CHAPTER 5

Matching Requirements for Ambient Assisted Living and Enhanced Living Environments with Networking Technologies

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5.1 INTRODUCTION

The increase in medical expenses caused by societal issues like demographic growth and aging puts a strong pressure on the sustainability of the health and social care system. Alternative solutions are needed to cope with a sustainable quality of life for elderly people.

The concept of Enhanced Living Environments (ELE) proposes broadening the concept of Ambient Assisted Living (AAL) to reflect more accurately the eco-system created by the combination of medical and ICT services. It aims at the prolongation of a self-conducted life of assisted persons, reducing the dependency on intensive personal care to a minimum. Thereby, it increases the quality of life for the affected group while substantially decreasing the costs for society and supporting ever-more increasing requirements coming from different stakeholders. ELE encompasses the latest developments associated with the Internet of Things, towards services designed for a better help and support for people, or as a general term, to better live their life and interact with their environment.

Both, in AAL and ELE, a multitude of heterogeneous services, involving different stakeholders, have to interact via a common network environment. Hence, infrastructures have to become pervasive, supporting an increasing number of distributed devices that will need to communicate

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between themselves, as well as with centralized communication endpoints. In the context of mobility, temporary co-location of devices will be exploited to build dynamic networks, without a pre-structured infrastructure, or to complement existing communication infrastructures with ad-hoc ones. The current networking infrastructures are mostly based on the Internet, and were not designed to support the varying requirements for the dynamic interaction processes between human beings, sensors and systems, e.g. in a machine-to-machine communication style. Host-based addressing is the foundation of the Internet, however, it cannot simply scale to support the dynamic connections being established, sometimes opportunistically, between various wireless devices and corresponding health services. The content itself is dynamic, thus the infrastructure has to be both flexible and content-driven, or at least elastic in nature.

Thus, AAL/ELE services need highly scalable, flexible, and dynamic networking infrastructures to cope with such requirements. This is where we witness today a raise in interest towards the use of novel technologies, like Software Defined Networks (SDN), Network Virtualization, Cloud platforms, and many others. However, the wide adoption of such technologies for the benefit of AAL/ELE has little been studied up-to-now.

The contribution of this article to understand the technological barriers hindering the widespread real-world usage of AAL/ELE systems as mentioned in Memon et al. (2014), and to identify technologies which may help to overcome them. The book chapter is structured as follows. In Section 5.2 we briefly review the application domains of AAL and ELE. Domains, applications, and stakeholders are summarized and characteristics are inferred and exemplary illustrated for the use-case *closed loop healthcare*. Section 5.3 highlights the underlying communication architecture. Based on these discussions, requirements for AAL/ELE applications are summarized in Section 5.4, while available and upcoming networking and inter networking technologies are analyzed based with respect to these requirements in Section 5.5. Key derivations are discussed in Section 5.6, and the chapter is concluded in Section 5.7.

5.2 CLASSIFICATION OF AAL/ELE DOMAINS AND APPLICATIONS

The environment in the AAL/ELE domain is very diverse and heterogeneous. This concerns the application side as well as the various involved participants. To illustrate the challenges in such an environment we highlight the following AAL/ELE examples.

The first example highlights self-monitoring of health parameters. The patient stays at his/her home, where (s)he measures parameters like weight, or metabolic age or fat percentage on a digital scale with a body analyzer. The device is connected to a personal eHealth Gateway, where a Personal Health Record (PHR) instance resides. The data are transmitted in regular time intervals to the gateway and saved in the local PHR. To achieve resilience of the monitored data the eHealth Gateway distributes copies at trusted PHR mirrors, e.g., maintained by relatives of the patient. The data is accessed to investigate time series and trends of the monitored parameters. Here, the patient and relatives are the main actors involved, and it involves a privately-owned data network.

The second example involves the integration of medical data originating from various sources. Such data sources can be divided into different types, depending on who manages the data within the system. One type of data sources are Electronic Health Record (EHR) and Electronic Medical Record (EMR) systems, where medical data is managed by the medical personnel. Other types can be the aforementioned PHR systems, where the data are managed by the patient. Another type of data sources could be the PHR systems, where it is the patient who manages the data. It should be noted that such a scenario is focused on integrating the medical data, which is located "somewhere" in the network and can be stored in multiple copies. In this case, the patient shares his/her data with other users in the network through setting adequate content access rights. After that, such data can be downloaded by a doctor, analysis services or medical systems with which the patient (the owner of the information) wishes to share his health data.

These examples illustrate, that monitoring data of patients gathered by heterogeneous sensors play an essential role in AAL/ELE. Various AAL/ELE stakeholders own or have access to different sensors and monitored data. This data has to be shared between the different stakeholders to generate additional value. These interactions between the stakeholders may occur in regular intervals, event-based, or on demand resulting in a dynamic interaction process. Further, the examples highlight different involved domains, the medical domain and the home domain.

In the following, we want to broaden this view on AAL/ELE involving the main application scenarios and stakeholders from our point of view.

For that, we distinguish between four application domains: (i) medical domain which deals essentially with medical health data and thus imposes dedicated requirements on systems and processes; (ii) care domain which focuses on specific services to support the daily life for people with special needs and requirements; (iii) lifestyle which describes further non-critical services to support daily life; and finally (iv) safety & security which includes dedicated monitoring and control functions at home to improve the safety of people with special needs. The different domains are highlighted in Table 5.1.

In relation to these domains, the following potential stakeholders are considered: (1) AAL/ELE customers (e.g. elderly persons), (2) physicians, (3) caregivers, (4) family members and friends, (5) public authorities, (6) service providers and (7) sensors. We extend the definition of stakeholders presented in Rashidi and Mihailidis (2013) by family members and friends, public authorities and sensors. The latter one is referred to as a passive stakeholder. Other possible stakeholders in the AAL/ELE context such as manufacturers and advocacy groups are omitted. These stakeholders represent a heterogeneous group in the AAL/ELE environment, ranging from customers in AAL/ELE systems to experts who monitor, guide or help people, and sensors that record or pass on information to other people. All participants have different system requirements and usage purposes. A comprehensive analysis of actors and stakeholders can be found in Nedopil et al. (2013).

Based on the specific scenario and the corresponding AAL/ELE function we identify the stakeholders that play an essential role. The resulting classification illustrated in Table 5.1 is discussed in the following. AAL/ELE customers affect all domains. Experts like physicians or caregivers are primarily relevant to their expert area. Family members are active primarily in the care domain and lifestyle. Public authorities are involved in the regulation of health care systems. Service providers and sensors can be found in all application domains.

The next sections provide a description for each domain and discuss the resulting challenges for today's ICT systems. Further, we characterize the domain by defining different key attributes: (1) the actors involved, (2) the required services for the operation, (3) the required architecture and (4) general system requirements. Based on this analysis, we detail a specific AAL/ELE scenario, namely patient monitoring.

Table 5.1 Domains and involved stakeholders. Stakeholders which play an essential role for an application domain are marked with an "x"

	Customer	Physicians	Caregivers	Family and friends	Public authorities	Service providers	Sensors
Medical domain	x	x			x	x	x
Care domain	x		x	x	x	x	x
Lifestyle	x			x		x	x
Safety & security	x			x	x	x	x

5.2.1 Involved Domains and Key Attributes

In the following we discuss the presented application domains in detail.

Medical Domain

One of the main applications in the eHealth and AAL context is telemedicine. The main driver which differentiates this kind of service from any other service classes is the inherent treatment of personal medical health data. The main focus is to support health treatment processes through telecommunication services so that physicians can deal with patients separated in space and time. Collected vital parameters of patients can be monitored online, anytime, anywhere, on any device being used by physicians. Further on, electronic systems can analyze trends and correlation of collected health data such as blood pressure, glucose level, weight, mental activity, or physical fitness and thus offer additional information for physicians to improve health care processes for both the patient and the physician. Additionally, a physician has the possibility to get in contact with the patient by different means like, email, text messages (pre-defined messages, free text), chat, phone service, or even multimedia based communication services.

For the collection of health data, different sensors are used. Sensor networks such as body area networks and home networks are important building blocks of a telemedicine platform. User identification, privacy and security and finally usability are essential service features to be considered. At the physician side data representation, user-interface and interoperability with other health applications and even legacy systems are important issues to be considered.

The treatment of medical health data imposes stringent requirements on the system design and implementation processes driven by privacy and security requirements and could even go to medical product validation processes.

Finally, it is important to note, that next generation health services based on digital platforms have to support interoperability and close interworking with further applications and users from other domains like care givers, insurances, etc.

Care Domain

This domain summarizes applications for the care and welfare of people. It includes the daily care of elderly people and the care of people with specific requirements, conditions and even diseases. Thus, services and data from the medical domain are of basic importance for the care domain as well to implement health monitoring and health treatment processes.

In addition to that, additional services to support individual care for social, mental and physical fitness, even physical security, are important functions in the care domain. Hence, beside the typical vital parameters, more general parameters like the personal feeling and the movement patterns of the assisted people are of interest. Monitoring the actual situation of a person at home (fall monitoring), prevention of dangerous situations (fall prevention, alarming of different events), nutrition motivation and support, and even support for the management of the daily living are functions which can be supported by next generation communication services.

Further on, easy to use communication services with other stakeholders such as family members, friends, care organizations, and public authorities extend the requirements for the ICT platform by a broader usage of interactive multimedia services.

The following applications may be seen as a relevant subset of applications in the care domain:

- care services of daily life without a physician involved
- care for mental and physical fitness
- care for diseases (dementia, alzheimer, etc.)
- monitoring and stimuli for nutrition, drugs, etc.
- services for motivation of elder people and social care such as social interaction via interactive multimedia services (chatting with other people, singing, playing games, etc.)
- monitoring dangerous situations at home and habits by sensors and remote management of different functions at home (smart home)

Lifestyle

Another field of application are services for living and lifestyle. In addition to the domains mentioned above, entertainment services like TV and interactive multimedia are vital services that represent a high share in the daily use. This category contains also all the helping functions in coping with daily life, such as shopping and performing of administrative procedures and the handling of everyday activities.

Since a non-discriminatory and inclusive usability of communication services is one of the essential requirements of any public service, also in the AAL/ELE context, dedicated services from public authorities have to be offered. Especially ill or elderly people have specific needs for information and services from the public. This imposes additional system requirements on usability, data provisioning and interoperability on existing services in the eGovernment and smart city context. Some examples in this application domain are:

- communication and social networking
- interactive multimedia and TV services
- electronic tools for the needs of everyday life such as electronic shopping aids, assistance with administrative formalities and use of e-Government services, guidance in cities, parks, and other public places.

Safety & Security

This category includes services that contribute to the safety and protection of elder people. The category includes also services that may need to work outside the home such as activity monitoring for family members and dedicated monitoring services to prevent dangerous situations, such as the monitoring of oven and gas in the kitchen or the front door.

The following services may be considered as a relevant subset of services in this domain:

- status information for family & friends (location of people, social activity, etc.)
- warning/alarm services (gas, electricity status, etc.)
- identification of abnormal situations

Applications in this domain may provide critical data for other domains, e.g., in the event of an alarm or warning.

Summary

The different domains involve various actors, require diverse network services and network architectures and have to consider different criticality of the data for transmission and storing. The following system requirements can be summarized:

- Actors in the communication process: Different actors (physician, patients, family members, care giver, etc.) will use the system at the same time, imposing different requirements on the technical platform with respect to QoS parameters, real-time behavior, or sensitiveness of data.
- Required services: (real time) Monitoring of the user by sensors and wearable devices, bidirectional communication services, monitoring of specific events, data collection functions, and alarm service infrastructure.

- Required architecture: body area network, home network, data collection function, and access to a network service.
- System requirements: flexible communication services for patient-physician interaction, customizable user interfaces (treatment specific defined by a physician), reliability and accuracy of sensor data, increased privacy.

5.2.2 Closed Loop Healthcare as Typical AAL/ELE Application

The goals of any closed loop healthcare system (Modre-Osprian et al., 2014) including patient monitoring are: (a) a high recall in detecting emergencies immediately; and (b) high precision, to prevent invalid emergency detections and alerts as a consequence of misinterpretations. Requirement (a) is mandatory to provide a trustworthy service quality to the affected persons in case of emergency situations. Requirement (b) is essential for economic reasons, since invalid emergency alerts may unacceptably increase care costs and decrease trustworthiness. Further, it is desirable to extend a pure emergency detection service by an emergency prediction service, which attempts to recognize a critical health condition before it escalates into an emergency. As a reaction to the detection of such critical situations, the service may assist the person in preventing the emergency, e.g., by suggesting appropriate medication.

In general, closed loop healthcare involves periodically transmitting routine vital signs and, in some cases, alerting signals when vital signs cross a specific threshold. Depending on the type of usage and the specific environment, the accuracy of the monitored data may vary. Additional functions like the data recording and analysis may allow to trace anomalies, and to infer specific illnesses. The current work done in closed loop healthcare includes, among others, home monitoring (Lee et al., 2000), wireless systems for digitized EKGs (Khoor et al., 2001), hospital-wide mobile monitoring systems (Pollard et al., 2001), mobile telemedicine (Hung and Zhang, 2003; Pattichis et al., 2002), and real time home monitoring of patients (Mendoza and Tran, 2002).

A variety of approaches previously made attempts to address the issues of reliable and efficient message delivery from deployed sensors to central processing units (an analysis is shown in Braem et al. (2008)). The problem is finding a trade-off between reliability and energy efficiency, because any closed loop healthcare system will need to maximize the amount of delivered messages, with minimum energy consumption. In an ad-hoc environment, the success of message delivery is not only related to the consumed power, but also depends on the cooperation of neighboring devices. As specified in Varshney (2007), it is impossible to use a single method to coordinate multiple entities in a dynamic and complex environment. Apparently, closed loop healthcare has become an interdisciplinary topic and needs more intelligent technologies than other subjects (e.g., artificial intelligence). For example, the Ambient Cardiac Expert (ACE) monitoring system (Gondal et al., 2007) is a cardiac closed loop healthcare system which collects physiological data observed by sensor networks (together with gene expression data) to predict the heart failure rate. Clinical data monitored by attached sensors on patients' bodies is used to generate training data to predict the odds of heart failure.

Hospital Domain

For the use-case closed loop healthcare, physicians are typically interested in the monitoring of time series of sensor information in high accuracy. Thus, they are able to track problems, and even identify specific illness. Further, detailed logging information of the environment and the data monitoring have to be recorded to fortify the confidence of the data.

Although the usability of applications and corresponding sensors is an important feature, physicians put the accent on accuracy and traceability of the available data set.

Care Domain

Care givers are more interested in periodical information, to be able to react if something is happening. Sensor accuracy has not be so high since it does not aim at identifying specific illnesses, but to be able to react if problems occur. Further, emergency predictions may be of interest.

Sensors and actors should not be perceived by the end-user in the care domain, since they typically aim at long-time monitoring of health parameters. In case of alarms, care givers are able to check health parameters of the elderly fast and uncomplicated. Hence, the involved stakeholders in the care domain may prefer usability over accuracy and reliability.

Lifestyle

Patients use monitoring apps for actual self-check. In most cases, they are interested in their current condition, e.g., after running, or a short time series showing for instance the cardiogram in the last 30 minutes.

Accuracy in such cases is not so important, as the user/patient cares only about a rough trend of the result. Typically, he is not interested in the exact value, but in a specific interpretation like the current condition on a qualitative scale, the raise of a problem, or he wants to know if regularly training enhances his pulse frequency. For that, the end-user places a large accent on usability.

Safety & Security

Taking safety and security into account, the end-users are mostly interested in an identification of emergency situations. This includes suddenly occurring emergencies like falls or accidents, and impending dangers like deteriorating health parameters, which might be prevented with an appropriate emergency prediction. Further, spouse and relatives may profit from telemonitoring services, since they are able to check the health condition of their loved ones.

Sensors and applications have to be integrated in the daily life of the elderly resulting in high usability demands. Accuracy and reliability of the system are also of high importance, since relatives or emergency services are typically not on site and can check the state of the end-user.

5.3 COMMUNICATION SERVICES TO SUPPORT AAL/ELE INFRASTRUCTURE

Within the above-mentioned domains, communication services between the different actors are an integral and crucial part of the entire AAL/ELE system. Involved networks includes body area networks, sensor networks, middleware in the home network, the wide area network as well as local networks at the involved actors. The various stakeholders, their individual actors and the networks are shown in Figure 5.1. Communication between the devices in body area networks and sensor networks is done based on Machine-to-Machine (M2M) techniques (Chen et al., 2014). Available data like EKG, blood pressure and temperature is typically transmitted to data collection functions using local wireless technologies (e.g., WLAN, RFID, ZigBee) or via cellular networks. Such technologies are at the heart of projects such as eMotion ECG or TruVue, and are used to monitor, for example, an elderly's well-being and detect critical situations that prompt care givers take actions (Park and Jayaraman, 2007). The data is usually sent from the patient, using a combination of point-to-point and point-to-multipoint networking technology, to a central repository. The communication layer

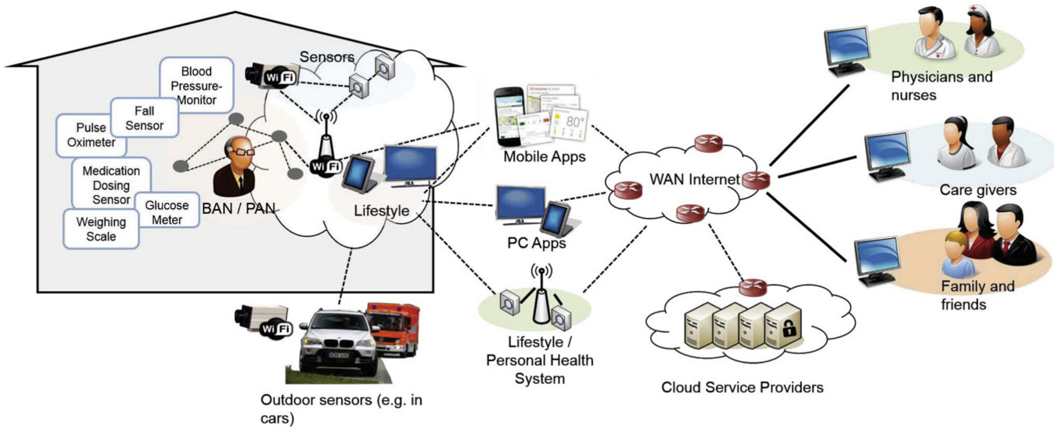

Figure 5.1 The different actors in AAL/ELE require an adequate network infrastructure.

needs to combine cross-layer management with underlying transfer mechanisms, over transmission protocols.

In addition, multimedia equipment like smart TVs and other user equipment communicate using fixed or wireless networking technologies. Specific middleware and set-top boxes are additionally integrated to provide AAL/ELE services as well as typical network functions like connectivity, Network Address Translation (NAT) or firewalling. Users and AAL/ELE services are further connected to actors in the medical and care domain, as well as to the typical consumer services like entertainment.

We understand an ICT-based AAL/ELE system as an ICT platform which supports independence, increases safety and supports health care for people with special care needs. This includes any person which can be served by smart networking techniques that can ensure an easier and safer living at home. Thus, a next generation AAL technology platform has to support the needs of a broad range of applications and their context and requirements, offering services and supporting a wider set of potential stakeholders. In particular, the AAL/ELE networking infrastructure has to be adaptable to incorporate AAL/ELE application demands and extensible to integrate a wide range of requirements coming from stakeholders.

To better illustrate Figure 5.1, we refer to the closed loop healthcare scenario. A patient wears trendy and non-intrusive sensors, usually in the form of smart bracelet (that features built-in electrodes or biosensors for reading and recording single-channel electrocardiogram (ECG) and temperature measurements, and time and location). The wearable device sends monitoring readings over short- and medium-range communication (i.e., using WiFi, Bluetooth, or ZigBee). If the users also carries a smartphone, the bracelet would connect with it, and in turn the smartphone becomes a communication hub, sending the data out towards a processing unit (via broadband communication, i.e., 3G or 4G). Otherwise, the bracelet still is able to send the data out whenever an opportunity occurs (e.g., whenever a WiFi Access Point is encountered).

On the Cloud/processing side, each patient is described by a patient/medical/psychological profile (e.g., an electronic health record). When the patient uses the medical service, the data from the smart bracelet is used to learn/construct this record (e.g., his daily walking routine is linked to his typical ECG rhythm — a medical profile of the patient, what is considered for this patient to be "normal" medical condition).

This personalized medical model of the patient can be further used to detect unusual situations — e.g., when his heart rate gets off the charts (i.e., by comparison with the medical profile) an alarm can be raised to the care giver. His usual medical record can be used by his physician to identify a possible health problem and to establish a personalized medical pro-active treatment to prevent possible health conditions in the future).

For this example scenario, the medical service just described has to put the patient entirely in control of his personal health data. The patient should be able to control what data/alarms can be seen by whom, or what data is to be sent to which end user. This separation between end users leads to a better control the medical data. For example, the patient might feel more secure if he does not show his current location to everyone in the family (for privacy reasons), but only shares it with his care giver.

Figure 5.2 depicts the standards and organizations working on enabling the introduced scenario as introduced by (Drobics et al., 2012). Different standards specify communication protocols for data sources and sensors, application host devices, WAN devices and health reporting network (HRN) devices. The multitude of available standards and frameworks results in a complex environment making it difficult for end users to pick the right products for his needs. Organizations like the Continua Health Alliance aim at providing a survey of interoperable products and supporting the end users.

5.4 REQUIREMENTS OF AAL/ELE APPLICATIONS

In the following, we derive general requirements that are imposed on the technical infrastructure by AAL/ELE applications. It is based on the classification and characterization conducted in the previous sections.

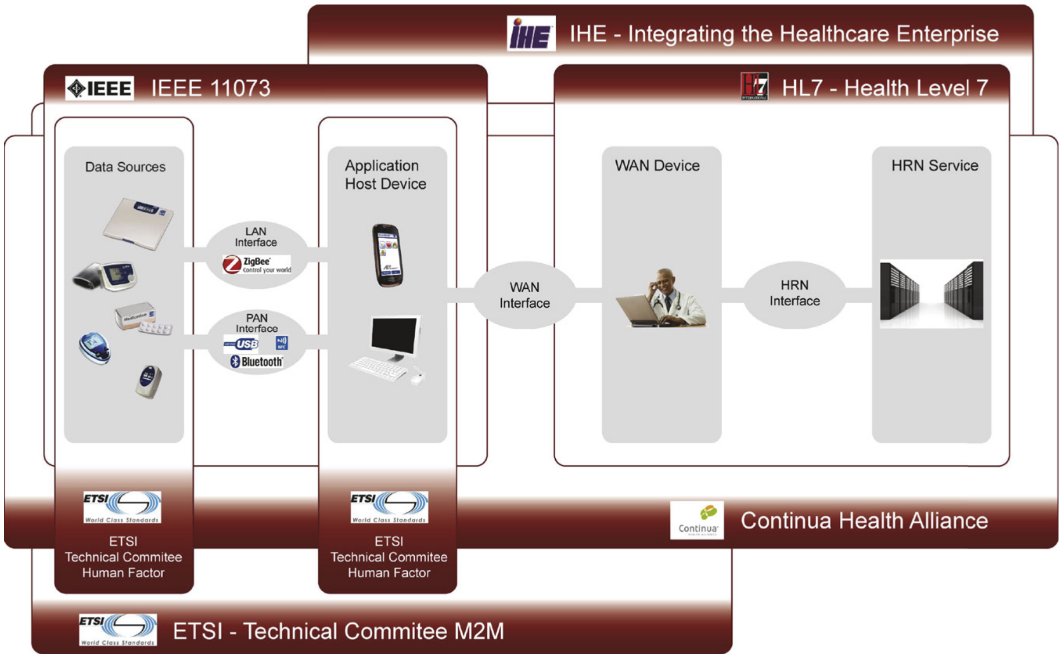

Figure 5.2 Technical overview of relevant standards and involved organizations.

Requirement 1 (SLA): AAL/ELE Need Dedicated Service Level Agreements (SLA) Between Actors and Network Service Provider

With respect to the many different and diverse AAL/ELE applications, we have to differentiate between the following communication service classes, which impose different requirements on the network:

1. Exchange of data, e.g., medical health data;
2. Real time communication, either as peer-2-peer communication or multi-peer communication based on voice, video and data;
3. Sensor data exchange — M2M communication;

The requirements of these applications have to be mapped to the underlying technical parameters of the system infrastructure, e.g., network Quality of Service (QoS) parameters like maximum bandwidth, minimum jitter, maximum packet loss or the average packet delay. In many cases, however, it may be sufficient that an upper limit for the provided QoS is ensured. For the example of health monitoring it is desirable that the transmission of data is done in a timely manner so that the transmitted information can be incorporated within the medical, simultaneously-held consultation. This provides at the network level the requirement for an upper limit on the packet delay. More general, in the next generation communication world, as exemplified by the AAL/ELE services, additional QoS parameters are becoming increasingly important. These are for instance the maximum end-to-end delay, and the reliability/availability of the service:

- Maximum end-to-end delay: this means that all parts of the system infrastructure have to be considered. A notification of a sensor may traverse different networks until it is processed and an appropriate action is triggered. Hence, this includes the transmissions and processing delays of the involved components.
- Reliability/availability: This includes the awareness of the status of the system and its components, e.g., the application has to know, whether a sensor is active or not, or whether the generated data is valid or not.

The heterogeneous environment and the huge variety of AAL/ELE applications exacerbate the fulfillment of these requirements. This includes varying channel conditions of wireless technologies resulting in bandwidth bottlenecks or energy-saving mechanisms of mobile devices increasing the delay.

In addition to the QoS requirements as summarized above, AAL/ELE applications stimulate additional system requirements, which are essential for achieving real added value for the end-user and the different stakeholders in the communication scenarios. These requirements are presented in the following.

Requirement 2 (Costs): Low Upfront Infrastructure Investments for the User's Premises Equipment

This requirement highlights the need for re-usability of existing network elements like Set-Top-Boxes, home gateways, smartphones, tablets, or special purpose devices for the different application scenarios. The different services should be independent of the final HW/SW platform, and the system should adapt the user interface to the device capabilities. This allows a step-wise introduction of different AAL/ELE services and is the basis for a positive business case per service. Thus, remote maintenance and service update mechanisms of the network elements in the home network will be important functions. Initial attempts are TR069 or the OSGi Alliance supporting the "dynamic download of Apps", meaning the support for integration of dynamic software components (often called bundles) into AAL platforms. Adaptation and extensibility are important properties of AAL/ELE platforms: Consider a platform being installed on the house premises of an elderly to support him with various activities. The platform includes the programs to support specific functions (remind the patient about medication, supervise some activity, etc.). However, in the future, we would want the platform to add additional functionality (i.e., the patient develops new symptoms for which additional support is required, or the family want to add additional monitoring sensors, etc.). The "dynamic download of Apps" is all about creating the infrastructure with minimum functionality (i.e., low upfront investment), and have the possibility to support dynamic download and execution of additional software components in the future, when and if needed.

Requirement 3 (Usability): Intuitive User Interfaces, Enhanced Usability Due to Self-* Capabilities and Easy Operation/Configuration of the Service

Usability is essentially important for two reasons: (i) on the one hand to support the requirements of handicapped end-users (ill or very old); but even more important, (ii) to ensure a very high data accuracy. We refer here to two aspects: First, it is the usability of the user interface, which is an important feature of AAL applications, since most end users (including the medical personnel) may not be familiar with the use of technology. Second, there is the data accuracy, which is highly relevant for usability. If a data item from a sensor is not valid according to the process definition, the corresponding information is potentially rendered useless. This also includes usability issues related to the configuration and setup of the AAL/ELE application and easy maintenance.

For the medical area, the usability requirement further addresses the appropriate representation of the data. This is required to get the relevant information with added value for the user. Further, the demands for data set accuracy are more stringent, i.e., to missing or changed data.

Requirement 4 (Security): Privacy and Data Security to Implement Different Security Levels for AAL/ELE Services

If specific security levels have to be defined and even validated, dedicated network architectures have to be defined beforehand to do so. For instance, the patient's vital parameters have to be transported via the network without any related to the actual identity of the patient.

Requirement 5 (Sensor Interoperability): Sensors — Interoperability for Data Collection

Many different types of sensors or even special purpose equipment from different markets and industries like health, care, smart home, smart grid, entertainment, games, or business, request an interoperability of the different sensor devices within the home network. This includes also wearable devices connected in a personal area network or sensors interconnected by a home LAN. Despite the interoperability of sensors with each other this foremost includes the interoperability between sensors and a data collection function in the home network. The data sources must have different interfaces ranging from the analogue signal to wired and wireless interfaces. Accordingly, appropriate adapters have to be defined. It is important to note, that it is not clear if sensor data has to be immediately converted into a common format at the sensor or only in a "transferable" signal; e.g. an analog signal into a digital signal. The processing of the data is then performed at a later stage at a server somewhere in the network.

Requirement 6 (Data Characteristics): Sensors — Data Transmission Characteristics

Based on application requirements data will be sent a) continuously in a well defined order, or b) only when specific levels are passed or events happened, or c) only if requested by a user. By this, the amount of data to be transported will be limited, saving networking resources but contributes also to the privacy requirement. The network, however, has to be able to support specific requirements of the sensors like guaranteed delivery or a maximum latency.

Requirement 7 (Application Interoperability): Interoperability at Application Level Between Sensor Devices and Back End Systems

Data generated by sensors in the home network has to be exchanged with back-end systems. Dedicated standards have been developed for ensuring this interoperability above network level like DICOM, IHE, HL7, and/or Continua (Rogers et al., 2010). For a more detailed analysis of such standards, their roles and challenges for interoperability, we further refer to Moorman (2010).

DICOM (or, Digital Imaging and Communications in Medicine) is a standard for handling imaging data. The standard assists communication between various image based modalities and accessories to each other. It provides reliable protocols for integration of image data between imaging, nonimaging modalities, devices and systems. The functional elements broadly comprise of Protocols, Objects, Services, Service Class and Conformance (National Electrical Manufacturers Association and others, 1993).

For managing non-imaging data, HL7 (Health Level Seven) provides protocols for exchange, management and integration of clinical and administrative electronic health data. Health Level Seven is considered by many as the accepted global standard for exchange, integration, sharing and retrieval of electronic health information in Hospitals.

IHE (or, "Integrating the Healthcare Enterprise") is more of a strategy to integrate various health-related workflows, using standards such as DICOM and HL7 (or, as Henderson et al. (2001) defines, it is a "multi-year initiative that creates the framework for integrating applications, systems and settings across the entire healthcare enterprise"). IHE accomplishes the integration by a four stage process: a) interoperability problem identification; b) integration profile specification; c) implementation and testing and d) integration profile conformance statements (Kuperman, 2011).

5.5 NETWORKING TECHNOLOGIES AND THEIR IMPACT ON THE AAL/ELE REQUIREMENTS

This section highlights the drawbacks of current networking infrastructures, and discusses why they do not meet the requirements of AAL/ELE services. Afterward, different networking technologies and paradigms, seen as building blocks for a future Internet, are presented. The focus of this section is on the question whether network technologies today can meet requirements of future ALA/ELE infrastructures. The results are summarized in Table 5.2.

Drawbacks of Current Networking Infrastructures

AAL/ELE services rely on the use of current telecommunication infrastructures, such as mobile and fixed telephone operator networks and the Internet. The Internet itself was built around a "best-effort" philosophy, meaning that no guarantees are provided concerning the data transmission. For many services, this is acceptable when no specific QoS requirements have to be fulfilled, enough network bandwidth is available or the applications don't generate high volumes of data.

Different strategies are available to deal with the "traffic management problem" beyond best effort in networks. This includes over-provisioning, reserved bandwidth — either on physical links based on transmission technologies like WDM or dedicated IP protocols like RSVP —, priorities — e.g. Ethernet priority bit or priority fields of the IP —, or flow-control mechanisms between sender and receiver. For traffic management reasons, even dedicated network architectures are implemented by network operators like the well dimensioned IPTV network infrastructure. The IP-based

Table 5.2 Impact of specific technologies and functionalities on the defined requirements. ** denotes that the requirements can be fulfilled completely, * that the provided functionalities may provide a significant improvement towards the fulfillment of this requirement.

	SLAs	**Costs**	**Usability**	**Privacy/ security**	**Data inter-operability**	**Sensors**	**Application interoperability**
DSFs		*	*		**		**
Network virtualization	*			*			
SDN	*	*	*	*		*	
Application-awareness	*	*		*		*	
Cloud/NFV		*					

IPTV service is based on a network infrastructure separated from the "public" Internet network elements to ensure proper system performance. This differs to the progressive download of video packets used to transport a video stream over a best effort network service like Apple-TV. Here the application level implements additional mechanisms to cope with best-effort network behavior.

Although these techniques may address at least some of the introduced requirements, they have several limitations resulting in a limited deployment and market acceptance. Among these are the missing support of content-centric networking, security, end-to-end QoS support via different network domains, Interdomain Name-Based Routing, or the IP hourglass bottleneck.

Dynamic Software Frameworks (DSFs) to Support AAL/ELE

Such software frameworks provide a dynamic component model, where application and components (called bundles) can be dynamically integrated and removed without a reboot. Communication between the components is typically realized using an abstraction layer. This allows the flexible and easy interconnection of appliances and devices in a home network. Examples of such systems are the specification by the Open Service Gateway initiative (OSGi, OSGi Alliance (2015)) and the flexible Smart Home service delivery platform provided by the Home Gateway Initiative (HGI, Rogers et al. (2010)).

The OSGi specifications standardize secure and reliable service delivery and provisioning, for remote life cycle management of services, and for bridging different networking standards. Applications and components, coming in the form of bundles for deployment (or plug-ins), which are tightly coupled, dynamically loadable collection of classes, jars, and configuration files. OSGi was originally conceived to be a gateway for managing smart appliances and other Internet-enabled devices in the home. From there, several efforts continued towards adopting OSGi as an open and standard platform for telematics services, with applications ranging from mobile phones to the open-source Eclipse IDE. Various OSGi-based middlewares, like Sensor Node Plugin System (SNPS) (Di Modica et al., 2013), the Alcatel Lucent's M2M E2E solution, and others, look at sensors and services able to be used and composed over the Internet, providing support for composition in complex applications.

OSGi, however, provides limited interoperability support. For example, in SNPS, Base Stations (BSs) implement the logic for locally managing several attached sensors. Many such BSs may be attached to different physical networks, but in this case the communication between the two bundles are implemented as Remote Services (R-OSGi). This means, that independent services have to be developed by a BS manufacturer to provide the bridge between proprietary protocols and a SNPS allowed data format. R-OSGi provides for this a specific OSGi bundle, offering the support for remote communication with other bundles living in different runtime contexts. The resulting communication between come at the cost of additional complexity in the application development.

Hence, other initiatives addressing the interoperability between different technologies emerged. One such initiative is the Home Gateway Initiative (HGI), who aims at providing ways to deliver services in the digital home. HGI is an open forum launched by a number of telephone and manufacturing companies in 2004, with the aim to release specifications of the home gateway. The initiative takes as a basis the work undertaken within existing bodies such as ITU-T, Broadband forum, DLNA, or OSGi Alliance. It aims at producing requirements for a residential gateway enabling end-to-end delivery of services. To ensure interoperability it closely works together with manufacturers.

At the basis, a universal template facilitates interworking between home devices and smart home applications. This universal template is a component of a logical abstraction layer used to provide smart home services to broadband consumers. The aim of the abstraction layer is to allow smart home applications authored by different companies to easily connect to devices using one of several smart home interface technologies. The applications do not need to know which interface technology is used, but only the device capabilities that are described in the template. The home gateway (HG) plays a central role in the digital home, interconnecting computers, devices on the home network, and the Internet, all while supporting Quality of Service and remote management. Service providers are increasingly looking to deliver HG-based consumer services such as energy management, media server, and home network diagnostics. Pairing the dynamic and modular OSGi technology with HG-specific Application Programming Interfaces (APIs) and protocols will greatly extend the service capabilities of the home gateway.

In 2009, the OSGi Alliance and the Home Gateway Initiative (HGI) made a partnership to enable broadband service providers to offer more flexible applications to residential customers. Under the agreement, OSGi

Service Platform will eventually be integrated into the home gateway, creating a software execution environment that will facilitate the deployment of new service capabilities into the digital home.

Different other initiatives and projects rely on OSGi like Qivicon, also targeting at home networks, or UNIVERSAAL and OPENAAL (Wolf et al., 2010), both aiming at sensor nodes and middleware in the AAL/ELE context. The EU-funded UNIVERSAAL project aims at producing an open platform along with a standardized approach for making it technically feasible and economically viable to develop AAL solutions. For that, it defines and provisions a reference implementation of a platform that facilitates the realization of AAL systems.

Similarly, the joint open-source initiative openAAL develops a middleware for ambient-assisted living scenarios based on research results of several German and international projects. The goal is to have a platform that enabling the easy implementation, configuration and situation-dependent provisioning of flexible, context-aware and personalized IT services.

Impact on the Requirements: These technologies have an impact especially on interoperability of sensors and applications and may fulfill the requirements 5 and 7. Due to reusability of data functions and sensors in other contexts, the amount of necessary equipment and therewith the costs can be reduced, and the usability may be increased (requirement 2 and 3).

Network Virtualization

Network Virtualization (NV) enables the operation of multiple logical networks upon a shared physical infrastructure (Chowdhury and Boutaba, 2010). It permits distributed participants to create almost instantly their own network with application-specific naming, topology, routing, and resource management mechanisms. The role model includes physical infrastructure providers, virtual network providers and operators, and also application service providers and enables an automatic interaction between the different roles including brokering of virtual networks with certain SLAs (Meier et al., 2011). VN is thus seen as an enabler for application tailored networks with specific resource guarantees across multiple separated administrative domains.

Impact on the Requirements: NV may provide resource guarantees for a virtual network and enables the logical separation of different virtual networks and thus primarily addresses the requirements 1 and 4. It fulfills requirement 1 as long as the involved applications are well-known and can

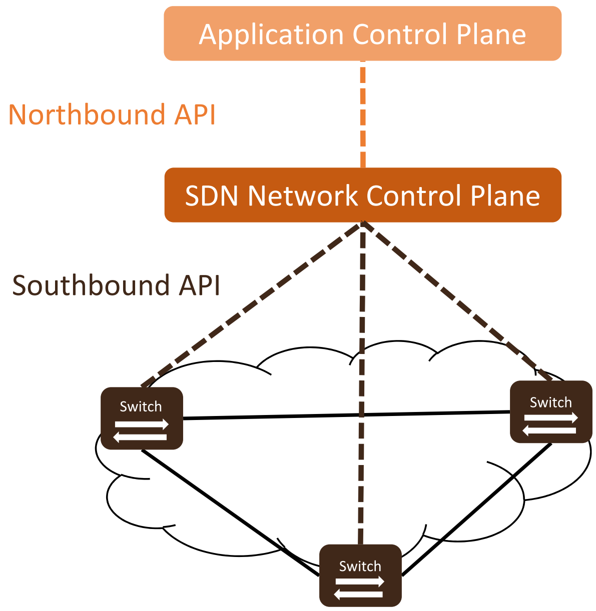

Figure 5.3 SDN Interfaces.

be controlled. Otherwise additional mechanisms are required to enable a control of specific applications within a virtual network.

Software-Defined Networking

The goal of Software-Defined Networking (SDN) is to increase flexibility and innovation in the network and, thus, to improve the efficiency of network operation and the service quality as well as lead to reduce of CAPEX and OPEX. This is facilitated by the removal of the network control plane from the distributed network devices to a logically-centralized control entity, which enables the introduction of new open interfaces between the application, the data-plane, and the control plane (Jarschel et al., 2014). With these interfaces, the network control plane can be realized as a freely programmable software, which can essentially be described as an operating system for the network. The network operating system, often called "controller", is responsible for all forwarding decisions within the network it controls. The network devices forward the traffic according to the rules set by the controller.

Figure 5.3 illustrates the relationship of involved control planes and interfaces. The "Southbound-API" represents the interface between data- and control-plane. Current SDN implementations often use the OpenFlow protocol (McKeown et al., 2008) as a realization of this interface. The OpenFlow protocol handles the communication between the individual network devices and the controller. Each of the network devices maintains a set of "flow rules" matching individual network flows in so called "flow tables". The term "flow" refers in this context to packets matching a general set of header fields either out of layers 2 to 4 of the ISO/OSI stack or headers defined by the operator of the network. Additionally, a flow rule contains a set of one or more actions that define how a packet matching the rule should be handled as well as flow statistics.

When a packet reaches an OpenFlow-enabled SDN switch, it is buffered and the packet header is matched against the rules in the flow table. In case of a successful match, the action(s) specified in the rule are executed. If there is no matching rule in the flow tables, the packet is either dropped or an OpenFlow "packet-in" message containing the packet header is sent to the controller for processing. The controller calculates the action the network element should take with regard to the packet and communicates it. Furthermore, the controller can specify a flow rule and send it to the network element(s). This way all following packets of the flow are treated the same way by the network and the controller does not need to be involved any longer.

The controller can also introduce new flow rules or modify existing ones without being triggered by an incoming packet. For example, the controller may adhere to a pre-programmed schedule or implement a network policy. This is where the flexibility of SDN comes into play. Where traditional network devices would have to be reconfigured by an administrator, SDN enables the automatic and seamless implementation of changes in the forwarding behavior of the network. These changes can be triggered by external entities via the other key SDN interface — the "Northbound-API". This interface makes application-awareness in the network feasible as it opens up a communication channel between the applications using the network and the controller, which can then utilize information provided by the applications to adapt its policy and the network traffic on different levels of granularity.

Research related to AAL/ELE aims at enabling a less complex management of home networks (Kim and Feamster, 2013) or a dedicated resource control for specific applications (Zinner et al., 2014; Jarschel et al., 2013).

Impact on the Requirements: SDN allows a dynamic, more centralized control of the network and its data flows and thus addresses requirement 1. The externalization of the network control plane reduces network equipment costs and impacts requirement 2. Due to the vendor-independent access to networking hardware usability is simplified (requierement 3). Additionally, SDN may also be used to separate data flows and to control network resources. Thus, it also addresses requirement 4.

Application-Aware Networking

Application-Aware Networking (AAN) is an approach to improve the service quality in networking scenarios with limited resources (Staehle et al., 2010; Wamser et al., 2014; Jarschel et al., 2013; Qazi et al., 2013; Ferguson et al., 2013; Huang et al., 2013; Georgopoulos et al., 2013; Thakolsri et al., 2009). Application needs are incorporated in the network management decision in a dynamic way. Thus, in the case of limited resources, a quality-related decision can be made that enhances the service quality.

For that, services are divided into groups with similar quality demands according to their requirements. The packet forwarding in the network is carried out in relation to these groups with regard to the available resources. The requirements are determined on the basis of application information. Application information are, for example, status of the application (e.g. idle, active, downloading, content synchronizing), type of application (e.g. chat, browsing, interactive application) or inherent application parameters (e.g. video buffer level, precaching ability). By monitoring the application information, decisions and actions are taken that affect packet processing, packet forwarding or the network settings. The aim is to better address critical applications and to distribute the traffic according to the actual requirements of the applications, i.e., by allocating more network resources to them.

A key component to realize AAN is application-specific monitoring. This application monitoring can be done on network entities inspecting the data packets (Wamser et al., 2014), or by passing relevant monitoring from the application to the network via specific interfaces (Zinner et al., 2015).

Impact on the Requirements: Based on application information, a better and more accurate quality-of-service agreement can be made (requirement 1). Furthermore, with respect to requirement 2, the targeted use of application information may help to distinguish between critical and non-critical applications, in order to reduce the utilization of resources and, ultimately, the costs. Furthermore, safety-critical applications might be detected on the network and can be specifically treated with the help of other networking technologies (requirement 4). Further on, by utilizing application information, the network might have the ability to better support specific requirements of sensors like guaranteed delivery or a maximum latency (requirement 6).

Cloudification/Network Function Virtualization (NFV)

Cloud Computing (Vogels, 2008; Fox et al., 2009) describes the idea of outsourcing computing power and storage in Internet data centers. Services or small devices are virtualized and pushed into the Internet, to work in large-scale datacenters. This allows to access an almost unlimited number of computing resources. For service providers, the cloud paradigm brings a good maintainability and the ability to scale the utilized resources on-demand with respect to their current requirements. For the AAL/ELE environment, the cloud paradigm can provide both scalability and energy savings as well as computing power to support of a large number of devices.

NFV in this context allows dynamic and programmable network functionality. Dedicated functions are virtualized, implemented in software, and executed on standard server hardware. Just as in the cloud, not only services on the Internet can be instantiated but also parts of the network architecture can be provided in a flexible way. Features that are present and written in software, can be used interchangeably on different hardware, which reduces costs.

The FP7 project Fusion (Griffin et al., 2014) particularly works towards cloud-like systems for interactive services and execution resources. To achieve this goal, design issue, necessary interfaces, and algorithms for dealing with service provisioning and scaling are discussed. In the area of AAL/ELE a dynamic provisioning of interactive services in the cloud might allow to transfer specific services from the user's premises to the cloud. The trend to utilize the cloud to centralize specific functions recently jumped over from the application domain to telecommunication networks, where it is known as NFV (Chiosi et al., 2012). Here, network providers want to leverage standard IT virtualization technology to consolidate data plane packet processing and control plane functions in WAN networks instead of using proprietary middleboxes. In the context of Cloudification/NFV, SDN is seen as an enabler for a flexible forwarding of data flows to specific virtualized functions and to allow a proper service chaining.

In the EU H2020 INPUT (INPUT Consortium, 2015) project, this idea is further contemplated. The aim of this project is to develop personalized cloud services. It means that for each user, an individual cloud application can be made available. Personalized services can better meet the exact requirements and can be specifically modified to meet the conditions of the individual person. An additional aspect that comes here into play is the better security in personalized, encrypted cloud instances.

Impact on the Requirements: The scalability provided by using and paying for resources on demand is seen as enabler to reduce capital expenditures for equipment and also the operational expenditures. Hence it primarily addresses requirement 2.

5.6 KEY DERIVATIONS

The above definitions and requirement analysis aims to create an understanding of the applicability of upcoming networking technologies for AAL/ELE. Although much research has been conducted, AAL/ELE systems have not made it yet to a widespread real-world usage. We argue that the corresponding technical requirements of operating such systems have not been fully understood yet. Hence, there is a lack of a clear identification of the requirements that are needed for assessing technical concepts for their suitability of AAL/ELE.

In order to provide an assessment methodology, we (1) identify four domains that essentially need to be taken into account in an AAL/ELE system. Furthermore, we (2) determine the corresponding users and actors that interact with each other. We (3) discuss possible application cases and define, based on the cases, (4) seven technical requirements which have to be fulfilled to ensure a proper market acceptance.

Following this, we investigated promising networking technologies, challenging whether they fulfill each AAL/ELE identified individual requirements. Our analysis shows that none of the existing technologies is able to fulfill all the presented requirements, i.e., that several technologies have to be combined to enable a proper acceptance of AAL/ELE.

Further, there may also be requirements which may not be fulfilled by one specific technology, but where several technologies might be combined, e.g., network virtualization, SDN and application awareness. The communication between the involved technologies, however, needs to be realized using open interfaces to enable fast innovation and adaptation of new technologies. We believe all these will need to be addressed in the near future, to advance properly the AAL/ELE domain towards its true market potential.

5.7 CONCLUSION

The increase in medical expenses due to societal issues like demographic ageing, puts strong pressure on the sustainability of health and social care systems. Different AAL/ELE technologies are today being developed, but systems do not yet take place at a relevant scale.

The chapter is a step towards a better understanding of the requirements of AAL/ELE, its domains and stakeholders. Based on an inductive approach we derived seven requirements highlighting the need for specific SLAs, a high degree of flexibility in the involved networks, and a good usability. In a second step we evaluated several technologies against the requirements and identified which requirements can be fulfilled by them. This approach can be adapted to help to classify other technologies and gauge the potential benefits of using them in the context of AAL/ELE. Their main features can be identified and weighted, and the implementation of the system can be planned accordingly.

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