End-users' AAL and ELE service scenarios in smart personal environments

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Chapter 5

End-users' AAL and ELE service scenarios in smart personal environments

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Abstract

This chapter presents results from ambient assisted living (AAL) and enhanced living environment (ELE) service identification and testing performed within an AAL lab. Possible end-user testing groups and scenarios of 'AAL as a service' and 'ELE as a service' (ELEaaS) platforms are described and specified. Firstly, protocols and services classifications are presented according to the end-user-specific requirements from communication and information point of view as the chapter aims to show how end-users, caregivers and service providers can be prepared for the challenges of the market.

The aim of the test group is to verify and validate the platforms and services for the ELE created, integrated, described and specified. The testing is based on the platform technology and depends on the user requirements' analysis and ongoing work throughout use-cases. Existing living labs experience has been used and enriched by customized information and communication services known from the information and communication technologies sector. Description of the ELEaaS is done in general terms along with the testing needed to be performed against the general type of provided functionalities. Furthermore, customization of

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the services, applicability to the needs of all stakeholders, flexibility for data exchange, integration and interoperability between different versions and types of platforms need to be also verified.

5.1 Introduction

The need of test groups for service development, verification and validation is an essential part of the service creation process in information and communication technologies (ICT). Technical and contextual testing is one thing. Social perception of the service in the fields like medicine, caregiving for elderly, patients and children is another thing. The resistance from the service has social and psychological roots and there is a need of time to overcome it [1] (see Chapter 3).

The vast enrichment of the services provided to the end-users and high requirements for customization changed the way to perform the business. Telecoms, Internet Service Providers and other utility companies need to respond to the market demands and change the services they provide towards ambient assisted living (AAL) and enhanced living environment (ELE) domains. There is a possibility also to see new utility companies of caregiving services soon that will offer remote and local ICT services related to active ageing and health management [2]. The portfolio of such services and its dynamic and intensive testing is essential for good perception of the market. The lifetime of specific service is becoming shorter than usual and typical phases of requirements, analyses, design, testing and implementation tend to be also shorter than before. The vast number of new devices interconnected and linked to the cloud lead to new solutions that need continuous updates in features and therefore continuous testing [3,4].

This is especially true for the sensitive services for elderly, ill people and children, and medicine-related applications and fitness applications where the importance of the service for personal life or well-being is essential for the end-users and makes the service requirements very high [5,6].

The main difference in ‘ELE’ and ‘AAL’ as terms is that while AAL is more related to the patients and elder’s supportive services, ELE is a broader term. It is enriched by services and applications for good living for everybody. In this sense, the technology is applied to support better family life and better life in the society [7]. The aim is to incorporate the idea of ELE into future smart cities, smart homes and smart businesses and other similar Internet of Things environments [8]. Most of the proposed solutions are virtualized at different levels [9,10]; however, there are still challenges that need to be addressed [11]. There had been many projects funded worldwide [12] on the AAL topic. More or less, they have been related to medical problems, specific product or specific application to be created and tested. The experience gained in AAL labs worldwide, in different hospitals and countries to support electronic services for doctors, caregivers and patients, is a good starting point for interconnectivity and virtualization [13].

Most of the work on the subject is done in isolated small user groups. The interconnection between these islands is the next step ahead. There are attempts for service globalization and virtualization throughout devices like Fitbit [14,15]. Some countries, such as the United States, are advanced in electronic records development. There are projects that attempt to highlight standardization and legislation issues [16]. The use of general type of equipment in hospitals and medical equipment at home are two different activities that need to be mapped. The necessity of interoperability with other technologies available on the market [17] should be supported by all available devices. ICT service development based on AAL as a service (AALaaS) and ELE as a service (ELEaaS) is still far from being mature or even feasible. Furthermore, the standard requirements to the hospital appliances, and home and personal equipment are different. Often local standards and rules prevent data mapping and analyses and the use of the analysed data by medical doctors and patients. This convergence process may continue for decades worldwide, and to be implemented in customized ways in different countries. On the other hand, global health insurance companies may play a significant role for this aggregation process, stepping to the market in many countries at the same time.

This chapter is organized as follows: state of the art, stressing on the tendency of the market and market needs; living labs architectures and their possible expandability and interconnection; end-user groups description paying attention to the requirements; moving data from sensors to the cloud and back to actuators, stressing on data modelling and availability; use-case scenarios in AAL/ELE environment interconnection; and service definition and abstraction. The reader could find further reading at the end of the chapter.

5.2 State of the art

Composition of ICT services for AAL and ELE needs special attention, not only in regards to the dynamic requirements and performance of the services, but also in relation to the interoperability and traffic engineering [17]. Existence of sensing technologies of different types, software and hardware, different generation and the necessity to connect everything in a network is a challenging task for standardization organizations and markets also. Many solutions that are more of less proprietary ones should be interconnected via gateways, regardless of the place and time [16]. Medical-related standards are very strict and the end-to-end (E2E) technological solutions are still expensive.

Target groups for testing include primary, secondary and tertiary end-users of the AALaaS and ELEaaS services. The primary users include patients, elderly, children and active living people who like to measure and keep track on personal physical status [4,14]. The group of secondary users consists of caregivers or family members, whereas the group of tertiary users includes insurance companies, hospitals, municipalities, medical and patient associations [15]. When defining the ICT services, there is a need to address all end-users and adaptively customize the services. This requirement is usually solved through service parameterization and intensive testing [18].

The socio-economical point of view on end-users and software system testing is presented in [19]. Most of the companies test the social effect of the service throughout different kinds of surveys. However, customers tend to avoid surveys due to the time limits and annoying questions they should answer. Smart ELEaaS and AALaaS services need to assess the end-user satisfaction indirectly by observing the end-user behaviour or emotions expressed during the service usage. Using broad range and variety of different test groups, including pilot projects like AAL labs, is important during service analysis and validation. Therefore, the pricing and the offering of these services is not a straightforward process, which needs smart marketing strategies, analysis and design [20].

The E2E approach towards the ELEaaS and AALaaS needs special attention due to the required protocol conversions. Cloud/edge/fog/dew computing, as well as the variety of sensor technologies, allows vast virtualization of the platform and services. This will create possibility for independent platform development and testing throughout platform planes and hierarchical levels (see Chapter 9). Service virtualization will allow the services to cross the national boundaries. Recently, smart dust computing, smart pills (see Chapter 8) and textile sensing technologies in wearables enhance the capability to measure and sense the status of the people. There is no strict definition on what extent this process could be applied to and who is ruling it, that is, a patient or a medical doctor.

Another important issue in this topic is related to the local legislation and global standardization. Medical standards are very demanding towards both critical and not so critical platform parameters. On the contrary, living, the home automation and environment automation standards are more relaxing. The trade-off between the strict and not so strict requirements will need special research and analysis in the following years [16,21].

There is a need for an end-user profiling that will allow setting services per profile. Services for elderly are different from the services for children. Services for people with disabilities are different from services for the people with dementia. The focus of this chapter is on a few possible profiles and use-case scenarios aiming to reach interoperability between them.

Special attention is being paid to the cultural requirements. There is a big difference in elderly's care systems in countries such as Germany, Norway and the United Kingdom on one side, and Bulgaria, Romania and Bosnia and Herzegovina on the other side. These details will influence the profiles and services implementations in different environments. The marketing of the platforms and services in different societies should be highly customized too [18]. The challenge from a technical point of view is how to parameterize in values generic and customized parameters of the services that will allow easy service creation, testing, implementation and usage [22].

During last decades, there were many projects and conferences on AAL. With new ideas for smart environments the enhanced living solutions are also becoming increasingly popular. The existing solutions, however, are still very specific and experiments are still defragmented. There is not one common approach towards

AAL labs consolidation and internetworking. Chapter 9 deals with the development of a personal living platform from this point of view. Some highlights also point to the main features of the existing solutions that might be helpful in getting the overall picture of the market and technology today.

The study described in [23] demonstrated a hybrid approach towards the users and agents in general within an AAL environment including robots. The use of location services in an AAL is shown in [24]. Specific verification technology is presented in [25]. Behavioural semantics and time constraints are considered in [26,27]. Abstraction of services modelling is presented in [28]. Model specification is demonstrated in [29]. Everyday activities abstraction is shown in [30]. A language for formal service description is proposed in [10]. Differences between the application-level testing and infrastructure level testing are demonstrated in [8]. An approach, based on privacy preserving sensors for activity recognition in smart homes, is discussed in [31].

A broader approach towards service definition could be seen in [32]. A classical approach for service assessment is shown in [33]. Possible implementations are demonstrated in [34]. Using bio robots in assisted living is developed in [35]. Robots are widely applied in rehabilitation services, remote assistance for surgery, training of special disabled groups remotely and many more. The movement of the patients is commanded by the rehabilitator and the robot could repeat the same patterns many times for proper exercise. Remote sensing is also used to record and analyse the activity of elder or disable person. This is further used for setting proper rehabilitation and exercise programme.

A broad collected experience in service and application validation is presented in [36]. Walsh presented experimental results of end-user testing in the community [37]. AAL house is shown in [38]. An advanced idea about Internet of Sensors could be seen in [39]. A nice experiment on quality-of-life estimation is shared in [40]. A living-lab-feature is presented in [41]. A testing and usability evaluation approach is demonstrated by Dias in [42].

Some of the applications are quite developed like in [43]. Standardization and further globalization, however, are still not considered well [15].

An active ageing application is presented in [44]; the tests had been carefully managed. Many use-cases could be found in [45]. This is a detailed report with an impressive completeness. Use-cases are classified based on the type of the event or activity.

The testing group selection is essential for the final results obtained [46]. There is a need for broad assessment with support from many possibly different end-users worldwide. Due to the complexity of the service customization, it could be done at different layers and on different scale. The numerical scoring approach proposed by many authors towards testing is not to be the only one possible for the end-user judgement, of course. Part of the tests in gerontechnology could be misunderstood, guided in a wrong way, depending on a specific condition of the testing group members, etc. The best approach is to use a combination of socio-economical, physiological and technical approaches towards testing [42].

5.3 Living lab architecture

The end-user groups' definition and profiling are based on the accumulated living labs experience and state-of-the-art analysis [20,38,47,48].

An AAL lab usually occupies a small (open or closed) area where one or more persons could use supplementary ICT services for better living. A typical AAL system includes sensors, actuators, controllers, gateways and special equipment such as respirators, robots, wheelchairs, smart phones, tablets, home servers, switches, routers and other smart devices. These are connected through controllers to one or more management consoles and through the gateways to the rest of the world. Some of the devices could be partially independent, for example, robots or wheelchairs, while other devices are dependent on the entire configuration, for example, sensors. The mobility of some of these objects is also a matter of configuration. By allowing object mobility the network, and the platform, is becoming partially ad hoc. That means that some critical and basic functionality relies on fixed devices and infrastructure while the ad hoc part on the top is software-defined one that relies on the presence of other devices. In this sense, the created personal living environment (PLE) is also considered as being software-defined and distributed.

Most of the living laboratories are developed for special purposes and only volunteers work and live there. The fast technology development towards the real market with millions of implementations is a step that still needs to be done. The Technology Readiness Level (TRL) of AAL laboratories is either 4 (i.e. laboratory testing of a prototype component or a process) or 5 (laboratory testing of an integrated system). Part of the verification process in the AAL laboratories is also performed as some features of TRL level 6. Pilot experiments with integrated solutions in some hospitals cover partially also the TRL 7 [49]. The services, however, are being developed in their boutique versions and are still expensive. As a conclusion, one may state that there is still a long way to go before reaching the status of having products ready for the massive market.

A typical AAL lab works as part of a corporate/home Local Area Network (LAN) and is based on known access network technologies such as ZigBee, EnOcean, Bluetooth, Wi-Fi, Ethernet, 3G/4G/5G, etc. The experience gained in AAL labs is LAN-related or wireless LAN-related by nature (Figure 5.1). Many hospitals use Bluetooth equipment for short-range equipment management like surgery consoles. The use of equipment in some of the frequencies might be dangerous, however [50]. There is a vast amount of analyses and research done on the electromagnetic compatibility of devices and possible interference between them. However, there is still lack of a single solution applicable worldwide.

A typical AAL lab network is shown in Figure 5.1. It is heterogeneous by nature as it may include both fixed and mobile devices and utilize different communications technologies like Bluetooth, ZigBee, 3G/4G/5G, Ethernet, Wi-Fi, etc. Part of the equipment is fixed for the comfort of the end-user seating in a wheelchair. For example, a personal digital assistant or a tablet could be part of the wheelchair dashboard, and sensors/actuators on the windows and doors are also

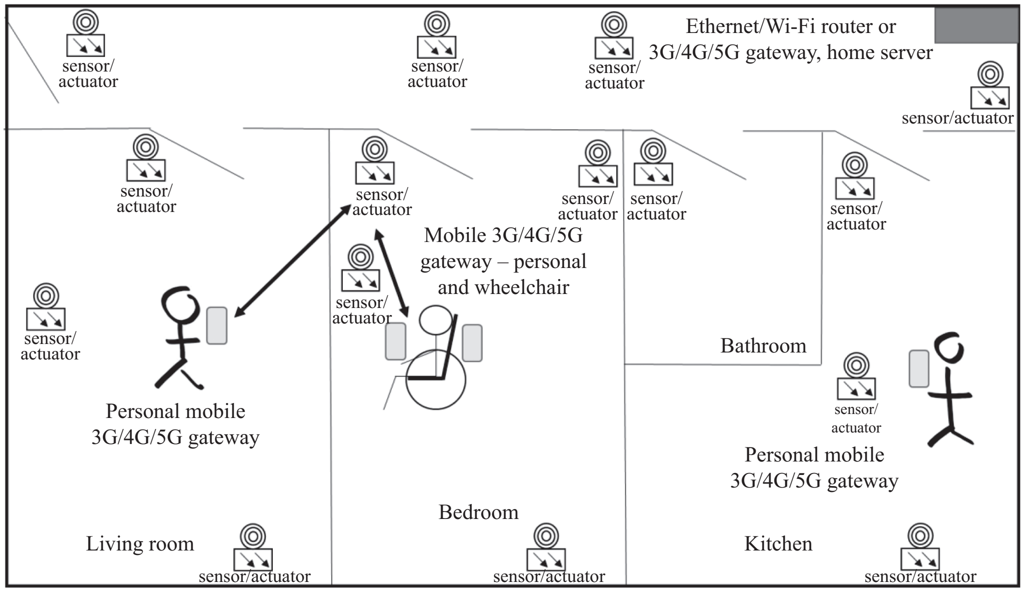

Figure 5.1 A heterogeneous AAL living lab network

fixed; while other sensors on cloths, kitchen appliances or sport equipment could be mobile. Even though it is easy to receive signals and collect data from different devices, significant delays will be faced if part of the network is arranged in ad hoc fashion, which may lead to frequent changes in the network topology [51,52].

An AAL lab network also includes one or more gateways for communication with the external world. For reliability reasons, the use of at least two different channels should be considered when the data is critical for the people's health. A home server acts as a front point in a dew computing infrastructure [53,54]. It stores the raw data from the lab and possibly makes preliminary data analysis, time stamping, location stamping, that is, data acquisition. Smart home servers could raise an alarm if a critical state is reached [55].

Different objects, connected in such a network, may form different systems, for example, for lighting, power supply, wheelchair mobility, medical treatment, activity management, infotainment, air conditioning, configuration, administration and management, etc. All systems could be interconnected to form a smart environment (see Chapter 9) [55].

The virtualization of services allows to move parts of the services to the dew, fog or cloud for data storing, processing, analysing, mining, decision-making, etc. [56]. Though this raises obvious issues like privacy and reliability (due to connectivity requirements) that need to be addressed, this approach nevertheless makes the local configuration and management easy. In fact, it is a step forward to the remote configuration and management, offered by third-party bodies. Local infrastructure will be used for access and edge parts of the network and additional storage area networks (SAN) on the global plane will form the cloud. The level of virtualization depends on the specific implementation of the services. There is a tendency to move all data processing and raw data storage to the cloud level (see Chapter 9) [54]. Being distributed and smart in nature, the PLEs exist on the top of the ICT facilities and communication networks (including software-defined networks) and provide services in a way like the social networks.

5.4 End-user groups

Testing scenarios could be seen from the perspective of different subjects and objects in the platform. End-users are disabled people, active ageing people, medical doctors, family members, nurses, physicians, insurance companies, system administrators and maintenance personnel. In some cases, one may speak about end-devices like robots, controllers, wheelchairs, servers, management applications or just objects involved in a machine-to-machine communication. Identification of all players in the system, whether they are humans or not, is critical for the reliability and usability of the system. It reflects protocols and interfaces to be applied. End-users and end-devices could be primary, secondary and tertiary users and devices.

Figure 5.2 demonstrates the complexity of the testing scenarios. The considered scenario presents the main features of the PLE of a child, who is a primary user, is equipped with different sensors, for example, for temperature, localization, activities. The child is connected to his/her parents through a data sharing and the alarm management used is based on the data processing. The main communication activity is performed via messages. The full testing of such a PLE includes the child, parents, all sensors, actuators and gateways, the PLE customization and

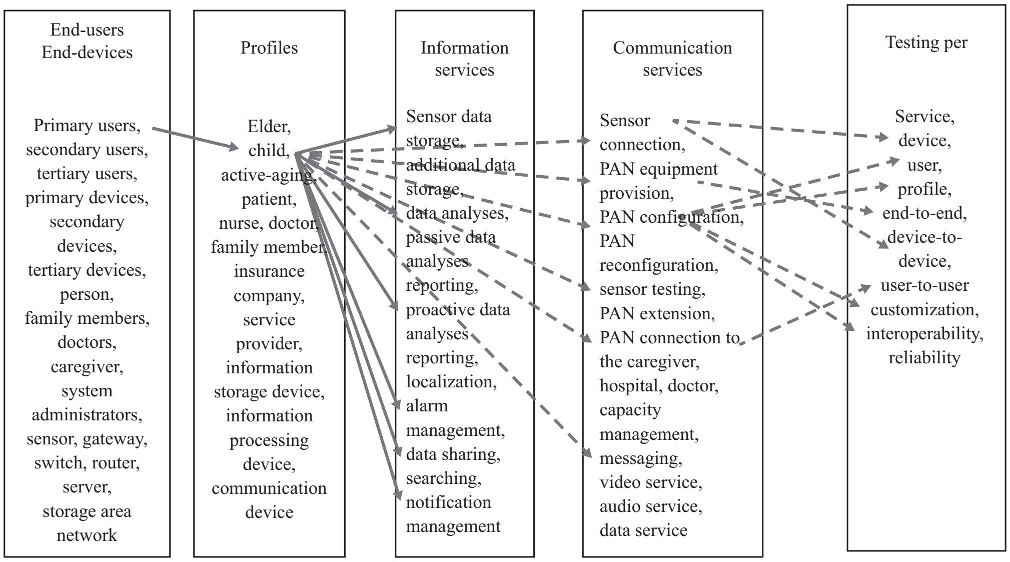

Figure 5.2 Subjects, objects, profiles, services, devices and tests in a sample testing scenario

configuration, E2E service, device-to-device communication, data transfer, security, etc. Security especially needs attention at all platform layers.

This chapter tries to separate the ICT at the access, edge and cloud level of the AALaaS and ELEaaS platforms. Definitions of the precise data models and data processing flows are essential for the platform success on the market. Integrated profiles and relation to the use-cases are considered in [18]. The document presents details on selected use-cases, profiles, transaction and data models, as well as standard conformance to be taken into account.

Performance tests of the platform connectivity should check logical and physical interconnections. The ELE platform needs a back-up for internal and external connections. The same rules need to be applied to all platform layers, and the SAN with doubled, quadrupled and eightfold connectivity is a good example. It should be capable to work without an external connection by keeping all necessary data locally while getting connected. Attention should be paid to the gateways, interfaces, applied protocols, data exchange formats, etc.

The ELEaaS definition is not possible without having clear requirements on functionality, precise data models and data processing vision. An ELE platform supports a variety of functions, for example,

- Critical functions (including alarms) needing a regular 24/7 attention.
- Basic functions supporting the active living such as washing, cooking, entertaining, cleaning and even services' configuration and administration.
- Additional functions, related to standalone management applications, home backup servers, statistical tools, data backup and restore, alarm function on subscriptions, extensions of the existing services as graphical tools, data analytical tools, data filters, etc.

It is easy to define internal and external services based on the functionality of the ELE platform. Internal services are mostly related to the daily activities of the end-user like washing, bathing, cooking, cleaning, ordering, dressing, resting, taking medicines, etc. External services involve different type of connections, for example, with social networks, caregivers, insurance companies, family members, doctors, friends, system administration, etc. External services are mostly related to data processing, storage, mining, statistical analysis, service subscription, service configuration and management. These may include also notifications when new functionalities are deployed in the cloud.

Service parameterization is an ability to set values for performance support separately from the running code. It could allow also data measuring that will ensure the service quality in a completely predictable way. Parameterization is also related to the states of the service and its reaction to the specific activities from the end-users/devices. There is no place for wrong behaviour or misinterpretation of the end-user/device reaction. This should be kept as a rule even in the case of device damaging or completely misinterpreted behaviour of the end-user.

Service scenarios are defined using ontology or sequence charts together with data models. They use standard communications protocols like TCP/IP, UDP/IP, 3G/4G or others like HTTP, Message Queue Telemetry Transport, MODBUS TCP, etc. The data models explain messages used in different scenarios, and data storage, mobility processing, mining and dependence. Scenarios could be client/server or peer-to-peer [54]. The data processing, mobility, presentation, dependencies, relations and associations represent all data processing, storage and mining services, and require efficient storage designs to cope with the vast volumes of data [57], while being able to apply virtually different algorithms for big data analysis and artificial intelligence [58,59].

The collected experience in different AAL labs worldwide demonstrated the capability of the ICT to solve different tasks related to the people with partial disabilities. The vast development of the 5G technology towards active life or just well-being life sets additional possibilities to build smart homes, smart PLEs and smart living standards that are highly customized. The main testing could be performed using the existing facilities. Virtualization of the ELE services or simply going to ELEaaS at dew/fog/cloud level allows further unification of platforms and possible service globalization.

5.5 From single user and single sensor to the cloud and back

Figure 5.3 demonstrates a typical AAL environment where each end-user sets up and utilizes a Wireless Personal Area Network (WPAN) while communicating (working together) with other users in the same Wi-Fi domain. The connection between different WPANs and the Wi-Fi could be arranged through a WPAN coordinator, whereas the connection to the external world is done via a gateway. The gateway could be set up on a smartphone and placed at any point in the lab. (For simplicity, the gateway, the WPAN coordinator and the Wi-Fi router are shown together on the upper right corner of the figure.) Each WPAN is configured separately and could involve cooperative sensors/actuators, which may work also in an ad hoc manner. For instance, the temperature sensor for the patient in the wheelchair could be read by/visible not only to him/her but also by/to the caregivers in the living room and in the kitchen. The priority to clear the sensor data, change sensor configuration, set up notifications, updates, etc., could be delegated to one of the WPANs.

Figure 5.4 depicts the same testing scenario by further showing the two possible options for WPANs interconnection. Apart from being done via a WPAN coordinator, as an alternative, communication between different WPANs could be set up in an ad hoc manner. To allow the latter, all WPANs need to work on the same communication channel, which may lead to a possibility of interference. This issue, however, may be considered not so serious for transmitting non-critical data [54].

Depending on the configuration, part of the sensors/actuators could be associated permanently with a WPAN, whereas other sensors/actuators may not be. For instance, the sensors/actuators on the left-hand side in Figure 5.5 are associated permanently with WPAN1 and sensors/actuators on the right-hand side – with WPAN2. The sensor/actuator in the middle, however, is not associated with any of

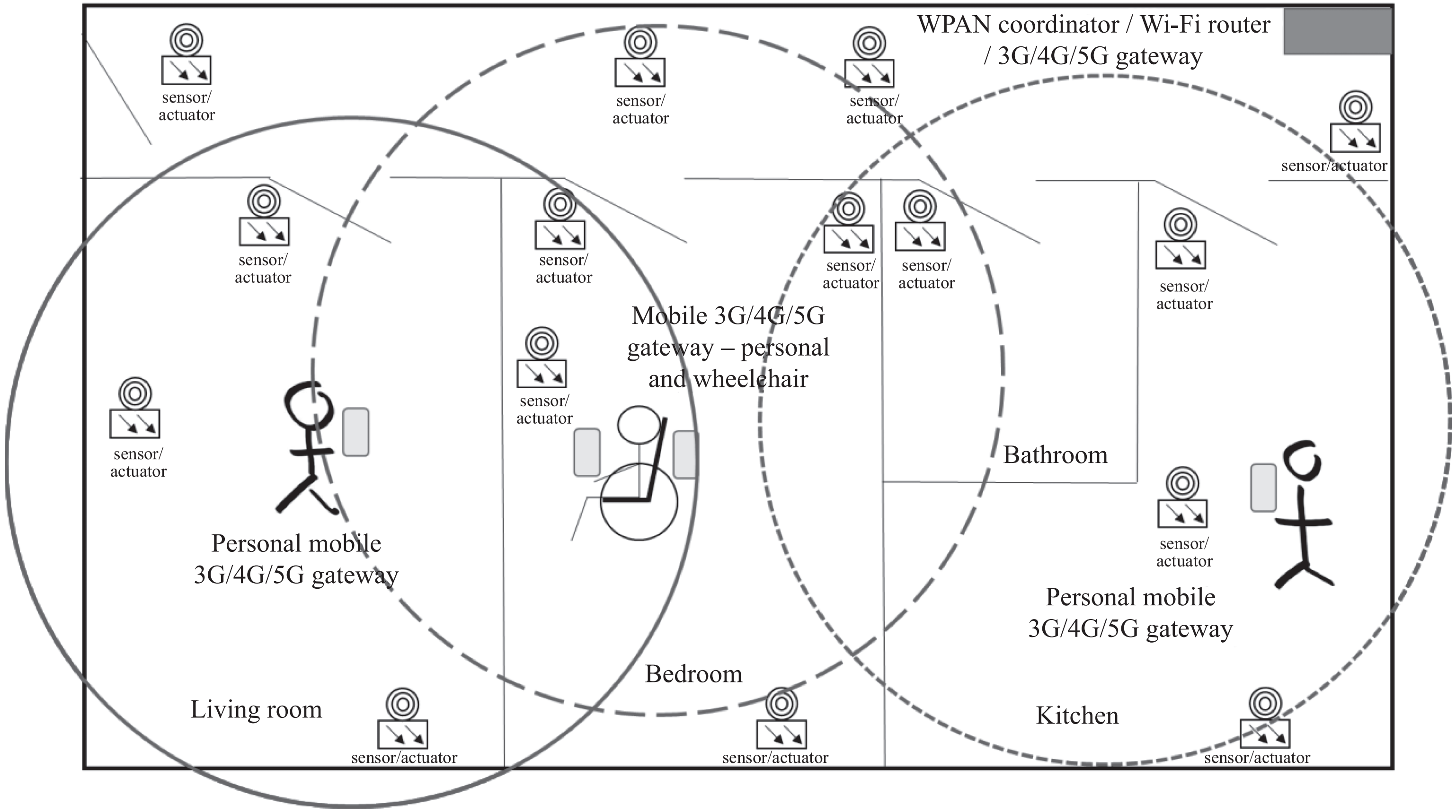

Figure 5.3   A living lab communication infrastructure, based on WPANs

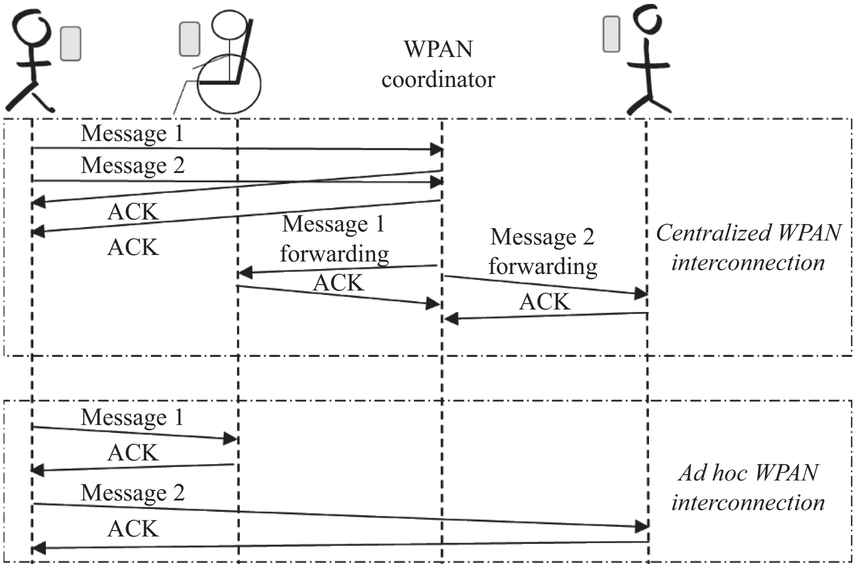

Figure 5.4 Centralized and ad hoc connectivity options for WPAN interconnection

these WPANs and is visible from both. The communication of this ‘free’ sensor/actuator to the WPANs is performed in an ad hoc mode; it could send data to both WPANs independently. Some of the WPANs could be also coordinatorless. All sensors that share the same communication channel listen, receive and retransmit all incoming messages.

Figure 5.6 shows a strict sensor/actuator association, whereby the sensor/actuator in the middle is associated with WPAN2. It sends and receives data only through the WPAN2 central (master) node. In many medicine-related applications, this scenario is considered as a more reliable one and thus is recommended especially for data-critical sensors/actuators. Other non-critical sensors/actuators could be associated or not with WPANs, depending on the circumstances. Similar situation may appear in other application areas such as public transport, hospitals, shops, business buildings, parks, streets, etc.

Communication with sensors is usually in the range of a few bytes per minute, whereas communication with the WPAN coordinator is rather complex. There might be voice/video/audio sessions involved with rates ranging from 8 kbps up to 500 kbps. The WPAN coordinator keeps client applications and supports the interface to the end-user. It keeps raw data temporarily along with most recent reports/medical advices, received from the cloud. Therefore, the data is only partially stored and processed at the WPAN coordinator but completely in the cloud. It includes also all logs related to the use of services, and their configuration and management.

The flow of reports backward is a very important part of the services provided to the end-user. These include configuration and management reports, reports for the client, report for the applications, backup-related reports, etc. Based on the

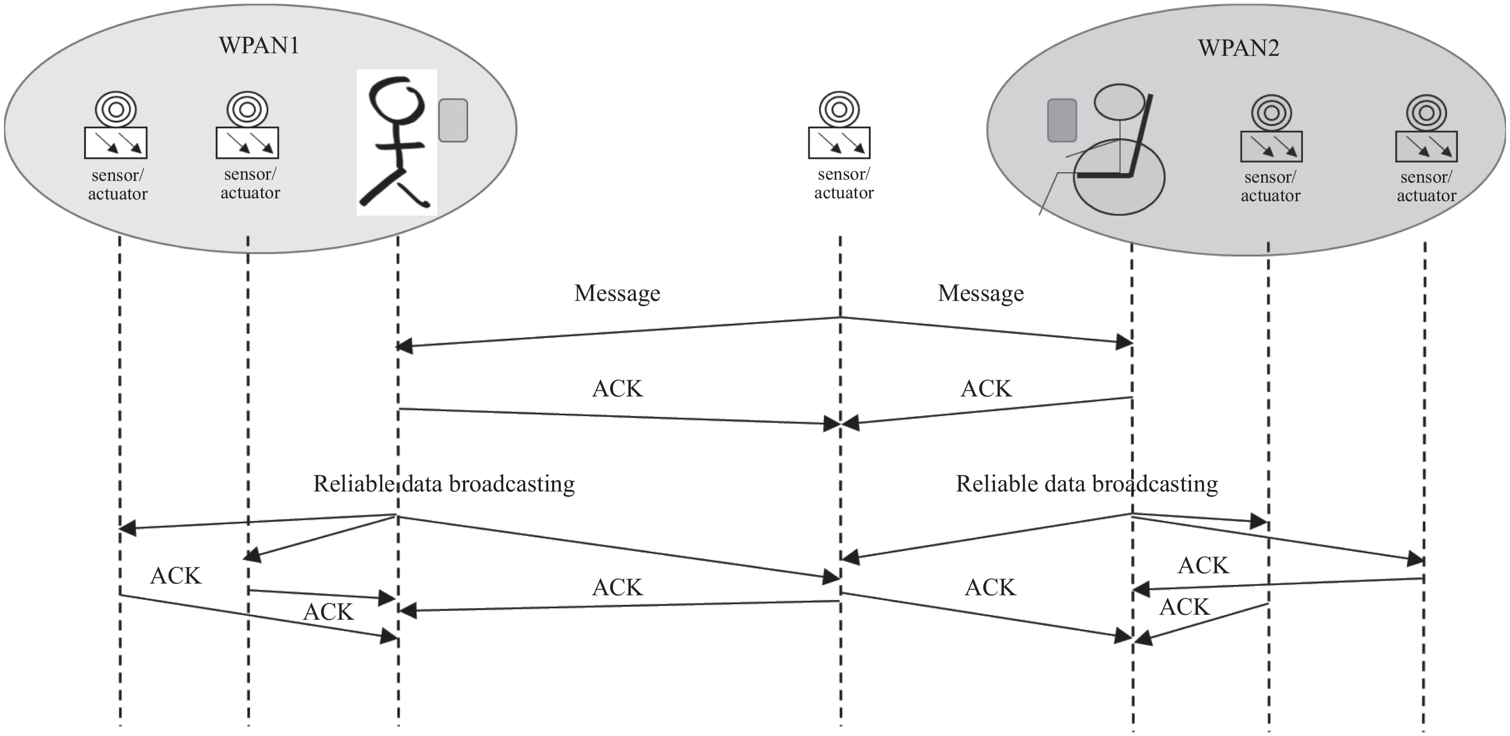

Figure 5.5 Coordinatorless and coordinator-based sensor/actuator configuration (for the sensor/actuator shown in the middle of the figure)

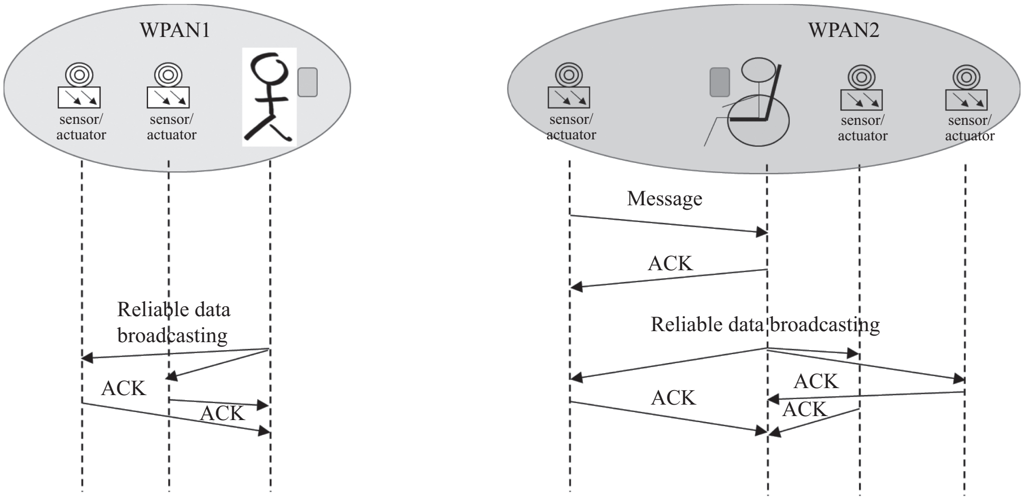

Figure 5.6 Coordinator-based strict sensor/actuator association (the sensor/actuator in the middle is associated with WPAN2)

utilized technology, further in this chapter some highlights of atomic ICT services, as well as complex E2E service compositions, are provided.

5.6 Scenarios

Some scenarios are more related to the complex services, which are a composition of elementary or atomic ICT services as explained in Chapter 9. Many scenarios could be similar for many end-users (and their profiles) like patients, elderly and people on rehabilitation, etc.; some other scenarios are more specific, like going to the party, visits at home, etc. Thus, it is important to distinguish daily routine activities from unusual behaviour and try to identify situations that require alarms (by minimizing false alarms as much as possible).

Everyday activities are usually based on schedules. Some of the schedules are strict such as taking medicines, getting up from the bed, going to the bathroom, etc. Other activities are more relaxing and their order is not strict, for example, dressing, having a breakfast, reading and walking around the house, etc. Services at home could be divided in small modules, that is, more specialized services or atomic services such as moving wheelchair straight, back, right or left; open/close a door/window; increase/decrease the light intensity, temperature or music/sound volume; call the caregivers/relatives, etc. The composition of these atomic services forms complex scenarios to be supported like the one detailed in Table 5.1. Some of the activities shown in this table are considered more important than others. This is the reason for setting up priorities. Each scenario and the possible schedule of the atomic services could be different depending on the customer habits.

A typical communication, supporting a ‘getting up from/going to the bed’ scenario, is shown in Figure 5.7. It involves different sensors and actuators, located in the bedroom, concerning opening/closing windows, getting up from/laying

Table 5.1 Daily activities and possible priorities

Daily activities	**Priority**	**Schedule 1**	**Schedule 2**	**Schedule 3**
Cooking	Medium	Using ready recipe with navigator in the kitchen	Adding new recipe to the navigator in the kitchen	Free style cooking with kitchen navigator off
Bathing	High	Refreshing	Partial bath	Complete bath
Dressing	High	Day	Night	Outside
Walking in the house	High	Typical in-house walk	Checking all rooms	Specific task
Walking outside the house	Low	Routine walks [60]	Adding route	Free walk tracking
Location service	Medium	Strict	On demand	Disabled
Going to the shop, cafeteria, other homes as a guest	Medium	Routine tasks	Adding a point	Free shopping
Going to the hospital or for rehabilitation	High	Compulsory	On demand	Occasionally
Ordering and cleaning	Medium	Everyday	On demand	Scheduled

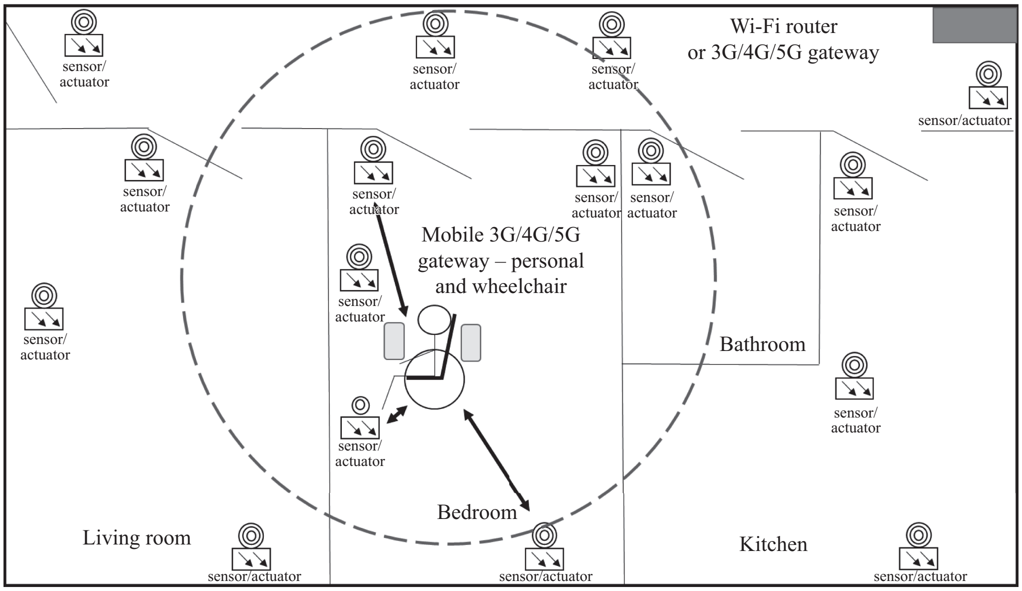

Figure 5.7 A typical communication, supporting a 'getting up from/going to the bed' scenario

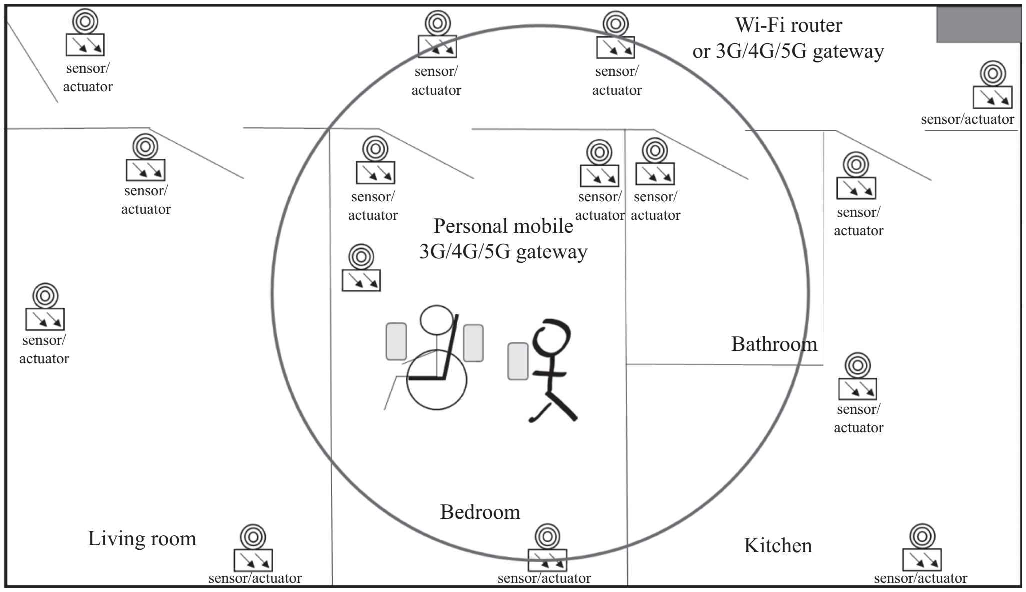

Figure 5.8 Use of a caregiver's WPAN as a supplementary communication infrastructure

down in the bed, opening/closing the door, turning light on/off, moving within the room and listening to the music, etc.

Some services could be activated to check more precise details in the patient condition like sitting on the wheelchair, pressing the wheelchair left or right arm, standing from the wheelchair, pushing the backside with head, etc. In many cases, this could be an indication of the condition of the elderly and necessary data could be notified to the rehabilitation personnel and/or the doctor. Sensors on the floor could be used to track the movement of the patient and to detect his/her incidental falling.

Similar scenarios will be performed when dressing next to a wardrobe, cooking in the kitchen, bathing in the bathroom, entertaining in the living room, etc. Schedules and scenarios could be used to track how often all these activities had happened and in which order.

The caregivers' WPANs could be used as supplementary communications infrastructures, for example, for service logging and notifications. There is a need to associate the sensors, actuators and data to the patients in this case. When the patient coordinator and gateway is not activated or is temporally out of order, the caregiver's WPAN could be used instead for a short time (Figure 5.8). The activation and configuration of such a service could be used for backup purposes or separately as a main service. The priority of such a service is essential from a security point of view.

The personal assistant or caregiver could be a human being or a robot (Figure 5.9). Depending on the configuration of the network the end-user might act as coordinator and gateway. The caregiver device will be like a router for the

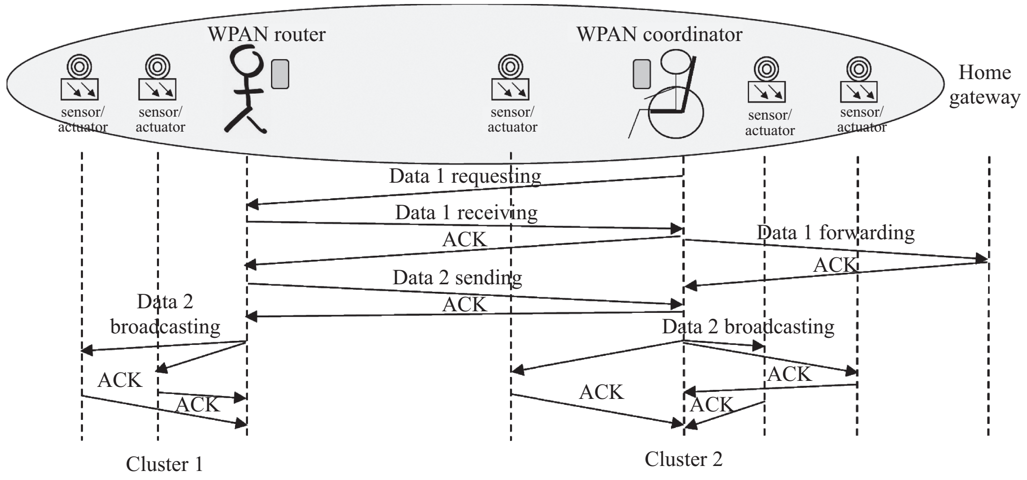

Figure 5.9 Patient's and caregiver's mobile devices, acting interchangeably as a coordinator and a router in a WPAN

sensors in the network. The scenario presented uses Wi-Fi connectivity to the home gateway, ZigBee technology between the coordinator, the router and the sensors in the two clusters. When the patient could coordinate the network, the roles of the coordinator and/or routers could be changed. The caregiver or personal assistant could be a human being or a robot. Depending on the network configuration, the patient's mobile device might act as a WPAN coordinator whereas the caregiver's device may act as a WPAN router for some of the sensors/actuators in the network. The scenario presented in Figure 5.9 utilizes a Wi-Fi connectivity between the WPAN coordinator and the home gateway, and a ZigBee technology between the WPAN coordinator, the WPAN router and the sensors/actuators in the two clusters shown. The role of a WPAN coordinator could be played also by the caregiver's device; in that case the patient's device will act as a WPAN router.

In the case when a robot is a caregiver, the scenario in Figure 5.9 is also valid. It is a matter of future research and analysis to prove if functions of a WPAN coordinator could be trusted to a robot. Many of the scheduled everyday tasks in a house could be delegated to the suitable robots.

A special set of services could be comprised by notification services. The end-users need different level of notifications and alarms, for example, through a panic button with a predefined procedure on how to proceed when used. Some notifications are just related to the logging process, which could be local at the dew computing level or more general at the fog/cloud computing level. The transfer of logs and log analysis provided by the service provider could support the service maintenance and development as well as the service customization (see Chapter 9). There is a need for relation between activities and corresponding notifications made as shown in Table 5.2. Sensors/actuators should be classified at least at three levels: critical, non-critical and basic. The classification levels should be related to the activities necessary to be performed.

Table 5.2 Activities and two-level-priority notification services in ELE

Activity	High-priority notification	Low-priority notification
Falling	To the local personnel and the doctor, emergency call	To the service provider for logging, home server, relatives
Pushing panic button	To the local personnel and the doctor, emergency call	To the service provider for logging, relatives, home server
Critical sensor threshold at warning level	To the local personnel and the doctor	To the service provider for logging, home server and relatives
Critical sensor threshold at long warning level	To the local personnel and the doctor, checking through other sensors and/or communications channels	To the service provider for logging, technician, relatives
Critical sensor threshold at emergency level	To the local personnel and the doctor, emergency call	To the service provider for logging, relatives and home server
Walking	If outside typical area, to relatives and caregivers for tracking	To the service provider for tracking and logging
Cooking	Kitchen appliances working and no movement in the kitchen	Logging, recording, updating
Taking medicines	To the local personnel and the doctor, to the end-user's records	Health records
Dressing	Abnormal situation or order	Home server or personal records
Bathing	Abnormal situation or order	Home server or personal records
Dining	Abnormal situation or order Changing, customization, free style dining	Home server or personal records
Sensor/actuator deconfiguration	Technical support at urgent or non-urgent level depending on the type of sensor/actuator	Personal records for checking
Sensor/actuator configuration	Technical support at urgent or non-urgent level depending on the type of sensor/actuator	Personal records for checking

For example, when the pulse of a patient is going above 150 beats per second, this might be an indication of a problem with the patient, but also could be an indication of technical problem with a sensor/actuator. In this case, the state of notification is raised as ‘warning’ and the measure of the pulse is repeated at least three more times in the next few minutes. Other parameters measured by nearby sensors are also checked carefully, such as body temperature, room temperature, noise level, blood pressure, etc. Technically damaged or faulty devices should be immediately isolated.

In the case of technical problem identification for a particular sensor/actuator, the sensor/actuator should go to a deconfiguration state. In the case of emergency-level identification, the emergency team should be called automatically.

Special schedules and scenarios are necessary for the states and events that are considered dangerous. In relation to a patient, there is a need of a preliminary analysis for events like:

- No use of bath for more than 12 h
- No meals and liquids taken for more than 12 h
- Medicines are not taken
- Staying in the bed for more than 12 h
- Being awaken for more than 18 h
- Walking around without sitting for more than 6–8 h
- Walking less than 100 steps daily
- Running less than 1 km daily

All events could be also classified in accordance to the emergency level and personal activity thresholds. For example, running is a normal event for children, walking for all people, staying in the bed for more than 12 h might be a symptom of disease, too much walking might be a symptom of stress, etc.

Scenarios while walking in the park, going for shopping and travelling by public transport are similar to those defined at home (Figure 5.10). Part of the sensors is publicly accessed and others are not. The associated logging service need to track the path of the user/patient and conditions during walk like, for example, temperature, humidity, moisture, rain, wind, etc.

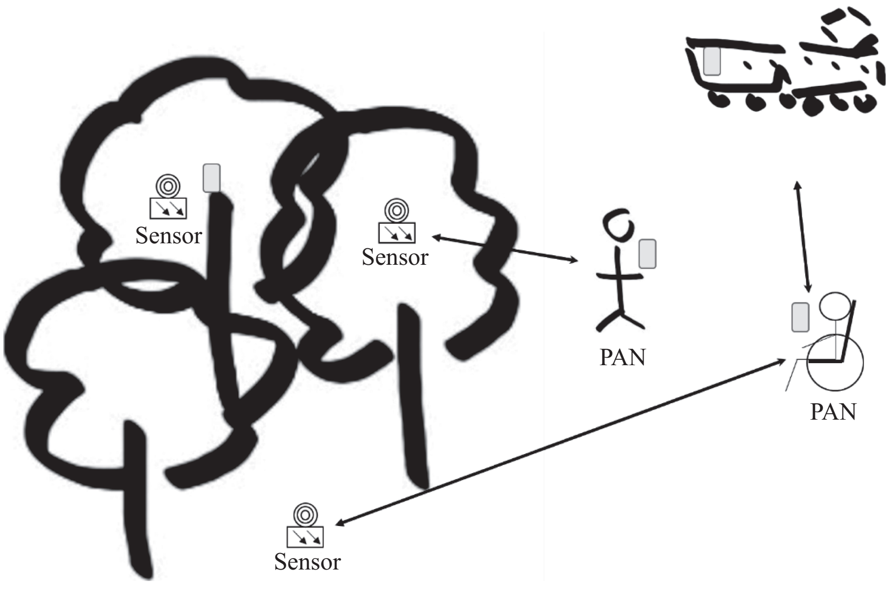

Figure 5.10 Scenarios during walking in the park, shopping and travelling by public transport

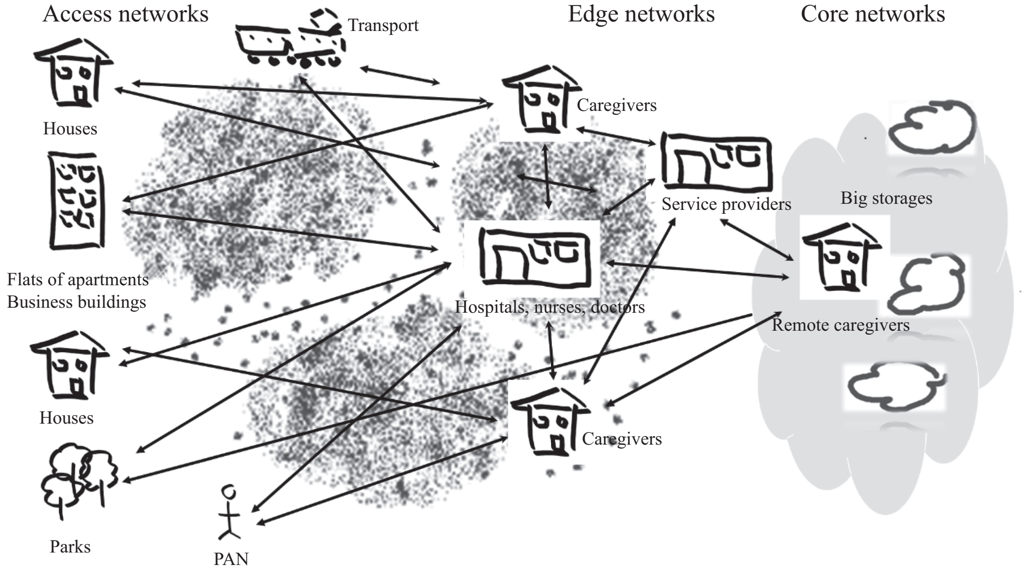

Figure 5.11 Different types of communications involved in an 'out-of-home' scenario

The remote assistance from doctors, caregivers and suppliers requires special configuration. Once the user/patient gets out of the home, she/he may need frequent or continuous communication with caregivers, nurses, doctors and service providers, as illustrated in Figure 15.11 (for simplicity, the service provider's connectivity to the end-user is not shown in the figure). The scenario could be very flexible and customized, based on the client interface software and service virtualization in general. Furthermore, virtualization of the network will allow collection of raw data through different devices via gateways with standard interfaces and data records. This also allows implementation of the software for searching and analysing, and of more globalized services regardless of the basic sensor types in the access part of the network. Remote sensing, configuration, advising and social contacts will improve the presence of the patients in the society and their feeling of being useful and valuable citizens.

The same scenario (or connectivity model) could be used for patients' communication with third parties, such as social networks, insurance companies, patient associations, professional associations, etc. The main differences are in the definition of notifications and allowances throughout the access, edge and core parts of the networks. This applies also to the data presentation between dew/fog and cloud storages.

5.7 Customized ELE ICT services

The attempt to classify the ELE end-user scenarios, presented earlier, allows to start defining the corresponding ICT services. The need for atomic services, composite services, aggregated services and managed services has been already mentioned.

Part of the services are local, others are global. All issues, concerning details of the service definition, could be left to the service providers to deal with. The main set of services for consideration is presented later.

Communication services for primary users could be:

- Sensors/actuators setup and interconnection (e.g. in a wireless sensor network, WSN)
- Sensors/actuators testing (under different scenarios)
- WPAN equipment provision
- WPAN configuration and reconfiguration
- WPAN extension
- WPAN connection to caregivers, nurses, doctors, etc.
- Capacity management
- Messaging
- Video service
- Audio service
- Data service

Information services for primary users could be:

- Sensor (raw) data storage
- Additional data storage
- Data analysis and mining
- Passive data analysis reporting
- Proactive data analysis reporting
- Localization
- Alarm management
- Data sharing
- Searching
- Notification management
- Reporting

Communication services for secondary users could repeat those of the primary users partially. This is true in all cases when the caregiver's equipment is used as a backup for the primary user. Secondary and tertiary users also need services like:

- Network connectivity through fixed and mobile networks
- Optional user interfaces and multihoming
- Multitasking capability
- Time scheduling and management

Information services for secondary and tertiary users are a place for big data analytics and could be very rich, such as:

- Customized applications for caregivers, nurses, doctors, service providers, technicians, insurance agencies, patient organizations, social networks
- Sensor data storage, management, backup, access, analysis and mining
- Additional data storage, management, backup, access, analysis and mining

- Data analysis customized for different users
- Passive data analysis reporting
- Proactive data analysis reporting
- Localization support
- Alarm management
- Data sharing
- Searching
- Notification management
- Configuration management

5.8 Conclusions and further research directions

In conclusion, one may point out the necessity to analyse in details the outcomes from the experienced living laboratories and to select the most appropriate way for their possible interconnection. The establishment of networks of living environments with a good scaling option will allow the deployment of AAL/ELE services in different regions and possible interconnection with other local and global services and providers.

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Biographies

Serge Autexier has a background in Computer Science and Artificial Intelligence (doctoral degree/PhD 2003 from Saarland University, Saarbrücken, Germany), especially semantic knowledge representation, reasoning, change management with applications to software development, mathematics and intelligent environments. He is head of the Bremen Ambient Assisted Living Lab which belongs to the Cyber-Physical Systems department of DFKI in Bremen. His research focuses on intelligent assistance for humans, especially mobility assistance, low-threshold man–machine interaction as well as safety and security of assistance processes. He has more than 60 publications and is member of the Working groups on 'User Focus' and 'Interoperability of AAL Systems' of the German Commission for Electrical, Electronic & Information Technologies of DIN and VDE and member of the Technical Committee of the OpenURC Alliance promoting the Universal Remote Console.

Rossitza Goleva received her PhD in Communication Networks in 2016 and MSc in Computer Science in 1982 at Technical University of Sofia, Bulgaria. She was part of the research staff of the research Institute of Bulgarian PTT between 1982 and 1987. Since 1987, she is with Department of Communication Networks at Technical University of Sofia. At present, Rossitza works on communication networks, communication protocols and software engineering. Her research interests are in Quality of Service in communication networks, communication protocols, traffic engineering, cloud and fog computing and performance analyses. She is an IEEE Member, involved in IEEE Bulgaria section activities, has more than 85 research publications, was part of more than 30 research projects including and EU COST IC1303 AAPELE action.

Nuno M. Garcia holds a PhD in Computer Science Engineering from the University of Beira Interior (UBI, Covilhã, Portugal) (2008) and has a 5-year BSc (Hons.) in Mathematics/Informatics also from UBI (1999–2004). He is Assistant Professor at UBI and Invited Associate Professor at the School of Communication, Architecture, Arts and Information Technologies of the Universidade Lusófona de

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Rumen Stainov received his BS and MS from the Technical University Ilmenau, Germany, and his Dr.-Ing. from the Dresden University of Technology, Germany. Before joining Fulda University, he has been a Professor of Time at the University of Aachen, Germany. In fall 1997, in fall 1998, in spring and summer 1999 he has been Visiting Associate Professor at Boston University (USA). From fall 1999 through summer 2002 he has been full-time Associate Professor of Computer Science at Boston University. He is currently Professor of Computer Science at Fulda University of Applied Sciences, Germany. His research interests are in the field of networking, distributed systems, mobile communications and peer-to-peer networks. He has more than 75 research publications; he wrote 5 technical books and was leading investigator in 12 research projects.

Dr Ivan Ganchev is a Senior Member of the Institute of Electrical and Electronic Engineers (IEEE), the IEEE Communications Society, the IEEE Consumer Electronics Society, the IEEE Internet of Things Community, the IEEE Smart Cities Community and the IEEE Consultants Network. He received his doctoral and engineering (*summa cum laude*) degrees from the Saint-Petersburg State University of Telecommunications. He is a Deputy Director of the Telecommunications Research Centre (TRC), University of Limerick (Ireland), an Associate Professor from the University of Plovdiv 'Paisii Hilendarski', an ITU-T Invited Expert, and an IET Invited Lecturer. Dr Ganchev was involved in 35+ international and national research and education projects. His research interests include novel telecommunications paradigms, future networks and services, smart ubiquitous networking, context-aware networking, mobile cloud computing, Internet of Things (IoT), Internet of Services (IoS), ambient assisted living (AAL), enhanced living environments (ELEs), trust management, Internet tomography, mHealth and mLearning ICT. Dr Ganchev has served in the Technical Program Committee of 200+ prestigious international conferences, symposia and workshops. He has authored/co-authored 6 books (including 2 edited books) and 240+ research papers in refereed international journals and conference proceedings. Dr Ganchev is on the editorial board of and has served as a Guest Editor for multiple international journals.

Dr Constandinos X. Mavromoustakis is currently a Professor at the Department of Computer Science at the University of Nicosia, Cyprus. He received a five-year dipl.Eng (BSc, BEng, MEng) in Electronic and Computer Engineering from Technical University of Crete (2000), Greece, MSc in Telecommunications from University College of London, UK (2001), and his PhD from the department of Informatics at Aristotle University of Thessaloniki, Greece (2006). Dr Mavromoustakis is leading the Mobile Systems Lab. (MOSys Lab., http://www.mosys.unic.ac.cy/) at the Department of Computer Science at the University of Nicosia, dealing with design and implementation of hybrid wireless testbed environments and MP2P systems, IoT configurations and smart applications, as well as high-performance cloud and mobile cloud computing (MCC) systems, modelling and simulation of mobile computing environments and protocol development and deployment for large-scale heterogeneous networks and new 'green' mobility-based protocols. Dr. Mavromoustakis is an active member (vice-chair) of IEEE/R8 regional Cyprus section since January 2016, and since May 2009 he serves as the chair of C16 Computer Society Chapter of the Cyprus IEEE section. Dr Mavromoustakis has a dense research work outcome (more than 200 papers) in Distributed Mobile Systems and spatio-temporal scheduling, consisting of numerous refereed publications including several Books (IDEA/IGI, Springer and Elsevier). He has served as a consultant to many industrial bodies (i.e. member of the Technical Experts for Internet of Things competition at Intel Corporation LLC (www.intel.com) for the ChallengeMe, etc.), he is a management member of IEEE Communications Society (ComSoc) Radio Communications Committee (RCC) and a board member the IEEE-SA Standards IEEE SCC42 WG2040 whereas he has served as track chair and co-chair of various IEEE International Conferences (including AINA, IWCMC, ICC, GlobeCom, IEEE Internet of Things, etc.).

Ciprian Dobre is Professor within the Computer Science Department, University Politehnica of Bucharest (Habil. since 2014, Dr since 2008 with Cum laudae). He currently leads the activities within Laboratory on Pervasive products and services, and MobyLab. Ciprian Dobre's research interests involve research subjects related to mobile wireless networks and computing applications, pervasive services, context-awareness and people-centric or participatory sensing. He has scientific and scholarly contributions in the field of large-scale distributed systems concerning mobile applications and smart technologies to reduce urban congestion and air pollution (MobiWay, TRANSYS), context-aware applications (CAPIM), opportunistic networks and mobile data offloading (SPRINT, SENSE), monitoring (MonALISA), high-speed networking (VINCI, FDT), Grid application development (EGEE, SEE-GRID), and evaluation using modelling and simulation (MONARC 2, VNSim). These contributions led to important results, demonstrating his qualifications and potential to go significantly beyond the state of the art. Ciprian Dobre was awarded a PhD scholarship from California Institute of

Technology (Caltech, USA) and another one from Oracle. His results received one IBM Faculty Award, two CENIC Awards and three Best Paper Awards (in 2013, 2012 and 2010). The results were published in over 100 chapters in edited books, articles in major international peer-reviewed journals and papers in well-established international conferences and workshops.

Ivan Chorbev, PhD, is an Associate Professor at the Faculty of Computer Science and Engineering at the Ss.Cyril and Methodius University in Skopje. He has participated in more than 70 scientific papers in journals and conference proceedings, book chapters and has performed several researches stay as visiting scientist. He is an author of two books. He has been part of or coordinated several national or EU-funded research projects. The fields of his research interests include combinatorial optimization, heuristic algorithms, constraint programming, web development technologies, application of computer science in medicine and telemedicine, medical expert systems, assistive technologies, knowledge extraction and machine learning.

Vladimir Trajkovik, PhD, is University professor at Ss.Cyril and Methodius University in Skopje, Macedonia. He has published more than 160 research papers presented in international conferences or journals in Computer Science and Engineering. He is author of three books and nine book chapters published by International publishers. He has participated in more than 30 international and national educational, research and applicative projects. He was coordinator of 15 national and international educational, research and applicative projects. His research interests focus on distance education systems, algorithm design, distributed environments, ambient and assisted living systems and connected health systems.

Eftim Zdravevski, MSc, completed his master studies in data mining in 2010 at the Faculty of Electrical Engineering and Information Technologies at the Ss. Cyril and Methodius University in Skopje, Macedonia. In March 2011, he started his PhD studies at the Faculty of Computer Science and Engineering in Skopje. From 2008 to 2015 he worked at NI TEKNA – Intelligent technologies as developer-researcher where he designed and implemented information systems and data warehouses, and worked on fraud detection and other machine learning related projects. Since 2010 he works as teaching and research assistant at the Faculty of Computer Science and Engineering. He is a MENSA member since 2004. During his research career, he has published over 30 papers in international conferences and journals. His active fields of research interests are: big data, machine learning, data mining, cloud computing, expert systems, knowledge based systems, decision support systems, intelligent information systems, data bases and data warehouses, processing of sensory data, parallel algorithms, etc.