A CONTEXT-AWARE PLATFORM TO SUPPORT MOBILE USERS WITH PERSONALIZED SERVICES

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Abstract: The emergence of ubiquitous computing, enabled by the availability of portable devices and advances in (wireless) networking technologies, has increased the need for personalized and adaptive services in mobile environments. Users are not anymore only using computing facilities on their desktop machines in a relatively predefined office environment, but they require having access to various services as they move from one location to another, from one device to another and from one network to another. This paper presents a context-aware platform for supporting mobile users with personalized services. The platform is capable of handling different types of context sources (e.g. sensors, readers, agents), offers sophisticated mechanisms in matching the mobile user's preferences with services that are available at the visited location, and provides these services in personalized and adaptive manner to the user conditions. As a proof of concept, we deployed an e-tourism prototype on top of the platform that assists tourists during their travels by providing them with context sensitive services about nearby points of interests.

1 INTRODUCTION

Mobile and Ubiquitous computing have increased the need for mobile users to expect accessing preferred services, whenever they want and wherever they are. Users do not have to explicitly specify and configure their working environment each time they move from one location to another, from one device to another and from one network to another. The necessary adaptation to cope with the changing environment should be initiated by services rather than by users.

Making use of contextual information is essential to cope with and timely react to changes in such environments and hence achieve adaptability, reliability, and seamless service provisioning.

Context information may include any information that characterizes the user operating-environment. Baldauf in (Baldauf, 2007) presented a survey on context-aware systems that contains various definitions for the term. Most of these definitions are based on concrete examples and categories, and it is still difficult to determine, whether a particular kind of information can be regarded as context. In practice, four types are commonly introduced: the location which includes people and entities that are in or nearby (*where the user is*), the identity which determines the user's profile, the role and preferences (*who is the user*), the activity that is occurring or may occur around (*what*), and the time (*when*).

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

Users, device and session mobility are also challenging as services need to dynamically adapt to network changes and heterogeneity, occasional disconnections, resources availability (i.e. bandwidth), and device capabilities (Keeney, 2003). The necessary adaptation to cope with the changing

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environment should be initiated by services rather than by users.

This paper describes the approach we have adopted for supporting mobility and context awareness, so that mobile users could be provided with personalized services while moving from one location to another. This approach focuses on the development of a platform that allows developers to spend less effort on the characteristics that are common across various applications for mobile users and focus on the specific objectives of these applications. Managing context and mobility at the platform level clearly facilitates context aware programming by providing tools for discovering relevant context, for processing it, and for disseminating appropriate information to services in various domains such as e-Tourism and e-Transport applications.

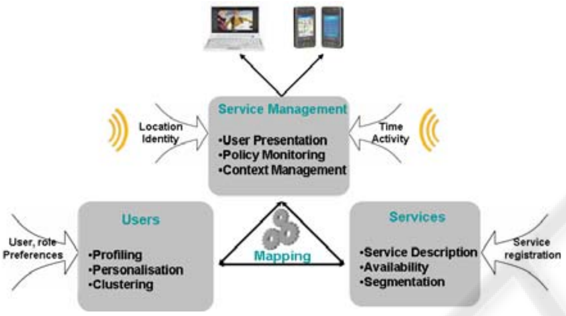

Figure 1: Generic view of the framework components.

A generic view of our 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 evaluating changes in the different context attributes (e.g. weather, user location, time, end-user device…), and uses the user preferences to find matching services. 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.

The paper is organized as follows. Section 2 relates our work to existing approaches. Section 3 presents our overall architecture for providing personalized services in mobile environments. Section 4 describes the algorithms we adopted for the segmentation and the prediction models in provisioning a visiting user with personalized services. Section 5 describes an e-tourism prototype scenario that illustrates our approach. In section 6 we summarize and point to future work.

2 RELATED WORK

Several approaches have been proposed for building prototypes of context aware platforms (Dey, 2001, Setten, 2004, Chen, 2004, Kuck, 2007). Dey, et al. (Dey, 2001) proposed the Context Toolkit framework to support collecting and transforming contextual information using widgets, interpreters and aggregators. Each widget is responsible for acquiring a certain type of context information. The aggregators collect context from widgets and interpreters and act as proxies to applications.

COMPASS (Setten, 2004) is a context aware mobile personal assistant which provides users (e.g. tourists) with context-aware recommendations and services. It retrieves and provides information about the user's context by contacting appropriate context services (i.e. location, user and time contexts) and uses a *registry* that contains information about the third party services providing the content such as museums and restaurants information.

Chen et al. (Chen, 2004) used OWL in their Context Broker Architecture (CoBrA), where a broker agent is responsible for maintaining and aggregating a shared model for context information. 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.

Kuck et al. (Kuck, 2007) presented 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.

3 THE OVERALL PLATFORM ARCHITECTURE

The development of the platform is based on a generic architecture that supports context aware service discovery. The architecture is represented by a generic layered stack that describes the main functionalities of our context aware system. Figure 2 shows a five layer model that separates the concern of each layer among acquiring, processing context information, and providing users with services that best fit their current context. 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.

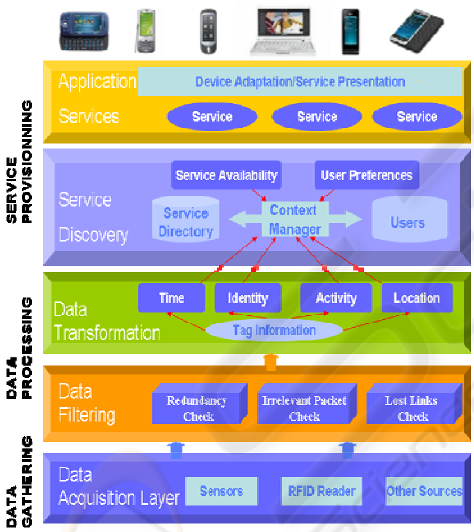

Figure 2: The overall Platform Architecture.

3.1 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 sensors that deliver different kind of information to the base station such as temperature, noise, etc... The sensor network is 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 3 provides an example of sensor network nodes distribution. In this configuration, nodes 1, 2, 5 are stationary nodes, while node 4 is mobile.

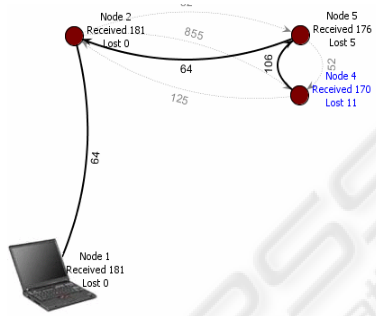

Figure 3: Mobile and Stationary Nodes Distribution.

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 4.

```
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 ]
```

Figure 4: Incoming Sensor Network Packets Log File.

3.2 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 (Ridhawi, 2008). Mechanisms used by the data processing layer include filtering and transforming the received raw data.

3.2.1 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. The duplicate removal limits the amount of data to be processed by reporting the data read once.
- 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. We are more interested in knowing about links between stationary and mobile nodes.
- Lost links removal: 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. This means that the user has moved to another location.

3.2.2 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. For instance, the geographic x-y coordinates obtained from a GPS are translated into physical locations (street, city…).

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. In our implemented prototype, we used transformation rules that translate stationary node’s tag ID into a building name (i.e. location) and a mobile node’s tag ID into a mobile user (i.e. identity).

3.3 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 web service return a list of services that best fits the user current context. The context manager then selects the services that best meet user preferences according to her/his profile. The result of this process is that the user is provided with a list of services that match her/his current context and that are tailored to her/his preferences.

4 PERSONALISED SERVICE PROVISIONING

In the service provisioning process, a user is provided with all the services she/he has subscribed to and that are available in her/his current location. Because the user may not be aware of other services that may be of interest to her/him in that location, there is a need for a mechanism to advertise the appropriate services to the user.

This paper presents two approaches to suggest to the user personalized services adapted to her/his profile and preferences.

4.1 Using Services Segmentation

This approach consists of segmenting the services available in the user’s location using historical records. Each resulting segment is a set of services used by people who have similar profiles and preferences. Services in each segment are similar between themselves and dissimilar with services of other segments. A user who was provided a service that belongs to a segment might be interested in the other services in the same segment. These services will be suggested to the user to increase his awareness about the services available in his current location. It should be noted that this does not excludes the possibility that a user may be interested by more than one segment.

The service segmentation can be achieved using several data mining techniques including decision trees and cluster analysis. In this work we use an algorithm for clustering massive categorical data with class association rules namely SCAR (Berrado, 2008); it has been shown that SCAR outperforms other clustering algorithms when dealing with high dimensional categorical data. It adopts a supervised approach to clustering: first SCAR transforms the unsupervised clustering problem into a supervised learning problem by adding artificial contrasts, then identifies the candidate clusters using class association rules, Metarules are then used to merge the clusters to form the final segments. It should be noted that SCAR can be used to segment mixed data after the continuous attributes are discretized (Berrado, 2009).

4.2 Using Service Prediction

Prediction is another approach to suggest services that are adapted to the user profile and preferences. Random Forests is one of the most accurate supervised learning algorithms developed by Breiman (Breiman, 2001). Random Forests for classification is a classifier consisting of a collection of single trees grown each from a bootstrap sample of the same training data set.

To classify a new data instance, it is put down each of the trees in the forest and the class that most trees agree on is assigned to the new data instance.

The prediction requires the presence of historical data that describes a set of users' profiles, preferences, and the services they have used. A random forest can then be built for each service taking as predictors the users' profiles and preferences.

If a service was not provided to the user, we proceed to prediction using the random forest of that service to determine whether it should be suggested to the user or not.

5 CASE STUDY: PROTOTYPE APPLICATION IN E-TOURISM

A prototype application for e-tourism was deployed on the platform that will assist 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….).

The sensors were installed in three different buildings in the campus of the University representing three regions in France: « Le Lac », « Les Alpes », and « La Cote d'Azure ».

A mobile user "Bob" was detected in building 1 which, in our prototype, represents the touristic region "Le Lac".

Six services are available in that location which are: 1) Hotel - 2) Hiking - 4) Camping - 5) Swimming - 6) Fishing.

Each service is described by a set of attributes and the time of the day where the service can be provided. Each service can also be either enabled or disabled. Figure 5 shows an example of a service description.

```
<Service>
        <Name>Swimming</Name>
        <Attribute>Sun</Attribute>
        <Attribute>Water</Attribute>
        <Attribute>Sport</Attribute>
        <Time>daytime</Time>
        <Enabled>Yes<Enabled>
</Service>
```

Figure 5: Service Description.

Based on his user profile described in Figure 6, Bob will be offered some services in "Le Lac" Region.

According to his profile, "Bob" is interested in camping and hunting services. Since camping is available in his visited location "Le Lac", the service will be provided to the user.

```
<User>
        <Profile>
                <Sex>male</Sex>
                <Age>25</Age>
                <Job>Farmer</Job>
        </Profile>
        <Preferences>
                <Sun>high</Sun>
                <Sport>medium</Sport>
                <People>medium</People>
                <Confort>high</Confort>
                <Nature>high</Nature>
                <Calm>high</Calm>
        </Preferences>
        <Services>
                <Service>Camping</Service>
                <Service>hunting</Service>
        </Services>
</User>
```

Figure 6: User Profile.

To suggest additional personalized services to Bob, we made use of a dataset that describes the profiles, preferences, and the services used by a set of 500 tourists that have visited 'Le Lac' region. Services in the dataset were segmented using SCAR algorithm. The Camping service that is provided to Bob belongs to a segment which also includes Hiking and Fishing services. Hence, these two services were also suggested to Bob.

The prediction model was then applied on the remaining services in that location to determine whether they should be suggested to the user. For each of these services we applied the prediction function using their corresponding random forest model and by taking Bob's profile and preferences as predictors. The prediction process revealed that the Swimming service could also be suggested to Bob.

Finally, the service provisioning algorithm checked if the current time falls into the time where the services can be provided as specified in the service description. Figure 7 is a snapshot describing the services that Bob received.

Figure 7: User Personalized Service Provisioning.

6 CONCLUSIONS

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 to evaluate different context information to provide each user with appropriate 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.

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 segmentation and prediction mechanisms.

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.

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