AWARENESS: A project on Context AWARE mobile NEtworks and ServiceS

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Abstract— **An increasing number of mobile devices, sensors and consumer electronics are equipped with (wireless) networking capabilities. These devices communicate via different types of networks, and together enable a complete new generation of applications: context-aware and pro-active applications. These applications make use of the context of their users, and of the resources (in terms of network capacity, devices) that are currently available. The AWARENESS project focuses on a service and network infrastructure that enables rapid and easy development of context-aware and pro-active applications in a secure and privacy-conscious manner. Particular attention is paid to mobile applications in the healthcare domain, specifically to tele-treatment of patients with chronic pain and tele-monitoring of epileptic seizures and uncontrolled movements in spasticity. This paper gives an overview of the AWARENESS project, and describes interim results and research issues that the project addresses to realize the AWARENESS infrastructure and mobile health applications that run on top of it.**

Index Terms—**context aware, mobile applications, mobile health, service middleware**

I. INTRODUCTION

In recent years we've seen an increase in number of mobile devices and mobile applications, running over different types of networks (e.g., WiFi, GPRS, UMTS, Bluetooth) that enable any-where, any-time kind of applications. The user is getting flooded with these applications and the information they provide. The traditional way of developing application does not suffice anymore, and we need more user-centric applications that are tailored to the user and his current needs and situation.

To address this, next-generation mobile applications will need to be context-aware, which means that they will be able to react on changes in the end-user's context, such as available resources (e.g., type of network and device characteristics), user preferences, user environment (including location) and situation. In the vision of the AWARENESS project (http://awareness.freeband.nl), a human user is always and everywhere surrounded by a networking environment ('ubiquitous') that is able to detect, or sometimes even determine the identity of, the user and the (upcoming) context information that is (or might become) relevant to service provisioning ('attentiveness').

The AWARENESS project focuses on an infrastructure for context awareness that enables (pro-active) responsiveness of applications, and validate this through prototyping with mobile health applications. Pro-active responsiveness means that applications can timely react on (predicted) changes in the context of the end-user.

Mobile health applications make it possible to monitor patients who might get in a disease-related dangerous situation and even to treat patients at a distance. Nowadays, in many situations patients are very restricted in their independence and often have to stay inside a medical care centre or in their houses in order to avoid unexpected manifestations of their disease. Examples concern epileptic seizures or hypoglycaemic conditions in diabetics, especially during the time that their treatment is being set-up or adjusted. Smaller medical sensors combined with higher bandwidth and more reliable mobile network technologies make it possible for such patient to be monitored and even treated anytime and anywhere. This allows them to live more 'normal' lives, and improve their quality of live and well-being. AWARENESS intends to investigate and to demonstrate the feasibility of the mobile health treatment concepts, i.e., a treatment independent of time and place utilizing a context-aware mobile service infrastructure. See [2] for an elaborate tele-monitoring scenario and other scenarios that are considered in AWARENESS.

This paper gives an overview of the research done by the AWARENESS project, and describes interim results and research issues the project addresses.

A. Structure

Section II provides a definition of context. Section III describes the overall AWARENESS architecture. Sections IV, V and VI zoom in on respectively the AWARENESS network infrastructure, service infrastructure and health applications. Section VII describes the Integrated Demonstrator and our cyclic approach for its development. Section VIII ends this paper with conclusions.

II. CONTEXT INFORMATION

Contextual information matches any relevant object in the user's environment or user description: examples are the user's place and time, identity, available resources, user preferences. Contextual information can come from different network locations, protocol layers and device

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entities. Its distributed nature, incompleteness, semantic variety and privacy-sensitivity make proper dealing with context hard to achieve. For the definition of context we base ourselves on Dey [6]: context being *any information* that can be used to *characterize the situation* of an entity, where an entity can be a person, place, physical or computational object that is considered *relevant to the interaction* between a entity and an application. It is important to recognize that some data for a particular application can be context information, whereas for another application it can be the prime data-element. For instance, room temperature is key data for your home climate-control system, whereas the same room temperature can be context-information that allows for better interpretation of physiological information obtained from your body sensors. Context is never used as a term that describes the key elements of the interaction between an entity and an application.

III. Overall Architecture

Figure 1 shows a high-level overall functional architecture adopted by the AWARENESS project.

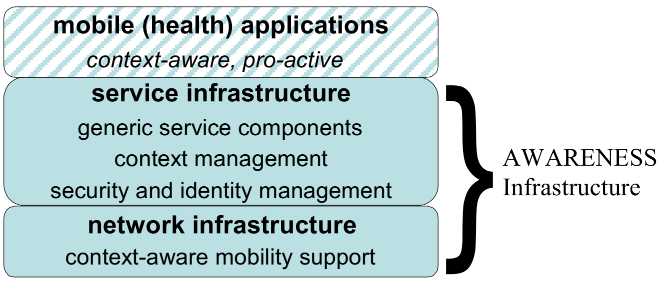

Figure 1 High-level functional architecture

In this architecture, functional concerns are structured into three layers. The network infrastructure layer is responsible for the access to and use of communication networks, including context-aware mobility support. The service infrastructure layer is responsible for the delivery of services required by the applications or end-users. The mobile application layer provides the end-user applications, which in the case of AWARENESS are mainly mobile health applications. The network infrastructure layer and the service infrastructure layer together form the AWARENESS infrastructure. An open research question is what functionality is generic enough to be in the AWARENESS infrastructure, and what functionality more specific and should be in the application layer.

IV. Network Infrastructure

The network infrastructure provides context-aware connectivity in a dynamic and predominantly mobile network environment where unmanaged and managed networks co-exist. We discern two main processes: (i) the influence of general context information on the functions associated with network operation, and (ii) the generation of specific context information that describes (the state of) the network operation to interested parties such as applications and services [5]. Naturally, these two processes may coexist and mix. In the first case, the user's social context could influence the way session setups are handled by the network infrastructure. For instance in case of a medical emergency more network resources can be allocated irrespective of the involved costs. The second process might provide context describing the available network resources to an application on a mobile host that needs to upload high volumes of data: in case of the availability of a high capacity network, the application chooses or prefers its data to go over this network instead of a lower capacity network.

Keeping network-specific context information local is essential in many cases. For instance, it does not make sense for a mobile device to gather access network information, send it to an external service or application to combine access network context with other context information and then get it back to be able to select the optimal network. A more optimal solution is to process context information locally on the mobile device and include external context information. Furthermore, many network specific context attributes are too specific to be useful for external entities.

AWARENESS focuses its effort on context-aware mobility support in the following three areas [5]:

A. *Terminal-oriented context-aware mobility support.*

The objective is to inform applications on a mobile host about their network context. We propose a system-level facility on the mobile device that is responsible for collecting and supplying context information to applications running on this device, which allows applications to adopt their behaviour [17]. In addition, applications may use such a mobility support facility to influence the active connection, for instance requesting the use of a high-bandwidth network in case of a medical emergency.

B. *Managed network oriented context-aware mobility support.*

The managed network infrastructure is a source and consumer of context information. An important part of the context information in the network is *presence* related, which is information on reachability, availability, and status across all communication channels (e.g., networks, applications, transports over internet, wireless and wireline). The leading presence-standard is IP Multimedia Subsystem [1], which is standardized by 3GPP and 3GPP2, and is based on IETF's SIP/SIMPLE [12]. We propose to use SIP/SIMPLE for realizing a context-aware network infrastructure with the focus on secure and privacy sensitive context exchange between a managed network owner (for instance telecom operator) and external entities [5]. This context exchange will be aligned with emerging OMA specifications in this area.

C. *Context-aware mobility support in ad-hoc networks.*

The objective is to provide and process network context in ad-hoc networks with no or intermittent infrastructure access. As with managed-network support, presence is an important part of the context information. Additionally, reachability, physical location, type of movement, local radio interference, etc. can enable or significantly improve communication services such as VoIP or tele-monitoring. The ad-hoc case should support the same or similar services as the managed-network case, but without the benefit of a fixed, well-know server infrastructure and with little or no configuration by the users. The establishment of different levels of trust between the nodes of an ad-hoc network is another significant challenge to gracefully limit available services with diminishing trust.

V. Service Infrastructure

The service infrastructure consists of generic software components that support easy and rapid development of pro-active and context-aware applications. It consists of a distributed, decentralized set of components that provides reconfigurable (and sometimes even programmable) generic services for context-aware applications. This section describes the functions and mechanisms that AWARENESS focuses on and need to be incorporated in adaptive, mobile middleware to be able to support ubiquitous, attentive and context-aware mobile applications.

Our approach towards the functional architecture decouples context concerns from action (communication and service usage) concerns, under control of an application model. This allows an effective distribution of responsibilities inside the service infrastructure. Components handling context (context wrappers, reasoners and context provider discovery) are separated from application specific components, allowing them to be developed and maintained by different parties. The first architectural specification of the service infrastructure is described in [7]. The research, design and proof-of-concept software implementations focuses in the following areas:

A. Authentication, Authorization, Accounting (AAA) and user management

User management and AAA related functionalities such as access control, identity management, privacy and security are essential for the success of the AWARENESS infrastructure. Security systems for wireless heterogeneous infrastructures are generally bound to static access policies that make them very difficult to seamlessly and dynamically adapt to new constraints. This situation is due to the lack of consideration for context in existing security systems. As the environment evolves, the context changes and so should security. We refer to this as context-aware security [10]. In addition to context, we propose to use policies to increase flexibility of access control functionality.

Our identity management solution will be based on a *virtual identity* concept that allows users to define different sets of profile attributes for different interaction roles and to control what personal information to share with whom. It allows for anonymous browsing, single sign-on and profile extensibility with context information. We've implemented a prototype using accepted security protocols for communication confidentiality and integrity (HTTPS), authentication (X.509 certificate-based PKI) and access control (ACLs) [11]. Furthermore we work on protocols that deal with the management of (groups of) users and of multiple identities of these end-users.

B. Context processing

Context processing is about how to get the relevant contextual information by acquiring and interpreting context. We propose to do this using a hierarchy of context sources. The building blocks for this are the wrapper and the various reasoner components [7, 15]. Context reasoning is about deducing entailed context information by combining context information that originates from the various, possibly heterogeneous context sources. It includes interpreting low-level context into higher-level context, e.g. longitude, latitude information into address and even into "at home". Aggregation, pre-processing of context, inference and prediction of context is researched in combination with context models including the so-called Quality of Context (QoC) We study in particular the use of rule-based reasoning techniques for this.

Context-aware applications will behave differently when the context changes. We propose to embed this context-aware application logic in the service infrastructure to enhance performance, scalability and flexibility. This application logic has the form of reaction rules [8].

C. Context and service discovery

State-of-the-art service infrastructures assume the availability of computing nodes that are permanently attached to a fixed network infrastructure that offers high bandwidth in combination with low latency. However, these assumptions do not apply to mobile networks. The dynamicity of mobile computing environments requires constant adaptation of the service infrastructure and the mobile applications. This in turn requires the use of new techniques such as reflection and ontologies, taking into account context information and security constraints. For example the mobile health domain (e.g., tele-treatment applications) requires flexible distribution of functionality and adaptive (application) protocols depending on available bandwidth and other context information. Run-time discovery of services is also an important functionality that is needed to improve dynamic behaviour. Discovery in AWARENESS will therefore be context-aware and ontology-based to increase adaptability [4].

VI. Health Applications

The AWARENESS infrastructure will be validated in the healthcare domain. AWARENESS will develop a mobile health service platform and tele-monitoring and tele-treatment health applications. The mobile health service platform runs on top of the AWARENESS service and network infrastructure, and provides mobile health specific (domain) functionalities to the mobile health applications. Part of the mobile health service platform is a health Body Area Network (Health BAN) that collects sensor data and sends this to health care centres or healthcare professionals.

For the tele-monitoring application we focus on affected neuromuscular functions because of the sudden and only partly predictable exacerbations. Applications concern epileptic seizures and the uncontrolled movements in spasticity. These differ in the sense that in the case of the epileptic seizures the response time, the interpretation of the sensor data and the importance of the context put much higher demands on the platform. For monitoring epilepsy we need to be able to sense and combine heart rate and activity parameters, whereas for monitoring spasticity the focus will be on biomechanical variables and muscle activation. When an epileptic seizure or another acute medical problem is detected, a health professional, volunteer aid or relative will – depending on nature of the problem and the user's context – be directed to the current location of the patient.

The dynamicity of mobile computing environment poses new challenges for the mobile health applications, especially on how to do signal conditioning, data reduction and automatic detection of sensor failures based on single and multiple sensor data. Part of this research question is how to allow varying degrees of data reduction, and thus of bandwidth needs and consequently increasing distributed intelligence, in order to allow graceful degradation in case of limited bandwidth.

For the tele-treatment application we focus on treatment of patient with chronic pain. Patients with chronic pain have to maintain a tight balance between underactivity and overactivity, since both are harmful and increase the pain. Specialists can remotely monitor activity, health status and general context information (e.g., location and time), and adjust treatment parameters according to the particular abilities and progress of the patient. Treatment parameters will include when and how to provide feedback to the patient. Remove feedback includes visual, audio or vibration signals recommending the patient to be more or less active. While at the start of a treatment specialists will need a broadband connection to get all sensing data to feed them into an individually tailored model, once the best treatment parameters have been established the treatment intelligence can be further automated and located within the Health BAN, thereby reducing the needed bandwidth.

An important challenge in the tele-treatment concept is the distribution of the intelligence in the network, i.e., to develop mechanisms within the service platform for a flexible distribution of sensing functionality, feedback and control functions and information processing algorithms. Depending on the context, this intelligence should be located closer to the subject (limited intelligence and bandwidth) or closer to the central server system (higher intelligence because more processing capacity is available, including modelling but requiring higher bandwidth). An extreme case that has to be addressed is if there is no network connectivity at all, e.g., due to a lack of coverage or drained batteries. We propose a modular design of the signal processing and data interpretation chain, enabling distributed processing that can be optimized in relation with the bandwidth of the network and the required service level.

VII. INTEGRATED DEMONSTRATOR

AWARENESS is a so-called Integrated Project, which means that the project will provide a proof-of-concept of the research results by providing an integrated demonstrator. We follow a cyclic approach in which each cycle provides an improved and extended version of the integrated demonstrator. The main focus of the demonstrator is on the health applications that AWARENESS will develop, running on top of the AWARENESS service and network infrastructure.

The demonstrator version at the time of writing (end of 2004) implements a service platform that supports seamless mobility, (limited) context awareness, a health Body Area Network and two applications: a mobile health trauma application and a tourist application. The mobile health trauma application implements tele-monitoring of trauma patients (vital signs monitored are: ECG, heart rate, respiration frequency and blood oxygen saturation). The tourist application is part of the demonstrator to show that the AWARENESS infrastructure is also suitable for non-health applications. The tourist application shows the user a map of his location, including various nearby points of interests, based on user preference. The demonstrator extends and integrates software components from the predecessor projects 4GPLUS [18], MobiHealth [9] and WASP [13]. This demonstrator was shown at IST 2004 event in November in The Hague.

Figure 2 contains a simplified view of the demonstrator architecture. The mobile health trauma application uses a Body Area Network (BAN) to gather measurements of the bio-medical signals, and transmits these signals to mobile health Core Services after processing. The tourist application receives the location and points of interest data from services in the core domain, and shows these to the user. The Mobility Manager is part of the infrastructure and uses Mobile IP to provide seamless handovers between available networks. It is implemented as a client-side, system-level component. .

The Mobility Manager provides support for seamless mobility in the core network. The 3G Network Services simulator provides a simulation of a 3G (UMTS) network, including remote APIs to allow access to network capabilities such as determining the location of a user (using Parlay X). The Service Platform offers context-aware logic and profile management, including user identification and point of interest services. The Map Provider is an external service provider that provides maps of the current location of the user. The mobile health core services provide the server-side logic for the mobile health trauma application.

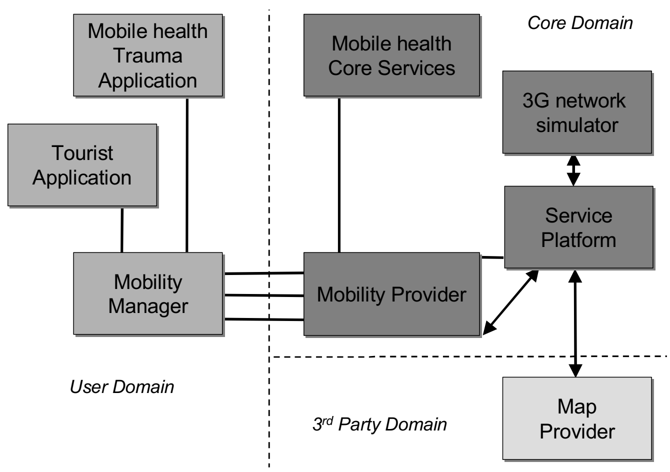

Figure 2 Demonstrator architecture

VIII. Conclusions

The AWARENESS project is working on an infrastructure that supports context-aware mobile applications in a secure and privacy-conscious manner.

The AWARENESS infrastructure supports context-processing and other generic service functionalities such as identity management, user management, presence, authorization and discovery. The functionalities are decoupled from the application logic to makes it easier to develop context-aware third-party applications.

The AWARENESS infrastructure offers context-aware mobility in a dynamic network environment where unmanaged and managed networks co-exist. Context-aware mobility is supported in two ways: (i) the network takes the context of the user into account when controlling the connectivity that is provided to the user, for instance dynamic routing protocols, security settings and network selection; (ii) the network is a source of context information, for instance presence information and available bandwidth.

AWARENESS will develop a mobile health service platform and health applications. The health applications will support tele-treatment of patients with chronic pain and tele-monitoring of epileptic seizures and uncontrolled movements in spasticity. The mobile health service platform includes a health Body Area Network that collects vital signs and other information from a patient and uses context information to decide how to make this information available to healthcare professionals.

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