INTRODUCTION

The 3rd Generation Partnership Project (3GPP) conceived and developed the IP multimedia sub-system (IMS) [1] architecture with an aim to enable telecom operators to support new services and applications easily and rapidly. To achieve these goals, the IMS uses Internet technologies and protocols. However, the IMS architecture did not pay much attention to the issue of actually creating and deploying services efficiently. Moreover, to develop a service for the IMS requires telecom-development expertise and a working knowledge of the network architecture. In fact, the newly created services must be adapted for the underlying networks.

Nevertheless, it can be promising for the telecom operators to allow developers to use the current telecom services and to include them in their mashups. To give developers that possibility, these services must be manipulatable using open interfaces.

This is the main motivation for the development of a service broker (SB) within the telecom network, that is, to provide a gateway that can accept requests from the Internet and translate them into a form that can be understood by the operator network. In this way existing services, such as voice calling, conference calls, and messaging and location, as well as future telecom services, can be exposed to Internet-based service and content providers (SPs) through lightweight APIs with a fast integration flow, independent of operators. Then, new, value-added services can be launched easily on top of the broker concept to reach a large mass of users.

The SB concept is beneficial for all four primary players involved in the business model: operators, SPs, SBs, and users.

Operators receive compensation revenue for their investments in communication networks, exposing functionality to external parties and monetizing information from their networks. Global coverage is of the utmost importance for SPs because the success of many services is measured in the number of users. Multi-operator connectivity with hundreds of millions of mobile users provides a great advantage to SPs.

SBs add value with brokering services through global connectivity with telco networks. They receive their revenue by brokering service and by providing hosted services or content. Revenue sharing among the players seems to be a very big opportunity for the SB concept where strict borders between telco and SP providers and their roles are becoming irrelevant. Sharing the new value-added services, content, and advertising are based on partnership agreements between trusted players.

Users receive benefits through transparency and access to a worldwide set of operator-independent services. They directly impact service development and selection and can obtain revenue through their own mash-up contents or services.

Although the SB can be used to expose all the services provided by the telecom operators, this article is not intended to cover such a broad scope. Instead, the goal of this article is to provide the reader with useful information about our experience with the implementation and deployment of a specific SB, the location service broker (LSB). We first explain the LSB concept and subsequently describe the architecture, highlighting the most notable implementation choices. We conclude the article with a sample mash-up implementation.

ABSTRACT

In recent years, costly and slow integration has created an unnecessary gap between the telephone companies (or telco) and IT worlds. However, collaboration between Internet and telecom standards is essential for future development. The service broker concept has been developed to fill this gap. Indeed, the service broker provides a flexible layer in the telecom architecture to bridge these two worlds. Such a concept is essential to coordinate the diverse future services and provide mash-up opportunities through a single point of entry.

In this article we present the concept and an actual implementation of a specific service broker: a location service broker. Moreover, we also present a sample mashup called MoPoint that we implemented to better demonstrate the functionality of the location service broker. MoPoint is a Web site where the user can see the current location of his or her mobile displayed on a map along with local weather and advertisements.

Service Broker Architecture: Location Business Case and Mashups

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LOCATION SERVICE BROKER

Video, streaming, location, presence, content management, and mobile-TV, in addition to traditional communication services, are a few examples among many potential broker roles, based on operator network capabilities. Context-aware services are dependent upon information that can be provided by the operator, or as we have studied, by the broker.

Service and information brokering rapidly has become a much desired feature for SPs targeting global audiences. Reaching a majority of the mobile users could become a problem if the SP must adapt to each operator information system. Several aspects must be considered when connecting to operator networks: technical integration, service level agreement (SLA), security, and billing, to name a few. In most cases, the service provider must sign an SLA with the operator to agree on what information can be accessed and at what cost. Billing solutions in the operator networks are used to aggregate usage information. Even if some of the provided services are considered high-margin, the number of service users will increase, thus making up for the decreased margin. Security must be addressed due to the sensitivity of the information exposed to the SP. It is essential to ensure that APIs exposing operator services are not vulnerable to malicious (or denial of service [DoS]) attacks that can disrupt or abuse the native service. This can be achieved by carefully selecting the information exposed to the SP and by using industry-standard security mechanisms. SBs can alleviate the integration burden of the SPs by exposing standard interfaces.

A positioning service was selected as the first example of a broker enabler to prove the brokering concept. Figure 1 shows how the LSB acts as a location information broker between SPs and location servers in operator networks.

On the southbound access, the LSB manages connectivity toward operator positioning systems through the Open Mobile Alliance (OMA) [2] Mobile Location Protocol (MLP) interface [3]. On the northbound access, the LSB uses Simple Object Access Protocol (SOAP)-based interfaces, based on Parlay X [4] for the location service and a proprietary interface for authorization service. The authorization interface sends a short message service (SMS) with a uniform resource locator (URL) and a passphrase to validate the mobile user. Authentication is performed using the information contained within the SMS, and the service provider cannot access information about the user until the user accepts the service.

The northbound access to the broker system is available only to the SPs who have an SLA with the broker. The broker also transforms location information according to service provider requirements as described in the section on implementation (below).

BASIC USE CASE

A basic use case of the LSB is an SP requesting the location information of a particular user (Fig. 2).

A prerequisite for using the LSB is a partnership agreement between an SP and the LSB. Also, the end user must consent to be positioned by the SP. Thus, before the location information of an end user can be requested from the LSB, the SP must request the LSB to handle the authorization from the end user. End users are registered and authenticated through an SP registration interface. The LSB uses SMS for authorization.

After the prerequisites are fulfilled, an SP can request the location information of authorized users. The SP sends a location request for a particular user or a group of users identified by mobile subscriber integrated services digital network (ISDN) number identifiers (MSISDNs) or an alternative pseudonym(s), depending on the selected privacy solution. If the positioning of a particular MSISDN is authorized with the user’s consent, the request is transformed within the LSB to an MLP location request and sent toward the operator. The positioning system in the operator network returns the position result. The LSB transforms the response to a Parlay X SOAP-based message and sends it back to the SP.

PRIVACY

In the mash-up concept, a user’s private information is exposed and propagated over a traditional operator network border and shared between multiple external parties. Privacy handling in the brokering model is difficult because operators traditionally have a more protective
way of handling end-user privacy than SPs have. This is mainly because the privacy handling by the operators is heavily driven by regulatory bodies, whereas for SPs, regulations are not as strict.

The LSB follows the recommendations given in the privacy guidelines of the OMA [2] with some simplifications. Operators can rely on the fact that the privacy of their customers remains intact while they still can offer additional services for their customers.

An additional privacy protection can be performed using a privacy solution with a user’s pseudonym identification. In this case, the LSB authenticates the end user without revealing the real identity of the user to the service provider.

Even if the SB and operator have an established trust relationship, forwarding of location information is such a privacy-sensitive issue that there are no clear guidelines for handling it. For example, some unresolved issues remain if the user and the owner of the mobile subscription are different persons.

According to our experiences, the operators do not trust the SPs to manage the privacy or the anonymity of the end users. However, most of the operators trust the broker node to handle end-user privacy. In turn, SPs do not share the view of protective privacy handling but rather expect the operators to open up their networks.

**ARCHITECTURE**

The purpose of the broker is to provide a proxy for accessing telco location services globally using a single interface and access point.

The Open Service Access (OSA)/Parlay X Web services specifications [4] already provide interfaces to expose telecommunications capabilities and among others, also the terminal location [5]. However, most operators do not provide support for this interface, but for another location protocol, namely, MLP [3]. There are a number of variants of MLP; for example, FiCom [6] defines some deviations from the base specification.

One of the benefits of the LSB architecture is to hide such deviations, as well as MLP versioning differences from the SPs. The deployment overview of the LSB is shown in Fig. 1.

To accommodate the privacy issues described in the previous section, an authorization mechanism was implemented. In our architecture, users of the service can accept or deny being located when registered to an SP service. We used SMS as a mechanism for authorization because it uniquely identifies a single user or terminal. We sent the authorization requests using the Ericsson Internet payment eXchange (IPX) (http://www.ericsson.com/solutions/ipx) because it already provides connectivity for con-
Implementation of the broker architecture.

From the first day of the project, it was clear that the deadline for the first delivery could not be altered because of a demonstration at an external event. This made the choice of implementation strategies and tools very important. Java has good support for all of the features and technologies required and a rich set of development and deployment tools.

After we analyzed the available tools for building Web services with Java, we decided to use the following:

- Apache HTTP server
- Apache Axis2 Web service engine (for SOAP)
- JBoss application server
- MySQL database

The reason for using Axis2, as opposed to the Web service support of JBoss, was that we made the initial implementation of the Parlay X SOAP interface for Apache Tomcat using a specific version of Axis. To keep the code intact, we decided to keep Axis2 and use it when deploying on JBoss (Fig. 3).

The front-end Java components were implemented as servlets and deployed as Web archive (WAR) files, within the application enterprise archive (EAR) file. The classes in the domain subsystem were implemented as stateless session and entity beans. Entity beans were stored in the attached MySQL database, and the object-relational (O-R) mapping was performed with an orm.xml file rather than with annotations. We used a mapping file instead of annotations because we felt that the code should not be polluted with database mapping but rather remain as plain old Java objects (POJOs).

The connectivity packages toward the operator networks were divided into messaging and location services. The messaging service provides a service for SMS sending, whereas the location package provides a set of subscriber locators with a common interface. Due to different versions of MLP, we decided to hide the actual subscriber locator implementation with a common interface and use a factory pattern for creating the correct locator implementation.

To access the location services of the operator, we initially used an API and a software development kit (SDK) provided by Mobilaris called Pacific Ocean (http://www.mobilaris.com). An SDK gave us the capability to develop the location beans because it includes an emulator for testing locally prior to deployment. This was sufficient for deployment where the operator was using Mobilaris. However, the broker should integrate with a multitude of operators, which required our architecture to also adapt to proprietary positioning protocols, as well as modified versions of MLP. Therefore, for a production implementation of the broker, an MLP stack supporting a multitude of back ends is required.

Accuracy

The global system for mobile communications (GSM) network-based positioning of subscribers is performed using one of the following technologies:

- Cell global identity timing advance (CGI/TA)
- Enhanced cell global identity (E-CGI) GSM
- Cell global identity (any time interrogation) or CGI/ATM
- Uplink time difference of arrival (U-TDOA)
- Assisted global positioning system (A-GPS)

Accuracy of the positioning depends on base station density, as well as the positioning mechanism [7, 8] that is used. Thus, the accuracy of the location result varies a few hundred or hundreds of meters to several kilometers.

In MLP, the position of the terminal can be represented by one of the following shapes [3]: point, linestring, polygon, box, circulararea, circulararcarca, ellipticalarea, multilinestring, multipoint, multipolygon, and linestring. All shapes, except point, indicate some uncertainty regarding the current location of the terminal. The terminal is within the area defined by the shape and an additional parameter in MLP, the LevelOfConfidence, which expresses the probability of the terminal being located within the given shape.

The northbound interface as defined in [5] does not include shapes, but the result of the
location query is given by latitude, longitude, altitude, and an accuracy parameter, that is, a circle or a circular sphere. Therefore, the result from the operator positioning system must be converted by the broker into a circular or circular sphere representation. We used the worst case scenario when converting the shape into a circle or circular sphere. We calculated the distance from the center point of the shape received from the operator network to all coordinates of the shape. We then used the greatest distance as the radius of the resulting circle or circular sphere. The distance calculations were implemented as a utility library based on algorithms defined in [9].

DEVELOPMENT ENVIRONMENT

The development PCs were running Linux; both openSUSE and Ubuntu distributions were used. The deployment servers (Intel Xeon @ 2.40 GHz) were running openSUSE on virtual hosts.

The Eclipse Web Tools Platform (WTP) project is an extension to the Eclipse platform. It provides tools for developing Web and Java EE applications. Eclipse with the WTP plug-in was used as the main implementation environment. We used the Callisto release to install the plug ins for Eclipse. The concurrent version system (CVS) was used as the version control system of all artifacts.

LOCATION SERVICE SAMPLE

As a part of the project, we implemented a sample mashup called MoPoint to better demonstrate the functionality of the LSB.

MoPoint is a Web site where the user can see the current location of his or her mobile terminal displayed on a map in addition to local weather and advertisements. It is also possible to see the location of other users. Each user that registers must consent to be positioned. This is done using the authorization service provided by the LSB, which we described previously. The Web site for a registered user is shown in Fig. 4. As is typical for mashups, the components of the MoPoint Web site use different technologies and providers.

The MoPoint exploits the location service provided by the LSB. We used SOAP/Parlay X on the interface between the LSB and the MoPoint service. The geographical coordinates received from the LSB are then used as request parameters for other services integrated into the MoPoint Web site.

To mash up the location information with maps, the Google Maps JavaScript API (http://code.google.com/apis/maps/documentation/) was used for embedding Google Maps into the MoPoint Web site. Based on the geographical coordinates received from the LSB, the current location of the user is displayed on a map. Because the service is based on the location information of mobile users, we wanted the sample service also to be available for mobile browsers. Due to the limitations of mobile browsers, it was more challenging to find a suitable API for the mobile version. Because most of the mobile browsers do not have support for JavaScript, we used the Yahoo! Maps Map Image API (http://developer.yahoo.com/maps/rest/V1/mapImage.html) for embedding maps into the MoPoint Web site in small devices. The Map Image API returns a reference to a portable network graphics (PNG) image. In both desktop and mobile versions of the service, the user can select to display only his or her own location, location of a friend, or both on a map. The selection of the version shown to the user is accomplished by determining the browser capabilities. From the HTTP request, it is easy to detect whether the request is WAP- or Web-specific, and consequently, use this information to select the type of user interface.

The MoPoint uses the XML feed from weather.com (http://www.weather.com/services/xmlsoap.html) to display the local weather. The weather.com site provides a service, that when given the name of a city, returns a weather.com location identifier, which is used to retrieve weather information. Conversion of coordinates to the name of a city is accomplished using our own conversion utility. The MoPoint Web site also contains advertisements that are location-based. The advertisements are retrieved from the MoPoint database.

Problems with the current sample mashup are related to privacy issues, mainly because there are no clear rules how privacy should be handled in this kind of scenario. Thus, we implemented only a simplified privacy solution. As the number of mobile users who are allowed to be positioned was very limited in this prototype, we agreed that each user who authorizes to be positioned accepts that the location information is visible to other registered users.
Thought. Thus, it was essential that we had people with a telecommunications background, as well as people familiar with the Internet business, involved in the project.

### Related Work

The SB concept we present in this article focuses on two main features:

- A proxy for accessing telco services using a single interface and access point
- Service component templates that attract more Internet developers to develop telecom value-added services

There is a significant amount of work that deals with LSB solutions. Some work is focused on device-centric solutions. For example, TraX [10] defines a middleware that offers an interface for obtaining position data directly from a mobile device bypassing the operator. Other proposals define broker-based models [11, 12]. However, currently, to the best of our knowledge, there is no description in the literature of the effort required to bridge the telco and Internet worlds that offer mash-up opportunities through a single point of entry.

Parlay OSA has developed a set of telecommunication standard interfaces to provide more concentrated and powerful service component templates [4]. However, not all telecom operators provide support for Parlay X. Moreover, Parlay X supports only a limited number of services and it does not provide the capability to easily add support for new telecom services or to extend the features of the supported ones.

An important project was developed by the BT Group: Web21C (http://web21c.bt.com). Web21C supports the aggregation of telco and Web 2.0 services and their mashup into new value-added services. With this tool, BT created high-level service-oriented-architecture (SOA)/Web services interfaces to seven sets of functionality: voice calling, conference call, messaging, authentication, location, subscriber profile information, and contacts. However, Web21C is limited to offering broker services from a single operator only.

Another initiative was promoted recently by Telefonica: Wims 2.0 (http://www.wims20.org). It is mainly a framework to investigate and promote the convergence between Web 2.0 and telecom new generation services.

### Conclusions and Future Work

In this article we presented an SB architecture offering a location service and a sample mashup to demonstrate the functionality of the LSB.

During the implementation, we observed that the delay in obtaining the location information from the operator network varies. The accuracy of the location results also varies. It also is surprising that there were so many different variants of the MLP in use. This required that our own MLP stack was implemented, which was part of the original implementation plan. One of the major challenges we faced during the sample mash-up implementation was to find a map provider. Our requirement was to have maps for mobile devices in which we could display our own points of interest. For PCs, there are several freely available APIs of this type. Because we could not find a provider with interfaces for both device types, we decided to use two different providers.

According to our results, there were significant differences in positioning accuracy between second generation (2G) and third generation (3G) networks. In urban areas, where micro- and pico-base stations are used, 3G networks produce slightly more accurate results than 2G networks. In rural areas, 3G users are positioned by a base station further away because fewer base stations are required in 3G networks. Thus, the uncertainty area was very large, and positioning results were less accurate than in 2G networks.

We discovered some corner cases in 3G networks, resulting in erroneous locations due to the base-station configuration and limitations in the provisioning protocol. For example, problems occurred if a mobile was located very close to the base station. We were able to improve the accuracy by manipulating the uncertainty area. Further improvements could be achieved by taking into account neighboring cells.

Fourth-generation long term evolution (LTE) will provide future improvements in this area. Improved network architecture, multi-antenna technologies, wider use of micro cells, and enhanced positioning protocols will provide more accurate positioning. According to the first estimations, positioning accuracy will be at the level of tens of meters.

Many challenging issues still must be faced in the architecture. Traditionally, the parties involved in this architecture have very different ways of working. This causes problems, for example, when setting up trials with mobile users: SPs prefer trials with an unlimited number of customers, whereas operators prefer to limit the number of users. Views of privacy differ and implementing a feasible privacy solution turned out to be more challenging than initially thought. Thus, it was essential that we had people with a telecommunications background, as well as people familiar with the Internet business, involved in the project. We also included lawyers in the project.

Quality of service in terms of delay and location information accuracy is also one of the issues for future studies. The delay in receiving location information from the operator network is sometimes too long.

Some services in operator networks, like location, are not included by the roaming agreements. This is due to different location solutions in operator networks and regulation.

There are also unsolved issues related to the brokering of additional services such as pres-
ence, instant messaging, and content distribution. Therefore, brokering with more than one service may require additional studies, especially related to the possible performance effect.

REFERENCES


BIOGRAPHIES

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