Universal Smart Energy Communication Platform

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***Abstract*—Online data collection is crucial for increasing efficiency of energy consumption and reducing environmental impacts. Moreover, utility market liberalization and parallel EC requirements on smart measurement brought new challenges for utility and telecommunication providers. More Advanced Metering Infrastructure (AMI) networks have been proposed with not clear widely accepted solution. Our study investigates feasibility of cost efficient measurement architecture based on already deployed network and home access technologies. Developed system running on the smart home gateway acts as a multi purpose enabler providing a real time smart meter data collection and visualization, but can be used for any home automation services as well.**

I. Introduction

The liberalization of utility markets and in parallel systematic need for more efficient utility consumption (electricity, gas, water) brought a demand for accurate, immediate and online data collection from smart meters for society, utility providers and for individuals as well [1], [2].

The research for the most suitable communication platform for Advanced Metering Infrastructure (AMI) which is the core part of modern smart grids is currently very active among different research and industry institutions. There are several possible solutions like Power Line Communication (PLC), 3G/4G mobile network, VDSL/ADSL broadband network, Wireless M-Bus, etc. Each of these technologies has certain pros and cons and is intended to be used in different part of AMI. E.g. the PLC is frequently discussed as perspective solution for AMI, but actual state of PLC technology has limitations on communication range, data throughput, national directives and also full deployment of PLC data access will generate additional costs in power line network infrastructure [3]. Moreover, the full PLC network deployment and maintenance for all utility providers will generate additional financial cost.

On the other hand, the wired and wireless broadband telco operators have already deployed a network infrastructure with sufficient throughput and in parallel have already deployed the Internet access enablers (IP routers) which can serve as home gateways for smart metering or any other home automation service. Therefore, mobile of fixed telecommunication networks seem to be a sufficient platform for the utility metering. Nevertheless, the current challenge for telco operators is to orchestrate such generic solution for the smart utility measurement within their network [4]. The next open issue is if home gateways are able to collect and process data according to HGI recommendation [5] and in parallel coexists with other access technologies [6].

Currently, there are many new solutions for smart home gateways at the market [7], but generic drawback of these solutions is those are dedicated just for specific service or product or provide generic but cost ineffective solution [8]. Therefore, it is necessary to come up with new generic, cost effective solution for smart utility measurement which will be based on actual residential access gateway technologies and already deployed data networks. Furthermore, the access technology should provide sufficient quality of service (QoS) for machine to machine (M2M) type traffic and sufficient level of network security [9].

In our study we investigated the readiness of residential gateway access technology for the utility smart metering. We proposed and demonstrate middleware solution providing the binding between the home access technology and home automation systems at standard IP router. The demonstrator provides a user friendly utility data-handler accessible locally or remotely through smart devices. Moreover, the proposed solution is open for other home gateway applications.

The rest of paper is organized as follows. The Section 2 is providing a brief background for the smart metering service category. New universal integration platform for home automation - openHAB, which we used as a key component in our proposed platform, is introduced in the Section 3. The Section 4 presents the architecture and design of our openHAB-based smart metering demonstrator. All results and outputs of our performed study are summarized in the Conclusion.

II. Service Category Smart Metering

The smart metering refers to the use of intelligent utility (energy, gas or water) meters and measuring instruments in order to make the utility consumption more visible and to enable automatic utility management. Smart meters bring an end to estimated bills and home visits from meter readers because they can record and report utility consumption automatically and remotely [5]. Utility companies are going to invest in smart metering infrastructure to become more efficient in how they engage with their customers.

The service category Smart Metering as a part of smart grid and smart home automation concepts is currently attracting a lot of attention of research [10], [11] and also industry communities and will play an increasingly important role in residential and commercial buildings, because the energy usage in these buildings is responsible for about 40% of the EU's total energy consumption and represents about 36% of CO_2 emissions in the EU and about 40% in the US. Therefore, buildings should be at the centre of any solution to reduce GHG emissions. Due to mentioned facts the finding of optimal solution for smart metering is in the strategic scope of many standardization organizations [12] and initiatives, e.g. Home Gateway Initiative (HGI) [5].

III. openHAB Platform

There are many studies [13], [14] proving that if users are more informed and have the information about utility consumption available in real-time, clear and comfortable form (e.g. through their smartphones or tablets) it affects their behavior in order to save more energy. Hence, it is really important to provide a user friendly environment for utility management as a part of whole smart grid concept.

In this section, the openHAB (open Home Automation Bus) platform [6], which was used as a communication and integration technology for developed smart metering demonstrator, is described. The openHAB project aims at providing a universal integration platform for all things around the home automation including also the utility metering. It is a pure Java solution, fully based on OSGi. The Equinox OSGi runtime and Jetty as a web server build the core foundation of the runtime. openHAB is designed to be vendor-neutrala and brings together different bus systems, hardware devices and interface protocols by dedicated bindings. These bindings send and receive commands and status updates on the openHAB event bus. This concept allows designing user interfaces with a unique look&feel, but with the possibility to operate devices based on a big number of different technologies. Besides the user interfaces, it also brings the power of automation logics across different system boundaries [6].

A. Communication Mechanism

The openHAB has two different internal communication channels, an asynchronous Event Bus and a stateful repository which can be queried. The event bus is the base service of openHAB. All bundles that do not require stateful behavior should use it to inform other bundles about events and to be updated by other bundles on external events. All protocol bindings (which provide the link to the real hardware devices) should be communicating via the Event Bus. As a technical foundation, the OSGi EventAdmin service [15] is used by openHAB. It is important to note that openHAB is not meant to reside on (or near) actual hardware devices and as thus to remotely communicate with many other distributed openHAB instances. Instead, openHAB rather serves as an integration hub between such devices and as a mediator between different protocols that are spoken between these devices. In a typical installation, just one instance of openHAB is running on some central server.

Not all functionality can be covered purely by stateless services. Due to this reason openHAB also offers the Item Repository which is connected to the Event Bus and keeps track of the current status of all items. The Item Repository can be used whenever it is necessary to be able to access the current state of items. E.g. a user interface needs to display the current state of items in the moment of the user access.

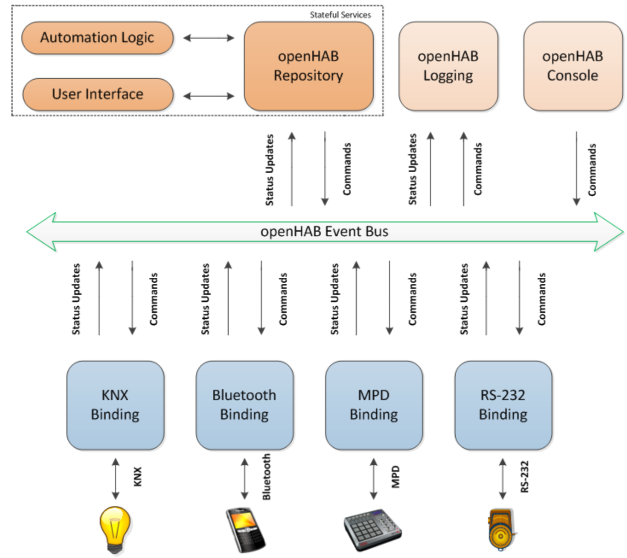

Fig. 1. Generic openHAB communication mechanism

Also the automation logic execution engine always needs to be informed about the current states. The Item Repository avoids each bundle to cache states themselves for their internal use. It also makes sure that the state is in sync for all those bundles and it provides the possibility to persist states to the file system or a database, so that they are even kept throughout a system restart [6]. The diagram (see Fig. 1) shows generic communication mechanism of openHAB platform.

B. openHAB User Interface

The openHAB provides a generic textual configuration for its user interfaces. The so-called Sitemap is a tree structure of widgets which define different pages of a UI and their content. Widgets can be associated to items, for which they should show the status and/or control elements. The definition of the Sitemap is quite abstract by design. It is supposed to be a suitable UI model for different kinds of user interfaces, so that the user does not have to configure each of them in case he sets up multiple UIs. If a UI has further requirements on top of the Sitemap, it is still possible to introduce additional configuration options which are then specific for the UI in question [6].

Even though the openHAB is vendor and system independent solution and described user interface can be implemented above any platform, there are four standard UIs available. The default web based UI is called WebApp.Net and can be accessed through any web browser to remotely control openHAB system. The UI is implemented in the bundle org.openhab.ui.webapp. It registers a servlet with Jetty and processes incoming requests. The UI makes use of the Sitemap definition file in order to render the pages [6]. Users can construct custom HTML blocks and thus create own web UI design. Another web-based UI is using the GreenT technology which provides instantaneous communication between the web user application and the openHAB runtime.

The openHAB provides also two native user interfaces for mobile devices running iOS or Android systems. Since both mobile clients are open-source users can modify their design

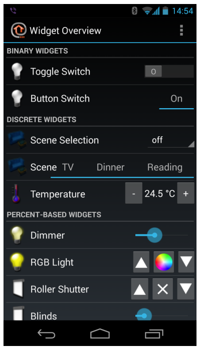

Fig. 2. HABDroid - example of openHAB UI application

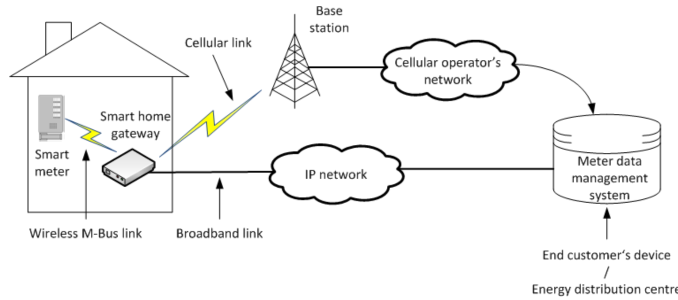

Fig. 3. Generic home energy management scenario

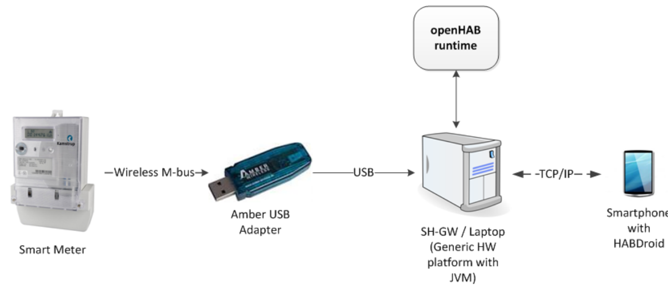

Fig. 4. Smart metering openHAB-based demonstrator

and content. The Android client is called HABDroid (see Fig. 2) and this UI was used within the developed demonstrator which is described in the following section.

IV. Development of openHAB-based Smart Metering Demonstrator

In energy management systems, domestic appliances (washer, heater, etc.) would communicate through a local network while terminal devices (e.g. fixed and mobile phones, home gateways) act as gateways to telecommunication networks. The connection is established among both external platforms (e.g. via the broadband connection) and local agents able to optimize energy usage in the home. This optimization requires an energy gateway function somewhere in the home which is able to monitor/control the consumption of the equipment [5].

The energy gateway function can be instantiated in various physical components, ranging from the smart meter, a dedicated device with specific connectivity, or in the home gateway itself. The choice of location depends on several factors such as the need to preserve the installed base, or a planned new gateway deployment. E.g. the HGI architecture [5] focuses on the case where this function is embedded in the Smart Home Gateway (SH-GW) [16]. The IP routers available on today's market have sufficient computing power so together with developed middleware can serve as multi purpose SH-GWs including the smart metering service.

A. Generic Home Energy Management Concept

The main idea behind this research work was to provide a cost effective solution for smart metering which will utilize already available fixed or mobile network infrastructure of telecommunication operators and provide a user friendly access to measured data. The subsequent goal was to achieve overall energy efficiency in the home network so that each device is running in an energy efficient manner. Integration with the existing customer network is a key requirement in order to optimize the efficiency of home energy management, and so fits well to the scope of the HGI. The generic concept the home energy management scenario is shown in Fig. 3. Different household appliances are connected with the smart meter which regularly forwards the information about energy consumption to the smart home gateway. As the communication technology between the smart meter and SH-GW the PLC or very perspective wireless M-Bus can be used.

Smart home gateways usually provide more WAN interfaces (e.g. Ethernet, VDSL/ADSL or 3G/4G) to interact with remote utility management systems or end user devices. The choice of proper technology depends on many factors, nevertheless all of them are utilizing the TCP/IP platform. Therefore, the most challenging task is the design of middleware application running on SH-GW and implementing all needed logics for capturing, processing and forwarding utility data. Hence, developed middleware plays a key role of our smart metering demonstrator.

In order to convince users to be more energy consumption aware, it is really important to provide them (not only to utility providers/distributors) with measurement data in real-time and attractive form. There many user friendly solutions to visualize data, e.g. DLNA (Digital Living Network Alliance) smart TV, UPnP (Universal Plug and Play) media frameworks [17], openHAB technology or social networks, but usually the bindings between smart meter and the visualizing application are missing. Therefore, our demonstrator is addressing also this issue.

B. openHAB Solution for Smart Metering

The architecture of developed demonstrator is shown in Fig. 4. We have used the smart meter KAMSTRUP [18] as a source of consumption data compliant to Open Metering System (OMS) specification [19]. The consumption data is transmitted using Wireless M-Bus technology. The update interval of the consumption data transmission was configured to 10 seconds to provide fast feedback on the electricity consumption. The meter uses the Wireless M-Bus Application Protocol [19] to regularly broadcasts the value of the meter registers using a WMBus SND_NR message.

Data from smart meter is received by Amber Wireless M-Bus USB adapter [20] connected to the SH-GW. This module

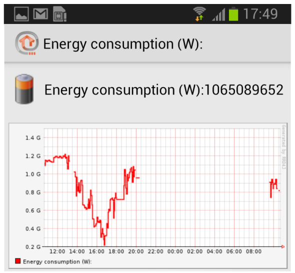

Fig. 5. Graphical presentation of energy consumption in HABDroid

is designed for smart meter reading applications enabling an easy integration of PCs, mobile terminals and service terminals into a wireless M-Bus network.

The developed middleware running on open-WRT based SH-GW integrates all functions needed for reading of measurement data from wireless M-Bus module, processing it and sending to end user mobile device by the help of openHAB platform. Once the data is loaded via M-Bus adapter, it is transformed from hex to decimal form and sent to openHAB runtime. OpenHAB runtime via created binding collects all information and processes it. After that, the collected data is sent to the end device or any management system defined by IP address for further processing or graphical representation. In our demonstrator, we have used the smartphone with HABDroid client for a graphical presentation of actual electricity consumption (see Fig. 5).

V. Conclusion

EC regulations require a smart metering utility data, but the current EC regulations do not recommend specific communication technology. Therefore, industrial and academic bodies as well are currently investigating the maturity of already deployed network technologies. In our work we present the results of extensive experimental development achieved in cooperation with mobile and fixed operator. The demonstrator successfully validated technological readiness at the side of residential broadband access and at the side of IP router technology serving as smart home gateway as well. Our developed smart metering demonstrator is offering cost effective solution utilizing already deployed network infrastructure and state of the art communication technologies with very required user interface running on mobile devices. Due to that it brings a number of potential benefits; e.g. consumers have constantly available information about their energy consumption. Therefore, they are able to estimate bills from the provided information and thus manage their energy consumptions to reduce their expenses. Moreover, the solution follows the HGI and OSGi recommendations and can serve as a multi-purpose data-handler running on a smart home gateway to support and drive new services offered by service providers and being open for any 3rd party applications at the same time.

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