DEMAND MANAGEMENT COMMUNICATIONS ARCHITECTURE

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ABSTRACT

The purpose of the paper is to communicate the progress of the second year of the Active Demand Management project (GAD Project) in different areas, especially related to its communication architecture. This experience will support the different agents of the Electrical Sector in order to assess new regulatory requirements, improve service quality and overall energy efficiency, being the key tool in defining a new electricity marketplace for Spain.

INTRODUCTION

The objective of GAD project [1] (Spanish acronym of Active Demand Management) is to investigate and develop an intelligent network system in order to improve the energy efficiency of electricity generation. This higher efficiency is achieved by actively modifying the consumption profile of low and medium voltage users.

The GAD system allows final consumers to contribute to the Electrical Sector energy efficiency flattening the Demand Curve by moving end users consumption from peak to valley as illustrated in figure 1.

Users will receive commands from the system to reduce its consumption. A load manager will process these commands. This manager will decide which electrical loads will be affected by the commands received. This mechanism enables higher levels of renewable energy generation in the country and avoids operational inefficiencies. Lessons learnt will also help to manage the future Smart Grids [2] with an ever-growing use of renewable energy sources.

In the following sections network design methodology and advances in communication architecture definition will be shown, with a more in detail discussion of the simulations being performed to test and tune the whole system performance and its suitability to achieve business model needs.

Figure 1 – Electricity Demand Curve flattering improves electricity generation efficiency (source: REE website www.ree.es)

METHODOLOGY AND DESIGN STAGES

Designing a network, and especially a wide-area network (WAN), is a task requiring many single steps and information. Although there are good references on the topic [2-5], the most suitable methodology strongly depends on each single case. The design process involves several stages that progressively define the network architecture, its technologies and its defining parameters. A simplified process of the design process used in GAD Project follows.

The first step is to identify the different elements that should be connected through the network and its communication needs. Once these needs are considered, they are formally specified, detailing their parameters and assigning priorities. The requirements formal specification allows a selection of potentially suitable technologies. In this stage, the existing network resources (transmission medium, protocols, etc.) are considered to leverage synergies with the proposed architecture.

The former process gives a qualitative description of the network architecture. A more in depth analysis of the proposed solution is performed by means of simulation. Simulation is a powerful tool that provides a controlled environment to test business cases and to benchmark overall network performance. Simulation is iteratively used to
improve network design.

**GAD COMMUNICATIONS ARCHITECTURE**

Network architecture has been divided into four segments: High-level WAN, Trunk WAN, Access WAN and LAN.

- **High-level WAN** is composed of the control centres of the Electrical Sector agents, namely the System Operator, Distributors and Commercial retailers. These agents interact by means of a high-performing optical network using web services in a secure Virtual Private Network (VPN). These web services implement the high-level demand management logic, which is a collaborative and interactive distributed application.

- **Trunk WAN** is the network segment between the control centre of the Distributor and Low Voltage (LV) Transformers. It spans high and medium voltage lines over the transport and distribution grid. Several technologies coexist in the Trunk WAN, but all of them converge into an IPv4 network, allowing for effective end-to-end communications over the whole distribution grid.

- **Access WAN** spans from the LV Transformer to the consumers’ WAN devices. These devices are a power meter for Automatic Metering Service (AMS) and an electrical load controller (which manages electrical loads inside a customer's premises). A device is introduced next to the LV Transformer to perform AMS and GAD management tasks. Devices in the Access WAN network use the communication system developed by the PRIME Project [6-8] for efficient use of the narrowband powerline CENELEC A band.

- **LAN** is the segment of the network inside a customer premises. The target devices (electrical loads) of the GAD Project are placed in the LAN segment, and control commands are issued by the load controller to these devices. The load controller is a gateway between Distributor and LAN. It manages communication with Distributor and Commercial Retailer agents and manages the intelligent electrical loads of the customer.

Some state of the art communication protocols are being used to ensure availability of the best-suited technology for the GAD Project. One of these is the PRIME Project lead by Iberdrola, which has published a fully functional MAC layer for narrowband powerline communications in July 2008.

**CURRENT DEFINITION STATUS**

According to the paper the GAD consortium delivered to CIRED Frankfurt 2008 [9], during the last year we have been working on the protocol specification and procedural behaviour for every agent.

The communications network structure is already defined, the different technologies in each OSI level for each agent are specified. The requirements of interfaces, the algorithms and data structures are pending for approval; the analysis of the workload is now under simulation phase in different work packages of the GAD project.

**Communications among agents.** The algorithms to communicate and implement demand side management orders are now ready, and will be used in the integration phase of the project. Data input and scenario definition will be in place to launch integration and test phase, according to the project schedule and business models needs.

First generation services implemented by the system assess the most demanding legal requirements and provide demand management services that lead into a real benefit for all the players involved. Some of these services are the ability to manage domestic electrical demand automatically and apply real-time pricing (RTP).

Distributor communicates with end-user devices by means of DLMS/COSEM over IP as shown in Figure 2.

**Access WAN segment.** A whole simulator of PRIME has been developed, composed of a powerline emulator, a Physical (PHY) layer, a complex Medium Access Control (MAC) layer and IP Convergence layers. This simulator is being used to characterize the behaviour of the Access WAN segment in normal conditions. Protocols are under study to minimize the traffic load impact in the network.

**LAN segment.** A set of different environments are now under simulation too (KNX) using XML over IP network models (see Figure 3 and 4 for reference).
The detailed communication procedures and different protocol characteristics are now being stressed:

- **Security** of message passing algorithms and user registration procedures.
- In-house device management with the minimum information coming in/out of the LAN.

GAD Project network architecture is now under simulation phase to test and ensure the functionalities and scalability of the services provided.

**SIMULATION OF NETWORK PERFORMANCE**

The WAN of the GAD Project requires careful design and planning which makes simulation a critical decision tool. The GAD Project is performing a full set of simulations over realistic scenarios using the OMNeT++ [10] network simulation framework. OMNeT++ is open source and provides a full set of internet based protocols ready to use by means of the INET extension, as IPv4, IPv6, TCP, UDP, Ethernet, and many others.

Although INET is a versatile environment, there is no simulation model for PRIME protocols. CEDETEL, a research centre contracted by SIEMENS, has developed a full simulation model composed of:

- A physical medium model, emulating propagation losses, insertion losses, collisions and noise (thermal, narrowband and impulsive).
- A PRIME PHY interface model based of physical phenomena [11-15], which allows the transmission and reception of PRIME frames supporting automatic gain control, zero crossing detection, receiver sensibility, different modulations (DBPSK, DQPSK and D8PSK), noise and convolutional decoder effects.
- A PRIME PHY based on an statistical model for fast and massive scenario simulation.
- A PRIME MAC layer according to the specification in [7], which will be complete in early 2009 supporting beacon transmission, addressing, multiple packet, promotion among many other features.
- A functional convergence layer between IPv4 and PRIME MAC to allow IP communications on the simulated environment over PRIME.

This model is being used in scenario simulations for traffic-shaping, network benchmarking and network tuning [16-17]. In Figure 5, the model of a PRIME interface card developed in OMNeT++ is shown.

Simulations will characterize: the medium access performance under heavy concurrency conditions, the Access WAN mean transmission rate, end-to-end latency and system scalability among other figures of merit.

Simulation results are expected on March 2009 and are key to determine potential network performance and service quality of the GAD Project.

**CONCLUSIONS**

This paper shown the current status of the GAD Project network architecture. GAD consortium is now finishing and validating the definitions, simulating the new Demand Management scenario, stressing business models and
technical results to ensure the viability of the project, before jumping into prototyping and test fields.

During the last year, the consortium finished the high-level application protocol among System Operator, Commercial Retailers and Distributors, implemented security procedures, simulation models and improved network architecture definition.

The availability of finished simulation models and benchmarking information will help assess network performance objectives in 2009, and will lead to a field trial of the final Demand Side Management system developed in GAD Project.

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CEDETEL is the research organization chosen by SIEMENS to design the architecture of the WAN network of the GAD Project. Ericsson leads the Communication Architecture, with the R&D center CITIC, and Iberdrola will lead the Integration Phase. All of them are part of the communications WP (Work Package) of the GAD Project.

REFERENCES


