DEVELOPING PERVASIVE SERVICES FOR FUTURE TELECOMMUNICATION NETWORKS

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ABSTRACT

Pervasive computing promises a new and radically improved paradigm for user interaction with services and applications. Although mainstream research and development in this area is focused on user interaction aspects, the infrastructure for providing such a demanding paradigm needs to be in place before we can hope for widespread usage of pervasive services. The IST project Daidalos aims at integrating pervasive computing with global telecommunication networks. Through this integration, it will be possible to utilize existing and future heterogeneous networks for developing and deploying user-friendly pervasive services for the European market. This paper presents Daidalos' view of pervasive computing. It discusses how Daidalos pervasive computing platform, integrated with a heterogeneous all-IP network, provides a promising approach to developing interoperable pervasive services.

KEYWORDS

Pervasive, Ubiquitous, Network services

1. INTRODUCTION

The importance of mobility in the everyday lives of European citizens is now widely accepted, and many new technologies and services have sprung up in support of mobile users. However, the resulting communications and computing environment is complex and confusing for end-users.

Daidalos is a Sixth Framework IST Integrated Project with 49 partners from 16 different countries whose long-term goal is to create the support for mobility needed by users today. This will be achieved by seamlessly integrating a range of heterogeneous technologies, and providing users with a range of personalized services, without them needing to be aware of the complexity of the underlying technologies and infrastructure. In particular, the project has a strong focus on broadcast and multicast capabilities, as well as on the development of services and applications based on pervasive computing, intelligent context-awareness and extended personalization.

In Daidalos the term "pervasive systems" is used to refer to mixed physical-digital environments that are saturated with computing and communications, and that are seamlessly integrated with human users and their computation and communication needs.

The implementation of pervasive systems represents a major challenge since it entails innovations in a number of areas. Such a system needs to be able to link to and interact with a dynamically changing set of different devices, and must be flexible enough to incorporate new services, devices, knowledge and interfaces for personalization. It also needs to distribute profile and context information to the network, services and system components that require them, while at the same time adhering to the user's privacy requirements. To meet this challenge Daidalos aims to provide a universal and open service platform that can offer pervasive services to application developers in such a way that the underlying network technology becomes fully transparent.

This development will be achieved using a scenario-based approach. The basic idea is to develop a number of scenarios and use these to extract requirements, identify functionality, evaluate the architecture as it is formulated and eventually to test the final system developed. This process is described in the next section. Section 3 discusses issues relating to privacy and security while section 4 describes the service platform architecture. Section 5 covers related research and 6 presents conclusions.

2. DAIDALOS SCENARIOS

A complex pervasive system offers countless possibilities regarding its physical scope and deployment, configuration, user-interaction, service provider integration, and end-device support. In order to balance the need for a suitably flexible system (i.e. a generic platform) against those of having sufficiently concrete, implementable, and realistic applications, a scenario driven design approach was adopted. This involves a multi-stage process:

1. Collect a wide range of scenarios from many application areas without focussing on technical constraints.
2. Identify common key components from this pool of scenarios with respect to individual recurring functions, physical sensors that are commonly used, system elements and features.
3. Compile a new and smaller set of short scenarios using these common components as building blocks.
4. Analyse the resulting scenarios from numerous stances: preconditions, security/privacy, implications for deployment, implications for the architecture, service provisioning, end-device, network integration and interfaces.

Two important scenario domains have been identified for the Daidalos architecture as a whole. The first is that of the "Mobile University". This is based on the wish to adapt European academic institutions to the needs of the mobile citizens of today. In the case of pervasive systems the scenario demonstrates the possibilities of a service platform architecture with strong network capabilities in a university environment.

In this scenario the actions of two particular students are traced through the day from their arrival on campus to their retrial at the end of the day. This includes a number of purely work activities (e.g. collaborative links with remote students, access to nearby devices, the automatic transfer of files, etc.) through mixed social/work activities (such as alerts to notify of arrivals on campus) to purely social activities (such as finding a canteen for a group of students to have lunch together).

From this single scenario many requirements and implications can already be illustrated: the need to handle communications sessions from numerous terminals using context information, to control session-handovers between devices (and networks – including broadcast), to organise group-based decisions (e.g. which network cost level to use) and group interactions, to define groups of friends and to specify their allowed access to personal information such as location.

The second scenario, "Automobile Mobility", is even broader in terms of diverse end-devices, physical scope, and integration of different networks. It addresses the challenge of integrating a car's networking, navigation, communications, and I/O resources into an overall environment. This scenario covers a combination of business, leisure and other day-to-day activities. In this, people pursue goals such as meeting a particular person at the airport, or accessing company presentations while traveling as a passenger in a car using various networks (mobile radio, broadcast, hotspots). Another aspect of this is the continuity between activities at home or in the office and those in the car. The scenario even covers an emergency after an accident where ad-hoc co-ordination of emergency staff needs to be undertaken and, for instance, the ambulance has higher network priority when it needs to access patients' medical data.

Once again this scenario provides a host of requirements that will be used to steer the development of the Daidalos platform.

3. PRIVACY AND SECURITY

One important idea of pervasive computing is that computers are hidden and their use no longer has to be explicitly triggered. While this is beneficial from a usability aspect, it raises serious issues from a privacy point of view. In addition to the problem – which already exists in today's systems – that users do not fully understand the processing of sensitive data in such complex systems, one consequence of pervasive systems is that users may not even realize when the system is processing personal data. As it is thought that computing power will be available in a ubiquitous way, this happens more or less all the time proactively irrespective of whether the user actually wants to use some functionality of the system or not.

Moreover, pervasive systems aim to support the user in the best way in all situations. To do this, a considerable amount of personal data has to be processed and stored in order to recognize these situations. This goes far beyond the personal data handled by today's systems, e.g., the location information kept in GSM systems. The sensitivity of this process is increased by the fact that many context-aware services need to access the user's private context information. Hence this must be stored at a centralized point in the infrastructure. This requires a high amount of trust in the respective context management provider, which must provide a flexible and fine grained access control function to restrict access to the user's context information.

In order to let the user control the amount of personal data being disclosed to certain services or users, the concept of multiple identities is widely adopted in privacy research. This means that a user can act under several identities and control the disclosed information in the context of each identity, e.g., location information can be disclosed in the context of one identity and the postal address can be disclosed in the context of another identity. Potential attackers must not be able to link those identities as belonging to the same user. As such a link can be drawn on information in each layer, protection against this linking threat requires a holistic solution across all layers. Therefore, the concept of multiple identities will be supported by Daidalos from the very bottom of the network up to the service platform. This will provide an important contribution to privacy in this integrated project.

Pervasive computing means that the user may use services and devices in their vicinity in a seamless way. This means, in the case of a mobile user, that devices and services of foreign providers may be used. As a result trust relationships – that today are rather static – have to be established in a very dynamic manner. Therefore, automatic negotiations, e.g., relating to the protection of the user's privacy, must take place. It is not feasible to assume that a user will configure the device each time a new service is used. The same holds for the creation and choice of the identities, which must be supported by the system itself, based on the result of these negotiations.

While privacy is by far the biggest challenge in the context of pervasive systems, the classical security issues must not be neglected. This includes the protection of the user's private data stored on the device or in services, the protection of the services themselves as well as charging. The latter is of particular importance in view of the huge investment that is needed – and must be repaid – for a pervasive environment. Often, the protection goals of different stakeholders are in conflict, e.g., identification for charging against privacy protection. These conflicts must be resolved in an acceptable way for all stakeholders, to create a multilaterally secure service use.

In Daidalos, a consistent security and privacy framework considering multilateral security will be developed. This framework will be evaluated in close cooperation with other activities in order to balance security/privacy functions and the system's functionality as well as costs.

4. DAIDALOS PERVASIVE SERVICE PLATFORM ARCHITECTURE

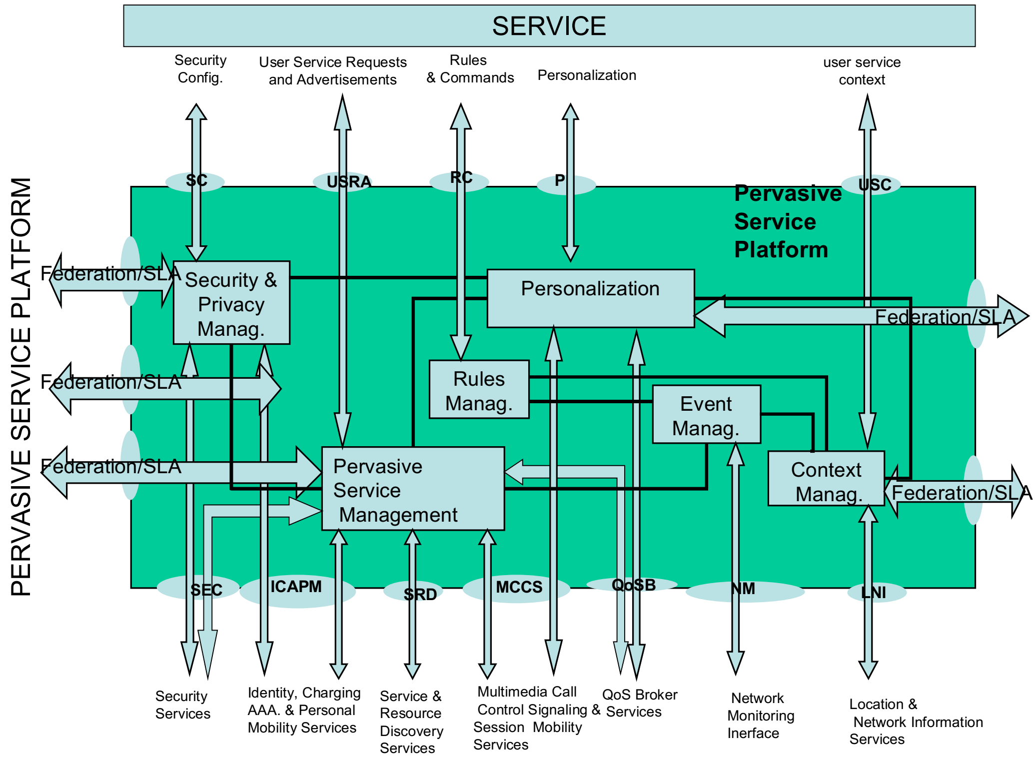

Figure 1: Overall Architecture

The architecture of the pervasive service platform comprises a set of software components that enable the efficient deployment and usage of pervasive services, as shown in Figure 1. The inter-working of these sub-systems can be summarized as follows. The Context Manager controls access to information about the user's current situation (e.g. location, available services and networks, personal preferences). In order to track the dynamically changing context, events can be fired whenever relevant changes occur and these trigger the evaluation of Rules to determine whether the Pervasive Service Manager should be notified to adjust the services or present new services which have now become relevant to the user. When this occurs, the Pervasive Service Manager, with the help of Personalization, selects new service components and adapts the necessary parameters for these components to the user's preferences. In this way, the Event, Context and Rule management sub-systems form an alliance to allow an easy way for services to be aware of a user's preferences and context. The Pervasive Service Manager acts as a hub to control the lifecycle, visibility and scope of all contributing services. To ensure the privacy of the user, the Security and Privacy Manager supports the use of Virtual identities for restriction of access to personal information.

The Pervasive service platform (PSP) is an integral part of the overall Daidalos architecture. It cooperates with underlying Service Provisioning Platforms (SPPs) to achieve its main task: the provision of pervasive services to the user.

The SPPs support the end-to-end service delivery across many different networks. In particular, the SPP subsystems will be focused on E2E network protocol management. The purpose of an SPP is to provide full telecommunication support for real-time and non-real-time session management, including establishing, managing and terminating sessions in a multi-provider federated network. An SPP platform interacts also with other parts of the Daidalos architecture in brokering the QoS, A4C and other enabling services on behalf of the PSP and the user (including the personalization of the enabling services according to the service context - the user's profile being an integral part).

In Daidalos pervasiveness is realized by aiming the architecture towards context awareness and a high degree of personalization, and by focusing on service discovery, selection and composition processes which themselves are integral parts of the pervasive service management process. Service discovery and composition processes are interrelated. They are carried out in two forms: ***proactive*** (service composed without any or with a predefined initial request, and declared as a new service in the service repository), and ***active*** (service composed when QoS, A4C or profiling requires). Both technologies are used in this project, the former carried out mostly in the terminal, in the session initiation phase, while the latter is carried out by the PSP and SPP in cooperation.

Inter-working – both horizontally by means of federation and vertically - of several business and system actors in the service management process, as well as inter-working between a variety of enabling services (A4C, QoS, service context delivery, delivery of various network and signaling services) are very complex processes, and require well-defined procedures (supplied by predefined SLA/SLS agreements). These issues are particularly challenging here. Another related area is that of deployment across a wide range of devices and nodes: platform components will be deployed on network nodes as well as on users' end devices. This introduces delegation and synchronisation challenges.

5. RELATED RESEARCH

Relevant research falls into the broad areas of location and context awareness, and pervasive or ubiquitous computing. Research on context awareness has in general focused on location, as a key aspect of the user's context. Knowledge of location may enable further deductions concerning the user's situation. Research on location-awareness started with indoor environments such as intelligent rooms that detect the presence of users (Pentland, 1996; Mozer, 1998). However, the approaches adopted can generally not be transferred to an outdoor world due to scalability and deployment reasons.

In the outdoor environment the wide deployment of mobile GSM communication systems has resulted in new applications of location awareness. Systems have been developed, for example, which use the location of their users in order to switch incoming calls to a base station nearest to the user. Today, this location information is used by GSM providers or third parties to provide simple location-based services such as providing the user with information on nearby gas stations or hotels.

Independent location-based services providers are emerging slowly. They are mostly based on location information from GSM networks, which can be enhanced in accuracy by triangulation. Some integrate location information from GPS devices. (Autodesk; CTMotion).

Current research trends in this area aim at integration of more context information from the user's spatial environment. Examples of this include temperature, humidity, lighting conditions or the state of the user's device (Beigl et al., 2001; Schmidt et al., 1999). A possible source of spatial data comes from Geographical Information Systems (GIS). Nexus (Nexus) is a project aiming at a platform for context aware services based on a spatial data model combining GIS data with aggregated location information from heterogeneous sensors. Besides common queries, location-based events are supported to allow a seamless integration in the user's life. Recent work has attempted to use more sources of context information than the user's spatial context, e.g., user's activity or daily routine (Marmasse et al., 2000).

There are several large research projects in the area of ubiquitous and pervasive computing. They typically consist of more or less loosely coupled small projects doing research in specialized fields, and do not aim at a single platform integrating all results. An example is Oxygen (Oxygen) aiming mainly at a decentralized network of communicating parts. The system is adapted according to the user's wishes derived from speech and visual interaction. ICEBERG (Iceberg) integrates different communication technologies in an internet-like service architecture. Terminodes (Terminodes) aims specially at communication without a communication infrastructure by ad-hoc networking. Dataman (Dataman) is a rather communications oriented project, too. Future Computing Environment (Future Computing Environment) uses context information mainly in the adaptation of man machine interaction.

From this discussion it can be seen that currently deployed systems are primarily location-based systems. Generally they are based only on GSM communication. Current research is mainly fundamental work developing individual components of a pervasive system, but with the communication part or applications exploiting more context information than just location. While the requirements for middleware for pervasive and ubiquitous computing are being refined (Raatikainen, 2002), implemented system do not in general aim at global deployment but only at small prototypes running in closed, small environments, to explore the issues and possibilities. There are few projects aiming at a general but powerful platform for pervasive systems

6. CONCLUSIONS

This paper presents initial work on the development of a powerful and robust service platform for pervasive computing. This platform should enable the rapid development of sophisticated context aware services to support the user in their tasks in an environment "saturated" with sensors, and computing and communication devices. The challenge now is in the refinement of the architecture and in the implementation of sufficiently general managers and brokers able to handle all identified core services required.

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