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The Design of a Wi-Fi Enabled Cloud Monitoring Device

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The Design of a Wi-Fi Enabled Cloud Monitoring Device

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Abstract:

Cloud computing is increasingly used by corporations for storing digital information. As a result the ability to monitor and manage the power consumption of servers in a cloud network is essential. Significant amount of power can be saved by adding monitoring capabilities to the cluster of servers in the cloud. The need to monitor daily electricity consumption has become increasingly important with the ever growing demands for energy. Monitoring and quantifying power consumption enables engineers to notice problems with systems while in operation, and also better plan future systems from the data gathered. As a result, power quality (PQ) measurement concepts are evolving from instantaneous metering to continuous monitoring and recent developments in measurement technology make PQ monitoring systems more powerful. This equates to the construction and utilization of more flexible, compact and intelligent PQ systems.

The goal of this project was to design, construct and test a monitoring system that is cost-effective, reliable and easily deployable in any environment. The paper presents the detailed design of a flexible low-cost Wi-Fi enabled cloud monitoring device by undergraduate electrical and computer engineering students in a capstone senior design project class.

Keywords: Smart meters, Power monitoring devices, Embedded Systems design, Electrical and Computer Engineering capstone design projects.

1. Introduction:

Cloud computing is increasingly used by corporations for storing digital information. As a result, the ability to monitor, and manage the power consumption of servers in a cloud network is essential. "Cloud computing is a model for enabling convenient on-demand network access to a shared pool of configurable computing resources (e.g. network servers, storage, applications, and services) with minimal management effort or service provider interaction". Significant amounts of power can be saved by adding monitoring capabilities to the cluster of servers in the cloud which can result in tremendous electricity cost savings. In this project, a real-time monitoring device was designed and implemented in a two-semester senior capstone electrical and computer engineering course to monitor the power consumption of a cloud server. The system was implemented using off-the-shelf components with Wi-Fi capability. The acquired data was sent to a website for real-time monitoring of the power consumed by the server. An algorithm was developed (algorithm not shown) for the monitoring and the transmission of the data over a Wi-Fi network and for data visualization in a meaningful way. The monitoring device will enable a systems administrator to view real-time power consumption of the server cluster, and accordingly enable or disable individual servers or effectively perform job (task) scheduling allocation in consideration of the total amount of generated electricity when the cloud cluster is powered by green energy. The objective was to initiate students in the senior capstone design in the conceptualization and design of specific open-ended type engineering solutions, using state-of-the-art computer-aided design and modern engineering tools. This is a two-semester design project, students are paired up to work in a team on a project.

2. Design Methodology

The apparatus utilized for the purpose of gathering the data for this project was designed using open-source hardware that would enable the replication of the set-up inexpensively. Figure 1 illustrates a topology of the concept in a green power monitoring application. The following section details each component utilized in the system. The system would consist of two main sensing capabilities, AC and DC, the DC sensor is embedded in the photovoltaic solar array only and AC sensors on AC appliances (fridge, computer clusters, water pump, etc.). These sensors passed the captured readings to an Xbee modem for wireless transmission to a base station. The base station is connected to a Wi-Fi network that enables the relay of the data to a MySQL database on the internet. One of the fundamental goals of such a design is to enable the access of the AC/DC sensor data via the internet despite its location. This would ensure the ability to view the data in real-time from any location in the world. This accessibility advantage addresses the above mentioned goals of the Hadoop Cloud computing, the Zero Energy Home, and the performance of the ECO Pole solar and wind powered street lamps.

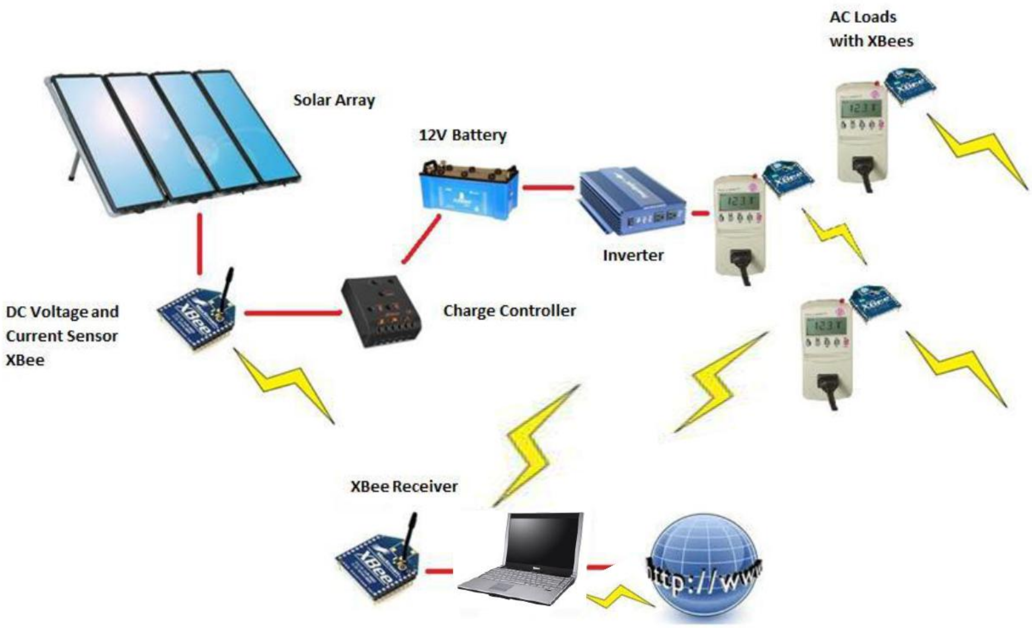


Figure 1: An overview of the system topology for green energy monitoring

3. Components

In this section, details of each component utilized in the system are presented.

3.1 DC sensor

The DC sensor chosen for the design was the Attopilot voltage and current sense breakout board Figure 3a. The sensor is capable of measuring 0-52V and 0-90A DC. The device works by converting the measured parameters to an equivalent DC voltage that is in the 0-3.3V range. This makes it safe for interfacing with the analog to digital (ATD) ports on a microprocessor. To ensure the potential drop across the solar array was measured at all times, the sensor was placed in parallel between the solar panels and the charge controller. For added flexibility of the device, a second current sensor better suited for sensing smaller currents values ranging from 0-500mA was included in the design. This second sensor was a Sparkfun multimeter kit modified to detect voltage changes in the ATD ports of the multimeter's processor.

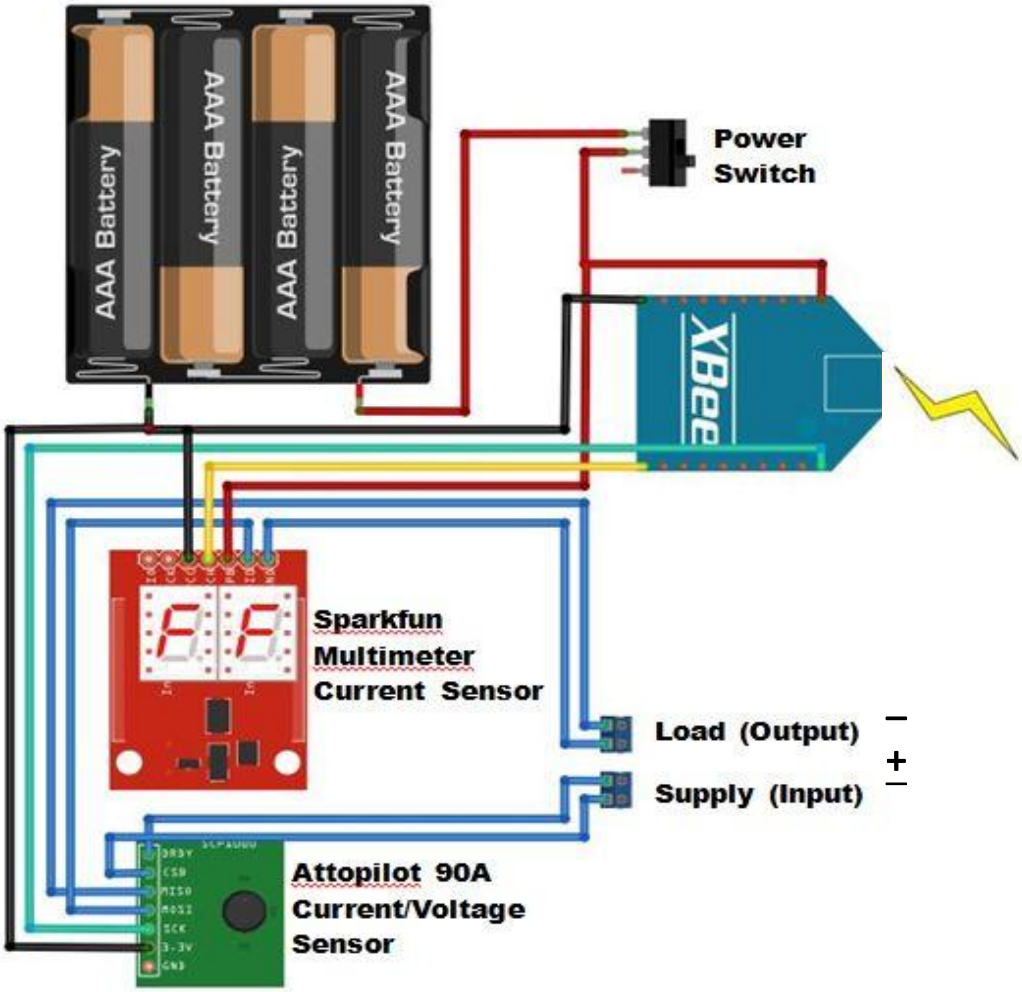


Figure 2. Hardware layout of the DC sensor

3.2 AC sensor

The sensing of the AC voltages and currents were once of the most challenging aspects of this project. The inherent complexities in measuring AC voltages needed a novel way to sample and convert the voltages into understandable values. This was accomplished by the use of an off-the-shelf component called the Kill A Watt (KAW) manufactured by P3 international [1,2], shown in Figure 3. The device functions by being placed between a wall outlet and the appliance being measured. A primary advantage of using a KAW was the dangers and difficulties in taming AC voltage/currents. All that was needed to accomplish this task was to tap into the ATD ports on the KAW microprocessor. The readings were then transferred to an Xbee wireless modem for transmission to a base station.

Specifications:	
Model	P4400
Operating Voltage:	115 VAC
Max Voltage:	125 VAC
Max Current:	15 A
Max Power:	1875 VA
Weight:	5 oz.
Dimensions:	5 1/8"H x 2 3/8"W x 1 5/8"D

Figure 3. P3 International Kill-A-Watt

3.3 Xbee module

The Xbee, series 1 IEEE 802.15.4, 1mW wireless modem (Figure 4) was utilized to provide wireless connectivity for the sensors. The modem is very inexpensive and relatively easy to configure and deploy. The Xbee comes in many flavors and the series used for this system was the baseline model with limited range and the least expensive. More capable models are available with Mesh capabilities and longer ranges.

Feature	XBee Series 1
Indoor/Urban range	up to 100 ft. (30m)
Outdoor RF line-of-sight range	up to 300 ft. (100m)
Transmit Power Output	1 mW (0dbm)
RF Data Rate	250 Kbps
Receiver Sensitivity	-92dbm (1% PER)
Supply Voltage	2.8 - 3.4 V
Transmit Current (typical)	45 mA (@ 3.3 V)
Idle/Receive Current (typical)	50 mA (@ 3.3 V)
Power-down Current	10 uA
Frequency	ISM 2.4 GHz
Dimensions	0.0960" x 1.087"
Operating Temperature	-40 to 85 C
Antenna Options	Chip, Integrated Whip, U.FL
Network Topologies	Point to point, Star
Number of Channels	16 Direct Sequence Channels
Filtration Options	PAN ID, Channel & Source/Destination

Figure 4. The Digi Xbee modem with specification table

4. Implementation

The following sections provide the details of the subsystem implementations.

4.1 AC Sensor Implementation

The Kill-a-watt AC sensor was interfaced with an Xbee radio. The XBee's Analog/Digital converter is set up to take a 'snapshot' of one sine-cycle at a time. Each double-sample (voltage and current) is taken 1ms apart and it takes 17 of them. That translates to a 17ms long train of samples. One cycle of power-usage is 1/60Hz long which is 16.6ms. Figure 5a shows the schematic of the kill-a-watt with an Xbee installed. The voltage and current sensor inputs were tethered to pins 15 and 20 on the kill-a-watt quad op-amp. Figure 5b shows a close-up of the kill-a-watt op-amp with the input wires attached.

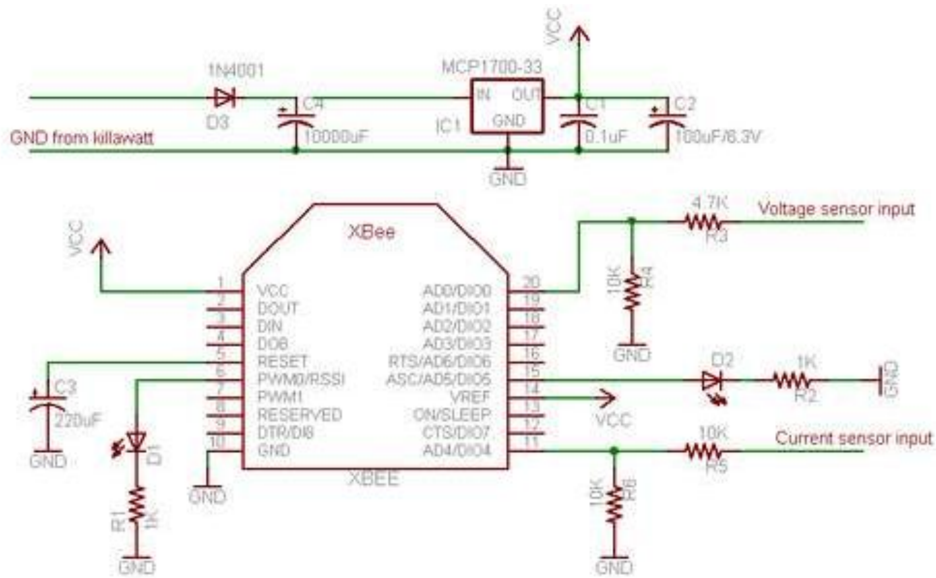


Figure 5a: Kill-a-watt with Xbee schematic

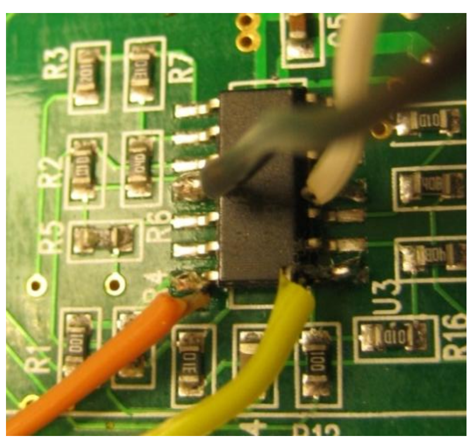


Figure 5b: Kill-a-watt quad op-amp with current and voltage sensor input wires attached

Figure 5c: XBEE interface to a Kill-A-Watt module

4.2 Base Station Implementation

The base station was designed with form factor in mind (Figure 6). The component layout had to be compact as the device must be able to be installed in tight quarters. The base station contains 2 Xbee receivers; for AC and DC sensors. This concept of having a receiver for each type of sensor was decided with scalability in mind. Each Xbee modem can be configured with a unique PAN ID. This enables each modem to operate independent of the other Xbee modems in the vicinity, and not have data conflicts. Xbees can have unique PAN IDs configured from hexadecimal values 0000 to FFFF which is a theoretical value of 65535 PANs. The microcontroller used in this project is the Arduino UNO and a Wi-Fly shield card for wireless internet access (shown in figure 6 below)

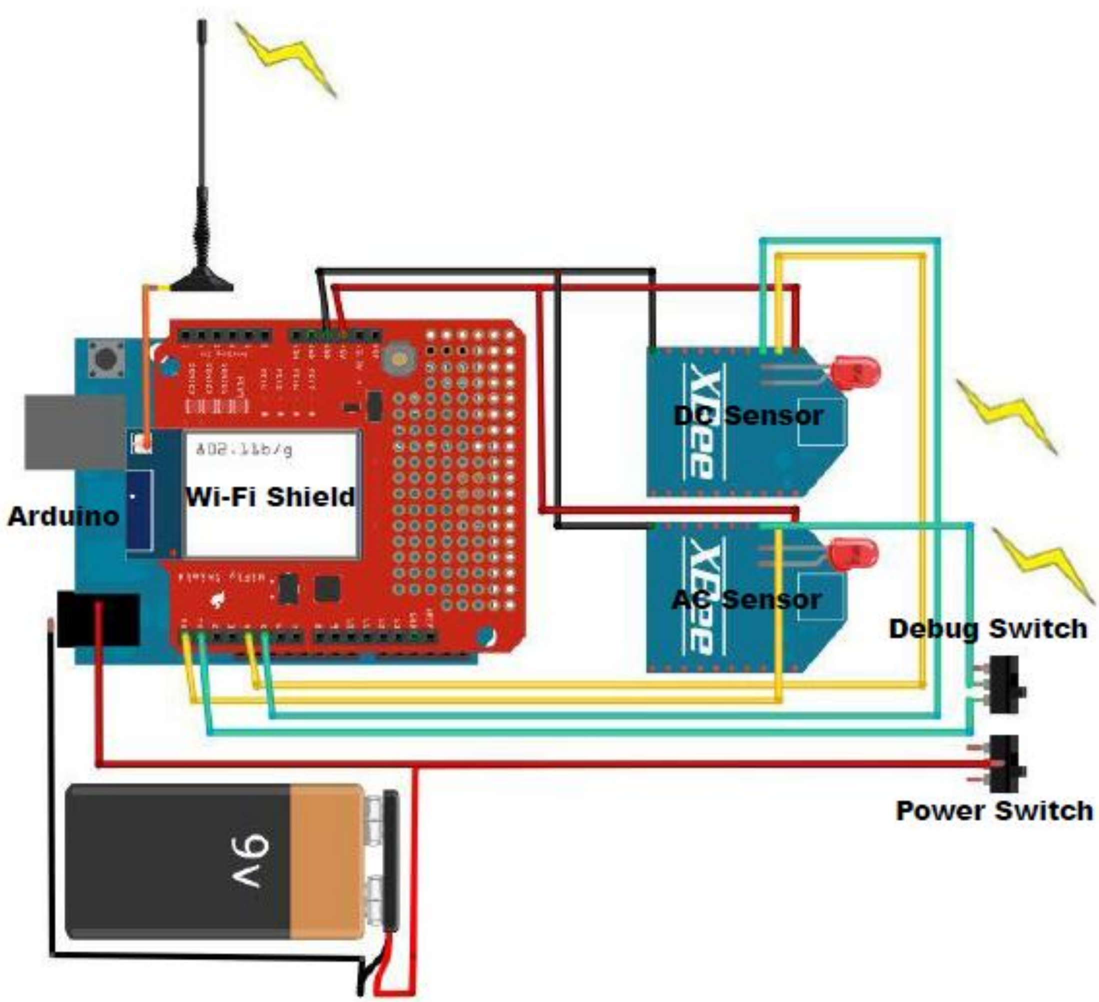


Figure 6. Hardware layout of the base station

Figure 7a shows the layout of the monitoring system described above for the Hadoop cloud computers comprising of 26 nodes. Figure 7b shows the Kill-A-Watt module including a wireless transmitter, monitoring the power usage of a cluster of 7 computers.

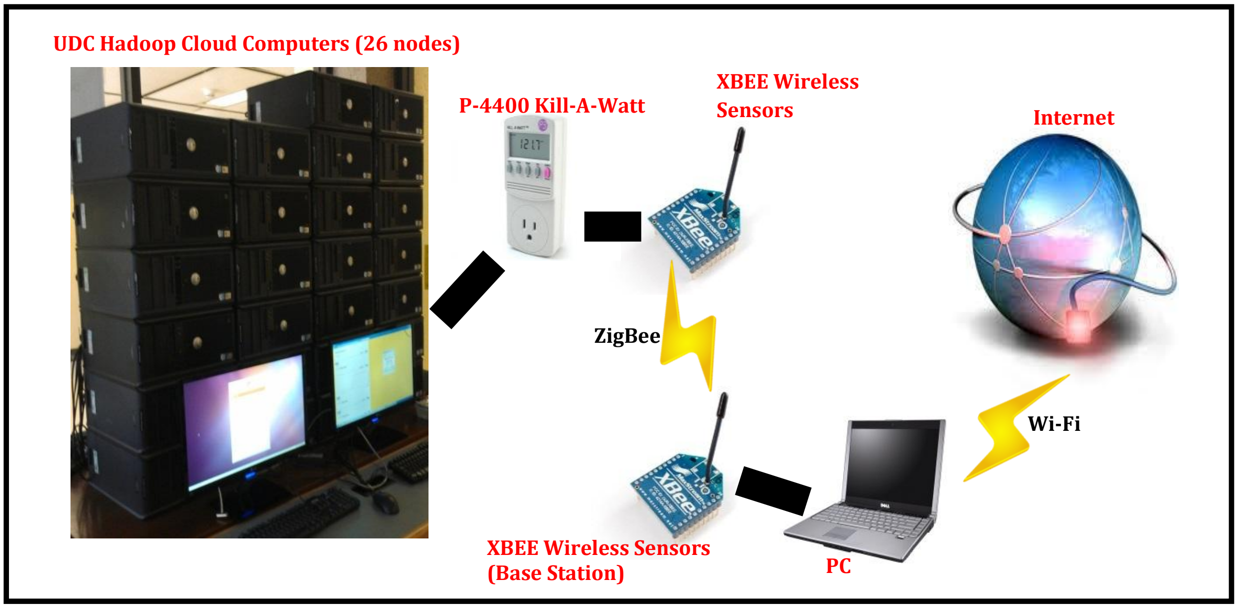
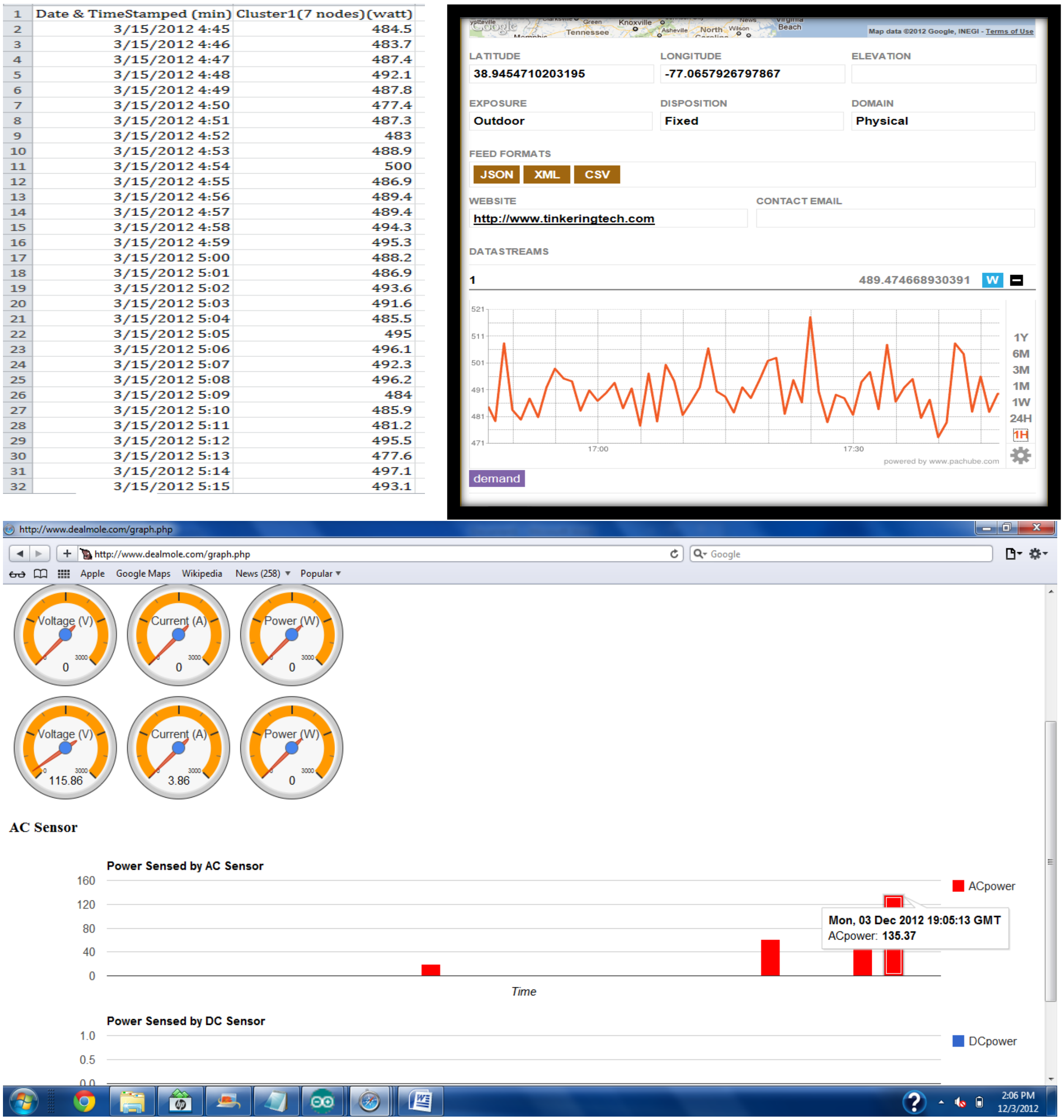


Figure 7a: Layout of the monitoring system for the Hadoop Cloud computers

Figure 7b: Kill-A-Watt module with wireless transmitter installed monitoring the power consumption of a cluster of seven computers

5.0 Snapshots of Sample test data:

The following screenshots, as shown in Figure 8, display the logged data in various forms including tabulated data, graphed data and the metering system, obtained using the power monitoring system on the cloud computers for a cluster of seven computers.



1	Date & TimeStamped (min)	Cluster1(7 nodes)(watt)
2	3/15/2012 4:45	484.5
3	3/15/2012 4:46	483.7
4	3/15/2012 4:47	487.4
5	3/15/2012 4:48	492.1
6	3/15/2012 4:49	487.8
7	3/15/2012 4:50	477.4
8	3/15/2012 4:51	487.3
9	3/15/2012 4:52	483
10	3/15/2012 4:53	488.9
11	3/15/2012 4:54	500
12	3/15/2012 4:55	486.9
13	3/15/2012 4:56	489.4
14	3/15/2012 4:57	489.4
15	3/15/2012 4:58	494.3
16	3/15/2012 4:59	495.3
17	3/15/2012 5:00	488.2
18	3/15/2012 5:01	486.9
19	3/15/2012 5:02	493.6
20	3/15/2012 5:03	491.6
21	3/15/2012 5:04	485.5
22	3/15/2012 5:05	495
23	3/15/2012 5:06	496.1
24	3/15/2012 5:07	492.3
25	3/15/2012 5:08	496.2
26	3/15/2012 5:09	484
27	3/15/2012 5:10	485.9
28	3/15/2012 5:11	481.2
29	3/15/2012 5:12	495.5
30	3/15/2012 5:13	477.6
31	3/15/2012 5:14	497.1
32	3/15/2012 5:15	493.1

Figure 8: Screenshots of data logging and graphs

Total project cost not including (data processing algorithm) is shown in Table I below.

Table I: Project Cost

Component	**Cost ($)**
Kill-a-watt	17.48
Xbee modems	92.00
Wifly Wi-Fi module	89.95
Attopilot 50V current/voltage sensor	19.95
Sparkfun Multimeter	19.95
Arduino UNO	29.95
Miscelleneous parts	50.00
Total	**$319.28**

6.0 Applications for this apparatus:

Apart from the development of a system to monitor the Hadoop cloud power footprint, other uses for the project have also emerged.

6.1 Implement the system in the zero energy home:

The University of the District of Columbia's CSIT Hadoop cloud would eventually be migrated to the university's zero energy home, as shown in Figure 9 below. The goal of this migration is to run the cloud using renewable energy resources, namely solar and wind energy. The data gathered from this project would enable better planning for the power needs of the cloud before the migration to the zero energy home [3]-[5].

6.2 Utilization of the logged data for time-series prediction methods

Research is currently active in a follow-up project to use the logged data for time-series prediction of the green power and scheduling of the computer clouds operations, predicting incoming green energy based on current and future weather conditions.

Figure 9: UDC Renewable Energy project

7. Conclusion:

A low-cost AC power monitoring system for computer clusters have been constructed and successfully tested. The testing of the system proves that such a system could be built very inexpensively with very impressive results. This project has set the basis for other two important projects in the applications discussed above, and will allow continuous monitoring of the Hadoop cloud computers at a relatively low cost.

Acknowledgement

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