Context-aware Group Management in Mobile Environments

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***Abstract*—The paradigm for ubiquitous communication aims at enabling people to contact anyone anywhere and at anytime in a convenient way. Though, this promising vision is mainly addressed from the perspective of individual users. The IST project MobiLife furthers this mobile communications paradigm by developing new applications and services. In addition to the requirements of individual users, MobiLife also considers the needs and concerns of groups of users.**

This paper presents an architecture that allows the management of mobile groups in heterogeneous communication environments and provides them with context-aware services. The architecture presented has been developed by and proposed within the EU IST-511607 project MobiLife.

***Index Terms*— ubiquitous computing, context-awareness, mobile groups.**

I. Introduction

Both mobile communication and Internet technologies have been important research areas throughout the past decade. The products and solutions to technical challenges so far, have had already significant impacts on people's communication habits and life in general. Now research efforts are under way to merge these technologies and to fulfil the vision of a world where information is ubiquitous and pervasive, i.e. available everywhere and at anytime. Already today users are able to access traditional telecommunications and Internet services via wireless networks, without limitations in time or place. But this vision calls for new types of services and service capabilities; for instance providing relevant information tailored to situations and user environment. This way, users will, unobtrusively, get personalised information tailored to their preferences and environment.

These new types of services and applications can provide users with richer and more accurate information. Thus, it is important that such a service support mechanism makes sure that these future services reflect the societal trends and concerns in terms of communication between individuals and thus, adapt to their various interaction modes. As yet, most available services and applications only support interactions of individual users. Though in society, individuals very often communicate and interact with others in groups. When groups of users have common interests or undertake common activities, they share, on a regular basis, information with each other. Therefore universal and ubiquitous services and applications must also enable users to reach and interact with groups consisting of many individuals.

The MobiLife project [1] is an IST-FP6 Integrated project that aims to advances in mobile application and service by innovating and deploying new applications and services based on the evolving capabilities of end-users devices, available networks and interactions modes in 3Gb (3rd Generation and beyond) systems [2]. To emphasize the social impacts of the projects vision, two focus areas are distinguished: 1) *self-awareness* that brings solutions to users in their local environments and 2) *group awareness* which enables people in a group to share information and to interact with each other [2].

This paper presents a system architecture and the related assumptions that address the specific needs of groups in mobile environments. The structure of the paper is as follows: In section II a review of existing applications and services for groups is given. Section III analyses the challenges of providing ubiquitous services and applications to groups. The approach how MobiLife aims to address these challenges is described in section IV, it also presents the interfaces and the functionality of the architectural block introduced. Section V discusses the assumptions for the management of mobile groups, while Section VI outlines the requirements and

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challenges in terms of information representation, trust and privacy policies, and distribution of the system among devices. Finally section VII concludes the paper.

II. Existing applications and services for groups

The concept of groups has been studied by the social sciences (i.e. sociology and psychology) for decades and is now also being researched in the areas of knowledge management as well as communications.

Looking at the Internet, it considers services for groups of people. Indeed many services for online groups exist today. For instance the Yahoo! Groups service (groups.yahoo.com) allows people to group together to discuss topics of common interest or share information (photos and files). Orkut (www.orkut.com) and Friendster (www.friendster.com) are 'networking' services that create a map of social ties between friends and associates that share similar characteristics. Presence and instant messaging applications support synchronous communication in large online communities (such as AOL IM, Microsoft and Yahoo Messenger or Jabber). Presence information provides indications about the current state and activity of a user, this forms part of the user context information. Instant messaging enables community members to exchange information in real time.

In the telecoms sector, the IP Multimedia Subsystem (IMS) in 3G Mobile Systems developed by the Third Generation Partnership Project [3], supports the provisioning and sharing of presence information and instant messages among large groups of mobile users in 3G networks. It addresses the need for providing such services to large communities of mobile users. Based on this architecture, the Open Mobile Alliance (OMA) has developed a mobile application framework comprising a number of service components like Instant Messaging, Presence Service and Group Management, that enables both operators and users to create and manage groups for online meetings and chats [4].

Aforementioned services are dedicated to groups, but they are all communication enablers between the members of the groups. Thus they serve their users independent of their physical environment and their differing settings. But, so far, they do not consider groups as distinct social entities which should be supported with services as single users are.

Besides commercial services researches have been done, targeting adaptive systems for groups. These systems use group modelling techniques and in particular group preference learning mechanisms to combine individual user models to model groups. While many user modelling systems have been developed since the early works at the end of the eighties [5], few adaptive systems for groups have been investigated [6].

In [7] MusicFX a group preference arbitration system allows the members of a fitness centre to influence the selection of the radio station played in the centre. Members specify their musical genre preferences and the group preference is computed using an arbitration algorithm.

In [8] PolyLens a collaborative filtering recommender system is introduced that recommends movies for small groups of users (two to three users) based on individual tastes. It allows users that know each other to create groups and ask for recommendation to the groups.

INTRIGUE [9] is a tourist information server that tailors the recommendation of attractions for tourists groups. A group is modelled as a set of partitioned subgroups having similar characteristics and preferences. Attractions are evaluated for each subgroup with regard to their preferences and an average is computed for the group by combining the satisfaction scores of the subgroups in a weighted way.

Masthoff in [6] introduces an adaptive television system for groups where different recommendation strategies are investigated. The work evaluates decision strategies and individual satisfaction rates for the domain of study.

These systems present group modelling techniques that allow the adaptation of specific services based on group preferences. However the evaluation of group preferences and the adaptation of services is made independently of the current context.

III. Challenges for providing ubiquitous services and applications to groups

In this work a group is defined as a number of individuals, sharing a criteria of membership and are bound through a unifying relationship (e.g. a family), or are willing to (co)-operate in order to follow a shared interest or to participate in a common activity. The assumption is that groups, as well as single users, should be provided with ubiquitous applications and services. The ubiquitous computing vision supports accessibility to services and applications in an unobtrusive and personalized way, i.e. in a way that requires minimal distraction to users when selecting and using them. A simple scenario that exemplifies this vision is given below:

Maria is travelling back home in her car in a suburban area, when a delivery van bumps into Maria's car. Maria is a little bit shocked but it seems that neither she nor the driver of the van are physically injured.

Her family management service directly informs Maria's family that she is unhurt but she is going to arrive late at the family's favourite restaurant where a table had been reserved. Due to Maria's late arrival the group event is automatically postponed to the next day.

Maria's car is damaged and she contacts the car insurance company. Drivers, who witness the accident, are contacted by the company. They receive a request via their mobile device to bear witness and to join a group for reporting the accident to the insurance company. All agree. An electronic form for "responsibility agreement" is filled in by Maria and the delivery van driver and then approved by the two witnesses.

To return home Maria could have taken a taxi, but she is notified by her MobiCar service that several car drivers that offer to share their car, have planed routes passing by Maria's home. Maria selects the service that best match her preferences and together with the driver, they form a new, ad-

hoc, non smoker group in an air-conditioned and electric car.

This scenario highlights situations where different groups (formed by family members, the accident witnesses and the victim, a car sharer and his passengers) take advantage of various services to undertake activities. To provide the services described in this scenario, first the challenges regarding group awareness, group management, and trustworthy communications needed to be identified. The various issues include:

A. *Enabling group awareness*

Group awareness refers to the use of context information related to a group that enables the provisioning of ubiquitous applications and services in order to address the group's concerns and needs. Context information characterises the situation of a person or a group of persons, a place, or an object that is considered relevant to the interaction between a user (or group) and an application [10]. Therefore a system that enables group awareness has to gather information about all entities relevant to characterize the situation of and within a group (e.g. person, place, etc). Also all group related information needs to be stored to produce a frequently updated interpretation of the context of a group, this group context is further used to unobtrusively select service categories and applications suitable for the group.

B. *Supporting group management*

Groups, as addressed in this work, differ from traditional online communities in that they are more dynamic and mobile. Motion is an integral part of everyday life, and ubiquitous technology must support mobility [11]. Also innumerable types of groups exist such as, family, classmates, colleagues, or even chess fanatics. Each of these groups differs, this can be in terms of lifetime, creation mode (e.g. ad-hoc or scheduled), membership update, internal policies etc. Therefore a system that enables group awareness has to keep the knowledge of all group characteristics and to adapt its behaviour to each group type. Because of the variety of groups the system has to provide group management mechanisms in order to enable creation, disposal and update of simultaneous existing groups as well as their related group profiles.

C. *Allowing trustworthy communications.*

A system that is truly ubiquitous and provides group awareness will encompass numerous parties (users, service providers) and support communications within and towards groups. To provide these kinds of interactions in a trustworthy and private manner, mechanisms need to be deployed which ensure that individual data is protected against threats, like identity theft, personalized spamming, eavesdropping, etc. These mechanisms must be flexible enough to allow various degrees of privacy and trust within groups, since groups may have unequal relevance for individuals. But even this might not be sufficient, in case a service itself is not trustworthy or corrupted, therefore additional user focused protection mechanisms are needed.

IV. GROUP CONTEXT FUNCTION

Within the MobiLife project, a system architecture has been initially developed that addresses the challenges listed above for providing ubiquitous services and applications to groups. The system features group management in mobile environments, enabling groups to be created and administrated. It also supports group awareness by interpreting group context and keeping track of group information in a group profile. For this reason, the system is referred to as Group Context Function (GCF). The objective of the system is to enable groups to access ubiquitous applications and proactively provide relevant services.

The Group Context Function offers twofold support to groups in ubiquitous computing environments. It enables groups to interact by providing group management and allows group awareness by defining the group context. The GCF is supported by and associated to other components of the MobiLife reference model (Figure 1).

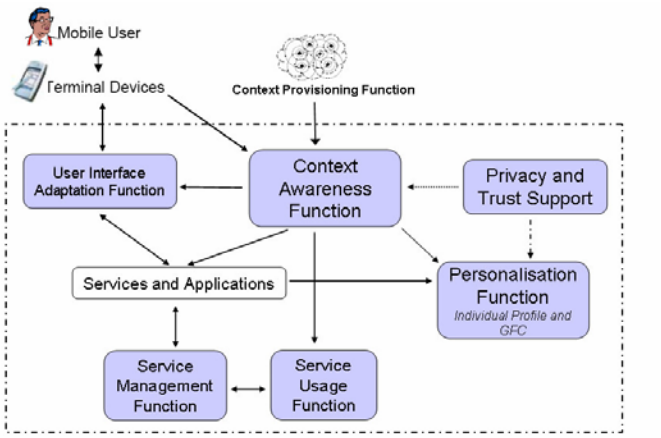

Figure 1: MobiLife reference model

- A Context Provisioning Function, that gathers context data within the environment, using different sensing mechanisms such as hardware sensors, monitoring software or complete sensor networks;
- A Context Awareness Function with the aim to collect and merge context information related to the single platform user, and the groups he is presently active. The MobiLife platform provides suitable services and applications based on this information;
- A Service Usage Function that operates on behalf of the context awareness function. It provides information about the services in the system and supports various forms of service triggering;
- A Service Management Function that supports the lifecycle of services;
- A User Interface Adaptation Function takes the available relevant context information to facilitate user interface adaptability for services and applications;

- Privacy and Trust Support is related to the context awareness function and the personalisation function and that is realized as data models or algorithms inside the related functions;
- The Personalisation Function that contains two instances providing on the one hand profiles and preferences for individual users and on the other hand the Group Context Function.

Note that the focus in this paper is on the interfaces and the internal structure of the GCF and the other functions are not discussed here. The functional view of the GCF is depicted in Figure 2.

A. *Interfaces of the Group Context Function*

The Group Context Function features four interfaces. The **environment interface** receives context data collected by the context provision function that characterizes the user and any other entity within the user vicinity (persons, services, etc). The **user interface** presents a front end for a user to manually manage a group, and to configure or access group profile information under given access control rights. The **application interface** is an interface, through which applications for groups and the Group Context Function exchange information regarding group management. Applications send requests on groups through triggers, whereas the GCF responds by sending group status information.

The output of the function, which we refer to as operational group context, is sent to the MobiLife context broker via the **service provisioning interface**. The operational group context gives indications about the types of services and applications that the group in the given context is likely to access. It also sends a description of the group context that the context broker can use.

B. *Functionalities of the Group Context Function*

In this section we detail the functionalities that compose the Group Context Function.

The **situation interpretation** and the **context interpretation** functionalities have the responsibility to describe group situation and context. The overall process that forms these descriptions combines reasoning techniques such as ontology-based reasoning and probabilistic methods. It ultimately aims to provide semantically enriched descriptions at different confidence levels. More precisely the situation interpretation functionality receives context data from the environment interface and determines the group situation. When personal user data is applied to determine the group context, individual constraints set by the user, need to be taken into account. Then the group situation description is further enhanced by relevant group history information to produce new interpretations and/or to further refine the descriptions of the group context. In the mean time the group history is updated with the just reasoned group situation.

The **group learning** function is responsible for learning models (or schemata) that link a group context to actions the group performs and/or to services and applications it has access to. It learns models by monitoring the group context and evaluates their relevance for the group. All accepted models related to actions of one group are stored in the group profile. The group learning element uses various reasoning paradigms. Namely, simpler deterministic rules can be learned using association rule mining techniques, whereas more advanced techniques, such as Bayesian networks and dynamic Bayesian networks (e.g. Hidden Markov models) use a probabilistic selection of suitable actions, which makes it possible to account for uncertainty. Also feedback-based techniques (reinforcement learning) can be used to update

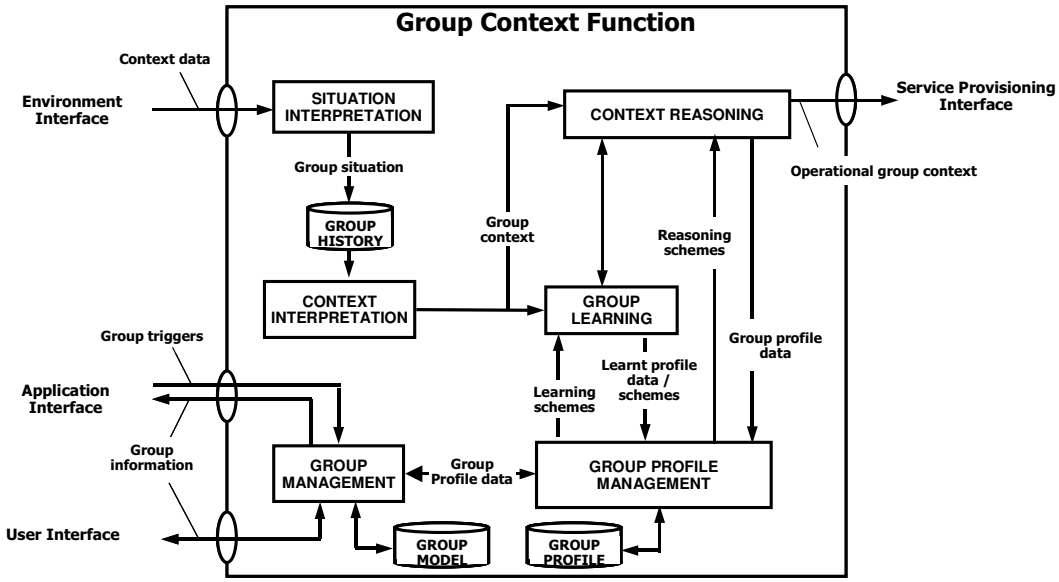

Figure 2: Functional view of the Group Context Function

learned models based on implicit or explicit feedback information.

The **context reasoning** is the counterpart of the group learning. It produces the outcome of the GCF, the operational group context that is used to further select suitable service categories. To do so, it uses the learned schemas that link the context to particular actions or sequences of actions.

The **group profile management functionality** administrates the group profile where all information about groups is stored. Information is composed of facts about the groups, rules and schemata. Thus it enables the creation, the update, the deletion and the retrieval of profile information of a group. The functionality applies group trust and privacy policies and personal user set constraints, in order not to divulge sensitive information to services and applications. Also the group profile management is in charge of regularly feeding the group history repository when important changes to the group happen.

Finally the **group management functionality** handles the group lifecycle and the transition between the states. It also stores the group models. Group models define the default trust and privacy policies and the triggers that are applicable to the newly created group. They are related to the rational of the group. So far two models are envisioned, i.e. models for 'group by activity' and 'groups by interest'. Additional models can be defined later. A detailed explanation of the manner groups are managed is given in the next section.

V. GROUP MANAGEMENT

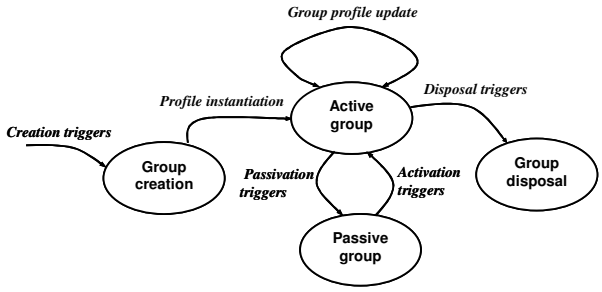

Figure 3: Group lifecycle

To allow management of groups there are different processes like 'group creation' and 'group disposal', and also different states like 'active group' and 'passive group'. Event triggers produce transitions between the processes and states. Default triggers as well as default management policies for groups are stored in group models. But the set of triggers is not limited. Event triggers may be defined explicitly by members as the group is created or in the active state. In addition event triggers are launched by explicit notifications of members or automatically by group information provided by the group profile. The processes, states and transition types shown in Figure 3 are discussed below.

The **group creation process** happens when users agree on creating a group or when the learning functionality of the GCF triggers the creation of a group (*creation trigger*). In this phase a group model is selected. Users that are contacted in order to become members of the group can refer to the group model to decide whether or not they want to participate and what kind of constraints they wish to set. Once the group has been created the *group profile instantiation trigger* initiates the **active state** of the group. There the group profile is instantiated using the information stored in the group model and additional information given by group members. Later it stores all information about the group and its members, e.g. preferences and policies that comply with the trust and privacy policies. During this phase, the group profile can be constantly updated with new information and users can join or leave (permanently or not) the group. When a group is active the GCF is also responsible for producing the current operational group context. In some cases, e.g. for groups that meet regularly, it may also be possible to enter a **passive state**. In this case however, the group profile cannot be updated any more. No new information about the group and its management can be inserted. The group members must define inactivation and activation triggers. By default groups remain in the **active state**. The second process is the **group deletion process** that is typically initiated by the group administrator who has determined the group as being obsolete. Other triggers are also possible. Groups may be dissolved as the group membership list has become empty or as the group has not been used for a time that exceeds the predefined group lifetime. The disposal process frees the resources used by removing the group profile from the group management functionality. The profile is not destroyed immediately, but it enters a candidate pool for removal. After a pre-established time, or if the group manager is running low on resources, the profile becomes removed and deleted.

VI. DISCUSSION

The realisation of the Group Context Function presented above is influenced by numerous technical questions that cover various aspects of the function.

--First the overall representation of information, both in terms of ontology and knowledge management mechanisms, is a crucial issue that affects the overall interoperability and the response time of the system. One of the key aspects related to representation from group perspective is about the selection or development and the use of an 'upper ontology', i.e. an ontology that provides standardised knowledge representation primitives not tied to a specific application. Other important representation related aspects regard the exchange of interpretation results and the representation of profiles as this affects not only the platform, but also the GCF itself. The GCF needs to interpret context and to make decisions about access rights, authentication, data management, security mechanisms applicable, etc. This automatic decision process must be guided by a group focused policy system that takes into account the user preferences and constraints (e.g. no messaging during meetings). Users will also have their own preferences on disclosure of their personal information to the

group context function for situation interpretation. The Group Context Function needs to decide if the user offers sufficient data to provide the group services. Hence, the user set constraints (e.g. e-mail information only disclosed to group members) need to be taken into the group policy system.

--Second the establishment of initial trust between group members and therefore within the group itself is essential for an active group membership of a user. In mobile environments users have an existing trust relationship with their operators, this can be extended to form the foundation for further trust relationships to other users, groups and services.

--Third to properly address the limitations of devices capabilities (storage, processing power, etc) in mobile environments, the distribution of the GCF among the devices of the group members and stationary servers must be investigated. For example, the reasoning and learning processes can be undertaken in a distributed manner using multi-agent systems (MAS) as they often require a considerable amount of processing power and memory. Synchronization needs to be considered in such a distributed solution when sharing related information among a large number of mobile users.

VII. CONCLUSION

This paper presented a system architecture developed in the framework of the IST project MobiLife that allows provisioning of groups with ubiquitous services and applications, by enabling group awareness, supporting group management and by facilitating trustworthy communications.

Group awareness is achieved in several steps. First, the group context is interpreted using context data gathered within the group environment. The operational group context, which provides information about service categories that would be needed by the group, is derived from the group context and from relevant group profile information. It is then used by the Context Awareness Function (this function is not documented in this paper). In addition the system is able to learn completely new group profiles and learning models for selecting suitable actions and services categories based on the group context.

The variety of the groups possible in mobile environments requires the system to apply group management. A model for group lifecycle has been defined that distinguishes groups states, processes and transitions. It defines the actions that are allowed to be taken and carried out by the group.

To realise these functional issues regarding the representation of information within the GCF, the distribution of the GCF and the creation of initial trust and privacy policies, which need to be further addressed, have been highlighted.

With such an architecture, it will be possible to provide advanced, group aware mobile services to the user. The purpose of this is motivated by a short scenario. The scenario has been outlined and the related platform requirements derived in sections II/III of this paper.

Finally we conclude that the architecture and derived information models extend Presence concepts with context and Group Management with social concepts, thus providing important input to both 1) the development of future mobile services and applications and 2) subsequent later standardization in the OMA.

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