Distributed Ambient management Platform for Heterogeneous devices and networks in an iNtelligent Environment

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Abstract: Existing and emerging technologies in the areas of mobile computing, wireless communications/networking, sensor and control devices, context awareness, user interfaces, etc., provide the ground for the support of human activities in a certain space. More specifically, these recent advances now allow the gradual "disappearance" of computers and/or other end-user devices into the environment creating a system that can facilitate everyday living. Such an intelligent environment system offers personalised, context-aware services that can support and improve everyday life. In spite of the large number and variety of devices, networking technologies and ambient intelligence subsystems there is a lack of a framework that brings the different relevant actors together and exploits the full potential of emerging technologies to meet the requirements of an intelligent-environment system. Intelligent environments necessitate new, advanced management platforms. This paper presents an approach for a Distributed Ambient management Platform for Heterogeneous devices and networks in an iNtelligent Environment (DAPHNE).

1. Introduction

Recent advances in the areas of mobile computing, networking, sensor and control devices, context awareness, now allow the gradual "disappearance" of computers and/or other end-user devices into the environment. This trend, widely known as ubiquitous computing [1], [2], has therefore become a topic of intense commercial and academic research. Ubiquitous computing provides the ground for new, fast growing markets of the information technology era, with increased business opportunities for manufacturers, operators, service and content providers. A prominent example of such an evolving market is the, so called, intelligent environment [3], [4]. An intelligent environment is a system that supports human activities in a specific space. It can be residential, corporate but also public. An intelligent environment offers personalised, context-aware services that can support, enhance and improve everyday life. Potential services include intelligent environment security, safety, energy management, climate control, social interactions, memory aids, emergency services, as well as care for elderly & disabled. An intelligent environment comprises an ambient network infrastructure, context-awareness and user-centric interfaces for the provision of personalised services. An ambient network infrastructure consists of a number of highly heterogeneous technologies. In this context, new management functionality is required. Furthermore, despite the galore of available devices, technologies and intelligent environment subsystems (such as voice controls, automatic pet feeding, etc) there is a lack of a framework for a truly integrated intelligent-environment system, making the ambient infrastructure as unobtrusive as possible and enabling the automated interaction with and among devices. In this direction, this paper presents an approach for a Distributed Ambient management Platform for Heterogeneous devices and networks in an iNtelligent Environment (DAPHNE) that will enable the provision of user-centric, context-aware services, and the management of heterogeneous ambient networks and devices. The paper is structured as follows. Section 2 explains the context in which the proposed framework is applied, through the presentation of a business case. Section 3 provides the requirements for the DAPHNE architecture. Section 4 introduces a generic DAPHNE architecture and discusses the functionality of its main components. Section 5 presents a sample scenario of the DAPHNE operation. Section 6 provides an overview of software technologies that can be used for the implementation of the corresponding platform. Finally, section 7 draws some concluding remarks.

2. Intelligent-environment business model

This section discusses a flexible business model for intelligent-environment application/service development and deployment, which is enabled by the DAPHNE platform.

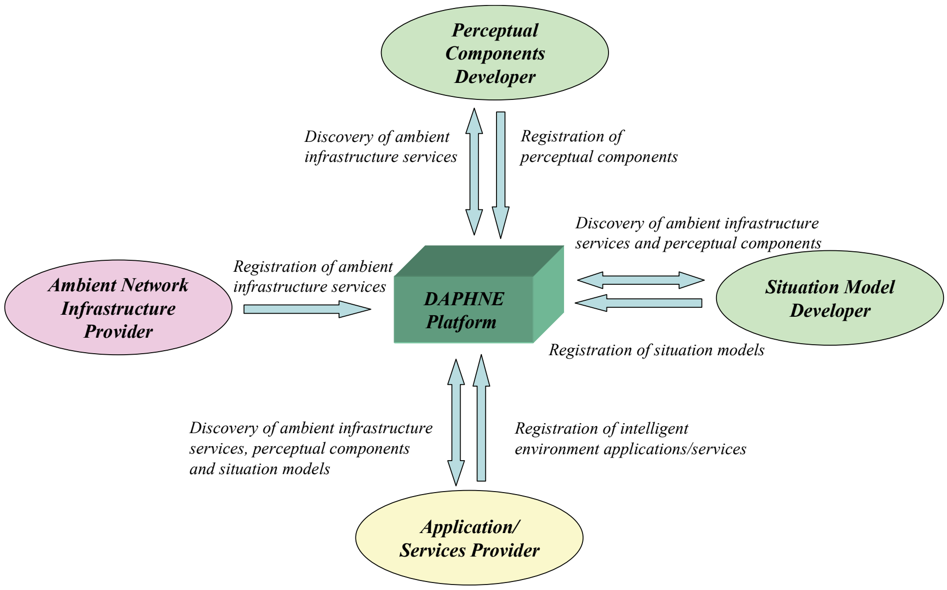

Figure 1: Overview of business model

The following main business entities can be identified (Figure 1):

- **Ambient Network Infrastructure Provider**: This entity installs and configures the infrastructure of the intelligent environment.
- **Perceptual Components Developer**: This entity installs and configures perceptual components which process input coming from the range of devices installed by the infrastructure provider. This input can be audio, image (photos and/or video), motion, temperature indications, etc. The outcome of the processing performed by perceptual components are, so called, “context cues” such as identification of people and their locations, tracking artefacts, accessing the status of devices within the intelligent environment, etc.
- **Situation Model Developer**: This entity combines available context cues provided by the perceptual component, so as to identify higher level contextual states and, finally, model the target context states (e.g. situations).
- **Application/Services Provider**: This entity develops intelligent-environment applications. It requires access to one or more situation models supporting the target application. Thus, Application Providers should be enabled to select the situation

models components of their choice and accordingly specify the service logic to be executed in each context.

The DAPHNE platform will enable the interconnection and inter-working between the aforementioned business entities, providing an "open" framework for the provision of personalised services in an intelligent environment context.

3. System requirements

A DAPHNE platform should be able to meet the following requirements:

- Integrating innovative intelligent-environment components into an overall infrastructure, which consists of heterogeneous networking technologies, sensing/control/computing devices and intelligent appliances. The platform will also comprise mechanisms for the effective management of such an innovative infrastructure.
- Providing personalised, context-aware services and advanced user interfaces. Context awareness components will include sophisticated perception and situation modelling capabilities. Likewise, pioneering user interaction techniques will be offered. Components that fall in this area should be able to interact with the ambient network infrastructure, and with the intelligent-environment applications/services, through high level interfaces.
- Facilitating the development, deployment, and coordinated operation, of user-centric intelligent-environment applications. The platform will provide suitable means for enabling applications to utilise the context-aware services and the intelligent-environment network infrastructure.

4. DAPHNE Architecture

A generic DAPHNE architecture (Figure 2), targeted to the requirements identified in the previous, consists of three main components, namely *Virtualisation of the ambient network infrastructure, Context awareness and advanced user interface mechanisms* and *Intelligent-environment service management*. The functionality of these modules is described in detail in the following sub-sections.

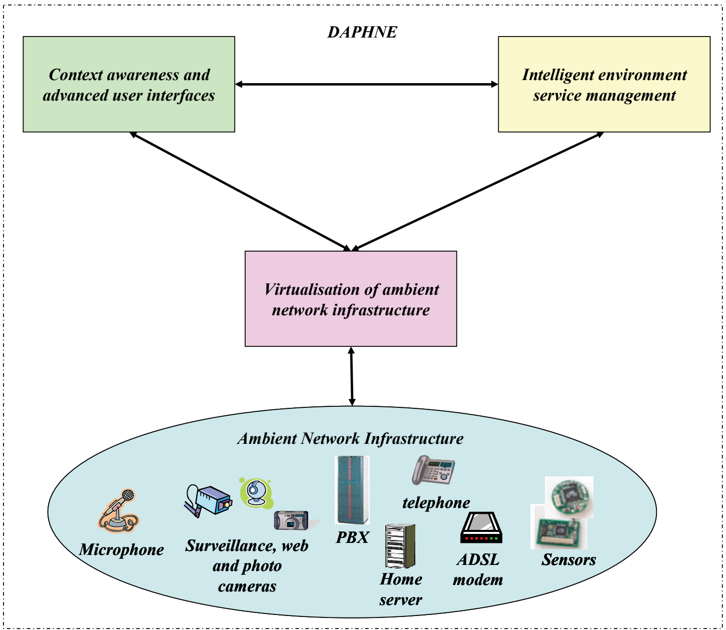

Figure 2: DAPHNE architecture

4.1 Virtualisation of ambient network infrastructure

The large number of devices potentially comprising an intelligent environment imposes the joint utilisation of many different networking technologies, both wireline and wireless, through which the various devices can be interconnected and remotely controlled. Wireline networking technologies used in home and corporate environments can be classified in two separate categories: Ethernet-like technologies and technologies based on power line wiring. Ethernet-like technologies include the familiar networking technology for Local Area Networks (LANs), mostly standardized as IEEE 802.3, and FireWire (also known as IEEE 1394) [5]. Power Line Communication (PLC) is a wireline technology that is able to use the current electricity networks for data and voice transmission. As a result, in a home or building context, appliances and devices can be networked without further wiring, allowing easy addition and integration into an existing infrastructure. Two of the most well-known PLC standards are X10 [6] and LonWorks [7]. With respect to wireless networking technologies the most widespread are WiFi [8] and Bluetooth [9]. WiFi is a set of product compatibility standards for Wireless Local Area Networks (WLANs) based on the IEEE 802.11 specifications. Bluetooth is an industrial specification for Wireless Personal Area Networks (WPANs). Bluetooth provides a way to connect and exchange information between devices such as Personal Digital Assistants (PDAs), mobile phones, laptops, PCs, printers, cameras, etc via a secure, low-cost, globally available short range radio frequency. Designed to be simpler and cheaper than Bluetooth or other WPAN technologies, ZigBee [10] is a published specification set of high level communication protocols designed to use small, low power digital radios based on the IEEE 802.15.4 standard for WPANs. Finally, another wireless communication standard designed for low-power and low-bandwidth appliances, such as home automation networks is Z-Wave [11].

Virtualisation of the ambient network infrastructure enables the integration, interaction and interoperation of different devices from different vendors and diverse networking technologies such as the ones outlined in the previous, concealing the complexity and heterogeneity of the ambient network infrastructure. Furthermore, as devices and network technologies evolve and new standards emerge an important requirement for the ambient infrastructure is to be open and reconfigurable, i.e. to allow the addition, removal and/or substitution of infrastructure components in a plug 'n play fashion. The virtualisation of the available intelligent-environment infrastructure, comprised in the DAPHNE platform, provides the means for the gradual introduction of new and promising technologies, even after the system has been set up and installed, thus allowing the intelligent environment to be flexible and dynamic. Moreover, the virtualisation functionality of the DAPHNE platform comprises high level interfaces for the interaction of intelligent-environment applications/services, context-aware middleware and advanced user interfaces, with the infrastructure. In order to realise virtualisation of the ambient network infrastructure, the implementation of the DAPHNE platform can be based on several middleware technologies, complying with the service oriented architecture paradigm, to efficiently handle issues such as interoperability, resource management and reconfigurability. Such technologies are discussed in more detail in section 6.

4.2 Context awareness and advanced user interfaces

An intelligent environment requires context awareness so that the system can provide the user with the necessary or preferred services in an automated manner. In general, context awareness refers to mechanisms that allow the identification of users, their tasks and their goals and the provision of context cues / streams that can be exploited by applications and for the appropriate adaptation of the system behaviour. Components for context awareness can be classified into perceptual components, context identification and situation modelling components and components for the interaction with users [12]. Perceptual components are used for collecting raw sensing data such as sensor streams (i.e. A/V streams) and extracting corresponding context cues. Context cues provide an abstraction of sensing information that is independent of specific applications and sensing technologies [4]. One single sensor stream may provide several context cues which can be combined for the computation of specific context. Perceptual components can be based on simple schemes such as calculation of statistics or more sophisticated algorithms [4]. The context cues obtained through the perceptual components are used to capture an elementary form of context indicating the identity and location of users and objects within the intelligent environment. The calculation of context from context cues can be based on neural networks, rule-based algorithms, etc ([12], [13]). Several sets of context can then be combined in order to model a specific situation. A situation model provides a reference of the state, of the relationships and of the interaction among the various entities of the environment (users, devices, services). The situation model can then be used to adapt the system behaviour so as to satisfy user needs or system requirements. Finally, the users should be supplied with advanced means of interacting with the system. User interfaces should be as "friendly" and as unobtrusive as possible. In other words, the goal of advanced user interfaces is to aid people in their every day tasks without requiring any specific technological skills. This can be achieved through the exploitation of recent technological advances such as wearable computing, automatic speech recognition techniques, etc.

4.3 Intelligent-environment service management

Services that can be developed and deployed in an intelligent-environment context include automated safety and security, care and control, and other innovative services targeted to making every-day human activity easier and improving the quality of life, especially of users with specific requirements, such as elderly and disabled people. Consequently, an important feature of the DAPHNE platform is the management of such advanced, user-centric, context-aware services in order to ensure the interoperability and smooth inter-working of different services, possibly coming from different providers. Service management should take into account user preferences and changing environment conditions so as to provide personalised services adapted to the current user needs. Service management in the DAPHNE platform addresses issues such as the dynamic development, deployment and discovery of services as well as service orchestration to ensure smooth interoperation of services. Application and /or service providers should be enabled to introduce and deploy new applications and/or services in a "plug and play" manner. In other words, the system needs to be capable of dynamically reconfiguring itself when additional applications/services become available so as to include and provide these in the framework of the intelligent environment. Furthermore, application and/or service providers should be able to exploit existing services, potentially combining them in order to provide more complex services. Dynamic development and deployment of services require means that allow services to advertise themselves and describe the capabilities, attributes and utilities these services offer. In order to enable the dynamic discovery of available services several discovery protocols have emerged. An overview of some of the most prominent service discovery is provided in [14]. The Open Services Gateway initiative (OSGi) Service Platform [15], comprises a Service Registry through which services can be dynamically registered and discovered. As is explained in further detail in the sequel, the OSGi framework is a very good candidate for the implementation of service management in the context of DAPHNE.

5. Operation

Figure 3 presents a sample scenario of the operation of the DAPHNE platform. A user within the intelligent environment issues a command towards the system through the advanced user interfaces. Assuming that the user has issued a voice command this involves an element of the ambient network infrastructure, namely a microphone, the associated virtualisation functionality, and the components offering context awareness (*phase 1*). The command leads to invocation of the intelligent-environment application/service (*phase 2*), which in turn asks the components offering context awareness (perception modelling and situation modelling) to acquire additional context information (*phase 3*). The additional contextual information (*phase 4*) is returned to the intelligent-environment service management (*phase 5*). The intelligent-environment service management takes into account the acquired context information, the specific preferences and other information such as device capabilities in order to provide the appropriate service (*phase 6*) and decide (if required) on a set of actions that will be issued towards the ambient network infrastructure (*phase7*).

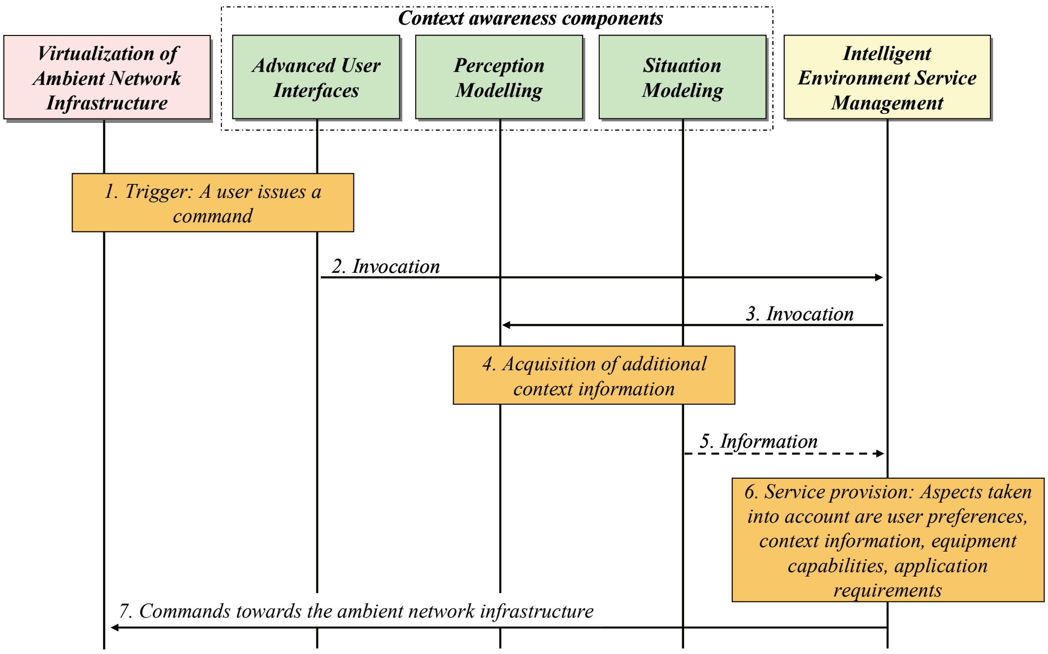

Figure 3: Sample scenario of DAPHNE operation

6. DAPHNE implementation aspects

This section provides a brief overview of some of the most popular existing software technologies, complying with the principles of service oriented computing, namely Jini, the Web services architecture, Universal Plug and Play (UPnP) and OSGi on which the implementation of the proposed DAPHNE platform can be based.

Jini is Sun's network technology for the construction of distributed systems [16]. Sun's vision is that Jini technology will be used to build adaptive networks that are "scalable, evolvable and flexible". However, an important drawback of Jini, in the context of DAPHNE, is that due to its design it is more suitable for small spaces and not for large corporate environments. Furthermore, Jini is strictly connected with Java, whereas other technologies, like UPnP and Web Services, are independent from a specific programming language.

Web services constitute an upcoming and promising middleware technology that is strongly supported by major application platform vendors [17]. It is based on common Internet technologies, like XML and HTTP. Since the introduction of this technology, three

XML-based protocols have become so widespread that the term Web services has become synonymous with the term: (i) the Simple Object Access Protocol (SOAP), which provides a message format for communicating with and invoking Web services; (ii) the Web Services Description Language (WSDL), which describes how to access Web services; and (iii) the Universal Description, Discovery and Integration (UDDI), which provides a registry that clients can use to discover available services. In the context of the DAPHNE platform Web Services concepts can potentially be used for the implementation of service descriptions and service registries.

UPnP [18] is a set of computer network protocols developed by the UPnP Forum. The UPnP Forum is an industry consortium led by Microsoft and is supported by a plethora of global players in Internet and telecommunications. Therefore UPnP is assumed to be a very successful approach. The goal of UPnP is to allow devices, such as computers, intelligent appliances and wireless devices to connect seamlessly and to simplify the realisation of ambient networks in home and corporate environments. This is achieved through the definition and publishing of the so-called UPnP device control protocols. UPnP is built on open, Internet-based communication standards, such as HTTP, TCP, UDP, XML, etc. UPnP should not be mistaken for Plug-and-play, the technology for dynamically adding devices to a computer directly.

The OSGi Alliance [19] is an open standards organization formed by Sun Microsystems, IBM, Ericsson and others in March 1999. The OSGi Alliance has specified a service platform that can be remotely managed. The core part of the OSGi specifications define a standardized, component oriented, computing environment for networked services. The OSGi Service Platform [15] provides mechanisms for the management of software components in a device connected to a network from any point in the network. Software components are libraries or applications that can dynamically discover and use other components. Software components can be dynamically installed or removed, updated, started or stopped, without requiring any interruption of the device operation or manual configuration of the associated network to which the device is connected.

UPnP and OSGi are fully complementary. It is a combination that is deemed to be very powerful and that can assist in fulfilling the goal of building an open platform. Hence, the implementation of the DAPHNE platform will be focused on these two latter technologies. More specifically, the virtualisation of the ambient network infrastructure will be based on UPnP. All the devices and networking technologies comprising the intelligent-environment infrastructure will be abstracted by means of UPnP services that will be provided to the context awareness components, the advance user interfaces and the applications/services. These UPnP services will realise the high-level interfaces for the interaction of the ambient network resources with the other modules of the DAPHNE platform. Regarding the management of intelligent-environment services and/or applications, DAPHNE will employ a combination of OSGi and UPnP. Services/ applications will be deployed on the DAPHNE platform as OSGi bundles, thus allowing the dynamic registration, activation/deactivation and discovery of services as well as the interaction between services provided by different vendors (application developers). In this manner the requirement for automated deployment, remote update and management of services/applications is met. On the other hand, intelligent-environment services/applications apart from interacting with each other also need to interact with the other modules of intelligent environment, i.e. the context awareness components and the ambient network infrastructure. This is achieved by using UPnP, through the virtualisation of each deployed application as a UPnP service. In summary, the cooperation between infrastructure, perceptual components, situation modelling components, advanced user interfaces, and services/application is achieved via the use of UPnP. Management of the intelligent-environment services in terms of dynamic development, deployment discovery and orchestration is realised with the use of OSGi.

7. Conclusions

Intelligent environments constitute a fast-evolving, emerging market, due to the advances in ubiquitous computing. An intelligent environment is a system that supports human activity in a specific space that comprises an ambient network infrastructure, context-awareness, advanced user interfaces and user-centric, personalised services. Intelligent environments necessitate new, advanced management platforms. This paper presented an approach for a Distributed Ambient management Platform for Heterogeneous devices and networks in an iNtelligent Environment (DAPHNE) that will enable the provision of user-centric, context-aware services, and the management of heterogeneous ambient networks and devices, in a future intelligent-environment context. The paper presented a business case so as to outline the overall context in which the proposed framework can be applied. Furthermore, the paper presented the requirements for the proposed system. A generic system architecture was introduced the functionality of the modules it comprises was described in detail. Moreover a sample scenario description of the system operation was provided. Finally, the paper presented an overview of software technologies that can be used for the implementation of the corresponding platform.

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