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Service-Oriented Intelligent Energetic Grid

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Abstract:
This paper introduces a proposal for a smartgrid management platform built on the distributed programming paradigm. Besides it is based on an information model and event architecture. The information model defines a set of clear interfaces to manage every "grid node". We built an actual implementation of a low-cost embeddable control/meter device that may even be attached to individual appliances. These devices behave as conventional autonomous remote distributed objects and provide full support for the information model and also for integration with the communication middleware. The resulting event architecture provides great flexibility to manage information flows from services and applications.

I. INTRODUCTION

Today there are many commercial devices that allow controlling any electric appliance, even in a remote way. Recently, concepts like smart grid or Advanced MeteringInfrastructure (AMI) emerge for electrical power managementand measurement purposes. However, related standards do not exist, nor programming interfaces, so they cannot be widely used yet. 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, this proposal offers the following valuable features:

- **Adaptability:**
It makes it possible to build Embedded Metering Devices (EMDs) to manage arbitrarylevel facilities, from individual appliances to whole buildings or larger.
- **Scalability:**
It scales easily with the number of nodes or equipments to be managed thanks to the middleware common services: event service, replication, indirect binding, etc..
- **Hierarchical**:
Different types of infrastructures maybe 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.

Low cost:
The EMD is cheap enough so that its cost is negligible in relation to the installation and maintenance of the controlled charge.

- **Low consumption:**
Obviously, the EMD powerconsumption must beinsignificant in relation to the controlled charge.
- **Flexible access**:
The platform is able to employ several communication systems, from telephone lines to any kind of wireless network with the appropriate gateway.

II. RELATED WORK

Recently, smart grids are becoming an interesting research field due to their potential and impact on industry, economy and society. Many works address the need of a dynamic behavior and configuration of smart grids. This is a requirement to implement the following functionalities in a smart grid:

- **Smart reactions to faulty conditions**: applications may monitor different measurement parameters to detect and predict fault occurrence in any part of the grid. Thus, Smart Grids should provide an adaptive control for power supply and consumption in case of system malfunction or when certain parts of the grid are down. In this situation, the grid may be reconfigured to isolate the faulty zone by using an architecture that provides dynamic control.
- **Dynamic load balancing:** usually, different parts ofthe grid are not fed with the same energy at the same time. Different consumption profiles or time zones contribute to unbalance the energy grid. In short, smart grids should adapt energy production to current consumption demands of users. Reconfiguration makes possible a smarter and automated redistribution of the load through the grid.
- **Flexible configuration**: a reconfigurable architecture provides a way to customize the infrastructure to the end users needs without additional hardware installation. For instance, users might manage and monitor every home appliance (including those that may be installed in the future) with the same "control panel.

A RECONFIGURABLE PLATFORMFOR

POWERMANAGEMENT

Our target is a generic platform suitable to develop advanced electric power management services and applications for any environment and provide core mechanisms and support for them. With this in mind, we employ object-oriented distributed communication middleware to deal with inevitable heterogeneity in smart grids and to provide a standard protocol for the whole system. That platform is called CoSGrid (Controlling the *Smart Grid*). When all of the system components can be managed as objects and they share the same information model, it is possible to establish logic relations among them. Therefore, the platform is based on the next components that are explained in detail in the next sections:

- The Embedded Meter Device.
- An information model.
- A set of core services

EMBEDDED METER DEVICES

The EMD allows encapsulating the sensor (electrical magnitude measures) and actuator (control) to show the appliance as a distributed remote object. This is a powerful abstraction that lets the platform operate in a seamless way. All of the services deal with remote object references, without any knowledge about the underlying device nature: sensor Our EMD current prototypes work with the Ice middleware .technology, network access, computing platform or any other detail. Every EMD must be capable to hold 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, as shown in Fig. 2 the EMD is composed of: a microcontroller, a network interface, an electrical switch for turning on/off the electric load and measurement devices for monitoring such electric load. Due to the distributed object oriented paradigm, each object in the EMD must implement a set of interfaces, that is, the contract with their clients. In this sense, a distributed object may be seen as a service: the client can access this service independently of its location (so called location transparency) and the technology in which it has been implemented. However, to provide these features different hardware requirements are needed.

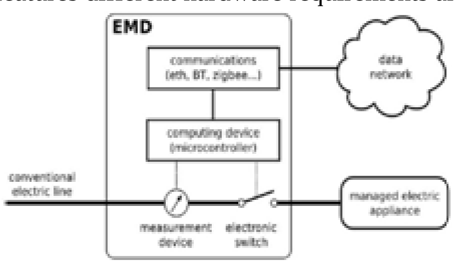

Figure.2. Block diagram of the general EMD structure.

We provide a classification of different EMD implementations according to their characteristics, goal or performance. EMDs can be classified in three different basic types (see Fig. 3 for an example of deployment):

A. Low range EMD (L-EMD)

For simple electric loads like a light or electric outlet, L-EMD can modify, know and transmit the state (typically on/off) of the controlled devices by implementing the *Control* interface (see section VI). If the infrastructure requires fine-grain measured values, EMD-L devices may implement the *BasicMeter*interface. Keep in mind that L-EMDs are designedto be integrated into appliances and devices that consumer will use. They should be cheap and easy to deploy, so the functionality they may provide should be simple too. To integrate them into the whole system, we need to build distributed objects into devices with a few K-words of memory and a single 8 -bit microcontroller. To achieve that it is used the picoObject approach. PicoObjects are being used to implement the smallest standard distributed objects (hundreds of bytes) in a wide variety of embedded devices, including the cheapest microcontrollers. In a common deployment, many L-EMD devices will be deployed. Each L-EMD needs a power line and a data connection as Fig. 3 shows in *ground* floor. A multi L-EMD may be used to reduce cost and simplify the deployment process. The multi L-EMD behaves as a set of L-EMD that are accessible individually and remotely, but it employs only a computing and communication device. We have built a prototype of a multi L-EMD device.

B. Medium range EMD (M-EMD)

This type of EMDs includes all functionality of the L-EMD but adds 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 if they were all a single one. This class of devices is designed for the installation in the low-voltage electrical panel. In order to implement these properties, this class of device requires a 16 -bit microcontroller, due to their needs of more memory and also more 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.

C. 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. Due to its goal, these EMD are accessible only to companies and they may decide whether it requires remote control. The power company may need this kind of functionality at upper level (perhaps at substations) but those EMD are essentially the same of H-EMD.

III. DEPLOYMENT AND CONFIGURATION

After the physical deployment of the EMDs has been done, the system administrator needs to identify and associate each object with the electric load it will monitor and/or control. We designed a service discovery protocol suitable to identify every node in the environment. 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 user or application specific information to each node, such as the location in the building, human readable description, etc. All of 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; a house owner may see and access all of the devices that control his appliances. Furthermore, middleware’s usually provide security at protocol level by using SSL/TSL encrypted communications.

IV. SCENARIO

This section describes an example scenario where high-level applications can be implemented over CoSGrid platform to provide smart services using reconfiguration and aggregation features. A schematic representation of such scenario is shown in Fig. All of these infrastructures are provided with L-EMD (or multi L-EMD) and M-EMD devices for electric appliance and floorof a power grid where CosGrid devices have been installed. User buildings may represent complex hospitals or business buildings that need generators in case of power blackout. Batteries to may be charged using wind generator or main power, and the remaining energy is inserted into the grid.

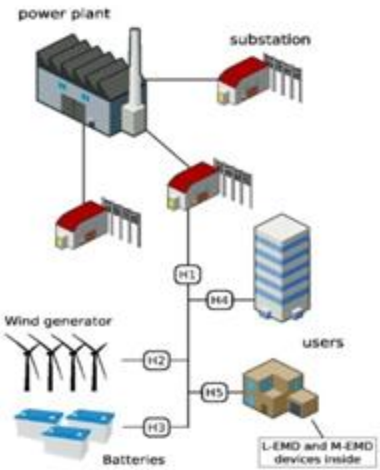

Figure. 5. Example scenario

Electrical panels, respectively. Thus, fine grain control and measurement of consumption or generation values can be done. L-EMD devices can monitor appliances like computers, lights, electrical sockets, etc. M-EMD devices are composites of L-EMD devices and control an entire floor (or a small building). Using the composite interface, clients can get statistical values from the associated L-EMD devices. However, if it is required by the application, each L-EMD device may be individually inspected.

H-EMD devices are also represented in the figure above, and typically monitor an installation or building:

- *H1*: controls and measures the power line fromsubstation. It is a composite object which provides statistical values from the other H-EMD nodes (there is a two level hierarchy of H-EMD).
- *H2*: controls and monitors the generated energy from the wind generator. It is also a composite of EMD devices of the generator system. Unlike the rest, it is expected that this EMD will provide negative consumption values due to energy generation.
- *H3*: this EMD just controls whether the batteriessystem should start providing power or they should stay disconnected.
- *H4 and H5*: monitor and control their respective buildings and both are composite objects.

V. CONCLUSIONS

The smart grid presents many common aspects with distributed system. The main problems like power demand and power losses can be solved by this method. We proposed the use of EMD with the sensor for efficient power management. We also provide a very low cost implementation of an autonomous reliable distributed system that makes it possible to interact with any components of the grid easily. Other goals include high abstraction level services (agent based) that analyze user behavior from their activities related to home appliances and in this way detect anomalous situations, accidents, security problems, etc.

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