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The Internet of Things for Ambient Assisted Living

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***Abstract*—The Internet of Things (IoT) is the logical further development of today's Internet. Technological advancements lead to smart objects being capable of identifying, locating, sensing and connecting and thus leading to new forms of communication between people and things and things themselves. Ambient Assisted Living (AAL) encompasses technical systems to support elderly people in their daily routine to allow an independent and safe lifestyle as long as possible. Keep In Touch (KIT) uses smart objects and technologies (Near Field Communication and Radio Frequency Identification) to facilitate telemonitoring processes. Closed Loop Healthcare Services take use of KIT technology and are capable of processing relevant data and establishing communication channels between elderly people and their environment and different groups of care-givers (physicians, relatives, mobile care providers). The combination of KIT technology (smart objects) and Closed Loop Healthcare Services results in an applied IoT infrastructure for AAL scenarios. Already applied IoT and AAL applications in telemonitoring and medication intake compliance projects show that these applications are useful and accepted by the elderly and that the developed infrastructure enables a new form of communication between people and people, people-to-people (P2P) communication. The personal communication between elderly people, their environment and relevant groups of care givers is an important aspect in AAL. Through the combination of KIT and Closed Loop Healthcare, a central AAL paradigm can be realized through the IoT, where the elderly live in their homes with smart objects, thus smart homes, communicating to the outside world in an intelligent and goal-orientated manner.** *(Abstract)*

eHealth; Pervasive Healthcare; Telemedicine; Near Field Communication (NFC); RFID *(key words)*

I. INTRODUCTION

A. *The Internet of Things*

The Internet of Things (IoT) is a technological phenomenon originating from innovative developments and concepts in information and communication technology associated with:

- Ubiquitous Communication/Connectivity,
- Pervasive Computing and
- Ambient Intelligence

These concepts have a strong impact on the development of the IoT [14]. Ubiquitous Communication means the general ability of objects to communicate (anywhere and anytime); Pervasive Computing means the enhancement of objects with processing power (the environment around us becomes the computer); Ambient Intelligence means the capability of objects to register changes in the physical environment and thus actively interact in a process. Typically, objects fulfilling these requirements are called "smart objects" [6]. Hence, the IoT is defined as the ability of smart objects to communicate among each other and building networks of things, the Internet of Things.

The known dimensions of the common Internet – from *anytime, anyplace* connectivity for *anyone* – are supplemented by the dimension *anything* [5].

Another explanation of the IoT is that the world's objects build a dynamic network which is connected by the Internet and sometimes designated as the network of networks.

It is expected that the IoT changes the web from being a virtual online space to a system that is embedded in the real physical world. Typical characteristics of the IoT are that

a) it creates new independent networks that operate with their own infrastructures
b) it will be implemented with new services and
c) it will apply new and different modes of communication between people and things and things themselves, including Machine-to-Machine (M2M) communication [2][10].

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The key players in enabling the IoT are smart objects, which are characterized by four technological attributes (implying the typical attributes of Ubiquitous Communication, Pervasive Computing and Ambient Intelligence):

- Identification
- Location
- Sensing
- Connectivity

Furthermore, smart objects can be active (local decision making is possible) or passive (sensor data is stored and can be read out – no local decision making is possible).

The major enabling technologies for smart objects are Radio Frequency Identification (RFID), Global Positioning system (GPS), developments in sensor networks, Micro Electro-mechanical Systems (MEMS) and further developments in wireless connectivity. RFID tags allow objects to be uniquely identified, to determine the location, to sense changes in physical data and to connect and communicate with a corresponding transponder.

The main goals in realizing the IoT will be to provide relevant information (only), in the right format, when and where it is needed and hence to bridge the gap between the web and the real world [2]. Additionally, the IoT will be a key part of the future Internet, which will be made up of the Internet of Services and the Internet of Things [3].

B. *Ambient Assisted Living*

Ambient Assisted Living (AAL) encompasses technical systems to support elderly people and people with special needs in their daily routine. The main goal of AAL is to maintain and foster the autonomy of those people and, thus, to increase safety in their lifestyle and in their home environment.

The necessity for such applications arises from the demographic change in industrialized countries where life expectancy is on the rise and the birth rate is in decline. These circumstances require innovative and cost-effective solutions to keep the health care expenditures within the bounds of economic possibility [8][11].

AAL applications include services, products and concepts to increase the quality of life, wellbeing and safety of elderly people. The main goal of AAL is to achieve benefits for the *individual* (increasing safety & wellbeing), the *economy* (higher effectiveness of limited resources) and the *society* (better living standards) [11][13].

The fields of needs for elderly people in AAL applications are:

- Health,
- Safety/Security,
- Peace of mind,
- Independence,
- Mobility and,
- Social contact.

The scope of applications in these fields is very broad. For this reason AAL environments are structured in three levels: Hardware (sensing, wireless networks), Middleware (data capture, data safety, IT integration) and Services (biosignal processing, application-orientated processes, community services) [4].

C. *The IoT for AAL*

AAL has a strong relationship to "Ambient Intelligence", which is one technology leading to the IoT. To enable increased safety and wellbeing in one's home, the home has to become intelligent with the help of smart items, which is the vision of Ambient Intelligence.

An AAL scenario is characterized by being connected, context-sensitive, personal, adaptive and anticipative. The IoT is supposed to being capable of providing all characteristics necessary for an ambient assisted environment. With respect to the fields of needs for elderly people it is possible to accomplish all fields through the IoT. The monitoring of chronic illnesses (health), on-demand provision with fresh food (safety), alarming systems (security), reminder services (peace of mind) and enabling people-to-people communication for instance with relatives (social contact) without recognizing the technology behind it are just a few mentionable applications of AAL through the IoT.

The commission of the European Union encourages this hypothesis by saying "The scope of IoT applications is expected to greatly contribute to addressing today's societal challenges" [10].

II. METHODS

A. *Keep in Touch*

Keep In Touch (KIT) has been developed as a technology for collecting and forwarding necessary (health) data for chronically ill and elderly people to monitor the health status and compliance in therapy. KIT is based on RFID in combination with Near Field Communication (NFC) and mobile phones. NFC is a wireless connectivity technology based on magnetic, inductive coupling and works in the free frequency band of 13.56 MHz. It enables short-range communication between smart objects just by bringing them close together [7].

With KIT NFC equipped mobile phones are capable of collecting application-specific data just by touching the respective object, which is also equipped with an RFID tag or NFC technology. The mobile phone, thereby, becomes a universal communication terminal for several medical devices or smart objects.

The paradigm of touching medical devices in the home environment has been evaluated concerning patients with Congestive Heart Failure (CHF) in a home-monitoring scenario [9].

The benefits of NFC in such scenarios are:

Figure 1. KIT blood pressure meter and NFC enabled KIT mobile phone. The communication is established by bringing the devices close together. After having been collected, the data (blood pressure and heart rate) is sent to a service center.

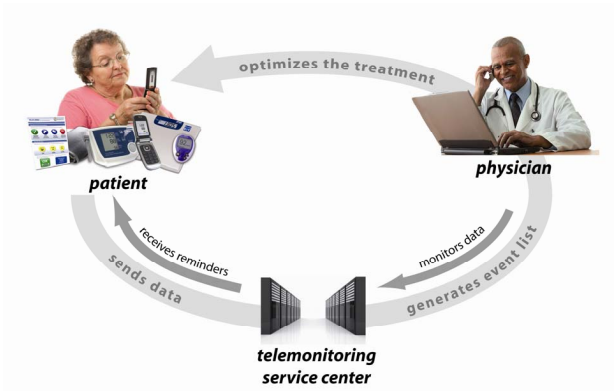

Figure 2. Closed Loop principle in healthcare. The data collected by the patient is sent to a service center, which is accessible by the treating physician. The physician monitors the health status of the patient and may give telemedical advice, if necessary, and thus improve the treatment.

- No manual interaction (data entry via keypad) on the mobile phone is necessary.
- The effort for maintenance and management of devices in comparison to other methods (e.g. Bluetooth) is low.
- It additionally provides access to data stored on RFID tags.

For collecting data via KIT every person gets a SmartCard (ID-Card), which is used to identify the patient and to launch a Java software application installed on the mobile phone. The launching process is also supposed to update the application if necessary. After that, data can be collected from e.g. a blood pressure meter (UA 767 plus NFC, AND, Japan) just by touching the device. A possible field of application for KIT encompass the daily documentation of blood pressure (see Figure 1).

The process for the acquisition and transmission of blood pressure would be:

1. Measure blood pressure as usual
2. Touch the SmartCard with the mobile phone
3. Touch the blood pressure meter to collect data
4. Touch the SmartCard again to signalize that the data acquisition has been finished.

B. Closed Loop Healthcare Services

Experience shows, that the collection and central storage of relevant health data only may not be sufficient to increase the compliance with and the success of a therapy. Additionally, it is necessary to proactively send reminders and feedback to the patient. The process of collecting data and obtaining feedback for the collected data is designated the "Closed Loop Principle". Figure 2 shows this with the patient on one side and the physician on the other with a service center, where the data is stored, in between. Both the patient and the physician have access to the data on the central service center and are able to communicate through it [15][16].

To achieve a closed loop health care process, the access for the physician is established through a secure website. The presentation of the collected data (e.g. blood pressure, body weight, heart rate) on the website comprises of both numerical and graphical elements and allows for a quick overview. In addition, a rule-based algorithm analyses the collected data and recognizes exceeding of certain thresholds, which have been defined previously. This functionality identifies persons with signs of upcoming severe events (e.g. that may need hospital stays) from patients who are likely to remain in their current health status. Persons with higher risk have priority in the event list of the treating physician who can give telemedical advice in the form of feedback or a reminder through the mobile phone, when necessary.

Thresholds for each patient and each parameter are defined resulting from the first five data transmissions of the patient. Initially, these thresholds are checked by the physician for plausibility to have a basis for the algorithm, which checks the threshold exceeding. Then each incoming data set is checked during data processing by the algorithm concerning threshold exceeding. Also missed data transmissions are recognized (e.g. if the patient forgets to send the data on a daily basis) and lead to an event in the event list of the physician. Once a week, patients are listed in the event list, even if there are no events (threshold exceeding or missed value).

The physician "on the other side of the loop" is obliged to check the event list once a day to be able to give telemedical advice (feedback/reminder) or react, when necessary, in a previously defined period of time. These services establish a patient-physician communication via collected data, especially when it is necessary in the case of an upcoming event.

III. RESULTS

Both KIT and the Closed Loop Healthcare Services resulted from projects in an eHealth and telemedicine context. They are part of telemonitoring and/or medication compliance projects [1][7][9][16]. All of these projects taught us that when it comes to the necessity of patient interactions, usability is very important.

First attempts with data entries via the keypad of a mobile phone showed, that especially elderly people have problems with typing in medical data manually [9]. To make our applications accessible to technically inexperienced people, we implemented new technologies to overcome the hurdle of data entry via keypad.

NFC and RFID (both enabling technologies of the IoT) fitted in our concept of data acquisition with a mobile phone as patient terminal. The KIT technology evolved from both technologies in combination with mobile phones. KIT offers the premises to apply telemonitoring systems in a clinical routine as well as at the home of a patient because of its intuitive handling. At the moment, a KIT based monitoring system is running in a public hospital for patients suffering from CHF in Austria routinely.

A recently concluded project [1] evaluated the acceptance and usability of a closed loop healthcare service using NFC technology in the AAL setting. The so called personal drug reminder system consisted of a NFC enabled mobile phone, an ID-Card and a medication compliance RFID tag board (MCTB), showing different statements concerning the daily medication intake compliance ("Taken as prescribed", "Taken higher dose", "Taken lower dose" and "Not taken at all"). The involved 14 persons were reminded of their daily drug intakes in the morning, noon, evening and night through a reminder on the mobile phone, if the taken medication was not documented using the MCTB in a certain period of time before.

The study showed that the system was accepted by the target group and increased the compliance concerning correct medication intake. Another output of the study was the feedback of the involved elderly people: It was of big importance for them to be well informed about the purpose and benefits of an AAL application.

Examining several elements of already applied KIT & Closed Loop Healthcare Services (mobile phone, blood pressure meter and MCTB regarding their characteristics as smart objects, it turns out that they are already smart objects (which are necessary for the IoT). Table 1 itemizes the elements with regard to their attributes as smart objects. The NFC mobile phone fulfills all attributes of smart objects, the blood pressure meter three out of four and the MCTB two out of four attributes.

TABLE I. KIT ELEMENTS AND CHARACTERISTICS AS SMART OBJECTS

	Identific.	*Sensing*	*Connect.*	*Location*
NFC mobile phone	yes	yes	yes	yes
Blood pressure meter	yes	yes	yes	no
MCTB	yes	no	yes	no

The combination of KIT (smart objects) and Closed Loop Healthcare Services result in an applied infrastructure for Ambient Assisted Living. Figure 3 shows the result of the combination of both technologies. On the one hand it includes data acquisition in the environment of the elderly person through the IoT and the connection to relevant groups of care givers on the other hand. Thereby, the connection enables communication

- to the treating physician for the monitoring of chronic illnesses and adaptations of medication and
- to relatives or mobile care givers concerning their social and personal needs.

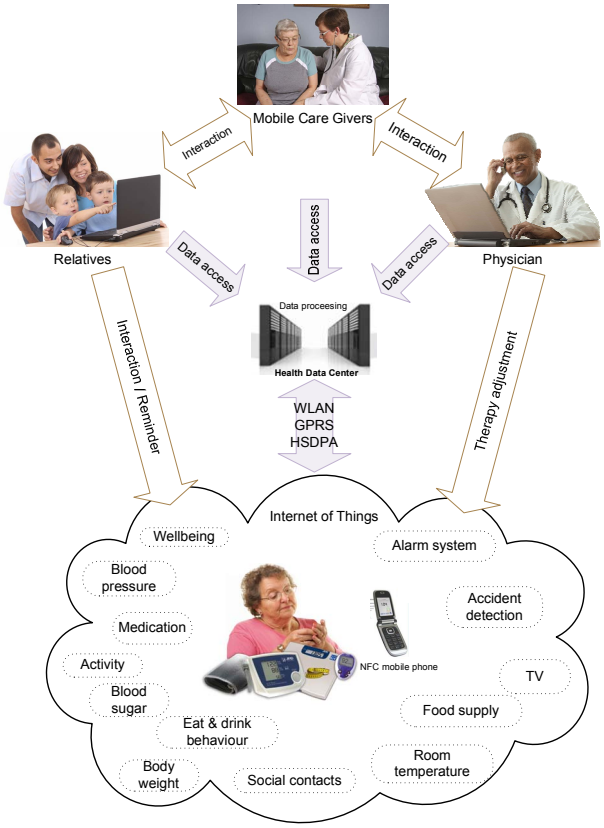

Figure 3. The IoT in an AAL scenario: The elderly people live in their homes, which are equipped with smart objects. The mobile phone acts as mobile terminal for the person and is capable of sending relevant data to a service center, where they are processed. Different groups of partners have access to the processed data and can interact directly by contacting the person or by interacting with the smart objects around the concerned person.

IV. DISCUSSION

As we expanded the scope of KIT we recognized that an RFID tag can be incorporated in nearly any device for any purpose. This matter of fact is already emphasized by several international programs and actions plans of the European Union (e.g. *The Internet of Things – An action plan for Europe*). It is possible to monitor the eating & drinking behavior as well as e.g. the alarming system of a house. These possibilities entail several benefits, especially for elderly people, who want to stay in their traditional, but ambient assisted environment:

- No expensive adaptations of the home are necessary.
- There is no feeling of being controlled (in comparison to installed cameras in the home environment).
- Self-determination about who has access to which data is possible.
- Additional monitoring of chronicle illnesses is possible.
- Increased safety through the feeling that there is somebody who cares.

Overcoming our problem with usability and therapy compliance in telemonitoring systems, we developed the ambition to create an application with high usability and intuitive handling. The usage of RFID and NFC technology, both enabling technologies of the IoT, lead us to an early application of the Internet of Things.

But for us the IoT does not only mean that the acquisition of relevant health data is facilitated, but also that the establishment of communication is getting easier and more effective. The Closed Loop Healthcare Services enable this kind of purposive communication e.g. with the treating physician and lead to another important aspect of future information and communication technology: Not only communication between people and things and things themselves will change through the IoT, but also the communication between people and people, the so called people-to-people (P2P) communication, which is an important aspect in Ambient Assisted Living. P2P communication will become intelligent and goal-orientated through the IoT (See Figure 3).

The economical factor of enabling AAL through the IoT should not be forgotten in this context:

"Even bigger potential comes though with the expected ageing of society with the associated rise of health care costs: The IoT will be essential in realizing the vision of ambient assisted living" [3].

This especially matters in context to the wide spread of mobile phones in the majority of the population in industrialized countries. The usage of an NFC enabled mobile phone as universal communication terminal for the IoT is also approved by designating mobile phones as interface to the world [2].

V. OUTLOOK

To fully exploit the IoT for AAL scenarios, remaining technical as well as organizational challenges will have to be resolved. Concrete application scenarios for AAL have to be worked out. On the technical side widely accepted standards for the IoT have to be defined to allow for a broader adoption in the future. Finally, more and smarter objects are needed. Currently we extend the system with smart medication blisters to facilitate advanced medication management in the near future.

VI. CONCLUSIONS

The combination of both KIT technology and Closed Loop Healthcare Services for elderly people can be utilized to realize the central AAL paradigm through the IoT, i.e. where the elderly live in their homes with smart objects, thus smart homes, accessible to different groups of care providers. The Internet of Things thereby enables communication between

- people and things,
- things and things and
- people and people

in a secure manner.

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