

Towards Ambient Intelligence and the Internet of Services in Healthcare

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Abstract

The emergence of the Internet of Services and the Internet of Devices opens new possibilities for societal computing scenarios. Ambient Intelligence (AmI) is a vision of an environment that puts the needs of the user in the center of the technological design process. An AmI environment consists of ubiquitous distributed devices such as sensors, displays, data memories which are embedded in everyday objects like walls, clothes, tables or the pavement. These devices are interconnected and seamlessly deliver applications and services to the user. AmI emphasizes the intelligence of the environments interfaces and the intelligence that can be achieved by correlating context information from different data sources. In this work we present an approach to transfer the AmI vision to the public services sector using the paradigm of service orientation and Cloud Computing. Based on scenarios in the healthcare sector the benefits and challenges of such transfer are presented.

Keywords: Internet of Services, Internet of Devices, Ambient Intelligence, Public Services; Healthcare

1. Introduction

Ambient Intelligence (AmI) is a vision created by the Information Society Technologies Advisory Group (ISTAG). ISTAG [1] refers to AmI as "the seamless delivery of services and applications" based on open software standards, user-friendliness and the convergence of network infrastructure. The ISTAG group does not define the term 'ambient intelligence' precisely, because "AmI is a set of properties of an environment that we are in the process of creating" [2] - which leaves inspiring possibilities for research. Other authors [3] [4] define the term more closely - it characterizes a

paradigm for the interaction between a person and his environment which means that the environment becomes aware of the human, his goals and needs. It also provides natural multimodal interfaces that place the user in the center of design.

The term "Internet of Services" describes broadly the transformation of the Internet from a content provider to a service provider. Specifically, it relies on the concept of web-based services that are offered in a standardized way [5].

Public services are those services that are required to be provided independent of profit, because they are advantageous and essential to all citizens. Examples include defense, healthcare, and utility services. In general, the state is responsible for their provision. Depending on the common understanding of the role of state different ranges of these services can be provided by private or semi-private commercial enterprises under some sort of regulation regime enacted by the state.

The remainder of the paper is organized as follows: in Section 2 we provide the needed definitions. We introduce our approach for transferring AmI to the public services domain in Section 3. Section 4 presents an experimental evaluation of the approach and Section 5 provides an overview of related works in other domains. Discussion of our approach and outlook to future research activities complete the paper.

2. Preliminaries

This section provides needed definitions and assumptions for our approach.

2.1. Features of Ambient Intelligence System

The vision of ambient intelligence is hold very broad and the distinction blurred. It leaves space for

ICT research in various directions pushing technology advances on multiple frontiers. AmI is guided by the concept of "human centered computing", i.e. technologies should be designed for people rather than making people adapt to technologies. Figure 1 describes the main features of an AmI system.

Non-obtrusive: The ambient vision includes that information technology is ubiquitously but unobtrusively deployed - supporting ubiquitous communication and computing. Ambient devices are embedded in every day objects like furniture, clothes or roads which are interconnected using various network technologies. The ambient devices are integrated into the environment, often invisible to the user. Yet they deliver interfaces for interaction with other devices or humans. The interaction of the ambient environment with the user is easy, comforting and does not require prior learning, the user may even hardly notice to use an interface.

Context-Aware: The ambient intelligent system is aware about the current situation the user is in. This includes physical conditions like location, weather, noise-level, and conditions that the user is not aware of, like humidity, the users blood pressure and oxygen saturation. The system recognizes persons including their personal profiles, preferences, contact information or latest activities giving it the possibility to derive complex context relationships. The system also understands the current mood of the person by sensing the current behavior, mimic, or voice pitch. The context awareness also includes adjacent devices like printers, displays, sensors or network availability. These devices may offer services to the ambient systems which are identified and used depending on the current situation.

Intelligent: The ambient system is active and responsive in an intelligent way. This means that offered services and interaction with the user are personalized according to the persons preferences, experiences or mood. The system may anticipate user behavior and act accordingly for example by answering calls on the users behalf because he is busy (see ISTAG scenario Dimitrios in [6]). Although the ambient system com-



Figure 1. Features of an Ambient Intelligent System

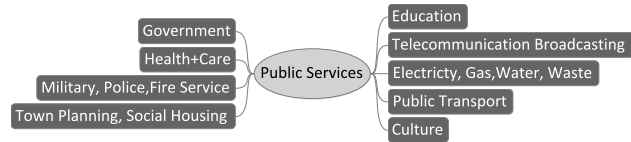


Figure 2. Public Services

prises of a myriad of devices and platforms, the system needs no configuration and it ensures data privacy autonomously, i.e. in a self-managed, self-healing and self-protecting way.

2.2. Cloud Computing

Cloud computing is commonly understood as a shift in the location of computation tasks, or in "the geography of computation" [7]. Most of the software components reside on infrastructures that are hidden from the user, their distribution is unclear, and the user relies on infrastructure provided by third parties. There are several general service models in cloud computing - Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS).

2.3. Public Services

Public services are those services that are required to be provided independent of profit, because they are advantageous and essential to all citizens. Their provision may be required by human rights (right of water, right of education), but can also be humanistically derived. Usually the government ensures that everyone can access and use these essential services, whereas a private owner may abandon the social obligation in disadvantage to those who are less able to pay, or where this service is unprofitable. In the past, public services that tend to be natural monopoly markets but are essential for all, like electricity, water, gas, telecommunication were ubiquitously offered at affordable prices by public financed institutions. After deploying a sufficient distribution network, in the recent past many of these institutions were privatized under regulatory supervision. Figure 2 shows a classification of the variety of services that are considered to be public services.

3. Transferring AmI to Public Services

The ISTAG working group emphasizes that one of the key actions is to provide AmI services in the public sector. The public service sector has the potential to develop a critical mass for the deployment of AmI

infrastructure especially when initiatives are not only lead nationwide but at the EU level [2][4]. Based on examples in the health sector in this section we derive an approach for transferring AmI technologies to public services.

3.1. AmI in Health Care

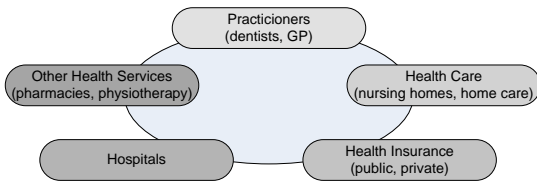


Figure 3. Health Service Entities

The public health sector accounts for approximately 8% of the GDP [8] in the EU and there are various efforts to develop efficient and effective health systems [9]. A multitude of entities are involved in health service provisioning (see Figure 3). There is a variety of publications available that show scenarios of AmI in the Health Sector. For a structured approach to ambient intelligence in health care we categorize and describe these scenarios within this section.

3.1.1. Ambient Medical Information Systems.

Recording the medical records of patients in a digital format reduces costs and improves medical care. By storing all images, allergy information, prior treatments in an electronic health record (EHR) we can allow entities that are authorized by the patient – like their general practitioners, hospital, pharmacies, social care service and health insurance – to access the patients data and thereby decrease paper work and transport. Illegibility errors will be dissolved and each of the entities will be provided with its relevant information for better service quality. For example with electronic medicine prescription the pharmacy closest to the patient can already order the requested pharmaceuticals although the patient is still in the consultation room. EHR can reduce redundant work as duplicate lab tests and can improve billing accuracy. Anytime a patient is undergoing tests, health consultation or receives prescriptions it will be automatically billed and stored in the EHR and the relevant information will be transmitted to the patients health insurance.

In the ambient intelligent scenarios [10] [11] it is envisioned that the EHR is available world wide, so that even on vacation or business trips the local physician can base the treatment on prior findings and billing of international travel insurances is facilitated.

Any data from diagnostic devices or sensors like blood pressure meters will be directly uploaded to the EHR or temporarily stored in the metering devices until a network connection is available. Based on semantics and pattern matching methods the medical record can be grouped into single incidents like colds, recurring chronic diseases, allergies or possible congenital diseases by relating to EHR of relatives. This will make the EHR easier to read and analyze – thus enabling the physician to make a more thorough decision.

3.1.2. Wearable Monitoring Devices.

Wearable Health Monitoring devices that are inspired by the AmI vision are integrated into clothing and are equipped with sensors that track relevant health data. As an example in [12] the authors show how piezoresistive yarns enable clothing with fully integrated textile sensors. These sensors are capable of recording physiological signals like heart beat, ECG, respiration and motion. Setting up a bluetooth connection between a mobile device and the sensor shirt enables the transmission of health data to the ambient system core [13] - the data will be uploaded to the EHR whenever a network connection is available. In a simple case scenario the device recognizes that the measurement parameters are outside predefined bounds and notifies the patient to take counteractions or alarm relatives, the patients general practitioner or emit an emergency call. An intelligent system cannot only detect abnormal physical conditions and raise an alarm but can also commence counteractions. Combining sensors with actuators, like in continuous glucose monitoring devices in a closed-loop system [14], will provide more secure medicament injection and emotional relief for the patient.

3.1.3. Ambient Assisted Living.

A broad research area of the EU commission is ambient assisted living (AAL) [15] [16] – about 30 projects with about 200 million Euro are currently funded. Faced with an increasing amount of elderly people that require care systems ambient intelligent technology can provide a solution to offset hospital care with care at home. An AAL system can support the residents in performing their daily activities, offset physical restraints and facilitate social interaction with their families, friends and carers. EU funded AAL research projects [16] all have one common goal – to make lives at home more easy and comfortable thus enabling residents to stay longer and independently in their homes. One large research area is the integration of all household appliances (kitchen appliances, media and support systems) into one system. That enables a control

through a single interface which can be facilitated through an intelligent e-servant. The e-servant can be controlled through an intelligent speech interface removing any need for remote controls, buttons and difficult to read manuals. In the Hearing at Home (HAH) project an ambient platform is used to focus sounds by appropriate noise reduction algorithms depending on the location and intention of the user. Other example scenarios range from ambient light system that aid well-being and natural sleep-wake cycles to household service robots. Other projects like CAALYX [17] and EMERGE [18] concentrate on measuring the vital signs of the residents, activity tracking, observing fall incidents and alarm caregivers in case of emergency. Another scenario are smart pill dispensers that can remind memory-impaired patients to take their medications on time and medication can be adjusted to the momentary health condition.

3.1.4. Health Knowledge. Health knowledge systems can provide practitioners, pharmacists, medical staff, surgeons with state of the art research, field tests and evidence-based medicine. These information feeds can be adapted to the specific area of application that the inquirer is specialized in. Further health knowledge systems that include databases of different diseases and treatments, symptoms, pharmacy drugs (instruction and contents) can provide an information basis for the public. Patients can search the knowledge database for their symptoms and vital signals in order to either find 24 hours treatment advice or any specialist in their area. An example is NHSdirect [19] an online health advice database in the UK.

3.1.5. Diagnosis. An example of intelligent diagnosis can be found in the field of cardiac monitoring. The EU project EPI-Medics [20] uses an intelligent personal ECG monitor (PEM) for the early detection of cardiac ischemia and arrhythmia. The PEM is able to constantly record the patients ECG. The PEM uses neural networks and a fuzzy processor in order to generate alarms and decide which cardiac incident occurred. Because the ECGs differ between patients, the PEM also considers prior ECG measurements that are stored in the EHR. With the use of this intelligent monitor the diagnosis time after the incident can be reduced and treatment can be commenced earlier.

3.1.6. Work Flow Process. A typical scenario of AmI process improvement is the smart display of

EHRs during rounds. When the attending physician is making his round and enters one of his patients rooms automatically the EHR for this patient is displayed on his mobile PDA. Another scenario shows how response times can be reduced by location based services: instead of transmitting alarm calls to a central location (e.g., nurses room) the closest medical staff member that has the ability to treat the incident can directly be called. In [21] we demonstrated how clinical processes can be optimized by Wi-Fi based location sensing of assets, patients and clinical staff. An interesting report [22] shows further ambient intelligence scenarios in a hospital environment, which were developed based on interviews conducted in 3 hospitals in Berlin. The ordering of consumable materials and pharmaceuticals is critical in hospitals and usually requires manual or semi-automatic demand planning. This can be time consuming for nurse staff. An ambient intelligent system can support the ordering of materials and the recording of consumption – even the production batch of an implant could be saved into the EHR. This would enable an optimized ordering process and tracking of material quality.

3.1.7. Security and Safety. In [22] hospitals staff also requests position sensing for the safety of mentally distressed people. Sometimes these people loose their sense of their current location and situation and get lost in the hospital. A system that shows the location on request can proof applicable for tracking these patients. Furthermore, an AmI system can also guide patients during fire emergencies. Lightning systems, surveillance cameras and loudspeakers that communicate the closest safe exit can facilitate evacuation of the hospital.

3.2. Overview of the Approach

The approach is presented in Figure 4. It begins with an evaluation of the specific healthcare scenario. The evaluation is documented as a process model in the BPMN notation [23]. This formalized scenario is then taken as a starting point for the introduction of AmI technologies with the facilitation of Cloud Computing. The main focus of the approach lies in the assessment of AmI technologies and corresponding healthcare services (ideally provided as SaaS) to support the specific scenario. We conduct the scenario evaluation as described in [24] and the technology assessment as described in [21].

The facilitation of Cloud Computing allows us to avoid typical problems of AmI introduction – missing

know how, insufficient application support for new hardware technologies, as well as integration issues.

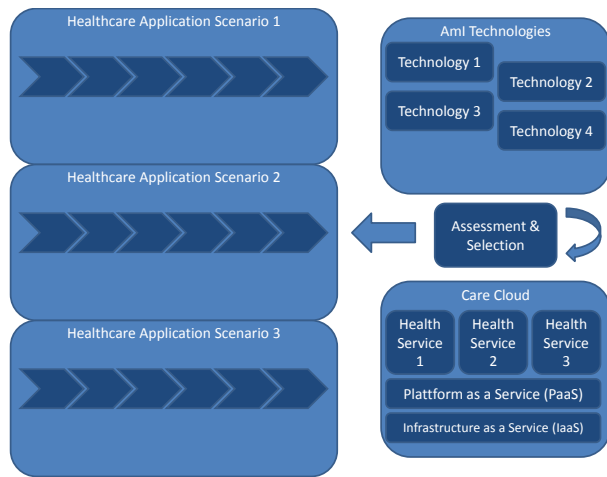


Figure 4. Approach for Cloud Computing facilitated Introduction of AmI in Health Care

3.3. Benefits of AmI in Public Services

Applying ICT in the public sector is more than facilitating and reducing costs of sending, storage and retrieval of information. Based on the presented AmI scenarios in health care there are several benefits from AmI in the public service sector: (i) better service quality (e.g., faster response times, better service goal achievement, and less mistakes), (ii) cost reductions, (iii) increase of self-service, i.e. public service outsourced to citizen, (iv) personalized services, (v) flexible and non stationary service provisioning, and (vi) less emotional stress for public servant and service requester.

4. Experimental Evaluation

Initial experimental results demonstrate that our approach can significantly improve the introduction of AmI technologies in the healthcare domain. Overall, participants in our experiments described our approach as well suited for this task.

A detailed field evaluation of our approach is currently under way. Within a joint research project with estimated investments of over 10 Million Euro we are collaborating with AmI technology producers, hospitals, pharmaceutical companies, and other research organizations to evaluate and demonstrate the benefits of the approach. While the project is scheduled to be completed in 2012, we expect first results within the next six months.

5. Related Work

The public educational system consists of all institutions that provide education. It not only comprises the school system, but also higher education and further personal training are part of the education system (cf. Figure 5). Due to scenarios and requirements similar to the healthcare domain (e.g., daycare) there are a variety of areas where AmI is used. The authors of [25] [26] present how AmI technologies can be used in classrooms to improve lecturers presentations and enhance the students learning experience. Ordinary remote learning is usually desktop based - but in the ambient scenario described in [26] the teacher can interact with a large display/projector image as if in a regular classroom. Features of a personalized education environment that have been presented are manifold: personalized textbooks generated depending on prior knowledge [27], education as a web-based service that is adaptive to the preferred cognitive method [28].

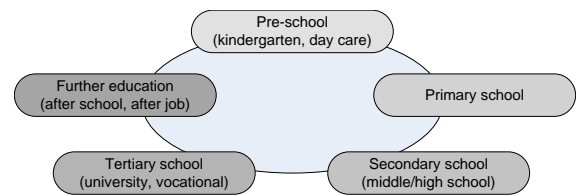


Figure 5. Education Entities

6. Discussion and Outlook

In this paper we introduced an approach for transferring the concept of AmI to the public services domain. It facilitates Cloud Computing and SaaS as current approaches for the provisioning of IT services. This allows us to alleviate some of the typical problems of AmI introduction – missing know how, insufficient application support for new hardware technologies, as well as integration issues. Our current work is focused on the practical evaluation of the approach within a joint research project with major German healthcare providers.

Acknowledgment

The authors would like to thank Dr. Michael Niedermayer and Christian Henke for their valuable input. We also appreciate the helpful comments from the reviewers.

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