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Consumers' privacy concerns and implications for a privacy preserving Smart Grid architecture—Results of an Austrian study

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ABSTRACT

Smart Grid applications, such as energy feedback systems, load shifting for smart homes, and smart charging of electric vehicles provide new possibilities to support the incorporation of renewables. Aside from technical feasibility, consumer requirements and concerns, particularly in terms of the protection of personal privacy, have not been the focus of Smart Grid developments. We therefore investigated consumers' Smart Grid related privacy concerns in private and business contexts and focused on the research questions: (1) who is perceived as a trustworthy authority for energy data storage? (2) What can pose as a privacy threat for consumers? (3) How should energy data be handled by an ICT infrastructure? We conducted a comprehensive online survey ($N = 240$) in Austria to gain an overview into the concerns and deepened our understanding by conducting two focus groups ($N = 15$). Our results indicate the importance of decentralized data storage, access control, as well as information transparency and the incorporation of privacy enhancing functionalities. Consumer-driven requirements and technical requirements led to a suggestion for a privacy preserving ICT infrastructure, following the paradigm of a service-oriented architecture. This architecture can serve as a reference for a future user-centered Smart Grid ICT architecture design.

1. Introduction

The restructuring of power grids from the traditional and centralized solution to a decentralized and demand-oriented Smart Grid is likely to entail considerable changes to public infrastructure over the following years. In order to face the ecological challenges associated with increased reliance on electric power, a flexible power grid enabling the integration of renewable, temporal dynamic energy sources is required. The opportunities for changes; however, afforded by shifts in energy infrastructure, should be tempered with caution due to the potentially far-reaching consequences [1]. Ensuring the systems' scalability, reliability and the interoperability between different system components [12,2] are some examples of technical challenges faced by the implementation of Smart Grids. In the future, the numerous applications of Smart Grids will depend on an information architecture which ensures the information transfer between multiple stakeholders, and incorporates information input from heterogeneous technical infrastructures [12].

In addition to these technical challenges, the consideration of consumer perspective presents a challenge to the development and implementation of the Smart Grid. Given that many personal activities are undertaken increasingly in conjunction with energy consumption, Smart Grid appliances could lead to a data gain of many of the details of daily life [16]. The advantages of implemented Smart Grid ICT (information and communication technology) infrastructures, e.g., providing the consumer with energy consumption feedback, smart car charging or automated load shift, are accompanied by the threat of trading the consumers' privacy [7]. The transition to a smarter grid increases the amount of involved parties, applications, and last but not least, the amount and the informative value of personal data [30]. Access to detailed and fine-grained energy data enables the determining and extracting

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of consumer daily activities, their behavioural patterns, presence (or absence) of occupants, technology usage in private households and in a professional context [30,4]. Accordingly, concerns by end user organizations, data protection authorities and cyber-security groups have already been voiced relating to privacy invasion engendered by the installation of Smart Grid infrastructure as smart meters. Conversely, in order to ensure trust in such technical infrastructure and hence future acceptance of such systems, *Privacy by Design* (PbD) guidelines [8] postulate the incorporation of users' privacy requirements into the system design: "*Keep it user-centric*".

Apart from the technical requirements however, commonly driven by the electric supplier [9], consumer requirements have rarely been considered in the development of Smart Grid infrastructure to date. This study therefore gathered **consumer-driven requirements** for Smart Grid ICT architecture with regard to privacy in order to improve future consumer acceptance, trust and participation. The study focuses primarily on consumers' perspectives in terms of **who is perceived as a trustworthy authority for energy data storage,what can pose as a privacy threat,** and **how energy data should be handled** by a Smart Grid ICT architecture.

The consumer-driven results are finally incorporated into the system design of an open and flexible service-oriented architecture (SoA), but could serve in principle as a reference for a Smart Grid architecture development that considers consumers' privacy concerns.

2. Related work

A Smart Grid is designed to connect power generation, transmission, distribution and consumers by ICT supporting a bi-directional information flow between consumers and utilities [16]. This ICT supported Smart Grid will affect the nature of the consumers' private environment e.g., their home or their company; creating smarter environments with regards to energy data processing. With Smart Grid technology, people will be able to understand how their household uses energy, better manage energy usage, control expenditure on electricity, and experience fewer and shorter power outages [7] in a private or business context. Furthermore the incorporation of cleaner sources of energy into the grid could be supported [7] by an improved alignment of energy demand and supply. A detailed matching of net status and demand allows the application of more transparent pricing strategies which could contribute to 5–15% energy consumption reduction [7] and cost reductions. An expensive extension of conventional energy supply network, e.g., for energy demanding companies, could therefore be avoided.

Aside from these various advantages of a smarter grid, precise indicators revealing activity patterns can be derived from the detailed information about energy usage [3,4]. Even the type of device or appliance being used is possible to determine without extensive effort [5]. From a legal perspective; however, aside from the identification of devices being used, the mere identification of the presence or absence of occupants poses serious questions with regards to the "right to be left alone" (Warren & Brandeis described in Ref. [33]) and article 12 of the human rights declaration [34].

This private energy consumption information, delivered as fine-grained smart meter data [3,4], could be of interest to different groups—e.g., public authorities, marketers, creditors, criminals, other unauthorized users [35] or business competitors. Consequently suggestions to protect consumers' privacy frequently focuses on possibilities to anonymize smart meter data. Algorithms for *Advanced Metering Infrastructure* that avoid to obtain habits and to identify certain appliances, while still allowing time varying tariffs and correct billing, are presented in Ref. [5,6]. Yet privacy and data protection within Smart Grid ICT infrastructures requires more than the anonymizing of smart meter data and ensuring energy data confidentially; rather it is a multi-faceted concept [13] which has to be addressed by multiple research disciplines.

In the related field of smart and context-aware homes, Meyer and Rakotonirainy [10] has already highlighted privacy as one of the most important dimensions to be addressed during development by taking the requirements of occupants into account. Privacy must be taken into account from the beginning of the developmental phase given that security and privacy are prerequisites for consumer acceptance of context-aware homes [14]. Consumers should be provided with transparent information on what data is being tracked, and being able to control who is accessing it and for what purpose [11].

Fhom and Bayarou [15] have made proposals concerning privacy protective Smart Grid systems. They emphasize that the addition of privacy enhancing technologies augmenting fully designed systems, leads ex post to additional financial and operational effort. Furthermore the authors call for an identification of privacy principles and requirements, especially for the Smart Grid system.

The first Smart Grid specific privacy protection principles were formulated by Cavoukian et al. [7]. They suggest the implementation of mechanisms which would allow consumers to control their electricity consumption and the release of personal information. This control would foster consumers' trust and ultimately their participation in Smart Grid implementations, but a detailed understanding of consumers' trust in the context of Smart Grid ICT infrastructure is still required.

In its most basic form, definitions of interpersonal trust rely on the fact that two parties are involved to create trust (e.g., [23–26]): the trustor (subject required to trust) and the trustee (subject in whom trust is placed) [27]. Furthermore with regard to the trustee, Mayer et al. [23] highlighted perceived trustworthiness as an important characteristic. Applied to Smart Grid ICT infrastructure, this implies that one necessary condition to establish the trust of consumers' (trustor) is to involve an authority (trustee) who is perceived as trustworthy. Additionally, the majority of trust definitions in the literature assume a certain degree of vulnerability of the trustor, which infers that trust occurs only in situations in which a threat is present, i.e., the trustor has to take on a certain degree of risk [27]. The investigation into what can pose a threat to consumers in the Smart Grid context is therefore an important variable to research.

Perceived privacy threats; however, for consumers, in terms of information collection, disclosure, and safeguarding [16], if considered at all, are lacking an empirical data basis especially in the context of Smart Grids. The gathering of empirical, consumer-driven requirements is rarely conducted or explicitly incorporated into the development and design of Smart Grid ICT infrastructures. To address this research gap, this study conducted an empirical and consumer-driven requirements analysis in addition to a set of technical requirements, addressing the design and implementation of a user centered and privacy aware Smart Grid ICT architecture.

3. Research questions

To address the need for empirical, consumer-driven research, this study aims to explore how a Smart Grid ICT architecture should be designed to meet privacy concerns of consumers, in both private and professional contexts. It is assumed, as with context-aware homes, consumer requirements will address the need for (energy) data transparency and control. Further requirements will nevertheless have to be specified to accomplish an entire ICT architecture design. This study therefore also focuses on who is perceived as a trustworthy authority for energy data storage; what poses as a pri-

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