Future Smart Grid Prosumer Services

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***Abstract*—The smart grid vision is towards a very dynamic and decentralized future energy network, where electricity will be produced in a distributed way; where customers will be not only consumers but also producers (hence called prosumers); and where bidirectional interaction between producers, consumers and other entities will be possible. Collaboration and near real-time interactions are envisioned between all stakeholders, which of course will need to rely upon timely-provided monitoring and control capabilities. To realise this emerging infrastructure several (business) services will be needed that will empower all stakeholders and enable them to realise the interactions expected. From the business side new, highly distributed business processes will need to be established to accommodate these market evolutions.**

I. Motivation

The smart grid is a system of systems i.e. it is a complex ecosystem of heterogeneous (possibly) cooperating entities that interact in order to provide the envisioned functionality. It is a complex infrastructure depicting system of system characteristics [1] such as interdisciplinary nature, operational and managerial independence of its elements, geographical distribution, high heterogeneity of the networked systems as well as emergent behaviour and evolutionary development. This new infrastructure will heavily rely on modern Information and Communication technologies [2] to achieve its expected functionality.

From the business side distributed business processes will need to empower the new interactions. The traditional static customer processes will increasingly be superseded by a very dynamic, decentralised and market-oriented process where a growing number of providers and consumers interact. Such an infrastructure is expected to be pervasive, ubiquitous and service-oriented. Service architectures, platforms, methods and tools focusing on a network-centred approach will need to be developed to support the networked enterprise. Understanding and managing the complexity of a critical infrastructure such as the energy sector is crucial and implies systemic risk analysis, resilient distributed information and process control frameworks.

The bidirectional information exchange will put the basis for cooperation among the different entities, as they will be able to access and correlate information that up to now either was only available in a limited fashion (and thus unusable in large scale) or extremely costly to integrate. Advanced business services are envisioned that will take advantage of the near real-time information flows among all participants. These real-world energy services will go way beyond the existing ones and enable us not only to become more energy aware, but also to optimally manage it. Prosumers in the smart grid may take into account real-time information and even engage in buying and selling energy online as well as having their environment being automatically adjusted to their behaviour and their energy saving goals.

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II. Towards an Information-driven Smart Grid

The smart grid will have to deal with multiple stakeholders, capture monitoring information and provide control capabilities for a large scale complex heterogeneous infrastructure. This is going to be challenging not only from a technical perspective but also a political one. Today we see a race among companies to place themselves as leaders in this emerging infrastructure and provide solutions. However as many of them gear towards quickly providing patches so that their existing product offers may be characterized as "smart grid ready", and not enough focus is given to openness, interoperability and co-operation. Hence we may run into a segmented infrastructure that may rapidly deliver a portion of the smart grid vision, but make it very difficult to further evolve it in the future, which in turn may lead in the longer term to stagnation of further developments, especially from third parties.

Today integration with business systems is done at an inflexible and usually business-relevant agnostic way – relevant only to the communication of specific data, but without a clear matching or even estimation of the effect on the business side. Furthermore due to the deployment of isolated and task specific solutions, we have ended up with infrastructures that are not interoperable, can not collaborate because of data-understanding barriers and even communication difficulties although e.g. physical proximity could in theory make that possible. The result is the existence of several horizontal and vertical media breaks, that are patched up with proprietary solutions and gateway/tunnelling approaches that complicate things further.

In a mixed, non-standardized and highly complex infrastructure such as the smart grid, business applications have a very hard way to dynamically discover, integrate, and interact with the sensing/actuating devices (e.g. home appliances, smart meters, electric cars) and services. Vice versa, the device world has very little chance of fostering intra-/inter- collaboration capabilities and take advantage of the opportunity to offer their functionality in tight interaction with enterprise functionalities. By abstracting from the actual underlying hardware and communication-driven interaction and focusing on the information available via services, we move towards a service driven interaction. Services can be dynamically discovered, combined and integrated in mash-up applications. By accessing the isolated information and making the relevant correlations, business services could evolve; acquire not only a detailed view of the interworking of their processes but also take real-time feedback from the real physical-domain services and flexibly interact with them.

A service based smart grid, where all of its functionalities are offered as a service seems as a promising way to go. We have already seen in enterprise world how service oriented architectures have prevailed and the "Internet of Services" and "Internet of Things" will further support the provision of generic monitoring and control functionalities as services. This approach will enable us to master heterogeneity by focusing on an information driven interactions.

III. Smart Grid Energy Services

We expect as mentioned several energy services to exist in the future smart grid infrastructure. These are to act as auxiliary services that can be integrated into applications and traditional systems in order to enhance their functionality. We will focus here mainly on some of the Prosumer targeted energy services as they are the key part in several smart grid visionary scenarios.

Timely energy monitoring is expected to be made possible. Information will be generated by discrete user-owned appliances and other devices, and be collected in-house (e.g. a local energy management system) or externally. Part of this information will be provided to third parties for further analytics, however it is expected that the user (and his context) will be able to have real-time access to it. While it is argued that this is not needed for simple visualisation of info to the end-user, the main benefit relies on the smart systems that will be fed with this info and assist automated decision support procedures that will assess user's context as well as energy efficiency goals, and at the end take control actions.

Timely control/management fine-grained capabilities are expected to provide management functionalities that go beyond simple ON/OFF appliance signals and consider the whole lifecycle of affected devices and systems as well as their operational context and goals. This coupled with monitoring will constitute the main building blocks for any more sophisticated solutions to build upon.

Energy Brokering is integrated directly or indirectly on all smart grid visions. Some speak only of user-reaction to energy provided price signals while others consider directly energy trading in online marketplaces. Clearly this should be automatized by agents that act on behalf of their users and consider complex goals e.g. user's behaviour, his calendar (daily expected tasks/places to visit), statistical information etc. While brokering by itself is only an enabling mechanism, the implications for applications build around it could have a significant impact on the dynamic operation of the grid.

Real-time Analytics and value added services are expected also to flourish. Utility computing and the steady increase in processing power will enable us to process huge streams of information and derive real-time analytics. These can be used for businesses to better position themselves in the smart grid markets as well as from citizens that may better understand their energy signatures and plan their energy brokering actions. Other value added services will also exist, addressing specific Prosumer categories and their needs e.g. energy prediction, energy optimization etc. at local and global levels.

Community Management services will be fundamental for the future smart grid with respect to Prosumer interaction empowerment. The smart grid envisions active user participation in order to achieve its goals; however we believe that the critical mass can only be reached by considering goal-driven communities, the interaction with which may have significant impact rather than addressing each Prosumer individually. The communityware smart grid [3] must support the creation of dynamic communities where the (mobile) user may connect and participate. These communities may be motivated by several aspects e.g. environmental, economic, social etc. It should be possible for users to easily create such ad-hoc groups, as well as join them while getting some guarantees on security, trust and privacy issues involved when affiliated and/or transacting in this context. Support for intra- but also inter-community collaboration is wished in order to increase networking effects.

Energy Application Stores will be required to manage the large number of energy related services and applications. There users automatically may find and install a variety of energy related applications and services in the multitude of (mostly mobile) devices expected to be in the smart grid era.

As an example of emerging services the NOBEL project [4] is currently realising energy monitoring and brokering services while the SmartHouse/SmartGrid project [5] focuses on energy monitoring, and price-driven control. Of course similar efforts exist also in various other R&D projects; however the real-time analytics and community support focus seem to be still in embryonic state.

IV. Conclusion

The future smart grid will be information driven and rely on services to empower the interactions among its stakeholders at multiple layers. This calls for open information exchange that considers interoperability, security, trust and privacy. Value added services to be offered to Prosumers will need to be developed over a federated infrastructure, where cooperation will be more eminent than ever.

References

[1] M. W. Maier, "Architecting principles for systems-of-systems," *Systems Engineering, John Wiley & Sons, Inc.*, vol. 1, no. 4, pp. 267–284, 1998.

[2] R. Katz, D. Culler, S. Sanders, S. Alspaugh, Y. Chen, S. Dawson-Haggerty, P. Dutta, M. He, X. Jiang, L. Keys, A. Krioukov, K. Lutz, J. Ortiz, P. Mohan, E. Reutzel, J. Taneja, J. Hsu, and S. Shankar, "An information-centric energy infrastructure: The berkeley view," *Sustainable Computing: Informatics and Systems*, 2011.

[3] S. Karnouskos, "Communityware SmartGrid," in *21st International Conference and Exhibition on Electricity Distribution (CIRED 2011), Frankfurt, Germany*, 6-9 June 2011.

[4] A. Marqués, M. Serrano, S. Karnouskos, P. J. Marrón, R. Sauter, E. Bekiaris, E. Kesidou, and J. Höglund, "NOBEL – a neighborhood oriented brokerage electricity and monitoring system," in *1st International ICST Conference on E-Energy, 14-15 October 2010 Athens Greece*. Springer, Oct. 2010.

[5] S. Karnouskos, A. Weidlich, J. Ringelstein, A. Dimeas, K. Kok, C. Warmer, P. Selzam, S. Drenkard, N. Hatziargyriou, and V. Lioliou, "Monitoring and control for energy efficiency in the smart house," in *1st International ICST Conference on E-Energy, 14-15 October 2010 Athens Greece*. Springer, Oct. 2010.