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Visualization Improvement of Best Servers Areas in GSM Networks

***Abstract**. The article deals with improving Best Sever boundaries determination in a mobile network. The described algorithm improves the basic positioning methods used in mobile networks as we know the real shape of Best Server area. Proposed method uses a combination of network parameters, which are obtained by continuous measurement in the mobile network, and interpolated data, which are used in places with the absence of measurement points. These parameters create a database of values that are necessary for identification of areas which are covered by the radio signal from particular Base Station.*

***Streszczenie.** W artykule przedstawiono ulepszony sposób lokalizacji użytkownika w sieci komórkowej GSM. Wykorzystywane do tego celu są informacje o pomierzonych parametrach i ustawieniach sieci oraz najbliższych stacjach przekaźnikowych, które wysyłane są przez użytkownika sieci. Na tej podstawie algorytm określa najlepsze rozwiązanie w wyborze serwera. (**Polepszenie wizji w rejonach zasięgu serwerów w sieci GSM**).*

Keywords: GSM, Best Server, Cell ID, Interpolation, Grid.
Słowa kluczowe: GSM, ID komórki, interpolacja, siatka.

Introduction

Nowadays, there are well known various methods for determining the location position of Mobile Stations (MS) [1]. The best method for the independent MS localization (without necessary additional network modifications) is to determine MS position from the side of GSM network (NBP - Network Based Positioning).

The basic positioning method is based on the Cell Identification (Cell ID) [2, 15]. An explored area with a surveyed MS is defined as a circular area around the active Base Transceiver Station (BTS) (see Fig.1 – hatched area 1). An accuracy improvement of this method is achieved if BTS uses sector antennas. This method faces to a circular sector by reducing the circular area 1 (see Fig.1- squared area 2).

Farther accuracy achievement of MS localization for BTS which covers areas over a distance of 550 m, can be reached by limiting area 2 on Fig.1 by network parameter Timing Advance (TA) [1, 11] shown in Figure 1 – dotted area 3. The accuracy of this method depends on the size of the covered area, ranging from hundreds of meters to several kilometers [8]. The main quality of this method is the independence from the type of MS and a low cost implementation into the real mobile network [3, 14].

Areas covered by particular sectors of the BTS can be determined using sophisticated software tools, which are used by mobile operators, to optimize their mobile network [4]. Graphical visualization of signal coverage is based on the known signal propagation models involving the terrain profile, as well as buildings, in the surveyed area. Although those sophisticated softwares are considered as the professional tools, their outputs do not every time reflect the actual situation existing in the surveyed area. This can be detected only by measurements performed in specific reception areas. Mobile operators perform regular measurements of several network parameters with the main purpose of the network optimization. Regarding those measurements the operator disposes an extensive measurement's database that is regularly updated.

This paper extends the contribution from [16] where is described developed algorithm for visualization the Best Server areas. The algorithm in [16] improves the basic positioning methods used in mobile networks to determine the location of mobile station.

This paper describes an improvement in the basic positioning methods used in GSM cellular networks that are based on the identification of Cell ID [7, 10]. It uses measured values of network parameters that contain information about the current network settings and reception conditions in the service and the six surrounding BTS [13]. Recorded information is sent by each mobile station during communication over the GSM cellular network. These parameters are consequently used as input values of the proposed algorithm for determining the Best Server area of the BTS sector.

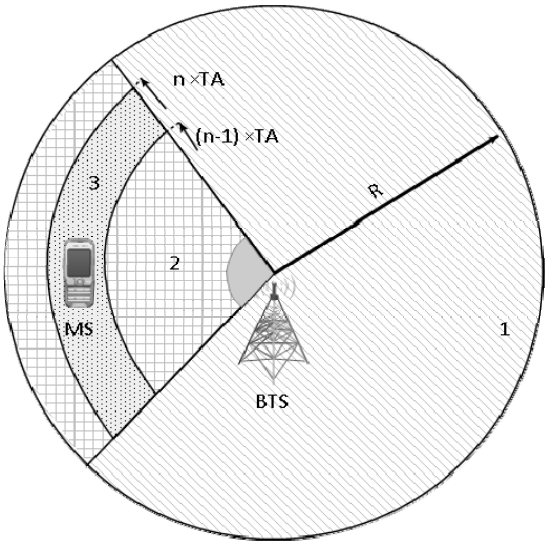

Fig.1. Basic localization method in GSM network

The Reference Database Preparation

Measurement device (NAM Logger) is used for obtaining selected parameters in the GSM network. For more information about NAM logger see [16].

Description of data logging process and visualization

The actual measurement is performed in Dedicated (speech) Mode (DM). DM mode is used with reason of comparison with existing localization methods. The comparison is based on measurement a circular area with a radius corresponding to the size *n x 550 m*, where n is the value of TA (see Fig.1, area 3) [5, 6]. Measurement is performed in the two following steps:

1. MS makes a Call Setup between MS and NAM Logger (call initiates MS, NAM Logger automatically answers).
2. Measured parameters are automatically saved into the internal memory of NAM Logger within a specified time period.

A specific mode of GSM modem called *Ericsson M2M Engineering Monitoring Mode* is used for acquiring network parameters [9, 12]. Using AT command *AT*EEMM* modem enables obtain the following network parameters: *Serving Cell, MCC, MNC, LAC, CellID, BSIC, Ch[RxL, C1, C2][RxLFull, RxLSub, RxQFull, RxQSub, TA, TN].*

The following parameters are recorded into the internal memory of NAM logger in pre-defined intervals:

- Current GPS position (Longitude, Latitude) for viewing the actual position where the measurements were performed.
- Cell Identification.
- Current receive level (RxLev) measured towards the traffic channel (TCh).
- Parameter TA for comparison of the proposed method with the original TA localization method.

Recording period is set to one sample per five seconds. The total area of measured route in the analyzed area is approximately 1.6 square kilometers. The data for described experiments were measured in Ostrava. During the monitoring the GSM and GPS antennas are placed on the roof of a car. Data-set consist of 1371 points. This area was divided into 4 traces (see Table 1), where each trace represents a different density of routes, see Fig. 2.

Table 1. Measurement density

Trace	Colours	No. of measured points
A	brown	379
B	brown+green	605
C	brown+green+red	870
D	brown+green+red+blue	1371

Description of visualization by developed application

The application (LoMo Map Viewer) was developed to generally visualize all parameters of the measured network. It allows visualizing of individual measured values together with their GPS position (see Fig.2). This visualization allows further analysis of acquired network parameters. LoMo Map Viewer consists of several layers. Over the base map layer is applied a layer consisting of individual measurements and other objects. There is also an ability to save and load the internal database as well as an import of several file formats.

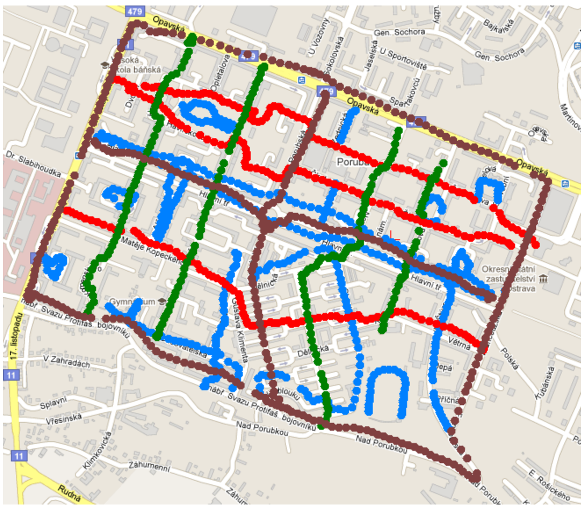

Fig.2. Application LoMo Map Viewer for visualization of the measured network parameters

Data Interpolation

Since our current solution is based on finding the best matching results based on features mentioned earlier in this paper, we obtain the nearest neighbors to a given query. Unfortunately, since the neighbors' identification is based on such features and the measurements are not spread evenly, the coverage is uneven and the nearest neighbors can be spread over a geographically distant place, making the determination of correct position more difficult. Also, it would be better to pre-calculate the missing points in the indexing phase instead of slowing down the retrieval phase which is time-critical.

To solve this issue, we should introduce additional data points in the areas not covered by the measurements. There are two possible approaches:

- Simulation - based on the knowledge of terrain, land usage and additional parameters, we can calculate expected signal levels in given places, creating a uniform grid with the simulated data
- Interpolation - we can take the current measurement and calculate interpolated data from geographically-adjacent measured points.

Since the first method is not ideal inside of cities without a suitable model which takes into account the buildings and multi-path signal propagation and our model did not offer measurement-based recalibration of interpolated data, we will concentrate mainly on the interpolation method in the rest of this section. There are many methods which are currently used for interpolation of measured data [14], [15], for example classic or Delaunay triangulation, moving least squares (MLS) method and other statistical or interpolation methods. However, some of these methods have problems with non-uniform distribution of interpolated data.

Our method uses the information retrieval approach which is also used in the whole solution. Firstly, we generate a uniform grid of interpolated points. For each of these points we calculate the interpolation as follows:

1. We look for a given set of k nearest neighbors (k-NN) in its vicinity (currently 8 neighbors).
2. If one of the neighbors is closer than the grid step, no interpolation is calculated.
3. The neighbors are sorted according to their distance and neighbors exceeding the maximal distance are removed.
4. Neighbors with distance increase exceeding maximal increment are removed.
5. Neighbors with low angular distance from existing neighbor are removed.
6. Neighbor weights are calculated inversely to their distance from calculated point.
7. The interpolation is calculated from at least two points, additional points are being added if the weighted distance does not increase over the distance calculated in the previous step.

The weighted calculation produces a new vector in the n-dimensional feature space. We can interpolate weights of individual data points, RX levels and the value of TA. Interpolated vectors are then stored in the index together with original data.

Since the original calculation took all data points into account, additional speedups were necessary. Currently, we use the grid-based solution, which splits the data points into cells of a grid, a range query is then executed and only grid cells in a growing radius around the cell with interpolated data are searched when looking for neighbors.

Even this approach has its limits, so in future, we plan to use a tree-based structure for fast k-NN search or a multi-grid approach.

In Figure 3, we can see an example of the interpolation method. In this example, we will limit ourselves to 32m x 32m sized cells with the limit of neighbors *k*=8.

In cells A0-A2, B0 and B2, there is already a data point present so we do not calculate the interpolation. Cells C0 and C3 have all data points on one side, which would lead to extrapolation. This is possible for a limited distance, but may lead to worse results.

We will illustrate our method on cells B1, C1 and B3 in greater detail:

- Cell C1 has 3 measurements in the neighborhood – p2, p7, p8, well distributed, all of them will be taken into account with similar weights.
- Cell B3 has 5 measurements in the neighborhood, p5, p6 and p9 will have similar weight whilst p4 and p7 are farther and their influence would be reduced.
- Cell B2 has 4 measurements in the neighborhood, but only p1, p2 and p7 will be used. Measurement p3 has a low angular distance to p1 and based on the setting may also exceed the maximal distance increment.

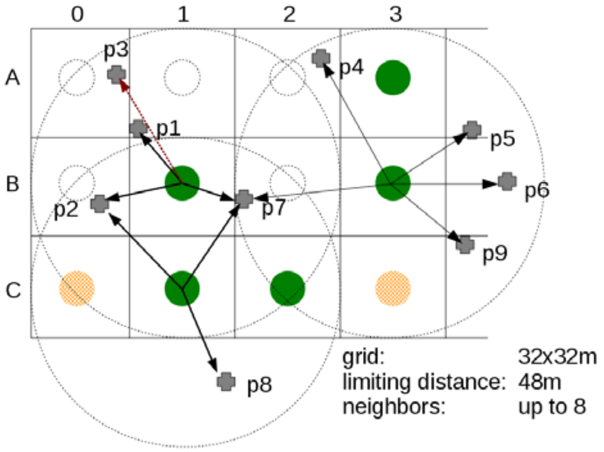

Fig.3. Example interpolation of data in rectangular grid

Method of best server visualization

Moreover, the LoMo Map Viewer is able to visualize the Best Server area of the main BTS sector. The algorithm for visualization of Best Servers is described in [16].

In the first step is divided a map raster into an equal parts and set up a grid. Generally, the denser grid, the more accurate final calculation is made. With the denser grid is necessary to have a greater variance of the GPS positions measured values to achieve optimal results in visualization.

The second step is to assign these values to the appropriate X, Y positions in the coordinate's grid. When the values are assigned the internal database of Cell ID is considered. In the case of a new unique value, it is stored into the database and indicated by different color.

The final Best Server maps are visualized in LoMo Map Viewer according to respective traces (see Fig.4-7). On the figures 4-7 is evident an accuracy improvement of the Best Servers boundaries while increasing density of measured traces. Especially within the analyzed area, the total number of Best Servers increased from the 20 (Trace A) to 22 (Trace D). This was caused by the recording new smaller sectors that occurred in this area since those could not be recorded in the measurement with lower density routes.

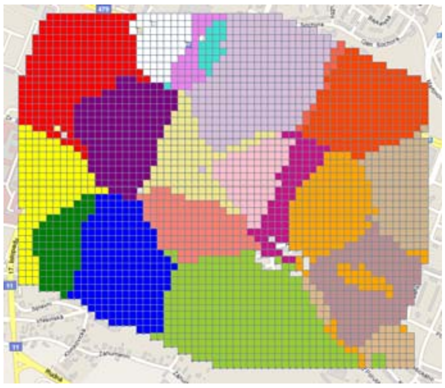

Fig.4. Final calculated map of Best Server for trace A

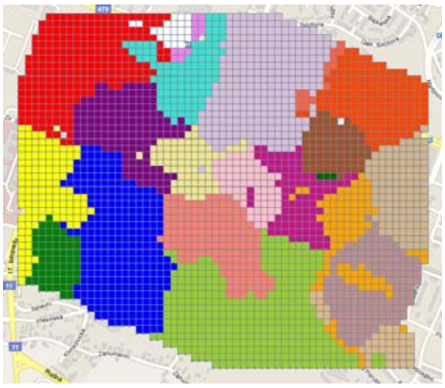

Fig.5. Final calculated map of Best Server for trace B

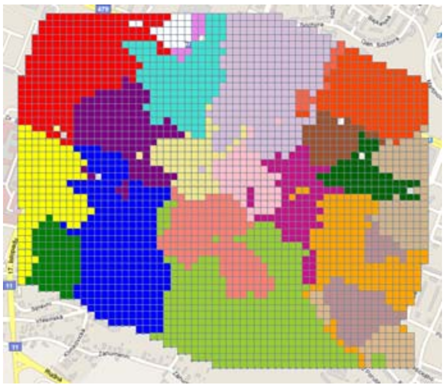

Fig.6. Final calculated map of Best Server for trace C

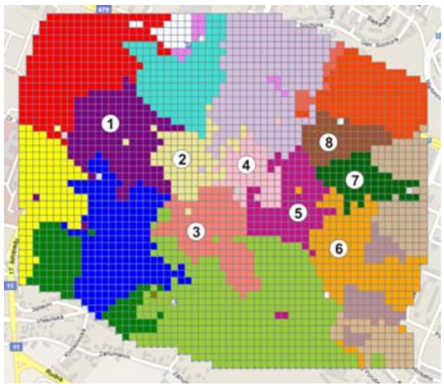

Fig.7. Final calculated map of Best Server for trace D

Output confrontation

There was made a comparison of described method to simulation software on the investigated area which includes 22 segments. The output (shape file) from the simulation software provided by the mobile provider was used as a reference model.

We also checked the influence of number of samples and density of monitored traces on accuracy of Best Server visualization (see table 2).

Table 2. The accuracy comparison

ID	Shape Filled [%]			
	Trace A	Trace B	Trace C	Trace D
1	62,56	53,71	49,82	62,98
2	63,53	50,35	53,58	63,53
3	67,78	81,70	79,59	83,63
4	83,33	57,65	61,58	70,82
5	39,96	42,78	46,23	53,82
6	22,42	21,79	41,68	42,08
7	0,00	0,11	69,53	75,39
8	0,00	41,57	39,96	59,94
overall average [%]	**42,45**	**43,71**	**55,25**	**64,02**

To avoid the lack of possible mistakes in the output comparison, we did not study the marginal sectors on the edges of investigated area. To compare our solution with the software output from mobile operator, we therefore used only minor Best Servers located inside the analyzed area (see Figure 7, ID 1-8). The results of this comparison (see Table 2) are determined by following conclusions:

- Rising density of measured traces increases a percentage matching of our solution with mobile operator's Best Servers (see bottom row in Table 2 - the overall average).
- The measured data in trace A does not contain all Best Servers situated in the investigated area because of the low density measured paths (compare Figure 5 and 7, ID 7 and ID 8). That is the reason why the visualized Best servers were distorted.
- The measured data in trace B also appears to be insufficient due to mostly missing Best Server ID 7. The overall shape's matching increased only slightly.
- The trace C shows the minimum acceptable level of measured density. Distance of measured routes is about 200 m. Data of trace C includes the visualization of all Best Servers located in the investigated area. The average matching exceeds 50%.
- The further increase in measure density (trace D) shows a significant rising in the overall percentage of Best Servers matching.

Conclusion

This article describes an improvement in the proposed algorithm [16] for visualization the Best Server area boundaries. The reference database composed of network parameters is based on a combination measured and interpolated data. Interpolated data are used in places with the absence of measurement points. There was also made an investigation into the influence a number of samples and a density of monitored routes on accuracy of Best Server visualization.

The result of Best Server visualization in LoMo Map Viewer is a real Best Server area that improves the basic operator's visualization shown on Fig.1.

The added contribution of proposed method is designed for small mobile network operators. It is common that large telecommunications companies use for rendering the Best Server areas sophisticated simulation tools such as Pegaplan, ASSET, HiPlan e.g. [17]. Some others non-conventional software also use a computational method such as ParFlow [18], which is based on a Lattice-Boltzmann computing [19].

Not only above mentioned software tools, but also accurate and up-to-date 3D street maps are very expensive. Thus, it makes those software tools inaccessible to small mobile network operators such as those running OpenBTS project. Some pilot trial for larger area GSM network based on OpenBTS project was presented in [20]. The OpenBTS project presents a perspective variant of non-commercial GSM network solution.

Telecommunications operators, however, perform periodic network parameter's measurements, while they need to optimize their network. Contribution of our method consists in a visualization of the Best Server boundaries based on a database of the periodic network parameter's measurements. This is for small mobile network companies an alternative way how to run the network optimization without any added investment.

The results of the Best Server's visualization, while performed a different measurement density, showed a necessity to carry on the research in the larger areas.

In the further research, we plan to focus on larger areas with lower density of BTS. The aim of this effort is to improve an accuracy of the introduced interpolation method.

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