ENCOURAGE architecture: support for heterogeneous smart grids.

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Our society relies on energy for most of its activities. One application domain inciding heavily on the energy budget regards the energy consumption in residential and non-residential buildings.

The ever increasing needs for energy, resulting from the industrialization of developing countries and from the limited scalability of the traditional technologies for energy production, raises both problems and opportunities. The problems are related to the devastating effects of the greenhouse gases produced by the burning of oil and gas for energy production, and from the dependence of whole countries on companies providing gas and oil. The opportunities are mostly technological, since novel markets are opening for both energy production via renewable sources, and for innovations that can rationalize energy usage. An enticing research effort can be the mixing of these two aspects, by leveraging on ICT technologies to rationalize energy production, acquisition, and consumption.

The ENCOURAGE project[1] aims to develop embedded intelligence and integration technologies that will directly optimize energy use in buildings and enable active participation in the future smart grid environment. The primary application domains targeted by the ENCOURAGE project are non-residential buildings (e.g.: campuses) and residential buildings (e.g.: neighborhoods). The goal of the project is to achieve 20% of energy savings through the improved interoperability between various types of energy generation, consumption and storage devices; inter-building energy exchange; and systematic performance monitoring. To reach this goal, the project designed an architecture that is depicted in Figure and whose components are:

- a *Supervisory Control* component, which implements strategies to orchestrate the operations of different subsystems like Heating, Ventilating, and Air Conditioning (HVAC) systems, lighting, renewable energy generation, thermal storage, taking into account that each subsystem potentially comprises a large number of embedded devices. The component will schedule energy-consuming appliances, like washing machines and HVAC (Heating, Ventilating, and Air Conditioning) systems, taking into account the energy produced locally by the user. The Supervisory Control will be focused either on supply side (local generation control), demand side (load management), or combination of both (energy management);
- a component for *Energy Brokerage and Business Intelligence*, which integrates the system with intelligent gateways whose embedded logic supports inter-building energy exchange. This brokerage agent will communicate directly with other buildings and local producers to negotiate possible use of the electricity produced locally in their premises. The component will provide services that will take advantage of the collected historical

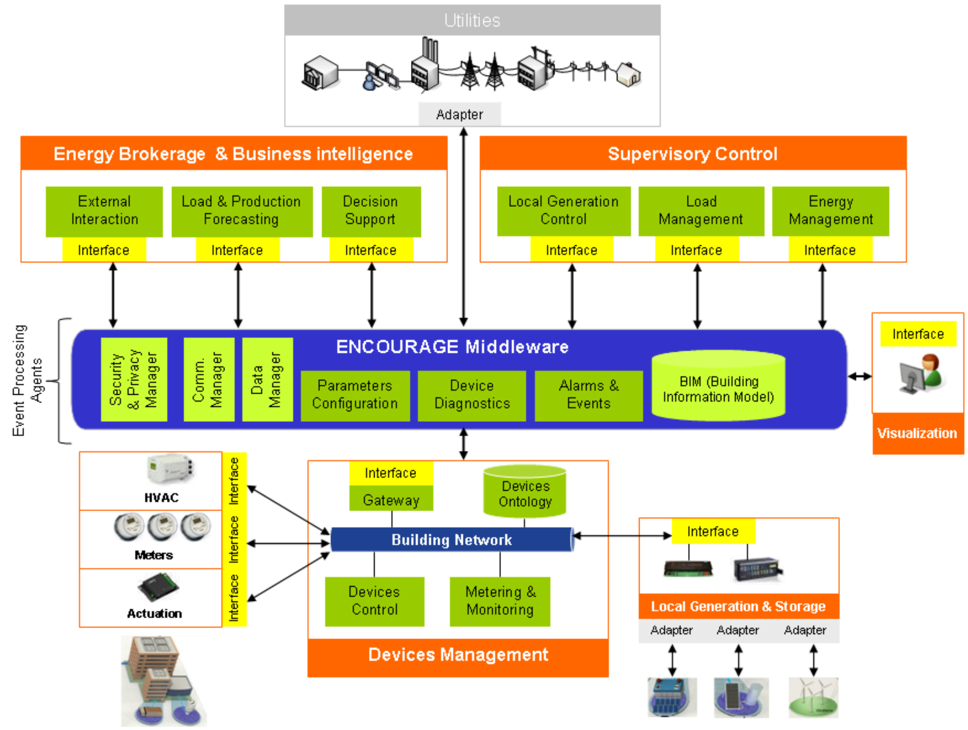


Figure 1. Architecture of ENCOURAGE

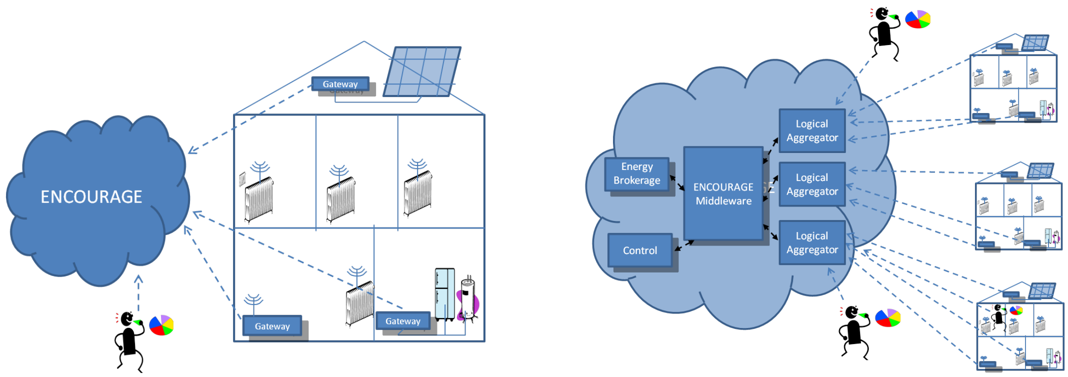
data on previous consumption patterns as well as load and generation forecasts, to make decisions in short-term about the participation in the energy brokerage, or in long-term about possible retrofits, equipment replacements and other capital investment actions;

- the *ENCOURAGE Building Network* (EncBN), which provides devices management, i.e. access and integration mechanisms for the various heterogeneous devices that either reside inside the building (HVAC equipment, sensors, actuators, meters / sub-meters, ...) or are located in the exterior spaces like the local generation and storage equipment.
- a *Middleware* that implements an event processing system that takes the data from the EncBN and processes it as a stream of events. The middleware can be seen as being composed of multiple event processing agents that exchange information between event producers, event consumers, and other agents. This approach will not only handle uncomplicated events but it will also allow for inference of complex events by combining simple ones. The middleware will be able to host various applications, such as the device diagnostics.

On the level of the EncBN, the project pursue its goals on the premises of supporting a division of the EncBN into meaningful units, to fight against the complexity that arises with large systems. The ENCOURAGE architecture further develops the results of ARTEMIS project eDIANA[2], as shown in Figure 2, by articulating the smart grid into Cells (living / working units) and macro-Cells (residential and non-residential buildings) to reach a new level of optimization not possible before.

The EncBN is identified with a set of Home Area Networks (HANs), each one composed by devices in the user's house and one or more smart gateways that control the devices and connect the HAN to the ENCOURAGE Middleware. We can suppose that these gateways were acquired from different vendors and that they provide different functionalities (e.g. renewable generation, HVAC, solar, ...). The current practice is to consider that the gateways do not interact, and that they provide a HAN divided into secluded and non-communicating segments. The ENCOURAGE architecture considers that the gateways aggregate themselves with the Middleware, causing the Cell to appear as a single entity.

To provide semantically meaningful division of the EncBN into units that can be easily mapped to final users, we communicate with the HANs via *Logical*



(a) Cell (b) Macro-cell

Figure 2. Division of the EncBN into semantically meaningful units

Aggregators, which are the entry points to the single entities the network is divided into. From the previous discussion, this entity can be identified with the Cell, and corresponds to one living / working unit. Each Logical Aggregator brings together a number of legacy embedded devices (gateways, sensors, actuators, ...), and rationalize their integration into the smart grid. With the goal of easing the integration of new vendors, and to increase the versatility of the platform, ENCOURAGE is determined to adhere to standards[3][4], which will be used for both the description of the internal data and, whenever possible, for the communication between the gateways and the Logical Aggregators.

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