Dynamic Context Aware Service Provision in Beyond 3G Mobile Networks

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Abstract. The evolution of mobile communication systems to 3G and beyond introduces requirements for flexible, customized, and ubiquitous multimedia service provision to mobile users. One must be able to know at any given time the network status, the user location, the profiles of the various entities (users, terminals, network equipment, services) involved and the policies that are employed within the system. Namely, the system must be able to cope with a large amount of context information. Present paper focuses on location and context awareness in mobile service provisioning and proposes a flexible and innovative model for user profiling. The innovation is based on the enrichment of common user profiling architectures to include location and other contextual attributes, so that enhanced adaptability and personalization can be achieved. For each location and context instance an associated User Profile instance is created and hence, service provisioning is adapted to the User Profile instance that better apply to the current context. The generic model, the structure and the content of this location- and context-sensitive User Profile, along with some related implementation issues, are discussed.

1 Introduction

The challenge with mobile, distributed computing is that exploits the user's dynamic environment with a new category of applications that are aware of the context in which they run. As context we define the combination of information relevant to the nearest environment of a user, such as the user location, the serving network, his terminal device, etc. Context-aware applications present information and services to a user, as well as automatically execute services and commands, sensoring context and its changes. Changes of the contextual environment, are modelled as events, and are communicated to the application for real-time service re-adaptation.

A context-aware service takes into account the current context of the user and based on this information it adapts its behaviour to the respective user's needs including personal preferences and environment's capabilities [1][2]. The contextual informa-

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tion can be encoded in various related profiles such as, the user preferences profile and the terminal, ambient, network, and service profiles. The combination of all these profiles constitutes the User Profile [3][4].

The issue of adapting service provision and providing personalised services based on user preferences is what 3GPP introduced in Virtual Home Environment (VHE) [5]. VHE is a concept for Personal Service Environment (PSE) portability across network boundaries and between terminals. Primary aim of VHE is to consistently present with the same personalised features, User Interface customisation and services in whatever network and whatever terminal (within the capabilities of the terminal and the network), wherever the user may be located. VHE is enabled by user profiles since they encode parameters that are essential to the user, such as the users' preferences for communication and service presentation on the terminal.

In particular, the User Preferences profile encodes desirable service provision features that are particular to an individual user. User preferences can be categorised into service-independent, which apply to all services that are accessed by the user and service-specific, which pertain to a particular application.

Since profiling information is exchanged among different administrative boundaries, to assure interoperability the XML [6] and the other XML-like languages (e.g., WSDL [7], SMIL [8], OWL [9]) are the best candidates for describing profiles. Moreover, profiles should be laconic so that they are transmitted efficiently. In situated–aware architectures user profiles must be dynamically composed since their constituting segments may be distributed. Contextual profiles influence greatly a service's deployment and execution, since context-aware services should adapt to context and related updates.

To enable third parties to develop context-aware services above mobile communication systems, various efforts have been undertaken by standardization working groups and fora towards the introduction of open, network-independent interfaces enabling context retrieval [10]-[13]. These interfaces provide applications with transparent access to network functionality (e.g., call control, location information, messaging, profiles retrieval), thus offering third party application developers the opportunity to create advanced, network-independent and context-full services with standard software engineering tools and general-purpose programming languages.

Let us now illustrate how all these technologies above should ideally work assuming a hypothetical, but realistic, service provision scenario. We assume that a mobile user is receiving real-time video news from an application provider using a large-screen WLAN-enabled laptop while at home. As the mobile user is boarding a vehicle to his office and changes from the large-screen terminal to a portable 3G phone, a context information server in the service support centre notifies the application of the location and the terminal and radio access update. Application successfully recognizes, by the user's profile or after interacting with the user, the user wish to change content (media) from video to text and a media converter executes content conversion.

The above is only one example of requirements for the flexible, customized, context-aware and ubiquitous multimedia service provision to mobile users that the evolution of mobile communication systems to 3G and beyond introduces. Definitely, in a system that aims to provide flexible and context aware service provision and adaptation, the knowledge of the system status as well as the various entities' states and events are significant factors. One must be able to know at any given time the network status, the user location, the profiles of the various entities (users, terminals, network equipment, services) involved and the policies that are employed within the system. Namely, the system must be able to cope with a large amount of context information.

However, in order for this scenario to be optimally and operationally deployed in real life, several technological requirements should be fulfilled by involved infrastructures such as:

- A sensoring infrastructure effectively monitors the context of the user (location, terminal, Radio Access Technology (RAT)) and notifies the application whenever the applicable context changes.
- The preferences of the user with respect to the application provision should be, at least, location-dependant, so the application retrieves the applicable application customisation set whenever the context changes.
- This implies that the favourite geographical areas of the user should have, at first, been defined and then, that for each of these areas the corresponding sets with the user preferences for application customisation have been defined and corresponded to them.
- The application scenario is defined in a standardised document, which describes all the alternative provisioning and media adaptation aspects it can support.

All these requirements further burden service provisioning. However, taking into account that development and deployment for end-user applications should be kept as simple as it can, as well as that the additional intelligence required by these applications for the step towards context awareness should be minimal, it is induced that the certain additional intelligence required should be transferred from applications to networks or middleware applications [2]. Furthermore, most of the requirements above concern some provisioning attributes and components common to most context aware applications. Hence, it would be beneficial, in terms of minimising complexity and potential useless interactions, if some common services and components were offered to open access, so these can be reused and shared among interested parties or applications. For example, an infrastructure provided for context monitoring and events notification can be easily shared by several applications. The same states also for some user profiling issues, since the information related to the favourite geographical zones of a user or its generic preferences for services consumption from within them could be shared among authorised applications of the specific user. The latter issues enhance our position for transferring the intelligence required for context awareness from applications to a middleware layer. This aspect is illustrated in Fig. 1. Adopting a middleware layer with open access to authorised applications and assigning to it the required intelligence for context awareness, simplifies and facilitates adaptation to context as well as development, composition and deployment of context aware applications, while minimises redundant interactions between applications and underlying network infrastructure.

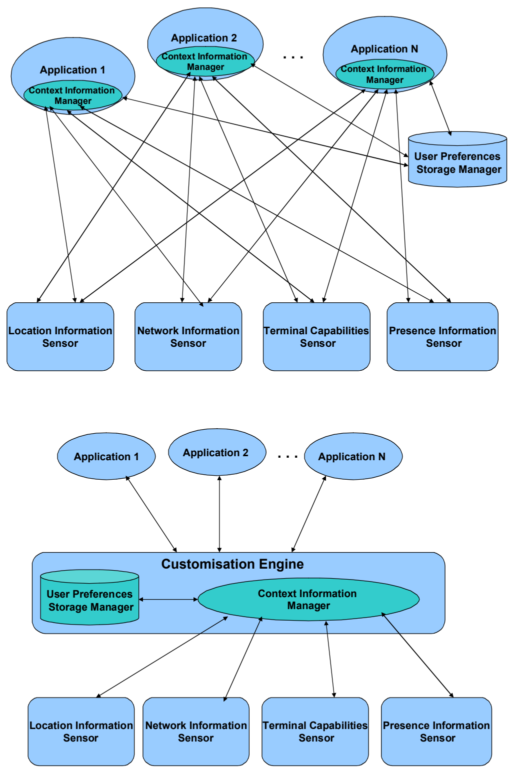

Fig. 1. Context awareness with and without mediation

Present paper focuses on location and context awareness in service provisioning and proposes an open and shared middleware framework that enables efficient management of location and context information. Furthermore, a more flexible and innovative model for user profiling is introduced that facilitates adaptation to context. The generic model, the structure and the content of a context-sensitive User Profile, along with some related implementation issues, are discussed.

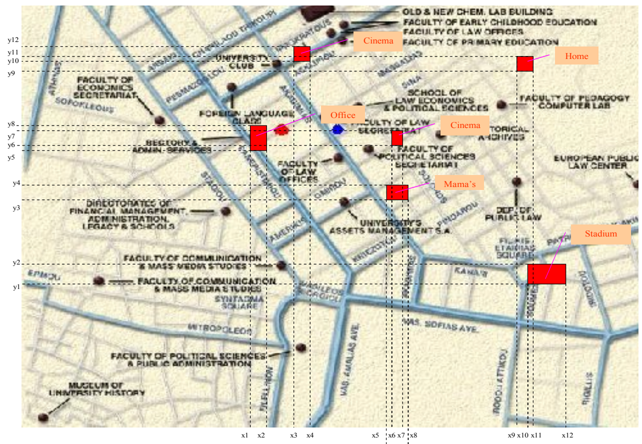

Fig. 2. User-defined Home Zones of a subscriber

2 Location- and context- sensitive user profiling

The User Profile is a key means to provide subscribers with truly location aware and customised services. Additionally to the service deployment and execution mechanisms, which take the user location into consideration, the management of user profiles can be also location sensitive. Location awareness in User Profiling is based on the concept of user-defined Home Zones. Each Home Zone comprises a geographical area into which a user wishes to experience personalised and customised service provisioning (e.g., the Home, the office, the car) [14]. Ideally a Home Zone should be as wide as the user wishes, so that truly customisation can be achieved. For example, a user may wish to experience differentiate service provision in each room of his house or office. In such a case each room should be considered as distinct Home Zone for that user. However, limitations in the location measurement accuracy induced currently by various positioning technologies, forbid Location Based Services (LBS) to distinguish among very narrow Home Zones. Due to this fact, certain distance among the defined Home Zones of a user, depending on the accuracy of the location measurements, should exist, so the position detection system can follow the moves of subscribers from one Home Zone to another. In the near future, when the location estimation technologies mature further, location based services shall provide users with more accurate positioning and Home Zone definition. Fig. 2 Illustrates the example user-defined Home Zones of a subscriber, along with the associated coordinates bounding each one.

In the proposed framework the location-sensitive user profiles are managed by the User Profile Manager (UPM) assisted by the available location and context sensors of the underlying infrastructure. Location sensor will be identified hereafter as the Location Manager. In this context, personalisation and customisation during service provision is achieved by discriminating the user preferences according to the location (e.g., Home, work) of the user and by maintaining different User Preferences Profiles (or Service Customisation Sets) for each instance (e.g., Home-, work-dependent profiles). Other contextual parameters that can be also taken into account are the serving RAT, the type of the Mobile Equipment (ME), the time of the day, or the presence status [15] of the user (e.g., lazy- or work- or mood- specific). These attributes constitute the user context. For each context an associated User Preferences Profile is created and hence, service provision is adapted to the User Preferences Profile instance that better apply to the current user context.

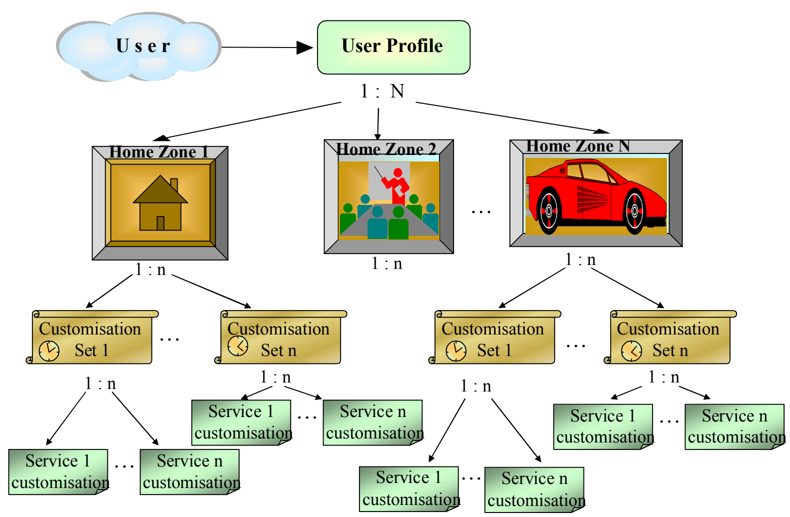

Fig. 3. Home Zone-sensitive user profiling

Fig. 3 depicts the Home Zone-sensitive user profiling approach. Each user is associated with a single User Profile that contains general information for the subscriber such as his general user preferences, the available terminal capabilities, the subscribed network capabilities, etc [3]-[4]. That User Profile consists of several, Home Zone-dependent, Profile instances that inherit from the User Profile and contain various, Home Zone-dependent, personal attributes such as the QoS values related to home use or travelling. A user may have one or more instances (or Service Customisation Sets) of a specific Home Zone profile; each individually customised by the user and associated, for example, with a specific time or period of the day or other context attributes. Each Service Customisation Set includes the applicable user preferences, with respect to the User Interface preferences, the Browser appearance, the preferred memory usage etc., and the service subscription Profiles, with the preferred settings for the subscribed services (e.g., for pricing) and associated privacy policies. The user experiences service offering according to the current active Service Customisation Set.

From that point of view each Home Zone-sensitive User Profile can be considered as a tree with the subscriber's identity (e.g., his IMSI, e-mail or SIP identity) at the root, the Home Zone and context attributes as nodes and the service customisation sets as leaves. Storing locally such a tree-like User Profile for each subscriber, finding his current Home Zone and context and crossing that tree from top to down, the UPM can retrieve the most up-to-date user profiling data each time it is required. Although in Fig. 3 only the Home Zone and time attributes are taken into account in the user preferences selection and service differentiation, further contextual parameters could be used, such as the type of ME and the serving RAT of the subscriber, for better elaboration and specification.

In that context, each subscriber upon registration with the proposed platform specifies his applicable Home Zones describing each one of them with addresses or street names. It is then up to the Location Manager of the platform to map the Home Zones specified by the user to the appropriate geographical coordinates or network areas (e.g. cell Ids, Location or Routing Areas), making use of a data base with the appropriate spatial information. Thus, whenever a user enters the platform and accesses an application, the UPM retrieves the current location and the required context attributes of the user in order to identify the Home Zone he is currently situated in and to retrieve the user preferences that apply to this specific Home Zone and context. This has as result only the profile that better applies to the current Zone and status of the user to be taken into account, customising the whole service provisioning accordingly. It is implicit that the user is always prompted to confirm the User Profile instance selection or alternatively to choose the one he desires.

```
<Profile112>
        <ProfType> General Preferences </ProfType>
        <ProfileID> GP112x </ProfileID>
        <ProfileURI> http://erotocretos.di.uoa.gr/profiles/profileGP112x </ProfileURI>
        <RefContextZone>
                <HomeZone> HZ1</HomeZone>
                <MTType> MT1</MTType>
                <RATType>RAT2</RATType>
        </RefContextZone>
</Profile112>
```

Fig. 4. Specification of a new user preferences set

Then, each time the subscriber specifies a new user preferences set, it is associated with the current Home Zone and context of the subscriber or the Home Zone and context indicated by the subscriber. For each new Home Zone or context value (e.g., new ME, or new RAT) occurs, a new node in the tree is inserted. Equally, for each new customisation profile a new leave is added to the tree. Definitely, a user preferences customisation set can be associated with more than one Home Zones and contexts, if the user wishes. For each active subscriber the UPM stores locally a data structure that represents the tree of his location sensitive User Profile. The data itself is not included. Instead a reference to the repository that stores each profile is kept, along with a unique data reference generated upon data creation and storage. The Home Zone and the context attributes are used by UPM to identify the path to the active profile data. To this end, a pointer that crosses the User Profile tree and points to the active customisation profiles is created for each user. The pointer is updated each time a change on active Home Zone and context occurs. Fig. 4 illustrates the specification of a new user preferences set for a user and its correlation with specific Home Zone and context attributes (defining the path to the associated profiling data in the User Profile tree). This data structure is inserted in the User Profile tree of the specific subscriber constituting a new leave in the User Profile structure. After insertion, this data structure will, also, be the result of search of UPM in this User Profile tree for the "General Preferences" profile of the subscriber that corresponds to the designated Home Zone and context. Retrieving this data, the UPM can, then, access the corresponding profile repository (specified by the referenced profile URI) to retrieve profile GP112x.

Hence, whenever a user accesses an application, the application requests by the UPM the applicable preferences set of the user. The UPM, then, retrieves the user location in order to identify the current Home Zone of the user, along with the context attributes required for profile identification (e.g., the ME type and the type of the serving RAT) to identify the current context and the applicable profile instance of the user and, finally, to retrieve by the corresponding repository the user preferences set that applies to the specific context. It is implicit that the user is always prompted to confirm the User Profile instance selection or alternatively to choose the one he desires. The UPM stores locally the current Home Zone and context of each user for later use and faster searching in the User Profile tree.

With location and context aware user profiling only the profile that best applies to the current Home Zone and status of the user is taken into account, customising the service offering accordingly. During service access, the underlying Location Manager (and the other context sensors) tracks the location (and the other context attributes) of the user and upon entrance in or exit from a Home Zone an appropriate notification is sent to the UPM notifying it for the new Home Zone the user entered. The UPM, then, retrieves the applicable user preferences in the new Home Zone of the user in order to announce them to the executing applications by the user and enable them to tailor their service provision to the user accordingly. Fig. 5 illustrates a User Profile instance transition induced by a Home Zone change. As the user moves from Home Zone 1 to Home Zone 3, it leads to a change of his current context from Context Zone 1 (Home Zone 1, Mobile Equipment 1, Radio Access 2) to Context Zone 2 (Home Zone 3, Mobile Equipment 1, Radio Access 2), which in turn leads to a different user preferences set (from User Preferences Set N to User Preferences Set 2). Such a change of the active User Profile instance triggers the UPM to generate and propagate an associated alert event, so that the applications and modules registered for receiving such alerts are properly informed.

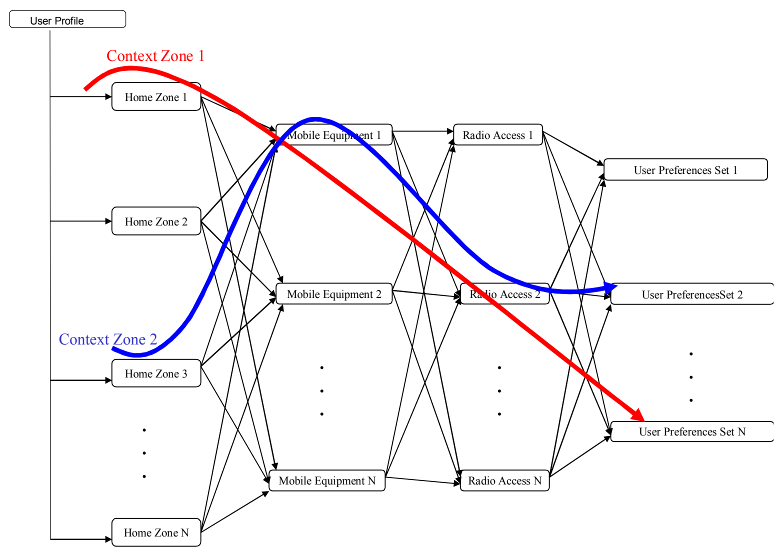

Fig. 5. User Profile instance transition induced by a Home Zone change

In Fig. 5, apart from the Home Zones, the ME and the serving RAT type context attributes are also used for further profile elaboration. Taking into account that within a single Home Zone a subscriber can switch from one type of mobile equipment to another (e.g., from a UMTS mobile handset to a PDA or laptop) and access different radio environments (e.g., from GPRS or UMTS networks to WLAN/WiFi or Bluetooth), further classification of user profiles within a Home Zone can be achieved. This is why we consider that the current Home Zone, current ME and current serving RAT attributes of a subscriber are the three key context attributes that uniquely identify the current context of a user. Hence, we define each triplet of type {current Home Zone, current ME, current RAT} as a user specific *Context Zone* that can be used for identifying the user status and customising the service provisioning accordingly.

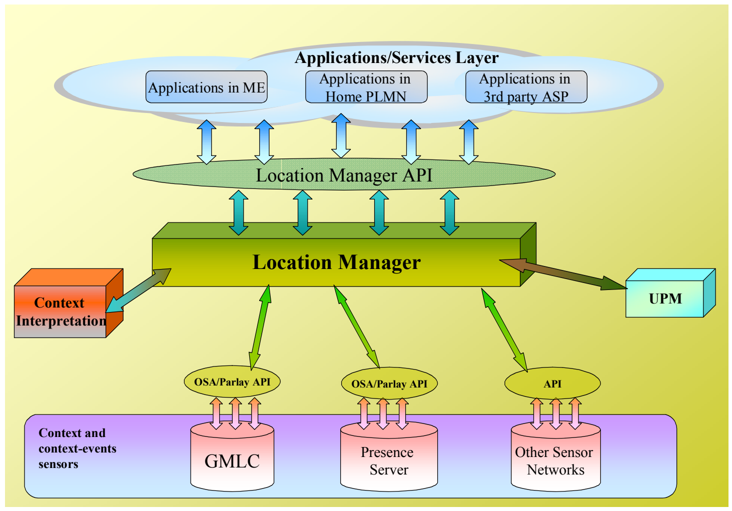

Fig. 6. Environment of the Location Manager

3 Location Management

The Location Manager constitutes an independent module responsible for retrieving, managing and exploiting the information related to the location and mobility of the subscribers. It interacts with the location and presence information's sources of the underlying network infrastructure (e.g. the 3GPP GMLC [16],[11],[12] or the Presence Server [15]) to track the location, presence and mobility of the subscribers [17]-[20]. To translate the retrieved raw location information into a recognizable and usable format instead of the geographical coordinates or network areas that the underlying Location Sensors or Server (e.g., the GMLC) provides, the Location Manager interacts with the appropriate Interpretation Component of the platform. Then, location, presence and mobility data and events along with the preferences of the corresponding subscriber, taken from the user profile, are processed to provision the user in the new location he entered. Fig. 6 illustrates the environment of the Location Manager. The users' location can be used, for example, to determine, based on the user's preferences, the reconfiguration policies that are propagated from the Location Manager to the underlying network infrastructure [17]-[20]. Combining the location information with the user preferences, the Location Manager is able to provide end users and any authorised entity internal (e.g., the Application/Service logic component) and external (e.g., the third-party Application/Service Providers (ASP)) to the platform with new advanced location aware services. Furthermore, it enriches the service provisioning approach of our platform with location information features, enabling better customisation and personalisation of the whole service offering.

Primary goal of the Location Manager is to enable easier development of LBS, hence it does not focus on the development of a specific application or service (location-based or not). Instead, our primary goal is to build a generic framework for location-sensitive service development and deployment that can accommodate any service or application, gathering the necessary informational resources and building blocks for facilitating development and deployment. To this end, we provide applications with an execution environment and some reusable and customisable location sensitive building blocks for structuring their functionality, while we hide from application developers the complexity and the physical interactions required for retrieving and adapting the location information. For transparency and independence the functionality provided by the Location Manager is accessed by internal modules of the framework as well as authorised ASPs through an open API provided to authorised entities [19]. We have designed the methods and built the services that we expect a location-based application/service to need frequently. In particular, this open interface includes methods that enable:

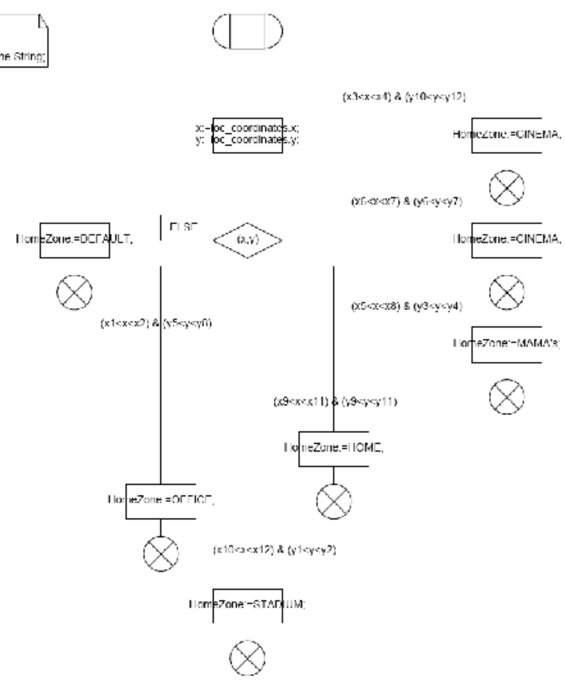

Fig. 7. Translation of geographical coordinates to applicable Home Zone

- Retrieval of the location of the specified user. Location retrieval can be immediate (in case that the current location of the user is requested) or deferred (in case that the location of the user when a specific event takes place is requested) [16], [17]-[20]. Making use of appropriate spatial data bases or GIS systems, the Location Manager is able to map the current raw user location taken by the underlying Location Sensors (expressed in geographical coordinates or network areas) to the requested higher-level format (e.g., street address or predefined geographical Zones (Home Zones)). Hence, the retrieved location information can be in a recognizable and usable format. Fig. 7 illustrates a simple algorithm that can be used for the translation of the geographical coordinates (x, y) retrieved from the underlying location sensors to the corresponding Home Zone of the user having defined the Home Zones of Fig. 2. It is based on simple comparison of retrieved coordinates against the coordinates bounding each established Home Zone for the user.
- Creation/Modification/Deletion of Location-sensitive Policy Classes. Such a policy class can be, for example, the registration of the Home Zones of a user with the Location Manager, so the Location Manager monitors the user mobility within them.
- Activation/De-activation of the Location-sensitive policies.
- Creation/Modification/Deletion of Policy Events. Such a policy event can be, for example, the crossing (entrance or exit) of registered Home Zones by their owner.
- Registration/Deregistration for receiving Location-sensitive event notifications. With this method the registered applications can receive notifications from the Location Manager whenever a registered event occurs (e.g., whenever a specific user crosses his registered Home Zones).
- Handling of event notification arising from the underlying network.
- Submission of notifications to the registered end-users and applications for the available policies, restrictions, updates, tariffs, reconfigurations and other events that are associated with the current location of the user or induced due to the location updates that occur.

4 User Profile Management

The architecture we propose for User Profile management enhances the 3GPP GUP architecture [3]-[4] with the concepts of Home Zones-based Profiles. Hence, it adopts the distribution and information model of the GUP incorporating, additionally, in its logic provision for enhanced context sensitivity. The enhanced GUP server proposed here is called User Profile Manager (UPM). The UPM interacts with the Location and Presence Manager, as well as the context sensors of the proposed framework to retrieve the location, presence and other contextual information needed to compute Home Zones and provide location sensitive User Profiling.

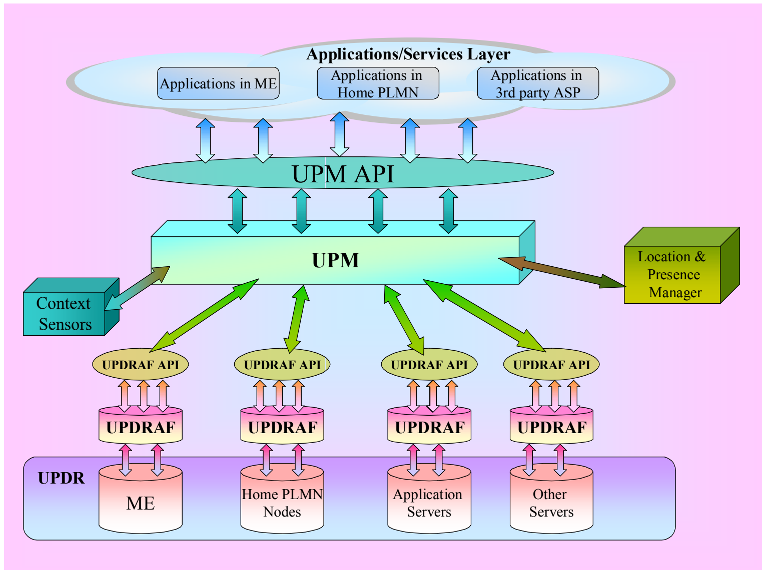

Fig. 8. Environment of the UPM

The UPM is responsible for managing the User Profiling information distributed in several data repositories across the network and disseminating the user-specific information to the requesting applications and services. It mediates between application/services and User Profile Data Repositories (UPDR), hiding from applications the underlying infrastructure and facilitating the interaction with the profiling sources. The applications that may request access to the User Profile data can vary from applications in the Mobile Equipment (ME) to applications in the Home PLMN or third party Application/Service Providers (ASPs). The UPM enables authorised applications to insert/delete or modify user profiling data in UPDRs, retrieve user profiling data upon request and receive profiling dependent event notifications, each time a registered events occur. Fig. 8 illustrates the environment of the UPM.

To hide the implementation details of the profiling architecture from applications and services and assure service transparency, the interaction between internal modules or services of the profiling architecture, as well as authorised third party applications, and the UPM is accomplished through an open Application Programming Interface (API) provided by UPM to authorized entities [19].

Profiling data stored in the various User Profiling components are identified by the identity of the associated subscriber/user, the corresponding Home Zone and context attributes of the User and the profile type. The specified methods provide:

- Creation/deletion/update of user profile data. These procedures are always related to a single subscriber, Home Zone and context, which are identified in the request. If Home Zone or context attributes are missing the current Home Zone and context of the identified subscriber is assumed.

- Retrieval of the whole user profile data or some specific components. The queried data are identified by subscriber identity, Home Zone and context attributes and the data reference. In case that Home Zone and context are not passed in the request the UPM retrieves the current Home Zone and context of the targeting user and returns to the requesting application the requested profile data that corresponds to the current Home Zone and context of the user.
- Listing of the existing profile items in the various User Profiling Data Repositories that are associated with the specified Home Zone and context of the targeting user.
- Creation/Modification/Deletion of profile-dependent policy events.
- Registration/Deregistration for receiving profile-dependent event notifications.
- Submission of event-driven notifications to the registered applications whenever some of the registered events occur. The synchronisation of the profile data kept by an application can be performed by last three methods (creation of a policy event (e.g. monitoring of the active preferences profile of a specific user for the application XYZ), registration for receiving notifications related to this event and receipt of associated notifications whenever an update of the active preferences profile is required (e.g., due to the user transition from Home Zone 1 to Home Zone 2)).
- Notifications to the users for the profile-dependent policies, restrictions, updates associated with the current Home Zone and context of the user.

The user profiling information is distributed and stored in various UPDRs. Each UPDR stores the primary master copy of one or several profile components. Possible candidates for UPDR are the ME, the HSS/HLR, and various application and management servers in Home PLMN or 3rd party Application/Service Providers. Synchronization between profiling data in UPDRs and UPM is required.

Access to UPDRs is accomplished through the associated User Profile Data Repositories Access Functions (UPDRAF). Each UPDRAF can be viewed as the front end to the underlying repository that realizes the harmonized access interface. It hides the implementation details of the UPDR from the rest UPM infrastructure. The UPDRAF performs protocol and data transformation where needed. The protocol between the UPDRAF and the UPDR is implementation dependent and not standardised. The UPDRAF can take also part in the authorization of access to UPDR. Through UPDRAFs the UPM can insert/delete/modify the underlying profiling data, read them, and receive synchronisation notifications whenever some change on profiling data occurs.

Example Interactions of UPM

A. Retrieving the user preferences

Fig. 9 illustrates the required interactions between the components of the UPM environment whenever an application accesses the UPM to retrieve the current user preferences of a subscriber. Interactions include:

1. An authorised application requests to retrieve some User Profile components of a specific subscriber. The application does not include the Context Zone parameter in the request.
2. The UPM authenticates the application and checks its authorisation to receive the requested data.
3. Since Context Zone is not provided, the UPM presumes that the profile data requested are those associated with the current Context Zone of the targeting user. Hence, the UPM contacts the Location Manager of the architecture to retrieve the current Home Zone of the user.
4. The UPM retrieves the type of the Mobile Equipment from the appropriate context sensor.

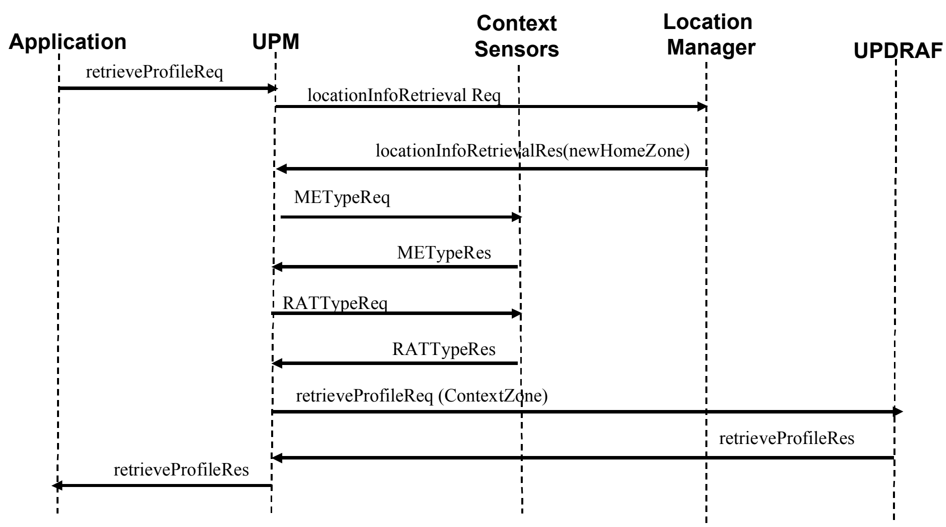

Fig. 9. Required interactions for retrieving the user preferences

5. The UPM retrieves the type of the Radio Access Technology serving the user from the appropriate context sensor.
6. The UPM identifies the current Context Zone of the user and based on that it crosses the Context Zone-dependent structure of the User Profile to identify the storage location of the requested components.
7. The UPM accesses the API of the identified UPDR to request the specified data. The UPM includes Context Zone and data reference in the request.
8. The UPDRAF searches the stored profiling information to retrieve the requested data and responds to the UPM.

9. The UPM responds to the application with the requested profiling data. Since the data requested by the application might are stored in several UPDRs, it is likely the UPM to have to interact with all involved repositories to request the data. In that case, the UPM should properly combine the returned data before responding to the application.

B. Profiling dependent event notifications

The example below presents how an authorised application remains informed and updated about changes on the active user preferences of the targeting subscriber, induced by changes on the current Context Zone of the user.

Fig. **10** illustrates the required interactions between the various components of the profiling architecture:

1. The application accesses the API provided by UPM to create a profiling dependent policy event related to a specific subscriber. The specific event intends to constitute the application aware of the changes on the active user preferences profile of the targeting subscriber.
2. The UPM authenticates the application and checks its authorisation for the requested operation.
3. The application registers itself to receiving notifications related to the aforementioned event.
4. Sometime, the UPM receives an event from the Location Manager of the architecture indicating that the specified subscriber has entered a new Home Zone. It is assumed, here, that registration of the UPM with the API of the Location Manager, according to the procedures described in section 0 for receiving such notifications from the Location Manager, has preceded.
5. The UPM contacts the Location Manager of the architecture to retrieve the current Home Zone of the user. This step can be skipped if the location notification received includes the new Home Zone of the subscriber.
6. Since the UPM has not received notifications from the associated context sensors for changes on the Mobile Equipment or the serving RAT of the subscriber, it assumes that only the geographical location of the user has changed. The UPM identifies the new Context Zone of the user and based on that crosses the Context Zone-dependent structure of his User Profile to identify the available profiles of the user in the new Context Zone.

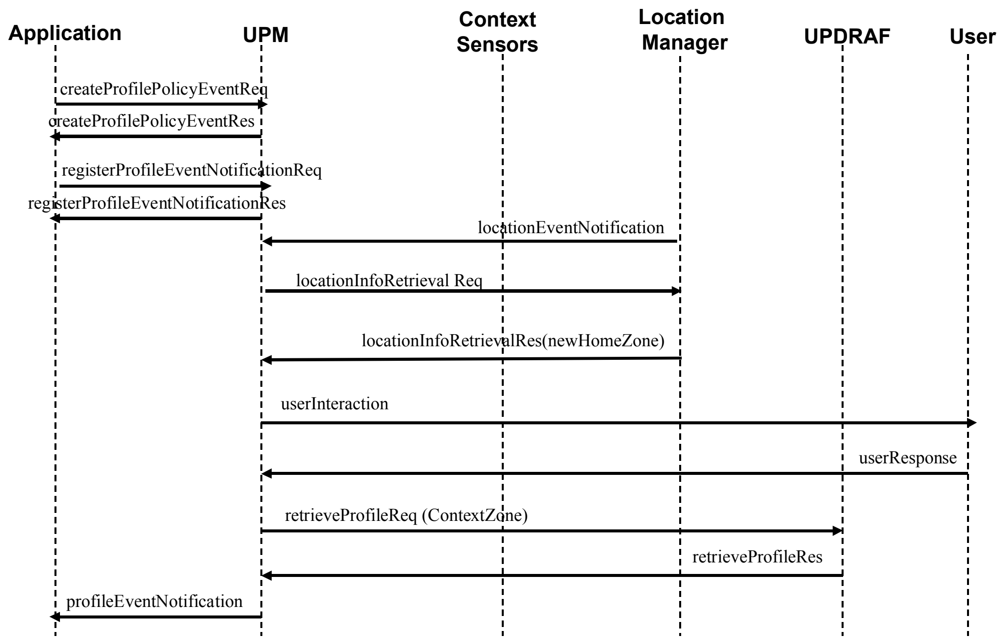

Fig. 10. Required Interactions for enabling profiling dependent event notifications

7. The UPM, optionally, interacts with the user to inform him about his available service customisation profiles in the new Context Zone.
8. The user selects and activates the desired profile.
9. The UPM updates the User Profiling pointer to point to the newly activated profile of the user, and locates the UPDR that stores the new profile components. Then, the UPM accesses the API of the identified UPDR to request the specified data. The UPM includes Context Zone and data reference in the request.
10. The UPDRAF searches the stored profiling information to retrieve the requested data and responds to the UPM.

The UPM notifies the requested application for the change occurred. The notification to the application can be a simple announcement of the change occurred on the user preferences, unless the application has requested to also receiving the new profiling data along with the notification (illustrated in

Fig. **10**). In the former, the application should contact again the UPM to receive the new data

5 Conclusions

Present paper focused on location and context awareness in mobile service provisioning and proposed a framework that enables efficient management of contextual profiles. Furthermore, a flexible and innovative model for user profiling was introduced. Innovation is based on the enrichment of common user profiling architectures to include location and other contextual attributes, so that enhanced adaptability and personalization can be achieved. For each location and context instance an associated User Preferences instance is created and hence, service provisioning is adapted to the User Profile instance that better apply to the current location and context.

Comparing the framework of location and context sensitive user profiles with the traditional, non-context sensitive, profiling architectures in mobile communications (e.g. the 3GPP GUP), someone can easily note that the former offers really challenging advantages to applications enabling their efficient adaptation to location and context, minimising, in parallel, the additional intelligence required to this end. The price to be paid for these advantages is mainly in terms of additional delay, which is due to the interactions required between UPM and location and context sensors. First results from evaluation of our framework show that in the worst scenario of its functionality, the UPM requires about 35 % more time than GUP to retrieve a requested profile and respond to an application (scenario of Fig. 9). However, taking into account that profile retrieval in the UPM approach takes place in two steps; the heavy one of Fig. 9, which is performed only once during an application execution scenario, and the lighter one of

Fig. **10**, which is repeatedly performed after the first profile retrieval (which requires almost the same time as a GUP-like profile retrieval), we conclude that the additional time expense that incurs the adoption of UPM greatly varies depending on the number of times that the scenario of

Fig. **10** is executed. Thus, in the execution scenario of a mobile application during the provision of which to a mobile subscriber the UPM is required to propagate ten times to the application the applicable user preferences, the additional time expense falls to 15 % of the respective GUP time. The latter result shows that for applications with high mobile characteristics, where the location and the context of the subscribers change often, the UPM is the ideal solution for enabling adaptation to context. Similar, for applications targeting to static end-users, the UPM solution has little to offer.

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