LoRa Communication for Autonomous Solar panel Cleaning Robots

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Abstract - *This paper present design and implementation of an effective long-range Wireless Sensor Networks (WSN) for real-time monitoring and controlling of autonomous solar panel cleaning robots using LoRa communication technology. The main objective of this project is to provide robust, long-range and comparatively a low-cost solution that meets industries requirement. Solar farming is a growing industry and demand for clean ecofriendly solar energy is raising. The utility grade solar plants are mostly located in remote locations like deserts where implementing infrastructure-based network is challenging, Also, Solar plants covers large area which is in in sq. km so range coverage is major concern. LPWAN is only technology which can fulfil all requirements. LPWAN stands for Low Power Wide Area Network, designed for sending small data packages over long distances. While short range technologies like Bluetooth, Wi-Fi, Zigbee are cheap, it is limited by distance, cellular technologies like 3G, 4G and 5G have more transmission rate and range but are more costly and high-power consuming. LPWAN has overcome all the cons of existing wireless technology by compromising on the data rate and featuring the long-range data transmission, low power consumption and being economical. Some of the technologies that comes under LPWAN includes Narrowband IoT (NB-IoT), Sigfox, LoRa and others. LoRa is a long range, low power, inexpensive technology for Internet of Things (IoT) developed by a company called Semtech. That's why it is ideal candidate to be implement in this project.*

Key Words: LoRa, IoT, LPWAN, Wireless Sensor Network, Semtech, Zigbee.

1. INTRODUCTION

Human beings have evolved from many communicating ways emerging from writing it manually to monitor it with the help of internet and other IOT devices. Desegregation of wireless Sensing Network in several and distinct sectors like industrial applications, distant health-care providing, agriculture system based on IOT and smart devices, environmental monitoring system, transportation sector etc. These technologies have imported and schlepped large-scale prosperity in the elevation and uplifting of the wireless communication as well as wireless devices. Several devices and technologies have been conceived in the recent years like WIFI, ZIGBEE, LPWAN, and currently in trend LTE.

This paper mainly focuses on how LORA or LPWAN are implemented in the industry with very less cost and higher efficiency with the help of IOT. The LORA or LPWAN do not require high data rates or bandwidth. They also consume very less power. There are many alternatives and solutions available in the market of automation in the industry. However, this solution and alternatives do not meet the needs and requirements of the industry and face several issues like more implementation cost, consuming more energy, poor performance and small area coverage. However, LPWAN or LoRa technology have the adequate feature that is more helpful and practical for industrial needs such as coverage can be up to 30km, less power consumption etc. The tasks in industry vary from analysing data, monitoring data to collecting and manipulating them. Monitoring data should be done as quickly as possible as appropriate actions have to be taken in order to save the result from getting affected by errors. This can be done with the help of Industrial Internet of things i.e. IIOT. Various data can be collected through single node with the help of different sensors like humidity sensors, temperature sensors, pressure sensors, flow sensors etc. All the sensors are capable of collecting data from deployed environment and process it correctly.

This paper presents advantage of LoRa communication in the monitoring and control of solar cleaning robots deployed in large area. All the sensors in the node are autonomous and intelligent, smart. The nodes in the system are able to communicate with each other to meet the system's requirement. It makes the system more intelligent. Wireless sensor network has the distributive ability. Due to which, it has a great ability of monitoring and controlling applications to get real time data and utilization.

2. LoRa TECHNOLOGY

LoRa, is part of LPWAN WSN technology. LoRa stands for Long Range. It is a patented technology developed by USA based company called Semtech. It works on Chirp Spread Spectrum Technology (CSS). Also, it has Forward Error Correction (FEC). LoRa provide a very long range, secure transmission and low power consumption. In case of power consumption, range and cost LoRa outperform every existing WSN technology.

There is LoRaWAN protocol developed by LoRa Alliance using LoRa technology. It is a open standard which addresses the Mac, network and application layers. By combining LoRa with LoRaWAN protocol we can achieve low power, wide area communication between remotely located sensor nodes and LoRa gateways for low latency and low bandwidth application like data monitoring and controlling. The LoRa and LoRaWAN protocol work on unlicensed ISM (Industrial

Scientific and Medical) bands. In India operational frequencies for LoRa is ranging from 865 MHz to 867 MHz It is license-free band for the use of low power equipment designated by Ministry of Communications and Information Technology, India. In Europe, 863 MHz to 870 MHz is license-free band. In this system we used 866 MHz as operational frequency.

A most of LoRa network work on a star-of-star topology which consist of three types of devices. It includes end nodes, LoRa gateway and LoRa Network server. In large scale industries as well as applications where, large area needs to be cover by WSN for that efficient and long-range communication requires and many existing wireless technologies not meet this requirement. Only LoRa technology suits in terms of covering large areas efficiently with low power consuming sensor nodes.

TABLE I. THE CHARACTERISTIC OF EXISTING WIRELESS NETWORKS

WSN System	**Long Range, High Data Rate (LTE)**	**Long Range, Low Data Rate (LPWAN)**	**Short Range, High Data Rate (WI-FI)**	**Short Range, Low Data Rate (ZigBee)**
Coverage	Large	Large	Small	Small
Range	Long	Long	Short	Short
Latency	Low	High	Low	Low
Bandwidth	200kHz-900MHz	500kHz-900MHz	2,4,3,6,5 and 60GHz	<2.4GHz
Power Consumption	Low	Low	High	Low
Topology	Star	Star and Mesh	Star	Point to point
Data Rate	High	Low	High	Low

The low power consumption, long range, low cost and independent of existing infrastructure make it good choice for large scale deployment like this project. This remote LoRa sensor nodes require very low power as well as supports features like WOR (Wake on Receive) and Deep Sleep make them more power efficient if we couple it with battery.

3. PROPOSED SYSTEM

The proposed system "LoRa Communication for Autonomous Solar panel Cleaning Robots" performs real time monitoring and controlling of solar panel cleaning robots deployed in large scale utility grade solar power plant. In this system LoRa transceiver are connected to each robot to maintain communication with each other and base control station.

In this system, Robot's onboard MCU collect and process the data from various onboard sensor and pass it to on board LoRa transceiver and this LoRa node send this data packet to the common LoRa gateway via relay node. This LoRa gateway acts as access point to the local network of base station. LoRa gateway transfer this data to local server and local database where it can be store and manipulate. Local server displays this data to base stations control panel. The local database and server are in sync with cloud server and cloud database. Local Lan push the data to cloud via internet. The remote admin can monitor and control whole system by login into cloud dashboard from anywhere.

This system is deployed and working on Azure Powers 140MW Solar Power Plant located in Rajasthan desert. In which multiple end nodes includes cleaning robots, weather stations, data logger, security sensors are connected to same LoRa network. This WSN covering total 550 Acres of land efficiently.

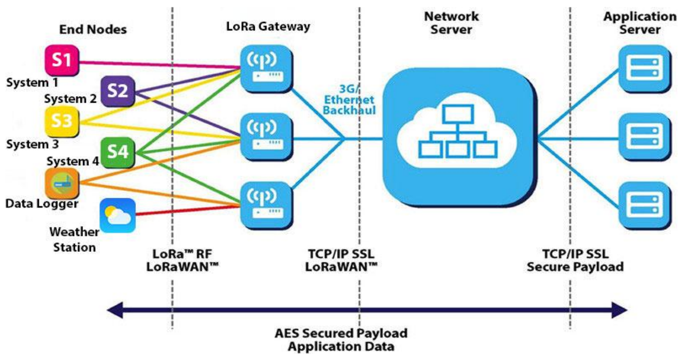

Fig. 1: Proposed system.

4. SYSTEM DESIGN

This system consists of end nodes, relay nodes, LoRa Gateway. Local server and Cloud server. The end node includes cleaning robots, service robots, weather stations, data loggers, security sensors. In case of cleaning robot various sensors like environmental sensors, proximity sensor, current sensor, dust sensor, ultrasonic sensor, photoelectric sensor, pressure sensor, etc., robots main control unit and motors connected to main MCU that process all information and passes it to LoRa transceiver. This transceiver transfer and receive data and control signals from LoRa gateway.

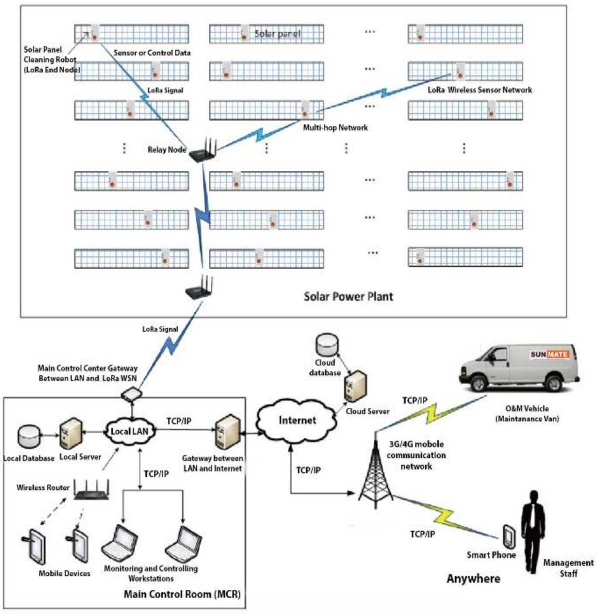

Fig. 2: System architecture

As shown in Fig. 2 End nodes communicate with Lora Gateway through Relay node which is head node of cluster. And then gateway sends the data to local server through local LAN. The local administrator can control and monitor the whole robotic system with local LAN, Infra-net or Local Wi-Fi zone created by Wi-Fi router which is connected to local Lan connection. Local server pushes the data to cloud server so the remote admin can access the whole system from anywhere using cloud-based dashboard.

5. TECHNICAL DESCRIPTION

A. Microcontroller (STM 32 arm cortex m4)

In this system we used STM32F4 microcontroller from STMicroelectronics as our main MCU. It is very capable microcontroller and based on Arm cortex m4 architecture. It is a 32-bit RISC processor core with 168 MHz frequency and up to 1 Mbyte of flash memory. It has 140 I/O ports with interrupt capability and 15 separate communication ports that support I2C, UART, SPI, CAN, SDIO, etc. communication interface.

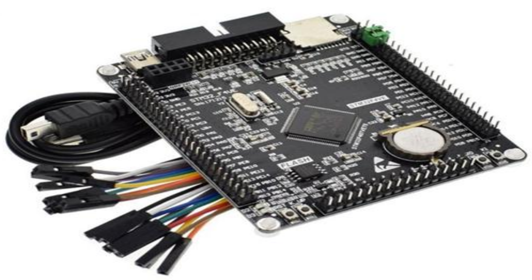

Fig. 3: STM32 F407VET6

B. SX1276 LoRa Transceiver module

The SX-1276 transceivers is the LoRa long range modem that offers ultra-long range chirp spread spectrum communication and it have high immunity to external interference. Also it minimize the current consumption. It is developed by Semetec with their proprietary LoRa technology.

It has 168db of max link budget. It gives constant +20dBm RF output vs – 100mW of V supply. Very low RX current of 9.9mA makes it power efficient. Supports FSK, GFSK, MSK, GMSK, LoRa and OOK modulation.

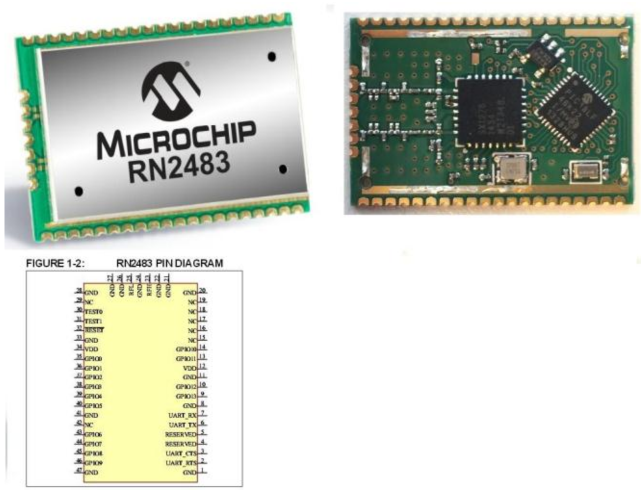

Fig. 4: SX-1276 LoRa Module

C. ATMega 328

The ATmega328 is a microcontroller from megaAVR family. It is an 8-bit microprocessor and have 32kb of flash memory to store the code. It has total 28 pins. It has 1KB EEPROM, 2KBSRAM and 23 I/O, 10-bit ADC. It supports USART and SPI communication interface,

It can store and retain the stored code even after removing power supply. The Rx and Tx pins are used to perform serial communication.

The LoRa transceiver is connected with this IC via SPI communication. And this ATMega328 connected to LoRa Gateway through UART communication for data exchange.

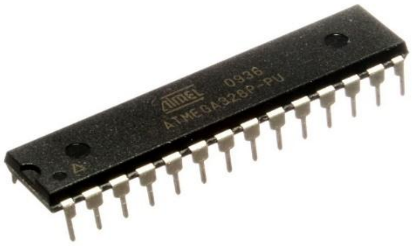

Fig. 5: ATMega 328 IC

D. Raspberry Pi 4

Raspberry Pi 4 is a single board computer with powerful Broadcom processor. It has Broadcom BCM2711, Quad core Cortex – A72 (ARM v8) 64-bit SoC clocked at 1.5GHz. It has 4 GB of Ram, Wi-Fi, Bluetooth, USB port, Micro HDMI output, etc. It supports 40 GPIO pins. Operating voltage is 5v and minimum 3A power required to run it. It is very capable device to use as LoRa gateway.

Fig. 5: Raspberry Pi 4

6. PROJECT IMPLEMENTATION

This LoRa WSN developed for Sunmate solar cleaning robots. It is interfaced with SunMate's embedded system and it is deployed in Azure Powers 130 MW solar power plant located in Rajasthan desert.

Fig.6: LoRa Node (Transceiver)

As shown in Fig.6 LoRa transceivers consist of SX-1276 LoRa module and ATMega 328 connected to robot through UART communication interface. LoRa nodes receive and transmit the system data and further push it to main control system of robots by UART interface.

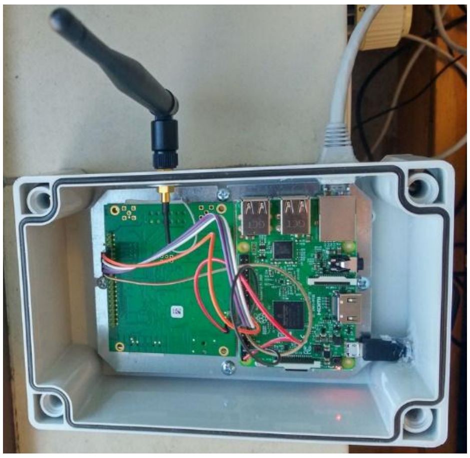

Fig.7: LoRa Gateway

LoRa gateway is made from Raspberry pi and SX-1276 LoRa module. Raspberry pi 4 collect data through LoRa communication and push it to local LAN through Wi-Fi or LAN port.

Fig.8: Implementation on Solar plant

Fig.8: LoRa Gateway setup in Solar plant

Fig.9: Cloud Dashboard

Cloud dashboard is used to control and monitor the robots from base station or remote location. Admin can login into dashboard and set necessary parameters, monitor robot's location, assign tasks, generate alerts

7. RESULT

The main aspect that was tested is range and strength of wireless communication. The current application needs large network coverage. LoRa works more efficiently when sender and receiver are both in line of sight. Obstacles affect the rang of wireless network, that's why we tested this system in open desert and urban area. A mobile transceiver is placed in car and gateway set in one stationary point to check effective range and maximum range of system. Effective range means strong network connection with no packet loss and without any transmission delay.

TABLE 2. TESTED RANGE OF SYSTEM

Range	Open Desert	Urban Area
Effective Range	5.8 km	2.26 km
Max Range Tested	7.6 km	2.80 km

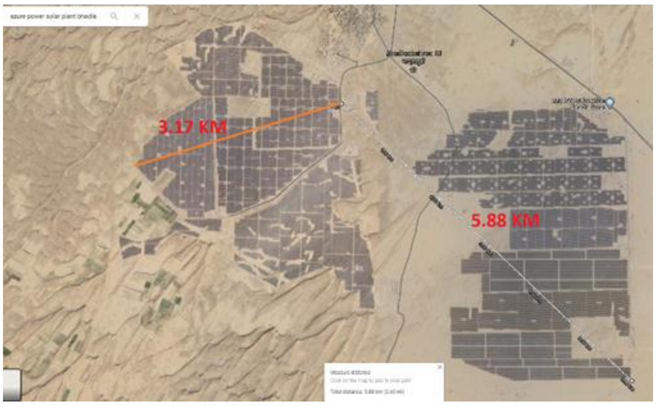

Fig.10: Solar Plant Range Testing

Fig.11: Urban Area Range Testing

8. CONCLUSION AND FUTURE SCOPE

An advance LoRa based WSN for controlling and monitoring of Solar panel cleaning robots is presented in the paper. The proposed system uses multiple wireless nodes connected with cleaning robots to send and receive sensor and control data using LoRa communication protocol. The operational data collected through wireless communication domain can be store and analyze to run robotic system efficiently to increase plants production. The goal of proposed system is to provide a cost-effective, long range, energy efficient, easy to deploy WSN.

The current approach has been implemented and tested on Sunmate robotic system and deployed at 130 MW Solar plant in Jodhpur, Rajasthan – India. The current LoRa WSN proven very efficient than previously used Wi-Fi technology. The results show that the power consumption reduced by 78%. And designed transceiver node can achieve a lifetime of 5.2 years with a 2500mAh battery. Implemented WSN covers whole plant with strong network coverage and tested range is ~7.6 km which is enough for local networking. This system provided remote access to control system of robots without packet losses. The urban area testing result show that range is influence by obstacles like buildings and tress. The solar industry is growing rapidly and this WSN is an effective communication technique for fulfilling its need. This system can be use in monitoring all aspects of solar plant.

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