Conveying and Handling Location Information in the IP Multimedia Subsystem

Miran Mosmondor, Lea Skorin-Kapov, Renato Filjar, and Maja Matijasevic

***Abstract*— The IP Multimedia Subsystem (IMS), specified by the 3rd Generation Partnership Project (3GPP), is a key element in the next-generation network (NGN) converged architecture. Extending the IMS towards provisioning support for location based services (LBS) will enable enhanced services and offer new revenues to the operator. Conveying location information in the IMS and connecting the IMS with a positioning system are still open issues. This paper presents the design and implementation of an IMS Location Server (ILS) integrating IMS with a positioning system. From the IMS perspective, the ILS serves as a service enabler for LBS. In order to demonstrate proof-of-concept in enhancing IMS-based services, two prototype service scenarios have been implemented: Location-aware Messaging (LaM), and Location-aware Push-to-Talk over cellular (LaPoC). Some work has been done by the IETF in the area of location information transport based on the Session Initiation Protocol (SIP). This paper proposes improvements in this area, primarily related to reducing the necessary amount of signaling with the specification of a new type of location filter. We have conducted measurements in a laboratory environment in order to illustrate our proposed solution and verify the benefits compared to existing solutions in terms of traffic load and session establishment time. Furthermore, we present a case study integrating the ILS with the Ericsson Mobile Positioning System (MPS).**

I. Introduction

Location awareness is an important issue affecting numerous human activities and even forcing the creation of a special scientific discipline called navigation in order to develop the means for location and travelling management. In recent years, location has acquired a completely new dimension through introduction of a special group of telecommunication services that explore location awareness. Location-based services (LBS) have become one of the most prosperous groups of emerging telecommunication services [1]. In their essence, location-based services successfully integrate three basic building blocks [12]: positioning systems, (mobile) communication systems, and location content.

Positioning systems serve as the entities for determination of an end-user's position in a suitably chosen reference frame in space. Position determination is conducted by combining several positioning sensors' outputs (satellite positioning, network positioning, radio positioning, etc.) with required quality of positioning service [11], which is usually referred to as *positioning sensor fusion*. Mobile communication systems provide reliable means for position reports and location content exchange between mobile units and the rest of the LBS system.

Location content refers to location-related information presented in various forms (charts and maps, numerical and textual content, multimedia, etc.) delivered either to the mobile unit or some third application (emergency call E112 service, for instance). Since location content is gradually shifting towards a multimedia form of presentation, it seems a natural step forward in LBS development to consider the utilization of the latest related communications technologies, such as the IP Multimedia Subsystem (IMS).

The IMS is an internationally recognized standard comprised of core network elements for the provisioning of end users with advanced multimedia services [2]. IMS-based services being deployed by operators today include Push-to-talk over Cellular (PoC), Presence, Instant Messaging, and wireline broadband VoIP services. A wide range of location applications built around existing and emerging IMS services may be foreseen, including:

- presence and location (friend location visible in address book)
- users sending messages or initiating IMS sessions only with other users located at a defined distance
- context aware adaptation based on user location (e.g. user's communication preference is changed depending on whether the user is at work or at home)
- users sharing their location via shared maps
- location aware multimedia information broadcasting

With the provisioning of user location information considered as a generic and reusable network-provided enabling technology, this paper proposes the introduction of a service enabler called IMS Location Server (ILS) located in the IMS Service Layer. The general aim is to provide a generic model for successful implementation of a variety of location services within the IMS. The ILS provides an interface towards a positioning system to retrieve user location information, thus providing the means of making this information available to other IMS application servers. The solution is independent of a particular service and is intended to support the enhancement of existing and emerging IMS-based services. A key issue regarding ILS deployment is integration with IMS signaling and specification of the ILS SIP interface. Having analyzed existing IETF documents (RFCs) [14][15][16] and drafts [13][17] and identified shortcomings regarding location conveyance,

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we propose a novel location filter to be included in SIP signaling. The benefits of our approach are demonstrated with a prototype implementation and performance measurements.

The basics of location information, the IMS, and SIP location conveyance are described in the following section. Section III presents the design and implementation of the proposed ILS. The solution is demonstrated with two different service scenarios, namely Location-aware Messaging (LaM), and Location-aware Push-to-talk (LaPoC). In Section IV we present a case study where we integrate the ILS with the Ericsson Mobile Positioning System (MPS). Section V describes tests that were conducted to measure signaling performance.

II. Background

This section provides a background to location information in general, the IMS, and SIP. Furthermore, the status of standardization in the area of SIP location conveyance is described.

A. Sources of location information

Location-based services depend on accurate and reliable determination of a mobile entity's position. Position is a place in (three-, two- or one-dimensional, depending on the application) space where an entity is at the particular moment in question. In order to achieve robust, reliable and accurate position determination, several positioning methods are usually deployed, either alone or as a combination. Due to its unbeatable performance compared with other methods, satellite positioning is considered a preferred method [3][11], while the others serve either as the augmentation, supporting methods when satellite positioning is not available, or as redundant methods. At present, only the US Global Positioning System (GPS) is fully operational, with the European Galileo system scheduled for 2008, and the Russian Glonass undergoing modernization. Satellite positioning methods do not only supply the latitude and longitude of the mobile object in question, but are also capable of providing several additional elements of his/her/its dynamics (velocity, azimuth, altitude etc.) [11].

Besides the satellite positioning methods and systems, there are several applicable positioning methods which do not rely upon satellite signals, but rather on certain terrestrial signals. First, there are network positioning methods, which utilize the mobile communication network signalling for determination of a mobile object's position (TOA - Time of Arrival, OTDOA - Observed Time Difference of Arrival and E-OTD - Enhanced Observed Time Difference) [12]. Then, there is an emerging and very promising group of terrestrial radio positioning methods that utilize the wireless signals of different wireless devices (WLAN, Loran C, RFID, UWB systems etc.). The goal of every positioning process is the determination of a mobile object's (pedestrian, car, train, ship, yacht, plane, spacecraft) position. It is usually obtained in the form of so-called geodetic position [14], that consists of the elements such as geographic latitude, geographic longitude and altitude. However, in certain cases it is possible and even favorable to avoid managing geodetic position, since the additional transformation would be needed for location content preparation. In such cases, the so-called civic address position [14][17] is used, which contains elements such as: street, town, county, country, road intersection etc. Position determined in such a way is further used for delivery of location content or location services to users who have asked for them.

Our focus in this work is not on positioning methods and systems as such, but rather on conveying and handling location information (obtained from positioning systems) within the IMS.

B. IP Multimedia Subsystem (IMS)

In the move towards a converged network architecture, the IMS represents a key element in the Universal Mobile Telecommunications System (UMTS) architecture supporting ubiquitous access to multimedia services. Originally specified by the Third Generation Partnership Project (3GPP) [2] (now embraced by other standards bodies including ETSI/TISPAN), IMS is considered to play a key role in merging the Internet and cellular worlds [10]. As the IMS is intended to be "access agnostic", it is applicable in any network with packet-switched functions (e.g. GPRS, UMTS, CDMA2000, WLAN, DSL, cable etc.), while interworking with legacy networks will be supported through gateways. While users with 3G terminals may have packet switched data access to the Internet even without the IMS, key IMS benefits include: Quality of Service (QoS) support securing enhanced service quality; service integration by defining standard interfaces over an IP-based infrastructure; and support for flexible charging.

Based on a horizontally layered architecture, the IMS provides open call/session control with interfaces to service and connectivity layers in both wireless and wireline industries. As shown in Fig. 1, the IMS consists of 3 layers: Service Layer, Control Layer and Connectivity Layer. Of the most significant protocols used in the IMS, we point out the Session Initiation Protocol (SIP) chosen by 3GPP as the protocol for session establishment, modification, and release.

The Service Layer comprises application and content servers to execute value-added services. The IMS allows for generic and common functions (implemented as services in SIP Application Servers) to be reused as building blocks for multiple applications and services. This implies the flexible introduction of new services offering rich user experiences, with fast time-to-market and simplified service creation and delivery. Accordingly, the proposed ILS provides location services to other IMS Application Servers (AS) via a standard SIP interface.

The Control Layer comprises network control servers for managing call or session set-up, modification and release. The key IMS entity in the Control Layer is the Call Session Control Function (CSCF) which is responsible for session control and processing of signaling traffic. The CSCF may take on different roles, depending on the functionality it provides: Proxy-CSCF, Serving-CSCF, or Interrogating-CSCF. The Serving-CSCF is the central entity located in the user's home network which is responsible session establishment, modification, and release. The Home Subscriber Server (HSS) is a user database, which serves as a central repository for user related information. The Media Resource Function (MRF) is

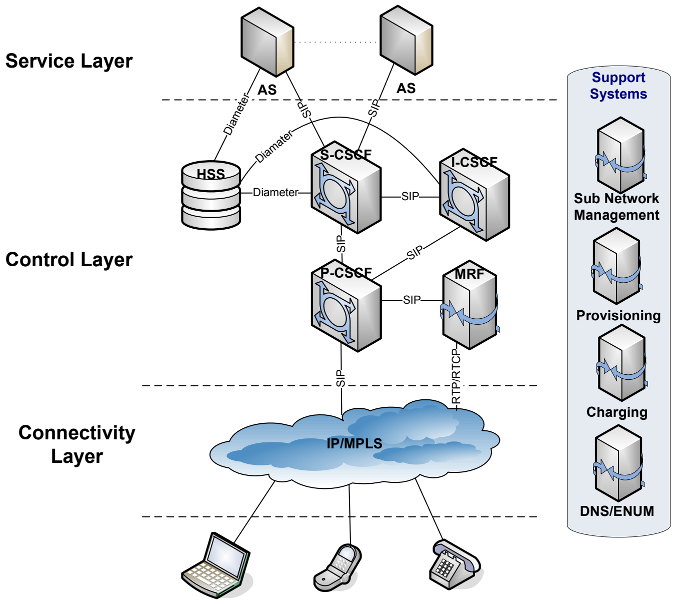

Fig. 1. Simplified IP Multimedia Subsystem (IMS) layered architecture.

responsible for the manipulation of multimedia streams, and provides a source of media in the home network.

The Connectivity Layer comprises routers and switches, both for the backbone and the access network.

C. SIP location conveyance

The Session Initiation Protocol (SIP) [19] has emerged as part of the overall IETF multimedia architecture, providing advanced signaling and control functions for a wide range of multimedia services. SIP is defined as an application-layer control (signaling) protocol for creating, modifying and terminating sessions with one or more participants, and has been adopted by 3GPP as the key session establishment protocol in the IMS.

Conveying location information over SIP is a relatively new issue and is not completely standardized, although there are several IETF documents dealing with this subject. Internet draft [17] defines an extension to SIP to convey geographic location information from one SIP entity to another SIP entity. It describes the extension to SIP needed for complying with the using protocol requirements specified in [15] when the location server is a User Agent (UA) or Proxy Server and the location recipient is another UA or Proxy Server. The extension covers end-to-end conveyance as well as location-based routing, where proxy servers make routing decisions based on the location of the User Agent Client (UAC). An example of location based routing is an emergency call. In such a case, the location of a caller is used to determine which Public Safety Answering Point (PSAP) should receive an emergency call request for help. The security and privacy considerations that must be applied to location conveyed with SIP are also described in [17].

The IETF proposes a protocol independent object format for conveying location information [14], extending the XML-based Presence Information Data Format (PIDF) to allow the encapsulation of location information within a presence document. As the baseline location format in PIDF-Location Objects (PIDF-LO), the Geography Markup Language (GML) 3.0 [7] was selected. Location can be transmitted by-value or by-reference. Location-by-value refers to a user agent including a PIDF-LO as a body part of a SIP message, sending that location object to another SIP element. Location-by-reference refers to a user agent or proxy server including a URI in a SIP message which can be exchanged by a location recipient for a location object, in the form of a PIDF-LO.

The main extension to SIP, proposed in [17], is the introduction of the *Geolocation* header to indicate that location is included in a SIP message. The *Geolocation* header provides either: (1) a content identifier (cid:) pointer to the body part containing the User Agent Server (UAS) PIDF-LO, or (2) a location-by-reference URI that may subsequently be "de-referenced" by a using protocol (which may be SIP or another protocol). A new error message (424 Bad Location Information) is also defined. This response code is a rejection of the location contents, within the original SIP Request. If the location was sent by-value, the error indicates the location information was malformed or not satisfactory for the recipient's purpose. If the location was sent by-reference, the error indicates that location could not be obtained using the URI.

In [17], a new option tag called 'geolocation' is proposed. This option tag is to be used in the *Require*, *Supported* and *Unsupported* SIP headers. Whenever a UA wants to indicate it understands this SIP extension, the 'geolocation' option tag is included in a *Supported* header of the SIP message. Beside SIP extension, an extension to the PIDF-LO is proposed with a new 'routing-query-allowed' element, defined in the 'usage-rules' element. When 'routing-query-allowed' is set, the receiving element may forward the location information to another element to obtain routing information, even if 'retransmission-allowed' value is 'no'.

Conveying static location in PIDF-LO bodies is straightforward. However, the difficult part about asynchronous notification of location information is that many forms of location are measured as a continuous gradient. Unlike notifications using discreet quantities, it is difficult to know when a location change is large enough to warrant notifications. Moreover, different applications require a variety of location resolutions.

Location filters are necessary to specify events that will trigger notifications to subscribers because location information is continuous and not discreet. We can not expect to flood the network (periodically or not) with responses carrying location information. Defined location filters [13] are XML documents which limit location notification to events which are of relevance to the subscriber. The following is defined as an initial list of Interesting Events:

- the resource moves more than a specific distance horizontally or vertically since the last notification;
- the resource exceeds a specific speed
- the resource enters or exits one or more GML objects included or referenced in the filter
- one or more of the values of the specified address labels has changed for the resource

III. Design and Implementation of ILS

In order to demonstrate the proposed ILS functionality and its applicability for different IMS services, we have implemented two proof-of-concept services enhanced with location information: (1) Location-aware Messaging (LaM), and (2) Location-aware Push-to-Talk (LaPoC). We present the IMS architecture incorporating the ILS enabler, LaM and LaPoC application servers, and discuss the ILS SIP interface. In the case of LaPoC, we have identified the need for extending the signaled location filter in cases when location information is required for a group of users, and the location distance between users is specified as a relative (rather than static) distance. We have conducted measurements in order to illustrate our proposed solution and verify the benefits compared to existing solutions (presented in Section V).

A. IMS Location Server (ILS)

The ILS is designed as a generic SIP Application Server (AS) located in the IMS Service Layer. Methods for determining user positions are not implemented within ILS; rather, ILS is responsible for delegating the location request to the positioning system. Using the terminology proposed in [3], the ILS takes on the role of a Location Services (LCS) Client and obtains location information from an LCS Server. All other ASs requiring location data may send requests to the ILS along a SIP interface (directly or via the Serving-CSCF node). Such a concept provides a central location in the IMS Service Layer that provides location data, rather than having each AS separately requesting data from a LCS Server. The architecture integrating ILS in IMS and connected with a generic Positioning System is shown in Fig. 2.

The simplest case involving a location request and response is referred to as the *immediate location request*, in which case a requesting entity asks for a location response to be delivered immediately after the location request is received [3]. In another case, a location request is sent to a server, but a response is received only when a certain condition stated in the request is fulfilled. Such a service is called a *deferred location request*. An example is a service initiator requesting to be notified when another user enters a certain area, such as a building or a city. Practical implementation of this service requires the location server to monitor the users' locations. Requirements become even more challenging when the designated area is not static, and a group of users is to be monitored instead of a single user.

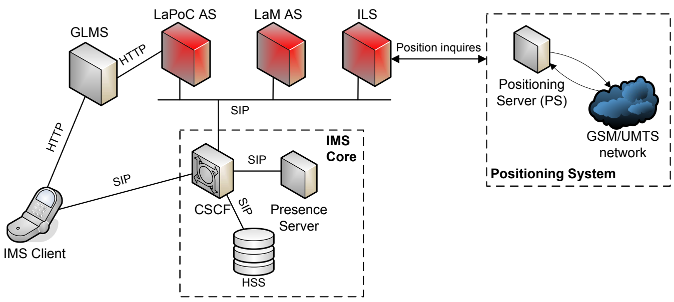

Fig. 2. Integration of the ILS in the IMS architecture.

B. ILS SIP interface

As mentioned earlier, the IETF is working towards standardization of SIP location conveyance. The usage of Presence-based GEOPRIV Location Objects (PIDF-LO) [14] carried in the body of a SIP message is proposed. Currently not addressed by any IETF draft or RFC is conveying location filters and triggered location responses. Internet draft [13] describes the format of these filters but not the details on the protocol for their exchange. Also, as mentioned before, Internet draft [17] deals only with end-to-end location information conveyance. IETF RFC 4079 [16] shows the applicability of the Presence architecture for distribution of Location Objects (LO). In this way, the SIP event framework, defined in [18], is indirectly suggested for conveying location filters and triggered notifications. Hence, the same principles that were used for standardization of the presence service in IMS can be used for location information. The SIP event framework defines a SIP extension for subscribing to, and receiving notifications of, events. It leaves the definition of many aspects of these events to concrete extensions, known as event packages. We propose the definition of a new SIP event package for location conveyance. The name for this package is 'geolocation'. This value appears in the *Event* header field present in SIP SUBSCRIBE and NOTIFY requests.

Location filters are necessary to specify events that will trigger notifications to subscribers. Several such events and corresponding filters are defined in [13], of which the *enterOrExit* filter is most suitable for both the LaM and LaPoC services. The *enterOrExit* filter triggers notification when a user enters or exits a named 2-dimensional or 3-dimensional region or list of regions corresponding to a GML feature.

C. Location-aware Messaging (LaM) service

The IMS Messaging service, as specified by 3GPP [4], incorporates one or more of two messaging types: *Immediate messaging* and *Session based messaging*. With *Immediate messaging* the sender expects immediate message delivery in what is perceived as real time. With *Session based messaging* a communications association is established between two or more users before communication can take place. Typical characteristics are instant or postponed delivery of the messages to the targeted recipient(s) and interaction with presence information where users are able to see who is on-line as well as their status.

We propose the idea of a new messaging service in IMS incorporating location information called Location-aware Messaging (LaM). The service can be described as a location triggered messaging service. It provides a mechanism for sending short multimedia (e.g. text, audio/video clip, picture) messages from one user to another user or group of users, whereby the sender can specify the area in which the recipients need to reside in order to receive the message. If the recipients enter the given area during the time interval defined by the message's lifetime, they will receive the message sent by the sender. The user posting the message is able to select where to leave the message, e.g. at their current location, at some predefined location (home, work, etc), or at a location selected from a map; specify area size, message lifetime and whether to receive a report when the message is received by another user(s).

Prototype implementation of the proposed service includes a Location-aware Messaging Application Server (LaM AS) which utilizes several IMS enablers, including the proposed ILS (Fig. 2). The SIP event framework, described earlier, is used for communication between LaM AS and ILS. Upon receiving a so called *post-it message* (current implementation includes support for text only), the LaM server composes a subscription for the position of the designated user with respect to the specified area, taking the expiration time of the subscription to be equal to the *post-it message* duration time. The *enterOrExit* filter was chosen for this purpose. If the recipient enteres the specified area during the post-it's lifetime, the ILS informs the LaM AS about the event. Since the LaM AS is interested only in a user entering a specified area, after message delivery a cancellation of subscription is sent to the ILS.

D. Location-aware Push-to-talk (LaPoC) service

A second service scenario that we propose is an extension to the classic Push-to-talk over Cellular (PoC) [5] service. PoC is one of the first IMS services provided by numerous network operators. In this walkie-talkie type of service, the user must press and hold a button when he/she wants to communicate, and can start talking only after being notified on the terminal. By releasing the button, users signal the end of their speech. Because Push-to-talk is a half-duplex service, only one user can speak at a time. In the IMS network, a PoC Server is responsible for control of the PoC application.

We propose a Location-aware Push-to-talk (LaPoC) service which extends the functionality of the PoC service to make it location aware. This means that the PoC Server is enhanced with the ability to establish and modify PoC sessions in the IMS system taking into account end-user location information. The new service demonstrates how to establish and modify a group PoC session only with users that are at a certain designated distance from the originating user (e.g. 1 km). For example, Alice wishes to have a cup of coffee with someone, and starts a group session with her buddies (Bob, Mary, and John) indicating that she wants to include only those buddies that are within 1 km of her current location. Their initial positions are shown in Fig. 3a, with a radius of 1 km around Alice illustrated with a red circle. As Bob is outside of the radius, he is not included in the group session. Later on, if Bob changes his location such that he enters the defined radius area, he will be invited to the session. Users that are already in the session will receive messages that Bob has entered the group conversation (Fig. 3b). Furthermore, if Bob, Mary, or John move away from Alice and leave the circle, they will be dismissed from the session.

The difference between LaPoC and the classic walkie-talkie solution is the possibility in LaPoC for the user to define

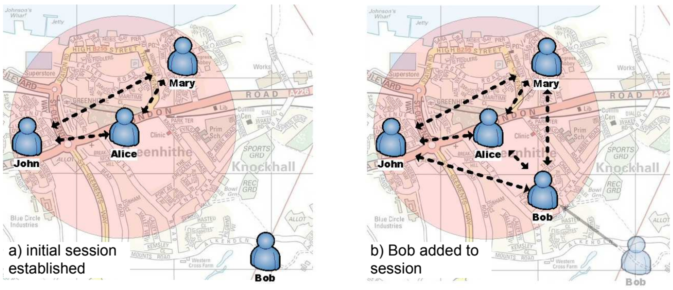

Fig. 3. Illustration of a multi-user Location-aware Push-to-talk session.

the coverage area. This area can range practically indefinitely, while in a classic walkie-talkie service the coverage area is limited by propagation characteristics of radio waves. Additional use cases for such a service include a person wishing to establish a PoC session only with selected colleagues located within company premises; or a policeman at a crime scene wanting to speak with other officers that are in the neighboring area.

The architecture of the prototype LaPoC system integrated in IMS and connected with a generic Positioning System is shown in Fig. 2. It consists of two new components; the LaPoC Application Server (LaPoC AS), and the previously mentioned ILS.

D.1 LaPoC Application Server

The LaPoC AS represents a PoC Server enhancement. Besides implementing classic PoC functionalities, the LaPoC AS is responsible for contacting the ILS to obtain information about which users in the group are inside the designated radius from the originating user, and which are not. It is also responsible for modifying the session in accordance with the location of session members. This means if one user moves outside of range from the originating user, the LaPoC AS will receive a notification from ILS and terminate the session. In the same way, when one user from the group enters the designated area, ILS sends a notification to the LaPoC AS which then includes him in the session.

The simplified session establishment sequence diagram is shown in Fig. 4. After receiving a SIP request for a group session, the LaPoC AS contacts the Group List Management Server (GLMS) to retrieve the group member list. The LaPoC Server then retrieves location information from the ILS for available users, to determine whether they are within range from the session originator. Most interfaces of the LaPoC AS are based on SIP, including communication with the ILS. While we illustrate direct signaling between the LaPoC AS and the ILS, this signaling may be routed via the S-CSCF node.

D.2 *groupInRange* filter

Having end-to-end location conveyance in mind, filters defined in [13] are satisfactory. However, in an architecture where we are using the ILS (an entity which is aware of location information for more users, and which is the recipient of queries from more location receivers) some improvements on signalization load could be made. In some cases the

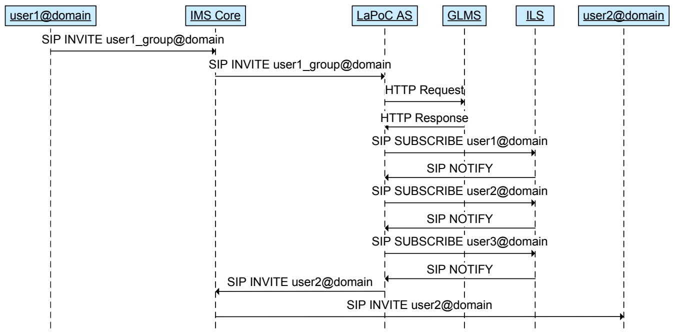

Fig. 4. Simplified LaPoC session establishment with *enterOrExit* filters.

recipient of location information is interested in the occurrence of the same location event but for more users. For example, in the LaPoC service a user is interested when some of his/her buddies enters or exits the same area. Using the filters defined in [13] will result in redundant transport of the same location filter for each buddy to ILS. To avoid re-sending the same filter for each group member, the whole list of users could be sent together with one filter definition to the ILS. This principle could be applied for any type of filter and that could significantly reduce initial signaling.

Furthermore, the existing *enterOrExit* filter allows only the definition of a static area. In the LaPoC service, there is a group of users that needs to be monitored for one dynamically changing location area. If we would like to apply this filter definition, we would first have to send an inquiry for the position of the originating user to form an *enterOrExit* filter and then send a subscription carrying filter for each user in the group (Fig. 4). Furthermore, during the session lifetime if or when the originating user changes their position, a new *enterOrExit* filter needs to be formed and again sent for each user in the group. This does not necessarily mean that any of the users have changed their state (entered or exited the defined area).

Another improvement that can be made having the ILS architecture in mind is related to the complexity of the location filters themselves. If we define the level of filters as the minimum number of targets that need to be monitored for one filter, all the initial filters defined in [13] are first level location filters. Second level filters must monitor two targets at the same time to check fulfillment of the event defined by this filter. In most cases, second level filters would involve location of sender and location of recipient, such as in cases when a user is interested in his/her distance relative to another user.

We introduce a new *groupInRange* filter to encapsulate the solutions of the mentioned disadvantages and reduce signaling between the ILS and LaPoC AS. This corresponding filter is defined with only a list of resource (user) identifications and range length. An example is given below.

The *groupInRange* filter enables the LaPoC AS to send the whole list of users and range length in one SIP message to the ILS and receive back a list of users with information regarding a particular user being in or out of range from the originating user (Fig. 5). Each time a user leaves or enters the range, a

```
<?xml version="1.0" encoding="UTF-8"?> <location-filter>
  <groupInRange>
    <range uom="urn:ogc:def:uom:EPSG::9001">100</range>
    <groupList>
      <userID>sip:bob@ericsson.com</userID>
      <userID>sip:carol@ericsson.com</userID>
      <userID>sip:dave@ericsson.com</userID>
    </groupList>
  </groupInRange>
</location-filter>
```

notification is sent to the LaPoC AS. A traffic analysis and comparison of the *groupInRange* and *enterOrExit* events is given in Section V.

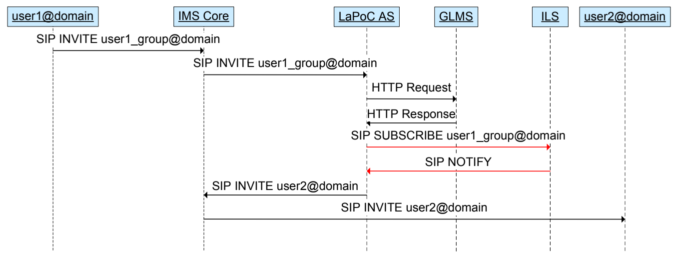

Fig. 5. Simplified LaPoC session establishment with *groupInRange* filters.

IV. Case Study: Integration with the Mobile Positioning System

In this section we describe the integration of ILS with a real positioning system, namely the Ericsson Mobile Positioning System (MPS). Ericsson Mobile Positioning System (MPS) [9] comprises the functionalities of two entities of a 3G network: Gateway Mobile Positioning Centre (GMPC) and Serving Mobile Positioning Centre (SMPC). It collects all available location-related information from the mobile communication network and performs the fusion of two main positioning services when they are available: satellite positioning methods, and network positioning methods (Cell-ID, E-OTD). By combining position mechanisms with location-specific information, MPS can offer customized personal communication services through the mobile phone or other mobile devices. The system is fully scalable and it supports both GSM (MPS-G) and UMTS (MPS-U). The MPS utilizes the Mobile Location Protocol (MLP) for data exchange with the Location Services (LCS) Client [6] (Fig. 6).

The reason for connecting ILS with MPS is interesting because the MPS Software Development Kit (SDK) that was used to emulate MPS functionalities does not support deferred location requests in its currently available version. On one side, the ILS receives location requests through a SIP interface, and on the other, it delegates the request through MLP to the MPS emulator. One major difference between these location requests on different interfaces is that SIP location requests can also carry location filters [13], hence the ILS SIP interface does have support for deferred location requests. A similar concept is going to be supported in the next version of the MPS

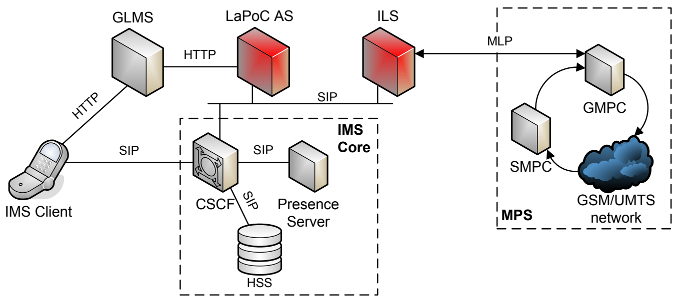

Fig. 6. LaPoC with MPS architecture.

SDK with so called spatial triggers. However, due to lack of support for deferred location requests in the currently available version of MPS SDK, the ILS sends location requests for each user periodically to MPS. When the ILS detects that one user has entered or exited the area defined by a location filter, it sends a SIP notification to LaPoC AS. Location signalization between the LaPoC AS and ILS is minimized, as described in the previous section, but periodic signalization with MPS presents a problem. In order to decrease this signalization, we implemented ILS in a way that the time between location requests to MPS depends on the user's velocity. For example, if a user stands still, the location inquiry period is maximized, but as the user starts to move, the period decreases. With this we have slightly improved the signalization amount between ILS and MPS.

V. MEASUREMENTS

This section describes traffic and performance measurements for the developed prototype LaPoC service. Several sets of measurements were conducted. First, measurements were conducted to compare the session establishment time of LaPoC with the classic PoC service for different group sizes. The second set of measurements was performed to compare signalization load between the LaPoC AS and ILS for the LaPoC service implemented with different location filter types, namely *enterOrExit* according to IETF and our proposed *groupInRange* filter. Finally, a comparison of the traffic load between the ILS and MPS implemented with periodic and improved non-periodic location querying was made.

The measurements were performed in the Ericsson Nikola Tesla (ETK) Research & Development Center research lab. The IMS Client, SIP Core and GLMS functionalities were realized with Ericsson PoC Reference Test Suite [8], while the MPS Emulator from the Ericsson MPS SDK was used to emulate MPS functionalities. The whole system was deployed on eleven computers, connected with a 100 Mbit/s Ethernet network switch (Table I).

The first set of measurements includes a comparison of session establishment time for the LaPoC and PoC services for different group sizes (Fig. 7). The session establishment time prolongation for the LaPoC service is expected and is relatively small if we consider the value added to the PoC service. Furthermore, results illustrate improvements in session establishment time that were made with definition of the

TABLE I
HARDWARE AND SOFTWARE CONFIGURATION

COMPUTER	HARDWARE	SOFTWARE
rlabsrv	Pentium 4, 1.3 GHz, 40 GB HDD, 512 MB RAM	Windows 2000 Server, IMS Clients
rlab2, rlab3, rlab5	Pentium 3, 800 MHz, 10 GB HDD, 512 MB RAM	Windows 2000 Server, IMS Clients
rlab4	Pentium 3, 800 MHz, 40 GB HDD, 512 MB RAM	Windows 2000 Server, LaPoC Server
rlab6	Pentium 3, 866 MHz, 20 GB HDD, 512 MB RAM	Windows 2000 Server, SIP Core Server, MPS emulator
rlab7	Pentium 3, 866 MHz, 20 GB HDD, 512 MB RAM	Windows 2000 Server, GLMS, IMS Location Server (ILS)
rlab8	Pentium 4, 3 GHz, 80 GB HDD, 1 GB RAM	Windows 2000 Server, IMS Clients
rlab9	Pentium 4, 1.3 GHz, 40GB HDD, 256 RAM	Windows Server 2003, IMS Clients
rlab10	Pentium 4, 1.5 GHz, 20GB HDD, 512 RAM	Windows Server 2003, IMS Clients
rlab11	Pentium 4, 1.3 GHz, 80GB HDD, 512 RAM	Windows Server 2003, IMS Clients

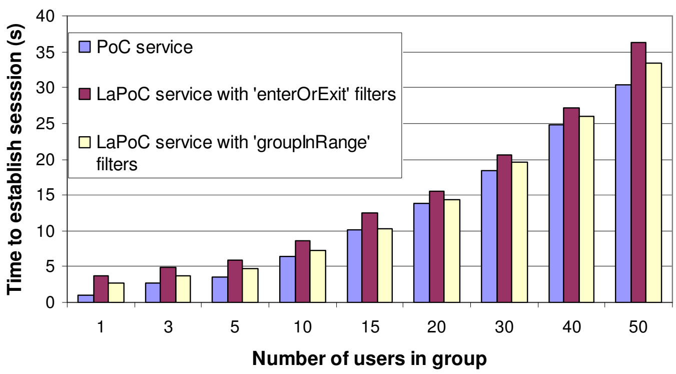

Fig. 7. Comparison of PoC , LaPoC with *enterOrExit* filters and LaPoC with *groupInRange* filters at session establishment time.

groupInRange filter (Section III). The reason for this time improvement lies in reduced traffic load between the LaPoC AS and ILS for the LaPoC service for *groupInRange* location filters. Fig. 8 shows that *groupInRange* significantly reduces the amount of signaling in comparison to the *enterOrExit* filter implemented according to IETF recommendations.

The third set of measurements compares traffic load between ILS and MPS implemented with periodic and improved non-periodic location querying. The first test was done to measure the quantity of signalization for various group sizes, where the location of all users was requested periodically every ten seconds. The second test was done to measure the quantity of signalization for various group sizes, where all users were static. In this case, location requests were sent non-periodically. Finally, the last test was done to measure quantity of signalization for various group sizes, where about 30-40% of users (phone routes) were static and the rest changed their position. In this case, location requests were also sent non-periodically. It is clear that aggregated traffic load between ILS and MPS increases with time. The results presented in Fig. 9 show the total sum of signalization for a one minute time period, dependant on the number of users in the group. For non-periodic testing where all users were static, the amount

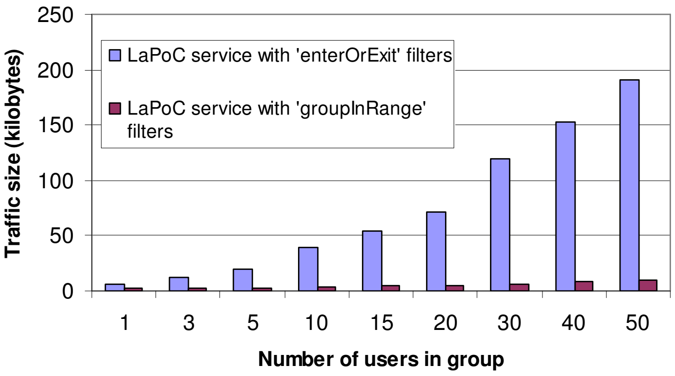

Fig. 8. Traffic load between LaPoC AS and ILS at session establishment.

of signalization is at its minimum. As the number of users that are randomly changing their movement speed increases, the traffic load increases. In our case, where 30-40% of users remain static, the traffic is still considerably lower than in periodic testing. If all the users in a group are moving with maximum speed, then the traffic load in the case with using non-periodic testing is equal to the worst case scenario when the location of all users is requested periodically.

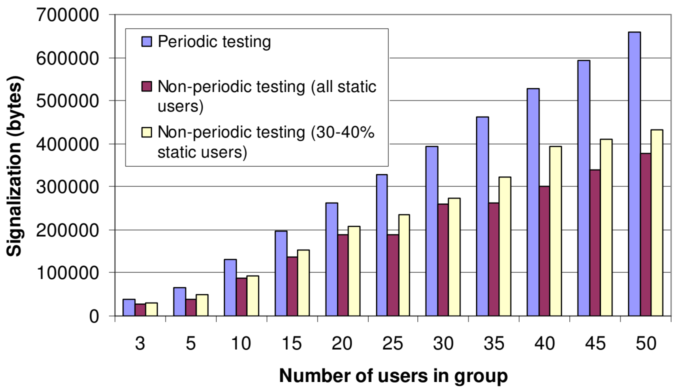

Fig. 9. Traffic load between ILS and MPS.

VI. Conclusions and Future Work

This paper proposes the introduction of an IMS Location Server (ILS) in the IMS network responsible for retrieving user location information, thus providing the means of making this information available to other IMS application servers. Novel location-enhanced IMS services were developed and integrated with the Ericsson MPS to demonstrate proof-of-concept and to provide a basis for performance measurements related to signaling. Improved SIP location conveyance is presented through definition of a new type of location filter. The emphasis was on location signalization with a positioning system that does not have support for deferred location requests, and on improvements to reduce signalization load.

Instead of using a laboratory environment, in our future work we will consider performing the same measurements in a real 3G network deploying IMS and a real positioning system. Furthermore, privacy related issues that have not been discussed in this article will be also studied in the future.

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