Sensing and Emulation Hardware for Advanced IOT Experimentation

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Abstract

The work described herein seeks to develop sensing and emulation hardware for use in the Internet of Things and Persuasive Technologies experimentation. This hardware will be utilised to ascertain a user's energy consumption patterns whilst also providing a context of how that energy is being used. Once inefficient energy usage patterns have been identified, persuasive technologies may be employed to affect a change in the user's behaviour. The proposed hardware platform should in itself be energy efficient whilst also providing a useful degree of resolution of the user's local environment so that the correct energy usage context can be ascertained.

Key words: Internet of Things, Wireless Sensor Networks, Persuasive Technologies

1. Introduction

The Internet of Things (IoT) has the ability to completely transform the world as we now know it. The amount of information that one could glean from having the IoT in place is almost unimaginable. Practically every item that one would come into contact with in his or her daily lives would not only be uniquely identifiable, but it would also allow one to search for and possibly interact with and obtain information on a myriad of objects throughout the world. Such technology, however, does not come without its costs. One cost in particular is the energy consumption required to interact with all of these objects.

Research into electronic components that use ever decreasing amounts of energy or that use energy more efficiently has certainly assisted in improving the outlook on the energy consumption required to have truly ubiquitous IoT. However it may not be enough considering the astonishing number of items that would require some degree of electronic intelligence. Thus it may be necessary to take a more proactive approach by persuading users of IoT technology to be more efficient in their energy consumption. This concept is the basis for the proposed hardware platform currently being developed.

A Persuasive Energy Node (PEN) is currently being developed which will not only capture a user's energy usage patterns, but it will also seek to create a context of how the user is utilising that energy. For instance, if the user has left his lights, computer and desk fan on but is not his desk, the energy the user is consuming is essentially wasted. The user can then be notified of his behaviour (e.g. he is sent an automated text message stating that he left his computer on), or, if the users allows it, the system that is monitoring the situation can turn the items off in his stead. The methods with which to persuade users to modify their behaviour is one of the key points of REDUCE, an EPSRC funded project which will directly utilise the PEN's[1].

2. Technical Approach

As shown in Figure 1, the envisioned PEN consists of two parts, the energy monitoring unit (Plogg) and the sensor unit which is connected to the top of the Plogg. The PEN has been designed so that the sensor unit can be detached from the Plogg so as to allow for the optimal placement of the sensor unit without having to be constrained by the location of nearby power points. The detached sensor unit would then be connected through the use of a 9-pin serial umbilical cable.

Figure 1. The Persuasive Energy Node (PEN)

The Plogg has the ability to measure the electrical characteristics (e.g. energy, power, RMS voltage, RMS current, phase, etc.) of any electrical appliance that is plugged into the front of it. It also has built in actuators so as to allow for the possibility of turning off and on whatever is plugged into it.

The second part of the PEN is the sensor unit and contains five sensors for detecting light levels, temperature, motion, noise and vibration. The unit also has an LED lamp installed

[1] FP7 projects such as IoT-A (http://www.iot-a.eu/public) and SmartSantander (http://www.smartsantander.eu/) may also utilize these devices in their research.

on the top of the unit which will be used to alert a nearby user that the sensors are actively acquiring data. The five sensors were carefully chosen to provide the greatest amount of information resolution whilst also being cost effective.

The light sensor has a spectral range of 330-720 nm with a peak in its spectral response at 580 nm. This sensor will be used primarily for determining if any room lighting is being used at the time energy usage patterns are being generated. As these sensors detect all forms of visible light, some calibration may be necessary to distinguish room light from natural light.

The temperature sensor used has a functional range of -40 to +125˚C with a scale factor of 10mV/ ˚C. It has an accuracy of ±2˚C and a ±0.5°C typical linearity over the functional range. This particular device was chosen because of its cost. There are more accurate devices on the market but they are considerably more expensive and hence not very practical for large-scale deployments.

The motion sensor is a Passive InfraRed (PIR) device. The sensor is capable of detecting lateral movements of approximately 20cm, within a distance of 2m from the front of the sensor unit across (over a110˚ horizontal arc across the front of the sensor). The sole purpose of this sensor is to determine the presence of an individual in the proximity of where energy consumption patterns are being generated.

Because it is possible that the motion sensors can give a false positive sensor event (e.g. someone walks by the desk of a user who is not there) a noise sensing circuit has been incorporated into the sensor unit. It is likely that this sensor may at best be interrogated every few seconds. Thus an electronic circuit was developed so that when a noise is detected, the circuit creates a voltage signal whose amplitude is proportional to the volume of that noise. The circuit would then slowly decay (decay time of about ten seconds) so that any noise made in the area, no matter how short the duration, can still be measured by the sensor unit.

A vibration sensor was installed to aid in ensuring the validity of the acquired data. It is plausible that under certain experimental conditions a user may attempt to falsify their context data by covering or moving the sensor unit. Thus if the sensor unit is tampered with, a notification will be sent to the network administrator alerting him to the fact that the sensor unit has moved. A command can then be sent by the administrator to reset the sensor once the sensor unit's status has been investigated.

Housed within the Plogg unit are several more circuit boards. The first of these is a TelosB mote which provides wireless network capability (see Figure 2) and is responsible for interrogating the various sensors. An optocoupler circuit (also in Figure 2) has been added on the communications bus between the Plogg electronics and the TelosB board in order to protect each board from potentially damaging voltage spikes that may arise on the data bus.

The last circuit board consists of a 4-port USB hub and a Peripheral Interface Controller (PIC). The USB hub has been added to aid in the communications between the TelosB and PIC and the rest of the gateways used in the proposed network. The primary function of the PIC is to provide a means for creating a virtual sensor by using its Pulse Width Modulation (PWM) output in combination with a simple RC filter. The PIC's PWM can then be programmed with a desired response so that this virtual sensor in effect emulates the response of a real one. This will aid in the characterisation of the network by providing each PEN with a predetermined sensor event. The PIC is also used to interrogate a high-side current shunt monitor circuit. This circuit provides a means with which to measure the electrical current passing through the PEN whilst it is in different states of functionality (e.g. acquiring sensor data, transmitting data, etc.). It is also used in resetting the vibration sensor circuit.

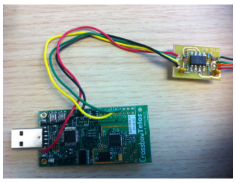

Figure 2. TelosB mote (left) and optocoupler board (right) which are housed within the PEN.

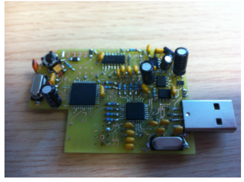

Figure 3. USB hub, PIC, current sensing and virtual sensor circuitry

3. Key Results and Discussion

The PEN is currently in its final stages of development with some of the circuit boards being mass produced. Thus a minimal amount of key results have been obtained thus far. Early versions of the PEN and prototypes of the circuits therein have been used in demonstrating the proof-of-concept of the PEN. They have also been used characterise the amount of electrical current required for the unit. The sensor unit draws approximately 20 mA at 3.3VDC thereby giving a typical power consumption of approximately 66 mW. The 4-port USB hub, PIC and supporting electronics, TelosB and optocoulper circuits utilise approximately 60-80mA of current (depending on whether the mote is transmitting data wirelessly) at 3.3 to 5VDC thus requiring approximately 300-400 mW of power to function.

4. Summary of the work, potential impact & Conclusion

It is expected that the PEN will have far-reaching applications. In both the REDUCE project and other European projects as well. Work is currently underway to rollout approximately 150 of these units in the CCSR. Future, large-scale deployments are being planned as well where these units will be installed in other university buildings and student accommodation sites. Whilst the unit currently being developed as part of the REDUCE project, such devices can be used in nearly all aspects of daily life so that wasteful energy usage can be minimised as much as possible thereby reducing the impact of ubiquitous technologies such as the IoT.