Remote Electricity Actuation and Monitoring Mote

S. O'Connell, J. Barton, E. O'Connell, B. O'Flynn, E. Popovici and S.C. O'Mathuna
CLARITY: Centre for Sensor Web Technologies, Tyndall National Institute, UCC, Cork, Ireland

A. Schoofs, A. Ruzzelli, G.M.P. O'Hare
CLARITY: Centre for Sensor Web Technologies, School of Computer Science and Informatics, University College Dublin, Dublin, Ireland

This work is supported by Science Foundation Ireland under grant 07/CE/1147
Introduction

Goal: Reducing energy consumption

Example: *The Service Sector in Ireland* - accounts for 40% of national electrical consumption - estimated 30% wastage

Identifying, monitoring and controlling individual sources of electricity consumption is key to reducing this energy wastage.

Intelligent plug actuation has been recognized as a solution to this problem.

The REAM: Remote Electricity Actuation and Monitoring

Smart control of appliances can be implemented.

REAM node in enclosure with mains extension board
REAM Node

- Based around the modular Tyndall Mote platform.
- Remotely actuate power to a mains power extension board
- Remotely sample the current, voltage, power and power factor of the attached load
- 0.5 sec updates
- 802.15.4 compliant

**Software**
- TinyOS
- Intuitive Java GUI
- Multihop networking

**Hardware**
- A PIC24 uC at 32MIPS
- Current transformer with Microchip MCP3909
- A solid state relay drives a larger mains relay for actuation to switch up to 13A at 230V
Overview of Tyndall WSN Capabilities

The Tyndall Modular Platform Configuration

- State of the art Modular, Heterogeneous Prototyping Platform for distributed ad-hoc WSN.
- Features: Modular, Flexible, Reconfigurable, Scalable, Robust, Expandable.
- To date upwards of 40 modular layers have been developed including:
  - Bluetooth, Zigbee 802.15.4, 433/868/915 MHZ, GPS
  - Over 20 sensor layers including Inertial Measurement
REAM Node

- 25mm uC Layer
- SPI
- Microchip PIC24
- SPI
- Buck Boost Converter
  - 250AC to 5V DC
- Current Transformer
- Microchip MCP3909
- Relay
- Mains Relay

Connections:
- To Load
- Mains

Diagram components:
- Mains Relay
- Microchip PIC24
- Current Transformer
- Microchip MCP3909
- Buck Boost Converter
- SPI
The REAM node prototype

REAM Top

REAM Bottom
## Specifications/Functional Tests

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plug layer with no load</strong></td>
<td></td>
</tr>
<tr>
<td>Power dissipated (relay on)</td>
<td>1 Watt</td>
</tr>
<tr>
<td>Current drawn by layer @ 230V AC</td>
<td>0.004 Amp</td>
</tr>
<tr>
<td><strong>Ratings</strong></td>
<td></td>
</tr>
<tr>
<td>Supply AC Voltage 50Hz</td>
<td>220-240 Volt</td>
</tr>
<tr>
<td>Maximum Current</td>
<td>13 Amp</td>
</tr>
</tbody>
</table>
### Specifications/Functional Tests

<table>
<thead>
<tr>
<th>Load</th>
<th>Current</th>
<th>Power</th>
<th>Power Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistor config 2</td>
<td>0.93A</td>
<td>214W</td>
<td>1</td>
</tr>
<tr>
<td>Resistor config 1</td>
<td>0.71A</td>
<td>200W</td>
<td>1</td>
</tr>
<tr>
<td>Analog Oscilloscope</td>
<td>0.34A</td>
<td>70W</td>
<td>0.88</td>
</tr>
<tr>
<td>Heat Gun (Medium)</td>
<td>3.46A</td>
<td>890W</td>
<td>0.99</td>
</tr>
<tr>
<td>Heat Gun (Full)</td>
<td>7A</td>
<td>1.8kW</td>
<td>0.99</td>
</tr>
</tbody>
</table>
Specifications/Functional Tests

Power profile of HP Compaq dc9700
Deployment

Deployment space:

- An 1.5kW electric with REAM plug actuator

- One Tyndall mote using PIR sensor

The living room of a shared apartment consisting of four people has been chosen for the experiment.

Typical building space with many people get in and out with little initiative in controlling the heating carefully over the day.
Results I

Wireless sensor nodes deployed within a given space have the capability to sense environment changes and communicate them directly to the REAM node for triggering power actuation of heating loads.

Heating loads are automatically switched on and off depending on space occupancy, contrasting with typical deployments where load actuation is decoupled from environment sensing.

Initial experiments have been conducted to show that energy saving gains can potentially be achieved from networking the REAM node to a wireless sensor network when applied to space heating in buildings.

Although the following results are specific to our deployment and space usage pattern, they serve as a starting point for further experimentation with the plug actuator and ambient sensors in large-scale buildings.
Results II

The data shows **periods when steady temperature is maintained whereas the space is unoccupied**.

Energy gains can be easily achieved with an automated **and intelligent control of the heat delivery** based on input from the space.

Need to evaluate:
- Power savings by keeping the electric load off
- Power waste from bringing the space back to its **comfort** temperature
- Time taken to **bring the space back to its comfort** temperature

Figure 1: Current drawn by the electrical heater against the space occupancy over a couple of evening hours.
Results III

In the setup the heater:
- activated at 19 minutes intervals, for a duration down to 3 minutes
- off for 38 minutes
- switched on again
It took 6 minutes to reach the comfort temperature.

Results:
- Switching off the load has prevented a 3min activity i.e. power saving, but has generated an extra 3min activity on start up - power wastage.
No energy gains have been achieved.

- In this deployment it is observed that any pause in heating longer than 30 minutes will generate power savings.
Conclusions

The REAM node
- Enables **intelligent actuation** of electric loads
- Uses on input received from environment
- Has resources available on the node to **protect sensitive data**
- Enables building optimised energy-efficient solution

**Difficulty**
Cannot know in advance whether a space will remain unoccupied for a sufficient time to achieve energy gains by switching off loads

**Future Work**
- Developing **pattern recognition** techniques to identify recurring patterns in the way a space is used to optimise decision making
- Deploying REAM nodes and Tyndall sensor nodes in spaces with **various occupation patterns** in order to investigate decision-making algorithms towards energy-efficient control of space heating