Services Provisioning in Ubiquitous Mobile Wireless Environments

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Abstract— **Ubiquitous computing has gained momentum over the last years with the expansion of mobile devices. One area of pervasive computing is context-aware systems which are applications designed to react to the constant changes in the environment. This project presents a context aware platform that handles context acquiring and processing and manages the service provisioning. The platform alleviates the process of high level application development and sets a common ground for building applications and services.**

The context-based platform objective is to support mobile users with personalized services. It offers sophisticated mechanisms in matching the mobile user's preferences with services that are enabled at the visited location, and provides them in personalized and adaptive manner to the user.
As a proof of concept, we present a case study on tourism where tourists are provided with services and information of interest based on their location and time. An application for e-tourism will be deployed on the top of the platform to assist tourists during their travels by providing them with context sensitive services. The user preferences, the current time, and the user current location are incorporated in the proactive formulation of suggestions on the tourist mobile devices about nearby points of interests (e.g. museums, restaurants….).

I. Introduction

Advances in wireless networking technologies and availability of portable devices have contributed to the emergence of ubiquitous computing. Mobile users are continually interacting with nearby environments without explicitly requiring specific needs. Their availability should be however leveraged to provide them with personalized services that have the potential to match their implicit needs.

Tedious interactions between end users and their mobile devices for service discovery are naturally restricted as their input capabilities are usually limited in comparison with browser-oriented search engines on their desktop computers. Making use of contextual information is essential to reduce the level of human machine interaction in delivering personalized and precise search results that are tailored to the user's current context and preferences.

The development of context sensitive services and their deployment remain, however, challenging as they require appropriate paradigms in interacting with different sensing entities, in gathering, interpreting and disseminating different types of contextual information, and self-adapting to changing environments.

In this paper we propose developing a platform that provides mechanisms for discovering relevant context, for processing it, and for disseminating appropriate services on the mobile users' devices. Hence, developers will need to spend less effort on the characteristics that are common across various applications and focus on the specific objectives of these applications. Different applications can be deployed on the top of the platform that provides personalized context-aware services in various domains such as e-tourism and transportation.

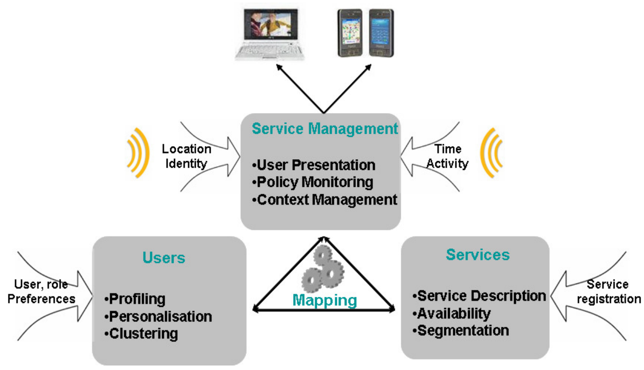

Fig 1: Generic view of the framework components.

A generic view of the context aware platform is shown in figure 1. The user repository holds user's personal information, services to which she/he has subscribed, and her/his preferences regarding service provisioning. For instance, the user might specify a time of the day where she/he wants to receive a specific service. The service repository carries information about the available services.

The platform operates by (i) registering a set of mobile users with their roles and their preferences, (ii) registering a set of available services at different locations, (iii) gathering and processing different context attributes (e.g. weather, user location, time …) and (iv) finding matching services by taking into consideration the user preferences.

The paper is organized as follows. Section 2 relates our work to existing approaches. Section 3 describes our context ontology and the user profile structures. Section 4 presents our overall architecture for providing personalized services

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in mobile environments. Section 5 describes a prototype scenario that illustrates the feasibility of our approach. In section 6 we summarize and point to future work.

II. Related Work

Several approaches were proposed for building prototypes of context aware platforms [1] [2] [3] [4] [5] [6]. Each one of them adopts a different architectural style in terms of context acquisition, context representation, and processing logic. Dey et al. proposed in [3] the Context Toolkit framework to support collecting and transforming contextual information using widgets, interpreters and aggregators. Widgets are software components responsible for acquiring context information and notifying subscribed applications when the context changes. Aggregators collect the context information from several widgets to decrease the processing requirement on the applications side, and interpreters act as proxies to applications. The framework adopts the key-value pairs for context modeling.

Chen et al. used OWL in their Context Broker Architecture (CoBrA), where a broker agent is responsible for maintaining and aggregating a shared model for context information [4]. The broker agent facilitates the distributed reasoning capabilities for service agents that make use of CoBrA by including a knowledge model and therefore removes the need to deal with the reasoning part for each service and application. CoBrA includes its own policy language, Rei, which controls access and enables security and privacy protection.

Gu et al. [5] designed the Service-Oriented Context-Aware Middleware (SOCAM) architecture which aims to provide an efficient infrastructure support for building context-aware services in pervasive computing environments. The middleware is based on a hierarchical ontology-based context model. The middleware converts various physical spaces where context is acquired from into a semantic space where context can be easily shared and accessed by context-aware services.

Kuck et al. presented in [6] an approach for the context-sensitive discovery of web services based on the matching of the user's context and enhanced service descriptions, stored in UDDI repository. Service descriptions contain inferred information about textual contents of a WSDL description as well as feedback information (e.g. the time of service recommendation).

Our work to supporting mobility and context aware computing complements these research projects by integrating the implications of mobility and the context to the platform middleware. Applications and services developed upon the platform can easily be deployed in various scenarios including e-Tourism and e-Transport.

The platform can also be used with third party services which need to register to the platform. These services are then advertised to users depending on the time and their location and the current devices. At the registration phase to the platform, each service subscribes to specific context information so that it can adapt itself accordingly.

III. The Platform Architecture Description

The proposed service provisioning platform is based on a generic architecture that supports context aware service discovery.

Fig 4 shows a layered architecture that separates the concerns of each layer among acquiring, processing context information, and providing users with services that best fit their current situation.

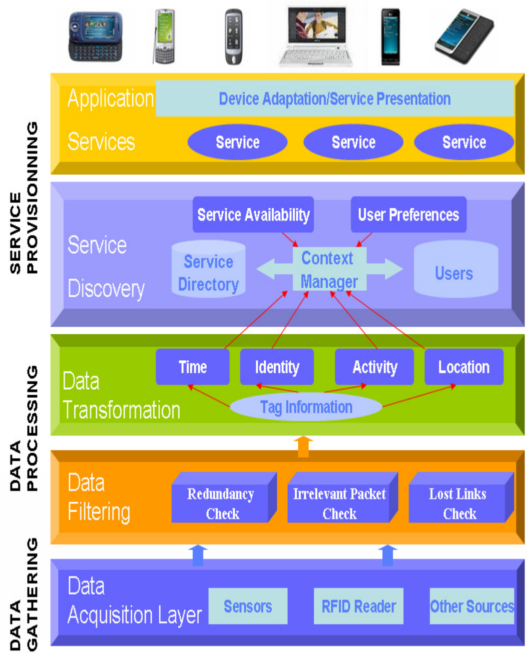

Fig 4: The overall Platform Architecture.

The architecture handles a variety of sensing devices, uses a context model that can be extended with new context data types, makes use of a generic description of services and user profiles, and provides services to a wide range of mobile users [7].

A. *Context Data Acquisition*

The data acquisition layer is in charge of collecting context attributes from various ubiquitous front end data acquisition hardware (e.g. RFID readers, sensors, and other automation devices). This layer listens for signals that hold information describing the context.

In our platform we have built a network of wireless sensors that deliver different kind of information to the base station such as temperature, noise, etc... The WSN has been also used to roughly determine the position of a mobile user by fixing some nodes at specific locations (i.e. buildings) and exploiting links that mobile nodes, carried by mobile users, form with fixed nodes while nearby.

Figure 5 shows an example of sensor network nodes distribution. In this configuration, three stationary nodes (3-5) are fixed in three different locations. Node 1 is connected to the PC which acts as a base station that collects data sent by other nodes. Node 2 was a mobile node carried by a user.

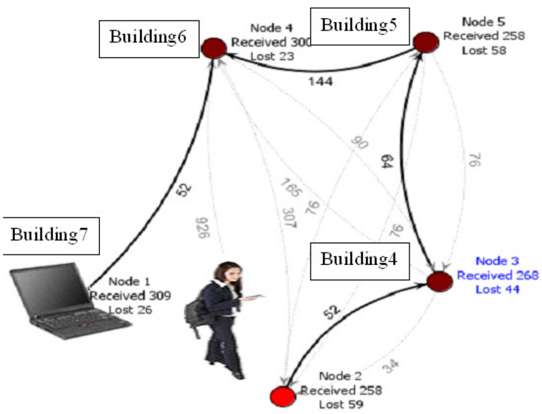

Fig 5: Mobile and Stationary Nodes Distribution

Because the data is received in raw format that may not be understood by the service discovery module, it is first forwarded to a data processing layer that transforms it into meaningful information. An example of incoming sensor network packets is shown in figure 6.

```
1236675155187 Message <MultiHopMsg>
  [sourceaddr=0x1]
  [originaddr=0x5]
  [seqno=0x9fd]
  [originseqno=0x511]
  [ttl=0x6]
  [id=0x21]
  [data=0x95 0x1 0x0 0x0 0xe 0xb 0x4 0x0 0x3 0xfe 0x4 0x0 0x3 0x0 0x2 0x0 0xa5
0x0 ]
1236675155703 Message <MultiHopMsg>
  [sourceaddr=0x1]
  [originaddr=0x2]
  [seqno=0x9fe]
  [originseqno=0x55e]
  [ttl=0xc]
  [id=0x21]
  [data=0xf9 0x1 0x0 0x0 0x3f 0xb 0x3 0x0 0x3 0x6e 0x4 0x0 0x3 0x0 0x5 0x0 0x64
0x2 ]
```

Fig 6: Incoming Sensor Network Packets Log File.

B. *Context Data Processing*

The basic goal of context processing layer is to generate concise and accurate information about the context that would be used in the context-sensitive service discovery [8]. Mechanisms used by the data processing layer include filtering and transforming the received raw data [9].

1) *Data filtering*

Different filtering methods could be applied to raw data depending on the types of used sensing sources and on the nature of the data required at the application level. The filtering layer holds a filtering policy repository to offer the flexibility to handle different filtering format. In our platform, the filtering has three main functions:

- Duplicate Removal: Since the data is sensed continuously, the sensors may re-send the same data read multiple times.
- Irrelevant data Removal: Some of the data received by the sensors is of no use to the service applications. For instance, the data received that reports about links formed between two stationary nodes does not provide any additional information.
- Lost links removal: Because a mobile node may change its location, we need to continuously update the mapping of mobile node to physical locations to keep the latest information about its current position. While a mobile user is in proximity to a building, the base station receives data describing the link between the mobile user node and the stationary node in that building. If the base station stops receiving data about the existence of that link within a time frame window, the link is reported as lost..

2) *Data Transformation*

Raw data presents little information until they are transformed into a form suitable for application-level interactions. So, from an application perspective, it is desirable to provide a mechanism that turns the low-level captured data into meaningful input. The transformation layer contains pre-defined rules for transformation depending on the type of the raw data.

This layer presents flexibility with regards to transformation rule definition, since they can be added, changed and deleted in an easy manner. Transformation rules are represented using policies.

C. *Context Service Provisioning*

In this layer, the context manager component has the role of matching the user context (e.g. location) with the appropriate services. The context manager also takes into consideration the user preferences to offer personalized services to each user.

Upon receiving the context information, the context manager sends a request to the appropriate third party services (i.e. web services) to find services that better match the user current context. The context manager would for instance ask a web service to find all the restaurants that are close to a user location. The web service returns a list of services that best fit the user current context. Fig 7 shows a simplified sequence diagram of context discovery process.

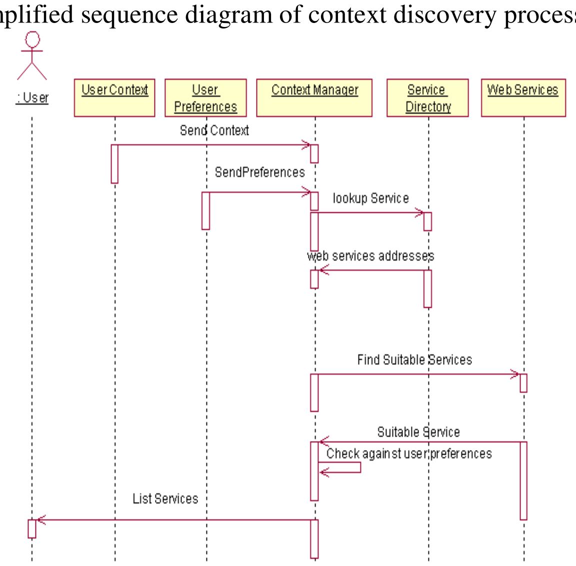

Fig 7: Sequence Diagram Describing Service Discovery Algorithm.

IV. SERVICES SEGMENTATION

In the service provisioning process, a user is provided with services that correspond to his preferences and that are available in his current location. Because the user may not be aware of other services of interest to him in a specific location, the platform includes an advertisement mechanism that suggests new services to the user. This mechanism uses services segmentation approach.

This approach consists of segmenting the available services using historical records**.** The resulting segments represent sets of services used by people who have similar profiles and preferences. Hence, a user who was provided a service that belongs to a segment might be interested in other services in the same segment. These services will be suggested to the user to increase his awareness about available services in his current location.

This segmentation process is done sing SCAR [10]. SCAR is an algorithm for clustering massive categorical data with class association rules. This algorithm transforms the unsupervised clustering problem into a supervised learning problem by adding artificial contrasts then learn the candidate clusters using class association rules. Metarules [11] are then used to merge the clusters to form final segments. The segmentation process is carried off line and the segments are updated as more usage data becomes available.

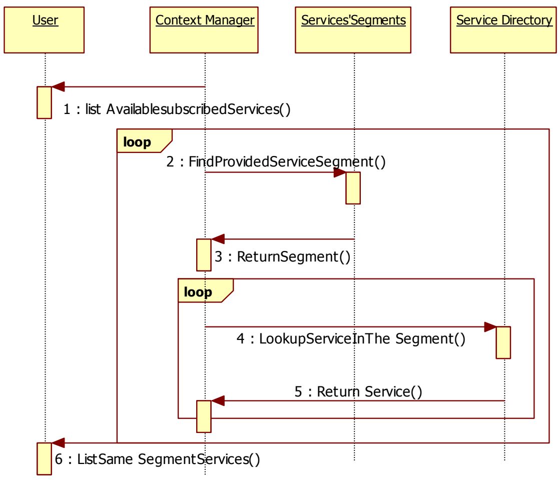

Fig 8: Sequence Diagram Describing Segment Service Provisioning.

Figure 8 is a sequence diagram describing the provisioning of the services available in the same segment as the services provided to the user. When a user is provided with the set of services that he has subscribed to, the context manager checks to which segment each of these services belong to. The services belonging to that segment are also suggested to the user.

V. A PROTOTYPE APPLICATION IN E-TOURISM

A prototype application for e-tourism was deployed on the platform that assists tourists during their travels by providing them with context sensitive services. We integrated user preferences and profiles, their current location, and the current time in the proactive formulation of suggestions on the user's mobile devices about nearby points of interests (e.g. museums, restaurants….). A tourist visiting a new location would like to be provided with the services that she/he has subscribed to when they are available. In addition, the tourist may also be interested in being informed about other services available in that location and that meet his preferences and profile which he has specified during registration.

Figure 9 shows an interface displaying the user registration of a tourist named "Yousra".

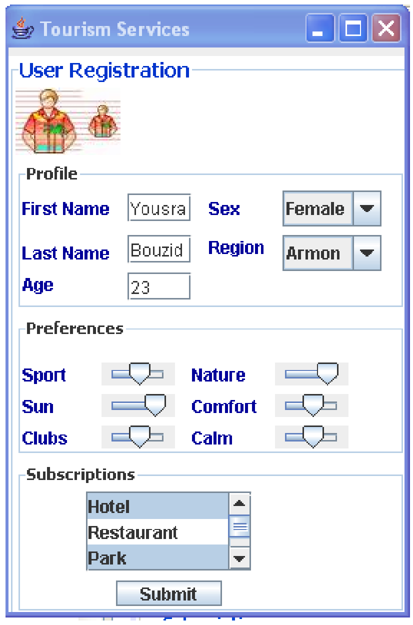

Fig 9 User Profile and Preferences Registration.

tMote sensors [12] were installed in three different buildings at Akhawayn University campus representing three regions: « Le lac », « Les alpes », and « La cote d'Azur».

A mobile user "Yousra" is detected in building 1 (region "le Lac"). Several services are available in that location including Hiking, Fishing and Park. As shown in figure 10, each service is described by a set of attributes and the time of the day where the service can be provided.

```
<Service>
        <Name>Hiking</Name>
        <Attribute>Nature</Attribute>
        <Attribute>Sport</Attribute>
        <Attribute>Clubs</Attribute>
        <Time>Daytime</Time>
        <Enabled>Yes<Enabled>
</Service>

<Service>
        <Name>Fishing</Name>
        <Attribute>SunWater</Attribute>
        <Attribute>People</Attribute>
        <Time>daytime</Time>
        <Enabled>No<Enabled>
</Service>
```

Figure 10: Service Representation

Based on the profile specified during the registration, Yousra has subscribed to Park and Hotel services. Since the Park service is available in 'Le Lac region', this service was provided to her.

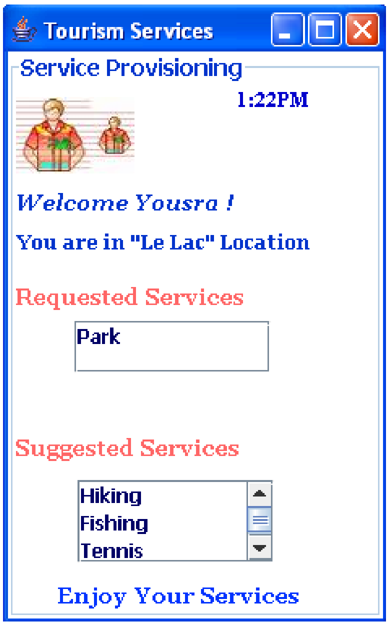

Figure 11: User Service Provisioning Interface.

To suggest additional services to Yousra, we made use of a dataset that describes the profiles, the preferences, and the services used by a set of 552 tourists that have visited 'Le Lac' region in the past [13]. The services in the dataset were segmented using SCAR algorithm into different segments. The Park service is part of a segment that contains also Hiking, fishing and Tennis services. These services are then also suggested to Yousra as shown in figure 11.

VI. CONCLUSION

In this paper we presented a generic platform for providing users with personalized context aware services in mobile environments. The platform offers mechanisms (i) to register a set of mobile users, their roles and their preferences, (ii) to register a set of available services at different locations, (iii) and by evaluating different context information, provides each user with matching services. The platform also provides activated services with appropriate context attributes, so that they can adapt accordingly. As a result, the user is provided with personalized services that fit her/his current context and meet her/his preferences. When activated, a service continuously receives appropriate context information from the platform and therefore adapts itself accordingly.

We showed the feasibility of the proposed platform architecture using a prototype scenario that illustrated the platform's basic concepts. A user visiting a new location is provided by a set of services she/he subscribed to. In addition, other services are suggested to her/him based on the segmentation approach.

We are currently in the process of implementing basic services related to e-Tourism and integrating mobile RFID readers as sources of context, so that we can deploy our platform in a working environment (i.e. city of Ifrane) to illustrate how it can be helpful in providing support to tourism, a vital sector in the Moroccan economy.

ACKNOWLEDGMENT

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