

Design of Fault Tolerant Automated Energy Metering System using GSM/GPRS Modems

K. C. Karthika* and P. Swaminathan

School of Computing, SASTRA University, Thanjavur, Tamilnadu -613401, India; karthikakc04@gmail.com, deanpsw@sastra.edu

Abstract

Objectives: The proposed system addresses a fault tolerant technique to overcome the two major problems that are faced currently in the automated energy metering systems, used in telecom tower management. **Methods/Analysis:** It is analyzed that the effective supervision in the telecom tower sites, is currently affected due to the problem of SIM card interchange between the GSM/GPRS modems and IP connectivity failure between the GSM/GPRS modem and the server, in the automated energy metering system. **Results:** The fault tolerant technique addressed, utilizes a master GSM/GPRS modem which is capable of communicating with all the GSM/GPRS modems in the client side. Whenever the IP connectivity gets lost in any particular GSM/GPRS modem, the modem automatically sends the energy meter readings through SMS to the master GSM/GPRS modem, which in turn sends the data to the server via RS232 link. The problem of SIM card interchange in the GSM/GPRS modems is taken care by assigning an ID for each energy meter and the energy meter readings are mapped against this ID instead of mapping against the phone numbers. **Improvements:** There is not a single fault tolerant technique addressed for GSM/GPRS modems until today. These two automated solutions reduce the manual dependency and prevent most of the human prone errors. The system can further be improved by incorporating the security measures addressed for the GSM/GPRS modems and also the network failure of GSM modem (while receiving the SMS) can be addressed.

Keywords: Automated Energy Meter, Database, Fault Tolerant, GSM/GPRS Modem, IP Connectivity Failure, SIM Card

1. Introduction

The Telecom tower operators are fighting a war against electricity theft and improper measurement of individual energy consumption among the clients, from the tower sites, leading to a loss of Rs.2,200 crore every year. The only solution that has been drawn against the issue is an “effective supervision” of electricity consumption from the towers. In order to involve such an effective supervision, some of the tower operators have incorporated automated energy metering systems at the towers.

The automated energy metering system involves an energy meter, connected to the Global System for Mobile Communications/General Packet Radio Service (GSM/GPRS) modem through a Microcontroller Unit (MCU)^{1,2}. The amount of energy consumed in the tower, is transmitted to the server through the GPRS data³. Thus a continuous

monitoring of energy consumption is made available at the server, leading to an effective supervision of various towers.

Although enough monitoring techniques are being introduced, there are some faults that have not been addressed yet. These faults in turn amount to a certain level of loss. The motive of the proposed idea is to address such faults and bring about a fault tolerant system to overcome the incurring losses.

2. Existing System Architecture

The existing system involves an automated energy metering system, where the energy consumption of various towers are monitored through the server.

The energy meters measure the actual energy consumption and transmit it using a GSM/GPRS modem to the server^{4,5}.

*Author for correspondence

2.1 Faults in Existing System Architecture

Though the amount of loss incurred in tower management, is reduced to some extent by the incorporation of automated metering systems, there are few faults in the existing system architecture that in turn lead to certain loss.

The major faults that the telecom tower operators face in the existing setup are as follows:

- If the Internet Protocol (IP) connectivity of any of the GSM/GPRS modems fails, then the corresponding energy meter details are not transmitted to the server. The current practice is to manually send SMS to the particular GSM modem and retrieve data. But this involves a lot of human effort, continuous texting until the connectivity is retrieved and chances of data loss are more.
- In the current practice, the energy meter readings are mapped against the International Mobile Equipment Identity number (IMEI) and corresponding phone number in the database. If the Subscriber Identity Module (SIM) cards of any of the two GSM/GPRS modems are interchanged accidentally, then the corresponding energy meter readings are not mapped against the respective IMEI number and phone number, resulting in wrong updation of details.
- The above two issues occur integrated under some circumstances, resulting in wrong data fetching.

3. Proposed System Architecture

The idea behind the proposed system architecture is to design a fault tolerant system that overcomes the above fault scenarios.

3.1 The Main Components of the Proposed System Architecture are:

- Energy meter setup as shown in Figure 1, to measure the energy consumption of any given load and display it in the Liquid Crystal Display (LCD) unit⁵.
 - A SIM 900 GSM/GPRS modem, attached to each energy meter, to transmit the measured energy to the server.
 - A Master SIM 900 GSM/GPRS modem, to serve as back up for any of the IP connectivity failed modems.
 - A server, to collect the details of transmitted energy consumption.
 - A web based application (Browser), to enable visualization of energy consumption details.
- System architecture is shown in Figure 2.

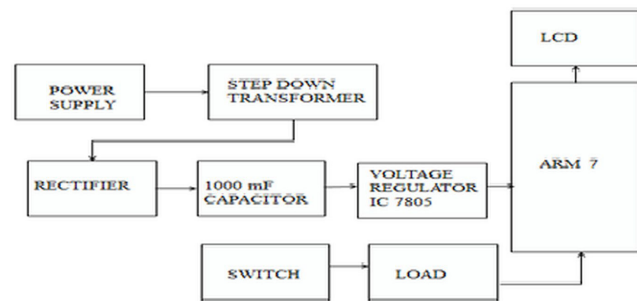


Figure 1. Design of automated energy meter.

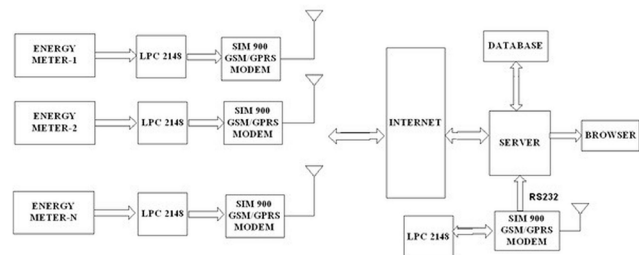


Figure 2. System architecture of fault tolerant automated energy metering system.

3.2 During IP Connectivity Failure

3.2.1 Main Flow

On switching on the load, the energy meter starts reading the electricity consumed and is transmitted via input/output ports of the controller to the GSM/GPRS modem.

The GSM/GPRS modem sends the following commands respectively, to connect to the server and post the energy meter readings to server^{6,7}.

```
AT+CIPSTART="TCP", "WWW.SERVERNAME.COM", "80"
```

```
AT+CIPSTART="TCP", "WWW.SERVERNAME.COM", "80"
```

```
13 (ASCII value for enter command)
```

```
AT+CIPSEND
```

```
13 (ASCII value for enter command)
```

```
POST "SERVERNAME", "Energy meter readings" (HTTP request methods to post data to server)
```

```
26 (ASCII value for ctrl+z)
```

The Server in turn runs the Hyper Text Transfer Protocol (HTTP) request and updates the Database. On successful updation of database, the server returns '0' to the GSM/GPRS modem, for acknowledgement.

3.2.2 Alternate Flow

In case of network failure, the server timeout is exhibited after 30 seconds of executing the above commands.

Thus the GSM part of the GSM/GPRS modem gets activated and executes the following commands respectively, in order to send the energy meter readings to the Master GSM/GPRS modem⁸⁻¹⁰:

```
AT+CMGF = 1
13 (ASCII value for enter command)
AT+CMGS = "Mobile number"
13 (ASCII value for enter command)
Energy meter readings
26 (ASCII value for ctrl+z)
```

On receiving the SMS from the GSM/GPRS modem, the Master GSM/GPRS modem stores the data in the microcontroller. The microcontroller reads the SMS using the command, "AT+CMGR = 1,1" and transmits the energy meter reading to the server using RS232 link. Usage of RS232 link instead of GPRS network is due to prevention of network failure at this end.

3.3 SIM Card Interchange Application

The SIM card interchange problem is overcome by allocating each energy meter an ID, such that the energy meter readings are mapped against this ID (instead of phone number) as shown in Table 1, which due to hard coding can never be changed and also has no impact even if the SIM cards are interchanged.

The IMEI number of the GSM/GPRS modem is first fetched using the command, "AT+GSN". IDs are hard coded to each energy meter and are mapped to the fetched IMEI number. Now, the Energy meter readings sent to the server is mapped against this IMEI number and Energy meter ID, such that any SIM card interchange will not affect the readings entered in the database.

3.4 During Occurrence of Integrated Issues

Based on the above two solutions, the occurrence of integrated issue can be solved as follows.

Table 1. Database before & after SIM card interchange

IMEI Number	Energy meter ID	Energy meter units (kWh)
X	1	8
Y	2	4

Consider two GSM/GPRS modems with IMEI be X, Y and their corresponding energy meter IDs be 1, 2. The incoming energy meter readings are mapped across the respective IMEI number and energy meter ID as shown in Table 2.

Assume that there is an accidental interchange of SIM cards between the two modems. Even then the database remains as Table 2, shown in Table 3, as there is no mapping of readings based on the phone numbers.

Now assume that there is network failure in modem 'X'. As per the above solution, the modem 'X' sends the readings it collected from energy meter '1' to the master GSM/GPRS modem, which in turn updates the server database through RS232 link. Here, the operator need not send any SMS to the failed modem to fetch its details, as the entire process is taken care automatically by master GSM/GPRS modem. Thus the dependency on phone number by the operator is also overcome.

4. Experimental Setup

The Experimental setup is shown in Figure 3.

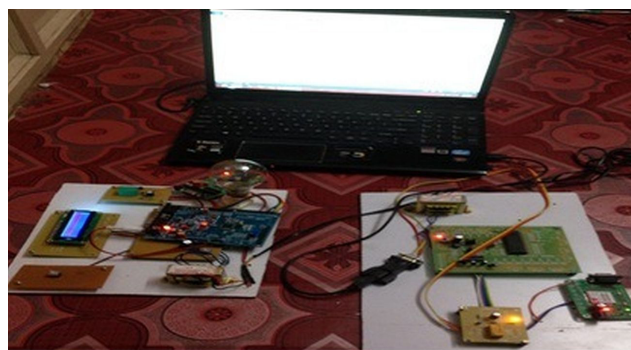


Figure 3. Experimental setup of Fault tolerant automated energy metering system.

Table 2. Database before SIM card interchange

IMEI Number	Energy meter ID	Energy meter units (kWh)
X	1	8
Y	2	4

Table 3. Database after SIM card interchange

IMEI Number	Energy meter ID	Energy meter units(kWh)
X	1	8
Y	2	4

5. Flowchart

5.1 IP Connectivity Failure Application

The flowchart of fault tolerant automated energy metering system during IP connectivity failure is shown in Figure 4.

5.2 SIM Card Interchange Application

The flowchart of fault tolerant automated energy metering system during SIM card interchange is shown in Figure 5.

6. Results and Evaluation

The Energy meter readings are successfully captured and monitored at the server side: i) by running HTTP request method posted from GPRS modem during network availability and ii) by transmitting SMS data from Master GSM/GPRS modem to server using RS232 link during network failure.

The Energy meters have been assigned each with an ID and were mapped to the energy meter readings instead of phone numbers, preventing wrong updation in the database.

The server output of the above diagnostics is shown in Figure 6.

7. Conclusion

The existing system architecture in telecom tower management requires an effective supervision of energy consumption, in order to overcome the incurred loss.

The proposed fault tolerant system is capable of providing effective supervision by overcoming the faults that are commonly occurring in the existing architecture.

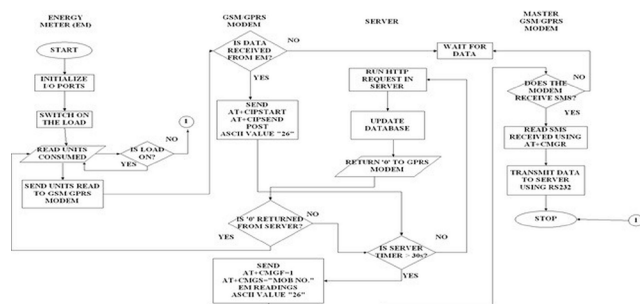


Figure 4. Flowchart of fault tolerant automated energy metering system - IP connectivity failure application.

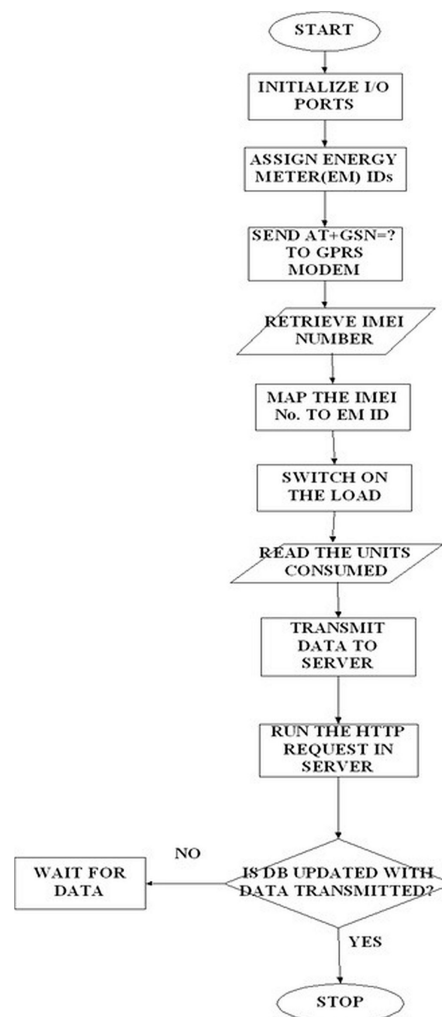


Figure 5. Flow chart of fault tolerant automated energy metering system - SIM card interchange application.

EnergyMeter	IMEI	Units
101-121	911328154822517	3
101-121	911328154822525	5
101-121	911328154822517	7
101-121	911328154822525	9
101-121	911328154822517	3
101-121	911328154822525	5
101-121	911328154822517	7
101-121	911328154822525	9
101-121	911328154822517	3
101-121	911328154822525	5
101-121	911328154822517	7
101-121	911328154822525	9

Figure 6. Server output of fault tolerant automated energy metering system.

Thus the challenges faced by the telecom tower management are overcome to certain level, reducing the amount of loss incurred.

Open issue that has to be addressed is the network failure of the master GSM modem (to receive the SMS sent from the other GSM/GPRS modems), in order to bring out a much more effective fault tolerant system. Future work can also include the investigation of security issues in the GSM/GPRS modems and the ways to overcome them.

8. References

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