INTEROPERABILITY IN AMBIENT ASSISTED LIVING (AAL)
Standardization of Sensor-data based on ISO/IEEE 11073

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Abstract: In the process of developing projects in Ambient Assisted Living (AAL), it is very important to avoid isolated and proprietary applications in the Information Technology (IT) infrastructure. Therefore standardization committees try to close the gap between these applications in developing appropriate standards for communication and software-architectures. The ISO/IEEE 11073 standard family and especially the standard specialization "ISO/IEEE 11073-10471, Independent Living Activity Hub" is the key for establishing interoperability in AAL. The scope is to establish a common software-architecture and communication between agents (any form of medical devices, e.g. Independent Living Activity Hub which represents a sensor network) and managers (software-tool for receiving data; e.g. sensor-data). Consequently the integration of different sensor-networks (agents) from different manufacturers to an ISO/IEEE 11073 manager could be achieved by plug & play interoperability if the agents are built up according to the standard guidelines. However, this study showed that it is possible to apply the standard to existing sensor-networks by designing the agent with appropriate mapping methods between manufacturer- and ISO/IEEE 11073 nomenclature. The flexible bodywork of the designed agent allows its application and use for specific sensor networks from different manufacturers without great effort, whereas the "once-implemented manager" can be applied for any ISO/IEEE 11073-10471 Independent Living Activity Hub.

1 INTRODUCTION

According to a study (Bundesministerium für Bildung und Forschung, 2009) about demographic change, Germany will have one of the oldest populations in the world by the year 2035. To prevent a sharp increase of social costs, products and new technologies have to be developed now. One approach is the possibility of enabling older people to have an independent life in their homes as long as possible. Ambient Assisted Living Technologies try to follow this objective in integrating intelligent assistance-systems in peoples' houses and flats. Modern sensor-techniques and IT-based evaluation of data, allowing the generation of behaviour pattern recognition, should support the safety of the inhabitants. In other words, current sensor-events are compared with predefined patterns and if the situation differs from normality an alarm will be triggered by the AAL-system.

In order to avoid isolated applications in this potential sector, international standards in IT-infrastructure and communication procedures should be used right from the beginning. So far mostly proprietary sensor systems are on the market, which are tailored to respective environments, user groups and use cases. The ISO/IEEE 11073 standard family for medical device communication aim at supporting the development of interoperable systems in the field of AAL. This study shows the relevance and benefits of the ISO/IEE 11073 for AAL-projects and in general. Moreover it shows how the standard can be implemented for existing sensor networks from different vendors that do not follow the standard guidelines on the part of the manufacturer.

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2 ISO/IEEE 11073 STANDARD FAMILY

The ISO/IEEE 11073 standard represents a standard for health informatics in the field of personal health device communication with the focus on establishing interoperability.

It has no special system requirements and therefore is not associated with nor limited to special hardware or software technologies or other protocols (McCabe, 2007).

The scope is to establish a common software-architecture and communication between agents (any form of medical devices or sensor systems) and managers (for instance personal computers) without focusing on the transport layer. Agents are collecting medical or behaviour-specific data about a person or the environment and transfer the information to the manager for data collection, displaying or further analysis. The information is available from a range of domains including disease management, health and fitness or ageing independently applications (IEEE Engineering in Medicine and Biology Society, 2008b).

The ISO/IEEE 11073 standards define both the bodywork of the agents and the communication-procedure between agent and manager. The individual agents are represented in specific device specializations (ISO/IEEE 11073-104xx, i.e. Independent Living Activity Hub, Weighing scale, Thermometer, Cardiovascular fitness and activity monitor), whereas the ISO/IEEE 11073-20601 presents the basic framework and communication for all agents. Generally the standard is applied on layer 7 of the ISO/OSI reference model and can be utilised independently of the medium of transmission.

The ISO/IEEE 11073-20601 ”Application Profile - Optimized Exchange Protocol” defines a common framework for an optimized exchange protocol as basis for all ISO/IEEE 11073 standards. It describes an abstract model for the bodywork of agents and constitutes a common communication procedure between agents and managers. So the purpose of the optimized exchange protocol is to provide the basis for supporting any type of agent.

The ISO/IEEE 11073-10471 ”Independent Living Activity Hub” represents the relevant device specialisation for the integration of smart home sensors in AAL-projects. Based on the Optimized Exchange Protocol this standard establishes a normative definition of the bodywork and communication between independent living activity hubs and managers in a manner that enables plug-and-play interoperability. In this context, independent living activity hubs are defined as devices that communicate with simple situation monitors (binary sensors), standardise information received from the sensors and provide these data to a manager (IEEE Engineering in Medicine and Biology Society, 2008a). Until now, this device specialization support the terminology of 10 sensor-types, which are shortly described in table 1.

Table 1: Supported sensors by ISO/IEEE 11073-10471 (IEEE Engineering in Medicine and Biology Society, 2008a).

Sensor-type	**Remark**
Fall sensor	Detects a person’s fall
PERS (Personal Emergency Response System) sensor	Detects when a ”panic button” is activated
Environmental sensors (e.g. smoke-, CO-sensors)	Detects any environmental aspect and generates a sensor event, if measurement is beyond a certain threshold
Motion sensor	Generates a sensor event, whenever it has sensed movement
Property exit sensor	Generates a sensor event, whenever it has sensed the exit of an occupant from the familiar environment (e.g. used for cognitive issues)
Enuresis sensor	Generates a sensor event when involuntary urination or bed-wetting is recognized
Usage sensor	Generates a sensor event at the start of use as well as at the end of use
Switch sensor	Generates a sensor event when recognizing a ”ON”- or a ”OFF”-state
Simple medication dispenser	Generates a sensor event when a dosage of medication has been taken or not within a certain time-period
Temperature sensor	Generates a sensor event when temperature has risen above or dropped below a certain level

3 MOTIVATION AND BENEFITS OF USING A STANDARD IN AAL

The main-objective of applying a standard in IT-infrastructure with special regard to medical devices is interoperability. According to IEEE (IEEE-USA, 2005), interoperability in healthcare does not only mean that healthcare systems must be able to communicate with one another, but also that they must employ shared terminology and definitions. Implemented systems should communicate in a way that systems "understand" each other and thus prevent the loss of information and allow the correct interpretation and evaluation of transmitted data. Standard Committees, like the International Standards Organization (ISO), provide standards to avoid isolated applications with their own communication structure and terminology.

The ISO/IEEE 11073 standards define a common core of communication functionality for medical and personal health devices and specify the use of term codes, formats and behaviours in a telehealth environment to favour plug & play interoperability (McCabe, 2007).

By establishing plug & play interoperability in AAL, new sensor-network solutions can be added to an existing manager without great effort. A standardised architecture and communication structure of both the manager and the sensor-network solution, which represents the agent, are prerequisites. As the communication flow always follows the same procedure and transmitted data have the same bodywork, one manager can be applied to more standard-conform agents. So the manager always receives data in the same format. As in AAL-technologies different sensor-types (see table 1) are useful, which are often not provided by one manufacturer, different data-formats have to be handled by the receiving system, if the sensors' communication protocols are not standard conform. Therefore the application of a common standard would close this gap and would enable plug & play interoperability of different sensor networks or single sensors.

Furthermore a standardised format would be a great advantage in AAL technologies for the implementation of behaviour pattern recognition algorithms and sensor data fusion.

Different Associations make an effort to spread and refine the standards. In case of the ISO/IEEE 11073 standards the Continua Health Alliance is leading. It is a group of technology, healthcare and fitness companies dedicated to establishing a system of interoperable telehealth solutions. These solutions should foster the independence of people to better manage their health (Continua Health Alliance, 2009). ISO/IEEE 11073 standardised sensor-networks can be certified by the Continua Health Alliance.

4 APPLICATION OF ISO/IEEE 11073 TO AAL

Generally, the ISO/IEEE 11073-20601 architecture consists of three models (parts), which interact with each another:

- the Domain Information Model,
- the Communication Model and
- the Service Model.

The ISO/IEEE 11073 family is based on an object-oriented systems management paradigm. Thus, data (measurement, state, etc.) are modelled in the form of information objects that are accessed using object access services (IEEE Engineering in Medicine and Biology Society, 2008b).

4.1 Domain Information Model

The Domain Information Model (DIM) defines the bodywork of an agent as a set of objects. Their attributes describe measurement data as well as elements that control the behaviour of agents. The DIM describes a hierarchical structure that represents all data an agent-device can communicate to a manager.

For the application of the Independent Living Activity Hub following classes of the ISO/IEEE 11073-20601 have to be implemented:

Medical Device System (MDS). Each Agent is represented by exactly one MDS-object. Its attributes define product-specific information, as well as the configuration of the agent and is primarily necessary for the identification of the agent at the manager. Moreover the MDS-class defines methods (services, events) for the data-access.

Metric Class. The metric class is the base class for numeric-, realtime-sa (sample array) and enumeration class, which represent the measurement-objects (Numeric, RealTime-SA and Enumeration).

Enumeration Class. An instance of the enumeration class represents status information (e.g. from a sensor), which is reported within an event report service. According to the specification all measurement-objects (sensor-event-objects) are instances of the enumeration class.

Considering this bodywork the class-architecture with its specific attributes has to be implemented. Each attribute of these classes has its own nomenclature and a specific data-type, represented in Abstract Syntax Notation 1 (ASN.1), which is described in detail in section 5. The nomenclature-definitions and nomenclature-codes (32-bit identifier) can be found either in ISO/IEEE 11073-20601, - 10101 or in the relevant device specialization. In table 2 one can see the attribute name to the ASN.1 notation mapping of the MDS class. For better understanding of the class-structure the example in table 3 shows an instanced object of the MDS-class. The tables for the Metric and the Enumeration class are similar.

4.2 Communication Model

The communication model describes the communication-procedure between agent and manager through state-machines. The communication is realised with certain services (association services, object access services) that are supported by both the agent and the manager. These services are specified in the service model of the ISO/IEEE 11073 standard.

4.3 Service Model

The service model describes in which way data are exchanged between agent and manager.

Association services control associations between agent and manager and are applied at the beginning and at the end of each communication-procedure. Therefore the following subtypes of association services are defined in the standard:

- Association request
- Association response
- Association release request
- Association release response

Object access services are used to retrieve information of the instanced objects, defined in the Domain Information Model. These services are necessary for both the configuration (registration) of new sensor networks (agents) at the manager and for the transmission of sensor-events from the agent to the manager. Therefore a *configuration event report* and an *agent initiated measurement transmission event report* are defined for the Independent Living Activity Hub.

Configuration Event Report. The Configuration event report is used by the agent, when the device is in a communication-state with the manager for the first time. The configuration of the agent is represented by a unique ID (Dev-Configuration ID) within the association request. If the manager does not know the configuration ID and therefore the device, a configuration event report is generated. In that service the agent transfers its configuration with all supported attributes to the manager. Static values of the object-attributes are also reported in the configuration event report, as they remain unchanged. After this procedure the manager knows about the device specialisation and no configuration event is necessary any more unless for instance a new sensor is added. In this case, the agent has to send a new configuration event report to the manager for the registration of the new sensor. Therefore, agents can have more than one configuration ID. Dynamic values, such as measurements are sent in later measurement event reports.

Agent- and Manager Initiated Measurement Transmission Event Report. An agent-initiated measurement transmission is sent by the agent, when the device has registered a sensor-event or has taken a measurement. Only dynamic values are reported in this service as static values are already known by the manager from the configuration event report.

5 THE COMMUNICATION FLOW AS A SET OF BYTE-STREAMS

In the ISO/IEEE 11073 standard family the Abstract Syntax Notation 1 (ASN.1) is used in the Domain Information Model (attribute data-types) and in the service model (format of the messages).

The Abstract Syntax Notation is a formal notation for defining data structures and messages. The great advantage of this notation is that it can be used platform-, provider- and application-independently for the transfer of protocol-messages. Especially today, when software developers face the problem of interaction among a multitude of heterogeneous computer-systems, a common language as well as certain rules for messaging is necessary (Hoss and Weyland, 2007).

ASN.1 describes data structures at a very high level of abstraction and thus separates the specification of data and how these data will be implemented in a particular language, like Java or C. So the design principle of abstraction is an important key of software development and the focus of using ASN.1 (Kaliska, 1993).

Table 2: **MDS-class** of Independent Living Activity Hub -Agent (IEEE Engineering in Medicine and Biology Society, 2008a).

Attribute name	**Attribute type (defined in Abstract Syntax Notation -ASN.1)**	**Remark**
Handle	Handle	Object identifier
System Model	SystemModel	Number of manufacturer and model
System ID	OCTETSTRING	Organizationally Unique Identifier (OUI; registration from IEEE) + manufacturer-defined ID
Dev-Configuration ID	ConfigId	See 4.3.2 Object Access Services
Date and Time	AbsoluteTime	
Attribute-Value-Map	AttrValMap	Defines the attributes reported in the measurement transmission event report; dynamic values
System-Type-Spec-List	TypeVerList	Defines the type of the agent according to the device specialization

Standard committees like the International Standards Organization (ISO) and the International Telecommunication Union Telecommunication Standardization Sector (ITU-T) use ASN.1 for their standard specifications (Hoss and Weyland, 2007).

For the messaging there are several coding rules, for instance Basic Encoding Rules (BER), Medical Device Encoding Rules (MDER), or Packed Encoding Rules (PER), which support encoding of ASN.1 syntax to a byte-stream and the vice-versa process of decoding. For each simple as well as structured ASN.1 data type there is a defined coding rule. This aspect is very relevant as far as the prevention of loss of information and the right interpretation of data by the receiver is concerned (IEEE Engineering in Medicine and Biology Society, 2008b).

The availability of different ASN.1 compilers supports the transfer of ASN.1 definitions into the specific programming language, considering the particular coding rules. For the implementation of the ISO/IEEE 11073 standard in this study, an open source ASN.1 to Java compiler has been used. With the help of that compiler predefined ASN.1 data-types of the standard can be transformed into classes of object-oriented programming language. Additionally each class has been provided with encoding- and decoding methods for transforming the instanced objects into a byte-stream.

6 IMPLEMENTATION

The chosen language for the implementation is Java due to its object-oriented approach. The first step for standard-conform implementation is to design an ISO-Agent, according to the Domain Information Model (DIM) of the Independent Living Activity Hub (see 4.1). The ISO-Agent is a prerequisite for the implementation of the ISO/IEEE 11073-conform communication-flow with the manager.

For the application of the standard, nomenclature definitions with their specific nomenclature codes according to ISO/IEEE 11073-20601, -10471 and -10101 and ASN.1 data-type definitions have to be used. Therefore a separate class with all required IEEE-nomenclature definitions has been implemented. These codes and definitions are necessary to set attributes correctly in the particular instanced objects. Furthermore all required ASN.1 data-type definitions (a total of 73) have to be translated with the help of the ASN.1/Java compiler into Java-classes. Whenever one of these definitions is applied, a new object of the relevant ASN.1 class has to be instanced. Thus the classes contain constructors as well as methods for encoding and decoding, required for standard-conform implementation of the messages.

The general bodywork of the agent has been implemented according to the ISO/IEEE 11073-20601 Optimized Exchange Protocol and to the device specialization ISO/IEEE 11073-10471 Independent Living Activity Hub. Therefore the classes MDS, Metric and Enumeration are required. Additionally, required mapping-methods between specific manufacturer-nomenclature of the sensor network and ISO/IEEE 11073-nomenclature are integrated in the Enumeration-class.

In order to have a clearly arranged and comprehensible bodywork, all static and predefined data are integrated within a configuration class. This class includes agent-specific definitions for the Domain Information Model (MDS-, Metric-, Enumeration-class) and for the messages. Another important element of this configuration class is the storage of the configuration IDs. Each sensor-object is assigned a unique configuration ID. These IDs are represented within a hash table. On the basis of the object identifier (Handle attribute) of each sensor-object, the keys of the hash table are established. In other words, each value of the Handle attribute (representing a sensor) is assigned a configuration ID. The configuration ID is necessary to set up communication with the man-

Table 3: Example of instanced objects of MDS class.

MDS-Object		
Attribute name	**Attribute value**	**Remark**
Handle	0	Each Agent has exactly one MDS-Object; therefore the Handle-value should be 0.
System Model	Number of • manufacturer: xxxx; • model: xxxx These numbers are specific values from the manufacturer;	These numbers are specific values from the manufacturer
System ID	• OUI: xxxxx; • Manufacturer-defined ID: xxxxxxxxx;	The OUI is the registration ID from IEEE. The manufacturer-defined ID represents the System-ID of the manufacturer.
Dev-Configuration ID	16384	According to ASN.1 definition of ConfigId, the value 16384 represents the first value provided for "extended configuration"
Date and Time	21-2009-3-11 13:22:26:885	According to ASN.1 definition of AbsoluteTime, date and time are presented in this format
Attribute-Value-Map	• OID: 2448, length: 4; • OID: 2881, length: 4;	According to ASN.1 definitions of AttrValMap, this attribute defines the attributes that are later reported in the measurement transmission event report. The values are represented with the nomenclature-codes of the standard and their length of bytes. • OID: 2448 represents Absolute-Time-Stamp; • OID: 2881 represents Enum-Observed-Value-Simple-Bit-Str;
System-Type-Spec-List	OID: 4167	The value 4167 represents the nomenclature-code for the Independent Living Activity Hub

ager. With the help of public-defined "get-methods", static information can be obtained in other classes. Attributes, containing dynamic data, always have to be instanced in the particular class.

The ISO-Agent Listener class can be seen as the core element of the generated software. Whenever the ISO Agent Listener recognises a data-packet from the sensor network, it has to generate an ISO/IEEE 11073 conform data-packet. These packets are represented as instances of the Enumeration class. Figure 1 shows a simplified use case of the ISO Agent Listener. For each supported sensor network system from specific vendors an own listener has to be implemented. The ISO Agent Listener is the lynchpin for the communication procedure. Each capture of a sensor data-packet and creation of an enumeration-object has to be followed by an association request. The association request is always the first message in the communication-flow between agent and manager. Figure 2 summarises the duties of the ISO Agent Listener.

The manager is also realised with a configuration class where static information is stored. Like the ISO

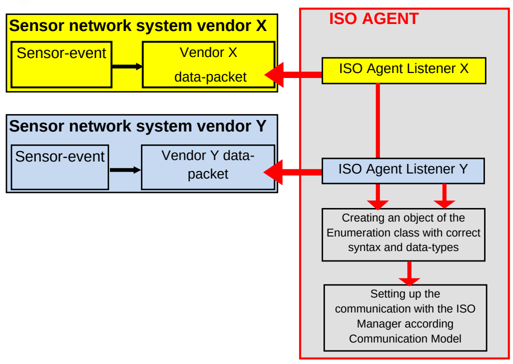

Figure 1: Use case of the ISO Agent.

Agent configuration class, the manager configuration has a hash table where familiar configurations IDs of the agent are stored (Note: the agent can have more than one configuration ID). Whenever the agent starts the communication with the manager, an association request is sent. Within this message the configuration ID of the particular sensor-object is transmitted. When the manager receives the association request, the information has to be decoded and a distinction of

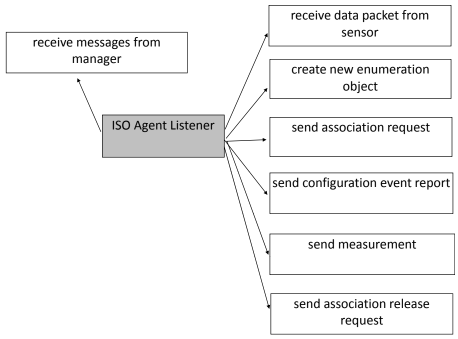

Figure 2: Duties of the ISO Agent Listener.

cases, whether the configuration ID is already familiar or not, is necessary. If the manager knows the configuration ID, the agent can continue with the measurement transmission event report; otherwise, the agent has to send a configuration event report.

Generally an objective has been to design an architecture that is as flexible as possible. Thus, new sensors and their appropriate mapping methods can be integrated without great effort. The implemented ISO-Agent represents its own sensor-network. Specific data of the system have been implemented in a particular configuration class. This approach is the basis for further integration of other sensor-network solutions and underline the flexible expandability. Therefore the implementation of a new configuration class and modification of the mapping methods should be the only job of a software engineer for integrating new sensor networks that are not designed according to ISO/IEEE 11073 guidelines right from the beginning (from the manufacturer). The manager and communication methods, however, can also be applied for other sensor-network solutions from other manufacturers without changing its bodywork. This point represents exactly the objective of using this standard, namely interoperability. The possibility of communicating with more than one agent is the key for interoperability and an approach to avoid heterogeneous IT-infrastructure.

7 CONCLUSIONS

The paper shows that it is possible to apply the standard to a sensor network that is not designed according to any standard guidelines at all. It shows how to integrate the ISO/IEEE 11073-10471 standard in a smart home setup with different smart home sensors from different vendors. The usage of interoperability standards in the AAL context is more and more essential as it is necessary for open and flexible platforms which are the basis to bring AAL applications to a larger market. Interoperable middelware components in AAL would also save money concerning the application implementation effort as it is reusable, not proprietary and not constraint to modules and sensors from a special technology provider or a certain application setup.

The integration of interoperability standards in AAL is a highly new field concerning the eHealth environment respectively the medical bed side treatment, whereas the usage of standards is a more improved effort.

During our work we have tried to implement the ISO/IEEE 11073-10471 in applications in different projects with different sensors and already see the benefit by developing modules which make the application independent from different kind of sensors and sensor data protocols. Anyway we have experienced some missing data fields and descriptions because of the different protocols of certain sensors from different manufacturers.

It will be a progress to bring the experiences into the development of the standards and the standard documents to work on a widespread usage of standards of interoperability.

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