A WEB OF THINGS (WOT) APPROACH TO SMART HOUSEHOLD ENERGY MANAGEMENT FOR SUSTAINABLE LIVING

Sita Ramakrishnan and Subramania Ramakrishnan
Clayton School of IT, Monash University, Victoria, Australia

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Abstract: With a focus on a software system that incorporates smart phones, web-enabled physical devices and RESTful APIs, this paper explores a system strategy for monitoring, integrating and controlling electrical devices to facilitate the management of electrical energy consumption in line with modern sustainability practices. Real-time feedback on energy consumption and associated costs for individual appliances in a household is the key to helping the consumers in their quest for sustainable living. The paper considers a case study of a household in Australia, having a grid-connected solar panel installed for electricity generation. The focus of the case study is dynamic adaptation of both grid-supplied and the solar-generated electricity for powering heavy house hold electrical loads with a view to reduce costs and greenhouse emissions.

1 INTRODUCTION

Modern ICT developments enable physical devices manage their interaction with less human intervention in order to avoid human bottleneck, and be more autonomous. However there are many difficulties in current internet architecture to accommodate various physical data sources, actuators and distributed computing elements. Autonomous networks of embedded devices are centered around data fusion which is the result of integrating a number of embedded devices such as sensors with the internet (Abdelzaher, 2006). Unlike traditional embedded systems, where the emphasis is more on computational elements and less on the links between the physical and computational elements, a cyber-physical system is designed as a network of interacting elements with physical input and output (Abdelzaher, 2006).

This paper considers Web of Things (WoT) and cyber-physical systems with a case study scenario for managing energy consumption to reduce costs and greenhouse emissions in a household by adapting the usage of electrical devices in the household. A layered architecture to address the distributed nature of embedded, autonomous cyber-physical systems and modelling cyber and physical resources in a unified framework are considered in this paper.

Increases in recent times in costs of electricity, gas, water etc., and the associated increases in environmental pollution, such as greenhouse emissions, are having an impact on lifestyles of people to adopt lifestyle strategies for reducing cost and environmental pollution. Real-time feedback on energy consumption and associated costs for individual appliances in an easily readable format is the key to helping consumers in changing their behaviour in their quest for sustainable living. Merging physical household devices with computing such as with embedded microprocessors and wireless communication is leading to the creation of so-called smart appliances. We explore the way in which these smart appliances can be administered through mobile web to facilitate the vision of web-enabled smart home for sustainable living.

The paper is structured as follows. The next section discusses advances in internet protocols and various home automation standards. Also discussed is the ability of 6LoWPAN standard to make the latest Internet protocol (IPv6) available to even the most minimal embedded devices and its suitability for embedding into household appliances. A system architecture for household smart appliances is then derived by augmenting accepted protocols of WoT and an extended WoT framework after a discussion on Internet of Things (IoT) and Web of Things (WoT). In Section 3, home requirements for managing electricity consumption are described. In Section 4, a case study is presented for a smart household energy management for sustainable living. Section 5 provides conclusions

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and possible future extensions.

2 WOT FOR SMART APPLIANCES

2.1 Internet Protocols and Home Automation Standards

The internet has been a great success over two decades with ubiquitous use of the network by billions of people. The internet paradigm has been very successful with heterogeneous networks, and the www model of uniform resource locators (URLs), the hypertext transfer protocol (HTTP) and hypertext markup language (HTML). This has resulted in IT architects, communication experts and others to innovate and add new protocols and uses for internet technology. Another internet advance has been the internet of things where the embedded devices, also named, smart objects, are universally becoming IP-enabled and an integral part of the internet. Examples of IP-enabled embedded devices are mobile devices, personal health assistance devices, home and industrial automation, smart metering etc (Guinard, 2010; Kamilaris et al., 2011).

There are many competing home automation standards such as the popular X10 in the residential market since 1978 (www.x10.com), ZigBee standard based on IEEE 802.15.4, and KNX, the European standard. Currently, monitoring and controlling embedded devices are predominantly done using services built on internet technology. Internet of things is a powerful paradigm which has combined the internet-enabled embedded devices and web services technology. Till recently, the complexity of communication standards, protocols and services meant that internet enabling happened only with the most powerful embedded devices.

The first global low-power radio standard was released by IEEE, which was the 802.15.4 low-power wireless personal area network (WPAN) standard in 2003. A new paradigm was required to enable low-power wireless devices with limited processing capabilities to participate in the Internet of Things (Hui and Culler, 2008; Shelby and Bormann, 2010). The 6LoWPAN standard makes this latest Internet protocol (IPv6) available to even the most minimal embedded devices over low-rate wireless networks (Design, 2011), and is well suited for embedding into home appliances.

Since typical households have cable Ethernet connections and Wi-Fi as the backbone network, extension via 6LoWPAN is possible without laying additional cables. Although deployment costs for both ZigBee and 6LoWPAN (IPv6) are low, ZigBee being a proprietary solution requires its own infrastructure as opposed to using LANs for 6LoWPAN/IPv6 [24]. Seamless integration to the internet is the attractive feature available with IPv6 over the other standards. IPv6 connectivity of smart appliances integrates these appliances to the internet network layer. Web servers running on the appliances are required to achieve web integration (application layer). The concept of Resource is a first class object in the REST (representational state transfer) style and every resource must understand the core operations (Richardson and Ruby, 2007). A smart appliance resource is accessed in a web-oriented manner using a lightweight REST architectural style. Any smart appliance resource is bound to a Uniform Resource Identifier (URI), which identifies the resource involved in an interaction between entities. It uses HTTP 1.1 as a true application protocol and its operations, GET, PUT, POST, DELETE. Each resource implements a set of these well-defined operations. Applications using web-enabled appliances can be developed using web languages such as Javascript, PHP, JSON (javascript object notation) and toolkits such as JQuery. Android and IPhone OS 4.0 run IPv6.

It follows from the discussion in this section that 6LoWPAN /IPv6 is suitable for smart home automation applications.

2.2 IoT, WoT and WoT Framework

The web is a very effective, user-centric, scalable, distributed platform with underlying technologies such as TCP/IP, HTTP, HTML/XML, JSON etc. This success has now been extended to incorporating real-world objects into WWW using web technologies, and this is called the Web of Things (WoT), as described next.

The Internet of things (IoT) (Papadimitriou, 2009) is about principles and technologies that enable the internet to get into the real-world of physical objects. IoT gives every device an IP address and lets it plug into the internet. In IoT, everyday devices and objects (objects that contain an embedded device) are connected by integrating these into the web. Examples of smart devices are sensor network, household appliances etc. Web of Things (WoT) is an extension to IoT (Zeng et al., 2011) and is about reusing the web standards and building on the success of web 2.0.

Well-established web standards and blueprints such as HTTP, REST, URI etc are used in WoT. This ensures ease of development with existing web frameworks in accessing the functionality of smart objects. In WoT, real-world objects such as consumer appliances are integrated into the WWW by representing them as web resources, which can be accessed using lightweight APIs based on REST principle (Ostermaier et al., 2010). In WoT, real-world objects including their sensors and actuators are exposed as URLS. End users are able to create physical mash-ups by composing personalized services based on physical resources. A simple WoT framework is proposed for our case study for home automation where the components are distributed among the devices and could also be in the supplier grid server (e.g. electricity company).

In WoT, HTTP is used as an application protocol rather than as a transport protocol, and the blueprint of Resource-oriented architecture (Guinard et al., 2010; Guinard, 2010) is followed for exposing the synchronous functionality of smart objects through a REST interface, known as Restful API. So, with WoT, one should be able to use universally accepted protocols to connect a number of physical objects in a loosely coupled, scalable manner.

A WoT framework to augment the accepted protocols to deal with some of the specific requirements of cyber-physical systems such as information-centric protocol, context-awareness, deterministic QOS etc is necessary to address the grand challenge of cyber-physical systems as envisaged by NSF (Dillon et al., 2011). Developers would benefit from a WoT framework that can hide low-level implementation details and provide an application development environment for faster system development (Kamilaris et al., 2011).

The WoT framework proposed by Dillon et al. (Dillon et al., 2011) consists of a number of layers from the physical device layer to program interface layer (Caporuscio et al., 2011). The layers are: WoT device, WoT kernel, WoT overlay network, WoT context and WoT API. The WoT framework is above the physical interface such as sensors, actuators, which interact with the physical environment (Dillon et al., 2011). A WoT framework allows the web world to control the physical world using the data to perform smart tasks such as smart home automation for sustainable living, factory automation etc. (Kamilaris et al., 2011).

WoT device provides a resource based abstraction for the devices. Each physical device is modeled as a WoT resource that has a universal identifier, name and a state. The pervasive REST architectural style promotes the use of Resource as a first-class object and entities are modeled as resources, which can act both as clients and servers (Erenkrantz, 2009; Caporuscio et al., 2011). WoT device interacts with smart physical appliances (resources) through their interfaces.

WoT kernel provides a low-level run-time for communication and management of WoT resources. WoT kernel uses the notion of continuation that has been used in AJAX and Mashups. It is responsible for detecting newly connected or disconnected physical devices and their resources. WoT overlay network provides a network aware logical abstraction on top of the current internet architecture such as TCP/IP. WoT context discovers and constructs contextual information from the event stream in the overlay. WoT API provides abstractions that allow developers to interact with the WoT framework. WoT resource is the abstraction unit. Application developers can interact with each WoT device.

2.3 System Architecture

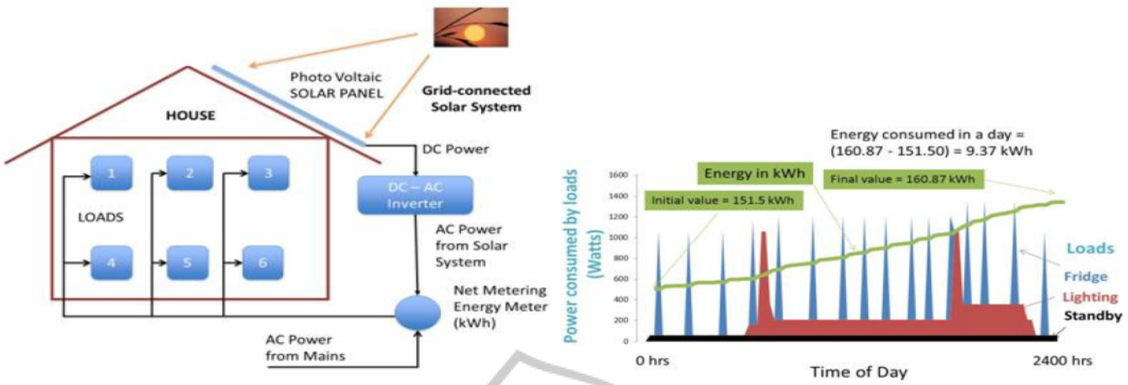
A system architecture for a Web of Things approach to smart household energy management for sustainable living is proposed in this paper by augmenting the accepted protocols of WoT and the extended WoT framework discussed above. The energy monitoring and consumption system is made up of the household energy appliances and devices with sensors for monitoring the energy data from various sources, a gateway software layer with a web server and database for manipulating and storing each smart appliance's energy consumption values in a lightweight manner, and a presentation layer with a mobile phone for showing the various energy consumption views of the appliances as per customer requirement. This four layer architecture (see Figure 2) is expanded with a case study scenario (see Section 4).

3 MANAGING CONSUMPTION

Figure 1 shows a typical house in Melbourne, Victoria, Australia, that has solar panels installed on the roof for local electricity generation.

3.1 Power Consumption

Electrical power is consumed by various loads used at the household. The house in Figure 1 (a) has many electrical loads (1 - 6) made up of light loads (lights, computers, television etc.) and heavy loads (washing machine, clothes dryer, dish washer etc.) The house meets its electricity requirements from both the electricity grid as well as the grid-connected solar system. We have assumed in this study that gas is used for other loads for cooking, heating and hot water.



(a) (b)

Figure 1: (a): A typical house with grid-connected solar panels and several loads, (b): Energy consumed by a few household loads in a day as a function of time

The operation of the various loads in a household depends on the lifestyle of the people in the house, the weather and the season. Figure 1 (b) shows an example of the power consumption of the household and of some loads as a function time of day over a 24-hour period.The loads in Figure 1 (b) are those which are mostly fixed in time most days, unlike loads such as washing machine, dryer or air conditioner which are 'manageable' loads that may be operated at any time of the day within its 24 hour period.

A typical pattern of the electrical power generated over a 24 hour day by a grid-connected solar panel is shown in Figure 1 (b). The pattern of solar power may vary depending upon the weather conditions during a day and the season in a year. It is assumed in the figure that the solar panels and the dc to ac inverter are rated at 1.2 kW.

Electrical power consumed by the various loads in the house is supplied from both the utility grid and the solar panels. This study aims to assist a person of the household to make decisions on the time of the day at which such manageable loads are operated for either reducing the electricity cost for the household, or for a reduction in the carbon pollution for the household.

3.2 Metering, Cost and Emissions

The cost of electricity to a household is based on the energy consumed by the household from the utility grid over a billing period, and so is the greenhouse emission for the household. An energy meter integrates over time the consumed power as a function of time to give energy as a function of time (Figure 1). In Victoria, Australia, net metering policy is used for houses that have grid-connected solar panels for local electricity generation. Figure 1 shows the net metering scheme for pricing electricity consumption by utilities. In Net Metering, both the Grid and the Solar are taken as sharing the connected loads at any instant of time. Both the energy flowing into the loads and the energy flowing into the mains from the solar system are metered. If the solar power is less than the connected loads at any time, any additional power above the solar power is metered as flowing from the mains. If solar power is greater than connected loads at any time, additional power from solar is metered as feeding into the mains exported to the grid.

Power utilities are not necessarily aware of specific household energy demands and sustainable living objectives in detail of their customers. They install solar panels and associated infrastructure equipment and wire the system appropriately as per regulation requirements to enable the power company to charge the customer for their electricity consumption over the billing period. Currently, the electricity billing system of a power company caters for the inclusion of the details of the solar energy exported from the solar panels and the total energy consumption by the entire household for a billing period of two months. However the bill does not detail a breakdown of the solar energy production and energy consumption by individual devices in hourly, daily, weekly, monthly fashion.

Currently, utilities charge a household for the net energy consumed from the utility grid at 21.6 cents (Australian) per kWh when the power is consumed during peak hours of 7:00 am to 11:00 pm and at 10.8 cents per kWh for off-peak consumption. The household is compensated at 62 cents per kWh for solar energy exported from the house to the utility. This rate is used to reduce the customer's bill amount for electricity usage. This can be seen as an incentive to promote sustainable living strategy.

A large proportion of the electricity generated in

Victoria is from brown coal, thus resulting in greenhouse emissions. So the energy consumed by a house hold from the utility grid has associated greenhouse emissions. In Australia, typical values of greenhouse emission for electricity generation from coal vary between 0.8 - 1.3 tonnes CO2 equivalent per MWh of electrical energy generated (Talberg, 2011). We have assumed a value of 1.2 kg CO2e per kWh for brown coal.

3.3 Customizing Sustainable Living

The objective of this study is to assist consumers to actively engage in a software strategy of efficient energy management by controlling and operating heavy loads from a dynamic consideration of various factors, such as solar energy generation, energy costs, greenhouse emissions, user requirements etc. In order to create a sustainable household, a customer needs to measure in real-time the power generated by the solar system and the power consumed by various loads on an individual basis as a function of time. The strategy must use the collected real-time data as well as past data, information on cost and greenhouse emission and, possibly, weather predictions from the web to display relevant information to the customer so as to enable making informed decisions on energy usage. For example, a customer may require adapting on the fly running of a heavy load during day time on a summer day when solar energy production is significant. This may not be feasible because of weather conditions. One may then need to calculate ahead of time the power used by the chosen machine (say, washing machine and dryer) and use the information to decide if an adaptation strategy of using a mix of solar and grid power for washing, or operate the machine during night time when off-peak tariffs apply. One therefore needs to measure the power and energy usage as a function of time and store this information for later use. Another customer may require information based on past data to analyze emissions and costs incurred, and there upon decide a change in lifestyle or use of energy-efficient technologies and appliances.

4 SMART ENERGY MANAGEMENT

4.1 System Architecture

The architecture for our case study in smart energy management for sustainable living is made up of four layers as shown in Figure 2. The device layer is made up of physical devices (solar system, appliances etc.) that we have included in our energy management scenario. The devices are plugged to the Ploggs, which are smart meter plugs (kWh) and data loggers at the sensing layer (www.plogginternational.com). In the Gateway layer, these plogg nodes are discovered and manipulated by software installed on an embedded device with Zigbee or Bluetooth communication capabilities. The gateway includes a micro webserver and provides RESTful API. The client layer software enables the householders to visualize their power consumptions in various formats as shown in Figures 2 on mobile phones or on the web.

4.2 Devices and Sensing Layers

The devices and sensing layers provide an interconnection to other layers by providing information back and forth on the measured power levels of individual physical devices as a function of time at prescribed sampling rates so as to accurately compute energy as a function of time from power values. The layers also provide appropriate control information to manage the operation of individual devices. The physical devices consist of power generating devices (solar panels) and loads or appliances in the house hold. Regulations do not allow customers to install a sensor on the metering system of the utility-grid because the metering system is an accurately calibrated system that is owned by the utility. On the other hand, the utility may not be able to measure or control individual appliances in the household because of privacy laws.

As shown in Figure 2, each heavy load has a sensor to measure the power consumed by each device as a function of time. A few light loads may be grouped to form a cluster that may be connected to one sensor. A sensor is attached to the inverter connected to the solar panels to read the power generated as a function of time by the solar panels. Such a sensing layer enables the discrimination of the power used by individual devices. As no sensor can be attached to the metering system of the utility, the software system must be able to compute the total power consumed by the house hold, the solar power exported to the grid and the power consumed from the grid at any instant time from the measured values of power consumed by individual devices and the power generated by the solar system.

Monitoring the power consumption of individual appliances is possible with Ploggs, a product of Energy Optimisers Ltd (www.energyoptimizersdirect.co.uk), as shown in Figure 2. Ploggs may be plugged into electrical

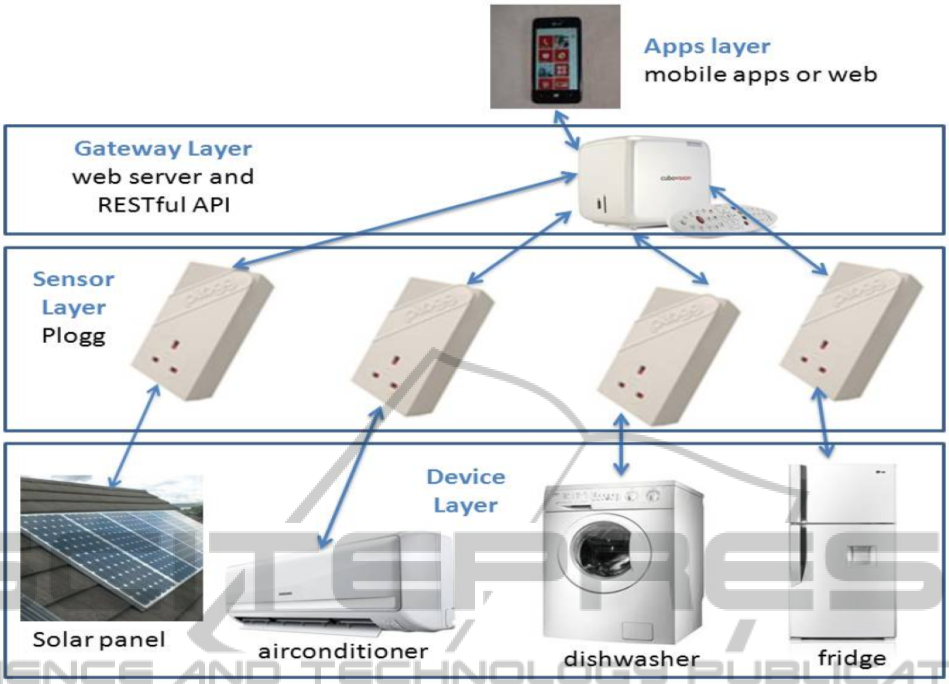


Figure 2: Four layer system architecture for energy management.

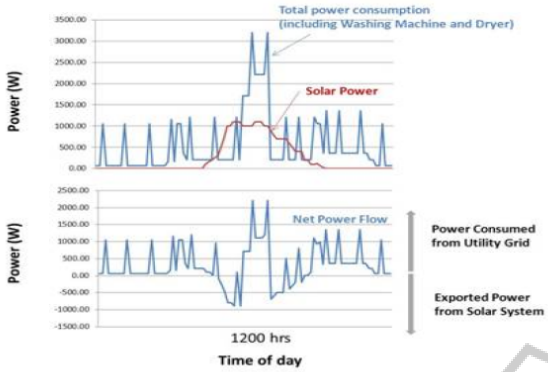
outlet to measure the power consumption of a connected appliance in real-time and/or monitor it over a longer time frame. It can also control the power consumption remotely over a network. Its internal clock allows the computing and monitoring of real-time energy rates as well. Time intervals can be set from every minute to once a month. Plogg is based on Zigbee wireless standard, which is used by various smart meter technologies. Plogg stores the measured electrical consumption data and wirelessly transmits the information to a smart phone, computer or system management software via the internet for further manipulation.

4.3 Gateway and Applications Layers

In the Gateway layer, Plogg nodes are discovered and manipulated by the software installed on a device with Zigbee or Bluetooth communication capabilities as shown in Figure 2. The Gateway software discovers the Ploggs by scanning the environment and makes them available as web resources. The gateway includes a micro webserver, which enables access to Ploggs over the web, and allows the management of Ploggs as structured URLS in a RESTful style.

The Gateway software communicates with the Ploggs and delivers to Applications layer the results, either as JSON (JavaScript Object Notation) documents or as HTML representation of power and energy consumption of devices. A RESTful web API is developed as part of the Gateway layer. A RESTful web API is a web service implemented using HTTP and four REST principles of addressability, statelessness, connectedness and uniformity (Erenkrantz, 2009; Caporuscio et al., 2011). It is hypertext driven and supports operations using HTTP methods (GET, PUT, POST, DELETE) and supports media types such as JSON (JavaScript Object Notation), XML etc. REST has an important concept called Resources, each of which is referenced with a global identifier (e.g. URI in HTTP).

The Application layer shown in the architecture (Figure 2) enables the user to visualize information in various formats on mobile phones or on the web. Modelling for context and for activity are combined as user preference in the user interface (Romero et al., 2010). The contexts under consideration in the energy management system are: weather, month, time of day, location (at home, away from home). At the request of the user, the application may display the power consumed by individual loads or the solar power generated over a day. It should also be able to display historic information of power or energy over a chosen period in the past, say over a month 2 years ago. Location-related remote operations when away from home are related to delay in coming home and may involve lights or air-conditioning being switching on remotely. The activities considered are: laundry,



(a)

		No Solar		Solar and Grid	
Use of Wash M/cand Dry		WM Day	WM Night	WM Day	WM Night
Energy from Grid (kWh/day)	Peak	11.44	7.32	7.36	6.18
	Off-peak	2.06	6.18	2.05	4.68
	Total	**13.50**	**13.50**	**9.41**	**10.87**
Solar export (kWh/day)		0.00	0.00	0.95	3.47
Cost (AU$/day)	Peak	$5.94	$1.58	$1.59	$1.01
	Off-peak	$0.28	$0.67	$0.22	$0.67
	Solar	$0.00	$0.00	-$0.59	-$2.15
	Service	$0.69	$0.69	$0.69	$0.69
	Total	**$6.91**	**$2.94**	**$1.91**	**$0.22**
Greenhouse Emissions (kgCO2e/day)		**16.20**	**16.20**	**11.30**	**13.04**

(b)

Figure 3: (a) - Computed results for the total power consumed and solar power. Case 1 - Use of washing machine and dryer during daytime; (b) - Comparison of results of costs and emissions for the two cases of Washing Machine used.

reverse-cycle air-conditioning, dish washer, small appliances such as iron, lighting, computer, telephone, vacuum cleaner, cooker etc.

An example of the power consumption and solar power generation over a day is shown in Figure 3(a) in which the heavy load of washing machine and dryer is operated during the day time when the solar power generation is high.

The lower figure in Figure 3(a) shows the computed difference between the total power consumption and solar generation to illustrate clearly the export of solar power to the grid. In order to make a decision on the time of a similar day in the future when the washing machine needs to be turned on, the application may be asked to display electrical powers over a day. A comparison of the day time and night time scenarios considered may also need to be provided by the applications. Such a comparison is shown in Figure 3(b).

Based on the results shown in Figure 3, the customer may choose an option of reducing cost or greenhouse emission.

5 CONCLUSIONS

We have presented in this paper a four-layered architecture for monitoring and control of web-enabled devices. It uses the Internet of Things approach where the focus is on interaction and interoperation between smart devices and between devices and people. This has been achieved through 6LoWPAN standard that includes IP for smart devices and enables the efficient use of IPv6 over low power low rate wireless networks. Physical devices use the sensing layer to communicate with the Ploggs, which can monitor and control the devices. The devices and sensing layers form the lower two levels of the architecture. The key aspects of Web of Things are to integrate smart devices into the web and abstract integrated smart devices to web services. RESTful web service has been presented as part of the architecture layer solution. The Gateway layer and the application layer interaction enable the information to be presented to suit varying the consumer requirements. For example, some consumers may want real-time information whereas others may want to look at past archived data to make decisions.

A case study of electricity management has been considered in this paper. It allows the consumer to use the past and predictive information of appliances and manage the operations of appliances efficiently to achieve cost reduction or GHG emission reduction. The results of electricity costs and GHG emissions are presented for operating a heavy load (washing machine and dryer) in a house in Melbourne, Victoria at two different times of a day when solar energy production is significant. The presentation of such results can assist the consumers in making decisions to change their lifestyle in using electrical devices at times of the day when cost or GHG emissions reduction can be achieved. We believe that the architecture presented can be extended to include other energy resources, such as gas, wind and stored solar energy. It can also be extended to include water management at household level where houses receive water from the mains as well as from stored water from rain water tanks.

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REFERENCES

Abdelzaher, T. (2006). Towards an architecture for distributed cyber-physical systems. In *Proceedings of NSF Workshop on Cyber-Physical Systems*. http://varma.ece.cmu.edu/Summit/CPS.

Caporuscio, M., Funaro, M., and Ghezzi, C. (2011). *RESTful service architectures for pervasive distributed environments*, chapter REST:From Research to Practice. Springer.

Design, E. T. (2011). The wireless embedded internet, part i. http://www.eetimes.com/design/embedded-internet-design/4216240/6LoWPAN.

Dillon, T. S., Zhuge, H., Wu, C., Singh, J., and Chang, E. (2011). Web-of-things framework for cyber-physical systems. *Concurrency and Computation: Practice and Experience*, 23:905–923.

Erenkrantz, J. R. (2009). *Computational REST: A New Model for Decentralized, Internet-Scale Applications*. PhD thesis, University of California, Irvine.

Guinard, D. (2010). Mashing up your web-enabled home. In *Adj. Proc. The International Conference on Web Engineering (ICWE 2010)*, Vienna, Austria.

Guinard, D., Trifa, V., and Wilde, E. (2010). A resource oriented architecture for the web of things. In *Proceedings of IEEE Conference on the Internet of Things*.

Hui, J. W. and Culler, D. E. (2008). Ip is dead, long live ip for wireless sensor networks. In *SenSys '08: Proceedings of the 6th ACM Conference on Embedded Network Sensor Systems*, pages 15–28, New York.

Kamilaris, A., Trifa, V., and Pitsilledes, A. (2011). The smart home meets the web of things. *Int. Journal of Adhoc and Ubiquitous computing, (IJHUC), Special issue on the smart digital home*, 7(3):145–154.

Ostermaier, B., Schlup, F., and Romer, K. (2010). Webplug: A framework for web of things. In *Proceedings of PerCom Workshops 2010*, pages 690–695.

Papadimitriou, D. (2009). Future internet - the cross-etp vision document. http://www.future-internet.eu. version 1.0.

Richardson, L. and Ruby, S. (2007). *Restful Web Services*. O'Reilly Media, 1st ed. edition.

Romero, D., Rouvoy, R., Seinturier, L., and Loiret, F. (2010). Integration of heterogeneous context resources in ubiquitous environments. In *SEAA'10*.

Shelby, Z. and Bormann, C. (2010). *6LoWPAN: The wireless embedded Internet*. Wiley publishing.

Talberg, A. (2011). Performance standards to reduce energy emissions. Parlimentary Library, Parliament of Australia.

Zeng, D., Guo, S., and Cheng, Z. (2011). The web of things (an invited paper). *Journal of Communications*, 6(6):424–43.