A Connectivity Sub-System to Enhance Existence of Internet of Things in Remote Areas of Sri Lanka by using Wireless Communication Interface

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ABSTRACT

The Internet of Things (IoT) is at the peak among emerging technologies and also a highly interested area of study from recent past. The devices connected in next five years' time are expected to be billions. The research study and implementation concerned here has based on IoT and expects to cater remote areas of Sri Lanka which are isolated and far away from contributing above mentioned milestone of IoT existence in year 2020 due to the mobile internet infrastructure limitations and wired network infrastructure infeasibility. The methodology selected for proposed solution is experimental and started by studying the typical IoT system architecture and then it has extended for an alternative connectivity sub-system using Wireless Ad-hoc Network (WANET) to exchange low band width data. Therefore Global System for Mobile communication (GSM) 2nd generation (2G) is used as it's better coverage throughout the country for the long distance component of the solution considering major service providers uneven GSM 3rd generation (3G) coverage for internet usage. Also an ad-hoc network is considered for the short distance component where mobility is required. Finally the end user experience has evaluated.

Keywords - IoT, WANET, Ad-hoc Network, GSM, RF

1.0 INTRODUCTION

During a general study of information exploration to update knowledge and to find out where technology is at present, it was recognized that the Internet of Things (IoT) has been at top of the Gartner's Hype Cycle as the most hyped emerging technology as at July 2014 [1]. Furthermore IoT has many potential advantages for further studies as well as research work.

The involvement of information & technology both in contrast with other emerging technologies in the competition as well as high prospects of new additions to existing knowledge is important.

Therefore it has been one of the best areas for current research study in Information Technology.

According to [2], "The IoT has been defined as the network of physical objects or 'thing' embedded with electronics, software, sensors and connectivity to enable it to achieve greater value and service by exchanging data with the manufacturer, operator and/or other connected devices. Each thing is uniquely identifiable through its embedded computing system but is able to interoperate within the existing Internet infrastructure".

As described above, the IoT consist of specific major components & unique characteristics as identified at the starting point of this work.

They are,

a. Electronics (Hardware)
b. Software
c. Sensors / Actuators
d. Connectivity
e. Exchanging Data
f. Existing Internet Infrastructure

2.0 RESEARCH PROBLEM

A significant gap was found in the background of implementation of IoT in Sri Lankan remote areas. Wired internet infrastructure cannot be expected in almost all remote areas due to geographical constraints in Sri Lanka as well as according to the particular requirements wired networks are not perfectly matched.

The leading mobile telephone service providers in Sri Lanka considered with this particular context are,

Mobitel [3] - The national mobile telephone service provider

Dialog [4] - A private mobile telephone service provider

Etisalat [5] - A private mobile telephone service provider

AirTel [6] - A private mobile telephone service provider

The main drawback identified as common to all above mobile telephone service providers are their coverage area of mobile broadband through GSM 3G/3.5G is not sufficient to reach most of the places within the country with reference to [3],[4],[5] & [6]. However, during extensive study it was revealed that respective GSM 2G network coverage of all above main mobile service providers is satisfactory. As it is not practical to send the entire sensor network data of IoT through wired technologies for a long distance wherever internet infrastructure is available, there should be a way to send sensor network data of IoT by using some other trusted third party network and 2G seems capable within the scope for certain extent.

The research question formulated accordingly was as follows,

"How to implement a connectivity method as alternative to existing coverage limited mobile internet infrastructure to enhance IoT existence of remote areas in Sri Lanka where use of wired network for internet is practically infeasible".

3.0 LITERATURE REVIEW

As found in following investigates, all of the research studies have considered to a certain extent about an implementation at the end to present the final outcome and their components and characteristics also were same or quite similar to the major components and characteristics of IoT.

The research study [7] explores a remote monitoring and control system for WSN through existing internet infrastructure using Ethernet. In addition to that the significant part of this work is the GSM connectivity to monitor & control the system using mobile phone.

As per the research question considered in this work, an alternative method was used instead of existing internet infrastructure. The technology used for this is GSM 2G and after creating the connectivity sub-system model, as an additional facility there is an opportunity to use even dumb mobile phones also to monitor and control the system using same GSM connectivity.

This particular work is quite similar to the idea on above research to connect through GSM to monitor and control. Therefore the above research study review was vital in the implementation of mobile phone connectivity sub facility.

The investigation [8] discovers another remote monitoring and control system for home with Android smart phone. This implementation also uses existing internet infrastructure and the significance is the control interface developed for Android mobile devices which are widely used at present and readily available almost everywhere to connect with IoT environment. In case of unavailability of internet the system would be unusable.

There was an extensive range of information in terms of developing an IoT environment using the Arduino microcontroller with internet shield,

which are the same hardware proposed in this research also. Therefore apart from the Android interface other IoT implementation work explained and found during the review was very useful.

According to the study [9] A Home / Office automation system has been implemented with wireless technologies and they are ZigBee, GSM & RFID. The ZigBee has been used for remote data communication to open & close doors only if RFID authenticates a legitimate user for the system while GSM also provides same functionality as ZigBee to open & close doors remotely.

Through GSM the above mentioned system sends or receives SMS respectively to trigger an actuator or acquire data from a sensor. This is a similar sensor network demarcated in the proposed system as well. The review on above literature was comprehensively related with the back end sensor / actuator network in the proposed IoT environment which is immaterial whether to use existing internet infrastructure or else the proposed alternative connectivity sub-system. Therefore the above research work also was vital in planning the back end network of proposed system almost perfectly, with the help of knowledge described there.

The research work [10] comprises another implementation of security monitoring and control system with ZigBee & GSM. In the relevant literature use of GSM AT commands has been discussed extensively.

In the proposed alternative connectivity sub-system GSM 2G is used as the technology and AT commands are used as method of instruction for GSM interfaces at front end as well as back end to take forward the data signals from sensors to third party GSM network for long distance duplex communication and extract from it at front end to use with conventional IoT control and monitoring devices connected to existing internet infrastructure. The vice-versa of this process also was applied when front end send data to actuators at the back end. Thus a both way / duplex communication method establishes within the proposed implementation for long distance.

Another application of Home Security described on [11] exposes WSN & GSM based implementation of IoT. In addition to use of AT commands as instructions there is a method of initiating voice calls through GSM for the purpose of security alert. It is advancement of conventional opinion as the system is capable of use both SMS and Voice facilities on GSM service.

From the knowledge acquired, it explores wide area of thinking and there would be potential improvements to the proposed implementation based on research question but not considered at this level due to restrictions on already defined scope of work.

The research study [12] discovers data from multi sensors with system architecture consists of Arduino & XBee. Similarly this work also includes sensors as well as actuators for both way data transfer and the transmission interface is powered by XBee. The significance of the implementation is rather than only monitoring the data received at any instance they are recorded in a cloud database also.

Arduino is the Micro Controller open source hardware used for the proposed research implementation also.

The study on [13] argues the effective use of IP, ZigBee and Arduino for IoT. The significance of this work is the introduction of a middleware which uses RESTful API via IP in addition to the typical infrastructure such as sensors / actuators, master & slave controllers and application on an appropriate device. There is a LAMP server running on the master controller PC with Linux. The requests to the server are sent through http URL and responses are received by lightweight data-interchange formatted string of JSON. An effort of having persistent data was observed from this research review similar to which found in previous. But the second one has some advanced features such as running a LAMP server on a Linux PC.

The system implementation on research [14] is again a remote monitoring and control system with both GSM and Bluetooth connectivity. In this application GSM has been used for long distances where Bluetooth has been used for short length of few meters around 10 - 100m.

As explained in some previous applications SMS based system has used there for data exchange through GSM. Even though Bluetooth covers only a short distance it is capable of exchanging data at around a 3Mbps speed. For proposed solution simple SMS data exchange on 2G GSM network was used and therefore high bandwidth communication with technologies such as Bluetooth can be used in future and it was valuable to gain knowledge on such during the particular review.

Another application on [15] exposes WSN & GSM based environmental monitoring system. Apart from the usual WSN and GSM setup there was significance and which is using Dual Tone Multi Frequency (DTMF) signals to send and receive commands. As described with DTMF various techniques learnt during the review is invaluable.

Furthermore most of the above systems studied were limited or isolated to precise area on the network probably with an intranet and the reason behind that also to be the problem identified in this research. Which is restricted mobile internet infrastructure and use of wired network for internet is practically infeasible in some applications. Therefore for particular applications, their scope of work had been set accordingly with limitations.

4.0 RESEARCH SOLUTION

The Typical IoT architecture components are shown in Fig 1.

With the connectivity subsystem in the solution, changes proposed for each corresponding component are given below.

A. Sensor / Actuator Network

Need to reconfigure as nodes of ad-hoc network (Back-end)

B. Sensor / Actuator & Public Network Interface

Replace with new connectivity sub-system interface

C. Public Network (Existing Internet Infrastructure - Ethernet)

Replace with new ad-hoc network and GSM 2G network combination

D. IoT Server (Ethernet)

Replace with new IoT server compatible with GSM 2G data send / receive in addition to Ethernet

E. End User Devices

Almost remain unchanged and compatible with existing environment (Front-end) and new addition is an interface to interact with Back-end by mobile telephone devices which does not have internet connectivity.

The main objective of this research work was to build an alternative connectivity sub-system model with wireless ad- hoc network and GSM 2G network combination for IoT implementation which supports for rural areas in Sri Lanka where use of wired network for internet is practically infeasible. The Proposed Alternative Connectivity Sub-system is shown in Fig 2.

5.0 METHODOLOGY

The method selected for this particular research was Experimental which has been mostly appropriate with the context. Experimental method involves standard practice of manipulating quantitative, independent variables to statistically analyzable data. The data was gathered by using an automated sampling done within the Microcontrollers to select finite number of data from infinite data space. The main objective of this research work was to build an alternative connectivity sub-system model.

6.0 IMPLEMENTATION

The initial requirement of implementation was to make a prototype to reflect functionalities of proposed solution based on the design illustrated on Fig 3 & Fig 4.

The implementation was realised with 4 modules built from the scratch according to a unique design which was part of the solution. The Typical IoT was represented by Module #1 shown in Fig 3. The proposed solution is represented by Module #2,3 & 4 collectively as shown in Fig 4.

In Module #1 operation the temperature data generated from LM35 temperature sensor with regular intervals and forward them to the EEPROM of the Microcontroller for persistence. The EEPROM slots read by the Microcontroller again and pass the data to basic HTML page which runs on a simple web server available within the same Microcontroller itself.

The wired configuration of particular module represents the typical IoT setup. In proposed solution representation Module #2, the temperature data generated from LM35 temperature sensor with regular intervals and forward them to the EEPROM of the Microcontroller for persistence similar to Module #1. In contrast Module #2 send particular data read from EEPROM to RF transmitter operates on 433MHz to forward the data in WANET.

Then Module #3 receives the data through RF and again pass to EEPROM. If the RF signal is not within the range the mobile device is used to capture data on close proximity by moving the Module #3 mounted on top of a Robot car.

Thereafter the data read from EEPROM is concatenated to a single SMS consist of 30 temperature data values as well as error count at the beginning of the stream. This particular SMS is then received by Module #4 and it passes extracted data to basic HTML page which runs on a simple web server runs within the Microcontroller to represent identical operation as done in Module #1.

The next section consist of in detail explanation about automated data collection and analysis done.

7.0 RESEARCH DATA

Serial #	Time Interval (Seconds)	Temperature Reading (°C)
1	6	28
2	12	27
3	18	28
4	24	27
5	30	27

Table 1. Data collected from Module #1, 2 & 3

7.1 Data Samples

The raw data samples obtained at Module 1, 2 & 3 are tabulated as mentioned in Table 1. A data sample obtained at Module #4 with 30 value data stream is tabulated as mentioned in Table 2.

7.2 Statistical Analysis

The relevant descriptive plots created as outcome of Statistical Analysis are shown below. They are Bar Chart as shown in Fig 5, Histogram as shown in Fig 6. and Line Plot as shown in Fig 7.

Serial #	Time Interval (Minutes)	Temperature Reading (°C)					
5	15	27	28	27	27	27	26
		27	27	27	28	27	28
		27	27	27	26	27	27
		27	28	27	28	27	27
		27	26	27	27	27	88

Table 2 . Data collected from Module #4

The all descriptive plots clearly reflect outlier data which are unusual to the expected dataset. Therefore this analysis is helpful in validating the précised data sets by avoiding unrealistic representations. Then the data collected was compared with and without outlier data to explain the effect on such consequence when using automated data sampling methods.

8.0 SIGNIFICANCE

The importance of this research study is not only the solution provided for the specified problem.

Maintaining following characteristics also significant. They are,

8.1 Low Bandwidth

The temperature sensor data transmitted through RF as a character array within bytes range. At the time of receiving data also similar and to achieve the requirement of data persistence there was no effort on finding additional data storage or high end database etc. Instead the byte range EEPROM of the Microcontroller itself was used for simplicity. The data received through RF is first written to EEPROM and then read back before concatenating the data to a less than 160 characters, which is a constrain of the technology itself. When sending through SMS also the 30 value block comprises in to single SMS length.

8.2 Low Power

At the time of designing the prototype also the low current draw was considered as a requirement to achieve less power consumption in view of saving battery power for long run.

The DC Voltage (in volts) & Current (in ampere) measurements of each module during operation are shown in Fig 8. The Module #1 having Arduino Ethernet shield for sensor data presentation through HTML draws a current of about 160mA in typical IoT scenario. For proposed system, Module #2 with RF transmitter consumes only 20mA due to high voltage of 12V uses to operate TX device itself while all other modules having devices with operating voltage of 5V even though the supply voltage usually operates at around 13V. The Module #3 having Arduino GSM shield draws a current of 110mA. For Module #4 it was around 270mA ween operates both Arduino Ethernet & GSM shields and the value is almost same as the sum of having Arduino GSM Shield or Ethernet shield alone. (i.e. with both shields draws a current of 270mA which is the sum of 160 & 110mA)

8.3 Low Cost

The budgeted cost for the entire system was Sri Lankan Rs.43,000. It consists of diagnosing facilities at each module etc. in testing environment. Therefore for a complete working system's cost with one node would be around Rs.30,000 to 40,000. For adding a sensor node to the system with slightly modified design, per node cost would be less than Rs.5000. Therefore as a low cost solution for similar problem in implementing IoT system in the country this would be an affordable alternative for small scale and entry level industries. Also the proposed work is a connectivity sub-system which can be applied to many subject areas throughout the country by connecting even from different parts of the world without the burden of having dedicated data connection at higher cost including maintenance etc.

9.0 DISCUSSION

As an overall evaluation it is to be expressed that the system implementation and data generated through it was successful in all 4 Modules #1, 2, 3 & 4. The technology used is not problematic but the design needs some improvements to have an acceptable rate in stability, reliability and consistency factors.

10.0 FUTURE DIRECTIONS

A design improvement to be done to ensure a high degree of stability, reliability and consistency on data extracting after receiving the SMS. Other recommendations for future works are as follows.

At final presentation of data on a basic HTML webpage through Microcontroller Web Server can be improved by adding cloud based graphical representations. There are many options for such and Windows Azure services, Embrio, Temboo, Xively, Thing Speak & Plotly are examples.

11.0 CONCLUSIONS

The expected low bandwidth, low power & low cost, IoT solution for rural areas in Sri Lanka as a duplex communication method for device monitoring and control was observed as a successful contribution in the domain of IoT. When rest of the world is in a clear vision of expectation to have billions of IoT devices in year 2020, the Sri Lanka's capability with this kind of implementations through extensive research study

to contribute the same is also a substantial achievement in the aspect of development of technology in the country to the next level.

12.0 ACKNOWLEDGEMENTS

It's my pleasure to express sincere gratitude and appreciations to Mr.P.Lakmal Rupasinghe for guidance as a co-author throughout the task and Mr.Prasanna S. Haddela for his coordination for the Project. Also to the lecturer of Research Methods Dr.Samantha Thelijjagoda for his directions towards this, Mr.Anuradha Jayakody and all other lecturers who were behind the long journey of Masters research studies at Sri Lanka Institute of Information Technology (SLIIT).

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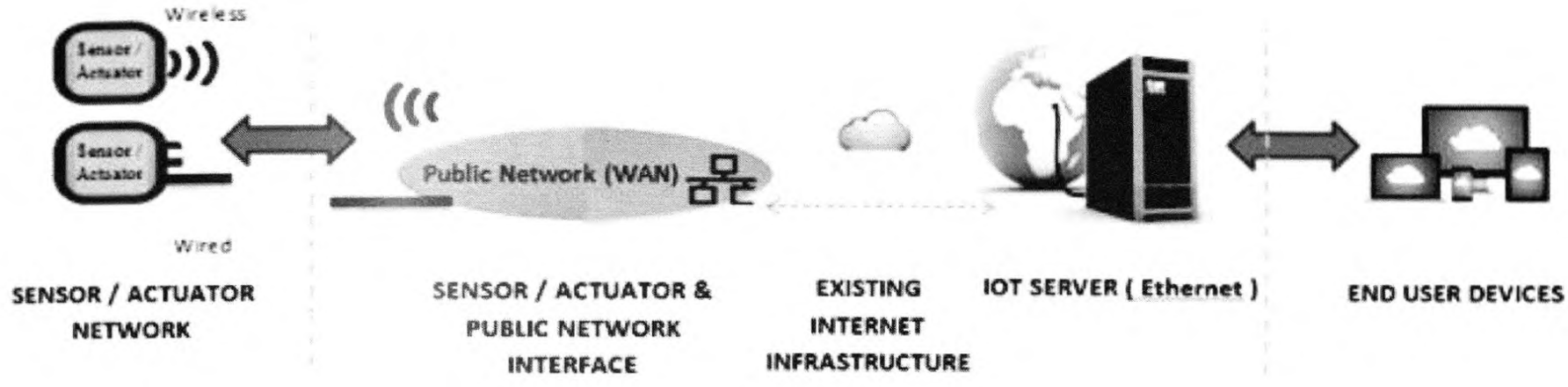

Fig 1 : The Typical IoT Architecture

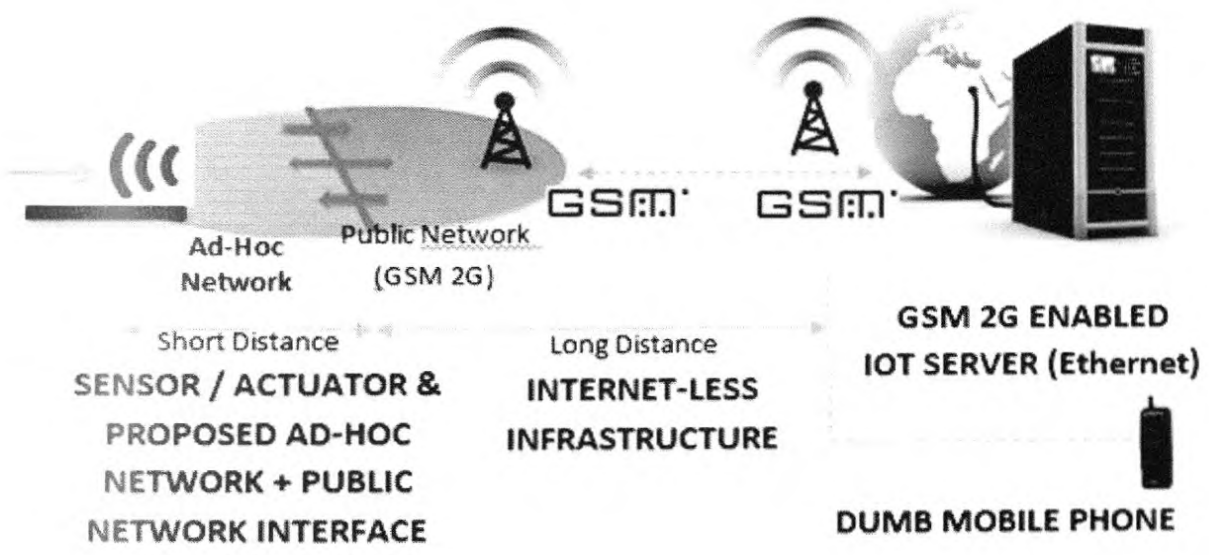

Fig 2 : Proposed Alternative Connectivity Sub-system

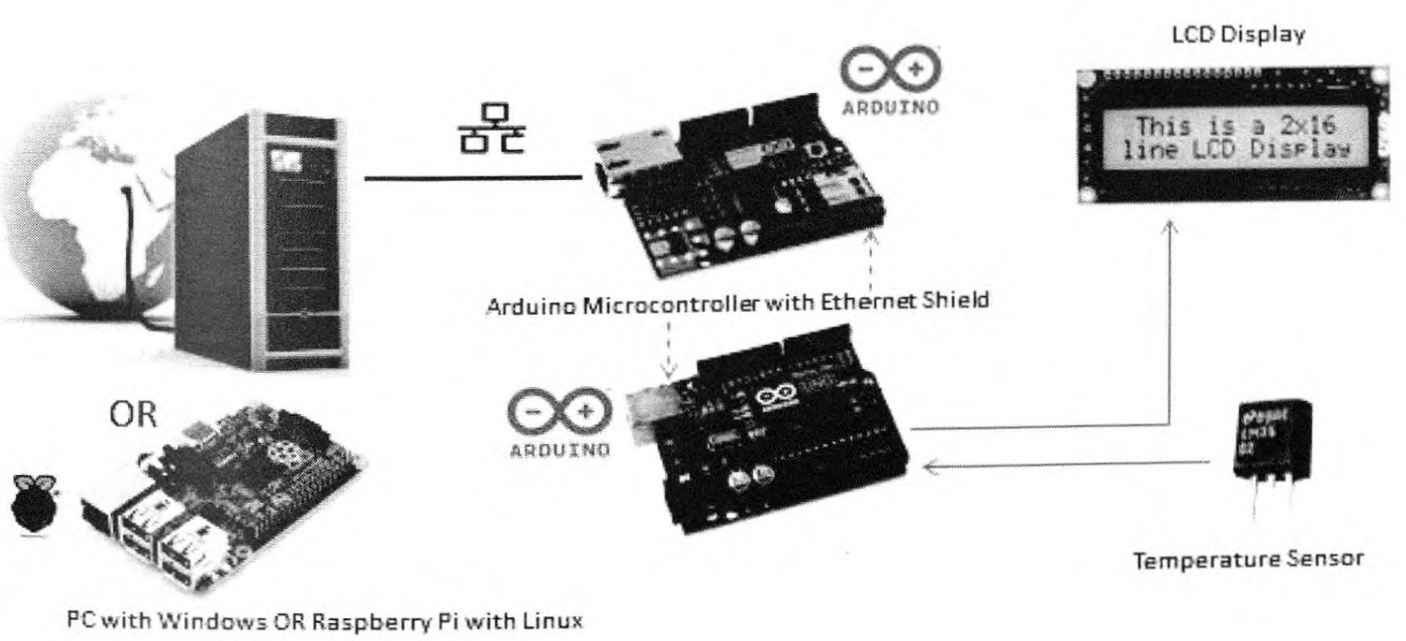

Fig 3 : The Typical IoT Implementation

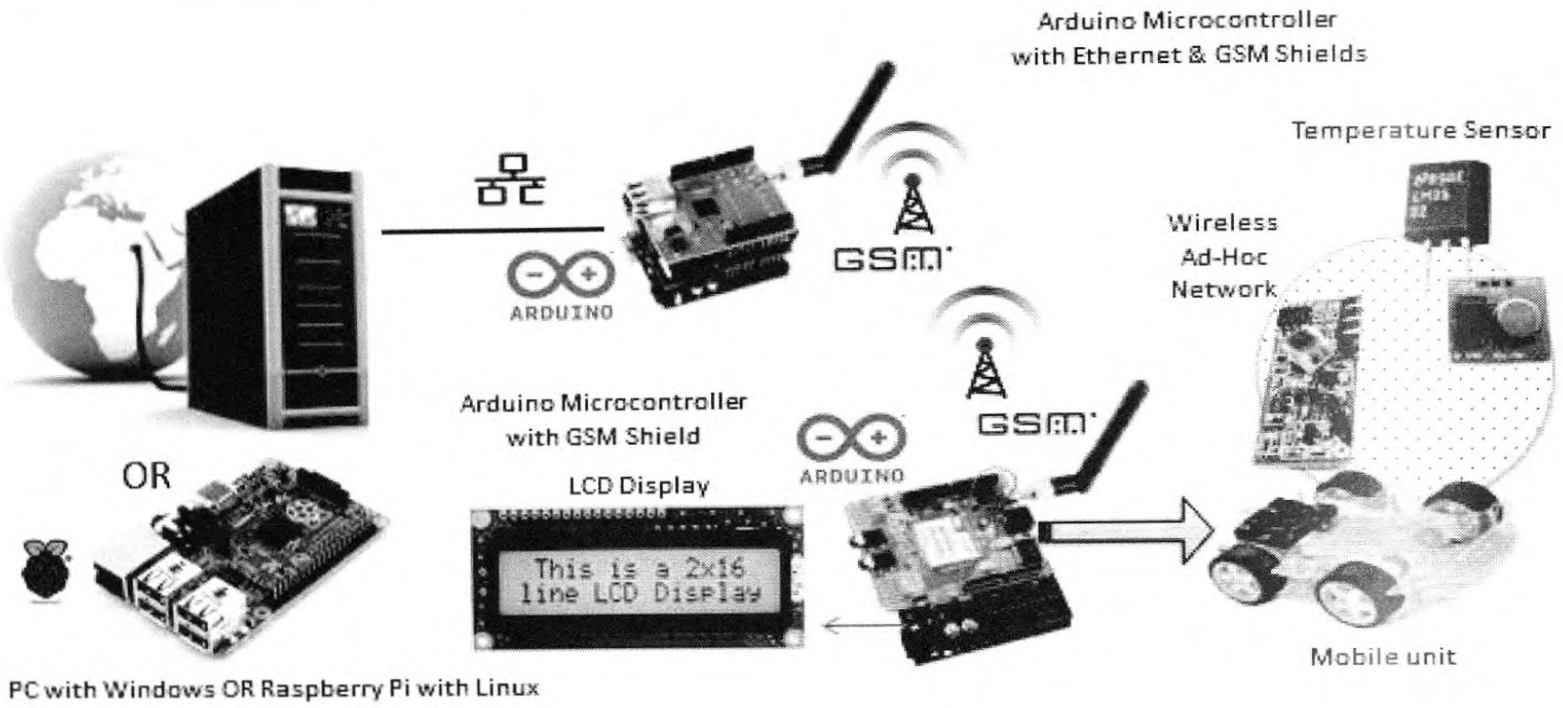

Fig 4 : The Proposed Solution Implementation

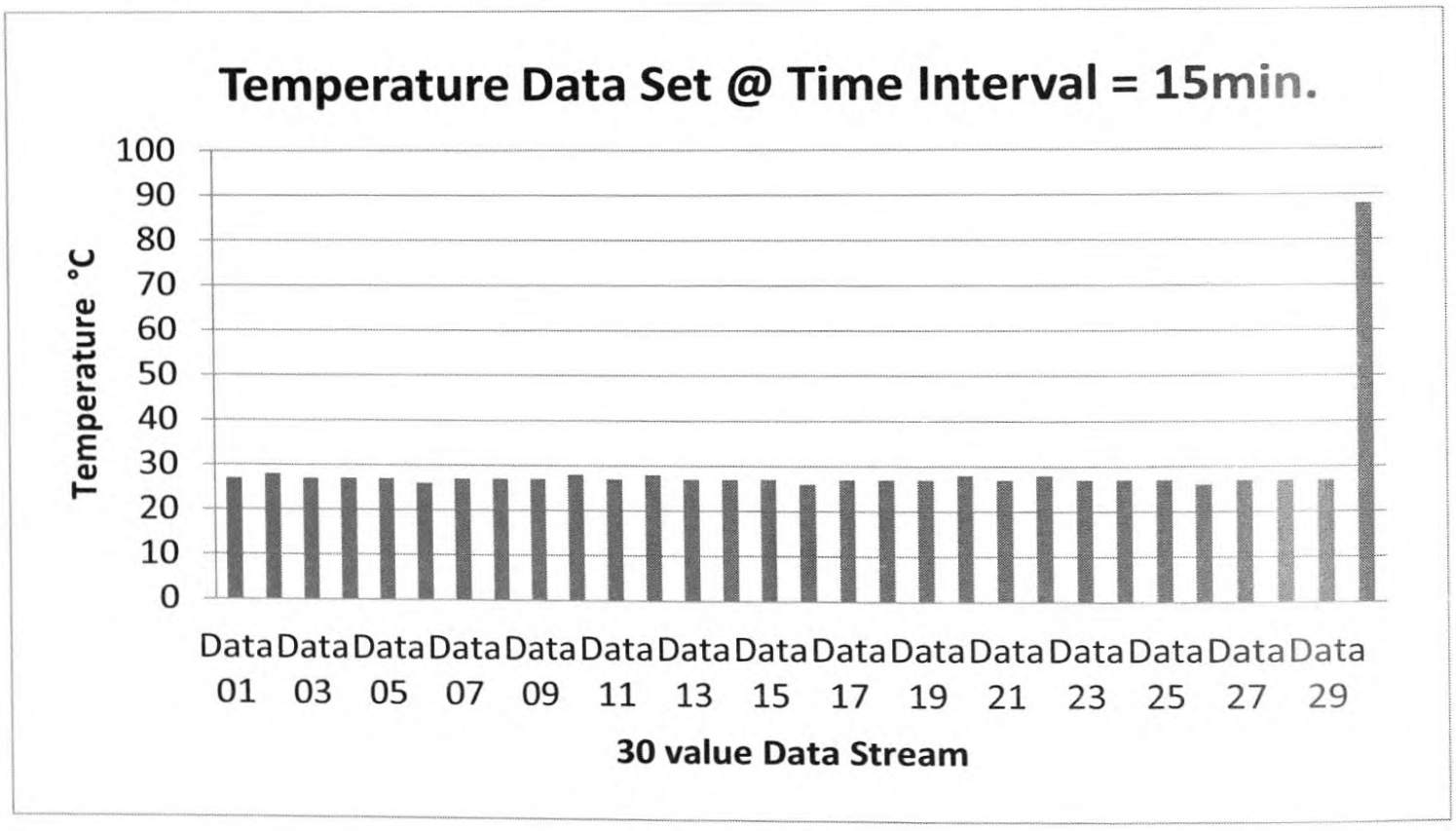

Fig 5 : Bar Chart

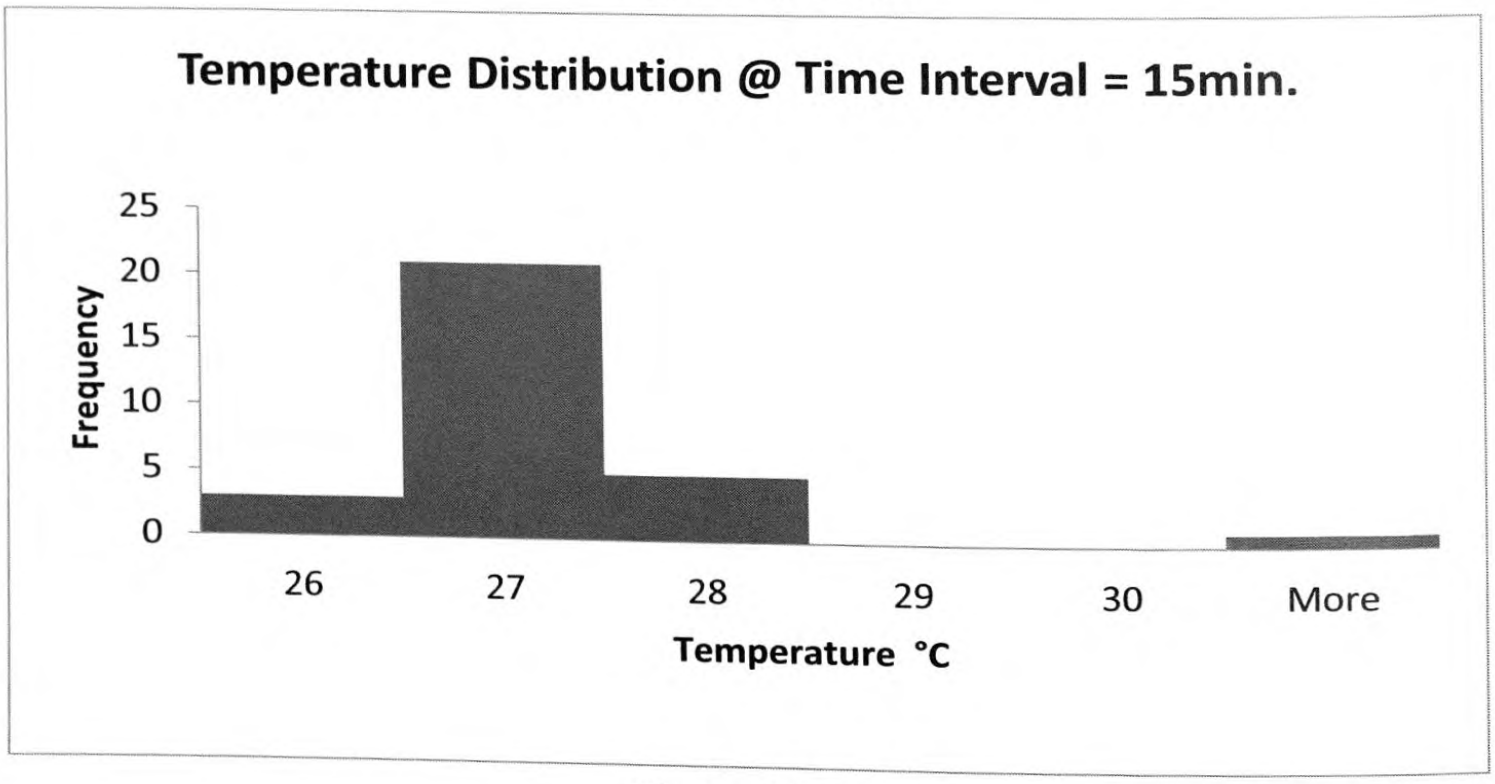

Fig 6 : Histogram

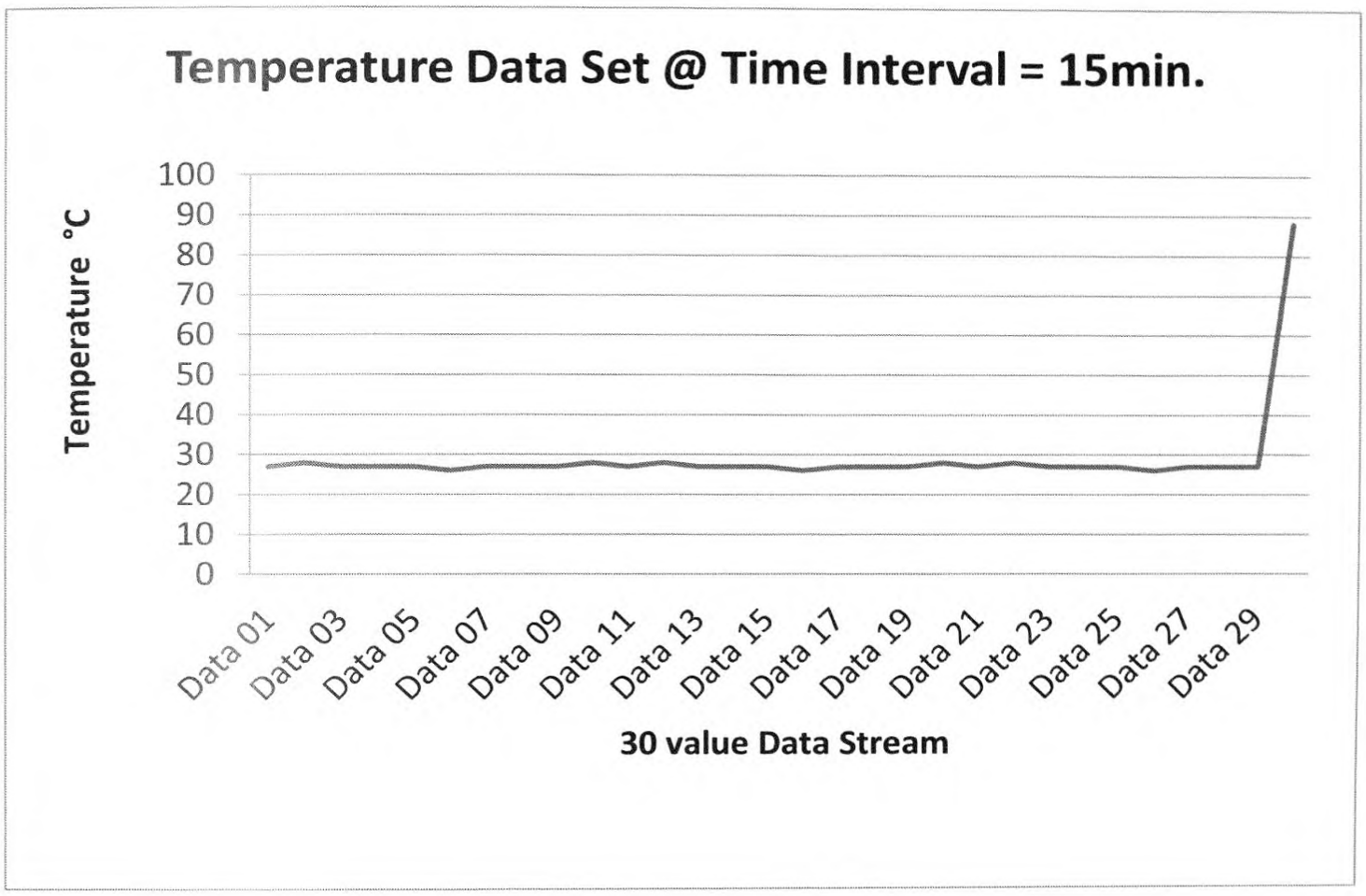

Fig 7 : Line Plot

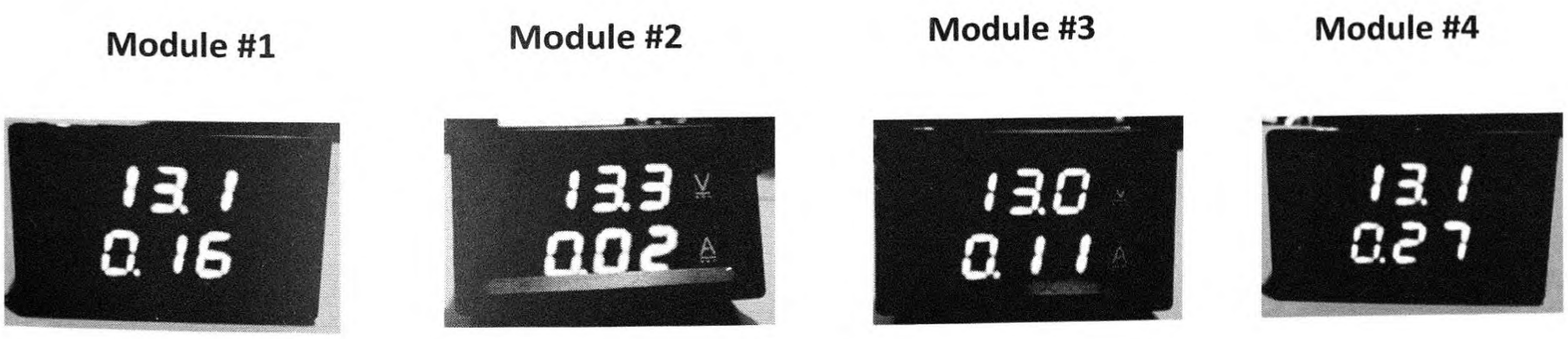

Fig 8 : DC Voltage (in volts) & Current (in ampere) measurements of each module