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ASPECTS OF SERVICE LEVEL FOR TRANSPORT LOCATION SERVICES IN GSM

In the article the methodic of GSM parameters evaluation is presented. The proposed solution of segmentation of the cell area according to TA parameter and SSR of neighboring BTS enables to increase the accuracy of transport location information. The exploitation of resources of GSM network as well as the delay of location information update can be reduced by sending empty SMS or SMS with incorrect header. Theoretic results were verified and approved by practical experiments.

ASPEKTY POZIOMU OBSŁUGI DLA LOKALIZACJI TRANSPORTU W SYSTEMIE GSM

W artykule zostało przedstawione wyznaczanie wartości parametrów GSM. Zaproponowane rozwiązanie podziału obszaru na komórki zgodnie z parametrem TA i SSR z sąsiednich BTS umożliwia zwiększenie dokładności informacji o lokalizacji transportu. Eksploatacja zasobów GSM jak również opóźnienie aktualizacji lokalizacji może być zredukowane przez wysyłanie pustych SMS-ów albo SMS ów z niepoprawnym nagłówkiem. Teoretyczne wyniki zostały sprawdzone i zweryfikowane przez praktyczne doświadczenia.

1. INTRODUCTION

The main parameters of GSM (Global System for Mobile Communications) SLA (Service Level Agreement) for LBS (Location Based Services) (GLS) services: location of the object accuracy (A), location answer delay (T), GSM resource usage (R), location platform maintenance cost (MC), location availability time (LA), area coverage (AC)

$$GLS = f(A, T, R, MC, LA, AC) \tag{1}$$

Each parameter could have different impact on service quality:

$$GLS = k_1 A + k_2 T + k_3 R + k_4 MC + k_5 LA + k_6 AC \tag{2}$$

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In GLS most important parameters are A, T, R. The parameters MC, LA, AC must be considered in network planning stage. Let the parameters k_4, k_5, k_6 be equal to 0 in this article. Then the expression (2) can be expressed

$$GLS = k_1 A + k_2 T + k_3 R \tag{3}$$

Each LBS user can choose priorities of these parameters and operator should ensure GLS according to user requirements.

2. SIGNAL STRENGTH RATIO MODEL – THE WAY TO ENHANCE LOCATION ACCURACY

In order to offer connectivity for a mobile user in network, the location of the user has to be known. The method of determining MS location, based on GSM network parameters such as Cell-ID (CID) and Timing Advance (TA) is presented in [1].

In most cases additional parameters of GSM network are used. This is because of the big error (to 35 km), which occurs when only one TA parameter is used. Mobile station (MS) measures the signal level (RxLev) of all the base stations (BTS) it can receive, and sends reports via MEAS_REP message to the BTS it is using at that moment. Thus, information about radio signal strength is available in the network. A 5-bit-long, binary coded RxLev value can be converted directly into a receiver-level dBm.

Several methods and parameters for database (DB) correlation using signal strength have been proposed or realized for positioning purposes in mobile communication networks [6]. The advantages of these techniques include avoiding accuracy degradation in non-line-of-sight propagation conditions. Any changes in buildings or city infrastructure would imply making new measurements to be included in the database. This turns the method into a costly solution.

In the signal strength ratio (SSR) [7] method, the database is constructed from calculated values. The calculations are based on the semi-deterministic model developed in COST 231 [4] for urban areas and on the empirical model according to Hata-Okumura for rural areas [5]. Information about the prediction area as building databases for urban areas is considered as well as digital height models from topographic maps. Starting from [4,5] results, the database can be constructed using information of the whole area segments. The number of the segments depends on TA parameter and signal level variation.

Area is divided into segments. The information about each segment is put into DB. It is taken from the middle point $A_{i,j}$ of each segment.

Fig.1. Dividing area into segments

Each segment is defined by CID_s , which is the identity number of cell-serving BTS, α_1,α_2 - space angles, $RxLev_s$ – the strength of the signal in segment from cell-serving BTS, $CID_{n1},..,CID_{nk}$ – the identity numbers of neighbor base stations, $RxLev_{n1},\ldots,RxLev_{nk}$ – the strength of the signals from neighbor base stations. Each TA zone could be divided into zones. Zone when TA=i, can be described as $Z_{i,j}$.

$$Z_{i,j} = f(CID_s, RxLev_s, \alpha_{i,j}, \alpha_{i,j+1}, CID_{n1}, RxLev_{n1},..., CID_{nk}, RxLev_{nk}) \tag{4}$$

The predictions are based on the semi-deterministic model developed in COST 231 [4] for urban areas and on the empirical model according to Hata-Okumura for rural areas [5].

In order to find the centre of the segment $Z_{i,j}$, the direction from base station to this point should be found as

$$\alpha_{i,j} = \frac{\alpha_{i,j} + \alpha_{i,j+1}}{2} \tag{5}$$

and distance to point

$$l_{i,j} = 550 \cdot i + 275 \text{ m} \tag{6}$$

When DB is constructed, the location of mobile object can be found. We can retrieve the information in the MEAS_REP message during the time period when the mobile phone is active or making the procedures of handover. The information contains: CID_{MSs} – serving BTS cell identity number, TA_{MS} – Timing Advance, $RxLev_{MSs}$ – serving BTS the strength of signal at MS place, $CID_{MSn1},\ldots,$ CID_{MSnk} – neighbor BTS cell identity number, $RxLev_{MSn1},\ldots,RxLev_{MSnk}$ – neighbor BTS strength of the signal at MS place.

When the information from the mobile station is received it could be compared with the information in database in order to find MS location segment.

First of all the set of segments where MS could be is found. CID_s should be equal to CID_{MSs}. TA_{MS} is equal to i. In this case, the set of segments is $Z_{i,1},\ldots,Z_{i,n}$.

When the set of possible segments is selected, the data of segments and data received from the MS can be compared. The answer will be the data closest to the received values from the mobile station. But even if the object is in the same place, signal level can vary in wide range. In order to reduce the possible error in location, it is advisable to compare the ratio of signal levels instead of comparing the strength of the signals. Inadequacy coefficient is calculated by summing differences of the signal level ratios among corresponding BTS

$$Coeff = \sum_{p=1}^{k} \left| \frac{RxLev_s}{RxLev_{np}} - \frac{RxLev_{MSs}}{RxLev_{n1}} \right| \tag{7}$$

The coefficient is calculated for all zones $Z_{i,1},\ldots,Z_{i,n}$. MS belongs to the zone with the minimal coefficient value.

We start by evaluating SSR model for both 2 and 8-dB standard deviation of path-gain measurement error. For comparison, the performance for E-CGI [1] is also included. The result of rural area is shown in Fig.2 and we see that even with 8-dB standard deviation of the measurement error, SSR is superior to E-CGI. The similar results are also in urban and suburban areas.

In rural areas E-CGI model with Hata-Okumura empirical model location error E_{xdB} in any distance d_{km} from serving BTS could be calculated:

$$\lg(d_{km} + E_{xdB}) = \lg(d_{km}) + \frac{PG_{err}}{44.9 - 6.55\lg(h_b)} \tag{8}$$

where h_b – the height of base station, PG_{err} – path-gain measurement error

For path-gain measurement error $PG_{err} = 2dB$: (9)

For path-gain measurement error $PG_{err} = 8dB$: (10)

SSR location error SSR_{err} in any distance d_{km} from serving BTS could be calculated

$$SSR_{err-xdB} = \frac{\sum_{i=1}^{n} E_{xdB} \cdot d_{BTSi}}{n^2} \tag{11}$$

Where n is the number of measured base stations.

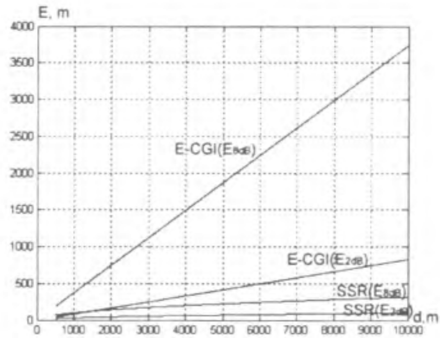

Fig.2. Position error with path-gain measurement error 2-dB, 8-dB (h_b = 100m, distance between BTS – 20km)

3. LOCATION UPDATE – DELAY AND RESOURCES

Short messages can be sent and received simultaneously with GSM voice, data and fax calls. This is possible because whereas voice, data and fax calls take over a dedicated radio channel for the duration of the call, short messages travel over and above the radio channel using the signaling path. As such, users of SMS (short message service) rarely, if ever, get a busy or engaged signal as they can do during peak network usage times. Radio channel has limited bandwidth, so message size impacts on delay. The best way is to send message with no content. The mobile phone communicates with the network in just the same way it does for every other text message, but no message is displayed to the user, and the usual sound signaling the arrival of a message does not occur either. But a "empty" message does create a record of "link data" in the network, which can be used to locate the subject.

Location update time by sending SMS could be prognosticated. Position request message from mobile positioning system (MPS) could be send when probability of location update is high. Location update procedure by sending SMS is shown in Fig.3.

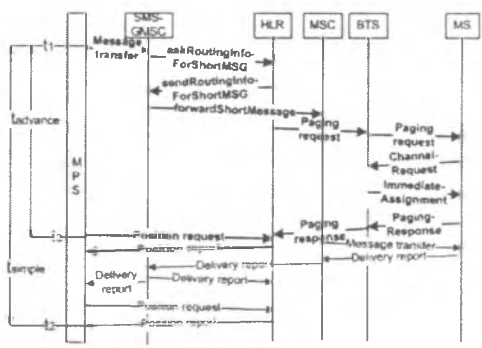

Fig.3. Location update by sending short message

Position request could be made when paging response message is arrived to HLR (home location register). Location update time t is calculated by summarizing operation times in each network segment and data transfer time between network segments. Because of very short operation times in network segments, compared to transfer times between network segments, operation times can not be calculated.
Total time is:

$$t_{simple} = t_{mtt} + t_{pr1} + t_{pr2} + t_{chr} + t_{ia} + t_{prs1} + t_{prs2} + t_{mt} + t_{dr1} + t_{dr2} + t_{dr3} \tag{12}$$

where t_{mtt} – message transfer from MPS to MSC (mobile switching center) time (SMS_{size}/0.450kbps), t_{pr1} – the time of sending paging request from HLR to BTS t_{pr2} – the time of sending paging request from BTS to MS (40bytes/0.782kbps), t_{chr} – the time of sending channel request (1byte/0.034kbps) , t_{ia} – the time of sending immediate assignment (25bytes/0.782kbps), t_{prs1} – the time of sending paging response from MS to BTS (16bytes/0.782kbps), t_{prs2} – the time of sending paging response from BTS to HLR, t_{mt} – the time of message transfer from MSC to MS (SMS_{size}/0.782kbps), t_{dr1} – the time of sending delivery report from MS to MSC (16bytes/0.782kbps), t_{dr2} – the time of sending delivery report from MSC to SMS gateway (SMS-GMSC) , t_{dr3} – the time fo sending delivery report from SMS-GMSC to MPS.

Because $t_{pr1}+t_{prs2}+t_{dr2}+t_{dr3}$ is less than 0.2% of total location update time, these times are not researched accurately.
In this case

$$t_{simple} = t_{mtt} + t_{pr2} + t_{chr} + t_{ia} + t_{prs1} + t_{mt} + t_{dr1} \tag{13}$$

Equation (12) can be expressed

$$t_{simple} = 0.02735 \cdot SMS_{size} + 1.21 \tag{14}$$

From equation it is seen that impact on location update time is made by short message size. So the minimal message size could ensure minimal location update time. That means minimal network resource usage and maximal location update quality.

Because impact on time makes just message size, it is easy to calculate possible location update time. Time also depends on network state and the quantity of messages that was sent at same time.

Message size SMS_{size} when message consists of header (42 bytes) and S symbols can be calculated by the following expression

$$SMS_{size} = 42 + (S \text{ div } 8)*7 + (S \text{ mod } 8) \tag{15}$$

Than the minimal message size will be: SMS_{size}= 42+(0 div8)*7 +(0mod8)=42 bytes and $t_{sms-0} = 2.359s$

Maximal message size will be: SMS_{size} = 42+(160div8)*7 + (160 mod8) = 182 bytes and

It is possible to get positioning answer after paging response in advance of delivery report arriving to MSC. Then

$$t_{advance} = t_{mtt} + t_{pr2} + t_{chr} + t_{ia} + t_{prs1} = 1.768s \tag{16}$$

In this case location answer delay (T) is shorter more than

$$\left(1-\frac{t_{advance}}{t_{sms-0}}\right)\cdot 100 = 25\% \qquad (17)$$

It is also possible to decrease network resource usage time by sending message with wrong header. This means that MSC will not send message to MS, and delivery report message will not be send back to network. Then air interface resource usage time could be reduced by
That means GSM resource usage (R) will be reduced

$$\left(\frac{t_{mt}+t_{dr1}}{t_{sms-0}}\right)\cdot 100 = 35\% \qquad (18)$$

4. THE RESULTS

According to the data received from one of the Lithuania network operators and using HATA formula, the levels of the signals between Vilnius and Kaunas are calculated. The results are obtained in case when CID_{MSs} = 101, TA_{MSs} = 1 and each sector is of 30 degrees is shown in Fig.4.

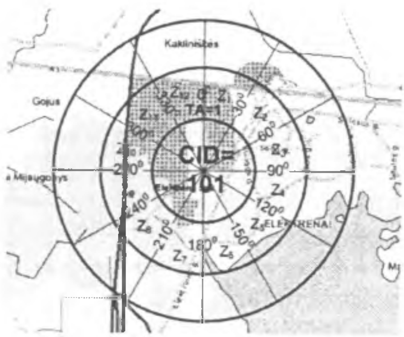

Fig.4. Real zones

The coordinates of serving and neighbor BTS are:

CID_s=101 (E243933, N544716), CID_{n1}=234 (E244023, N544710), CID_{n2}=287 (E243850, N544617), CID_{n3}=117 (E244737, N544629), CID_{n4}=340 (E244133, N544031), CID_{n5}=214 (E245043, N545421).

Table1

Database fragment of calculated values

CID_s = 101, $RxLev_s$ = 65.4 TA = 1					
CID_{ni}	234	287	117	340	214
$Z_{1.1}$	66.89	75.48	79.7	80.61	84.66
$Z_{1,2}$	57.56	73.48	79.53	80.05	84.74
$Z_{1.3}$	52.98	72.42	79.35	79.47	84.9
$Z_{1.4}$	45.93	72.37	79.7	78.99	85.22
$Z_{1.5}$	52.69	68.26	80.22	78.5	85.45
$Z_{1.6}$	63.55	67.48	80.55	77.98	85.98
$Z_{1,7}$	68.04	63.27	81.03	77.98	85.98
$Z_{1,8}$	71.23	63.27	81.51	78.37	86.06
$Z_{1,9}$	72.38	69.77	81.96	78.87	85.98
$Z_{1,10}$	72.38	71.93	81.66	79.47	85.76
$Z_{1,11}$	71.78	72.57	81.2	80.17	85.37
$Z_{1,12}$	69.57	74.42	80.55	80.72	84.9

All values are in dBm and are negative.

The indications of MS are measured at point E 24 39 49, N 54 47 26.

The results are: CID_{MSs} = 101, TA_{MS} = 1, $RxLev_{MSs}$ = -68dBm, CID_{MSn1} = 234, $RxLev_{MSn1}$ = -59dBm, CID_{MSn2} = 287, $RxLev_{MSn2}$ = -73dBm, CID_{MSn3} = 117, $RxLev_{MSn3}$ = -87dBm, CID_{MSn4} = 340, $RxLev_{MSn4}$ = -90dBm, CID_{MSn5} = 214, $RxLev_{MSn5}$ = -95dBm.

Table 2

Calculated results according to (7)

Zone	$Z_{1.1}$	$Z_{1,2}$	$Z_{1,3}$	$Z_{1,4}$	$Z_{1.5}$	$Z_{1,6}$
Coeff	0.391	0.216	0.275	0.462	0.276	0.321
Zone	$Z_{1,7}$	$Z_{1.8}$	$Z_{1,9}$	$Z_{1,10}$	$Z_{1,11}$	$Z_{1,12}$
Coeff	0.447	0.480	0.390	0.405	0.406	0.405

After calculating the coefficients, it emerged that the object is in the zone $Z_{1,2}$.

The correct angle is of 43 degrees. So it can be concluded that the location of the object was estimated correctly.

Also location answer delay (T) with different SMS size (0 symbols, 60 symbols, 150 symbols) and different load (SMS quantity sent at one time) was measured.

Table 3

Measured location answer delay (T)

Size	Load	Delivery time, s			Min time,s	Max time,s
		68%	95%	99.7%		
advance	1	1.803	1.853	1.877	1.75	1.882
0	1	2.833	2.968	2.998	2.502	2.999
0	12	3.408	3.563	3.599	3.004	3.603
0	40	3.958	4.117	4.149	3.560	4.153
60	2	5.698	5.889	5.901	5.451	5.905
150	1	6.044	6.268	6.297	5.451	6.299
150	4	6.115	6.317	6.348	5.556	6.349

5. CONCLUSIONS

Parameters : location of the object accuracy (A), location answer delay (T), GSM resource usage (R) are the main parameters of Service Level Agreement evaluation in GSM networks. The proposed method of dividing cells into segments enables to reduce the positioning error. The experimental results showed that exploitation of resources of GSM network as well as the delay of location information update can be reduced by sending empty SMS or SMS with incorrect header.
The further researches will be developed in the SLA evaluation according to other three - location platform maintenance cost (MC), location availability time (LA), area coverage (AC).

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