Performance evaluation of middleware for provisioning LBS in cellular networks

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Abstract - Location systems based on already-deployed cellular networks spend the resources of the underlying communications network. This paper proposes a middleware that reduces the consumption of resources and optimizes the location traffic load. This middleware, called MILCO (Middleware for Location Cost Optimization), is assumed to run on networks that can choose from among several location techniques (e.g. A-GPS, NMR, etc.). MILCO selects the optimum technique for each request, i.e. the location technique that provides the required quality of service (QoS) and minimizes resource operating expenses. In addition, MILCO takes advantage of ongoing location processes to reduce the overall expenditure of resources. The results show that MILCO reduces the rate of location-process failure and improves latency for location provisioning and resource usage in cellular networks.

Index terms: LBS, middleware, resource-consumption optimization, QoS, UMTS.

I. INTRODUCTION

Several location techniques can now be deployed in cellular networks: cell identification, terrestrial signal trilateration, satellite navigation, fingerprinting, angle of arrival, etc. Each shows different quality-of-service features, usually measured in terms of accuracy, response time, availability and consistency [1]. A wide variety of location-based services (LBS) are also available, each requiring different QoS depending on the purpose of the service. Thus, a location system's ability to process location requests from different LBSs directly depends on the features of the location techniques implemented [2].

Table I outlines the quality of service obtained by the most popular techniques. This table shows that none of the location techniques have excellent performance in all conditions. For example, cell identification methods have very good availability, but usually poor accuracy and consistency, since they depend on cell size; likewise, GPS techniques give

accurate positions but availability is poor indoors, etc.

Hybrid techniques have been proposed as a way to overcome the shortcomings of standalone location techniques. Hybrids combine measurements taken using several techniques in order to take advantage of the strong points of each one [3-7]. These techniques enhance the QoS offered by the system and allow more LBSs to be offered. However, the QoS figures obtained by these techniques are often much better than necessary, which can lead to an inefficient use of the network resources.

<table>
<thead>
<tr>
<th>Technique</th>
<th>Accuracy</th>
<th>Response time</th>
<th>Availability</th>
<th>Consistency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell ID</td>
<td>Fair/Poor</td>
<td>Very good</td>
<td>Very good</td>
<td>Very poor</td>
</tr>
<tr>
<td>Signal strength</td>
<td>Poor</td>
<td>Good</td>
<td>Very good</td>
<td>Very poor</td>
</tr>
<tr>
<td>TOA/TDOA</td>
<td>Good</td>
<td>Good</td>
<td>Fair</td>
<td>Good</td>
</tr>
<tr>
<td>AoA/DoA</td>
<td>Good</td>
<td>Good</td>
<td>Fair/Poor</td>
<td>Fair</td>
</tr>
<tr>
<td>Fingerprint</td>
<td>Good</td>
<td>Fair</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>GPS</td>
<td>Very good</td>
<td>Fair</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Hybrid systems</td>
<td>Very good</td>
<td>Poor</td>
<td>Very good</td>
<td>Good</td>
</tr>
</tbody>
</table>

The approach presented in this paper aims to match the QoS offered and demanded for each specific location query in order to optimize resource use in location systems. The paper is structured as follows. Section II explains the proposed approach. Section III presents the simulation tool used to carry out the performance analysis and the scenarios being simulated. Section IV analyzes the results obtained. Finally, Section V summarizes the main conclusions.

II. LOCATION MIDDLEWARE

A. System definition

The resources consumed by the location system belong to the infrastructure of the underlying cellular network on which
the location services are running. As a consequence, the resources used for location purposes are not available for other traffic. This paper proposes a middleware that optimizes resource use in location systems: MILCO (i.e. Middleware for Location Cost Optimization) [8]. MILCO manages all location processes, thereby reducing resource usage as long as the QoS requested by each specific location query is fulfilled. Several proposals for location middleware have been published recently [9-11], but they focus on technology independence, system integration and the quick development of LBSs without attempting to optimize resource use.

MILCO is designed to be implemented as a new piece of software inside location managers, e.g. inside Serving Mobile Location Centers (SMLCs) in the case of ETSI/3GPP notation [12]. Figure 1 shows a location system architecture that includes MILCO. This figure uses ETSI/3GPP notation. Each time a location request reaches the location system through the GMLC, it is delivered to MILCO. Then, MILCO selects the location technique that best fits the request, i.e. the one that is expected to achieve the requested QoS while minimizing the resources used. Finally, MILCO uses the network facilities to get the user's position and forward the result to the LoCation Service (LCS) client that requested it. This architecture can easily be extended to any cellular system (e.g. 4G PLMNs); the location manager need only include MILCO as the topmost application layer in the stack.

![Fig. 1. Location system integrating MILCO](image)

Figure 2 shows the steps that define MILCO's work for each location request: filtering, location-technique selection and result management. The filtering stage (represented by the blocks above the cost function) aims to filter any location technique that is known a priori to be unsuitable for the request.

![Fig. 2. Block diagram of MILCO](image)

Location techniques can be marked as unsuitable for three reasons: 1) there is an incompatibility (i.e. either the network or the user terminal does not implement the technique); 2) the location technique is unable to achieve the QoS being requested (e.g. the maximum accuracy achieved by the technique is worse than that requested); and 3) there is an input module that can handle the request without running the location technique. The second stage is location-technique selection. In this stage, MILCO selects the optimum location technique from the remaining set (i.e. after filtering). This is done using a cost function that ranks the resource consumption of location techniques. Finally, the third stage manages the results, i.e. procedures are chosen to handle failures, maintain a database with the previous location measurements and calculations, etc. The default behavior on location failures is to execute another location technique. In these cases, the requirement for the response time may be more constrained, since some time has been spent in previous location attempts.

B. Cost function

The cost function is the core module of MILCO. It ranks the location techniques according to their expected use of resources. This rank is used to select the location technique that spends the smallest amount of resources.

The cost function consists of several factors, which together quantify the network-resource usage. Thus, it is defined as:

\[
Z(LT_i, t) = f(a_1, \ldots, a_n; z_1(LT_i, t), \ldots, z_n(LT_i, t)),
\]

where \(Z(LT_i, t)\) represents the resources spent by the \(i^{th}\) location technique (i.e. \(LT_i\)), \(f\) stands for some function, \(a_i\) and \(z_j(LT_i, t)\) are, respectively, the weight and value of the \(j^{th}\) factor applied to the location technique \(LT_i\), and \(t\) is the time at which the resource consumption is going to be calculated.
Several functions \( f \) can be used to calculate resource usage. This paper proposes using a simple additive function with \( n \) factors to evaluate the performance of the module. It is defined as:

\[
Z(LT_i, t) = \sum_{i=1}^{n} \alpha_i z_i \quad (2)
\]

The selection of cost factors is generally left to the operator. For illustrative purposes, this paper proposes three: signaling volume, the use of low-bandwidth channels, and the energy consumption at the user terminal. Signaling volume penalizes techniques that involve exchanging large amounts of data. The use of low-bandwidth channels favors techniques that use wide-band channels, e.g., ones that do not need to cross the radio interface. Finally, energy consumption is included to penalize techniques that quickly drain the user's terminal battery.

C. Input modules

Input modules extend the functionalities of the cost function and improve performance. Two input modules are presented: location cache and concurrence manager. Location cache avoids running a location technique whenever user position can be estimated accurately enough. Location cache works on the basis of two hypotheses: an older user position is available and the user is close to this position. Several approaches can be used to verify that the terminal position is close enough to the last stored position. MILCO builds a database with the result of previous location processes and uses the age of the stored positions as a constraint for the location cache, i.e., it uses old stored positions only when they are not older than a threshold value. If the old stored positions do exceed the threshold value, the average speed of the terminal (calculated based on the stored data) is used to estimate the current position of the mobile station. Then, depending on the required QoS, this estimate can be accurate enough and new resources do not need to be spent in another location technique execution. Note that the more static the users are, the better the expected performance.

Concurrence aims to avoid collisions in location technique executions. A collision happens whenever a location request for a specific user is received while another one, with a higher requested QoS, is in progress. In such situations, the concurrence manager blocks the new request until the ongoing one is finished. The resulting position is then shared by the two requests, even though the QoS returned for some of them is better than necessary. This procedure should perform better as location traffic (per user) increases.

The location cache and concurrence manager help reducing the number of requests that reach the cost function. Hence, no location techniques are run for requests that use these modules. As a consequence, the overall amount of resources is reduced.

III. SIMULATOR AND SCENARIOS

A. The simulation tool

The simulator used in this paper was developed to test the performance of MILCO. The simulator doubly wraps the simulation area to minimize the impact of the edge effect on the results. MILCO is evaluated on urban cellular UMTS networks. An admission control algorithm was implemented. The control algorithm accepts new users as long as the target SIR of any of the ongoing calls in the cell does not drop more than 1 dB. Power control parameters are detailed in [8, 16]. A basic scenario is simulated in which several location loads ranging from 1 request per 30 seconds to 2 requests per second are applied. The base station layout consists of 100 Node-Bs (NBs) distributed uniformly throughout the simulation area.

The propagation pattern follows the Okumura-Hata model, with path-loss slope and zero-meter losses set to 4 and 23 dB, respectively. SIR is calculated according to [18], where spreading and orthogonality factors are 10 dB and 0.4, respectively. Accordingly, the cell coverage of each Node-B is estimated at 1135 meters. The distance between Node-Bs is 1400 meters. Most of the covered area is covered by more than one Node-B. This puts the simulation closer to reality and allows OTDOA, which is not possible in areas covered by only one or two Node-Bs. Handoffs are requested each time the received power or SIR in a Node-B or mobile station (MS) falls below a threshold. The handoff request is held until a new channel is allocated, as long as the received power and SIR are between the handoff threshold and the sensitivity of the terminal. If SIR or received power falls below the sensitivity level, the handoff is attempted for a maximum of 15 seconds. If no channel is allocated during this time, the service is interrupted and the user terminal backs off for an average exponential time of 5 seconds. Successful handoffs drop all ongoing requests at the mobile station. Table II shows the main parameters of the propagation pattern, which were taken from [17, 18].

The scenario is populated with a single pedestrian user. More users are not needed in this preliminary evaluation since the performance of MILCO is user-oriented. This is because MILCO makes decisions according to location-request features, which are finally targeted to a specific mobile station. Including several mobile stations constrains the access network (e.g., mobile-based location techniques, power-control algorithm, etc.). The impact of this on MILCO is left for further study. The user may move freely within the layout and go into buildings. Buildings represent indoor zones, i.e., signal reception is limited inside them. The user's speed (in both directions) follows a normal random variable, with a mean and standard deviation of 0.6 m/s and 0.18 m/s, respectively. The user's speed in both directions is updated once per second.
TABLE II
PARAMETERS OF THE PROPAGATION PATTERN

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum SIR</td>
<td>-9 dB</td>
</tr>
<tr>
<td>Sensitivity of the stations</td>
<td>-109.2 dBm</td>
</tr>
<tr>
<td>Maximum MS transmission power</td>
<td>21 dBm</td>
</tr>
<tr>
<td>Minimum MS transmission power</td>
<td>-44 dBm</td>
</tr>
<tr>
<td>Node-B transmission power</td>
<td>43 dBm</td>
</tr>
<tr>
<td>Handoff threshold for received power</td>
<td>-106.2 dBm</td>
</tr>
<tr>
<td>Handoff threshold for SIR at reception</td>
<td>-6 dB</td>
</tr>
</tbody>
</table>

B. Location techniques and MILCO

All location techniques available in UMTS (i.e. Cell-ID, OTDOA and A-GPS) are considered. A hybrid tight-synchronized OTDOA/A-GPS location technique [3] is also included to show the features of the hybridization upgrade. Table III shows the accuracy and response times achieved by each technique [19]. In this table, mean is the average value, range indicates the set of values that the variable can take, std is the standard deviation, det stands for deterministic and n.a. means that the parameter does not apply. Availability of OTDOA is computed based on the received power and SIR. This means that three or more BSs are expected to be seen in the MS in order to run OTDOA. Otherwise, OTDOA is not available at that instant/position. For satellite-based techniques, availability is checked in a different way. The scenario defines a default number of 5 satellites in sight. However, in indoor zones, this figure is uniformly distributed from 1 to 2 satellites [20].

TABLE III
QoS ACHIEVED BY THE LOCATION TECHNIQUES

<table>
<thead>
<tr>
<th>Location techniques</th>
<th>Cell-ID</th>
<th>OTDOA (AS)</th>
<th>OTDOA (NAS)</th>
<th>A-GPS (AS)</th>
<th>A-GPS (NAS)</th>
<th>Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution</td>
<td>Det.</td>
<td>Uniform</td>
<td>Gaussian</td>
<td>Gaussian</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range (m)</td>
<td>n.a.</td>
<td>[50...250]</td>
<td>n.a.</td>
<td>n.a.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (m)</td>
<td>1135</td>
<td>150</td>
<td>3</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Std (m)</td>
<td>0</td>
<td>57.73</td>
<td>0.90</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Response time</td>
<td>Det.</td>
<td>Exponential</td>
<td>Exponential</td>
<td>Exponential</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (s)</td>
<td>0</td>
<td>7</td>
<td>11</td>
<td>27</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All features of MILCO are implemented: cost function and input modules. Positions remain cached for 2 seconds. The cost function used is the one presented in Eq. (2). The quantification of the cost factors is shown in Table IV, where \( N_{NB} \) and \( N_{SAT} \) stand for the number of Node-Bs and satellites involved in positioning. Two modes are specified in Table IV for OTDOA and A-GPS: assisted (AS) and not-assisted (NAS). Assisted mode involves sending the assistance data to the mobile station, while not-assisted mode assumes that this information has already been sent. Simulations are run under the assumption that the assistance data (for OTDOA and A-GPS) expire after 30 seconds [21], i.e. new assistance information is required 30 seconds after reception. In the computation of the signaling volume, only the topmost protocol in the stack (i.e. RRC for all techniques except Cell-ID) has been taken into account. The estimate of the low-bandwidth channel usage is obtained by counting the number of times an interface is crossed and dividing this figure by the throughput of the channel. Energy consumption depends on the terminal's electronics. The authors propose a quantification based on the number of signal transmitters involved in the location technique.

TABLE IV
QUANTIFICATION OF THE FACTORS USED IN THE COST FUNCTION

<table>
<thead>
<tr>
<th>Technique</th>
<th>Signaling volume (bits)</th>
<th>Low-bandwidth channel usage (ns)</th>
<th>Energy consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell-ID</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>OTDOA (AS)</td>
<td>375 + 134 \cdot N_{NB}</td>
<td></td>
<td>N_{NB}</td>
</tr>
<tr>
<td>OTDOA (NAS)</td>
<td>268</td>
<td></td>
<td>N_{NB}</td>
</tr>
<tr>
<td>A-GPS (AS)</td>
<td>473 + 1199 \cdot N_{SAT}</td>
<td>\begin{bmatrix} 210^0 + 210^0 \cdot \frac{155Mbps}{384Kbps} \end{bmatrix}</td>
<td>N_{SAT}</td>
</tr>
<tr>
<td>A-GPS (NAS)</td>
<td>461 + 647 \cdot N_{SAT}</td>
<td></td>
<td>N_{SAT} + N_{NB}</td>
</tr>
<tr>
<td>Hybrid</td>
<td>653 + 134 \cdot N_{NB} + 1254 \cdot N_{SAT}</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The impact in the cost function is the same for all factors and the maximum value of a weighted factor is set to 1. Thus, the maximum value of the cost function is 3. The weights \( \alpha_j \) applied to the factors in order to achieve this behavior are 1.3651 \cdot 10^{-4}, 1.9152 \cdot 10^{-4} and 1.25 \cdot 10^{-1} for signaling volume, low-bandwidth channel usage and energy consumption, respectively. This static assignment of weights is proposed for evaluation purposes. Fine-tuning the weights is out of the scope of this work.

MILCO's performance is expected to depend on the traffic pattern of location queries. Two kinds of scenarios are simulated: single generic service and multiple specific services. The first scenario evaluates MILCO under unknown traffic conditions, i.e. with a wide range of QoS requirements so that several LBSs are included in the definition. In this scenario, the requests are generated by a single service that demands uniformly distributed accuracy from 10 meters (e.g. tracing, tracking and emergency services, etc.) to 2 km (e.g. location-based information, enhanced call routing, etc.). The response time required by this service is also uniformly distributed between 0 seconds, which means that the location must be provided immediately (e.g. urgent emergency services), and 60 seconds (e.g. push services). The time between consecutive requests is assumed to be exponentially distributed. The second scenario evaluates MILCO under more realistic conditions that take into account the already-deployed LBSs in current mobile networks. Accordingly, four services are used to generate location requests: emergency, tracking,
tracing and push service. Table V shows the main parameters of these services, where accuracy and response time stand for the maximum error and delay allowed. Time between consecutive requests is assumed to be exponentially distributed in all services. Emergency, tracking and push services involve a single request per LBS, while tracing service produces a burst of requests. The burst size is uniformly distributed from 1 to 5 requests, with an interval of 20 seconds between consecutive requests.

<table>
<thead>
<tr>
<th>Service</th>
<th>Average time between requests</th>
<th>Accuracy</th>
<th>Response time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency</td>
<td>30 min</td>
<td>50 m</td>
<td>10 s</td>
</tr>
<tr>
<td>Tracking</td>
<td>2 min</td>
<td>150 m</td>
<td>15 s</td>
</tr>
<tr>
<td>Push service</td>
<td>300 min</td>
<td>1500 m</td>
<td>15 s</td>
</tr>
<tr>
<td>Tracing</td>
<td>10 min</td>
<td>50 m</td>
<td>15 s</td>
</tr>
</tbody>
</table>

In all of the scenarios, both accuracy and delay constrain the QoS, i.e. failure to obtain one of them results in a QoS failure (3GPP allows other QoS approaches, but this study uses the most restrictive one).

IV. PERFORMANCE ANALYSIS

This section analyzes the performance of MILCO, focusing on the resources used by each LBS and the location traffic load. Standalone location techniques are included for comparison.

Figure 3 shows the percentage of successful LBSs in scenarios loaded with an average of 1 request per 30 seconds (0.033 requests/second), using only the cost function (i.e. input modules are disabled). In the case of a single generic service, the best results among the standalone location techniques are obtained by A-GPS and OTDOA. The hybrid technique is constrained by the long response times, resulting in a poor successful LBS rate of 60%. As expected, the low accuracy of Cell-ID seriously constrains its performance—it achieved the worst results of all the techniques. The cost function in MILCO outperforms all of these techniques, since it manages them in a more suitable fashion. MILCO successfully delivers 92.53% of the LBS requests. Results for the case of multiple specific services are similar, but with lower successful LBS rates. This is due to the higher QoS requirements of the location services.

Figure 4 shows the average number of location techniques run for each of the service requests, according to the simulated scenarios shown in Figure 3. Figures greater than unity are expected since the system tries to fulfill the accuracy requested by the service as long as the response time has not expired. Cell-ID, as expected, ran only once since more trials in the same cell delivered the same result. For single generic service, MILCO performed as well as the best standalone technique. The results for multiple specific services were completely different. The figures for the A-GPS and hybrid techniques were very close to one. This is because, in this scenario, the service response times were shorter than it was in the case of a single generic service, which penalizes the most time-consuming techniques (i.e. A-GPS and hybrid). Accordingly, there was no time to reattempt location after a failure using these techniques. The same applies to the OTDOA/A-GPS coupling technique. Standalone OTDOA had to be run several times per service request, since most of the time the required accuracy was better than that provided by OTDOA. MILCO's average number of techniques run per service request was higher than that of A-GPS, but its resource usage was 23.7% lower. This demonstrates that MILCO benefits from the strengths of all the location techniques, thereby improving the overall performance.

Performance is expected to improve through the input modules. Hereafter, all measurements are obtained by implementing location cache and concurrence manager. Figure 5 plots the unsuccessful LBS requests versus location load. The figures for single and multiple services are different. This is due to particularities of the QoS requested by the LBS in each scenario. Accordingly, in the single generic service
scenario, the unsuccessful LBS rates ranged from 4% to 8%, while in the multiple specific services scenario the same variable went from 17% to 36%. However, MILCO seemed to perform in the same way regardless of the scenario: the higher the load, the lower the unsuccessful LCS rate. This is due to the shorter time interval between consecutive location requests, which makes cache and concurrence features more likely to be used. This proves that the scalability of the proposed approach is guaranteed: for heavier loads, the input modules' performance reduces the percentage of unsuccessful requests. In the case of multiple specific services, improvements were more noticeable since the QoS requirements were higher. Also, the results obtained by MILCO were better than those achieved using a single technique, either standalone or hybrid.

**Fig. 5. Changes in unsuccessful LBS rates with MILCO**

MILCO's other strong point is reduced resource use. Figure 6 plots the average number of location techniques run per location process. This figure shows that, at lighter loads (i.e., rates lower than 0.05 requests/second), the average number of location techniques remains very close to 1. This is because, at these rates, concurrence and cache are not useful and only the cost function is used. Therefore, only a few processes have enough time to run more than one location technique (if necessary) and fulfill the response-time requirements. The higher accuracy demanded in the scenario with multiple specific services implies more LCS failures and consequently more techniques run in the same LBS in order to satisfy the requirements. The number of location techniques used falls as the load is increased, since input modules handle requests without running any techniques.

**Fig. 6. Average number of location techniques used by MILCO**

Figure 7 shows the performance of the cache input module. This figure shows that the cache impact increases as the load becomes heavier. This makes sense, since it is more likely to receive two or more requests involving short displacements, thus using the cache feature instead of running a usual technique. In fact, cache handles 16.98% and 52.57% of the requests in the scenarios with a single generic service and multiple specific services, respectively. The intensive use of cache in the location system results in a reduction in the average location techniques used per LBS and, consequently, an appreciable drop in resource use. This confirms the scalability of MILCO and reduces the average number of techniques used from more than 1.1 in the more lightly loaded scenarios to less than 0.7 in the more heavily loaded scenarios. Better results are expected as the cache time expiration is extended.

**Fig. 7. Percentage of requests handled by cache input module**

Figure 8 shows the average resources consumed by MILCO according to the definition provided in (2). In this figure, 100% of resource usage is achieved by means of the hybrid technique, based on the data shown in Table IV and the weights used in the cost function. Therefore, the average resource usage represents the cost of requests handled by MILCO in terms of the consumption of resources achieved using only the hybrid technique. OTDOA/A-GPS coupling is taken as a reference for this analysis, since solutions of this kind currently provide the most accurate positions. In lightly loaded scenarios, location cache and concurrence manager are seldom used. This means that MILCO is reduced to cost function. However, using only this feature, resource use drops
dramatically (i.e. about 60% and 20%, respectively, in the single and multiple service scenarios). This is because the location techniques used are selected based on the QoS demanded, the features of the network and the capabilities of the mobile station. Better figures are achieved when the load increases, thereby reducing resource consumption by up to 14.17% and 32.20% in single and multiple service scenarios, respectively. This improvement is due to the increased use of location cache and concurrence manager, since these modules satisfy location requests at zero cost.

![Graph showing resource usage with MILCO](image)

**Fig. 8. Average resource usage with MILCO**

Even though the location concurrence algorithm provides several benefits with regard to load and resource-usage reduction, its performance is far from optimum. Figure 9 shows that most of the LCS failures at higher loads are due to the concurrence manager (e.g. at 1 request per second, the concurrence manager was involved in 33.97% and 44.85% of the LCS failures in single and multiple service scenarios, respectively). Although insignificant (the percentage of unsuccessful LCSs at these rates is the lowest), this behavior indicates that input modules can be improved and that MILCO's performance can therefore be expected to improve.

![Graph showing percentage of unsuccessful LCSs](image)

**Fig. 9. Percentage of unsuccessful LBSs handled by concurrence input module**

V. CONCLUSION

This paper presents a middleware that reduces the use of network resources and maximizes the traffic load in location platforms. MILCO's three most important modules are: cost function, location cache and concurrence manager. Although the analysis of MILCO's performance is focused on UMTS networks, this middleware was designed to be implemented in any cellular network (e.g. 4G PLMNs). Two scenarios were simulated: a single generic service and multiple specific services. MILCO drastically reduced the unsuccessful LCS rate in all scenarios, which involves a greater location traffic load. This reduction is generated by the cost function and reinforced by the input modules. This benefit in traffic is complemented by a reduction in network resource use (defined as the average of several factors). MILCO reduces resource consumption by up to 14.17% and 32.20% in single and multiple service scenarios, respectively, compared with the figures achieved using hybrid A-GPS/OTDOA technology, the technique that consumes the most resources. Better results are obtained with the middleware than with other techniques.

MILCO allows input modules to be developed in order to improve its performance. Two are presented: location cache and concurrence manager. These input modules make MILCO scalable, since increasing the load involves reducing the unsuccessful LBS rate and the resource usage.

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