TAILORING THE NEXT GENERATION ENERGY MANAGEMENT TOOL FOR SMART CITIES

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Keywords: Energy Management IoT, Decision Support System, Smart Grid, Security and Privacy in the IoT, Cloud computing, Real Life Deployment

Abstract

In this position paper we propose a next generation eNeRGy management solution for smart cities based on the Internet of Things- IoT NRG Manager, to efficiently manage the energy locally produced and consumed. IoT NRG Manager is interoperable with the Internet of Things, it provides an Open Data API that allows third parties to access to energy related data. The privacy issues are addressed by a combinatorial approach of Privacy and Transparency Enhancing Technologies.

The IoT NRG Manager is built up by (i) a smart decision support system that measures, predicts and balances energy production, demand and storage and (ii) a Virtual Power Plant (VPP). In the context of this work the VPP is a high level design tool based upon load aggregation of near real-time metered energy demand and generation data at building/apartment levels. Selected data is aggregated up to city level, or user defined and selected levels such as district, neighbourhood, low voltage electricity network, district heating network etc. The VPP also facilitates the option to model 'what-if' scenarios through simulation of additional distributed energy resources (DER), electricity storage, electric vehicles etc. at tool defined building and/or city/district level.

On top of that are developed user-friendly web portals and functions that inspire new business models for all stakeholders (consumers, prosumers, city authorities, energy service providers, TELCOs, ESCOs, etc.).

Our tool is currently being deployed in two European cities: Plovdiv - the second largest cities in Bulgaria, and Rijeka - the second largest city in Croatia.

1 Introduction

Today, roughly half of the world's population lives in urban areas, consuming two-thirds of total primary energy and generating over 70% of global energy-related CO^2 emissions. By 2030 it is estimated that around 60% of the world's projected 8.2 billion people will be housed in cities and towns. This means that residents who live and work within a city will consume around 75% of the world's annual energy demand. If most of this demand continues to be met by fossil fuels, then cities and towns maintaining a business-as-usual approach will experience large increases in CO^2 emissions, greatly endangering the health of citizens and surrounding ecosystems. Fortunately, goals set by the European Commission state that by 2020, 50% of Europe's electricity networks should operate on 'smart' principles. The European Union (EU) target is that by 2020, at least 30-35% of electricity consumption is covered by Renewable Energy Sources (RES), compared to a 16% share recorded in 2006 [1].

Many EU cities are setting examples to follow in their quest to become energy independent, such as the Swedish city of Växjö, which meets over 54% of its energy demand with local renewable energy, city of Freiburg with 10% of electricity coming from renewables or the Spanish island el Hierro with 86% of its consumption coming from renewables aiming a 100% in the next years [2]. Therefore, local generation and the inclusion of new actors such as prosumers are key to achieve the energy efficiency targets for the next years.

In order to provide these benefits and meet EU targets, the smart grid must be able to seamlessly integrate various existing and/or new technologies – meters, sensors, data processing systems, etc. – with the physical infrastructure required to generate, transmit and distribute electric power [2]. Utilities and city authorities have long been using network systems such as SCADA to optimize resources and monitor assets to carry out preventative maintenance. However, the rich data sets generated and stored in these “silo” systems are found in a variety of formats and are not easily accessed by third parties, thus preventing the optimal management, control and efficiency of many city services (i.e. utilities, security, health, transportation, street lighting and local government administration).

On the other hand, today’s urban environments offer near-100% internet coverage and are equipped with pervasive sensors and a wide range of embedded and mobile devices (i.e. smartphones, smart vehicles, equipment sensors, air quality sensors, etc.) that generate significant amounts of data, in what is called the Internet of Things (IoT). Therefore, the fast grow of the IoT, which is integrating and unifying all the communication systems in a Smart City, and the continuous deployment of smart meters in public and residential buildings are opening up new approaches for the energy management in cities, strategies to incentivise the local generation and better tools to achieve energy savings and Green House Gas (GHG) emissions reductions.

To efficiently manage energy resources in cities, in this paper we propose an eNeRGy management solution based on IoT for smart cities: IoT NRG Manager, which is built-up by a *Smart City Database* (SCDB) and a *smart Decision Support System* (smartDSS) divided in two-level decision approach:

- *Local Decision Support System* (LDSS). It engages consumers and prosumers by capturing near real-time data related to their energy consumption, as well as energy production from their installed Distributed Energy Resources (DER), displaying it on a user-friendly interface via smart phones, tablets, PCs, etc., and provides support for decision making.

- *Centralized Decision Support System* (CDSS). It aggregates data from all LDSSs to provide city-level decision support to authorities and energy service providers. The CDSS generates a number of parameters, including city-wide energy production and consumption forecasts.

The security and privacy aspects are a major problem that must be addressed in any IoT solution. For the security aspect, IoT NRG Manager provides means of communication and end-points (web services) to ensure that the communication channel between utility’s AMI and SCDB is encrypted. This schema also applies for the inter communication between the high levels components (LDSS, CDSS and VPP). Regarding the privacy, it is addressed by a combinatorial approach of Privacy and Transparency Enhancing Technologies. More details are presented in section V.

Moreover a real deployment of the IoT NRG Manager is planned for 2015 in two European cities, in concrete, the second biggest city in Bulgaria, Plovdiv and also the second in Croatia, Rijeka. With more than 1000 new smart meters installed in the pilots, IoT NRG Manager provides functionalities to different actors in the energy domain.

In Section 2 we outline the main components of our energy management tool. In section 3-4 the logic architecture of the SCDB, smartDSS, CDSS and LDSS is depicted and the communications between components are explained. In section 5 we propose a security and privacy approach for the tool. In section 6 the magnitude of the pilots were the IoT NRG Manager will be validated and evaluated is described. Finally in section 7 we summarize our approach and propose directions for future work.

2 Smart City Energy Management Based On IoT

In Figure. 1 is shown a draft architecture of the components present in the IoT NRG Manager. The SCDB is where all the information regarding energy measures, building parameters and additional information (weather, energy prices, etc.) is stored. Interfaces and APIs provide all the necessary information for the smartDSS modules.

The *Automatic Metering Infrastructure* (AMI) of Rijeka and Plovdiv, communicates via utility interface with the SCDB. The smartDSS communicates in a bidirectional way with the SCDB. The Open Data API (OD API), gives access to information regarding consumptions of the pilot buildings, as well as, other information such as production with renewable energies and CO2 emissions in the city. The end-user or municipality (for public buildings) are the owners of the data generated and therefore they are responsible to allow or not the usage of their data in the OD API.

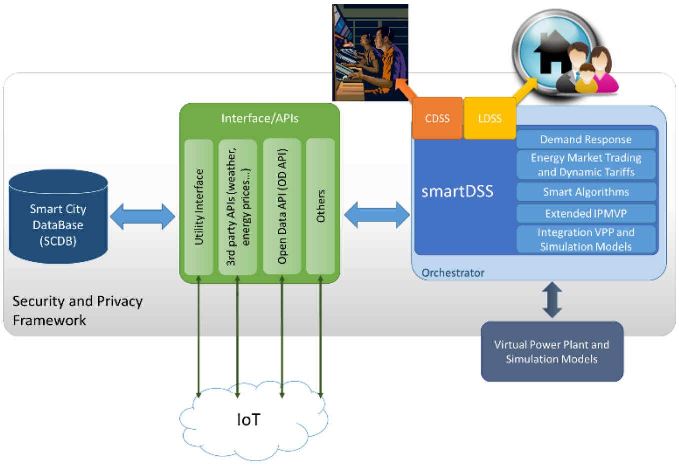

Figure 1. IoT NRG Manager components

The Orchestrator is responsible to ensemble and orchestrate the communications between the smartDSS and its different modules:

1. Smart Algorithms: Electricity, Water, Gas and Heating forecasting algorithms.
2. Energy Market Trading: Generation of the variable energy tariffs that allows dynamic prices of energy in the city and trading strategies of prosumers.
3. Virtual Power Plant (VPP): High level design tool based upon load aggregation of near real-time metered energy demand and generation data at building / apartment level. It allows also the creation of 'what-if' scenarios. (For more information see section IV – C)

Finally the CDSS and LDSS are the interfaces with the end-users; the CDSS for the Utility and Municipality of the city and the LDSS for the end-users, both private (citizens) and public customers.

3 SCDB

The SCDB is depicted in Figure. 2. It contains the database of IoT NRG Manager, and provides components to import data from external sources, as depicted in Figure. 1, and additionally provides interfaces for accessing energy related data collected from the main modules of the IoT NRG Manager (LDSS, CDSS, smartDSS and VPP). There is a special module, which allows access to data externally following the privacy and security policy of the IoT NRG Manager (See section V).

The database is divided in two main blocks, which matches the functionalities target for the LDSS and CDSS. Basically, all energy related information from meter up to building level is stored in the LDSS database, while all energy related information above building level is stored in the CDSS database, this include aggregated meter at city level (district wise and city wise) data and VPP data.

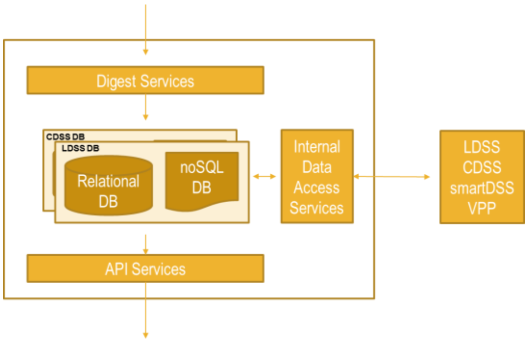

Figure 2. SCDB logic view

Booth LDSS and CDSS incorporates a relational database, where the relation of the smart meters is defined (apartment/home/business, building, district and city level) and a noSQL database to store massive energy information.

3.1 Open Data API services

Figure 3. OPEN API module

The API service component is responsible to grant access to the energy information collected and computed within IoT NRG Manager following the security and privacy policy. It provides an open API that allows 3rd parties to offer external services to the users of the platform. This component provides a set of different modules as shown in Figure. 3.

Component	Description
Energy Data	This component exposes the energy data stored in SCDB. Provides access to current and historical data, from meter level up to city level.
User Data	This component provides information from users following the privacy policy
Access Control	This module controls which information can be access through the open API based on the request and the type of external service accessing the data. It logs all the request and all data access from external services.
Privacy Policy	This module is used to set privacy policies for data access

The Open Data API is a tool that developers will use create the solutions that citizens and other stakeholders want.

4 IoT Decision Support System Engine

4.1 smartDSS

smartDSS is the acronym of “Smart Decision Support System”, which is a concrete solution comprised of: 1) a tool to measure, predict and balance energy production, demand and storage; 2) a tool to measure and verify reductions in energy consumption and GHG Emissions resulting from city energy use; and 3) user-friendly web portals and functions that will inspire new business models for all stakeholders (consumers, prosumers, city authorities, energy service providers, telecommunication companies, ESCOs, etc.). The Decision Support System leverages the cities’ intelligent electrical and thermal grids to empower all of the actors involved and enable optimal distribution and trading of decentralized renewable energies production in a city, as well as the integration of Combined Heat and Power (CHP) plants connected to the smart district heating and cooling grid.

4.2 CDSS

The CDSS (Centralized Decision Support System) Component of the proposed platform is responsible to aggregate and manage data at city and district level. That Component deliver a set of functions to end-users as Authorities, Energy Provider Services, ESCO, Municipalities, collecting data that comes from other components of the system. Moreover, the CDSS provides an interface specialized for the user typologies. Thus, each user accesses only to the tools useful to perform its activities. For instance, it can be considered the different approach in the data management of an Analyst and a Decision Maker. The aim of CDSS is to integrate measurements data, business model, simulation data and forecasting data in a view that allows the user to manage the different aspects with a unique tool. This, enables the forecast and planning renewable power generation available in the city, a real-time optimization and scalability (meaning its ability to be enlarged to accommodate that growth of data).

The CDSS allows the following activities:

- Get a continuous snapshot of city energy consumption and production
- Manage energy consumption and production data
- Forecasting of energy consumption data
- Planning of new energy “producers” for the future needs of the city
- Visualize, analyse and take decisions about the information provided by all the connected end points that are consuming or producing energy.

As it is shown in Figure. 4, it is composed by a back-end and front-end. In this task the HMI or Graphical User Interface (GUI) for CDSS is developed with a novel framework employing web technologies (HTML5, CSS3, JScript, Websocket) to provide a web 3.0 user interface. The CDSS provides the communication between VPP, smartDSS and LDSS and this makes it fundamental for the orchestration of the activities.

Moreover it provides functionalities to aggregate data in order to create the demand curves that can be used to analyse possible peaks and produce offers. Other important features of the CDSS are:

- Dynamic tariffs support
- Offers Demand/Response flow
- Forecasting data management
- Near real time data visualization
- Technical losses management
- Historical data visualization

It works in strict collaboration with the VPP component that is responsible to aggregate data at city and district level. This aggregation of data is the base to produce simulation, forecast and near real time data. Another important aspect to highlight about the CDSS is the connection with

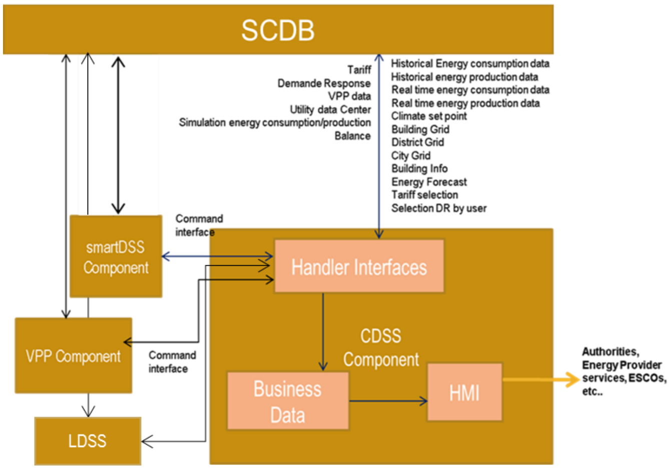

Figure 4. CDSS Architecture schema

the LDSS. This functionality allows to prepare dynamic tariffs and stimulate an engagement behaviour with the consumers. The CDSS moreover communicates with the smartDSS component in order to activate the forecast processes. The forecasting data are stored into SCDB where the CDSS takes the values. Thus, that approach produces many benefits, in fact the consumer can have reduced energy consumption and costs and, most important, can acquire a more conscious behaviour versus the environment.

4.3 Virtual Power Plant: A High Level Design Tool

VPP stands for Virtual Power Plant. Within current literature the term VPP has no firm definition [3][4]. The VPP in the context of this work is a high level design tool based upon load aggregation of near real-time metered energy demand and generation data at building/apartment levels. Selected data is aggregated up to city level, or user defined and selected levels such as district, neighbourhood, low voltage electricity network, district heating network etc. Figure. 5 illustrates the communication workflow between the VPP, CDSS and SCDB (both discussed above). The VPP is to act as the background calculation engine to the CDSS, where the CDSS is to act as an interface to the VPP initiating user commands to the VPP such as grouping schemes, what-if simulations etc. The SCDB acts as an intermediate between the VPP and CDSS; access to common data and storage of VPP computed data.

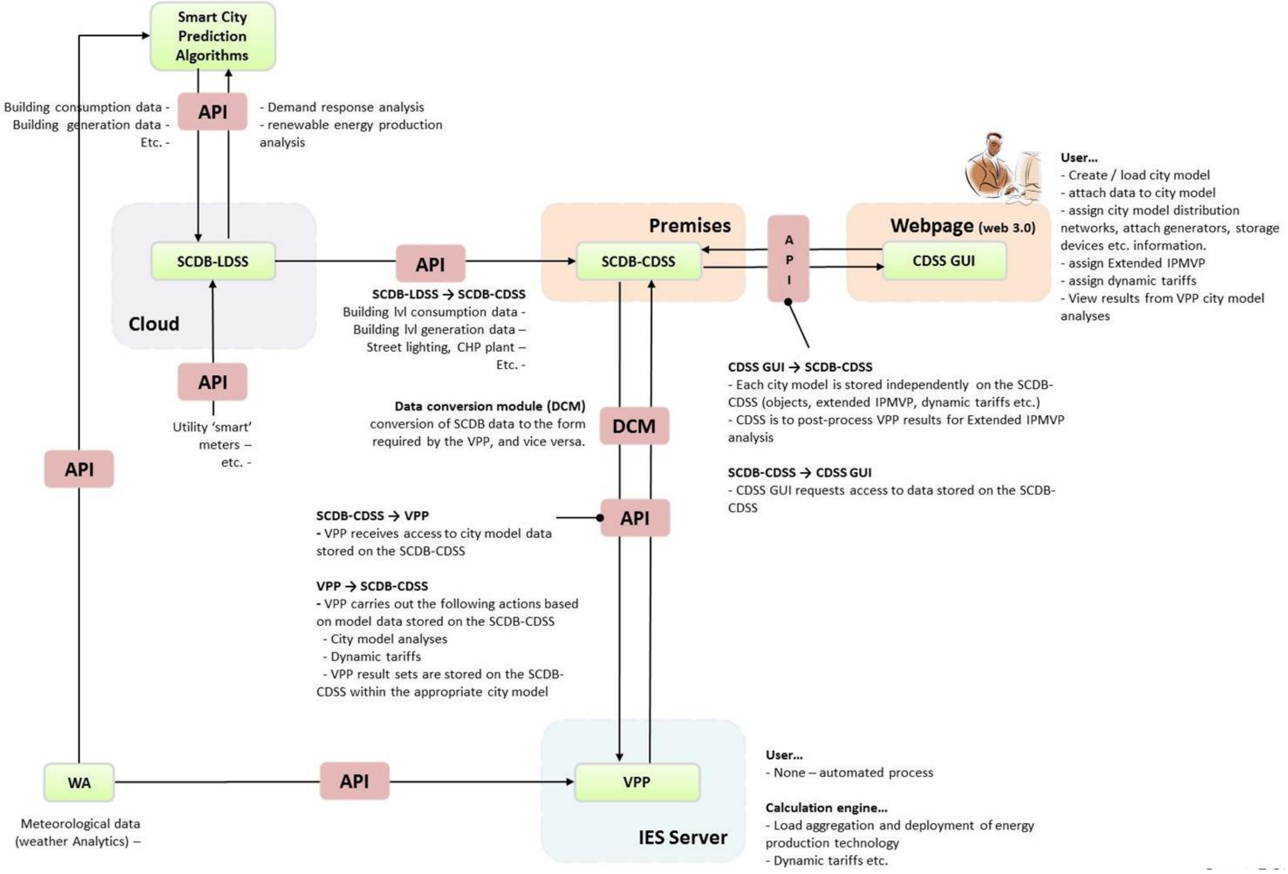

Figure 5. VPP communication workflow diagram

The VPP also facilitates the option to model 'what-if' scenarios through simulation of additional distributed energy resources (DER), electricity storage, electric vehicles etc. at tool defined building and/or city/district level. This feature is in addition to load aggregation of near real-time metered energy demand and generation data at building/apartment levels within the VPP. What-if scenarios use historical building and meteorological metered data stored on the SCDB as a driver for simulating results, rather than forecasting ahead in time.

An example of a what-if scenario is the simulation of photovoltaic (PV) panels at building level. The what-if simulations are directed towards providing feedback to the user on the following type of question: *If I installed 'x' renewable or low to zero carbon (LZC) technology to one or many buildings within a district, how much traditional energy in the sense could have been offset by installation of such technology*?. The user can analyse this information within the CDSS and opt to carry-out further what-if simulations.

Target users, city planners and utility companies, will be able to use the tool to gain an understanding of energy demand/generation at user defined and selected levels of interest ranging from high level city planning to the selection of individual buildings or user defined energy networks and so on. 'What-if' scenarios aid in future development and planning of cities.

4.4 LDSS

LDSS stands for Local Decision Support System. LDSS main goal is to engage consumers and prosumers on the efficient use of energy. The engagement is based on data, captured in near real-time, related to their energy consumption, as well as energy production from their installed Distributed Energy Resources (DER). The engagement is target throughout a user-friendly interface using every-day-use devices; smart phones, tablets and PCs.

Simplified interfaces show users energy usage, as well as energy produced. Comparison with previous periods, as well as other consumers/prosumers, in combination with recommendations on the optimal use of energy is expected to engage end users on the management of “their” energy.

Additionally, LDSS provides support for decision making, for instance, it advises how to achieve a demand response actions, which dynamic tariff is more convenient and the relation with other environment parameters (like weather) affects the user consumption & comfort.

Users’ comfort is guaranteed with the Smart Heating system of the LDSS. It provides to end users a tool, to modify at any time the target temperature of their homes. The control is composed by a main thermostat and individual thermostats. While the main thermostat is a logic device, each individual thermostat matches a physical one located at home.

KPIs for users’ behaviour and satisfaction with the LDSS are also considered. The measured data is collected for **each user separately** on **hourly** basis. Some of the KPIs considered are: active users/month, logins/month/user, how long people stay being logged, features (clicks)/month, advices page clicks/month - this is quite interesting as we have seen that some users only check advices, usually woman, and not checking consumption profiles, etc.

LDSS is the link between the energy provider and the end user, which is meant to be the tool for customer loyalty.

5 Security and Privacy

5.1 Security

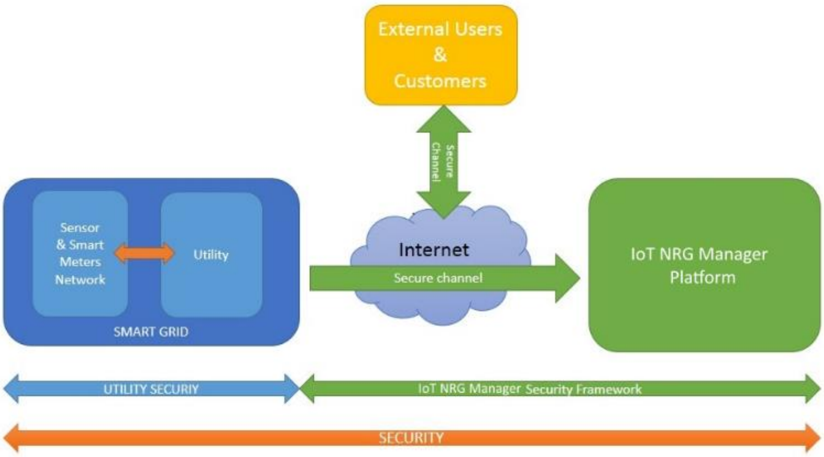

Figure 6. High level diagram of the security structure

Figure. 6 shows the main building blocks of the data flow chain in the IoT NRG Manager; (i) the smart grid, (ii) the end user and (iii) the backend-frontend service of the IoT NRG Manager. The block (i) is out of the scope of the IoT NRG Manager. The utility is applying industry standard technologies to ensure that the data they are managing can be trusted. At this level, IoT NRG Manager provides means of communication and end-points (web services) to ensure that the communication channel is encrypted. This is done using industry standard technologies based on TCP/IP with Secured SSL protocol or REST over HTTPS and Root Certificates X.509 v3. As IoT NRG Manager platform follows a SOA (service oriented) architecture, this schema also applies for the inter communication between the high levels components (LDSS, CDSS and VPP). The LDSS and the SCDB are developed on top of enControl™[1] platform, which provides a base API for the exploitation of the upload/download of metering and sensor data, including data aggregation and fusion capabilities. IoT NRG Manager provides services to its users through graphical user interfaces built on web technologies and native smartphone apps. Any component accessing to the IoT NRG Manager uses the API,

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[1] enControl™ platform is commercial property of Sensing & Control S.L. It is designed to allow agile management of data in the energy efficiency, security and automation fields - http://www.sensingcontrol.com/

exposed in REST form over HTPPS, and only accessible after authentication. It is worthy to comment that the different functions of the API are accessible depending on the type of user assigned.

5.2 Privacy

Privacy is different from security. Privacy does not allow trust, while security at least allows trust in the exchange of keys. ”Access control” is a metaphor used by both security and privacy. As a consequence authentication is the only source for protecting private data. In the early 90ties, data minimization at authentication time was the means to protect privacy [5]. This authentication time data minimization generated a set of successful mechanisms, whose most well-known example are digital signatures, Public key Infrastructures, and identity management [6]. In its most extreme case, anonymization [7] totally omits data for authentication. All these mechanisms are called Privacy Enhancing Technologies (PET). The usage of these mechanisms is limited due to the unwanted impact on the usage of data for management, e.g. usage of energy in smart grids. Other reasons range from cumbersome and hard-to use mechanisms to lack of trust.

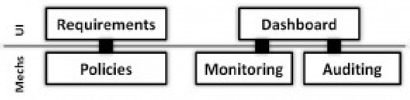

Figure 7. Transparency Topics

Trust in smart grids requires to balance billing, where authentication is needed, with deduction of consumption patterns, where authentication is not needed to for inferences. The key requirement for the IoT NRG Manager is that direct access of smart meters by suppliers is not a useful way to preserve privacy, and that statistical data are sufficient to accomplish both privacy and management of energy usage. In 2004 Park and Sandhu’s specification of usage control (UC) model approached this divergent interests [8]. While, however, UC is an appealing concept from privacy protection view but it also has increased resource demands due to the permanent monitoring of involved data. While UC is limited to centralized systems, distributed usage control applies the concept on decentralized systems. Though, the performance issues increase in DUC. The most recent extension and direction in privacy is a total openness or transparency, where dashboards execute both monitoring and auditing. The family of mechanisms maybe called Transparency enhancing technology (TET).

We propose to follow a combinatorial approach of TET and PET. On the one hand users obtain information how their data and for what it is used. A dashboard provides a choice and consent option for users. Though, energy related data from the IoT NRG Manager platform is needed by third parties like energy utilities or innovative energy efficiency services. To prevent performance issues of DUC coming along with TET on decentralized systems, PET are applied.

Energy related Data is stored in the SCDB providing statistical data to requesting entities. The only meaning for Third Parties to obtain those data is via the Privacy Proxy (PrP). PrP checks if the request is valid according to the IoT NRG Manager privacy principles which is basically to hide the usage of a single household within an anonymity set. At present, IoT NRG Manager experiments with differential privacy, where in theory privacy can be broken by the number of queries addressed to the database. The fundamental idea of differential privacy is to guarantee that in the worst case not more than a predefined amount of information about a single customer can be obtained per request. One option to obtain this guarantee is to add Laplace noise based upon the global sensitivity of the request and a differential privacy parameter.

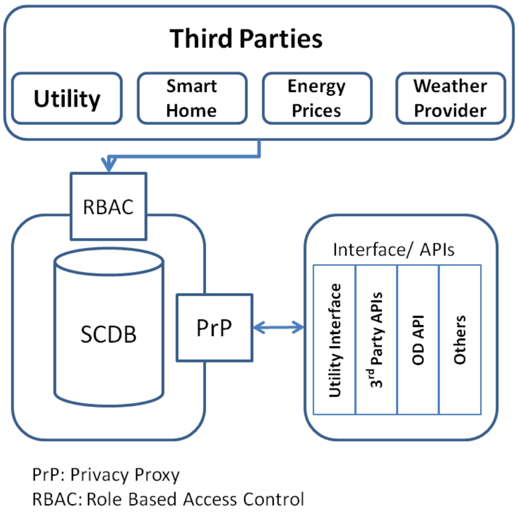

Figure 8. Privacy Protected Data Access

6 From Design To Reality: Deployment in Plovdiv and Rijeka

A principle objective of the IoT NRG Manager is to demonstrate the components proposed in two real-life European Cities with respect technological reliability, potentiality to participate in real energy markets, impact in terms of user engagement, feasibility of business models and energy and GHG emissions reduction. A substantial validation phase of more than 12 months is planned to enable enough data collection and tune the smartDSS and its components, as well as a solid evaluation of more than 6 months.

Plovdiv is the second-largest city in Bulgaria after the capital Sofia with a population of approximately 340.000 inhabitants. It is an important economic, transport, cultural and educational centre. It is the tenth-largest city in the Balkans, being a city with high population. The city of Plovdiv is represented by 29 buildings, including, one CHP Plant, two office buildings (prosumers), seven kindergartens (prosumers), one high school, one mayoral building, and 18 private residential buildings. They are representative of the city consumption and production profile. Additionally, the historical data from the distant meters and manually monitored meters will be integrated into the SCDB so that an excellent picture of energy consumption is built.

The CHP provides heat for the city, smart cool, and electricity for its own use. The two office buildings have PV panels installed and will act as prosumers, along with the kindergartens. The mayoralty building is the first smart cool user in the city of Plovdiv, and will also have smart electricity and heat meters installed.

On the other hand, with a population of approximately 144,000, City of Rijeka is the second largest city in Croatia. It is one of the first European cities that joined the European initiative "The Covenant of Mayors" in 2009 which connects cities with goals to exchange experience in implementing effective measures to achieve sustainable development through reduction of greenhouse gas emissions, increasing the use of renewable energy and energy efficiency. Rijeka has signed the Green Digital Charter committing to use ICT as a main driver to improve energy efficiency

Rijeka it is represented by 28 buildings, including several public buildings such as sports centre, the National Theatre, 5 primary schools and 2 kindergartens, as well as 3 residential. The deployment also includes the heating distribution plants within the city and the public lighting.

7 Summary and Outlook

In summary, instead of typical isolated energy management software incapable of reciprocal operation with other systems, IoT NRG Manager is able to take the most profit from the expansion of the internet of things, with the aim to improve the energy efficiency in cities. With our proposed solution, we build-up an infrastructure that makes possible the integration of various sources of data and makes them accessible to the end-users through two different GUIs - LDSS and CDSS, and also to third parties by means of an Open Data API, which is accessible only via the Privacy Proxy (PrP). PrP checks if the request is valid according to the IoT NRG Manager Privacy principles which is basically to hide the usage of a single household within an anonymity set.

As this concept is still in its development and implementation phase, extensive tests need to be carried out in the next months as well as a direct communication between end-users. It is expected that for March 2015, a first release of all the IoT NRG Manager components will be developed and integrated in both cities, and by October 2015 it will start the evaluation phase with the local utilities in Plovdiv and Rijeka, EVN TP and ENERGO respectively.

8 Acknowledgment

The research presented in this article is funded by the FP7 framework's ICT-2013.6.4 Optimising Energy Systems in Smart Cities, project iURBAN (www.iurban-project.eu), under grant agreement number 608712.

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