

# Multiagent Approach in Home Care Based on Open Architecture

Ondrej Biroš\*, Ján Karchňák, Dušan Šimšík

Department of Automation, Control and Human-Machine Interactions, Faculty of Mechanical Engineering, Technical University of Košice, Košice, Slovakia

\*Corresponding author: [ondrej.biros@tuke.sk](mailto:ondrej.biros@tuke.sk)

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**Abstract** The proposed paper presents multiagent-based architecture for home care system. In the first section, our motivation is described. The next section deals with basic hardware components and communication requirements. Third is brief introduction to multiagent systems followed by fourth section describes architecture for basic function of home care system. The fifth section deals with usability of wearable sensors to create synergic effect with home care system. The last section presents trials of wearable sensor's implementation.

**Keywords:** multiagent system, home care, wearable sensors, elderly

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## 1. Introduction

Most developed countries in the world, especially western countries, are facing important changes due to problems with aging population and increased costs of medical care. Because of increasing number of patients (due to age), health care is decentralised to more advanced home care systems [1]. Definition of home care according to The World Health Organization [2] states: Home care can be defined as an array of health and social support services provided to clients in their own residence. With low cost of hardware and modern technique of control such environment can be developed with reasonable price and effectiveness. European Union predicts that in year 2015 will be mortality rate higher than birth rate and this course will proceed in the future while the population ageing and rise of elderly in it will appear [3]. Similar situation is projected for USA as well [4]. According to current possibilities of ICT and various types of sensors and, of course, according to the expected demographical development, many research tasks are focusing on development of intelligent household environments [5,6,7,8,9] intended for vulnerable groups of population (e.g. seniors or disabled) for which is necessary to monitor distinct parameters (e.g. blood pressure, blood sugar). Such monitoring should be performed with intention to improve healthcare. It is suggested that observing should be executed remotely and without decreasing the comfort of the user. For this reasons, our department started developing service based on multiagent systems – MasCare.

## 2. Hardware Components

For hardware components, especially for developing and prototyping, Arduino platform had been chosen. Arduino is open-source, relatively cheap hardware platform and can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators [10]. Every Arduino board has a micro controller which uses special Arduino programming language. This language also offers Arduino development environment (IDE is implemented on several desktop operating systems).

### 2.1. Communication Protocols

For communication different types of protocols had been considered. Communication protocols can be generally divided into two groups – wired and wireless. We decided to use wireless protocol because of easy installation and reasonable price also modern wireless protocols can ensure high reliability of communication and co-existence with other wireless protocols. There are many wireless solutions available on the market such as ZigBee, Z-Wave, Bluetooth, Wi-fi and there are also many closed commercial solution. Z-Wave standard is partially open commercial communication protocol originally developed by company Zensys. Z-Wave is now maintained and developed by alliance consisting of manufacturer like D-Link, Verizon, NEC, Motorola and many others. Z-Wave contains only bare minimum which is needed for communication in smart homes, buildings and home care systems. Frequency band is 908 MHz in USA and 860 MHz in Europe. Protocol uses collision method CSMA/CA, frequency modulation. In the first version speed was 9,6Kb/s, in second 40 Kb/s with backward compatibility [11]. Disadvantage of Z-wave protocol is that parts of protocol are closed - this is why

number of devices is limited by manufacturer who belongs to Z-wave alliance.

IEEE 802.15.4 standard belongs to low rate wireless personal (LR-WPAN) area family. Standard is intended to transfer data on short distances. Unlike “big” wireless standards (e.g. wifi), IEEE 802.15.4 does not need any infrastructure, therefore they are used in small, cheap network in home and building automation or industry. From OSI model IEEE 802.15.4 describes two layers – physical and link layer. Protocol operates in unlicensed ISM bandwidth 868 MHz in Europe and Japan, 915 MHz in USA and 2.4 GHz worldwide and offers 27 canals. Communication based on this standard implements two types of devices: FFD – full functional device and RFD – reduced functional device. FFD supports full protocol and is capable communicate as PAN (personal area network) coordinator which is main (central) node in network. RFD is end device which can communicate only with one FFD above him in hierarchy of network. RFDs sends only small amount of data because of requirement of low power consumption. IEEE 802.15.4 focuses on low power consumption and can operate on battery for long time. Interfaces between layers are created through service access point (SAP) [12].

ZigBee standard is based on IEEE 802.15.4 protocol and extends it for more complex sensor networks and actuators and for bigger projects. ZigBee standards itself contains two more layers in OSI model – network and application and is developed by ZigBee alliance. Alliance consists of important hardware manufacturers like Schneider Electric, Philips, AT&T, Cisco, Honeywell (all manufacturers in [1]). ZigBee offers three types of topology: star, tree and mesh. In star topology is one central node called ZigBee coordinator which handle the network and create startup settings of network. All other devices are end devices. In tree and mesh topology ZigBee coordinator initialise network and handle setting such as encryption keys and startup parameters for other device. ZigBee also supports routers for extending network range. Advantage in ZigBee protocol is application profile in application layer. Profile defines type and purpose of the communication. Example of profile is home automation, which allows functions trimmer, light connect with movement sensor or with light sensor. Each profile has 16 bits identifier. Profiles are divided into two groups – public and private. Public profiles are defined by ZigBee alliance and private (proprietary) profiles are defined by commercial manufacturers. All private profiles have to be approved by ZigBee alliance to ensure interoperability. Security is based on symmetric encryption algorithm. The biggest issue is to ensure not to send private key through open channel [13]. For our goals we have chosen ZigBee protocol (Xbee ZB chips from DiGi international).

### 3. Multiagent Systems

There are many definitions of multiagent systems which can be found in literature. For example [14] or [15] defines agent as entity created to autonomously fulfil the tasks in real environment based on sensing and controlling actuators. The most common definition [16] divides agent to strong and weak. Weak agent has 4 basic characteristics:

- autonomy – agent can operate in environment by itself
- social interactions – agent communicates with other agent or human with special formal language
- reactivity – agents react on environment in real time
- proactivity – agent act initiative according to environment

Strong agent has all characteristics of weak agent plus mental capabilities (for example neural networks) or emotions. In general we can also define 3 types of agents [14]:

- reactive – acts with changes in environment,
- deliberative – act proactively, thinks and can have emotion,
- hybrid – combines reactive and deliberative agent.

Reactive agent and subsumption architecture were defined by Brooks in 1991 [17] as a criticism to system based on symbolic representation of environment. Reactive agents don't have symbolic representation of environment in which they are situated. They work on a simple algorithm: sense (sensing through sensor) – select (select appropriate action) – act (impact on environment with actuators). System based only on reactive agent looks intelligent from perspective of external observer.

### 4. Multiagent Architecture – MasCare

In our case home care system, we need to build system which in can be easily implemented different kinds of services for people with special needs. For example, elderly with Alzheimer disease have different needs than elderly with physical disability. Our architecture is software layer which can be implemented on different hardware and different communication protocols. The issue is only to write proper driver for communication (in our case, right now driver works only with XBEE networks) and listen on UNIX file socket. Driver sends data to higher level through different UNIX file socket. The control layer in which multiagent system is implemented is written in C++ on Linux platform and is receiving data through file socket.

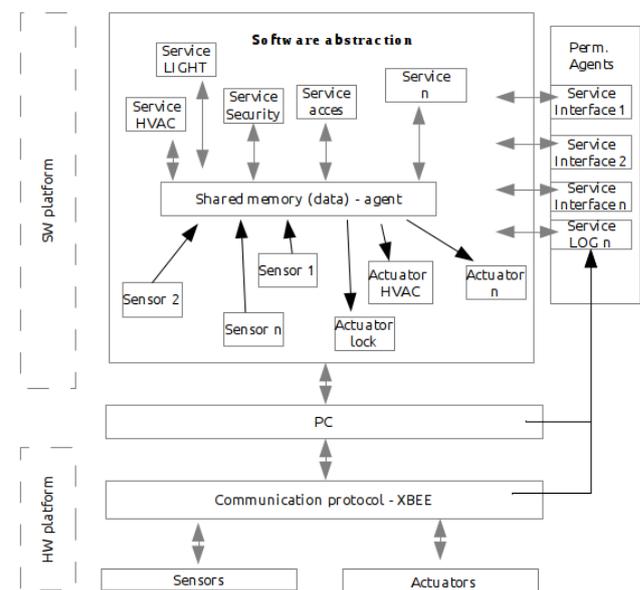


Figure 1. Architecture of MasCare

MasCare describes and implements architecture for basic smart home functions like security, light control, HVAC (heating, ventilation, air-condition) and access control.

In MasCare, there are 3 types of agent defined. Hardware agent is software abstraction of sensor or actuator in network. Second type is service agent and the third type is permanent agent. Permanent agent is in each system and is always on, these agent never sleeps - service interface agent (agent for graphical representation of system, graphical user interface). Bus agent manages access to all current data from sensor and sends data to actuators. Sending data to actuator is going through driver and communication network. Log agent manages databases and logs for whole system. Second function is to monitor long term changes in specific data. For elderly people or people with special needs we need to monitor long term changes, for example in physical activity or bathroom activity. For getting proper results we need to make sensor data fusion or use signal processing techniques to reduce number of false alarms due to data inconsistency. In MasCare we can define and create (C++ programming language) any service in system depend on implemented hardware.

### 5. Wearable Sensors

Wearable sensors are gaining importance in monitoring of user’s physical parameters such as ECG, heart rate, temperature or can be utilized for activity monitoring (walking, lying). There are various definitions of wearable sensors but all of them summarize that wearable sensor or any wearable device should be worn by user without compromising his/her comfort or performing of any of usual daily activity. There are other aspects of wearable sensors that should be considered, such as communication of device or how to asses obtained data. General structure of wearable system for remote monitoring of patient or any user [Figure 2](#) was presented by Patel et al. [4].

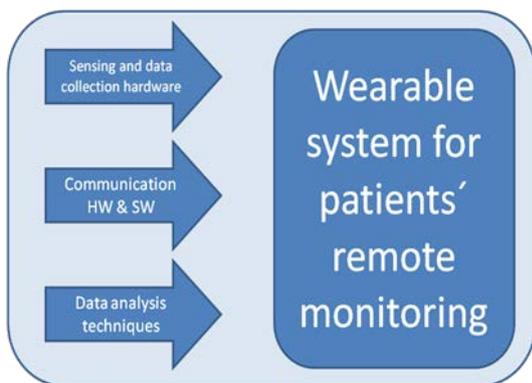


Figure 2. General structure of wearable system

Usually, wearable sensors are implemented in order to increase the user’s safety or to provide feedback information during any sort of training process, e.g. home rehabilitation. The vital condition of such observing is the possibility of remote monitoring, in other words, using wireless communication and very often are created so-called Body Area Networks (BAN). Each of the most used standards, such as Bluetooth or ZigBee has different data rate as well as power needed to transfer information.

Figure 3 shows particular standards with their power consumption and data rate [18]. It should be mentioned that neither of standards compared in Figure 3 are not intended for BAN while on the other hand, Bluetooth Low Energy is.

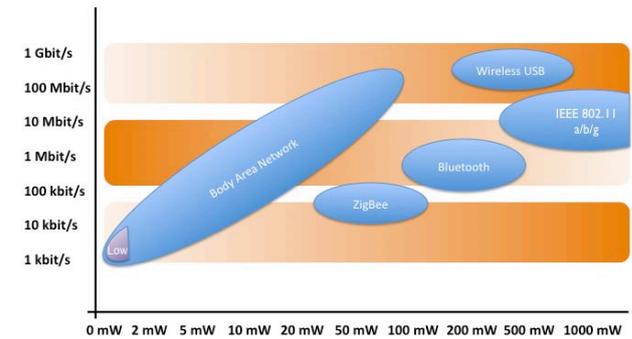


Figure 3. Data rate vs. power consumption

There are many commercial solutions of wearable sensors available. Lots of them are aiming on improvement of training process, daily activity monitoring (counting steps, stairs climbed, movement tracking and many others) or for research purposes. The very special but reasonable application of wearable sensors is in military field, especially in modern armour and equipment.

The main reason of using wearable sensors in telemedicine or smart household applications are the possibility of long-term monitoring, improving of safety and healthcare. In smart household environments for elderly, wearable technologies are utilised along with ambient environment monitoring. This enables creation of complex information concerning user’s activity and behaviour pattern. Ambient sensors are reliable in interior while wearable sensors can be used also in exterior. Obtained information may seem to be redundant but proper processing algorithms or multi-agent systems can gain advantage of that.

### 6. Activity Monitoring

For specific population group such as seniors, detection of fall is important due to its unpleasant consequences, e.g. broken bones or many others or even death. As mentioned above, ambient sensors are very suitable and accurate in terms of interior monitoring. It is possible to utilize non-invasive and non-worn solutions to detect fall, for instance using RSSI in a wireless sensor network [19] or using ultrasound sensor system [20]. However, such solutions are constrained by its intention to be non-intrusive, thus they are part of room’s interior and are not capable of fall detection in the room which is not covered by such system. On the other hand, wearable sensors with suitable algorithms and design can be worn without interrupting daily activities of user for a long time and can be placed in garment or belt. Moreover, wearable device for fall detection can be used out of the area covered by ambient sensors.

Fall is very specific motion event. When fall occurs, the acceleration usually exceeds value of 2,5g. Determining the fall occurrence only by acceleration values is insufficient solution. Threshold of 2,5g can be exceeded easily by jumping, stair climbing, quick sitting down and

many others. This concludes in need of additional information suitable for decision if the fall has occurred, for instance tilt. 3-axial MEMS accelerometer can provide information about acceleration and tilt can be derived (even if no acceleration is applied to the accelerometer, it still measures the Earth's gravitation). Designing of appropriate fall detection algorithm is vital. It must be able to detect fall reliably, with as little false alarms as possible. As wearable sensor for proposed application, we used prototypal board containing 3-axial MEMS accelerometer and gyroscope. Accelerometer provides acceleration data while gyroscope provides angular velocity. Reason for choosing gyroscope to supplement accelerometer data is that gyroscope is suitable for observing very fast changes in angular velocity, in other words, it can detect quick changes in its position. Tilt can be derived as well. This is incremental measurement so proper reference system and methodology is required.

Multiple-threshold approach has been used to detect possible falls. Acceleration is being monitored and compared with suitable threshold and if it exceeds proposed value, other thresholds are compared. In case that all thresholds are exceeded then, the most likely, user fell. Placement of sensor is important due to possible interrupting motion from usual daily activity. For this reason, we decided to place our sensor onto a belt. First trials of our algorithm were conducted in following conditions: sensor worn on belt in hip area, data was sent to PC via USB, experiment performed in laboratory. User was walking in the lab while some disturbance was performed by sliding or pushing of walker or small obstacles were present. Incoming data was real-time processed and when walker fell, alarm turned on. Absolute value of acceleration was the triggering threshold for other comparisons. After triggering, following 30 samples were monitored and compared along with samples from gyroscope. As mentioned above, when all conditions were true, the fall has occurred. Tuning the right values of thresholds followed and experiment was repeated and performed by 3 users with acceptable accuracy.

## 7. Conclusion

Various aspects of assisted living and associated services for elderly require modern technologies to be applied due to need of modularity of different solution's types in home care area. In this paper, we described an original open architecture based on multiagent system for home care. Different types of services for various kinds of diseases, affecting elderly, can be easily implemented into system. There is possibility of using wearable sensors for elderly monitoring, e.g. fall detection. In future work, we would like to implement services for distinct diseases, e.g. Alzheimer or some types of physical disabilities.

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principles, methods and tools in diagnostics and rehabilitation of seniors mobility.

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