General Assisted Living System Architecture Model

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Abstract. Novel information and communication technologies create possibilities to change the future of health care and support. Ambient Assisted Living (AAL) is seen as a promising alternative to the current care models so a number of researchers have developed AAL systems with promising results. The main goal of AAL solutions is to apply ambient intelligence technologies to enable people with specific needs to continue to live in their preferred environments. In this paper, we are presenting a general architecture of system for assisted living that supports most of the use cases for such system.

Keywords: Assisted living · Wearable sensors · Environmental sensors · Social networks

1 Introduction

Advances in communication and computer technologies have revolutionized the way health information is gathered, disseminated, and used by healthcare providers, patients, citizens, and mass media. This led to the emergence of a new field and new language captured in the term "e-health".

The importance of healthcare to individuals and governments and its growing economy costs have contributed its emergence as an important area of research for scholars in business and other disciplines. The recent trend in healthcare support systems is the development of patient-centric pervasive environments in addition to the hospital-centric ones. Such systems enable healthcare personnel to be able to timely access, review, and update and send patient information from wherever they are, whenever they want. In that way, pervasive health care takes steps to design, develop, and evaluate computer technologies that help citizens participate more closely in their

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own healthcare, on one hand, and on the other to provide flexibility in the life of patient who lead an active everyday life with work, family and friends.

There are technical requirements (instrument usability, power supply, reliable wireless communications and secure transfer of information) for the healthcare systems based on wearable and ambient sensors [1]. However, there are also concerns about the technology acceptance in the healthcare. Many authors have considered this issue. For example, Cocosila and Archer [2] are investigating the factors favoring or disfavoring the adoption of mobile ICT for health promotion interventions.

Ambient Assisted Living (AAL) has the ambitious goal of improving the quality of life and maintaining independence especially of elderly and people with disabilities using technology [3]. AAL can improve the quality of life by reducing the need of 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) [4, 5].

Most efforts towards building Ambient Assisted Living Systems are based on developing pervasive devices and use Ambient Intelligence to integrate these devices together to construct a safety environment [6]. But, technology limitation is that it cannot fully express the power of human being and the importance of social connections. In this concept, the usage of advanced information and communication technology (social networks) could be helpful in connecting people together and organizing community activities.

It is important for AAL systems to ensure high-quality-of-service. Essential requirements of AAL systems are usability, reliability, data accuracy, cost, security, and privacy. According to [7] to achieve this requirements it is important to involve citizens, caregivers, healthcare IT industry, researchers, and governmental organizations in the development cycle of AAL systems, so that end-users can benefit more from the collaborative efforts.

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

AAL systems are based on interoperability and integration of various medical devices. Nevertheless, the lack of standards and specification is one of the biggest obstacles for their commercial penetration on the market. In this context, AAL systems and platforms rely on different standards and specifications by various initiatives and groups, such as: Health Level 7 (HL7) [11] - supporting clinical practice and the management, delivery, and evaluation of health services; Continua Health Alliance

[12] which produces industry standards and security for connected health technologies such as smart phones, gateways and remote monitoring devices; ETSI [13] which provides harmonized standards for radio & telecommunications terminal equipment; AAL Europe [14] which is funding projects that involves small and medium enterprises (SME), research bodies and user's organizations (representing the older adults).

One major issue concerning AAL systems is the ethical problem due to the multitude and heterogeneous personal information continuously collected by AAL systems [15]. There is concern about possible negative consequences [16] such as:

- loneliness or isolation, resulting from the use of certain devices that replace human caretakers, which may be the user's only regular social contact;
- privacy issues - surrounding biometrics and "smart home" systems collect personal information;
- discrimination - wearable biometric monitors or mobility devices are highly visible and can make a person's disability very obvious.

These are the reasons why AAL systems need to be seen as tool for help and assistance rather than controlling device for what are people doing.

AAL is seen as a promising alternative to the current care models and consequently has attracted lots of attention. Although according to [17] there are three categories of Ambient Assisted Living interoperability services: (1) notification and alarming services, (2) health services, and (3) voice and video communication services, we found that systems for assisted living need to be more general and to support more services in order to be helpful not only for elderly and people with disabilities, but for all people who want to live healthy life in accordance with their everyday obligations.

The System for Assisted Living we present in this paper uses mobile, web and broadband technologies. Broadband mobile technology provides movements of electronic care environment easily between locations and internet-based storage of data allowing moving location of support. The most important benefits of our proposed system model are increased medical prevention, more immediate time response at emergency calls for doctors, 24 h monitoring of the patients' condition, possibility for patient notification in different scenarios, transmissions of the collected biosignals (blood pressure, heart rate) automatically to medical personnel, increased flexibility in collecting medical data. The proposed system model creates an opportunity for increasing patient health care within their homes by 24 h monitoring on the one hand, and increasing medical capacity of health care institutions on the other hand. This results in reducing the overall costs for patients and hospitals and improves the patient's quality of life.

2 Related Work

In the last several years Ambient Assisted Living is one of the most popular research areas among scientists. Thus, many sensors, technologies and systems are developed.

Ruiz-Zafra et al. [18] are presenting the m-health cloud-transparent platform called Zappa. Zappa is extensible, scalable and customizable cloud platform for the development of eHealth/mHealth systems. Its main advantage is the ability to operate in the cloud.

By using cloud computing, open technologies (open-source software, open hardware, etc.) and additional techniques the platform provides uninterrupted monitoring with the goal of obtaining some information that can be subsequently analyzed by physicians for diagnosing. In order to show the applicability of the platform the authors are introducing two m-health systems, Zappa App and Cloud Rehab, based on the Zappa platform.

In [4], Takacs et al. present a complex wireless and personalized AAL solution that includes telemonitoring, health management, mental monitoring, mood assessment as well as physical and relaxation exercises. Their approach is based on a novel computational and communication platform called Virtual Human Interface (VHI), specifically designed to bridge the gap between people and computers by using virtual reality and animation technologies. The main goal of the research is to create an open-architecture and reconfigurable system which is as independent as possible from individual manufacturers and wireless standards.

AlarmNet [19] is an assisted living and residential monitoring network for pervasive adaptive healthcare in assisted living communities with residents or patients with diverse needs. According to the authors (Wood et al.) the primary reason for developing AlarmNet was to use environmental, physiological and activity data of assisted living residents in order to improve their health outcomes. AlarmNet unifies and accommodates heterogeneous devices in a common architecture that spans wearable body networks, emplaced wireless sensors, user interfaces and back-end processing elements. Contributions and novelties of this work include extensible heterogeneous network, novel context-aware protocols and a query protocol for online streaming-SenQ.

Kleinberger et al. [5] are presenting an approach and several evaluations for emergency monitoring applications (research projects: EMERGE and BelAmI). The main goal of EMERGE is to support elderly people with emergency monitoring and prevention by using ambient, unobtrusive sensors and reasoning about arising emergency situations. Experiments were performed in laboratory settings in order to evaluate the accuracy of recognizing Activities of Daily Living (ADL). The interpretation of the evaluation results have proved that it is possible to measure ADLs accurately enough for detecting behavior deviations. But, according to the Kleinberger et al., to reach this objective it is very useful to include all stakeholders very early in the requirements analysis and development process for the prototypes and especially in the setup of the experiments.

Lopez de Ipina et al. in [20] present the CareTwitter AAL platform. They propose the adoption of passive RFID tags as tiny databases where a log of a person can be stored, so that other users with their NFC devices can access and manipulate the data in them. The data is encoded in the resident's RFID tags, and such care logs are then transferred into a public micro-blogging service Twitter. The CareTwitter platform stores a log for every new care procedure applied on a resident's RFID wristband, following a data-on-tag approach. CareTwitter makes data stay at any time with the resident and be available in real-time and without relying on wireless links. The experiments provided in the paper [20] have proven that the storage capacity of either a 1 K (wristband) or a 4 K (watch) Mifare RFID tag is sufficient for storing the care logs of a whole day. The integration of CareTwitter with Twitter proves the high potential of using interactions with everyday objects or people to automatically publish data into Internet, in this case, the log of residents in a care center, so that their relatives and friends can be kept up-to-date about them. The tweets published by CareTwitter are never made publicly available. Only users authorized by the residents or their family can follow them.

In [21] an Internet of things-based AAL architecture to support blood glucose management and insulin therapy is presented. This architecture offers a set of services for monitoring, interconnecting with the Diabetes Information System (glycemic index database), and ubiquitous access to the information based on the developed personal device (Movital), AAL environment gateway (Monere), web portal, and the management desktop application. The important aspect of presented solution is that most of the measurements and interactions with the patient are done at home. This enhances the self-monitoring blood glucose solutions and allows the interaction with the nurses and physicians through new technologies such as personal health card based on RFID and the Web diabetes management portal. According to the authors (Jara et al.), Internet of things allows the defining of solutions closer to the patient, physician and nurses, which allows an easier integration and acceptance of them. The evaluation of the proposed architecture has presented that nurses and physicians are very interested and open to these kinds of solutions, considering it very useful and suitable to be included in hospitals.

Mileo et al. [22] present a monitoring system, called SINDI, equipped with a pervasive sensor network and a non-monotonic reasoning engine. Proposed system, gathers data about the user and his/her environment, through a wireless sensor network. Combining different data sources, the system interprets the evolution of the patient's health state and predicts changes into risky states according to a graph-based computational model of medical knowledge and the clinical profile of the monitored patient. In this system, the results of context-aware interpretation of gathered data are used to predict and explain possible evolutions of the patient's health state in terms of functional disabilities, dependency in performing daily activities and risk assessment, as well as to identify correct interaction patterns. The advantage of the system is in providing various: suggestions (according to the medical practice and the results of the prediction reasoning task), alerts (when the system identifies behaviors or situations that are potentially dangerous for patient), alarms (when specific environmental or clinical conditions are detected), notifications (when the system receives new input or terminates the inference process) and reminders (according to an agenda).

We should also mention some of the recent developed assisted living technologies for commercial use.

BeClose [23] is an affordable, easy-to-use home monitoring and care giving technology for the elderly. This system indicates that everything is okay and provides independence and peace of mind for the user. The BeClose system consists of a base station and a variety of small sensors throughout users home. These electronic devices are designed to work together to make sure the user is up and about each day. If something is out of the ordinary, the system will alert users' family members and caregivers.

Basis has introduced Body IQ [24] in fall 2013. It is a proprietary technology that recognizes and displays users' activities automatically, like walking, running and biking, as well as sleeping. Body IQ ensures users to get credits for their efforts in real-time, including caloric burn, with no need to push buttons, switch modes or tag activities. It also automatically determines when users fall asleep and when they wake up.

Apple is said to be working on a wrist-worn device that would go far beyond telling time, allowing users to measure and track health and fitness data with a new wearable device – “iWatch”. Apple’s iWatch [25] is expected be able to operate independently of an iPhone or iPad. Reports have suggested that iWatch should debut in fall 2014.

According to previous brief review of literature and other works, not mentioned in this paper, there is need for general architecture of the system for assisted living to be proposed. The system for assisted living should be of help not only for elderly and people with disabilities, but for all people who want to lead healthy life.

3 General Architecture of the System for Assisted Living

The body sensor networks (BSN) are type of a wireless sensor networks (WSN) composed of sensors usually attached on human body or in some cases implanted inside the human body. The main 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 may vary and they mainly depend on the application and system infrastructure [26]. Two types of sensors could be applied: one capable to collect continuous time-varying signals such as accelerometers, pedometers, gyroscopes, electro-encephalograph (EEG) sensors, electromyography (EMG) sensors, visual sensors, and auditory sensors and the other 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 thus high wearability and 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 value of users’ 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 both from BSN and environment sensors, reliable assessments of persons’ behavior and the activities performed could be conducted. From sensor technologies perspectives, AAL applications are facing various challenges, among which, one of the most important ones is regarding the quality of collected data, which is the basis for further behavioral analysis [27].

3.1 Logical Architecture of the System for Assisted Living

In the System for Assisted Living that we are proposing in this paper, the body sensor networks are reading the value of users’ health parameters. The environmental sensors are reading the value of users’ environmental parameters. Additionally user can use applications that can measure (follow) users’ physical activities. All the data is gathered by users’ personal or mobile device, like 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 allow wanted services. The logical architecture of System for Assisted Living is shown on Fig. 1.

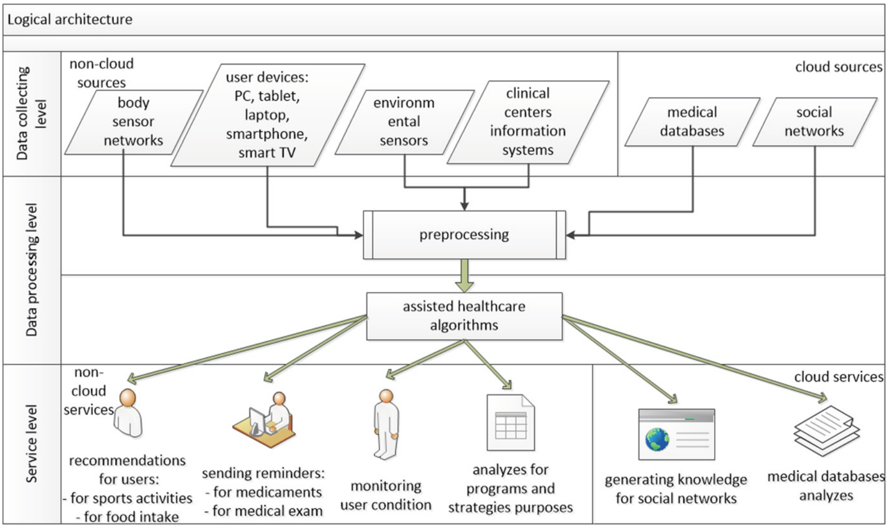

Fig. 1. Logical architecture of the System for Assisted Living

In the service layer different processes of different users can be integrated. This allows non-medical processes, medical processes, care processes and communications within social networks to be incorporated in the architecture of System for Assisted Living.

The whole interaction in the proposed system is request/reply based. If there is need for additional information then new request is raised. We should emphasize that the information generated from the social networks are reliable information and the information from personal profiles (age, weight, height, diagnose entered by end user) are unreliable information. This information should be confirmed by the medical records from clinical centers and then deployed on data generated by corresponding algorithms implemented in the social networks. In this way the tips (recommendations) generated from social networks are reliable or valid.

3.2 Physical Architecture of the System for Assisted Living

On Fig. 2 the physical architecture of System for Assisted Living is shown.

The System for Assisted Living deals with data relevant to following institutions:

– Clinical centers - monitor the health status and physical condition of users and provide recommendations and suggestions about the therapies and medicaments that users should take in order to improve their health.

– Medical databases - collect data from clinical centers and different databases, perform tests and experiments. They process and analyze collected data and based on their research draw conclusions, recommendations and suggestions for diagnosis, therapy and activities.
– Government organizations - make specific analysis of system data information and give recommendations for national actions, programs and strategies.
– Policy makers - can get filtered system data information, make specific analysis of it and give recommendations for non-government organizations, including programs and strategies.
– Social networks - allow direct communication between users, sharing their results and exchange of their experience. Social networks can send to the user tips based on the users' health condition, prior knowledge derived from users' health history and physical activities, and the knowledge derived from the medical histories and physical activities of users with similar characteristics.
– Services for environmental data - supply data for weather condition (weather temperature, atmospheric pressure, air humidity, wind speed) in users' environment.

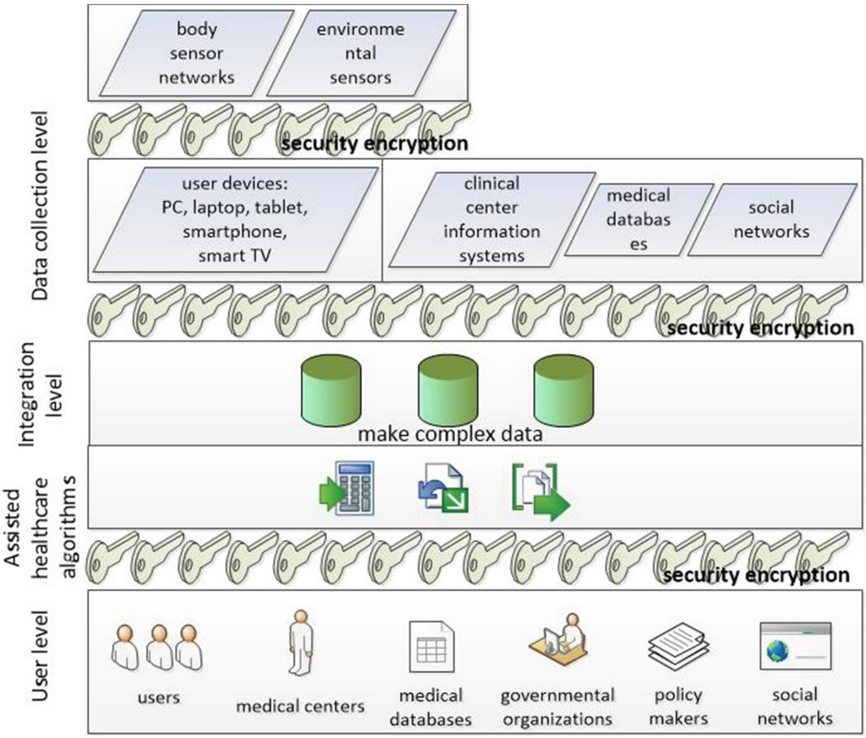

Fig. 2. Physical architecture of the System for Assisted Living

Data is collected from body sensor networks; users' PC, laptop, tablet, smartphone or smart TV; environmental sensors; clinical centers; medical databases; social networks.

In the integration level, collected data from different sources is being adjusted according to the standards and formats of the inputs of the assisted healthcare algorithms.

Collected data is processed according to the need or demand:

- for generating recommendation for users;
- for clinical centers - for monitoring the user condition or clinical purposes;
- for medical databases analyzes;
- for purposes of governmental organizations and policy makers;
- for generating knowledge for social networks.

Processed information is sent to: users (on their PC, laptop, tablet, smartphone or smart TV), clinical centers, medical databases, governmental organizations, policy makers or social networks.

The medical personnel can remotely monitor the users' medical condition, reviewing the data arriving from the users' personal or mobile device. In this way, medical personnel can quickly respond to the user by suggesting most suitable therapy as well as when to receive it, focusing on activities that are necessary for his rehabilitation and maintenance of his health, sending him/her (on his/her personal or mobile device) various tips and suggestions for improving his/her health.

The conclusions drawn from research data, while exploring medical databases, can be routed back to the clinical centers. These data can be used as additional knowledge for the individual analyzes of the users' condition. Clinical centers can exchange data and information with the social networks and thus have access to a larger group of users that can share research, recommendation and suggestion of the medical personnel.

Social networks allow direct communication between users and sharing their data. At the same time, the users' individual data can be compared with average data obtained using different collaborative filtering techniques. The social networks can learn from recommendation made by medical personnel and generate notifications and recommendation based on the most successful scenarios. These portals also can provide an interface and use data from a variety of medical databases and environmental databases (temperature, wind speed, humidity).

The complex structure of data from the social networks along with the data arriving from different clinical centers can be used by different medical databases for further analysis and research.

Governmental organizations and policy makers can get the data from social networks, clinical centers and medical databases, make specific analysis on it and give recommendations for national action by governments and non-government organizations, including programs and strategies.

The key stakeholders of the proposed System for Assisted Living are elderly and people with disabilities who needs monitoring of health condition, reminders for everyday obligations, and assistance in everyday routine and social inclusion. Family of the elderly and people with disabilities who need professionals to take care of their family members and want to remotely monitor health status can also use the system. People who want to lead healthy life can use system. By using the system they can monitor their own health condition and physical activities. In addition, Clinical centers can remotely monitor their patients and gather all kind of health data from different patients for further analyzes. Governmental, non-governmental organizations and Policy makers can get summarized health information from the proposed system that can help in generating health programs, strategies and policies. Industry, especially medical and pharmaceutical industries, can benefit from the proposed system by getting the health information that can help them in developing new devices, applications and therapies that are needed.

3.3 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 communicating data, replaying out-of-date information, or revealing the users' medical conditions. Specific security requirements will have a significant influence on the performance of the system:

– Data Storage and transmission: Local database (in users' devices) stores data received by sensors, in case there is always back up of data (they will be saved only some period). When there are problems in sending data to clinical center or social network some of data is not going to be send, so all transaction will be rolled back. When service is available the data will be sent. By this, the quality of service (QoS) facilities (demand for high reliability, guaranteed bandwidth and short delays) are provided [28].
– Data Confidentiality: 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.
– Authentication: Only an authenticated entity can access the corresponding data that are available for that entity; unauthenticated entities are denied when they try to visit data 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.
– Access Control: In traditional network security models, access control determines whether a subject can access an object based on an access control list (ACL).
– Privacy Concerns: 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.

System for Assisted Living has own security and privacy statements that explains how system protects users privacy and confidentiality and how will be treated users personal information.

3.4 Validity of Information

One of the most important issues in the system is information validity and confirmation. We divide system information validity in three categories.

Most reliable information (valid information) is information in the first category. This information originates from the clinical centers, medical databases, and sensors.

The second category (reliable information) is information generated from the 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 deployed on 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 or by confirming them with the medical records coming from healthcare institutions.

4 Use Case Scenarios

The general use case scenarios for System for Assisted Living are shown in Fig. 3.

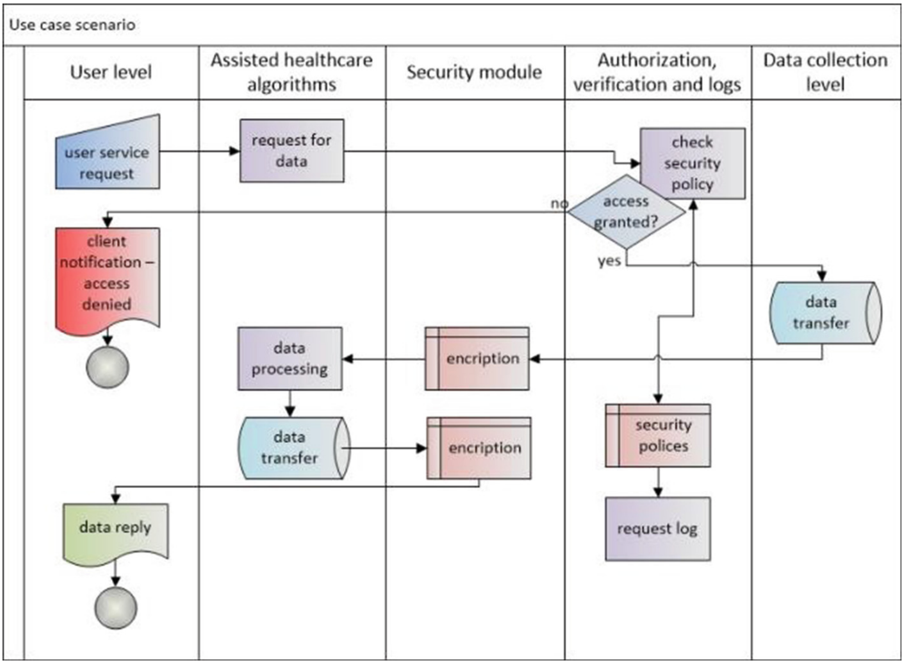

Fig. 3. General use case scenario

Scenario A:

The user switches on the application on his phone and starts his physical activities. Application reads the data (blood pressure, pulse, sugar level and type of activity, length of path, time interval). If irregularity occurs while reading the data, such as patient's blood pressure is quite higher than normal to perform the operation, the application sends signal and message with those data to the medical center. The application signals to user that there is some irregularity. Medical personnel review the submitted data and previous medical records of the patient. Based on the patient's diagnosis, treatment received and his activity currently carried out, along with the medical data received from the application, a recommendation is issued back to the application of the patient, to temporarily stop his activities and receive appropriate medicine (if by that moment it's not already received) or to reduce the pace of the activity itself. The application signals to the user that a message from the medical center has arrived. The user applies the recommendation from the medical center.

Scenario B:

Medical personnel review the patient's data (diagnosis, therapy received, activities done) and conclude that the patient did not receive his regular therapy and does not perform the recommended actions or has excessive over-activity. The medical center sends an urgent message to the patient to do an emergency medical examination.

Scenario C:

The user switches on the application on his phone and connects to the social network. He enters his personal data and therapy that has received and updates his Personal Health Record. User can share his PHR with other users of the network. Additionally, if the user assumes to have certain heart disease diagnosis he can enters that he has heart troubles. On the base on his PHR and results of performed physical activities (compared to the average results of the other users with the similar problem) social network give him a proposition if he has or not such diagnosis and advice him to talk to his physician.

Scenario D:

Medical database sends a request to the clinical centers to send data from a period for its users. Clinical Centers sends its data. Medical database sends a request to the social networks to send data from a period of time for their users. Social networks send its data. Medical database analyzes compares and investigates the collected data and its own available data. Medical database draws conclusions, recommendations and suggestions from the analyzed data. Medical database sends data (latest information) to the Clinical centers, about diagnostics, recommended therapies and activities for patients with certain diagnosis as well as suggestions for patients appropriately diagnosed.

Scenario E:

Policy maker sends a request to the social networks to send data from a period of time for its users that have heart disease diagnose. Social networks use collaborative filter to extract those data. Social networks send its data. Policy maker analyze data and give recommendation, make program and strategy for prevention of heart disease.

5 Conclusions

This paper presents a general model of assisted living system architecture. Generally, the main objectives of the proposed System for Assisted Living are:

(1) Help its users to actively participate in their health care and prevention, thereby providing: monitoring of users' health parameters and their physical activities (condition); 24-h medical monitoring; recommendation with tips on how to improve their health; opportunity for health care within users' homes; increased capacity of health institutions, resulting with reduction of overall costs for consumers and healthcare institutions.
(2) Alignment of the solution to the current state of technology.
(3) Collecting different types of data and combining them into complex structures of health data. The survey, analysis and research of such structures allows to understand the impact and the influence of applied therapy, physical activity, time parameters and other factors on the development of the health condition of the user. Such analysis can be further used by all stakeholders for diagnosis, treatment, therapy and prevention.

The presented architecture gathers all common features of assisted living system features and determines possibilities for various assisted living system deployments by presenting use cases scenarios derived from proposed architecture.

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