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IoT - Enabled Smart Huts for Sustainable Development

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Abstract **- Large scale urbanization has been a growing trend in the recent years with cities becoming the development centres, yet the rural economy still plays a major role in the overall development of any country. In a recent survey, nearly 69 percent of India's population lives in its villages, accounting for nearly 50% of the GDP of the nation. These rural areas range from being small settlements with less than 500 people to small towns. Similar scenarios exist in western countries also. In spite of their contribution to the economy, the smaller villages tend to receive less in the way of infrastructural investment. The key issues faced in these small villages revolve around a lack of reliable public transport system, emergency services and inadequate information about government subsidies for rural areas. Our idea is to extend the concept of Smart Cities to Smart Villages by utilizing recent technological developments and pay closer attention to the problems in these rural areas. Our solution in this paper is to introduce IoT technology to Huts in Villages through a straightforward demonstration of network of connected sensors and devices for information dissemination, managing energy usage and ensuring safety of the infrastructure. This enables us to address the basic requirements of domestic villagers.**

Keywords - Smart Village, IoT, Information dissemination, LORA, Smart Huts

I. INTRODUCTION

The development of smart cities and smart villages has garnered considerable attention in recent years for IT communities. With ubiquitous internet access through broadband and mobile internet, big data analytics and machine learning, IoT applications present opportunities remotely manage and control simple devices based on the real time data they provide. These devices are improving the infrastructure and how effectively this infrastructure can be used in cities like managing traffic lights, transportation, waste management, data management etc. for sustainable development. These services are relatively inexpensive to implement and should not be limited to implementations only in urban areas.

Currently implemented smart village initiatives largely concentrate on providing alternative sources of energy for villages and establish connectivity in these villages. The scope of smart villages needs to be broadened into managing the public distributions system, transportation, information dissemination etc. while using the existing infrastructure put in place for solar energy and connectivity. Our proposed solution looks at the implementation of smart villages from a micro level and aims to empower each household in the region. To make the village smarter, this proposal consists of solar powered huts with required sensors collectively called as Smart Huts. In this the Internet of Things and Machine-to-Machine communication plays a vital role in automatic functioning of devices in the huts. The architecture also consists of fire and smoke detection sensors which help in early detection of fire and ensuring safety of the people in the huts. For information distribution, the architecture consists of an LCD display which shows the availability of commodities in public distribution system, transport details and information about other important government schemes etc. With the help of communication module, the sensor data and other information can be sent to a common gateway and then stored in the village cloud. The huts act as peer-to-peer communication media, so the entire village can be benefited with the proposed architecture as shown in Fig 1.

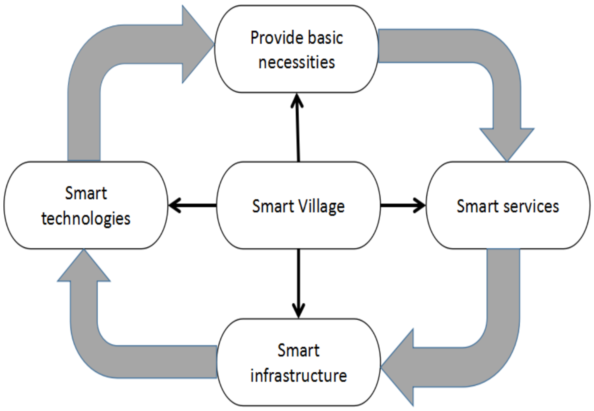

Fig 1. Proposed Architecture

In the Indian context, villages are the heart of the nation. A Smart Village means it should have access to sustainable energy services which helps in the development of the village. It should provide good education, healthcare, access to clean water and other necessities for the people in the rural areas. It should also provide security and safe living. The Smart Village concept described in this paper engages in efforts to combat the real barriers to energy access in villages, particularly in developing countries with technological, financial and educational approach. The Government of India through its "Digital India" initiative aims to connect 2.5 lack villages to the internet by 2019 and bring internet access through Wi-Fi to more than 2.5 lack schools, universities and public places. Many other initiatives such as Make in India, Start-up India, Smart cities, Smart Villages, which promote the development of the society on a larger scale. These initiatives collectively set up the opportunity for an IoT revolution of sorts in the country. This paper focuses on helping the poor people in villages and making their lives easier as well as providing them an opportunity to be part of a technological revolution.

II. RELATED WORKS

In a way, Mahatma Gandhi, father of the Indian Nation was the first to conceptualize Smart Villages. But even after seven decades, we are nowhere near realizing Gandhiji's vision of developing villages [1]. Almost 70 percent of India lives in villages where the social and economic conditions are sub-optimal. The country has often been touted as an emerging superpower even though most rural Indians fall in poor category. So, to provide a better living for the rural people, it is necessary to empower villages through technology and recent trends. Even now, mobile networks don't operate in many villages, but internet access can be provided using "White-fi" technology which delivers broadband internet [1].

Technologies have been constantly evolving. One such thing is IoT and after its impact it is considered as the fourth industrial revolution [2]. Living has been made easier for those in urban place to experience smart devices and connected habitats. While the urban populace is more connected to its devices, the rural populace is more disconnected to modern civilization and humanity than ever. In such a situation, IoT could well be the technology that helps bridge the gap between the urban and rural spheres of India. Two-Thirds of the Indian population lives in its villages and it is necessary to provide the concepts of health-care, education, livelihood support, etc. Those facilities, privileges and technology advancements that prevail in the urban place should also be offered to the rural areas [3], so that, it helps in the development of rural ecosystem.

Home automation systems are becoming more and more common in urban areas and have helped in reducing energy waste [4], it presents a novel way of actuating the various household devices using data from sensors to better manage energy usage. The systems use ZigBee and IEEE 802.15.4 for communication between the micro-controller and the appliances. The core functionality of a micro controller communicating with household appliances can be ported over to a village scenario where the energy supply is limited and energy conservation is important. To overcome the challenge of connectivity in remote areas, unconventional approaches like IEEE 802.11af referred to as White-Fi [5], which uses the unused TV spectrum or white-space can be used to supply wireless network in these remote places [6].

Managing energy usage in remote villages with limited energy supply and small populations that are located far away from urban centres present a challenge to the government and authorities. In Malaysia, renewable energy available from biomass resources and solar power was used to generate energy for a Smart Eco-Village [7]. This will be useful to cut electricity demand during peak periods.

Low Power WAN or LPWAN allows for newer devices to communicate via the internet. LPWAN can be operated at a very low cost and was used to make IoT applications in Rural African Villages [8]. IoT also plays an important role in the development of urban environment; here the LoRaWAN [9] can be used for data transfer as it provides long range low power wireless communication. It is being used for building IoT networks worldwide and offers secure data transmission. LoRaWAN communication can be used in rural areas because it provides coverage range greater than the existing cellular networks. LoRa wireless RF is mainly used for IoT communications, where it establishes connection between node modules and gateway, then transmit the data to the Cloud. A similar architecture was successfully implemented in Smart Water Grid Management system [10] implemented in Mori Village, Andhra Pradesh. LoRa modules were connected to sensors to measure the quality of water at various locations. Similar to that, even in many of the Indian villages, GSM network coverage is very poor. To keep in memory the cost option, we try to provide the connectivity at a low operational and maintenance cost, we have considered many alternatives. Finally, we decided to implement LoRa modules which installed at each hut communicating with a common LoRa gateway installed at the village centre. So, the Smart Hut project is also built-in with LoRa modules to achieve wireless data transfer in rural ecosystem. Smart Hut solutions are aimed to provide better living for the people in rural areas.

III. SYSTEM OVERVIEW

The proposed system is based on a remote rural village where the people don't get supply of electricity, proper GSM coverage and other necessities for their living. Fig 2 consists of Smart hut modules with solar panel to supply electricity to the hut. So the villagers need not be dependent on the electricity from the government. The Smart hut modules will have many sensors connected to the devices and it helps in conserving the electricity generated using solar cells. The node modules are connected to a common village gateway by establishing connection using communication modules. The sensor readings and the other trigger messages are sent and received using the LoRa module. Then the data will be sent to the village cloud, where, decision making and other alerts can be triggered. The solution nodes are also connected to the Cloud to send the necessary messages directly to the node modules. Here, the services provided from the Smart System are transport services, emergency services and the availability of the commodities in the public distribution system. Other government services can also be intimated using this system which will keep the rural people updated on the government schemes and facilities.

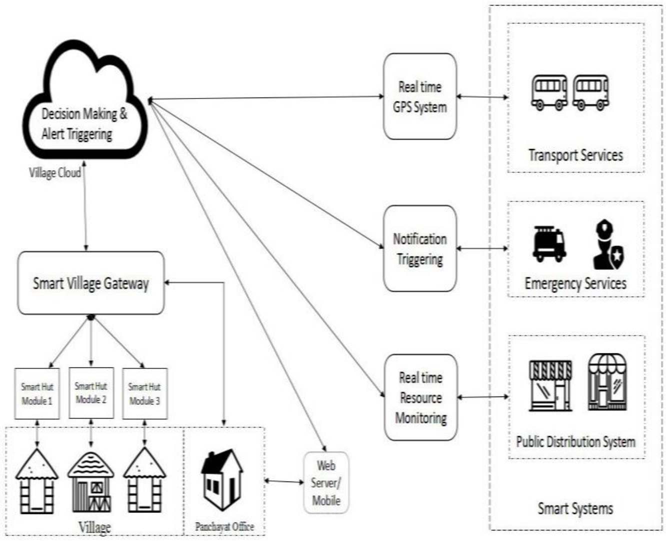

Fig 2. Overview of the Proposed System

The functionality depicted in Fig 2 is divided into six sub-categories to better explain them along with more details using the following.

A. Sensors

There are standard sensors attached with the Arduino microcontroller as a part of LoRa module for providing various details to automate the devices in the Smart Hut. Those sensors are namely LDR, PIR Motion, LM35, Smoke Detection, IR Flame Detection, Water level indication.

- LDR Sensor - A light-dependent resistor also called as photo-resistor is a variable resistor whose value decreases with increasing incident light intensity. When the light intensity inside a room is less, it will help switching on the LEDs or lights.
- PIR Motion Sensor - A passive infrared sensor is an electronic sensor that measures Infrared (IR) lights radiating from objects in its field of view. It detects the motion of the people entering the hut, based on the detection it will switch the lights on.
- Temperature Sensor (LM35) - A temperature sensor measures the hotness or coolness of an environment. The sensor's working base is the voltage that's read across the diode [15]. The temperature rises whenever the voltage increases. These give the temperature measurement of the Smart Hut environment and based on the readings the fan speed can be varied.
- Smoke Detection Sensor (MQ7) - The smoke detection sensor detects smoke, typically an indicator of fire. It is a simple drive circuit, which has high sensitivity to carbon monoxide and natural gas. It makes detection by method of cyclic high and low temperature and indicates using alarm.
- IR Flame Detection Sensor - This sensor is used for flame detection and is used for short range. It detects the range at which fire is present and indicates as close range, distant range or no fire.
- Water Level Indication Sensor - This sensor measures the level of water in the tank and also the level of salt present in the water. It will indicate the level of water so that the tank can be filled accordingly. It has three levels of indication, i.e., level high, average and low.

B. Smart Hut Module

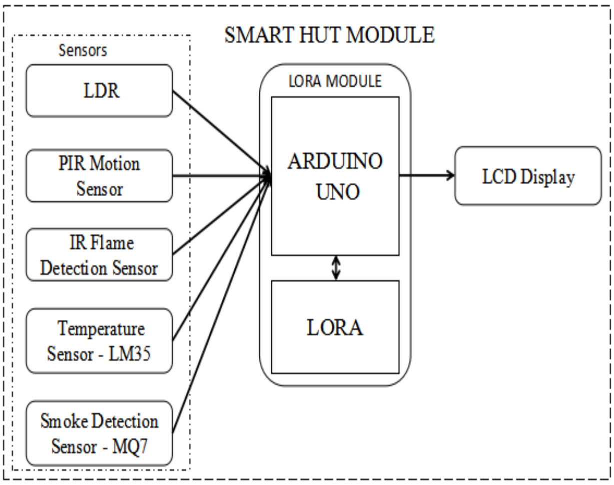

Fig 3. Smart Hut Module

The setup is shown in Fig 3, the Smart Hut is equipped with solar panels on the roof top and sensors are placed inside the hut. The power supply for the hut is generated from solar panels by storing the charge in battery. The necessities such as lights and fan are powered using the charge from the battery. This minimizes the wastage of energy, as it is necessary to automate the devices using sensors. In a scenario where a person enters a hut, the PIR motion sensor detects the motion of the person and then the LDR checks the intensity of the room, based on these readings the lights switches on. So, when the sensor doesn't detect the motion of a person or when the light intensity is high, the lights automatically switches off. Then, the temperature sensor detects the readings of the environment and it will automatically vary the speed of the fans accordingly. The IR flame sensor detects the fire at which range it is present and is indicated by close range, distant range and no fire. The smoke detection sensor senses the presence of smoke in that place and is indicated using alarm as shown in flow diagram (Fig 4). The LCD displays are used to give the information about the transport services when a bus is early or late and about the commodities available in the public distribution system and other relevant information. The LoRa module is connected to the microcontroller to establish connection and send all the sensor readings to the LoRa Gateway and in turn it sends the details to village cloud. From the cloud, the analytical processing will be taken place and the suitable alarms will be sent to the concerned person mobile phones.

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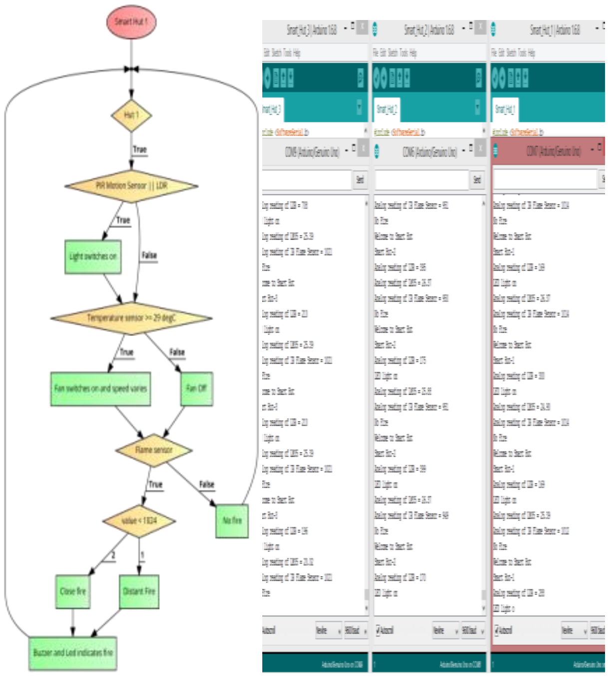

Fig 4. Flow of Events and Connectivity

C. Smart Village Gateway

The village gateway consists of a Raspberry Pi 3 and Lora module to receive all the data from the modules and send it to the village cloud. It can also send information from web-server to the to the Smart hut modules as represented in Fig 5.

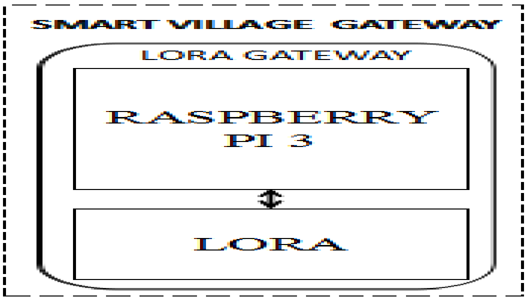

Fig 5. Village Gateway Components

D. Village Cloud

The Village Cloud is used to collect and store the sensor readings from the Smart Hut Modules. So with the help of this data, the analytical processing, decision making and alert triggering can be performed. If a module detects fire or gas leakage, it will trigger a notification to the emergency department and will provide the necessary services. These services will be automatically triggered based on the threshold for the sensors. Cloud-based representation is shown in Fig 6.

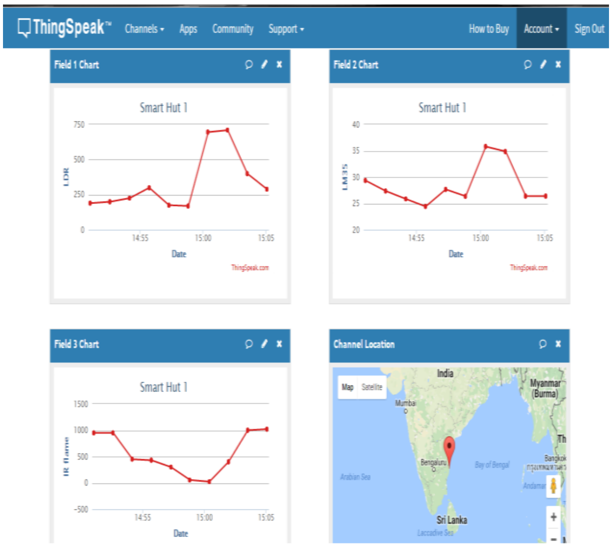

Fig 6. Cloud-based Representation

E. Solution Nodes

In this setup, there are three solution nodes which are used to ensure safety and updating the necessary information to the villagers. First, real time GPS systems are installed in transport services provided by the government, with this it will be easier to identify the bus location and will be intimated to the people in the LCD display placed in Smart Hut Modules. Second, notification triggering can be used to provide the emergency services when the Village Cloud detects the fire or gas leakage in Smart huts. This triggering will be generated automatically to the nearby emergency departments and necessary services will be provided. Third, real time resource monitoring can be performed in Public Distribution System and can be updated if the stocks are available. So it will be easier for the people to confirm the availability of commodities in PDS. This will also ensure that they get the necessities provided by the government. In this way, the government can provide many services such as gas service, good drinking water, etc.

F. Web page

The web page is created to provide smart solutions and monitor the effective functioning of the Smart System. The web page also displays the real time sensor values retrieved from the Village Cloud. It can be accessed from the panchayat office of the village. So, it will be easier to send related information to the panchayat office as well as the people in the village. Depending on the importance of the information, the alert can be triggered directly to the smart hut modules or to the panchayat office.

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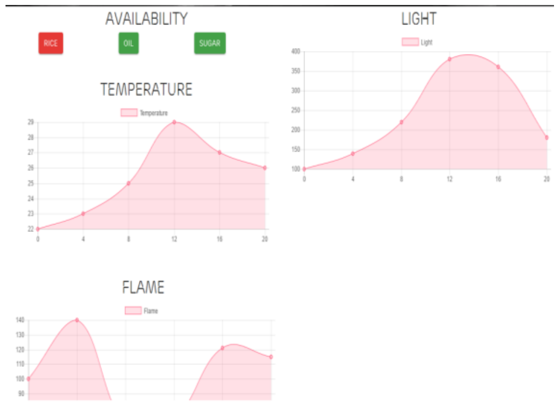

Fig 7. Dashboard Display

IV. SOLUTION ARCHITECTURE

Fig 8 shows the sequence of operations performed in Smart Hut with the help of sensors and communication modules. The Smart Hut module consists of various sensors that communicate with the microcontroller to automate the household devices. The modules and the gateway are connected to the LoRa module to transfer the data. The LoRa module sends an authentication request to the gateway to establish the connection before collectively sending sensor data to village cloud using the API key of the channel. Village cloud details were displayed on the webpage. The LCD is interfaced with a micro-controller to display the triggered messages from the webpage. The alert information and other messages can be triggered from the webpage, it will be received by the micro-controller placed in Smart Hut modules and will be displayed on the LCD.

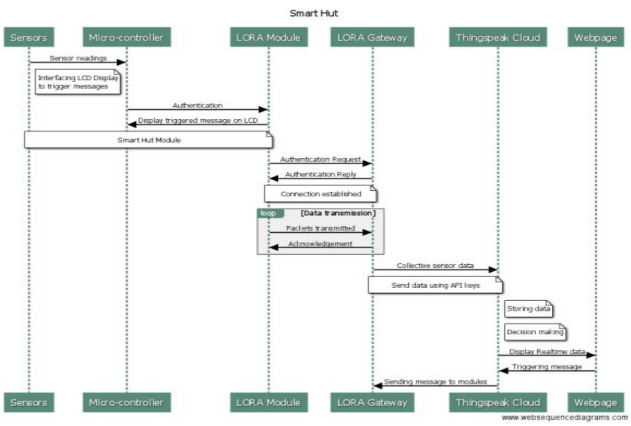

Fig 8. Smart Hut Connectivity

Fig 9 shows the sequence diagram of how the information about the transport service is sent to the node modules. The information about the bus delay or early departure can be informed to the villagers directly on the LCD display placed in huts. By this, it will help the people living in rural villages be aware about the arrival of the transport service provided by the government. The messages are sent from the webpage and then to the common gateway of the village followed by the gateway sending the messages to the node modules directly. This makes the information easily available for the people in remote villages. Information about other services can also be informed this way.

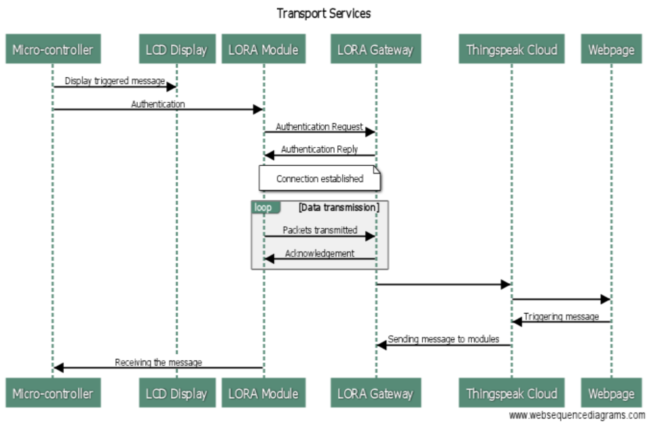

Fig 9. Transport Services

V. RESULTS AND DISCUSSIONS

The Smart Hut circuitry consists of various sensors, a microcontroller and communication modules. The sensors are interfaced with the micro-controller and the sensor data is sent to the Cloud using low power LoRa module for long range communication.

A group of remote villages can have a common office to provide government services and other facilities; it is always difficult for the rural people to know the availability of the goods and services provided by the government. This will make the people to visit the office to enquire about the particular services frequently. So, this can be made simple by sending a trigger message about the availability of services when and can be directly intimated through the LCD display placed in the huts. It will benefit the people living in remote areas and will keep them updated on the schemes provided by the government for their better living conditions.

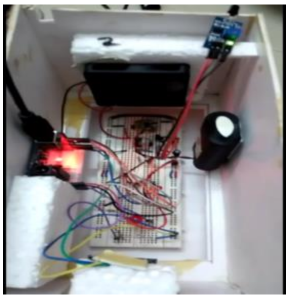

Fig 10. Prototype Fig 11. Inner View of Hut

Fig 10 shows the prototype of the Smart Village. This prototype consists of solar powered Smart Huts and different government services that are situated at a far distance. After the implementation, it will provide an efficient way of information delivery to the villagers. Fig 11 shows the circuitry of the Smart Hut Module. The module consists of LDR, PIR Motion, LM35, IR Flame and Smoke Detection sensors to automate the household devices and an LCD to display the triggered messages.

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Fig 12. LCD Output

The sugar available alert triggered from Public Distribution System to all the Smart Hut modules is shown in Fig 12. This LCD display is shown here to indicate the creation of easiness to the villagers in solving their day-to-day simpler problems and they get more time to concentrate on their developmental activities. Similar to this, most of other services availability will be displayed on real-time to bring the comfort to the villagers.

created_at	entry_id	LDR	LM35	IR Flame
2017-04-05 08:49:51 UTC	1	708	29.39	1021
2017-04-05 08:51:24 UTC	2	710	29.39	1021
2017-04-05 08:52:58 UTC	3	690	31.45	1021
2017-04-05 08:54:32 UTC	4	678	33.36	1021
2017-04-05 08:56:05 UTC	5	697	32.56	1019
2017-04-05 08:57:39 UTC	6	630	25.88	1019
2017-04-05 08:59:12 UTC	7	560	25.88	1012
2017-04-05 09:00:46 UTC	8	480	25.88	1014
2017-04-05 09:02:19 UTC	9	390	27.66	1012
2017-04-05 09:03:53 UTC	10	278	26.36	1021
2017-04-05 09:05:27 UTC	11	210	27.45	1014
2017-04-05 09:07:00 UTC	12	196	28.34	1014
2017-04-05 09:08:34 UTC	13	175	28.66	1014
2017-04-05 09:10:09 UTC	14	169	29.34	951
2017-04-05 09:11:41 UTC	15	179	29.87	950
2017-04-05 09:13:15 UTC	16	139	30.14	951

Fig 13. Sensor Readings

The sample output readings of the sensors present in the Smart Hut, which were transmitted and stored on the Village Cloud, are shown in Fig 13. The readings are generated to monitor the sensors and to take necessary safety measures when the threshold of the sensor is reached. Using the data on the cloud, alerts are automatically generated and sent to the webpage and safety measures can be provided.

VI. CONCLUSION AND FURTHER WORK

The paper focuses on rural development through the use of IoT devices and inexpensive sensors and actuators to improve the quality of living in rural areas. This is one way can prevent the people move from village to urban and to avoid the cities are over populated and citizens fighting for their basic facilities. In an effort to revitalize rural communities and make them more sustainable, we have to focus on developing the rural ecosystem. It is important to provide the technologies and other services present in urban areas to the rural areas. The future lies in boosting local development and making villages live, grow and progress. IoT is considered as the disruptive technology that can be used to provide the solutions as well as help the villagers for providing basic facilities for the development of the villages. Our attempt in this paper can setup the path for introducing IoT-based efficient solutions for the villagers in getting the necessary facilities without much hassle. A continuous development with the same focus can make villages more sustainable and affluent.

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