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IMPLEMENTATION OF RETROFIT DATA ACQUISITION SYSTEM USING LoRa FOR INDUSTRY 4.0

Anurag Nagar
M.Tech Scholar
Rajasthan Technical University
Kota, Rajasthan
anuraag7775@gmail.com

Vijendra K Maurya
Department of ECE
GITS, Udaipur, Rajasthan
maurya.vijendra@gmail.com

Tina Bhati
Department of ECE
GITS, Udaipur, Rajasthan
tina10bhati@gmail.com

Abstract- In the technological ocean of Industry 4.0, depending on individual's feasibility, industries are adopting various wireless communication methods for data monitoring, logging and controlling like WAN, Wifi, Zigbee, Mash, LoRa etc. This research paper present wireless de-facto Physical layer communication Medium i.e., LoRa with respect to cost optimization over long range communication, for machines/devices located in big plant. It includes brief finding of popular wireless technologies in Industry and details of Physical as well Lab demonstration on proposed implementation of LoRa with the objective of existing replacement of RS485. Although this experiment collects data in real time from slaves, but it can be logged in any data storage medium like on flash memory, SD card depends on individual requirements as well on cloud with internet connection. The laboratory work involves the implementation of most recent embedded hardware as well as embedded software to evaluate Temperature and Humidity parameters (most common parameter in industry).

Keywords—Industry 4.0, LoRa, BOM, POC, Industrial Automation

I. INTRODUCTION

Devices and Machines play a very vital role in industrial environment to monitor their smooth operation and control over them, needs some communication with them without human intervention.[1] Devices and machine usually have different kind of sensors [1], actuators etc that collects information about operating parameters.

Wireless communications are responsible for transmission and collection of information devices so that operational assessments and real-time adjustments can be done. Such as, a big Generator backing Oven process contains the number of Temperature and Humidity sensors, RPM etc. The relevant data need to continuously monitor and transmit via a wired or wireless network for analysis of quality production and intelligent controls on process. [2]

Line drivers and receivers are generally used to swap data between two or more points (nodes) on a network. Different manufacturers developed and provide standards to ensure compatibility between units for reasonable accomplishment of transferring data over specific distances and/or data rates.

A. LoRa - A Wireless Communication

To handle practical problems that is encounter in a usual communication network. The main disadvantage of cable cost and maintenance in RS-485 over long distance can be overcome by wireless technologies. [3] There are several wireless technologies available in market that can be use as a substitute of RS-485 mechanism. Every technology has their pros and cons.

The most optimise replacement of RS-485 can be achieved by LoRa Wireless technology. Since this technology have capability to meet the requirement over long range like RS-485, it widely accepted in industry and becoming de-facto standard for industrial devices and machine communication. One more additional advantage the LoRa technology is, along with data collection from sensor nodes it also transmits the data to cloud with the help of LoRa Gateway and plays a significant component of IIOT/ Industry 4.0 revolution. [4]

B. Introduction to LoRa

LoRa (short form of Long Range) is an RF modulation technique for low power and wide area networks (LPWANs). It is design by Cycleo of Grenoble, France and acquired by Semtech and get patent on it. LoRa is an extremely long-range data links. The range of LoRa communications in urban area is upto 3 miles (5 Km), and in rural area is upto 10 miles (15 Km) or more with the constraints of line of sight.

The Modulation technique used in LoRa is spread spectrum, which is based on chirp spread spectrum (CSS) technology. LoRa uses license-free sub-gigahertz radio frequency bands. The range of frequencies is different for different regions are shown in table I. [8]

TABLE I. RANGE OF FREQUENCIES FOR DIFFERENT REGIONS

Regions	Range of frequencies
Europe	433 MHz, 868 MHz
Australia and North America	915 MHz
India	865 MHz to 867 MHz

Asia	923 MHz

LoRa enables long range transmissions with ultra-low power consumption. It can be best suitable for of battery powered devices. The devices can use for 10 years. LoRa basically is physical layer and LoRaWAN (Long Range Wide Area Network) is protocols and covers the upper layers. [5] The data rate can be achieved between 0.3 Kbit/s and 27 Kbit/s and depends on SF. LoRa becomes the de facto wireless technology for Internet of Things (IoT) networks worldwide.

C. LoRaWAN-A Protocol

LoRaWAN protocol is an open-source protocol which enables smart IoT applications. The long-range communication link is enabled by the LoRa physical layer. While system architecture and communication protocol for the network are defined by LoRaWAN. It is a cloud-based MAC (Medium Access Control) layer protocol that behaves as network layer protocol which managed communication between end-node devices such as a routing protocol and LPWAN gateways. [6]

II. LoRa BASED IMPLEMENTATION

A New De-facto standard is evolved in Industry 4.0 that connect the industrial devices wirelessly. In this experiment the connection between machines is like RS485 Master-Slave architecture i.e., but devices/machines are connected wirelessly. The technology used here is LoRa, based on advantages above, which is most suitable to replace the RS485 connection Mechanism. Here philosophy of implementation is like RS485. Instead of the RS485 Modules (which support the communication mechanism) the LoRa Module is used for Master and Slave end. Details are as follows.

A. System Block Diagram of LoRa implementation in Industry 4.0

This setup of LoRa implementation is similar RS-485 Implementation in laboratory which is shown in figure 1. As the devices or industrial machines are connected in Master-Slave Architecture in RS-485 mode here for comparative study we made as it is but there is no physical Bus between them as these are communicating in wireless mode. One Device act as a Master i.e., LoRa enabled Master device it may be PC, or any Embedded System based device.

The other connected devices are act as slaves. Each slave has their own slave-ID. Slave may be located remotely and connected with master wireless mode. The Master is used to control the communication, collect information from slave device, and control the slave device/machine.

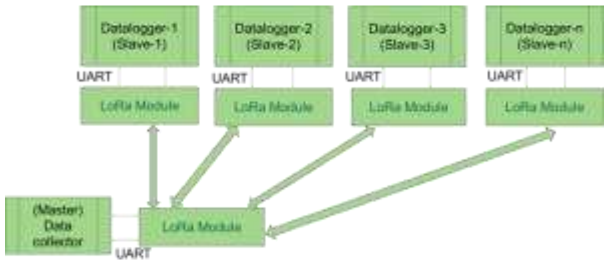

Fig. 1 System implementation of LoRa based communication interface

B. POC implementation of Circuit LoRa in Laboratory

To connect devices over LoRa, the devices should have basic hardware components so that it becomes LoRa enable devices. Figure 2 shows the essential components requirement for both Master and Slave. These are

- Microcontroller (May be PC or PCL)
- LoRa Module
- Power Source
- Any Sensor/Relays/Actuators/ Solenoids
- Any Display or Keypad (optional)

In block diagram sensor is not connected in master module.

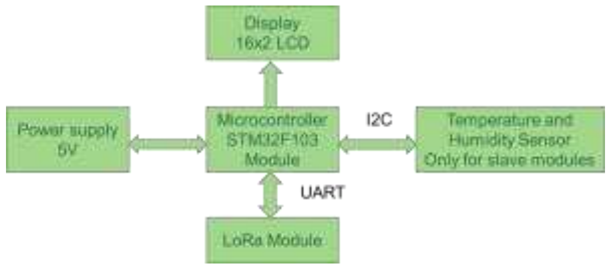

Fig. 2 Fundamental hardware block diagram for LoRa based Laboratory setup

C. Schematic of LoRa Enable Device

The schematic of LoRa enable device is shown in figure 3. For POC purpose following components is taken

- Microcontroller (STM32F103 Bluepill Board)
- LoRa Module
- Display (16x2 LCD)
- Temperature and Humidity Sensor (DHT112 for slave only)
- Keypad (optional)
- Power source (any 5V Adaptor)

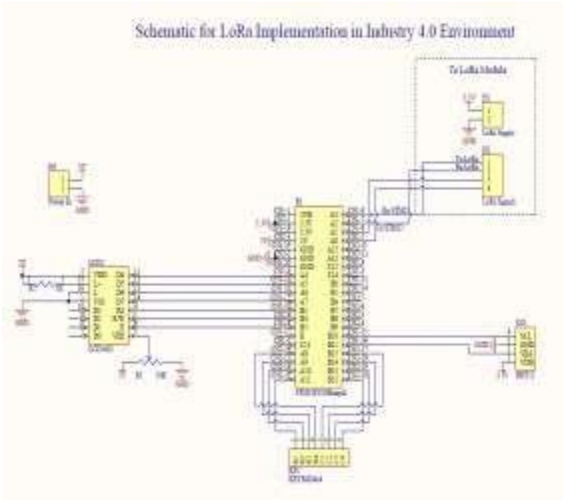

Fig.3 Schematic of LoRa enable device

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D. Board Bring Up and System Set Up in Laboratory for of POC LoRa

For POC purpose one master without sensor and two slaves with Temperature and Humidity sensor with 16x2 LCD display are used. LoRa system setup with all the components is shown in figure 4.

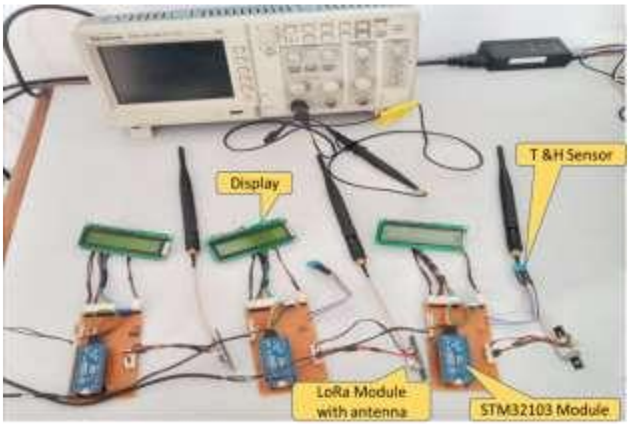

Fig. 4 LoRa system setup in lab

E. BOM (Bill of Material)

Bill of Material of for master module which includes all the components required for implementation of LoRa system is tabulated in table II.

TABLE II. MASTER MODULE LoRa

Component	Qty	Costing in INR
STM32F103Bluepill	1	350
LoRa Module	1	950
HEADER 2 Pin	1	8
Power Supply 5V	1	100
HEADER 4 Pin	3	36
LCD1602	1	150
Resistance 1K	1	1
Pot 10K	1	10
Master Module Cost		1650

Bill of Material of for Slave-1 Module which includes all the components required for implementation of LoRa is tabulated in table III.

TABLE III. SLAVE-1 MODULE-LoRa

Component	Qty	Costing in INR
STM32F103Bluepill	1	350
LoRa Module	1	950
HEADER 2 Pin	1	8
Power Supply 5V	1	100
HEADER 4 Pin	3	36
LCD1602	1	150
Resistance 1K	1	1
Pot 10K	1	10
Temp and Humidity Sensor DHT12	1	100
Slave-1 Module Cost		1705

Bill of Material of for Slave-2 Module which includes all the components required for implementation of LoRa is tabulated in table IV.

Table IV. SLAVE-2 MODULE-LoRa

Component	Qty	Costing in INR
STM32F103Bluepill	1	350
LoRa Module	1	950
HEADER 2 Pin	1	8
Power Supply 5V	1	100
HEADER 4 Pin	3	36
LCD1602	1	150
Resistance 1K	1	1
Pot 10K	1	10
Temp and Humidity Sensor DHT12	1	100
Slave-2 Module Cost		1705

The cumulative system cost of implementation of LoRa for data acquisition is tabulated in table V.

TABLE V. TOTAL POC COST LoRa

Module	Qty	Costing in INR
Master	1	1650
Slave-1	1	1705
Slave-2	1	1705
Total Set UP Cost		5015

F. Embedded Software Flow

The embedded software is written in C-Language for STM32F103 controller in Keil-IDE. For POC implementation two type of embedded software is written one for Master as shown in figure 5 and One for Slave as shown in figure 6. In Master software the flow of program is sequential. After power up hardware, program initialize microcontroller system through system initialize function then, program initialize relevant microcontroller inner hardware through program like: UART, GPIO for Display. After that program enters in continuous loop where, program continuously fetch Slave-1 and Slave-2 in defined interval over UART and collect their parameter of temperature and humidity and shows collected information on 16x2 LCD display.

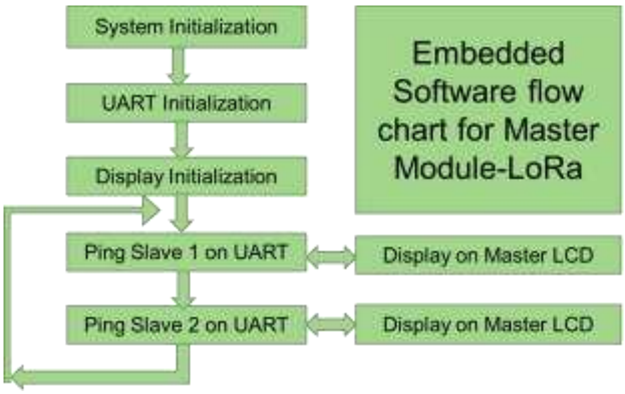

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Fig.5 Master Module software flow diagram

In Slave software the flow of program is sequential. The initialization process is like the Master software only some additional microcontroller hardware initialization, since it has additional temperature and humidity sensor.

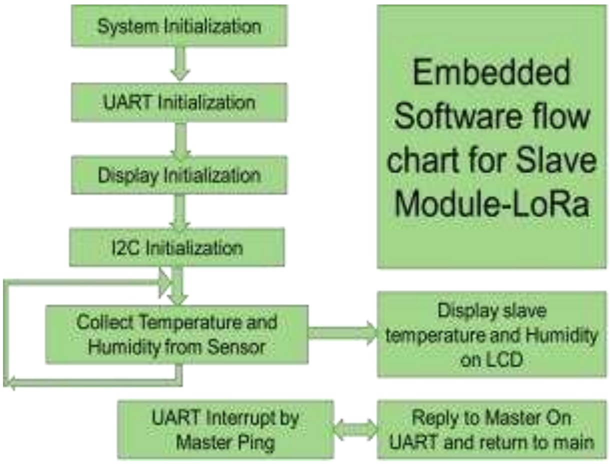

Fig.6 Slave module software flow diagram

After power up hardware, program initialize microcontroller system through system initialize function then, program initialize relevant microcontroller inner hardware through program like: UART, GPIO for Display and I2C for Sensor.

After that program enters in continuous loop where, program continuously fetch the temperature and humidity sensor and collect the parameter in defined interval over I2C and shown these on its own 16x2 LCD display the modules also keeps the last read parameter in RAM so that whenever the UART interrupt raise the Slave module share these parameters with Master module.

III. RESULT AND DISCUSSION

Testing is conducted in point to multidrop mechanism in that the master will send command to one of the slaves and gather the temperature and humidity data and shows the acquired data in masters display similarly master send command to another slave and gather the data and display it in parallel the slave is showing it own parameters but wireless. The setup functioning is shown in figure 7.

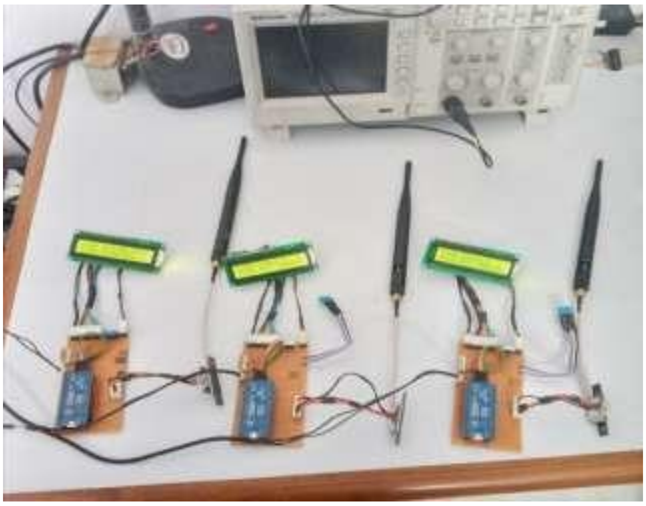

Fig.7 System testing results of lab setup (LoRa)

The live System shows the result on display as per algorithm is tabulated in table VI.

TABLE VI. LoRa SYSTEM LAB SETUP TESTING RESULT

<table>
<tr><th>Master Reading Slave1 Ping</th><th>Slave1 Reading</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th>Master Reading Slave2 Ping</th><th>Slave2 Reading</th></tr>
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IV. CONCLUSION

We have implemented data acquisition system using LoRa for industry 4.0. It is a wireless communication method for data monitoring, logging and controlling over long range for machines/devices. The BOM cost for POC is also mention. The system is able to record data and displayed the result directly on LCD display. This system works well in adverse industrial environment without any problem.

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