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Designing and Implementing an Open Infrastructure for Location-Based, Tourism-Related Content Delivery

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Abstract. The globally observed recession of mobile services market has pushed mobile network operators into looking for opportunities to provide value-added services on top of their high cost infrastructures. Latest advances in self and network-assisted positioning technologies, enable the provision of services that make use of the actual mobile user location. This paper presents the key points and considerations of a detailed approach for designing, developing and evaluating a very low-cost infrastructure, capable of providing tourism content related location-based services. The main effort is taken into allowing the potential integration of various market and technology stakeholders into such services, thus supporting open business models, while at the same time safeguarding end-user privacy.

Keywords: mobile services, location-based services, content delivery

1. Introduction

The existing 2/2.5G mobile market has reached saturation as analysts have predicted, but its effects have not been acknowledged earlier due to the high expectations of the emerging 3G markets. The pessimistic initiation of licensing and deployment of 3G networks led Mobile Network Operators (MNOs) into a global recession era, therefore nowadays business opportunities based on existing mobile and wireless networks are being further investigated [1, 2]. Effort has been taken by MNOs into looking for areas of providing value-added services on top of 2/2.5G networks, in order not only to make the most out of the existing infrastructures, but also to encourage usage and drive expectations for next generation of mobile networks. To provide such services, the integration of various components and base-services is required, which comes to break the current status of most MNOs, which have traditionally been formed as almost monolithic self-contained service(s) providers.

The need for integration of various market stakeholders in complex business models aiming into the provision of high-quality services, has been indicated not only by mobile market analysts, but also by Information Systems (IS) architects. The service-oriented approach [3], a whole new information technology (IT) perspective which is currently rushing into the industry, founds the concepts and offers the guidelines that render possible such complex collaboration schemes. Location working group (former LIF), Mobile Location Protocol (MLP) [4] and Mobile Positioning System/Mobile Positioning Protocol (MPS/MPP) [5] already exercise concepts that meet current Service Oriented Architecture (SOA) implementations common practices.

Nevertheless, design of services such as location-based ones will always have to face domain specific challenges concerning technical, economical or even ethical and social factors of the service application.

In this paper, we propose a design approach for a Location-Based Service (LBS) architecture that will support providing tourism-related location-dependent content to end-users, allowing:

1. Seamless integration of various market stakeholders into providing a large range of high quality location-based content delivery services,
2. Application of various pricing/billing schemes,
3. Full exploitation of state-of-the-art technology in positioning, mobile devices and network infrastructures,
4. Compliance with requirements and standards for personalization, Quality of Service (QoS) and privacy,
5. Low-cost implementation and upgrade roadmap from 2/2.5G to 3G mobile networks

Throughout the analysis, findings and standards presented by international working groups, e.g. Location Interoperability Forum (LIF), have been used from the IT perspective of designing a specific type of service. Although the term "tourism content" seems to be a rather restrictive parameter of the design, it will be shortly shown that it covers a large portion of the content that is usually provided under a location-based service. This led us to the conclusion that it is possible to provide a "design pattern" for all types of location-relevant services, which will allow for maximum flexibility and reusability, by proposing layers of services or components to provide the required functionality. It will be made clear that most of the issues identified and solutions described here are applicable to situations arising in other types of LBS.

Although our approach attempts to remain on top of an Internet Protocol (IP) supporting network layer, thus avoid interfering with particular Mobile (or other wireless) network infrastructures, specific issues of interoperability and integration have been identified and investigated. In addition, current market situation has been taken into account since ignoring capabilities of the market (e.g. capabilities of devices) or technology status would potentially render the architecture inapplicable.

The proposed architecture and findings are currently being applied to the M-Guide project, a EU-funded project under E-content programme [6], which is currently leading to a fully successful completion.The paper is being organized as follows:

In Section 2, key points of the infrastructure requirements are being presented. Section 3 outlines the proposed architecture and focuses on elements that are critical for the success of LBS provisioning. Finally, Section 4 offers a short evaluation of the design achievements, while in Section 5 we propose future work to be done in order to lead into a globally applicable design.

2. Design Considerations

The first step towards the design is to identify the range of the term "location-based tourism-related content delivery." Within the term "tourism-related," any content that might be of interest to the visitor of a location can be included. This content, be it static, of low refresh rate, highly dynamic, cultural, informative or of commercial usage, has an increased degree of interest to the "consumer," especially when he is in particular locations. The term "location" is a varying "size" descriptor, which might range from the actual spot where one is standing in a room, to just a rough approximation of a country. Needless to mention in this paper, "tourist" is very loosely related to the typical "tourist" and mostly fits the definition of "mobile equipment user."

It is obvious that a very large number of services related to content delivery fits this definition. To mention some of these, location map delivery, archaeological sites information delivery, festivities announcements, emergency or health services, transportation information acquisition, even in-doors museum exhibition presentations are all forms of this type of location-based tourism-related content delivery service.

When designing an infrastructure able to support such services, requirements that have to be met come from various sources: technical issues that have to be exploited and addressed in order for it to be applicable, regulatory and social/ethical restrictions that have to be met in order for the supplied services to be publishable, end-user expectations and requirements that have to be considered in order to achieve successful commercialization, etc.

The particular requirements presented here arise from a careful study of the 2/2.5G and 3G mobile network technical specifications, LBS related white papers and applied paradigms [7–11], modern IT system architecture concepts [3], regulations & standards [12–15], and finally, market and end-user surveys [1, 16, 17]. This comprehensive study led to the identification of the following key points that require careful consideration when implementing a location-aware service that aims into providing tourist information content:

1. QoS in quantifiable technical terms (response time, throughput, availability, scalability, coverage, accuracy, etc.)
2. QoS in nonquantifiable terms (quality of content, e.g. coverage, depth, media, multilinguality/mutliculturality, etc.)
3. Integration capabilities (relevant services support and integration capabilities)
4. Security (authentication, authorization, privacy, etc.)
5. Service-related procedures (e.g. activation / de-activation, billing, pricing, personalization, stakeholders interoperability, etc.)
6. Service-specific features (e.g. notification, positioning triggering)
7. Content-related issues (e.g. ontology)
8. Present and emerging technology capabilities (positioning, presentation, mobile networks, etc.)

Having carefully examined alternatives and the potential impact of decisions on the abovementioned key points, we come to several interesting conclusions.

End-users are not generally enthusiastic with high accuracy positioning schemes or very high data-rate demanding services. They rather prefer low cost intuitive services that will satisfy their expectations, within reasonable quality limits. Widely used equipment lacks high interactivity capabilities (i.e. means of passing information to the service and presenting content to end-users), but emerging devices vastly improve the status of the market.

Accuracy in positioning is not always a concern. For example delivering some sort of transportation information or providing a local directory service, require a rough approximation of the position. On the other hand, presenting information of an actual exhibit, which the visitor of a museum is looking at, requires not only the precise position one is located but also the direction of sight, whereas we can show that even that detail of information is not adequate. At this point, the proposed architecture suggests that "less accuracy" does not render LBS useless, but rather restricts the range of services that can be provided.

Almost identical content might be presented to end-user when she is visiting a museum or an open archaeological site, but equipment differentiation might be well outside typical aspects (e.g. display capabilities, channel usage, positioning mechanism and capabilities), thus allowing for a completely different degree of content exploitation.

Another issue is that some requirements, e.g. accurate positioning and enhanced content come with some extra "cost" to the end user. "Cost" is not only in financial terms which are mostly obvious. Positioning accuracy (e.g. through a global positioning system (GPS) module) and advanced display capabilities for example, might have a severe impact on device autonomy and size. Enhanced content (video, virtual reality representations, etc.) will require more bandwidth and even more powerful equipment (having indirect impact on autonomy and size).

When to locate a user is yet another confusing issue. A user-requested positioning, requires an extra step to be taken by the end user, who actually has to request to be located or explicitly state her location at the moment. Alternatively, the user can be continuously located (tracked) by the system which might initially be thought of as a preferred solution. Continuously positioning the mobile user is not usually required, even in case when the undoubted increase of requirements it implies in terms of infrastructure and equipment resources is not a problem. A typical example is a highly mobile user who is accessing some location-based directory of content, related to a specific position she has been some time earlier. While the user might be attracted to these particular sites of interest, mobility might cause the delivery of quite different content in subsequent requests for information, which might come up to be quite irritating. Thus the user should have the possibility to allow either continuous or on-request triggered positioning. We propose for totally avoiding automatic positioning instead of temporarily ignoring new position information, but certain applications could require two positional indicators ("live" position and "querying" position).

Finally, a very important observation that guides the proposed approach is network convergence; xxML/HTTP/TCP/IP "stacks" tend to provide a uniform roadmap for offering a very large range of services to each and every consumer-oriented device type.

3. System Overview

The approach for designing location-based content-provision services introduced in this paper is being presented in Figure 1. MNO or other wireless network details, such as various access points, Mobile Switching Center (MSCs), Visitor Location Register (VLRs), home location register (HLRs), etc are almost totally hidden and only interactions of higher-level components are being mentioned. Structural and operational analysis highlights various important aspects as follows:

3.1. Service Access Point

We define a Service Access Point (SAP) for a bunch of services, which is responsible for accepting customer requests. This is not required to be part of a MNO infrastructure and is basically a typical application server, presented in the form of a Uniform/Universal Resource Identifier (URI). This point is responsible for a series of actions, which among others include:

1. Authenticate and identify end-user, if such an issue arises. This is not a typical user-

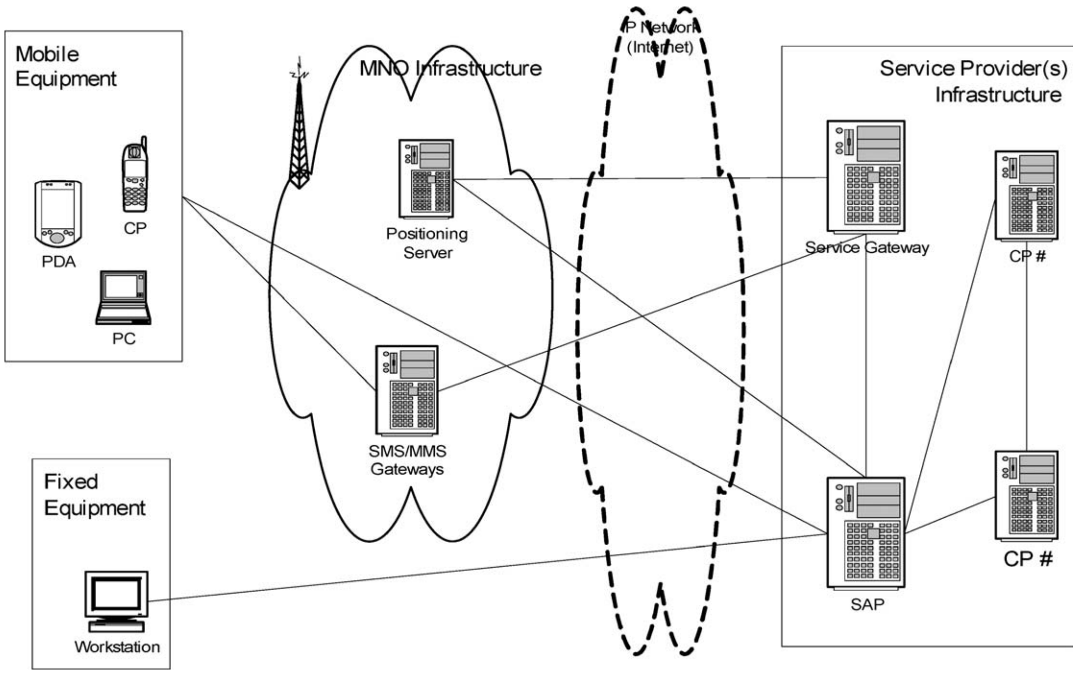

Figure 1. A typical abstract layout.

name/password challenge, although this is actually being supported, but also sophisticated authentication mechanism through network provided information. This approach helps into reducing interoperability issues but mainly safeguards end-user privacy and infrastructure misuse, as it will be shortly shown. User identifiers might be temporal (e.g. a temporary mobile subscriber ID, a temporarily assigned network address) or permanent (e.g. username/password challenge or MSID – Mobile Subscriber Identifier) and will be used later on by sub-service providers for pricing / billing, etc.

2. Provide a form of "directory" service for sub-service providers and network operators. This "directory" might well be published but is primarily for internal usage, which is identification of the stakeholder to deliver requests. This directory service is being used in order to determine the actual content provider depending on user preferences, the operator to provide network assisted positioning, etc.
3. Provide a placeholder for end-user preferences in a persistent manner, i.e. aggregate a global profile for the bunch of services. Organizing a global per-user profile restricts all content providers into using a common pool of information, but enhances usability which is a major concern when designing LBS. A mechanism of profile structure updates, triggered by sub-service providers can be easily implemented: e.g. post information to the SAP in a predefined format, in order for profile structure modifications to be requested. The SAP has to merge profile information into new structures, eliminating possible conflicts and repetitions.
4. Provide for a "service-side triggered" positioning procedure, in case end-user equipment is incapable of autonomously handling positioning. This is mainly the case when SMS/MMS channels are being used for interaction, while it can be applied to all other cases.
5. Serve as a node for non all-IP based channels, which coordinates requests and replies

between channel gateways and content/sub-service providers.
6. Host an optional cache of aggregated content in order to quickly fulfill requests by the clients instead of requesting content lookup for each and every content provider. Cache invalidation can be achieved either by typical policies (e.g. expiration) or by Content Provider (CP) triggered updates.

3.2. Positioning

Positioning is the next issue to be faced. There are generally two ways of determining user location:

1. autonomous positioning e.g. GPS, pseudo GPS and proprietary positioning systems and
2. network provided (or assisted) positioning, e.g. Cell ID, Enhanced Observed Time Difference (E-OTD), Assisted GPS (A-GPS), Radio Frequency IDentifier (RFID) etc

In the first case, the client has all the information necessary to identify its position, while the second case requires network assistance to be provided, even if the client has to supply critical information in order to be located (e.g. power indication, etc). Generalizing our service support mechanism, we extend our approach by including "manual positioning" as a third positioning type. "Manual positioning" refers to either manually identifying the actual coordinates of the location or to the indirect acquisition of location (e.g. road intersection, road numbers, etc). "Manual positioning" besides being a means of providing LBS even when using equipment incapable of geographical location identification, it also allows the support of alternative service applications, such as travel pre-planning, etc.

It should be obvious by now that, the above-mentioned mechanisms result in significant heterogeneity not only in the area of the actual positioning implementation, but also in the area where a location-based application is being concerned. In order to hide as much as possible this heterogeneity from Application Service Providers (ASPs), we separate positioning into three distinct layers.

The bottom layer is concerned with the actual calculation of the position. This layer is quite different in each and every implementation not only due to the various alternatives of positioning mechanisms, but also due to differentiation to details of the actual algorithms and infrastructures. Very little can be done in order to unify this layer other than defining the appropriate interfaces.

The second layer is the SAP positioning layer, which has to provide the actual end-user position to the application layer. This layer is separated in a server and a client part (components to extract device data where applicable) and its purpose is to determine the actual position supplier and extract information data, or provide a means for manually identifying position.

The top-level layer is the application layer, which has to determine whether new positioning is required, reuse of previous information is adequate or actual position is known (e.g. within query), then forward a request to SAP layer and ultimately return location information back to the end-user (within response). The aforementioned layers might make use of components (e.g. coordinates translators) or services, e.g. Geographical Information System (GIS).

An alternative solution that fits our architecture, but is applicable to emerging and next generation mobile devices, is the one roughly presented in Figure 2.

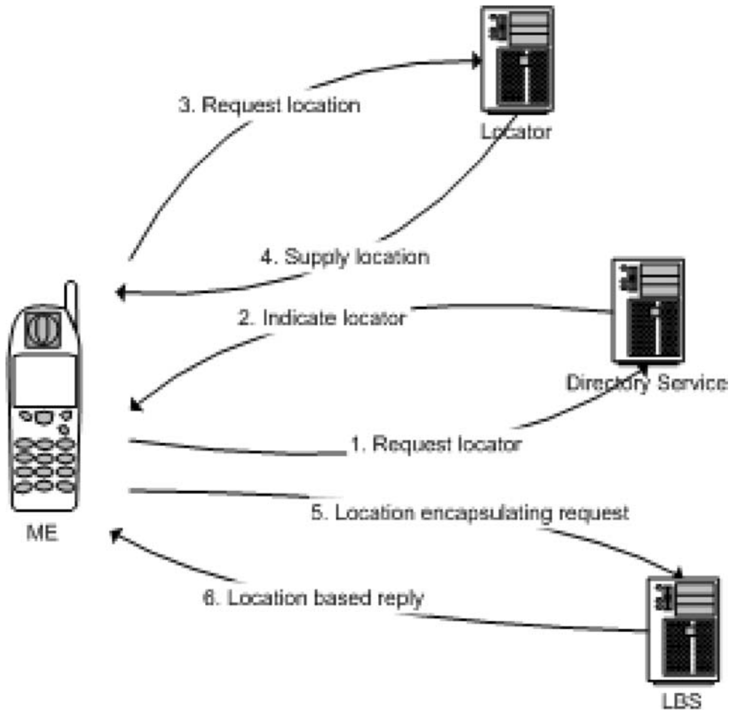

Figure 2. A positioning approach for next generation equipment location-based applications.

3.3. PUSH AND PULL SERVICES

At this point, we introduce a distinction of two types of the services which behave quite differently. The first one is a typical system where end-user acquires information “on-demand” (this will be named “pull” system) while the second one “pushes” information to the user when certain criteria are being met. The second form of service is a type of “alert” service, which notifies a user when certain time, location and preferences (or even action) conditions occur. In order to provide such a service, there are two mechanisms offered by the proposed architecture. The first is a quite simple one and mostly fits quite advanced mobile equipment such as Personal Data Assistants (PDAs) and state of the art mobile phones (smart-phones). The mobile equipment “carries” the appropriate client software-module to post data request to the server, triggered on time intervals or location change criteria. This solution introduces network usage even if no content is to be delivered to the end-user. Nevertheless this is the preferable solution when client or manual positioning is the case. More traditional devices could be possibly “alerted” via an MNO monitoring procedure that, through typical gateways, would alert the mobile user when potentially interesting information falls “within range.” “Within range” is not limited to “proximity”, but also covers a whole series of preferences and observed behavior filters that might be applied in order to select the content to be presented to the end-user. At this point, we have to mention that early implementations made use of Short Message Service (SMS) as an “alerting” mechanism.

“Push” services form a potential scalability and performance threat for an LBS infrastructure, because of the computational and bandwidth demands posed by the scanning of vast collections of data on each and every end-user movement. Thus in the proposed approach, we avoid stressing on “push” services though they are fully supported.

3.4. User Authentication and Identification

A critical part of the service is the user authentication and identification procedure. As it has already been mentioned, the SAP is responsible for authorizing end-users. Authentication is actually optional. For example, in case one is providing a free-of-charge service, no end-user authentication might be required at all. Neertheless, even a "free" service might require some end-user authentication in order for advanced personalization to be made possible. Our approach to authentication is based on an optional username/password challenge scheme. SAP is the only responsible for maintaining this user directory. Users have unique identifiers, usernames and passwords within the SAP, but anonymous usage is also permitted. When requests and replies are being exchanged between content providers and the client, the SAP identifier is always provided in order for the CP or ASP to authorize (and charge) the appropriate subscriber. Alternatively, ASPs or CPs perform no user identification and deliver data on behalf of the SAP, which is the actually charged partner. In this case, the SAP is the one to charge the particular users. This fully covers the CP/ASP/SAP part of the infrastructure. On the other hand, the network operator will pose charges on network usage and potentially add a premium on top of the traffic, which might even be delivered to various ASP/CPs/SAPs, etc. Additionally ASPs/CPs might charge content delivery depending on user location or user preferences (such as content quality, type or location-based advertising allowance), thus allowing for quite complex pricing/billing schemes.

Although pricing requirements might be easily satisfied, this is not the case with user identification when positioning takes place, especially when network provided positioning is used. Acquiring end-user location based on simple username/password authentication, opens a wide possibility for service misusage, taking advantage of the spying effect: one attaches a typical network positioned mobile device bound (logged on) to a specific user account on a person to be "watched" and requests positioning information through a secondary device, such as a fixed personal computer (PC) or another mobile device, on behalf of the above-mentioned account. If no network session data are used, location information can potentially be delivered to the "spy." This might be a well-accepted feature of some implementations, but the proposed perspective of privacy forces into taking measures for avoiding such situations. In the SMS/MMS (multimedia message service) channels case, this information is incorporated in the state of the gateway/SAP session that is established to fulfill a client request. On the TCP/IP typical channel the situation is a bit more complicated. Since the client requests position over an HTTP request, the MNO typically receives the request for locating the user by the SAP. Thus some user identifier must be presented (except than the username). Fortunately, the SAP already has the TCP/IP session information (source address/port) that is used in order for the user to be serviced. Typically end-user mobile equipment is behind a Network Address Translation (NAT) gateway and this address is not a real one, thus the TCP port number must be also be used in order for the related MNO to locate the correct user. The SAP can select the correct MNO either by the internal directory service (the source address of the request directly or indirectly identifies the MNO) or by the end-user information record. The MNO can identify the actual user through NAT layer information and GPRS IP (general packet radio system) address assignment records.

A quite powerful alternative is restricting request identification internally to the MNO, by allowing positioning servers to reply only to requests posed internally by MNO subscribers. In fact, only the information-requesting equipment is located. In this scenario, the client acts as an autonomous positioning equipment, at least as this can be faced under the SAP point of view.

Needless to mention that most of the authorization/identification related information being exchanged is encrypted and routing information (e.g. source address) is used in order to minimize potential compromising of privacy.

3.5. Content Structure

Content organization is another issue we have to face within the range of our infrastructure. Restricting content to "tourism–related" categories, might not actually vastly reduce the location-related content to be provided, but certainly poses some requirements on its structure. We have already seen very rich schemas for describing "tourism" content (e.g. Tour Markup Language TourML [18]), which attempt to fully capture the corresponding ontology.

From our point of view forcing the "over"-structuring of content is usually a source of problems to the content providers. It can also be shown that it is almost impossible to fully model content in a static manner that will provide the means for each and every content usage. This leads to a strategic decision that content providers must expose content that complies with a minimal set of requirements. These requirements include position information (in various forms, e.g. rectangles, series of points, etc.), language identifiers, labels, multiple classifications in a two-level hierarchy (though not a hard constraint) and a content rating scheme. Content classifiers are open to extension by CPs and are aggregated by the SAP. The first level is mainly proposed to be a means of defining end-user content selection preferences, but a more sophisticated scheme can make use of a free hierarchy. Content rating is required in order for "free of charge," "simple" or "rich" content classes to be differentiated by the SAP, so that it can be delivered to various clients, though the actual content manipulation is to be performed by the CP. Internally CPs might realize a more complex structure, but the SAP is concerned only about the above-mentioned tags. If required, usage of extra tags can be handled by additional user preferences, for which an extensible mechanism can be provided.

3.6. Presentation

Data presentation to the end-user can be realized by a wide series of equipment, which might range from high quality multimedia laptops to simple SMS capable mobile phones. Fortunately XML/XSL/XSLT (Extensible Markup Language/Style Sheets/Transformations) provide a quite powerful mechanism for implementing an author-once, publish-many mechanism, capable of covering a wide range of end-user preferences and equipment. At this point, one can identify that these are two-level transformations in order to achieve maximum reusability. The first level is an internal CP transformation that renders original data into a form that will comply with the SAP required minimal structure. The second level of transformations is the one that will transform the content in a way that it will fully exploit the capabilities of the end user device. Such rendering can result into simple text fragments to be posted over SMS, MMS fragments, WML (wireless mar language), HTML, or DHTML (dynamic HTML) pages and even advanced SMIL (synchronized multimedia integration language) presentations.

3.7. Application Gateways

The higher levels of the service design consider an infrastructure with a usually homogeneous underlying network, based on HTTP/TCP/IP layers. This is obviously not the actual case when considering, for example, traditional mobile messaging services. In order to hide the diversity of the underlying infrastructures, special gateways are required, which will allow for the servicing of non-SAP native requests to be fulfilled. These gateways receive client requests and deliver them to the SAP in a form they can be understood. It is obvious that in order for a uniform interaction to be achievable by all CPs, translation of requests is handled by a specific reception point of the gateway that analyses the content of the incoming message and forms the appropriate request to the SAP. When requests are replied the data are appropriately packaged and delivered to the actual network operator infrastructure components that will push it back to the requesting equipment through the appropriate "channel." Typical channels that require gateways are the SMS, EMS (enhanced messaging service) and MMS ones, while the functionality of such gateways is also significant for the implementation of alerting services.

4. Evaluation and Conclusions

The M-Guide project has offered a clear area for evaluating the concept of LBS as well as the various design and implementation decisions presented in this paper.

The approach has been shown to allow for the redirection between various sub-service providers and the integration of the services in order to provide a homogenous application to the end-user. Making use of standards and protocols (e.g. LIF, XML, HTTP), avoiding proprietary solutions and limiting interoperability requirements to a minimum renders the architecture capable of integrating various stakeholders with limited cost and implications.

Although the proposed solution has been tested on a single network operator, support for LBS is not restricted to a single network provider, even when positioning is performed by the MNO.

Despite its "tourism content delivery" orientation, the infrastructure can be made capable of providing more complex services with minimum impact on service providers, by making use of state-of-the-art client equipment features such as Java, DHTML, etc.

It can be shown that a powerful directory service, applied within the SAP, is adequate for creating a totally uniform platform for in-doors and outdoors LBS and quite heterogeneous positioning methods and capabilities (e.g. RFID, or wireless access point identification, etc).

Since motivation behind LBS is its potential beneficiary commercial exploitation, a preliminary techno-economic evaluation based on hypothetical deployment and commercialization scenarios has been attempted (not presented here). The effort focused into calculating basic financial indicators that showed the viability of the proposed solution. A full description of our evaluation scenarios and results can be found in [16] while the details of the methodology used in technoeconomic evaluation have being presented in [19].

5. Future Work

There are various aspects of the presented approach where potential improvements will lead to further benefits for the end-user and the content/network providers. These largely involve standards identification and adoption, as well as refinements of our current implementations.

An essential improvement would be to fully fit our design to the open service oriented architecture initiative, thus providing dynamic service discovery, etc. Introducing the attributes and rules that will enable the creation of a universal directory service to support each and every relevant information and service lookup is a step that should be made towards this direction.

Although Business-to-Customer (B2C) information interchange is sufficiently faced under our perspective, Business-to-Business (B2B) is partially dealt with. B2B data exchange is limited to areas where information is essential for servicing a particular user request, e.g. positioning, authentication, etc. However, B2B collaboration can be further exploited to subjects such as content modifications due to relocation, caching, restructuring service organization, etc. Further work on this area would potentially enhance scalability of "push services," another area which has not been fully exploited yet.

Work also needs to be done on roaming-user scenarios in order for the infrastructure to fully comply with market requirements, since handling and network positioning of roaming users is performed inefficiently.

Moreover, a more detailed techno-economical study is needed, based on specific deployment scenarios, taking into consideration up-to-date technological and financial data in order for a more precise profit/loss prediction of relevant service deployment to be possible.

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