Usage of Building Automation Infrastructure for Health-Care and Ambient Assisted Living applications

Volker Schuermann
Department of Electrical Engineering and Computer Science, Bochum University of Applied Sciences
Campus Velbert/Heiligenhaus
Phone: +49 2056 158740
Email: volker.schuermann@hs-bochum.de
Hoeseler Platz 2, Heiligenhaus, 42579, Germany

and

Christian Weidauer
Department of Electrical Engineering and Computer Science, Bochum University of Applied Sciences
Campus Velbert/Heiligenhaus
Phone: +49 2056 158712
Email: christian.weidauer@hs-bochum.de
Hoeseler Platz 2, Heiligenhaus, 42579, Germany

ABSTRACT

Due to improved living conditions and medical advances, the life expectancy of people increased significantly. But it also means that these days and especially in the future much more people are dependent from support in old age than in the past. The classical approach of the outpatient or inpatient care by qualified nursing staff is complicated, expensive and does not support around the clock care usually. More recent healthcare concepts rely on technology which supports people in their everyday life in their own apartments or houses. For this purpose usually specialized hardware and software components are developed, which are sometimes very expensive and complex. This paper proposes a massive simplification at this point by harking back to building automation infrastructure which is already available in many cases. In this paper it is a highly flexible and configurable UPnP based infrastructure which relies on web technology.

Keywords: Ambient Assisted Living, Health-Care, Building Automation, UPnP, Ambient Intelligence, Middleware, TCP/IP, web technology

1. Introduction

Demographic change and aging means that there are more and more older people and people with health problems, who want to extend the time they can live independently in their preferred environment as long as possible. Therefore their autonomy, self-confidence and mobility have to be increased. Ambient Assisted Living (AAL) technology supports the ambulatory care for this group of people. Industry and science have responded to this need and offered a variety of products in the recent years, such as wristlets made for monitoring of vital signs or sensors for fall detection. Thereby binary economic growth rates could be achieved in average [1] [2].

With the increasing use of current building automation systems in modern houses even in private homes a variety of sensors and actuators are available which can be also used for other applications such as Ambient Assisted Living. For this purpose appropriate networking of these components and an open and documented external interface are prerequisites. Since it is already state of the art to operate and configure building automation systems by means of smartphones or tablet PCs it offers itself to use the same interface for connecting external applications. Frequently, this is a web interface so that the established web technologies such as JavaScript [3], AJAX [4], Java Enterprise Edition [5] or ASP.net [6] can be used.

The approach presented in this paper goes a step further because the underlying building automation infrastructure does not only come with a web interface but also it is implemented completely in web technology. It is based on the established standard UPnP (Universal Plug and Play). UPnP is characterized by its high flexibility, extensibility and configurability. It is therefore particularly suitable as connection technology between the classical building automation and modern fields of application such as Ambient Assisted Living.

The paper continues as follows: Firstly, a closer look at modern building automation technologies is given. Special attention is given to web-based systems and UPnP. The following chapter provides an introduction to the AAL environment. The advantages and disadvantages of existing solutions will be shown and proposals for further improvements are made by combining these solutions with building automation infrastructure. Subsequently a concrete implementation proposal based on UPnP is described. At the end of the paper the main research results are summarized.

2. Web-based building automation systems

Within the range of the building engineering there are several technologies in the position to handle the role of a technology spreading middleware. One technology which is already today largely spread is BACnet (Building Automation and Control Networks). For example this was shown by the relocation of the German Federal Government from Bonn to Berlin and the renovation respectively the new construction of buildings. BACnet components of seven different manufacturers, altogether over 100,000 data points, were installed in the buildings and attached to a common BACnet management system [7]. Beyond that gateways are offered commercially for different fieldbuses such as DALI or EIB/KNX [8] [9].

The high start-up costs for large assets in the above mentioned scope are problematic. The start-up costs exceed the costs of the individual system components by far [10]. Therefore solutions are desirable comparable with the Plug&Play paradigm [10] well-established in the context of PCs.

One possibility to transfer Plug&Play on network level offers UPnP [11] [12]. This original Microsoft technology transfers the Plug&Play paradigm, as known from Windows operating systems, to TCP/IP networks and thus to Internet technology.

With respect to UPnP different roles are differentiated.

Device: Devices are physically present and offer services. Alternatively a Device can contain also several Embedded Devices with their own Services.

Service: Services are the smallest units in a UPnP network and represent the functions of a Device. A Device can hold also several Services. A Service holds a set of variables reflecting its status.

Control Point: Control Points access the Services so that they can change the Services' status by changing the status variables and administer the Services.

As soon as a Control Point joins the network it looks automatically for Devices by sending broadcast messages. Devices indicate their presence in the network like-wise by broadcasts. A Control Point receives information about services as XML message. If a Control Point and a service are bound together they communicate directly. Here it is also possible that the Control Point is informed automatically about changes in the Service's status by an event.

Transferred to the building automation a light bulb corresponds to a Service and a switch to a Control Point.

Since UPnP represents at first a universal approach different device classes are specified with the help of so-called Device Control Profiles (DCP). Thus DCPs for Media, Printer, Internet Gateways, HVAC (Heating, Ventilation, Air Condition) and lightning already exist. In addition dedicated DCPs can be simply defined in XML.

At present there are some ongoing research projects which are concerned with the use of UPnP in building automation. [7] and [13] describe a solution for pure TCP/IP networks. Other technologies must be tied up via commercial gateways. The architecture is realized by two UPnP networks. One network is used for Devices and one for Control Points. They are connected by a so-called Control Server. An additional networking of the Control Servers over a Backbone is likewise intended. Mobile devices such as smartphones and tablet PCs come predominantly to employment as Control Points like it is intended in [14]. Besides [7] describes an implementation for the UPnP follow-up technology DPWS (Device Profile for Web services).

A possibility to ensure IP addressability of field devices as demanded in [15] is described in [16]. As physical media beside Ethernet also the wireless technology IEEE 802.15.4 as well as simple bell wire is used.

One problem frequently addressed in literature is the missing user concept of UPnP [7] [17]. An extension of the UPnP specification in this regard represents the approach described in [17].

Especially for the employment in the building automation it is problematic that UPnP messages are very large. The usage of XML as data exchange format and the high protocol overhead result in several bytes to be transmitted even for simple actions like switching on a light bulb. This is necessary in spite of an action resulting only in shifting a bit in the long run. Therefore in [18] approaches for compressed UPnP message transmission are examined closer.

3. AAL sensor networks

There are basically two different system types in AAL context: On the one hand there is an active sensoring approach with sensors worn directly on the body. On the other hand there is a passive sensoring approach with sensors installed in the apartment of the affected person [19]. Furthermore by these approaches other applications are realizable such as the exact localization of demented people. By installing intelligent sensors (Smart Sensors - with integrated microprocessor) it is possible to recognize emergencies and summon assistance without the affected person has to become active.

The above outlined approaches, however, have two major drawbacks:

1. Many people do not want to wear any sensors directly on the body because it is inconvenient or they do not want to be stigmatized as needy.
2. The use of special passive AAL sensors in the home is associated with additional costs for development, installation and operation.

In recent years, especially for the aforementioned user group, a variety of apartments were built or modernized. For Germany only, an additional demand of 300,000 places is forecasted until the year 2015 [20]. In this context usually a modern building automation system, such as described in [21], is typically installed [19]. These installations are durable and stable in their value, so that they represent a sustainable investment. Such a system also includes a wide range of sensors such as light switches, door contacts, temperature and light sensors as well as motion detectors.

By smart evaluation of the relevant sensor data the same information can be gained as indicated by the above described specific AAL products. This approach relies extensively on pattern recognition in event sequences. The patterns of interest are to be identified and defined. The pattern recognition must be implemented using software technology.

Individual sensors themselves already supply a series of information from that the condition of a person can be derived. Thus, for example a pressed light switch does not only indicate the position of the person concerned. It also indicates that this person is able to stand up to reach the light switch and passed the distance to the light switch before. A door contact sensor at the entrance of an apartment for example can inform about a demented person being about to leave the house. As users of AAL systems often live alone the assignment of such events to a concrete person is usually unproblematic.

Considering not only each individual sensor separately but a combination of several of them in a more common approach of Sensor Fusion the conclusions drawn from the sensors are much more substantiated. For example, in the morning all light switches between the bedroom and the kitchen are actuated consecutively before the refrigerator is opened. This means that the person left the bed, could move through the apartment and prepared breakfast independently. Thus, it can be assumed with a high probability that adequate nutrition is guaranteed.

During a training phase sensor values can be recorded and stored in a database. By comparing current sensor values with stored behavior patterns one can draw very precise conclusions about a person's condition. For example, if someone who usually sleeps the whole night without interruption gets up several times at night and visits the bathroom or does not get up in the morning at the usual time, this could be an indication that something is wrong. In this case the system offers automatically to initiate an inquiry or to notify a nursing service. Similarly, an unusual long time of inactivity in the apartment can suggest that the person is unconscious and eventually overthrown.

4. AAL and building automation technology

Starting from the building automation middleware described in [21] this paper treats an ICT-based solution for (self-) management of daily activities of older and needy people at home. Central integration point is again Universal Plug and Play (UPnP). The total of 972 companies organized in the "UPnP Forum", including IBM as well as Microsoft, supports this technology. UPnP sets up the cross-vendor communication of devices in IP-based networks, such as communication of TVs with stereo systems and DVD players. However, UPnP includes also a "Home Automation Profile" which already defines services such as "Binary Light / Binary Switch", "Dimmable Light / Dimmable Switch" or "Temperature Sensor" as well as their collaboration. So it is for example possible to connect a "Binary Switch" with a "Binary Light" but not with a "Temperature Sensor".

The use of UPnP as integration interface has also the advantage that cross-technology bindings are possible. In this way you can turn on a lamp connected by EIB/KNX with a ZigBee switch. All communication runs thereby over UPnP. The ZigBee switch triggers an event, which is mapped to a corresponding UPnP event, and then it is passed to the EIB/KNX system. In order to make these technology-spreading bindings possible the properties of the respective communication systems have to be adapted to UPnP. For this purpose the middleware includes an abstraction layer providing this mapping for each connected communication technology.

The concept diagramed in Figure 1 extends the functionality of this abstraction layer by integrating the AAL specific functionality of each sensor type. Therefor a set of virtual AAL-Sensors is defined in this layer. Thus for example a motion sensor detecting no activity for more than ten minutes sends a corresponding signal automatically. A specific "AAL UPnP Profile" enables to integrate this functionality to UPnP. This DCP covers the respective services. Thus both physical and virtual sensors generate UPnP compatible events and distribute them on the network.

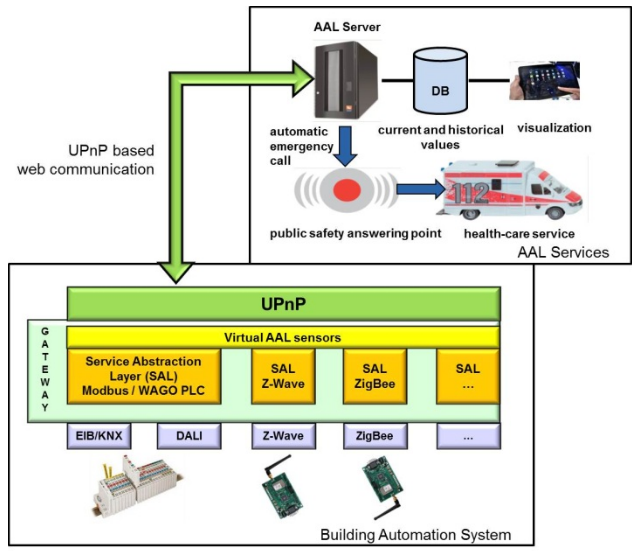

Figure 1: System Approach

The following code snippet on the next page shows a simplified representation of a specific AAL-DCP. This is the extension of the motion detector DCP with timer functionality. The motion detector is, among other things, represented by the `GetStatus` action and the corresponding state variable `Status`. In addition, there is another state variable named `StatusTimer`. It indicates the sensor's maximum permissible duration of monitored inactivity before a corresponding event is triggered.

The system concept presented in this paper provides the introduction of a dedicated AAL-Server to monitor and process these events. This server processes not only the events received via UPnP, but it also compares them with the associated behavior patterns stored in a database. Here various techniques, such as complex event processing [22], can be applied. During the deployment phase a multi-day training period is part of the concept to determine these behavior patterns.

```
<?xml version="1.0"?>
<scpd xmlns="urn:schemas-upnp-org:service-1-
0">
  <specVersion>
    <major>1</major>
    <minor>0</minor>
  </specVersion>
  <actionList>
    <action>
      <name>GetStatus</name>
      <argumentList>
        <argument>
          <name>ResultStatus</name>
          <relatedStateVariable>
              Status
          </relatedStateVariable>
          <direction>out</direction>
        </argument>
      </argumentList>
    </action>
    <!-- ... -->
  </actionList>
  <serviceStateTable>
    <stateVariable sendEvents="yes">
      <name>Status</name>
      <dataType>boolean</dataType>
      <defaultValue>0</defaultValue>
    </stateVariable>
    <stateVariable sendEvents="yes">
      <name>StatusTimer</name>
      <dataType>integer</dataType>
      <defaultValue>18000</defaultValue>
    </stateVariable>
    <!-- ... -->
  </serviceStateTable>
</scpd>
```

5. Conclusion

The system concept proposed in this paper demonstrates how an existing building automation infrastructure based on established standards can be used for new applications in the field of Ambient Assisted Living. This requires an open and documented interface of the building automation system. This interface enables access to the already existing sensors and actuators preferably via web technology. In this case UPnP is used for standardized communication between the building automation system and the AAL-Server. UPnP is especially suitable in our approach because it enables the definition of custom virtual sensor types.

The AAL-Server creates a behavioral profile of the user during an initial multi-day training phase and stores it in a database. During normal operation pattern matching is performed continuously. The analysis of the measured sensor values is performed by means of complex event processing. If necessary the system starts a pre-defined process. For example it informs a nursing service in case of a detected fall of the user.

Using already available sensors in apartments and their corresponding communication infrastructure for AAL applications instead of installing new AAL complete solutions leads to massive cost savings. Significant savings per apartment compared to traditional AAL solutions are quite realistic because there are no (or at least fewer) costs for development, installation and operation of an additional sensor network.

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