Data Processing within Ambient Assisted Living System

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Abstract - The increased aging population, especially in Europe, together with the increasing financial expenses of providing medical care, create the need for novel systems to provide self-care and home-care. The rapid progress of mobile technologies, sensors, Internet of things, cloud and fog computing, provides the necessary infrastructure for such systems to be developed. This work describes a data processing within an ambient assisted living system. The data processing include data from both environmental sensors and body sensors, capable of following activities and taking care of humans living in a specific healthcare environment.

I. Introduction

Ambient Assisted Living (AAL) has the ambitious goal of improving the quality of life and maintaining the independence of people (elderly, home-care patients) through the use of technology [1]. AAL can improve the quality of life by reducing the need for caretakers, personal nursing services, or the transfer to nursing homes. In this context, there are two goals: a social advantage (a better quality of life) and an economic advantage (a cost reduction for society and public health systems). So, it cause that the size of EU AAL market was 186 m Euro in 2017 and prediction for 2021 is to grow at 1.384m Euro [2]. But, the penetration of AAL technology is not as it expected, (0.3 - 0.7 %) with tendency to increases until 2021 (1.3 – 1.8 %).

AAL covers wide range of activities with creating care models and algorithms, enabling technologies and assistive solutions, monitoring of elderly people vital signs, home rehabilitation, ICT solutions connected with AAL, people with chronic conditions, wider population including the peoples with different impairments, robotic assistance for the elderly, sensing technologies for AAL, measurements devices and sensors connected according to Internet of Things and smart housing in general context [3]. Most efforts towards building AAL Systems are based on developing pervasive devices and use of Ambient Intelligence to integrate these devices to construct an environment appropriate to the user [4]. Technology influences the ability to express the power of a human being and the importance of social connections [5]. In this context, the usage of advanced information and communication technologies (social networks) could help connect people and organize community activities.

AAL systems need to ensure high-quality-of-service. Essential requirements of AAL systems are usability, reliability, data accuracy, cost, security, and privacy. According to [6], in order to achieve these requirements, it is essential to involve citizens, caregivers, industry, researchers, and governmental organizations in the development cycle of AAL systems, so that end-users can benefit more from the collaborative efforts.

As the research in AAL matures, data generated from AAL Internet of Things devices will benefit from the analysis by well-established machine learning techniques. There is also potential that new research in machine learning and artificial intelligence can be used on data generated from the sensors used in AAL [7].

The electronic health record (EHR) is a collection of electronic health information about an individual patient and a portion of the population, operated by institutions and healthcare holders. It is a mechanism for integrating health care information currently collected in both paper and electronic medical records (EMR) or Electronic Health Record (EHR) to improve quality of care [8]. A personal health record (PHR) is a health record where the patient himself maintains health data and information related to the care of a patient. PHR provides a complete and accurate summary of an individual's medical history which is accessible online, under strictly defined access permissions. One of the advantages of novel AAL systems is integrating data from AAL systems and smart homes with data from EHR or PHR. Although it is still in an early stage, aggregating data from different medical devices and integrating them with data from health records enable a comprehensive view of health data [9]. Presenting these health data can lead to more efficient and informed decisions by physicians, nurses, patients, and informal caregivers [10].

AAL is seen as a promising alternative to the current care models and consequently has attracted much attention. According to [11], there are three categories of AAL interoperability services: 1) notification and alarming services, 2) health services, and 3) voice and video communication services. A convenient way to integrate EHRs, PHRs, AAL, home care, and self-care systems is the approach of integrating them in a highly connected, robust, and reliable cloud platform, offering uninterrupted availability.

In this context, it is important to distinguish different groups of stakeholders. The AAL Association categorizes users into three groups:

- Primary users – senior citizens or disabled people who have AAL solutions installed at home,
- Secondary users - informal caregivers (such as family members and friends), companies, and organizations that are using AAL solutions for the benefit of end-users.
- Tertiary users - institutions and organizations (such as public sector, health, and insurance organizations) who are not in direct contact with AAL solutions but play a role in providing or financing them.

II. Smart home-based health monitoring systems

Smart home and health monitoring systems integrate different home appliances sensors from different health monitoring devices in order to gather data and create knowledge for its end users. The knowledge can be taken into consideration by medical practitioners for a different recommendation or additional information if they can access them. Some researcher state that it can be connected with patient's PHR and made available for usage [12].

In [13], a general architecture for AAL based on mobile and web technologies is presented. Mobile devices are used for collecting data from environmental and body network sensors, but also for easy access to specific personal data. Raw data is preprocessed, filtered by noise, and then processed using healthcare algorithms that transform raw data into relevant information which is distributed and used by different services. This model includes the processing of data aggregated from social networks needed to give different recommendations to the users and medical centers along with data collected by sensors.

Many researchers pointed out of specific usage of AAL based mobile applications in specific medical domain as cardiovascular diseases [14] taking into consideration quality characteristic of service [15].

"Smart Monitor" [16] is an AAL system based on video capturing and face recognition. AAL systems can be used in different medical health care centers, but they can also be used for home automation. This system belongs to a category of intelligent AAL systems because it can be configured to react on specific objects in movement, but also can automatically detect, track and recognize objects of interest and react on specific events without a qualified employee for monitoring and reporting. Different environmental sensors and cheap cameras enable this system to monitor a variety of activities at the premises where it is implemented.

Younghwan [17] describes a context-aware smart system for covering more significant areas. This system is mainly used for the prevention of crimes and different accidents. It is composed of two parts: a sensor network and a data processing server. An aggregator sensor network is built with cheap sensors connected and positioned in different locations. Different types of sensors used, generate very complex raw data. Data is processed by a data fusion server that processes the data using different algorithms and generates data in different formats. Similar system developed by Wood at alias described in [18].

III. Data sources in AAL systems

Body sensor networks (BSN) are types of wireless sensor networks (WSN) composed of sensors attached to the human body. The primary purpose of BSN is to measure the physiological signals and to provide information about human behavior. Therefore, the number, the type, and the characteristics of the sensors mainly depend on the application and system infrastructure [19]. Two types of sensors could be applied: one capable of collecting continuous time-varying signals such as accelerometers, pedometers, gyroscopes, electroencephalograph (EEG) sensors, electromyography (EMG) sensors, visual sensors, auditory sensors and others to collect discrete time-varying signals such as glucose sensors, temperature sensors, humidity sensors, blood pressure sensors. State-of-the-art sensors nowadays have high compact factor and are thus easily wearable with high biocompatibility. Wireless communication technologies such as Bluetooth or Zigbee, radio frequency identification devices (RFID), and Ultra-Wideband (UWB) could be employed to transmit the collected data.

The environmental sensors are reading the values of the user's environmental parameters. Moreover, the sensor technology can be applied to collect environmental information regarding the location of people and objects, information about their interaction, etc. Additionally, by applying data fusion techniques on the data gathered from both BSN and environment sensors, reliable assessments of a person's behavior, and the activities performed could be conducted. From the sensor technologies perspective, AAL applications are facing various challenges, among which, one of the most important ones is the quality of the collected data which is the basis for further behavioral analysis [20].

IV. Data processing in AAL systems

The data preprocessing phase includes checking whether the received data is from the right sensor of a WSN network. The results of this phase are still considered raw sensor data, and the data is sent to the next stages. The next step is data filtering, including noise reduction out of the received signals. Removing the noise present in the signals requires different techniques, depending on their nature. Since there is a possibility of noise, within the proposed system model, caused by the movement of the user, one way to eliminate this type of noise is the use of an adaptive filter. Another approach for

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such systems that have a fusion of different sensor data is to use methods and algorithms, including Kalman filter, Bayesian networks, and Dempster-Shafer [21].

The next phase is data verification, including generalization and additional data calculations. This phase of the data processing workflow aims to formalize and give an overview of the real situation of the user. In the case where the results are critical, a message is sent to the responsible medical staff and the user.

Essential aspects in this kind of systems are the timely transmission of data and the type of data that should be transferred, which has a significant role in determining the strategy to be used in case of delay. Based on the nature of the signals, whether it is a continuous transmission or not, they can be divided into:

- Wavy-dependent data requires no continuous data transfer. As a result, the transmission of data can commence only when data is requested from the system or periodic monitoring is scheduled.
- Wavy- independent data requires the continuous transmission of data for long periods, especially in critical and emergencies [22].

The increasing diffusion of home area networks, intended for the delivery of multimedia contents as well as home automation data, is a new challenge for networking, in general, and also for data delivery in AAL systems. Possibly time-critical data transmissions (such as those related to dangerous events or alarms) have to coexist with delay-tolerant ones. However, at present, most of the available domestic and building automation solutions provide ad hoc answers to the market requirements, and their heterogeneousness makes it very hard to organize an integration process, due to the lack of an interoperability-oriented design. Since the convergence of many traditional services over IP-based infrastructures drastically increases the amount of IP data traffic to be delivered to the users, questions about the Quality of Service management arise and must be taken into account.

There are some prominent causes of energy wastage in wireless networks: retransmission of lost packets, reload (overhearing), idle listening and re-broadcast (over emitting). In medical applications, however, recovery of lost packets through retransmission is not necessary, because health data must be in real-time. Any packet loss must be replaced with the latest update on the situation. Retransmission of packets also requires more memory to store nodes, which is usually limited in size.

Data received from the sensors may have been damaged, so the following approaches can be executed: (1) to accept the data, (2) remove and wait for the next load, (3) seek to reload. The selection of the proper strategy depends on the type of the loaded data. If the data is irrelevant or it is a type of data that loads often, then the second option is acceptable. If measurements are for more sensitive data, the third option should be applied.

Energy consumption also needs to be carefully analyzed to make an informed decision. One approach to save energy is the application of an efficient compression scheme. This method achieves a reduction in the amount of information that will be transmitted [23]. The following algorithms can be used in WSN: Lempel-Ziv 77 (LZ77) and Lempel-Ziv-Welch (LZW) (based on the methods for prediction by partial matching based on statistical methods), while Burrows-Wheeler Transform (BWT) reduces the amount of information and optimizes data compression. Benchmark tests done on these algorithms show that the algorithm LZ77 has maximum speed and minimum memory used [24].

Generally, body sensor networks are reading the value of the user's health parameters. The environmental sensors are reading the value of the user's environmental parameters. Additionally, the user can use applications that can measure (follow) the user's physical activities. All data is gathered by the user's personal or mobile device, for instance, a PC, laptop, tablet, smartphone or smart TV, and along with data from clinical centers, medical databases, and social networks are sent for further processing by assisted healthcare algorithms. The processed data (by assisted healthcare algorithms) are sent back to the end-users in order to provide the wanted services. The logical architecture of a System for Assisted Living is shown in Figure 1.

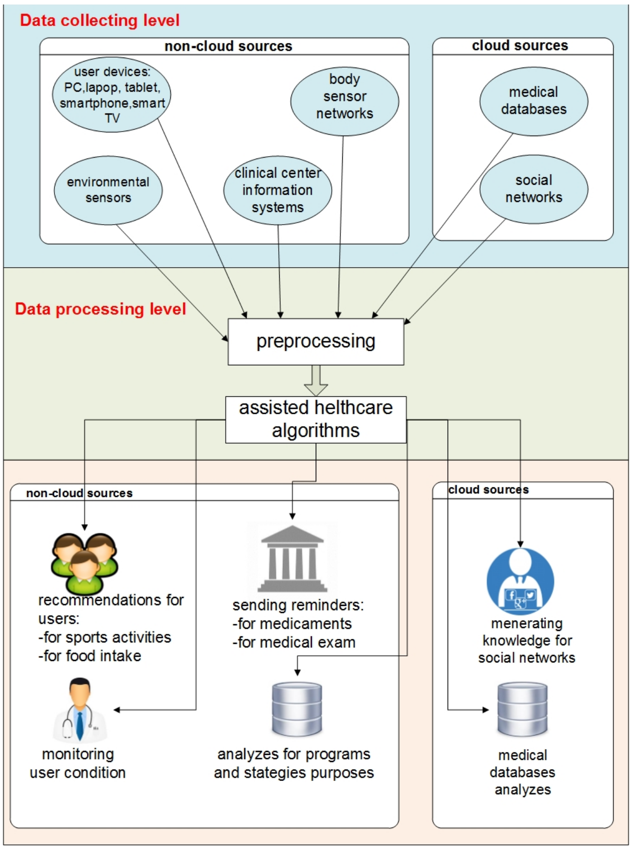

Figure 1. The logical architecture of the System for Assisted Living

A. Security issues

The fundamental goals of secure healthcare systems are safely exchanging the users' information and preventing improper use of illegal devices, such as intercepting transferred data, eavesdropping communications, using out-of-date information, or revealing the users' medical conditions or other private data. Specific security requirements will have a significant influence on the performance of the system:

Local database in users' devices stores data received by sensors for a limited time. When there are problems in sending the data to a clinical center or social networks, some of the data is not going to be sent. These systems clearly demand high reliability, guaranteed bandwidth, and short delays.

Most patients do not want anyone to know their medical information, except their family doctor or medical specialist. The solutions are to use a cryptographic algorithm to encrypt medical information and protect the necessary data.Only an authenticated entity can access the corresponding data that are available for that entity; unauthenticated entities are denied access when they demand information that they do not have the rights to obtain. For example, asymmetric cryptography (i.e., PKI) is often used, because these private keys are credentials shared only by the communicating parties.

Every user can choose what information can be private or public. User can choose his records to be public: (a) for medical purposes, (b) to all visitors of the social network, (c) to users in his category, (d) to none. In order to have medical support, the user has to agree to share personal information with clinical centers and medical databases, whose data are also protected.

B. Validity of information

One of the most critical issues in the system is information validity and confirmation. We could divide the system's information validity into three categories.

Most reliable information (valid information) is information that originates from the clinical centers, medical databases, and sensors.

The second category (reliable information) is information generated from social networks. This information can be confirmed (transferred in the first category) if confirmed by the medical records from clinical centers. This confirmation is then applied to data generated by corresponding algorithms implemented in the social networks.

Information from personal profiles (age, weight, height, diagnose entered by end-user) are third category information (unreliable information). Increase of validation of this information can be done by comparing them with average results using social network data or by confirming them with the medical records coming from healthcare institutions.

V. CONCLUSIONS

This paper describes how, by combining the processing power, low price, scalability, and reliability of the cloud platforms along with the evermore capable sensor available in smartphones and home environments is a combination we expect to bring forward assisted and enhanced living environments. Transferring the burdening processing of raw sensor data to the cloud and fog enables advanced algorithms to be used while saving battery power in the sensors and demanding insignificant processing capabilities in client devices. All these advantages are expected to promote this architecture and similar ones into the forefront of ambient assisted living systems.

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