Middleware-based Management for Smart Grids

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***Abstract*—We introduce a distributed-object based platform for managing, controlling and integrating large scale heterogeneous electrical installations[1]. It provides support for advanced metering infrastructures and smart-grids. Objects provide services for managing electric magnitudes and appliances.**

I. Introduction

Today there are many commercial devices that allow to control any electric appliance, even in a remote way. Recently, concepts like *smart grid* or *advanced metering infrastructure* (AMI) emerge for electrical power management and measurement purposes. However, related standards do not exist, nor programming interfaces, so they cannot be yet widely used.

In this paper, we propose a system for controlling and measuring the electrical power consumption for *large scale* and *heterogeneous* infrastructures. Intended to be used in smart grids, our proposal offers the following required features [1]: *a) Adaptability*. Our proposal makes it possible to build *Embedded Metering Devices* (EMDs) to control individual appliances which do not required to be modified. *b) Scalability*. It scales easily with the number of nodes or equipments to be controlled. *c) Availability*. Because of its distributed nature, our proposal allows that network segments temporarily isolated due to some failure may still continue to work in an autonomous way. *d) Hierarchical*. Different types of infrastructures (house, building, residential area, etc.) may be integrated in a transparent way.

Furthermore, our proposal also provides other advanced features that are desirable in smart grids: *a) Small size*. In many appliances, the EMD may be very small and simple, as small as to be installed in an electrical junction box or even inside the bulb lamp base. *b) Cost*. EMD is cheap enough as its cost is irrelevant in relation with the installation and maintenance of the controlled charge. We estimate the cost is about 3€ in the case of a home light point. *c) Low consumption*. Obviously, the EMD power consumption must be insignificant in relation to the controlled charge. *d) Flexible access*. The platform is able to employ several communication systems, from telephone lines to standard Internet connections. *e) Access transparency*. Transparent and homogeneous remote access is allowed even with technologically different communication and computational resources. *f) Conventional tools*. It allows using well-known and well-tested protocols and software tools.

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II. Related Work

Many research works about smart grids have been recently carried out [1]. In [2] ZAMI, a ZigBee based AMI for monitoring electric system of buildings, is introduced. The AMI is separated logically from the rest of the system. In [3] a service based system to build AMIs using web services is introduced. It provides hardware and protocol abstractions but the need of a XML parser implies more hardware resources.

Most of the literature about smart grid is focussed on measurement tasks [4] . Recently, multi-agents based proposals have appeared (like [5]). However, they do not provide results about hardware/software requirements for a real installation.

III. A Platform for Power Management

Our target is a generic platform suitable to develop efficient electric power management services for any environment. With this in mind, we provide a basic set of features useful to compose valuable services supporting presented features.

A. Communication middleware

The platform is based on standard object oriented middlewares. Thus, the system may be seen as a set of distributed objects that share information via remote method invocations. The middleware provides a uniform, generic and fully specified application protocol. There are many general purpose middlewares supported by the industry. Our EMD current propotypes work with CORBA [6] and Ice [7].

B. EMD implementation

Every EMD must be capable of running one or several distributed objects of the selected middleware. EMDs are *autonomous* and just need conventional networking support, like routers, bridges or gateways between technologies.

Generally, an EMD is composed as shown in figure 1: a microcontroller, a network interface, an electrical switch for turning on/off the electric load and measurements devices for motorizing such electric load.

Due to the distributed object oriented paradigm, each EMD must implement a set of *interfaces*, that is, the contract between itself and the clients. This software interface is specified using a interface definition language like IDL in CORBA or Slice in Ice. In this sense, a distributed object may be seen as a service: the client can access to this service independently of its location and the technology in which it has been implemented.

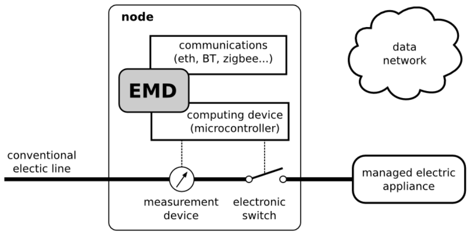

Fig. 1. Block diagram of the general EMD structure.

C. Hierarchical Control and Management

According to the their characteristics and levels of performance, EMDs can be classified in three different types (see figure 2 for an example of deployment):

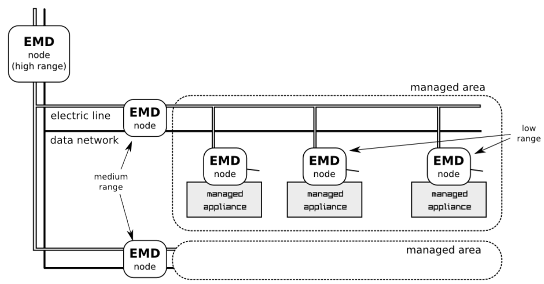

Fig. 2. Example of deployment where different types of EMD are used.

1) Low range EMD (L-EMD): For simple electric loads like a light, electric outlet or toaster, L-EMD can modify, know and transmit the state (typically on/off) of the controlled load but it cannot measure it. For integrating it into the whole system, we use the picoObject approach [8]. The picoObject is the smallest implementation approach (hundreds of bytes) for standard distributed objects in a great variety of devices, including the cheapest microcontrollers.

2) Medium range EMD (M-EMD): This type of EMDs includes all the functionality of the L-EMD but including some basic properties for measurement of consumed power, voltage and electrical current. Furthermore, to deal with scalability issues, M-EMD provides aggregation mechanisms that let us read and modify any amount of devices, as it all of them were a single one. This class of devices is designed for the installation in thee low-voltage electrical panel.

In order to implement these properties, this class of device requires a 16-bit microcontroller, due to their need of more memory and in/out ports for several sensors. M-EMDs may support, if desired, routing functions between the managed (local) area network and the global (external) system network.

3) High range EMD (H-EMD): This class of devices requires a more powerful embedded device because they may store logged data (collected remotely or locally) about measurements and power statistics, voltage and current. H-EMDs are a good example of the *smart meters* supposedly provided by the electricity supplier.

Fig. 3. Our L-EMD prototype: ethernet interface, PIC16F876A microcontroller and three triacs for power control switching.

D. Deployment and configuration

After the physical deployment of the EMDs has been done, the system administrator needs to identify and associate each one with the electric load it will control and monitor. We have designed a protocol to discover and identify each node in the environment [9]. The node can periodically send asynchronous messages to advertise itself and its features. With the advertisement information and an administration software tool, it is possible to add data to each node, such as the location in the building, human readable description, etc. All this information is propagated up in the hierarchy when required.

For security and privacy reasons, the access to the system follows a role-based schema. The visibility and access privileges depend on each actor role; the house owner may see and access all the devices that control his appliances.

IV. Conclusions

We have briefly presented a distributed-object based platform for building scalable AMIs and smart grids using conventional tools and protocols. It integrates transparently in every node measuring and controlling capabilities using low-cost and resource-contrained devices

We are working on applications over this platform for automatic testing maintenance of the electrical installation, notification on failures and the integration in smart environments like home-automation.

References

[1] R. Hassan and G. Radman, "Survey on Smart Grid," in *Proceedings of the IEEE SoutheastCon 2010 (SoutheastCon)*. IEEE, 2010.

[2] H. Y. Tung, K. F. Tsang, and K. L. Lam, "ZigBee sensor network for Advanced Metering Infrastructure," in *2010 Digest of Technical Papers International Conference on Consumer Electronics (ICCE)*. IEEE, 2010.

[3] S. Chen, J. Lukkien, and L. Zhang, "Service-oriented Advanced Metering Infrastructure for Smart Grids," in *2010 Asia-Pacific Power and Energy Engineering Conference*. IEEE, 2010.

[4] K. H. Han, S. W. Choi, B. C. Park, and J. J. Lee, "An implementation of a wireless sensor network-based meter reading system," in *SenSys '09: Proceedings of the 7th ACM Conference on Embedded Networked Sensor Systems*. New York, NY, USA: ACM, 2009.

[5] M. Pipattanasomporn, H. Feroze, and S. Rahman, "Multi-agent systems in a distributed smart grid: Design and implementation," in *2009 IEEE/PES Power Systems Conference and Exposition*. IEEE, 2009.

[6] *The Common Object Request Broker: Architecture and Specification*, 3rd ed., Object Management Group, 2002. [Online]. Available: http://www.omg.org/spec/CORBA/3.1/

[7] M. Henning and M. Spruiell, *Distributed Programming with Ice*, Revision 3.3.1, May 2008.

[8] F. Moya, D. Villa, F. J. Villanueva, J. Barba, F. Rincón, and J. C. López, "Embedding standard distributed object-oriented middlewares in wireless sensor networks," vol. 9, no. 3, 2009.

[9] F. J. Villanueva, D. Villa, M. J. Santofimia, F. Moya, and J. C. Lopez, "A framework for advanced home service design and management." Las Vegas, NV, USA: IEEE Computer Society, 2009.