Distributed Web-based Management Framework for Ambient Reconfigurable Services in the Intelligent Environment

V. Stavroulaki · K. Demestichas · E. Adamopoulou · P. Demestichas

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, not only in the context of the home but also in the corporate and public sectors. Intelligent environments necessitate new, advanced management mechanisms. This paper presents an approach for a ***D****istributed Web-based* *m****a****nagement* ***f****ramework for ambient reconfigurable services in the i****n****telligent* ***e****nvironment (DAFNE).*

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1 Introduction

Recent advances in the areas of mobile computing, wireless communications/networking, sensor and control devices, context awareness, user interfaces, etc., now allow the gradual "disappearance" of computers and/or other end-user devices into the environment. This trend, widely known as ubiquitous (pervasive) 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 and 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 fact, it is believed that a powerful ambient network infrastructure will be based on the successful combination of these heterogeneous technologies. In this context, new management functionality is required. Previous work within this area, in the context of the IST project MONASIDRE [5] has addressed the complementary use of different wireless access technologies as well as the cooperation of network operators in a composite radio environment. In a similar direction the IST project "Ambient Networks" [6] is investigating solutions for the cooperation between heterogeneous networks belonging to different operator domains in a plug and play manner. Further on-going work in this direction, in the IST Project E2R [7], focuses on adaptive, self-organized, reconfigurable networks. These are features essential in an ambient network context. However, the focal point of the aforementioned research is closer related to wide area networking technologies, and not close to higher (middleware/application) layers. Research on advanced ambient intelligence has also been targeted to the improvement of the usability of home networking [8], restricting the focus however solely in the networked home environment. Further related work has also attempted to enhance the home environment and create a basis for ambient assisted living, as well as extending the home environment outside the home, including the car, the office and the surroundings for the duration of a journey [9]. Work in the aforementioned areas has confined service offering to legacy networking/communication solutions, while sometimes augmenting these services with emerging perceptive functionality (e.g., voice enabled interfaces).

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 not only in the context of the home but also in the corporate and public sectors. The realisation of an intelligent environment requires new and enhanced management concepts. In this direction, this paper presents an approach for a ***D****istributed Web-based m****a****nagement* ***f****ramework for ambient reconfigurable services in the i****n****telligent* ***e****nvironment (DAFNE)* that will enable the provision of advanced, user-centric, context-aware services, and the management of heterogeneous ambient network and computing devices (sensors, actuators, appliances, computing elements), in a future intelligent environment context. The discussion evolves 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 DAFNE framework. Section 4 introduces a generic DAFNE architecture, and describes its operation in an intelligent environment context. Sections 5–7 present the design of the main components in the DAFNE architecture. Section 8 provides an overview of software technologies that can be used for the implementation of the corresponding DAFNE framework. Finally, Section 9 presents some concluding remarks.

2 Business model

This section discusses a flexible business model for intelligent environment application/service development and deployment, which is enabled by the DAFNE framework. The DAFNE framework abstracts the heterogeneity of the ambient network infrastructure, and the details of the context-aware middleware. In the context of intelligent environments the following main business entities can be identified.

- Ambient Network Infrastructure Provider: This entity installs and configures the infrastructure of the intelligent environment.
- Perceptual Components Developer: The Perceptual Component Developer 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 (i.e., extracting more sophisticated context) and finally, model the target context states (e.g., situations).
- Application/Service Provider: This is the entity developing intelligent environment applications. The Application/Service Provider 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 DAFNE architecture will enable the inter-connection and inter-working between the afore-mentioned business entities, providing an "open" framework for the provision of personalised services in an intelligent environment context. Figure 1 provides a high-level view of the interactions of the main business entities with the DAFNE framework, during the various phases in the development of the intelligent environment. The depicted interactions evolve as follows. The Ambient Network Infrastructure Provider installs and configures ambient infrastructure elements and registers them with the DAFNE framework. The Perceptual Components Developer "discovers," via the DAFNE framework, the available infrastructure elements and based on these installs and configures perceptual components. The Situation Model Developer, in turn, discovers by means of the DAFNE framework installed infrastructure elements and perceptual components. The Situation Model Developer uses and combines the available context cues and models context target states, which are also registered with the DAFNE framework. Finally, the Application Provider discovers available context models and accordingly specifies context-aware services, which are also registered with the DAFNE framework.

In summary, following the trend of service oriented computing, the DAFNE framework provides each of the business entities, identified in the previous, the ability to register their services, whether implemented in hardware or software. The DAFNE framework also provides mechanisms that enable installed infrastructure elements, perceptual components, developed context models and applications to find each other and work together towards the accomplishment of a task. Section 8 provides a more detailed overview of some of the most popular existing middleware technologies,

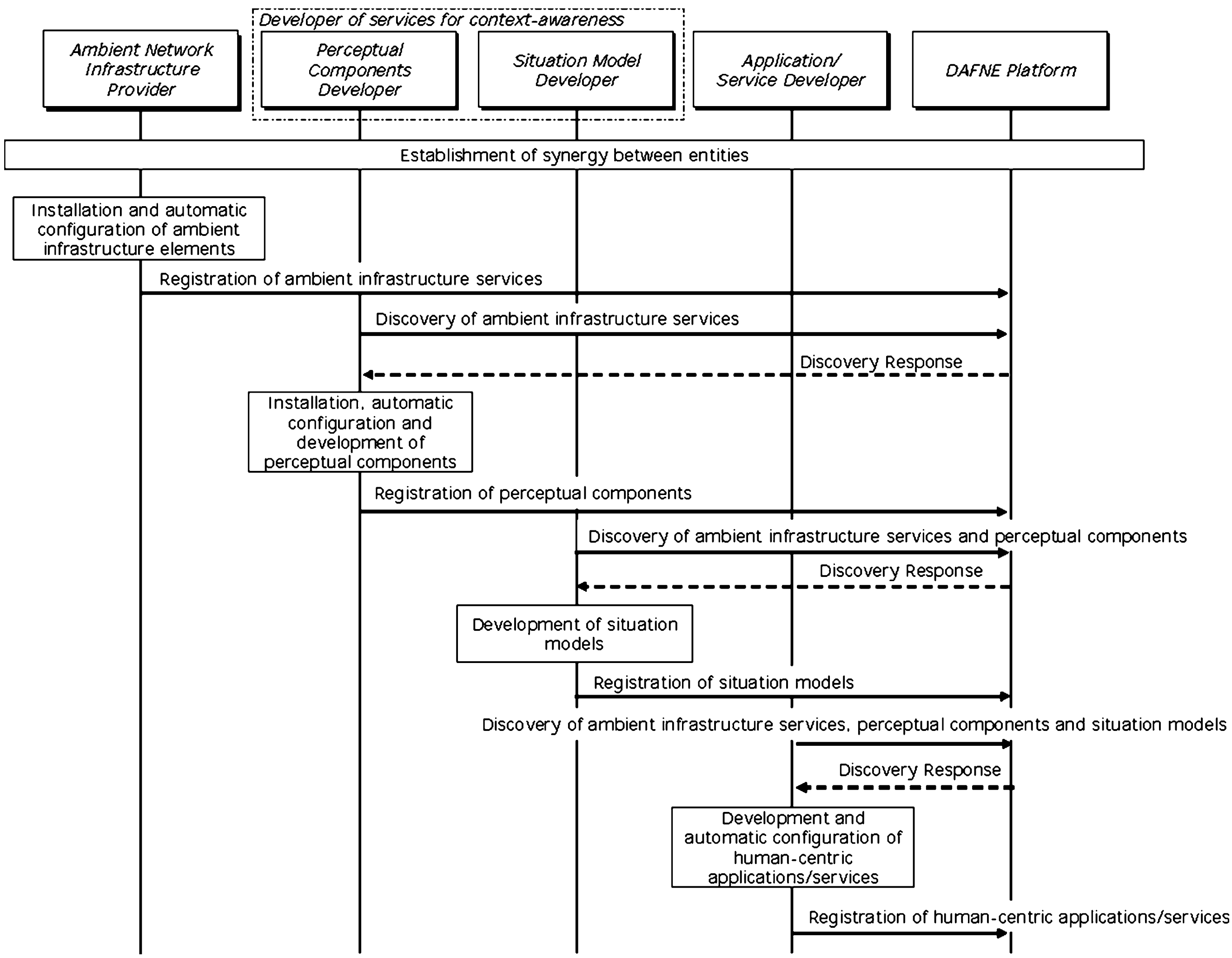


Figure 1 Phases in the development of the intelligent environment and interactions of main business entities

complying with the principles of service oriented computing.

3 Requirements

The DAFNE architecture, a service oriented management framework for intelligent environments, will be capable of the following main aspects:

- Integration of innovative intelligent environment subsystems and components into an overall infrastructure, which consists of heterogeneous networking technologies, sensing/control/computing devices, and intelligent appliances and effective management of such an innovative intelligent environment infrastructure.
- Provision of advanced, personalised, context-aware services and user interface mechanisms. Context awareness will consist of sophisticated perception and situation modelling (reasoning) 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 interactions.
- Enabling easy development and deployment, as well as coordinated operation, of user-centric intelligent environment applications. Appropriate mechanisms that enable the exploitation of the context-aware services and the intelligent environment network infrastructure by applications need to be provided. Service coordination (orchestration) should also be supported by the DAFNE framework.

4 Design and high level operation of DAFNE framework

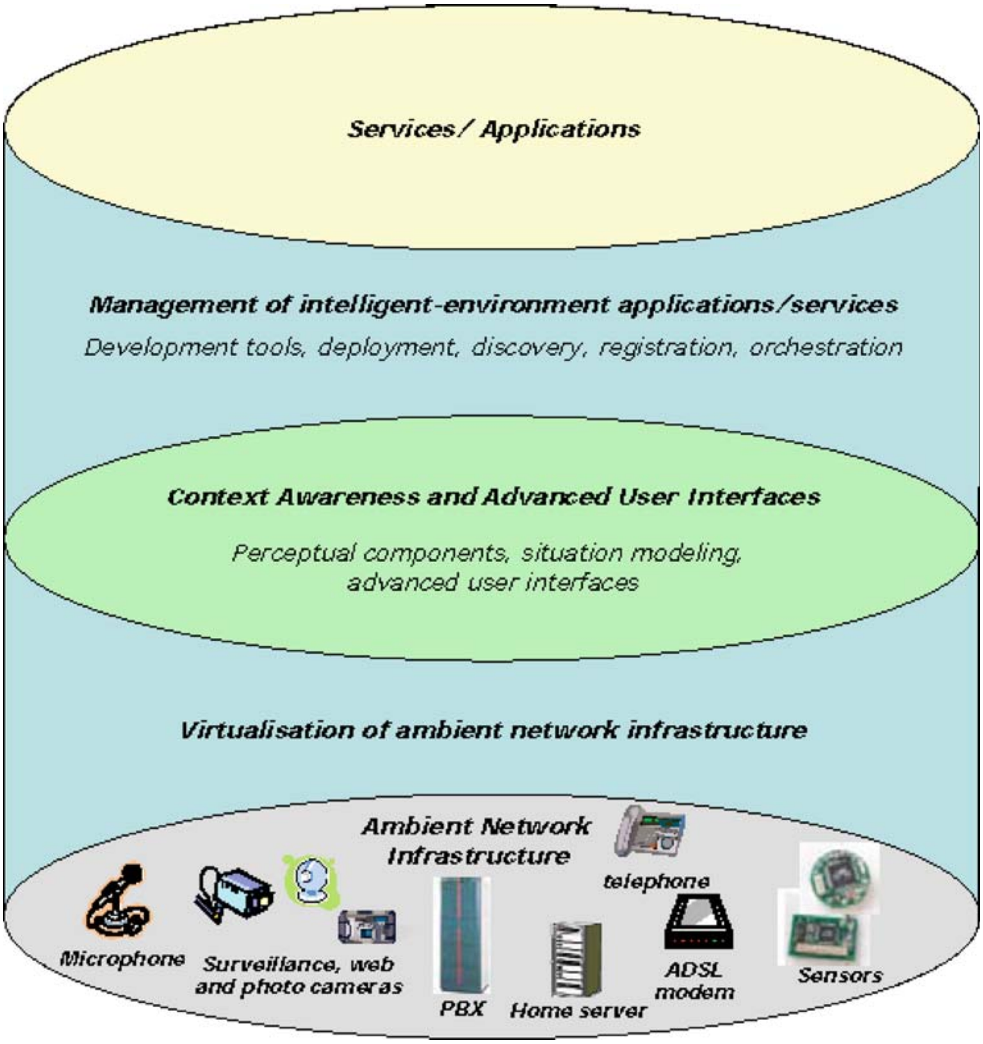
A generic DAFNE architecture, targeted to the requirements above, consists of three entities (Fig. 2).

- Virtualisation of the ambient network infrastructure. The infrastructure consists of networking technologies, as well as sensors, actuators, intelligent appliances and computing devices. Virtualisation of the ambient network infrastructure enables efficient exploitation of the infrastructure, through high-level commands, which are offered to the developers of the intelligent environment applications/services, context-aware middleware and advanced user interfaces.
- Context awareness and advanced user interface mechanisms. The framework contains components that can offer contextual information. Context awareness consists of sophisticated perception and situation modelling (reasoning) capabilities and advanced user interaction. Components that fall in this area will interact with the (resource virtualisation layer of) the ambient network infrastructure, and with the intelligent environment applications/services, through high level mechanisms/interfaces.
- Management of intelligent environment applications/services, which facilitates the development and deployment of intelligent environment applications/services. Applications can exploit two aspects. The first is that the framework can offer context events to intelligent environment applications/services. The second is that the framework enables intelligent environment applications to issue actions towards the ambient network infrastructure, through the resource virtualisation layer which will allow direct access to them. Moreover, service orchestration is provided allowing applications/services to run in a coordinated manner (thus resolving feature interaction problems).

Figure 3 depicts two scenarios regarding the potential high-level operation of the DAFNE framework. In Fig. 3a the trigger for the DAFNE operation comes from the advanced user interfaces, e.g., from a voice command issued by a user of the intelligent environment. In principle, the command involves an element of the ambient network infrastructure, namely a microphone, the associated virtualisation functionality, and the components offering context awareness (*phase a*). The command leads to invocation of the intelligent environment application/service (*phase b*), which in turn asks the components offering context awareness (*perception modelling and situation modelling*) to acquire additional context information (*phase c*). The additional contextual information obtained (*phase d*) is returned to the intelligent environment application/service logic (*phase e*), which will be applied (*phase f*), in order to decide on a set of actions that will be issued towards the ambient network infrastructure (*phase g*).

In Fig. 3b the trigger comes from the components offering context awareness (*phase a*). For example, these components may understand that a certain resident is at a certain location of the intelligent environment space, at a certain time. The information leads to invocation of the intelligent environment application/service (*phase b*). The intelligent environment application/service logic is applied (*phase c*), in order to decide on a set of actions that will be issued towards the ambient network infrastructure (*phase d*).

Figure 2 DAFNE architecture



5 Virtualisation of ambient network infrastructure

This section provides an overview of the ambient network infrastructure and the design aspects of the virtualisation of the ambient network resources.

5.1 Overview of ambient network infrastructure

The ambient network infrastructure of a future intelligent environment will comprise a large variety of devices, which can be interconnected and controlled remotely, and a plethora of networking technologies. The envisaged set of devices consists of sensor devices, intelligent domestic appliances, consumer electronic devices, actuators, computing devices (cell phones, PDAs, laptops, modems, residential gateways). Networking technologies may be wireline, relying on Ethernet, FireWire, LonWorks, PowerLine, or wireless, relying on WiFi, Bluetooth and ZigBee.

In the following, an overview of the main networking technologies and communication standards that are currently being used in home and corporate environments is provided.

5.1.1 Wireline networking technologies

Wireline networking technologies used in home and corporate environments can be classified in two separate categories: Ethernet-like and technologies based on power line wiring (PLC-based technologies). In Sub-section 5.1.1.1, Ethernet and IEEE 1394, which are the two most important local area networking technologies, are outlined whereas, in Sub-section 5.1.1.2, communication solutions based on power line wiring are presented.

5.1.1.1 Ethernet-like technologies Ethernet is a familiar networking technology for Local Area Networks

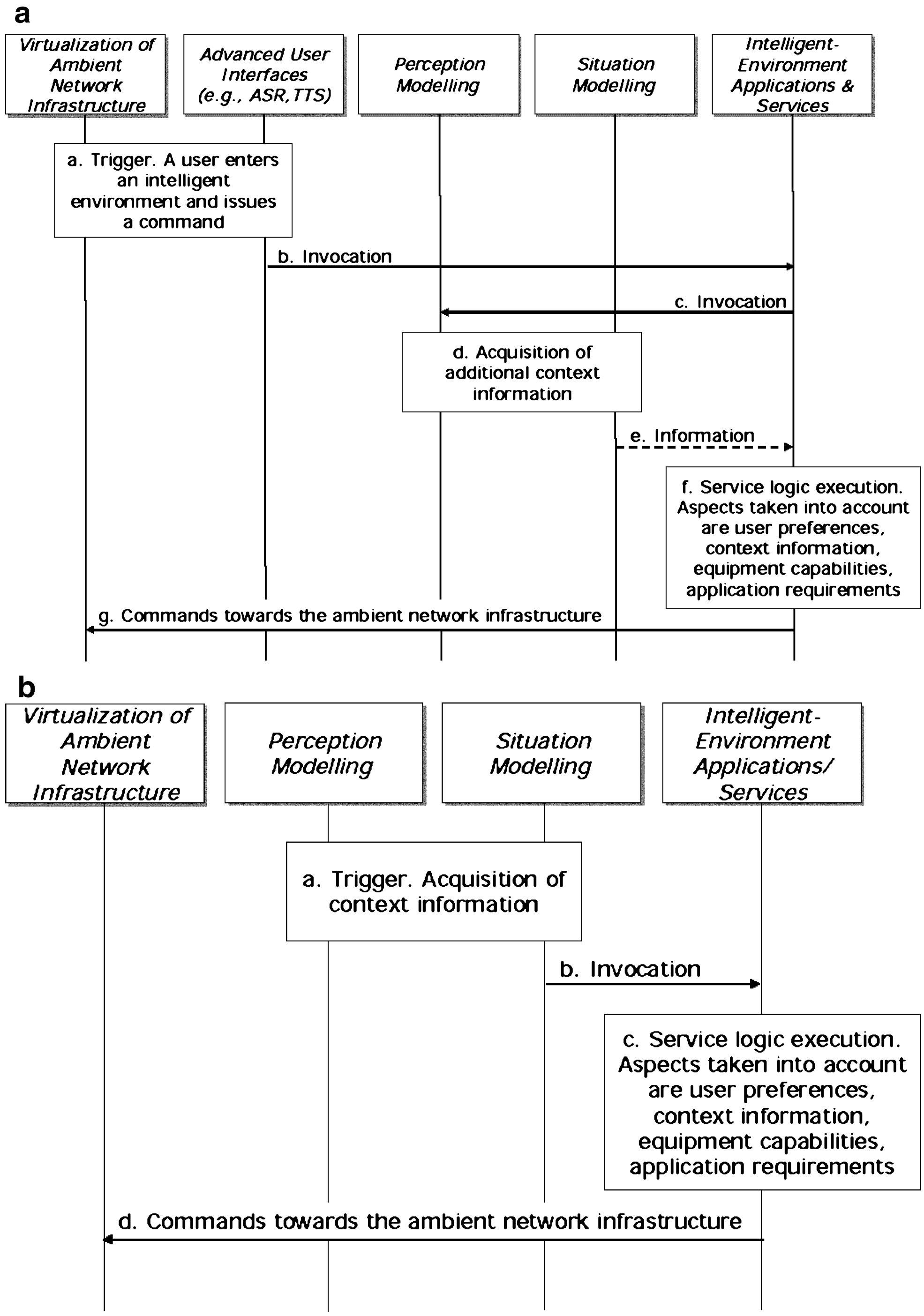


Figure 3 High-level operation of the DAFNE framework: (a) Trigger from the advanced user interfaces: (b) Trigger from the components offering context awareness

(LANs). Ethernet is mostly standardized as IEEE 802.3, and it has become the most widespread LAN technology in use, largely replacing all other LAN standards, such as token ring, FDDI, and ARCnet.

FireWire (also known as IEEE 1394) [10] is a serial bus interface standard offering high-speed communications. It is commonly used for connection of data storage devices and digital video cameras. It can also be used instead of the more common Universal Serial Bus (USB) due to its faster effective speed, higher power distribution capabilities, and because it does not need a computer host. It allows peer-to-peer device communication, such as communication between a scanner and a printer, to take place without using system memory or the CPU. FireWire, combined with appropriate software, is perfect for creating ad-hoc networks.

5.1.1.2 PLC-based technologies Power Line Communication (PLC) is a wireline technology that is able to use the current electricity networks for data and voice transmission. PLC technologies present a major advantage; the same wires that carry electric power to a device can also be used to send control networking information. Thus, in a home or building context, consumer products can be networked without further wiring, allowing appliance and consumer product manufacturers to increase customer satisfaction and provide new services. In the following paragraphs, the main characteristics of the most widespread PLC standards, including X10, UPB, INSTEON, BACnet and LonWorks, are presented.

The first PLC standard appeared in 1975 and is known as X10 [11]. X10 is an industry standard for communication among devices used for home automation. Household electrical wiring is used to send digital data between X10 devices. The digital data consists of an address and a command sent from a controller to a controlled device. More advanced controllers can also query equally-advanced devices to respond with their status. If a device is not X10-compatible, then an X10 receiver is required to control it. Devices that are not X10-compatible can receive on/off commands, and perhaps dim commands, as well (e.g., in the case of products such as lamps), by plugging them into an X10 receiver (also called X10 module) which receives and translates X10 signals. Commands are sent to devices using a controller. A controller may be a mini timer, a motion sensor, a remote control or a computer interface.

X10 remains the most widely available PLC technology, although a number of higher bandwidth alternatives have been proposed, including, UPB, INSTEON, BACnet and LonWorks.

UPB [12] and INSTEON [13] are X10-based protocols. UPB is a new power line protocol that offers improved performance and reliability over X10. INSTEON is a wireless home-control networking product, marketed by Smarthome. The system comprises a development framework for home automation, incorporating dual band (radio frequency (RF) integrated with power line communications) mesh networking. It is intended to address some of the technical problems of X10, while retaining backwards compatibility.

LonWorks [14] is a networking framework specifically created to address the unique performance, reliability, installation and maintenance needs of control applications. LonWorks systems enable all critical functions like security, lighting, elevators, power systems, safety systems and HVAC devices to be integrated into a single smart system. LonWorks defines a protocol stack consisting of seven layers, called LonTalk, following guidelines from ISO OSI reference model. LonTalk has been standardized in the "ANSI/EIA 709.1 Control Networking Standard."

BACnet [15] is a data communication protocol for building automation and control networks. It defines a set of hardware and software rules that dictate how data and control information passes across the network. It is an ASHRAE, ANSI, and ISO standard protocol.

5.1.2 Wireless networking technologies

The most widely available wireless networking technologies are probably WiFi [16] and Bluetooth [17]. WiFi is a set of product compatibility standards for Wireless Local Area Networks (WLANs) based on the IEEE 802.11 specifications. A WiFi hotspot may have a range of 45 m indoors and 90 m outdoors. Bluetooth is an industrial specification for Wireless Personal Area Networks (WPANs). Bluetooth provides a way to connect and exchange information between devices like PDAs, mobile phones, laptops, PCs, printers and digital cameras via a secure, low-cost, globally available short range radio frequency.

ZigBee [18] 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. It is designed to be simpler and cheaper than other WPAN technologies such as Bluetooth. Transmission range is between 10 and 75 m. Z-Wave [19] is a wireless communications standard developed by Danish company Zensys and the Z-wave alliance. It is designed for low-power and low-bandwidth (9,600 bps) appliances, such as home automation and sensor networks. Its range is approximately 30 m indoors and more than 100 m outdoors. Z-Wave utilizes a mesh network topology.

5.2 Virtualisation of the ambient network infrastructure

As was already introduced, despite the plethora 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, where devices are able to interact autonomously while at the same time keeping the ambient infrastructure "transparent."

It is obvious that an intelligent environment requires support for integrating the resources and concealing the complexity and heterogeneity of the ambient network infrastructure. Virtualisation of the ambient network infrastructure will enable the integration, interaction and interoperation of different devices from different vendors and diverse networking technologies. Moreover, as devices and network technologies evolve and new standards emerge an important requirement is for the ambient infrastructure to be open and reconfigurable, i.e., to allow the addition, removal and/or substitution of infrastructure components in a plug and play fashion. Augmenting the ambient network infrastructure with reconfigurability through the virtualisation of ambient network resources enables 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.

In other words, the DAFNE framework will comprise resource virtualisation functionality in order to facilitate the introduction of new networking/computing components and provide a high level mechanism enabling the developers of intelligent environment applications/services, context-aware middleware and advanced user interfaces, to interact with the infrastructure.

In order to realise virtualisation of the ambient network infrastructure the DAFNE architecture will employ middleware technologies, complying with the service oriented architecture paradigm, to efficiently handle issues such as interoperability, resource management and reconfigurability. As was mentioned in the previous, Section 8 provides a brief overview of some of the most popular technologies that can potentially be used for the implementation of the DAFNE framework.

6 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 enable 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 adapting the system accordingly. In this scope the following components for context awareness can be identified [20] (Fig. 4):

- perceptual components, which deal with the collection of sensing information from the ambient network infrastructure and the extraction of corresponding context cues
- context identification and situation modelling components
- components for the interaction with users that deal with the implicit collection of user input and presentation of system output

This section addresses in more detail the functionality of components for context awareness. 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 calculation of specific context. Perceptual components can be based on simple schemes such as calculation of statistics or more elaborate schemes and algorithms [4].

The context cues derived by the perceptual components are combined and used to capture an elementary form of context indicating the identity and location of users and objects within the intelligent environment.

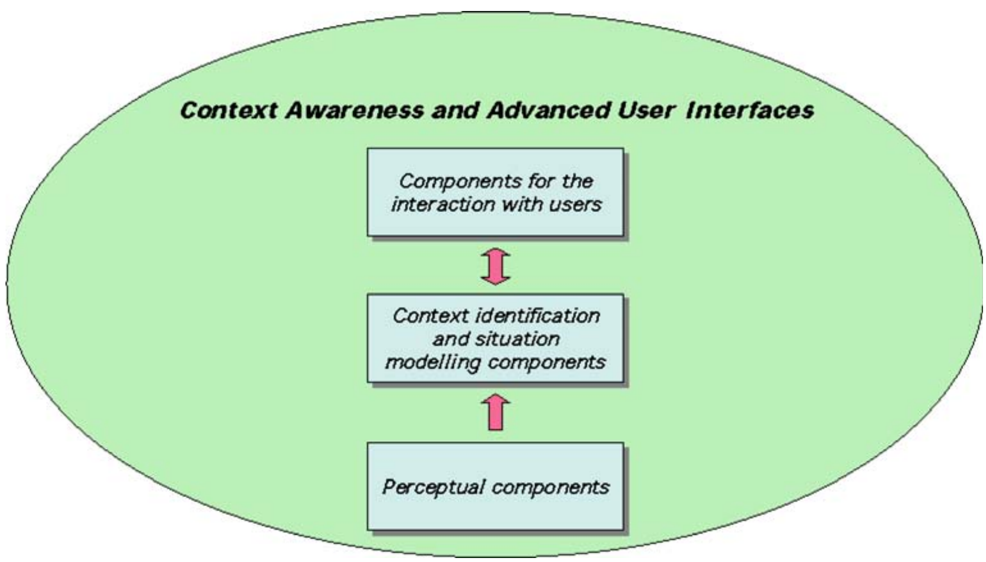


Figure 4 Components for context-awareness

The calculation of context from context cues can be based on neural networks, rule-based algorithms, etc. [20, 21]. 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 be used to adapt the system behaviour so as to satisfy user needs or system requirements.

Finally, in the scope of ambient intelligence advanced forms of interactions with users are necessary. User interfaces should be as friendly and as "invisible" as possible. The interfaces should assist people in their daily tasks without requiring any specific technology know-how. Furthermore, user interfaces should profit from recent technological advances such as wearable computing, automatic speech recognition techniques, etc.

7 Management of intelligent environment applications/services

An intelligent environment provides a framework for the development and deployment of innovative services, like automated safety and security, care and control, targeted to making everyday human activity easier and improving the quality of life, especially of users with specific requirements, such as elderly and disabled people.

In this direction an important feature of the DAFNE framework is the management of such advanced, user-centric, context-aware services. Service management will take into account user preferences and changing environment conditions and will provide personalised services adapted to the current user needs. Figure 5 depicts, in general terms, the aspects taken into account by the logic of intelligent environment applications/services.

Service management in the DAFNE framework addresses issues such as the dynamic development, deployment and discovery of services as well as service orchestration to ensure smooth interoperation of services.

Development and deployment of services should be as dynamic as possible, i.e., application and/or service providers should be able to introduce new applications/services in a plug and play fashion. This means that the system should be able to dynamically reconfigure 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 this context, a service registry/directory is necessary through which application and service providers can publish the services these offer and service requestors can search for available services. Service requestors are entities within the

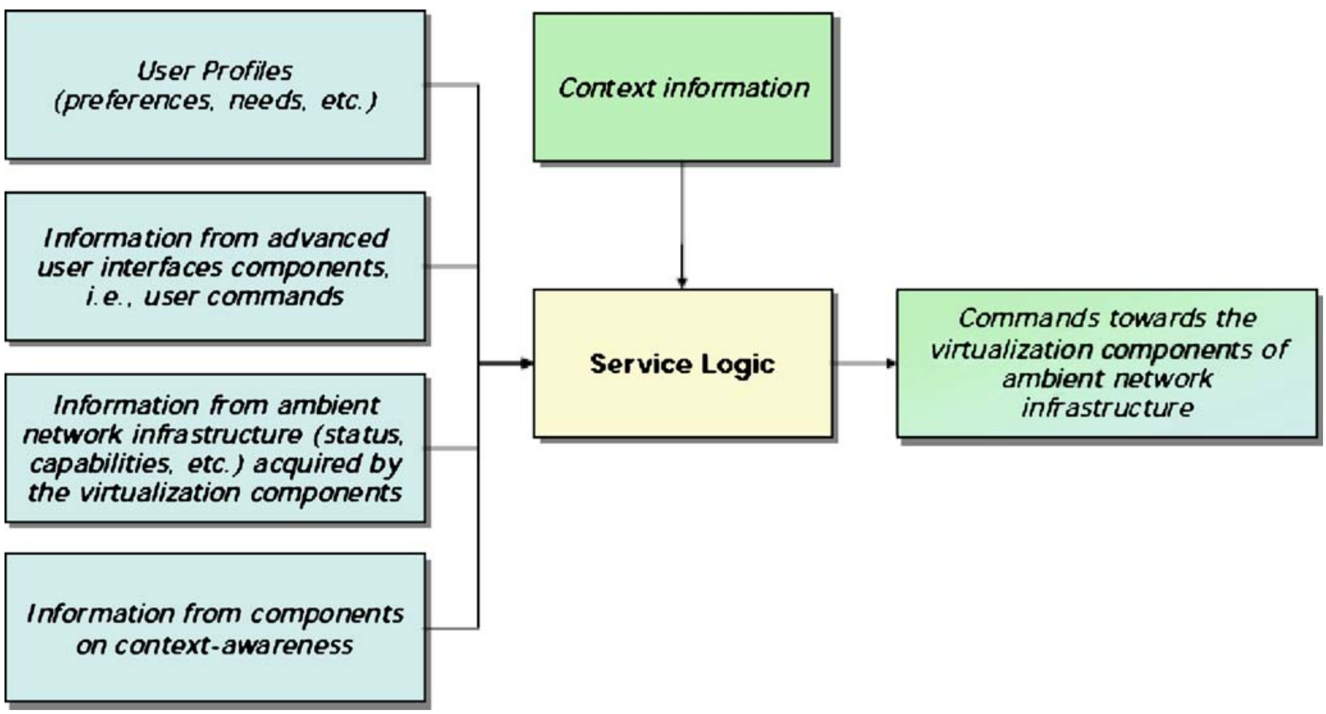


Figure 5 Aspects taken into account by the logic of intelligent-environment applications/services

intelligent environment like for example, service providers requiring information on existing services they can exploit by combining them to provide applications.

In order to enable the dynamic discovery of available services several discovery protocols have emerged. Some of the most eminent service discovery protocols are the Service Location Protocol (SLP) developed by IETF, Jini technology developed by Sun, Simple Service Discovery Protocol (SSDP) used by the UPnP Consortium led by Microsoft, Salutation by the Salutation Consortium and the Bluetooth Service Discovery Protocol. A more detailed overview of these different discovery protocols is provided in [22].

Finally, in order ensure the interoperability and smooth inter-working of different services, possibly coming from different providers service orchestration is a critical aspect of service management in the DAFNE framework.

8 DAFNE middleware 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, UPnP and OSGi on which the implementation of the proposed DAFNE framework can be based.

Jini is Sun's network technology for the construction of distributed systems [23]. 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 DAFNE, 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 are an upcoming and promising middleware technology that is strongly supported by major application framework vendors [24, 25]. 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: (a) the Simple Object Access Protocol (SOAP), which provides a message format for communicating with and invoking Web services; (b) the Web Services Description Language (WSDL), which describes how to access Web services; and (c) the Universal Description, Discovery and Integration (UDDI), which provides a registry that clients can use to discover available services. In the context of the DAFNE framework Web Services concepts can be used for the implementation of service descriptions and service registries.

Universal Plug and Play (UPnP) [26, 27] 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 (Open Services Gateway initiative) Alliance [28] is an open standards organization formed by Sun Microsystems, IBM, Ericsson and others in March 1999. The OSGi Alliance has specified a service framework 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 Framework [29] 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 DAFNE architecture can be focused on these two latter technologies. More specifically, the virtualisation of the ambient network infrastructure can 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 DAFNE architecture. Regarding the management of intelligent environment services and/or applications, DAFNE will employ a combination of OSGi and UPnP. Services/applications will be deployed on DAFNE 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.

9 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. Although a large variety and number of devices, networking technologies and intelligent environment subsystems are currently available there is a lack of a framework for a truly integrated intelligent environment system, in which the ambient infrastructure is as unobtrusive as possible and the interaction with and among devices is performed in an autonomous fashion. The realisation of an intelligent environment requires new and enhanced management concepts. In this direction, this paper presented an approach for a *Distributed Ambient management Framework for enhanced reconfigurable services in the iNtelligent Environment (DAFNE)*. The context in which the proposed framework can be applied was described. Furthermore, the requirements for such a framework were outlined and a corresponding, generic, architecture was presented. The design and operation of the framework in an intelligent environment context were described. Finally, an overview of software technologies that can be used for the implementation of the corresponding framework was provided.

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