC+5NC	11	5,9%	17,0%	53,0%
SC+5NC	63	61,0%	97,6%	100,0%

Table 2, 3 and 4 show the improvement of the accuracy in another perspective. Table 2 and 3 represent the percentage of the samples that the positions are calculated and classified according to the error levels. Table 4 compares the accuracy level of the positioning errors calculated before and after the postprocessing with Kalman Filtering. Results are given in percentage in order to better compare the changes.

Table 3. Positioning Accuracy results after postprocessing

After Postprocessing with Kalman Filter		Percentage of the samples below the error level R<x meters		
Base Stations (SC for Serving and NC for Neighbor Cells)	SNR (dB)	R<50 (m)	R<100 (m)	R<200 (m)
SC+2NC	11	-	-	-
SC+2NC	63	2,4%	32,6%	98,5%
SC+3NC	11	1,9%	14,3%	36,5%
SC+3NC	63	54,3%	94,4%	100,0%
SC+5NC	11	8,8%	21,6%	64,9%
SC+5NC	63	66,9%	100,0%	100,0%

Table 4. Improvement of the Positioning Accuracy

After Postprocessing with Kalman Filter		Accuracy Improvement		
Base Stations (SC for Serving and NC for Neighbor Cells)	SNR (dB)	R<50 (m)	R<100 (m)	R<200 (m)
SC+2NC	11	-	-	-
SC+2NC	63	0,35%	2,74%	7,18%
SC+3NC	11	0,50%	3,30%	5,45%
SC+3NC	63	2,60%	3,40%	1,00%
SC+5NC	11	2,90%	4,60%	11,90%
SC+5NC	63	5,90%	2,40%	0,00%

As seen in Table 2, the accuracy for positioning of the MS increases due to good signal levels received by MS.

The postprocessing with Kalman Filter shows better results, except where the signal levels are too low and the neighbor cells are not contributing to the quality at the MS side.

As can be seen in Table 4, the number of the accurate positioning is increased where the signal levels are low:

8. Conclusions

It is still impossible to choose only one best method for geography like Istanbul, considering all the studied methods mentioned above. For an optimum result, requirements and solutions must be segmented then re-categorized accordingly.

Any off the shelf product will not be matching the required accuracy in the geography. In the city centers Cell-ID based location techniques may work with an acceptable accuracy for most of the needs, except for emergency requirements. The optimum solution will be the SS, Cell-ID, DCM and Kalman Filtering techniques working in combinations. Single technique may yield a wide range of accuracy starting from 150m up to several kilometers. Because of the combination of the techniques followed by postprocessing method (DCM and Kalman Filter) the accuracy may be increase 5% to 20%.

So far, studies have been targeted to find a method that would use the existing infrastructure of the mobile networks, and the existing mobile terminal of the users, but the obtained results show that the low accuracy problem can not be overcome. Therefore, the new solutions are on the way to be as standards in the coming networks and handsets.

The study shows that the accuracy may be improved easily if the handsets are equipped with the location finding hardware and software. Formerly high end handsets become cheaper day by day with extra features on them. The integration of the low orbit satellites to the wireless networks

9. References

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10. Acknowledgment

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