

Tanzania Humanitarian Project Proposal

GSM Data Link for Monitoring and Control of Solar Satellite Access in Mto wa Mbu, Tanzania

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The project uses the cell phone network in Tanzania to deliver signals from secondary schools to an inverter that will power on their internet. There will also be a monitoring system to shut down the internet if there is 15 minutes of inactivity or the batteries that power the internet drop below 50% of total capacity.

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Introduction

Since 2008, MSU faculty and students have traveled to Mto wa Mbu, Tanzania to install computer labs with wireless access to the internet^[1]. The internet access is provided by a solar powered remote satellite uplink. Currently, this system is turned on for a given period each day for internet use and turned off the rest of the time in order to conserve energy in the solar batteries.

The project goal is to create a system that allows an individual school to access the internet system remotely by way of a cell phone signal. The system providing the internet will power down at a specified period after the last internet usage is detected. This will aid in conserving energy as well as increasing the life span of the batteries. A detector will also be needed to measure the amount of power left in the batteries. Once a given battery level was reached, the system would power down. An alert would be sent to the proper authority to notify them of the system malfunction.

Background

As part of an ongoing project, ECE 480 design teams from Michigan State University have been rigorously pushing the boundaries of technological improvements in rural parts of the world. In the past few years teams have designed and installed computer lab stations using solar power where grid power was unavailable. These stations are provided with internet access through a satellite system also powered by solar technology. Operating a satellite dish continuously over an extended period of time is not feasible because of its power draw. Operating the system for a period of four hours at a 100 Watt hour draw rate will consume about 10% of its charge. Currently, because of this, the system is only powered on from 1pm to 5pm every day and, alternatively, charges during the other hours of the day.^[2] The team objective is to design a system which gives internet on demand instead of the current system which only provides a static time slot for use. This will allow users to gain access to the internet at request while still maintaining a significant amount of system power. Operating in Tanzania, the system is powered by VLRA batteries based on a sulfuric acid mixture that is immobile and gel-like. Due to the nature of these batteries, maintaining a capacity over 50%, and more ideally 70%, will increase the life of these batteries tremendously. These VLRA batteries have a cycle life of around 5000 cycles when operating from 100 to 90% charge, and the life expectancy will drop logarithmically to around 500 cycles operating at 50% discharge rates. During previous attempts to design an internet on demand system based on radio communication several difficulties occurred. These associated difficulties included signal attenuation, line of sight problems, and drew significant power from the system when trying to transmit over a period of five miles.^[3]

In this proposal, the design will overcome these issues by using a more reliable underlying structure. The Global System for Mobile (GSM) cellular coverage in Tanzania is very reliable, and controlled by large communication companies very similar to those of T-Mobile and AT&T in the United States. This will allow us to instantaneously transmit on and off signals without significant error. By implementation of cellular devices an internet on demand system can effectively and reliably be created for the schools in Tanzania.

Objectives and Design Specification

Internet on demand is an incredibly useful resource for education. Implementing a system that can provide internet on demand is necessary to maintain knowledge in an ever growing competitive world. The objective is to design a system that will allow our colleagues in Tanzania to request internet access and have it turned on for them instantly. In addition to internet access granted on request the system should have capabilities to monitor itself, monitor the remaining battery power left in the system, and signal for help when a system flaw is detected. As previously stated, the system operates for a specified period of time during the day and is shut down. Instructors and students in Tanzania have requested the ability to use the system as specified intervals over the course of the day. To achieve this goal without sufficiently consuming all power, our system will need to boot up and be active while the users want access, and be able to shut down automatically when activity stops. We will also be able to notify users of remaining system time if the system has been powered on for too long. With the flexibility of SMS text message based communication we will be able to communicate these things very reliably and can even encrypt our messages so that telemarketing and advertisement messages cannot interfere with our design. Overall, the main objective of this design is to implement a system that can communicate with itself from multiple locations and trigger on a larger system while actively monitoring both of these systems.

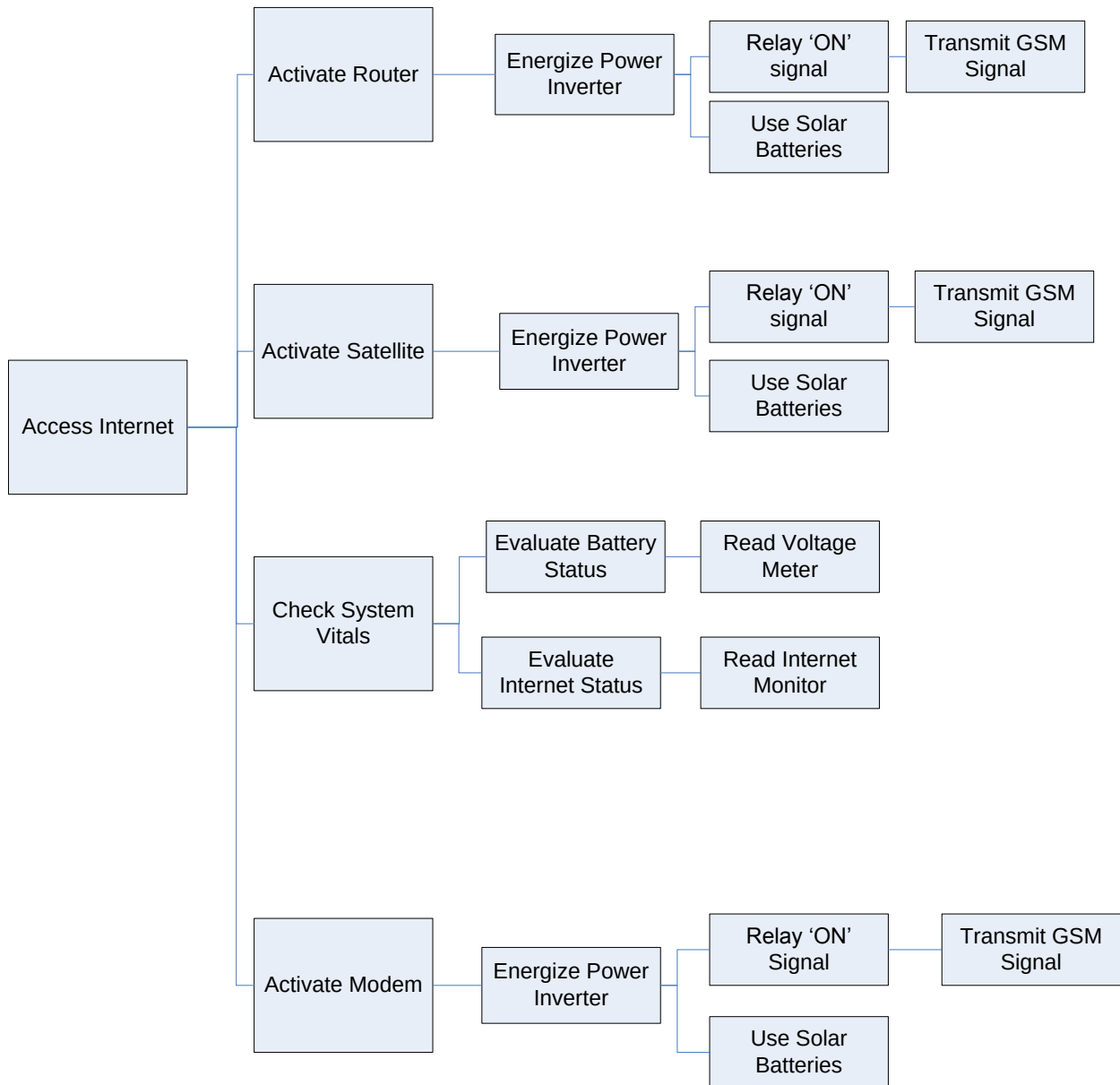
In this design, the underlying technology for communication is already provided. The team will be using the Global System for Mobile (GSM) communications technology. This provides a significant advantage because there is already excellent GSM antenna coverage, provided by 5 different service providers, where these schools are located. The frequencies that are provided in Tanzania are combinations of 900 MHz and 1.8GHz carrier frequencies. This is different than the frequencies used in the United States where 850 MHz and 1.9 GHz frequencies are used.^[4] Since the design will require operation on a multitude of frequencies, a Quad-Band GSM chip that, with very minor changes, can operate on any of the four frequencies will be used. This Quad-Band module, GSM/GPRS Module – SM5100B^[5], will allow active testing of the design inside the United States without the need to substitute a different

GSM chip for use in Tanzania. This module will be coupled to Arduino Uno (Revision 3)^[5] micro controllers which will be used to monitor power consumption, battery charges, and a multitude of other possible sensors in the future.

The subsystem will operate off of the batteries at the primary school where the internet connected satellite dish is located at all times. A need for a subroutine that is very cautious of power usage will be required for all times while monitoring incoming request signals. When a request for access is detected the main microcontroller will need to power on the SamlexPower DC-AC inverter currently powering the internet system in Tanzania. This inverter has a remote access switch that will allow us to turn it on with a simple uninterrupted HI signal.^[6] In addition to these functions the battery charge which will be monitored using an external circuit. This circuit will signal the micro controller if the battery charge drops below a specific value. This system will also monitor the power output from the solar panels and send out a notification if significant deviations from expected values are detected.

Another important part of this device will be logging how much power is being used over the course of a period of time. With the system powered up we can relay information with an internet server to track and record these values. We will also be able to log what times of the day has most active use and for how long the system is generally used for. This information will be highly beneficial for predictive failure analysis.

Fast Diagram



Conceptual Design

A. Introduction

In order to meet the sponsor's requirements, an internet monitor, a turn-on message request system, and a battery capacity monitor are designed to be used in this project. If we can achieve these, we will successfully create internet-on-demand for the schools in Tanzania.

(The GSM package used below includes a GSM shield, an Arduino Microcontroller, and an antenna)

B. Block Diagram of the Design

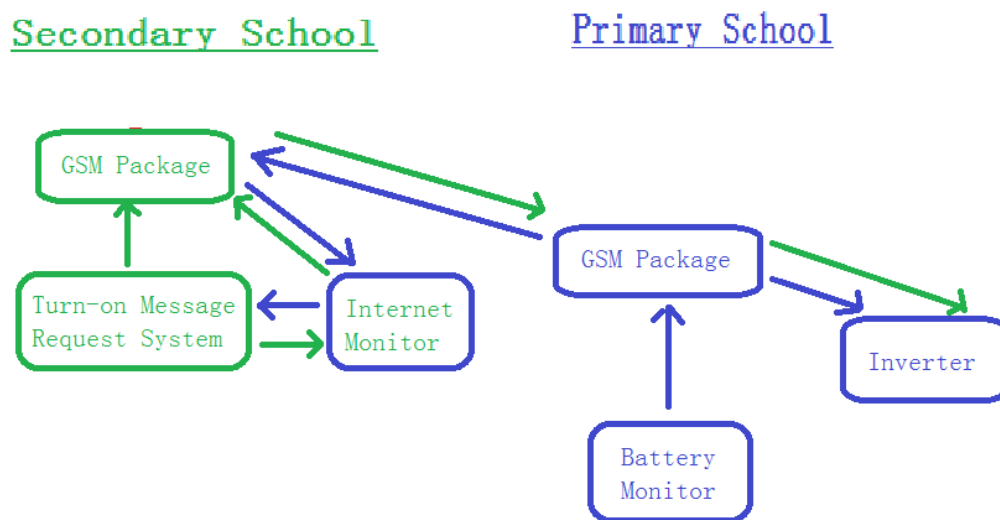


Figure 1 - Block Diagram of the design layout

C. Detail of Conceptual Design

1. Turn-on Message Request System

The Turn-on Message Request System includes one or two press buttons and a simple LCD Screen. Users could press the button to send a request through the GSM package to turn on the inverter in order to power up the satellite and the router in the primary school. Then, after the internet is turned on, the GSM package in the Primary school will send a signal to the secondary school to show the on message

on the LCD Screen. Also, repressing the button once after they complete using the Internet will make the Turn-on Request System stay at the off position.

2. Internet Monitor System

The Internet Monitor System will consist partially of functions from the GSM package and Turn-on Message Request System. During the monitoring process, the GSM package in the primary school will send a ping signal to the secondary schools to check the status of the secondary schools' request system. If the request system stays at the on position, the Internet Monitor System will consider the secondary school is using the internet. Otherwise, the Internet Monitor System will count the time of inactivity and turn off the inverter after 15 minutes.

3. Battery Capacity Monitor System

Most chemical batteries have an output voltage range which is linked to the battery power capacity. Therefore, a circuit program which converts the battery voltage output to the percentage level will be used to monitor the battery power.

After the information is observed and passed through the Arduino and GSM shield system, an e-mail which contains the battery power level will be sent to a certain website as the battery power drops every 2-5 percent.

4. Other Conceptual Designs

The GSM network has been determined to be used in our design. There was discussion about which kind of network should be used in our design. We assumed three possible methods: GSM signal, RF signal, and wire line network. Because all three methods have their own advantages and disadvantages, this problem is solved in the Proposed Design Solution section.

Proposed Design Solution

In the conceptual design, there are several challenges:

1. How to test the three basic systems introduced in the Conceptual Design part?
2. What communication method should be used in the design?
3. Is the battery monitor system really feasible?
4. What should the cut-off percentage of the battery be in order to retain the most life cycles?
5. Will our designed system consume a lot power?

After discussion, there are a few ideas to solve these problems:

1. The three systems could be tested on the bread board first
 - a) As introduced in Conceptual Design part, the Turn-on Message Request System includes one or two press buttons and an LCD. Then it is possible to build the press button on the bread board to send a signal through two GSM packages and then show the status on the LCD. If the status on the LCD is correctly shown, the system should be considered to be working properly.
 - b) The Internet Monitor system should only monitor the status of Turn-on Message Request System (TMRS). It is possible to put several LED on the bread board to show the success of the Internet Monitor system. While TMRS stays on, the LED should also be on. When the TMRS turns off, the LED should be turned off after approximately 15 minutes.
 - c) The Battery Monitor system is a data based monitor system. Two weeks of data will be stored in the GSM package. This data will be the reference for determining percentage of battery capacity. A voltage divider is needed in this system in order to proportionally transfer the 12-14V output voltage to the 4-5 volts needed to adapt the voltage limit of the GSM package. To test this system, several LEDs will compose binary numbers to show the capacity of the battery on bread board.

2. The GSM system is chosen after doing the Feasibility and Selection Solution Matrices.

Engineering Criteria	Importance	Possible Solutions for Remote Internet on Demand			
		GSM Link	Radio Link	Wireline/Fiber optics	
Communication Between Remote Locations	5	9	1	9	
Data Processing	2	3	3	3	
Minimal Power Consumption	3	3	1	9	
Internet Monitoring	3	3	3	3	
Hardware Platform	4	9	9	9	
Maturity of technology	4	3	9	9	
Stability/Safety	5	3	1	1	
Totals		132	100	164	

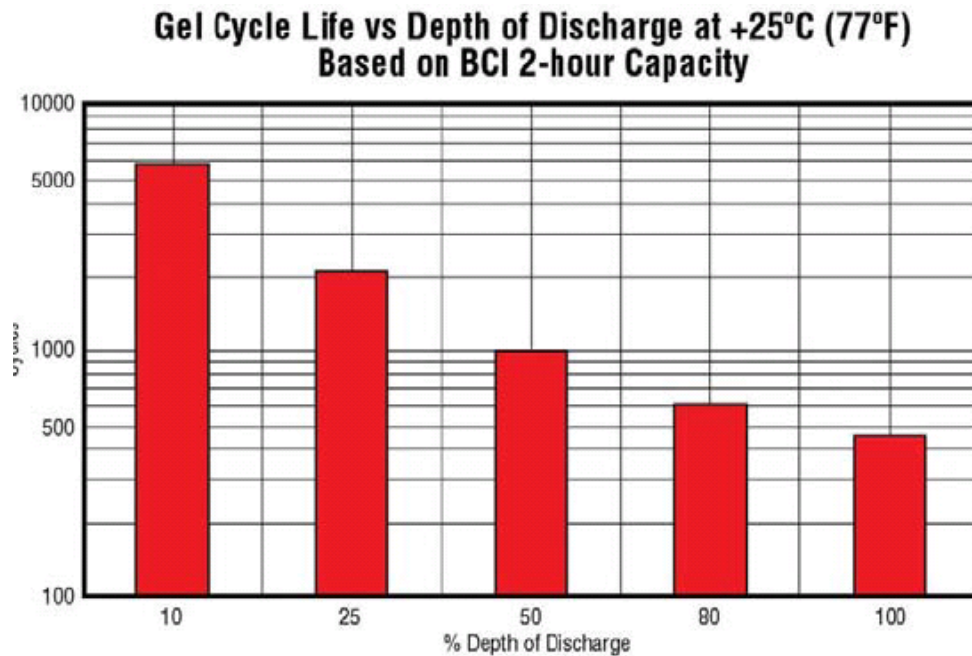
Figure 2 – Solution Selection Matrix

Feasibility	Importance	Possible Solutions for Remote Internet on Demand			
		GSM Link	Radio Link	Wireline /Fiber optics	
Cost	5	3	3	1	
Technical	4	9	9	9	
Safety/Stability	5	3	1	1	
Time	3	9	1	1	
Totals		93	59	49	

Figure 3 – Feasibility Matrix

- Although some batteries' capacity is proportional to their output voltage, it might not be viable in our system. Therefore, a power calculation system will replace the voltage monitor system because power is another possible factor which could be proportional to the battery capacity. A small value (1ohms-100ohms) resistor will be connected in series to our load. Then an Ampere meter will test the current across the resistor. Since the voltage output is fixed in time, the output power will be determined at any given moment. Comparing the data to the prior data to determine the percentage of battery capacity is a good way to determine the capacity. Additionally, in order to minimize the power consumption, a switch will be connected in parallel to the resistor. Then the resistor will only be connected in the circuit while the system is calculating the instantaneous power.

4.



From the Deka Dominator 200Ah Gel Cell data sheet shown above, turning off the battery before it reaches 90% gives the battery 5000 life cycles which means the battery could be used for about 15 years. In addition, there are five batteries in the school, each with 14.1 volt output voltage and 200 Am power. So the overall energy of the battery should be: $14.1 \times 200 \times 5 = 14100 \text{ Watthours}$. The satellite and router consume 91 Watt. For 5 hours a day, it will consume 455 Watt-hours which is 3.227% of the total battery energy. Therefore, 90% is a feasible choice for the cut-off percentage of the battery capacity.

5. The GSM Shield has 0.125 mA working current with a 5 volt input voltage. This means the GSM Shield will consume 15 Watt-hours over 24 hours. Then, assuming the GSM package will consume 100 Watt-hours over 24 hours, it is still negligible. Therefore, the power consumption is no longer a problem for our system.

Risk Analysis

When developing the design, there are many risk concerns that must be taken into consideration. These risks are brought about by many factors surrounding the project. The origins of these risks range from the power consumption of the design to environmental hazards that are prevalent at the installation location of the final product. It is vital that the design take these risks into consideration for a successful and robust final product.

Power is one of the concerns that must be taken into consideration. The location of the final product receives its power from batteries that are charged by solar panels. Other locations use intermittent power that is being conditioned. This situation leads to the risk of the product consuming too much power from the batteries. There is also the risk of the power consumption of the whole system increasing when the schools are given the ability to turn on the internet at any time. After discussion of the current power consumption of the system with the sponsor, it is seen that the addition of our product will not cause overconsumption of power. Since the objective of the product is to make the internet available on demand, an increase in power consumption by realizing this is a low concern but is still being taken into consideration so that power is still saved.

The system being designed makes use of cell phone communication for activation. This brings up the risk of other cell phones that are not part of the system calling the phone and unintentionally activating it. Such a situation would waste the purchased minutes of the phone and also create unintentional use of power. Another issue would be downtime of the cell phone service we would be using. Downtime of the cell phone service will also cause a downtime in our own system when trying to activate it since communication with it would not be possible. This has been labeled as high risk and has been taken into discussion.

The location of the product brings up many risks. One of the risks is the high possibility of mice or rats chewing through the wiring of the product. Another is the risk of the system overheating due to the temperature of the location. Both risks could lead to a shortened lifespan, instability or the ceasing of functionality of the system. Wiring is a crucial component of any system making rats a high risk factor. Considerations for robust wiring components have been taken into discussion. Until our product is implemented into the system, it will be difficult to gauge the risk that overheating and the overall environment has on the product. These are also situational risks. It is for these reasons that temperature is placed as a moderate risk.

Project Management Plan

Personnel

1. Ivan and Jeff
 - a. Arduino programming and GSM Shield Integration (2/8 – 2/20)
 - b. Develop a communications methodology for system (3/14 - 4/3)
 - i. How to handle phone calls to system
 - ii. What kind of messages to send for communications
 - c. Reporting mechanism for system health and data logging (3/5 – 3/28)
 - i. E-mail or website reporting
 - ii. Reporting to local technicians
2. Ken and Drew and Koy
 - a. Identify Battery monitoring system (2/6 – 2/19)
 - i. System integration with Arduino
 - ii. Development of a DAQ system
 - b. Design Day presentation development (4/2 -4/19)
 - c. Antenna design
 - d. Internet Signaling System (2/28 – 3/30)
 - i. Parallel development of pushbutton and infrared system

Facilities

1. Arduino microcontrollers
 - a. Ordered from online retailer
 - b. Software created or obtained online
2. GSM Shields
 - a. Ordered from online retailer
3. Battery Capacity Meter
 - a. Will be fabricated or bought
4. System internet signaling system will be fabricated
 - a. Parts ordered as functionality more strictly defined
 - b. Push button or possibly remote control/infrared

Budget

Equipment	Number	Cost/Item	Total Cost
Arduino Board	2	29.95	59.9
GSM Shields	2	99.95	199.9
Battery Meter/DAQ	1	100	100
On/Off System	1	50	50
Demonstration Equipment	1	100	100
Antenna Supplies	1	50	50
Total			559.8

References

- [1] Phasing in Technology and Communications for e-Learning in Secondary Schools in Tanzania; Erik Tarkleson et. al, 12/15/2011
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