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A Proposal of Efficient Energy Management System for Load Balancing in an Unstable Networks

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In this paper, an energy management system for an unstable community wireless network is proposed. The targeted network environment of this system is unstable due to frequent power loss, and it has no local administrators. Thus when power cut off, the system needs a lot of time to recover. Proposed system can be managed by remote. Moreover, when power cut off, the system will automatically detect the problem and starts supplying power from the redundant energy backup system with no operation.

1. Introduction

Energy plays an important role in our daily life as well as in the national economy of the country. The energy demand is increasing day by day with the growth of population. Developing countries have high energy deficiency problems. Most of the developing countries including Nepal depend on hydro power for the production of electricity. The production potential of electricity from hydro power is huge but due to lack of technological advancements and economical supports, these hydro-electricity power plants are difficult to install and run. So the production of electricity is not enough for the people's living in these countries. Furthermore, there is no contribution of other renewable sources in national power generation. The regular shortages of electricity infrastructure are the major factor to keep people of these countries in darkness. Developing countries have scheduled power cut-off for several hours a day. This caused a negative impact on developmental sectors of the nation. Inadequacy of energy supply is a significant obstacle for the social and economic development of the country.

Recently the use of renewable energy i.e. solar energy is growing in Nepal. In the rural areas where grid system cannot be reached yet, solar energy can be the supporting energy to raise the living standard of the people. In the urban areas as well where there is frequent power cut off, the use of solar energy is growing parallel with grid supply. Initial cost of installation is high in solar power but there is no frequent expenditure for the electricity after the installation is completed. So people can be happier in using solar power.

We are working to support students in villages of Nepal to use internet facilities for e-learning. Since year 2011, we continued to construct the community wireless network (CWN) in Kaski district of Nepal. Figure 1 illustrates our CWN network that was built in Nepal. We provided internet service in two schools of this district which are our research locations. We installed solar power units to power the network devices of CWN. These solar power units have no any automatic controlling mechanism to control the devices and regulate power. Moreover, near the schools, there are no local administrators or local engineer for maintenance of our system. Therefore, we must maintain our system by remote. And unstable power supply also makes our network unstable. So, energy management to keep CWN stable is very important problem for our research works.

To solve this problem, this paper proposes an energy management system (EMS) for using solar power effectively. It supports the available grid supply for the energy management of network devices in those schools. A goal of this research is to connect schools with stable network supported by our EMS. We aim that students can gain knowledge by using our CWN and broaden their knowledge in different sectors of education.

2. Literature Survey

In developing countries, e-learning is one of the services that can be operated over Internet, but there are hurdles in its implementation. One of the major hurdles is frequent network unavailability or disconnection. Shortage of electricity is a big problem in developing countries. Areas are affected by regular scheduled power cut offs. There exists hours of power cut off in an average throughout the year. It is a major cause of an unstable network. When there is power cut off, the wireless devices will not function so there will be network disconnection. If there is no power supply in the wireless radios and antennas, the network will be disconnected in the regions that it is connected through its medium. Therefore network is unstable[1)].

Many rural regions such as in Nepal, India, Bangladesh of South-Eastern Asian countries and most of the African countries, especially in developing regions of those countries, do not have good connectivity solutions which are economically viable. In order to provide internet access in these countries, government and INGO are working to provide wireless services in these areas. Partial-mesh networks in Himalayan regions were built and this network is still working thereby providing community networking services in the remote village of Nepal. However, these networks are not stable as compared to the networks built in urban areas. The lack of proper electricity and network infrastructure in rural area and high installation cost as compared to urban areas are the two major hindrances in building stable wireless network. Wireless Network in rural areas is not stable due the power outage and link failure due to signal loss[2)]. The main goal of the project "Smart home energy monitoring and management system" is to develop a system such that it will be capable to keep a track of each and every appliance in home and the user will be able to acquire all

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appliance energy consumption parameters. Along with this, the energy consumption parameters of each individual appliance will be sent to gateway where an intelligent algorithm will be running to manage all the appliances as per user requirements. The user can monitor the parameters of each individual load using an android smartphone which will also work as a data setter to set various user programmable parameters like high/low cut-off voltage, etc. By automatically turning off loads when not in use, the system can provide energy savings in home and offices. Applications for this system include workstations, open offices cubicles, home offices, and home entertainment systems[3].

Operational energy use of a building is the largest component of life-cycle energy use and occupies around 80% of the total life-cycle energy use. However, the actual operational energy use of a building has a significant difference with simulated energy use of the building at the design stage. Operational management of buildings needs to be adaptable to unforeseen and ever-changing modes of operations. The needs require the development of innovative method that enables proactive control of operational energy use in buildings. If such method could be usable, the method could be an effective tool to zero energy buildings by monitoring and mitigating the difference between the actual performance and the targeted performance at the design stage[4].

3. Current Infrastructure

3.1 Previous work

Our CWN is connected between three remote areas of Kaski district namely Dhital, Kaskikot and Pokhara city. Pokhara is a major city of this district. The main server station is located at Pokhara. Figure 1 shows a location of our CWN installed in this district. There are schools in Kasikot and Dhital. These schools are now connected to internet through our CWN. Solar and its backup battery are installed at the station in Pokhara. The school in Dhital is also installed with solar and backup battery. Figure 2 shows a solar backup system in Pokhara installed in year 2013.

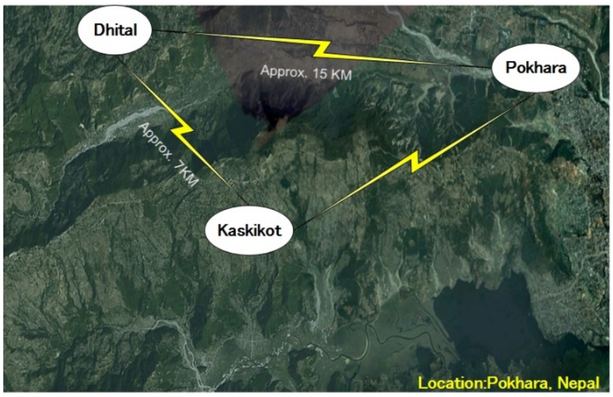

Figure 1 Location of our CWN

Figure 2 Solar Backup System in Pokhara Station

3.2 Unstable Network

Considering the fact for providing internet facilities in the schools, our selected area is rural village of Nepal which is situated in between mountains. So due to land topology of the region, wired internet connection is very difficult to install and is very costly. So the better option for the internet connection in this area is wireless connection. However this connection is not efficient and stable. The reason behind the unstable network is frequent power cut off which occurs 20 hours per day at maximum level. This leads to link failure. The focus of this research is to stabilize the unstable network by stabilizing the electricity. When there is power cut off, the wireless devices will not function so there will be network disconnection. If there is no power supply in the wireless radios and antennas, the network will be disconnected in the regions and the network is unstable.

3.3 Electricity Problems in Current Environment

Presently there is single solar panel and single battery installed for backup support mechanism in Pokhara and Dhital. These are directly connected with the devices through inverter to power them. Considering time interval of power cut off and time for charging battery, the backup power is insufficient to power the devices connected to it. During the time of power cut off, the computers in school can’t be powered as the power from the backup power is insufficient.

The backup solar is used for powering the network devices, so cannot power computers to access internet in schools. Thus accessing internet is only functional during day when electricity is available. And in Nepal there is rarely electricity available during day. Electricity is available mostly during night hours. Moreover, there is loss of power from battery after power cut off is back when user forgets to turn off other appliances like lights, fans etc. that are connected to the battery. These appliances are unnecessarily drawing power from battery.

Presently there are no monitoring devices to monitor the power utilization from the battery. So the battery is used till it can power the devices. This makes capacity of the battery very weak and decreases the life expectancy of the battery. Thus, it creates problems of battery damage very often and adds economic burden. Again, due to frequent power cut off and improper power from sources, there is link failure in the connection. This causes instability in the network and also sometimes physical damage in the devices, increasing the maintenance cost of the network.

Addressing all these issues, this paper is focused in improving the energy backup mechanism for the school to

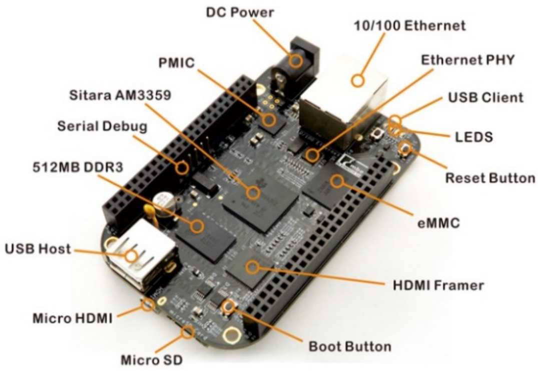

Figure 3　BeagleBone Black

power the network devices and computers available. Development of the EMS system to monitor the status of the battery, power consumption of the network devices, computers and remote controlling of accessories appliances through web for stable electricity supply and stable network is the focus of the research.

4. System Requirement

4.1 BeagleBone Black

The BeagleBone Black (BBB) is a low-cost, community-supported development platform for developers and hobbyists[5]. It is low-power open-source hardware single-board computer produced by Texas Instruments in association with Digi-Key sand Newark element[6]. It also supports open source software development. The current version is BBB Rev C. It can be used to capture analog signals and digitize them. Figure 3 shows hardware of BBB.

The BBB is the main board for monitoring and managing all the devices. It manipulates and controls the electrical appliances (ON/OFF) in real time. Here electrical appliances include all the network devices and the computers that are used in the School. This devices can be used with sensors for different purposes, like integrating cameras for remote viewing of the physical condition of the battery, routers, switches etc., security of the network devices, a server for data storage and for intermediary interface, remote control of devices by web application.

4.2 Functionalities of BBB

Figure 4 illustrate a functional structure of BBB. All the processing and calculations are executed in BBB. BBB is installed with Angstrom Linus distribution, and set up with IO python library. Further it is also used as web server.

4.2.1 Processing Unit

The processing unit of BBB functions for reading battery voltage as input from battery and energy parameters (voltage, current) of devices which are connected at load. For processing and calculation in BBB, scripting is done in python code. Python script in BBB makes pin assignment for both input and output of the board. Calculating the power consumption, remaining voltage in battery, all are done in processing unit. Processing for monitoring devices, generating signals for controlling devices are also done by the processing unit of the

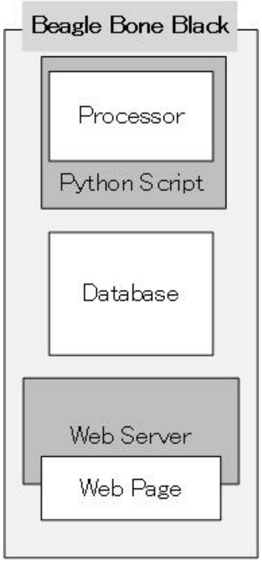

Figure 4　Functional Structure of BeagleBone Black

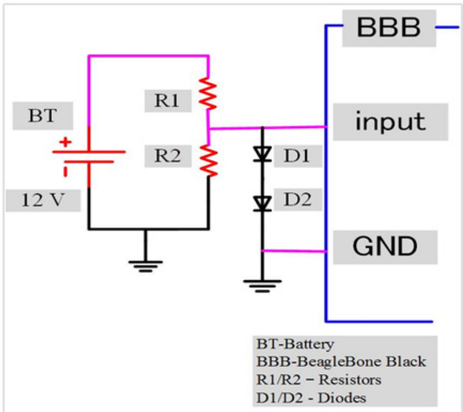

Figure 5　Potential Divider as Voltage Divider

board.

4.2.2 Web Server

BBB functions as the web server when installing lighttpd in it. We integrate PHP to handle the required server side logic, then use MySQL database to store calculated data received from battery and devices. These information can be displayed in the web pages and can be viewed and accessed by remote users through web pages. Remote users can even control the devices connected to the board.

4.3 Voltage Sensor

Voltage sensor shown in Figure 5 is a device used to get input voltage from the battery. The potential divider is used as a voltage sensor. It is connected across battery and used to obtain a desired fraction of total voltage that is suitable for inputting as input signal to BBB. This battery voltage of 12V, is converted to less than 1.8V to input to ADC pin of BBB. This converted voltage is read by the BBB in order to perform further calculations. We restrict our voltage below 1.8V as it can destroy the board if the voltage is exceeded.

5. Proposed System

5.1 Overview of Proposed system

Figure 6 is the system overview of the proposed system in which the EMS system will be utilized to support the current CWN network for continuous power supply. School 1 and school 2 are the target school where our system will be implemented. Students in each school will access internet provided from the main server of Pokhara area. We will also implement our system in this main server area and the relay node as well.

5.2 Basic Idea

By considering the problems of power outage in the current CWN area, we propose an EMS system. We have divided the proposed system into three parts. They are (1) reading voltage part, (2) main processing part, and (3) load part. Figure 7 illustrates how all these parts interact with each other. The reading voltage part is "Source" in the figure. It is for taking input values as battery voltage to the BBB. The source has two pair of battery bank which works one after another functioning for shifting of battery mechanism which is discussed in section 3 of main processing part. The main processing part consists of monitoring of devices status, calculating input and power of devices and controlling the devices from the system automatically and from the web by remote user. The load part is connected to the loads of system. The loads of the system ("Load" in the figure) are energy utilizing devices that utilize the power from the battery.

5.3 Reading Voltage Part

This portion of the proposed system is the first part of the system. This is the source (input portion) of the EMS. Figure 8 illustrate the reading voltage part. It includes the pair of battery bank for shifting battery and sensor for inputting input signal from the battery. The input is focused for reading voltage from the battery through the voltage sensor for further calculations and processing.

5.4 Main Processing Part

The main processing part functions for the data processing and for the controlling/monitoring of the devices. Figure 9 shows the monitoring system in this part. All the processing and calculation is carried out in the BBB. Receiving inputs like voltage, current from input and output for calculation and monitoring is done within BBB.

5.4.1 Monitoring System

The monitoring of devices (regardless whether it is currently being used or not) is a function in the main processing part. It also monitors the battery status during input and monitors data flow between the schools of the CWN network. The system keeps on monitoring and updating the devices' status in database on web server. It keeps the track record of the devices presently in use and not in use. The list will be displayed indicating which devices are currently in use and which are not.

The user, who is inside (or outside) of CWN area, can check updated values through the web pages on their smart phones and computer. The system itself can terminate and start the device,

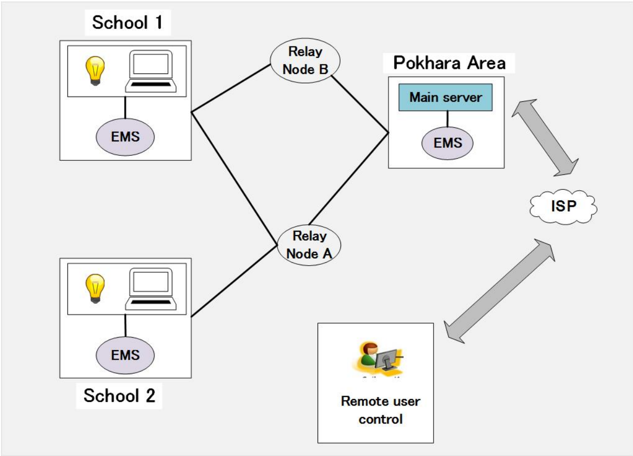

Figure 6 System Overview of Current CWN

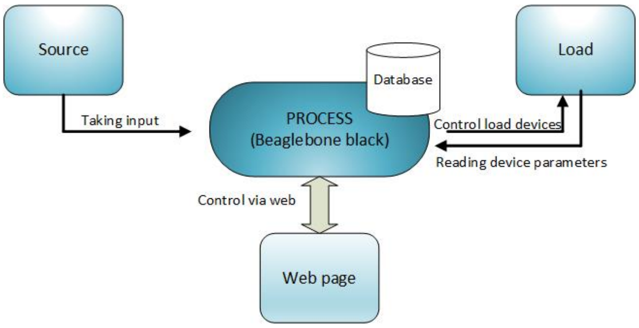

Figure 7 Structure of Proposed System

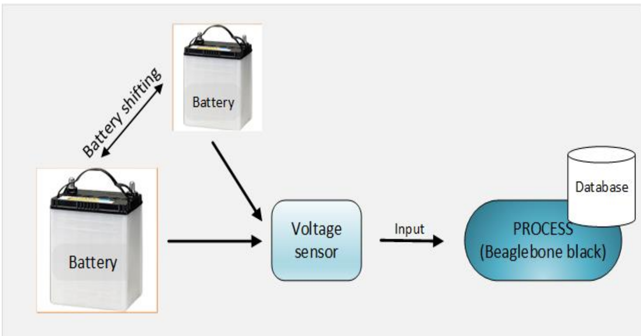

Figure 8 Mechanism to Read Voltage

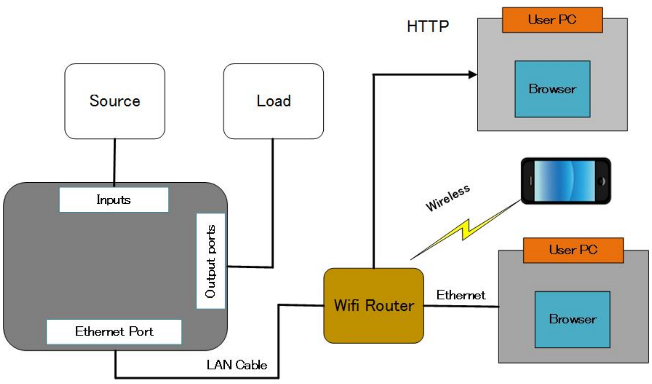

Figure 9 Monitoring System

analyzing its need in the current situation. User from remote place also can make decision to select terminate/start the device thus making use of efficient EMS for proper utilization of the available energy.

5.4.2 Calculation

When the BBB receives the voltage signal from the voltage sensor, further it does is the processing of the received voltage. Since voltage from the battery is analog component, the analog to digital (ADC) portion of BBB converts the received voltage to digital signal. Then it calculates the actual voltage of the battery that is the present capacity of the battery in terms of voltage and stores in the database of the webserver of the BBB. It also calculates the power consumption of the devices that are presently in use. Comparing the present capacity of the battery and the power consumption of the devices, the BBB calculates the time remaining for the battery to support the devices that are presently in use. Making use of the time remaining, user can decide the devices to turn off or not.

5.4.3 Battery Shifting Mechanism

Initially the network devices, computers, electrical appliances will be powered up by battery 1. When this battery goes low, then it shifts to the second battery. Figure 10 illustrate the battery shifting mechanism for use in the EMS system. Both the batteries will be in charging condition. When the battery 1 starts getting low, the system will generate the alert signal. So the EMS will now take action to changes from first battery to the second. And now the devices connected will be powered up by the battery 2. After the battery 2 comes in action, then Battery 1 remains in charging only. Battery shifting circuit will be implemented using the control mechanism of relay. The time duration of shifting will be maintained very low.

5.5 Load Part

The load part is the end part of the system. It includes network devices like routers, switches, antenna that require continuous power for stability of network even the users are not accessing internet. The power in this unit must not be disconnected. Next, the load part includes is the devices for accessing internet, like computers in the schools. Each school is provided with around 15 computers. So, this portion requires high power consumption. The battery backup design is made to power up all these devices.

6. Research Plan

6.1 Overview

Thereafter, our research plan is carried in three phases. The first phase is to develop the Battery Monitoring System (BMS) which is the initial phase of the system. In this phase, the battery voltage reading mechanism will be developed by installing the voltage sensor to BBB. The task of BMS is to monitor the battery parameters. Second phase is to develop the remote monitoring system (RMS). These functions are for remotely monitoring the devices which were setup in the CWN area. It can monitor from within the area as well as from other places such as Japan. Third phase is to develop the Load Control System (LCS) that controls the load devices which are

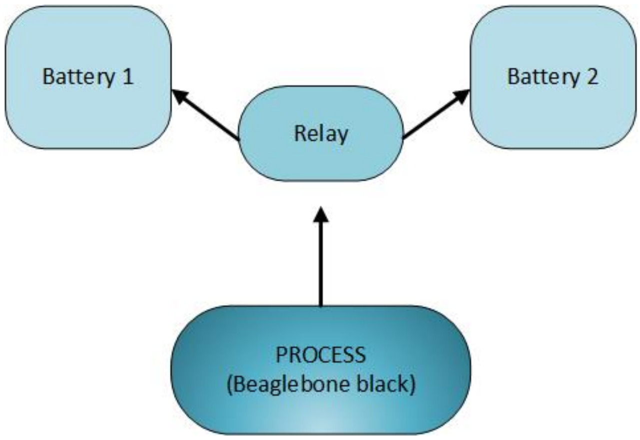

Figure 10 Battery Shifting Mechanism

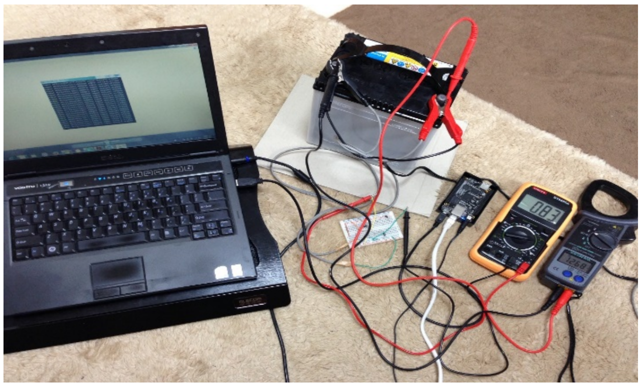

Figure 11 Experimental Setup

connected to the system.

6.2 Current Progress

So far, we have interfaced the BBB to read the inputs from the battery and calculated its actual voltage. Figure 11 shows the experimental setup of the battery monitoring system. We have set up BBB with Angstrom Linux distribution. Angstrom distribution is Linux version specifically designed for embedded devices. And further we set up the board by installing the IO python library. We installed the lighttpd as web server.

6.3 Future works

In future, we will be having study on analyzing circuit for load monitoring to interface the load with the BBB. We will program the BBB to get data from the load devices and calculate power consumption. We will further work to compare the time difference that the backup system can support the working devices by the calculating the performance parameter of these devices. We will develop firmware for processing the power consumption of the individual load devices. We will be working for balancing the power distribution between the loads. Those devices which are consuming power but are not in function are detected by the system and turn them off. Network devices are given high priority for power supply, so that network devices are continuously powered and the network in CWN remains stable.

We will further work for interfacing web control techniques to update devices status in the web and controlling individual devices through it, updating source and load parameter frequently in database and accessing it to web and displaying it in real time. We will make user friendly web application for desktops and mobile. We will be testing our proposed system here in Japan and implement it in Nepal in the real field.

We still have more research to be carried out to make the system more efficient and functional.

7. Conclusion

Our plan for providing CWN to the people of developing country will be possible when there is stable power supply. Providing only complete CWN network is not sufficient for the schools to allow students to access internet for their online study. The strong energy backup system has to be built to provide energy stably for the devices to work well. In this paper we proposed the EMS system that can monitor and control the EMS devices via Internet. Installing solar backup and utilizing it in efficient manner is our focus. Solar backup mechanism will support the grid supply wherever available and it will be made capable enough to work standalone. After the system is developed, energy can be properly utilized on our CWN. So if we are able to utilize the available energy in proper way, we can get positive outcomes.

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