Design and Implementation of a Home Automation System for Smart Grid Applications

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***Abstract*-- A home automation system for smart grid is designed and implemented. The system monitors temperature and humidity and controls air conditioning, lights and appliances. The Message Queuing Telemetry Transport protocol and Django web framework are used. A graphical user interface is developed to enable the user to control the devices remotely via a website.**

I. INTRODUCTION

A recent report by the United States Energy Information Administation projects that the world energy consumption will increase 56% by 2040, and 24% in residential electricity demand by 2035 [1].

The constant developments in mobile technology and the rapid advancements in embedded systems have made it possible to integrate mobile technology into the design of home automation systems. Home automation allows the controlling and monitoring of various home appliances by a single system and brings greater convenience, better security, as well as higher energy-efficiency to home users. The integration of home automation systems into the future smart grids will give consumers the ability to control their house system and save energy efficiently. Recently, residential energy management has become an active topic of research [2]-[4]. The involvement of smart grid in home and building automation systems has led to the development of diverse standards for interoperable products to control appliances, lighting, energy management and security. Smart grid enables users to control the energy usage according to the price and demand.

In [5], smart home interfaces and device definitions are introduced to allow interoperability among ZigBee devices produced by various manufacturers of electrical equipment, meters, and smart energy enabling products. An Intelligent Self-Adjusting Sensor for Smart Home Services based on ZigBee Communications in presented in [6]. Unlike using Zigbee IEEE 802.15.14 as standard for home automation, our design uses Message Queuing Telemetry Transport (MQTT) Publish/Subscribe Protocol [7] and Django Web Framework [8] in order to give users the capability to integrate many open-source devices with open-source tools and site mobile optimization.

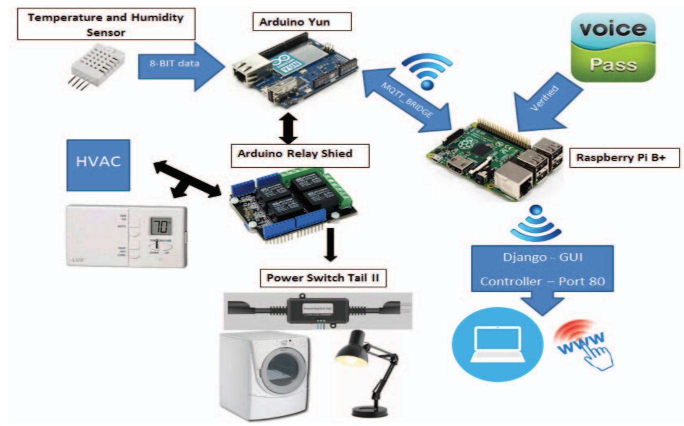

Fig. 1. Schmatic of the Home Automation System.

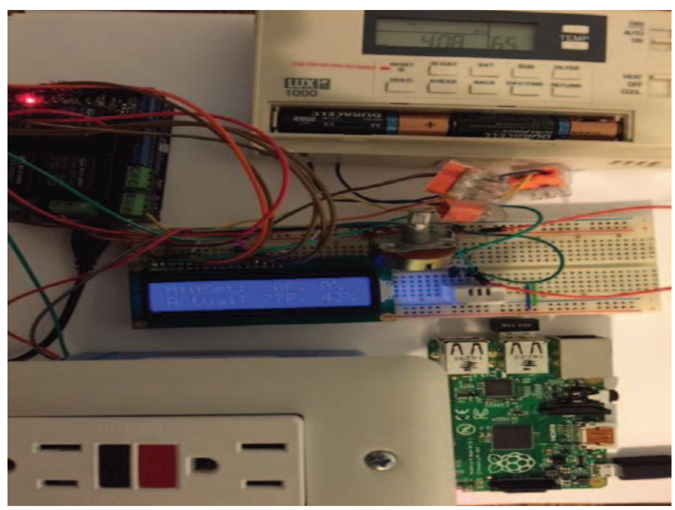

Fig. 2. Hardware Implementation.

The MQTT pub/sub protocol is a machine-to-machine "Internet of Things" connectivity protocol used to communicate and send messages between machines that have the capability of connecting to a network (e.g., Arduino YUN and Raspberry Pi B+). The Django and JQuery Mobile are used in this design to optimize the site interactivity and security.

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II. Hardware Implementation

The schematic of the designed home automation system is shown in Figure 1 and the hardware implementation is shown in Figure 2. As shown in Fig. 1, temperature and humidity data are acquired and parsed into a microcontroller, which through the MQTT protocol, gets published into the MQTT broker. The receiving microcontroller (the Rapsberry Pi) will subscribe into the MQTT broker via the MQTT bridge, gets the sensor data and loggs into a graphical user interface (GUI) developed through Django. As Fig. 1 shows, the user can input data through the GUI to change temperature, turn on/off lights, or control any appliance that is part of the network. In our design lighting switches, an HVAC unit and a washing machine were included in the system design, however, any other home appliance could be integrated into the system.

III. Software Design

The idea of using open source language in this project led to the selection of Django, a high–level Python Web Framework. It is free, open-source, stable and it avoids many common security mistakes: SQL injection, cross-site scripting, cross-site request forgery and clickjacking. Furthermore, its user authentication system provides a secure way to manage user accounts and passwords.

The developed GUI is shown in Figs 3 and 4. As shown in Fig. 3 the user can monitor the temperature and the humidity. In addition, the user can change the function of the different appliances. For example, as shown in Fig. 3, the user can set the HVAC to cooling. Upon pressing the submit botton, the user is rerouted to a new page and prompted to enter the new settings for the device selected.

In addition to controlling the HVAC unit (as shown in the snapshop in Fig. 3) the user can switch on/off lights and turn on/off appliances that are connected to the network such as a washing machine in our design. The system is designed to also plot the real-time data acquired by the temperature and humidity sensors (which are not at the same location as the thermostat). For example, in Fig. 4, the temperature readings from the sensor and the temperature setting inputed by the user are plotted as a function of time. The graphs were generated using the RDDTool software package, a subset of Django.

IV. Conclusions

This design has successfully implemented and tested both hardware and software of Home Automation Device. The proposed MQTT Pub/Sub Protocol, in conjunction with the Django Web Framework, enables dynamic communication between machine to machine in a home control system. This enables users to implement, manipulate and control many devices into one central control system. Users can observe the actual readings and adjust the settings for the desired values at the same time.

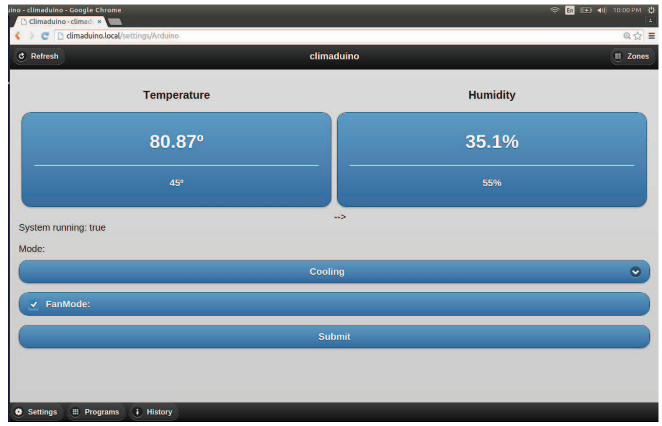

Fig. 3. System Graphical User Interface

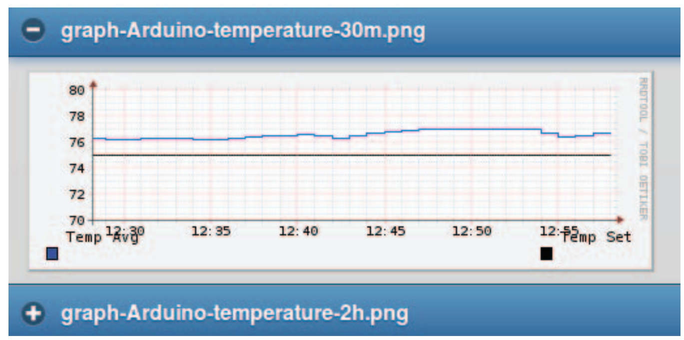

Fig. 4. Sample Graphed Temperature Data

References

[1] J. J. Conti, P. D. Holtberg, J. A. Beamon, A. M. Schaal, G. E. Sweetnam, and A. S. Kydes, Annual energy outlook with projections to 2035, report of U.S. Energy Information Administration (EIA), Apr. 2010 [Online]. Available: http://www.eia.doe.gov

[2] A.-H. Mohsenian-Rad and A. Leon-Garcia, "Optimal residential load control with price prediction in real-time electricity pricing environments," *IEEE Trans. Smart Grid*, vol. 1, no. 2, pp. 120–133, 2010.

[3] M. A. A. Pedrasa, T. D. Spooner, and I. F. MacGill, "Coordinated scheduling of residential distributed energy resources to optimize smart home energy services," *IEEE Tranactions on. Smart Grid,* vol. 1, no. 2, pp. 134–143, 2010.

[4] A. Molderink, V. Bakker, M. Bosman Johann, L. Hurink, and G. J. M. Smit, "Management and control of domestic smart grid technology," *IEEE Transactions on Smart Grid*, vol. 1, no. 2, pp. 109–119, 2010.

[5] D. Han and Jae-Hyun Lim. "Smart home energy management system using IEEE 802.15. 4 and zigbee." *IEEE Transactions on Consumer Electronics*, vol 56, no. 3, pp, 1403-1410, 2010.

[6] Byun, Jinsung, et al. "An intelligent self-adjusting sensor for smart home services based on ZigBee communications." *IEEE Transactions on Consumer Electronics*, vol. 58, no. 3 pp. 794-802, 2012.

[7] http://mqtt.org/

[8] https://www.djangoproject.com/

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