UOIT
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Energy Safety & Control Laboratory
ESCL

Simulation Analysis for the Design of High Performance Smart Meter

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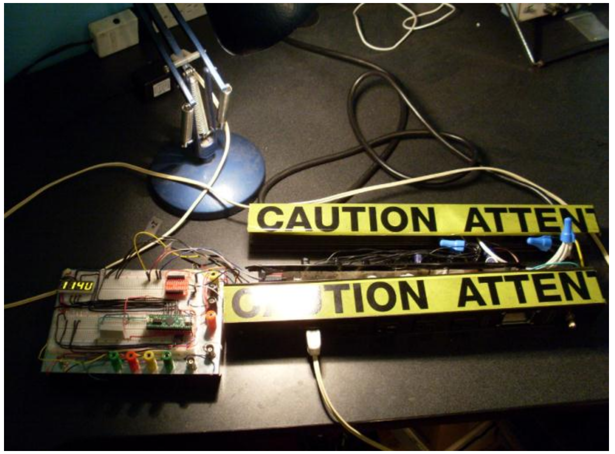
Introduction

- The significance of controlling utilities and resources is crucial in space programs for prolonged living in microgravity conditions.
- The smart meters today = automated reading units, or ARU, capable of computing the power consumption and cost for the consumption in accordance to the time of the day, and day of the week.
- The advanced metering infrastructure (AMI) = a system of utility meters that measure the consumption and provide the information to the utility companies, as well as the consumers interested in keeping the usage costs low, or wanting to supply the electricity back to the grid [1].

Introduction

- The AMI systems are pursued due to the significant empowerment for the end users, and the information reliability for the utility companies; it would replace the thermostats and auxiliary controllers in order to provide consistent information for the consumption trends for water, gas and electricity.
- Defining and standardizing the AMI systems represents a significant roadblock for the producers of the smart meters, the utility companies, and the end-users.
- As part of the research on clarifying the AMI systems, the Energy Safety and Control Lab has considered the intelligent multi-agent systems as a sound foundation for reducing the ambiguity about the AMI.
- The intelligent agent is a software component that is situated, autonomous, reactive, proactive, flexible, robust, and social [2].
- The intelligent multi-agent AMI can be programmed to provide the standard performance indicators: Specific, Measurable, Accurate, Relevant, Timely, Evaluative, and Recordable.
- Electricity trends: the end-user consumption and generation trends would include apparent power, VA-hours, phase voltage difference, current frequency, voltage frequency, current harmonics, voltage harmonics, power factor, reactive power, real power, kilo-watt hours, VAR-hours and price.
- Gas and water trends, the flow rates, the amount consumed and the price for consumption are the consumption trends.

Demonstration



Technical merits:

- Requires safe handling
- Point of improvement: fitting the assembly inside of the power strip

Benefits:

- Allows to dynamically monitor and control remote loads via a computer
- Does not need internet connection or wi-fi; broadcast is performed on a separate baud-line

Achieved results:

- A working physical prototype with embedded computational engine
- Accompanying control and monitoring software

Future Goals:

- Integrate the power strip device with the AMI system
- Create a specific agent responsible for the power strip

Energy Conservation Using Smart Meters

- The accessible monitoring of the utility use on the utility provider side and on the consumer side is a way to conserve the energy and save money.

In order to meet the end-user requirements for intelligent tracking of resource consumption it was deduced that some key questions that an intelligent AMI would need to answer include the following:

- How much is spent?
- Where was spent the most?
- Why losses occur? For example, can the AMI intelligent multi-agents detect whether the consumption losses are due to current or voltage lags, harmonics, or the excess operation of the system during the peak hours?
- What are the potential errors arising from the complexity of wiring and connectivity?
- Can a specific appliance be easily monitored and controlled either/both schedule-wise and consumption-wise?
- Can a specific limit (time-based, consumption-based, trend-based) be set to a particular appliance?
- Can the system ask (in case the user is demanding/abusive/unreasonable to the meter intentionally or on accident): “Are You sure?” And what are the signs/limits/set points to ask such question?
- Can a particular appliance still be monitored if it has been repositioned? What indicators would the appliance have?
- Can AMI detect the introduction of a new device on the line?
- Can AMI start observing a particular appliance once it is turned on and start comparing it to the performance of certain other device in the system?
- Can AMI detect where electricity is generated and control the output either for the grid use, or for the consumption independent from the grid?
- Can AMI detect whether the supplier system is loaded or supplies energy consistently?
- Does AMI have safety notification and alarm? And what are the cases that lead to this notification?
- What is the security performance of the AMI? Can it send the utility specific information to the supplier without them having the access to the private information about the end-user’s consumption trends?
- The ability of the AMI to answer these questions, on top of having to supply all the utility provider required information, would ensure that the AMI system satisfies some significant key performance indicators for energy conservation and control, at least for the present day.

Smart Meter Network Design

- In ESCL we concluded that it makes sense for the utility companies to install a single smart meter that would meet the information needs, mentioned before, of the supplying company and, simultaneously, let the end-user know the consumption trends via the device of their choice (a computer, a cell-phone, or a tablet).
- However, the “smartness” of the AMI for the user would be based on their own choice and preference of the accommodating devices designed to be integrated with the AMI supplied/supported by the utility supplier.
- This and the understanding of the intelligent AMI as a composition of elements, led the research at ESCL to conclude that using a multi-agent intelligent system approach would be the qualified method for creating a respectable intelligent AMI.
- it was decided in ESCL to create a simulation of an intelligent AMI such as it would yield a basis for a physical device which would allow the users to be in control based on their perception of smart systems and their lifestyle; so as the researchers involved in making the simulation would be consciously satisfied that the intelligent AMI could indeed be the right tool in the right hands.
- The true barrier of making the whole picture crystal clear to the industries and people interested in the smart-meter technologies is putting a number to the description of the intelligent multi-agent systems and the before-mentioned KPIs, such would make the AMI model proposed by ESCL to be the AMI to rule them all.

Smart Meter Network Design Continued

Part of the House	Place/Rooms/Devices

Case	Wall Outlet/ Water Link/ Gas Link	Power Strip	Switch/ Valve	Utility AMI	Electr. Power Panel	Main Primary Controller/ Computer/ Phone/ Tablet	Facility/ Structure (motor, HVAC, boiler, laundry machine)	Equipment (regulated blinds, automatic door or window, automatic sprinkler)
1	S,L,A	S,L,A	S,L,A	S,L,A	S,L,A	S,L,A	S,L,A	S,L,A
2	S,L	S,A	S,L,A	S,L,A	A	S,L	S,L,A	L,A
3	S,L,A	A	S,L,A	S,L,A	S,L,A	S,L	L,A	A
4	S	A	S,L,A	S,L,A	L,A	S,L	S,L,A	S,L,A
5	-	S,L,A	S,L,A	S, L	S,L,A	S,L	S,L,A	L,A
6	S,L,A	-	S,L,A	S,L	S,L,A	S,L	S,L,A	L,A
7	S,L	S,L,A	S,L,A	S,L	-	S,L	S,L,A	L,A
8	S,L	S,L,A	S,A	S,L	-	S,L	S,L	A
9	S,L	S,L,A	L,A	S,L	-	S,L	S,L,A	S,L,A
10	S,L	S,L,A	A	S,L	-	S,L	S,L,A	L,A
11	S,L	S,L,A	-	S,L	S,L,A	S,L	L,A	L,A
12	S,L	S,L,A	S,L	S,L	-	S,L	S,L,A	S,L,A
13	S,L	S,L,A	S,A	S,L	S,L	S,L	A	S,A
14	S,L	S,L,A	S,A	S,L	L,A	S,L	S,L	S,L,A
15	S,L	S,L,A	S,L,A	S,L	-	S,L	S,L,A	S,L,A

	Humidifier & Moisture Control W. Loads: Boiler G. Loads: Boiler, Heater	LWM W. Loads: LWM Faucet G. Loads: Dryer	4 outlets Smoke Detector		

Figure 1. Residential Outline of Utility Organization

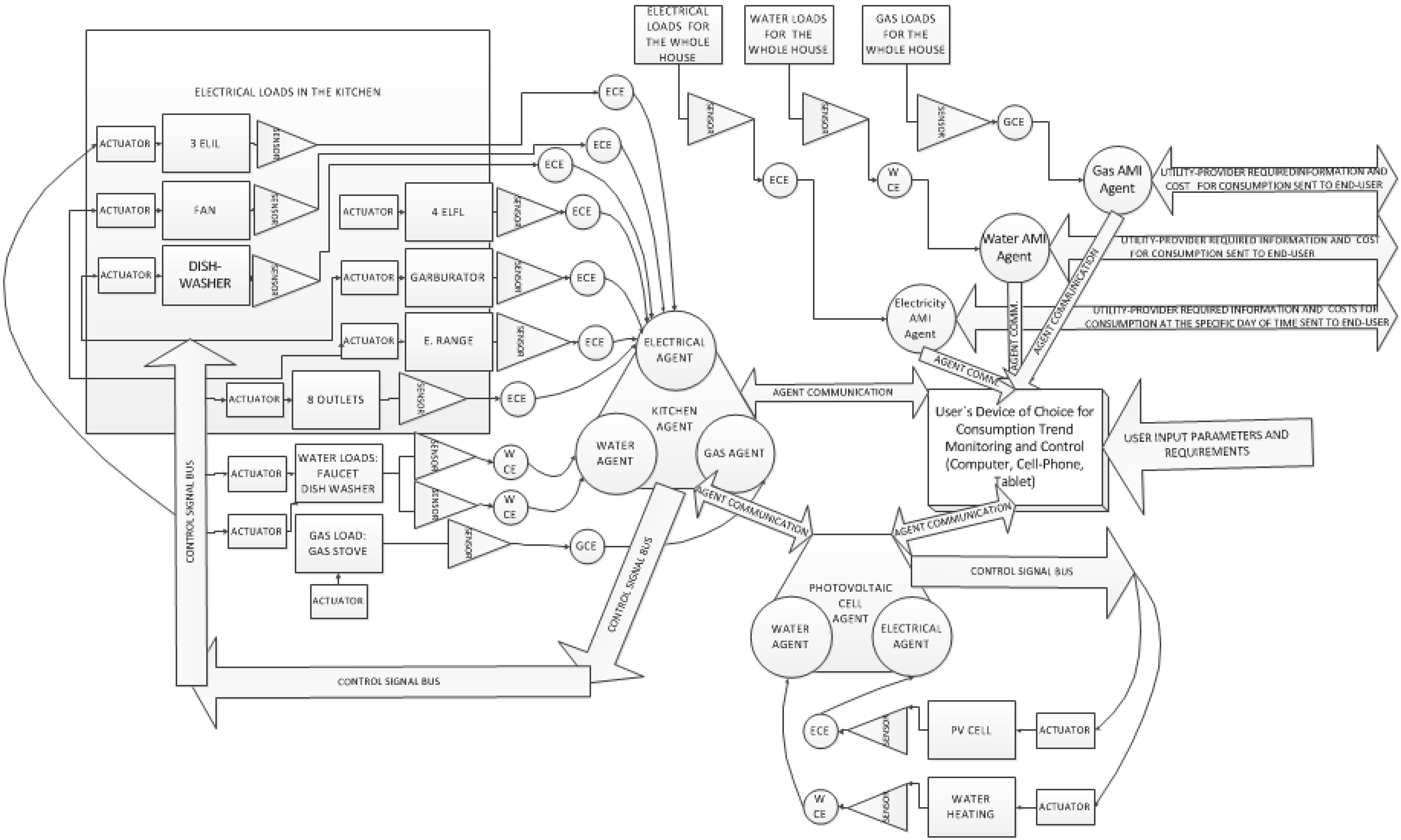


Figure 2. Flowchart by the use of the utility-provided AMI in integration with intelligent multi-agent system for a single lifestyle scenario.

Smart Meter Network Design Continued

- It was decided that the option of the case number 15 presented the best association of the sensor, logic, and actuator components for the devices connected to the AMI. The reasons for this choice are presented below:
- The sensors allow for monitoring aspects of resource consumption and the possible factors such as temperature, humidity, and/or presence and feed this data to the agent for interpretation and decision making.
- Logic is available on each component, and hence each component is programmable to give the feedback on the consumption patterns at a specific location or for a specific appliance. Also, the presence of agent logic on each component allows the end-user to install a particular device in a specific location and room and assign the agent as the representative of that place, and have multiple agents in the same room interact to meet the requirements set by the end-user
- The actuators are located on the power strip, switch/valve, facility/structure, and on the equipment in order to have distributed control over the consumptive devices.

Simulation Design Continued

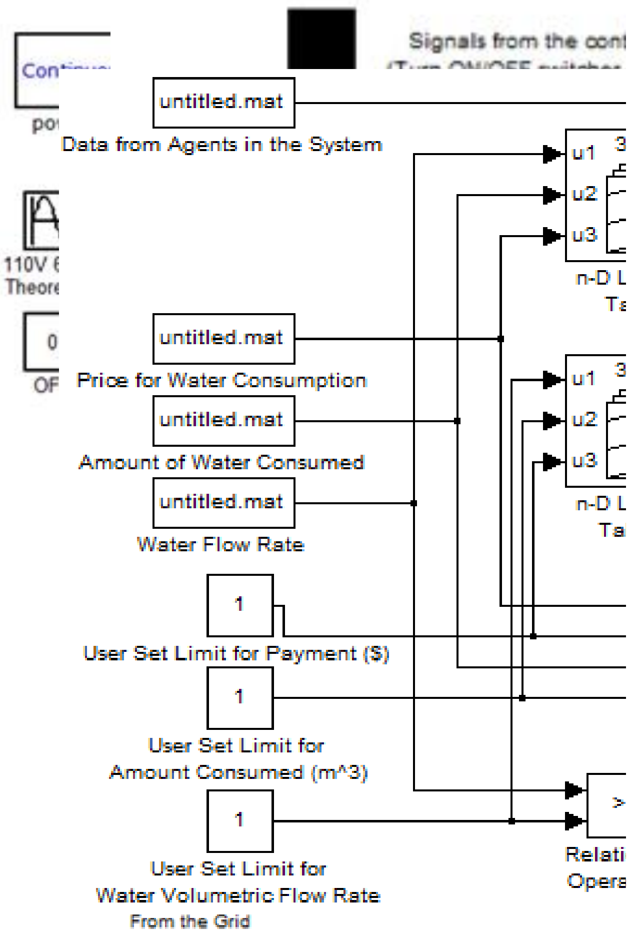


Table 2. Data for Electricity Consumption

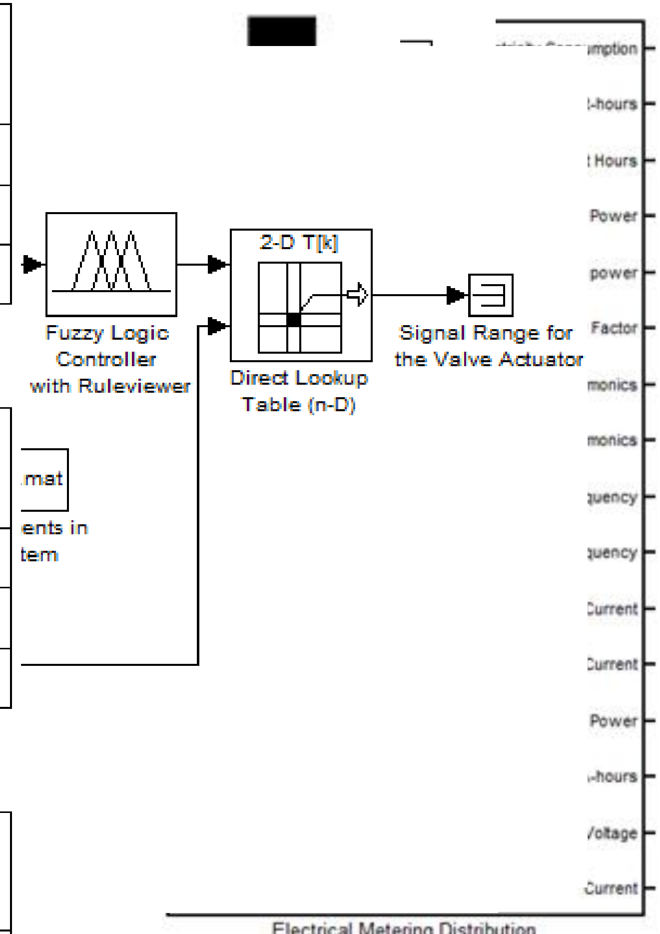
Period of Time	Amount of Electricity Consumed (kW-hrs)	Price for Water Consumption ($)
08-Feb-11 to 06-Apr-11	2263	142.61
06-May-11 to 13-Jul-11	1292	162.72
08-Aug-11 to 06-Oct-11	1872	239.81

Table 3. Data for Water Consumption

Period of Time	Amount of Water Consumed (m^3)	Price for Water Consumption ($)
02-Jan-11 to 02-Apr-11	71	192.06
02-Apr-11 to 02-Jul-11	11	73.38
02-Jul-11 to 02-Oct-11	107	263.27

Table 4. Data for Gas Consumption

Period of Time	Amount of Gas Consumed (m^3)	Price for Gas Consumption ($)
18-Feb-11 to 18-Apr-11	338	319.45
19-Apr-11 to 21-Jul-11	146	202.74
22-Jul-11 to 19-Oct-11	635	160.94



Conclusion

- The work done thus far by ESCL is only a stepping stone into standardization of intelligent AMIs.
- Further simulation and analysis will be performed in order to streamline the AMIs to convenience of both the utility-providers and the end-users.
- The hardware aspects of the AMI will be analyzed for compatibility of the work done thus far.
- Furthermore, work is to be done on integrating the AMI and the HR management software tools for complete management of energy resources at the work-places.
- The work done at ESCL was done to create a concrete view of intelligent AMIs as tools that would be as intelligent as the people using them.

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Audience Questions

Thank You for listening!