DOKUZ EYLÜL UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

AUTOMATIC RECORD KEEPING OF ELECTRICITY METERS USING LONGE RANGE WIRELESS RADIO FREQUENCY TECHNOLOGY (LoRa)

by

İsmail ERSOY

October,2022

İZMİR

AUTOMATIC RECORD KEEPING OF ELECTRICITY METERS USING LONGE RANGE WIRELESS RADIO FREQUENCY TECHNOLOGY (LoRa)

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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled "**AUTOMATIC RECORD KEEPING OF ELECTRICITY METERS USING LONGE RANGE WIRELESS RADIO FREQUENCY TECHNOLOGY (LoRa)**" completed by **İSMAİL ERSOY** under supervision of **ASSIST. PROF. DR. REYAT YILMAZ** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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AUTOMATIC RECORD KEEPING OF ELECTRICITY METERS USING LONGE RANGE WIRELESS RADIO FREQUENCY TECHNOLOGY (LoRa)

ABSTRACT

The total installed base of Internet of Things (IoT) connected devices worldwide is projected to amount to 30.9 billion units by 2025 by the development of the Internet of Things (IoT) technology. It is observed that IoT devices are used in many areas of our lives. Smart home, energy monitoring, sensor control, etc. The most common communication methods which are used in many applications are GSM, Wi-Fi, ZigBee, Bluetooth, Microwave, and LoRa. LoRa (long-range area network) technology provides low power consumption and wide area coverage (LPWA). Nowadays the integration of IoT technology has become a necessity to enable remote reading of electricity meters.

In this study, we combined the LoRa and microwave link because of the ability to send more data and to longer distances. It has been shown that this transmission is possible by using a long-range area network and microwave link together. With the extensive application of this work in the country's electricity sector. It is possible to combine two unlicensed band wireless communication technologies. The promoted platform will have many transmits and a wide smart grid for reading electricity meter readings.

The data of electricity meters were read through the prepared software. Using LoRa wireless communication technology, the data read and collected at the gateway were sent to the data collection and evaluation center without any loss via microwave link.

Keywords : Low power wide area network (LPWAN) , Low power network (LPN) , Long Range Area Network (LoRa) , Microwave , Electricity Meter Reading

ELEKTRİK SAYAÇLARININ UZUN MENZİLLI KABLOSUZ RADYO FREKANSI TEKNOLOJİSİ İLE OTOMATİK KAYDI

ÖZ

Dünya çapında Nesnelerin İnterneti (IoT) bağlantılı cihazların toplam kurulu tabanının, Nesnelerin İnterneti (IoT) teknolojisinin geliştirilmesiyle 2025 yılına kadar 30,9 milyar birime ulaşması bekleniyor. IoT cihazlarının hayatımızın birçok alanında kullanıldığı gözlemlenmektedir. Akıllı ev, enerji izleme, sensör kontrolü vb. Birçok uygulamada kullanılan en yaygın iletişim yöntemleri GSM, Wi-Fi, ZigBee, Bluetooth, Mikrodalga ve LoRa'dır. LoRa (uzun menzilli alan ağı) teknolojisi, düşük güç tüketimi ve geniş alan kapsamı (LPWA) sağlar. Günümüzde IoT teknolojisinin entegrasyonu, elektrik sayaçlarının uzaktan okunmasını sağlamak için bir zorunluluk haline gelmiştir.

Bu çalışmada, daha fazla veri ve daha uzun mesafelere gönderme yeteneği nedeniyle LoRa ve mikrodalga bağlantısını birleştirdik. Bu iletimin uzun menzilli bir alan ağı ve mikrodalga bağlantısının birlikte kullanılmasıyla mümkün olduğu gösterilmiştir. Bu çalışmanın ülke elektrik sektöründe özellikle bölgesel elektrikte kapsamlı bir şekilde uygulanması ile sayaç okumaları için akıllı bir şebeke oluşturmak için büyük bir adım atılmış olacak. Çalışmanın başarılı sonucu nedeniyle, iki lisanssız bant kablosuz iletişim teknolojisini birleştirmek mümkündür, bu platformda birçok gönderi ve elektrik sayaç okumalarını okumak için yeni ve büyük bir akıllı şebeke olacaktır.

Elektrik sayaçlarının verileri hazırlanan yazılım üzerinden okunmuştur. LoRa kablosuz iletişim teknolojisi kullanılarak ağ geçidinde okunan ve toplanan veriler, mikrodalga link üzerinden kayıpsız olarak veri toplama ve değerlendirme merkezine gönderilmiştir.

Anahtar kelimeler : Düşük güçlü geniş alan ağı (LPWAN) , Düşük güç ağı (LPN) , Uzun Menzil Alan Ağı (LoRa) , Microwave , Elektrik Sayacı Okuma

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CHAPTER ONE
INTRODUCTION

1.1 Introduction

The number of Internet of Things (IoT) applications increase rapidly, and the diversity of usage areas is increasing in parallel. IoT devices and services take the place of monotony human tasks such as sensing information, generating data, or maintaining request-based various services (Gubbi, Buyya et al. 2013). It is possible to see the use of devices and objects with remote connection features in every field, especially in smart city applications, health services, asset monitoring, transportation, and agriculture.

To this date along developed the embedded sensors and actuators, different communication technologies have become available to meet various communication requirements in different fields and this helps to realize the IoT technology. The main aims of usage of these devices in smart city applications allow to develop and produce smaller connected nodes to sense, control and monitor the environment for business and public welfare purposes (Karadeniz 2019). Thus, closer monitoring and control of systems or structures with complex structures, consisting of many different physical subsystems or in hard-to-reach points, and end-to-end management of the system can be facilitated. Thus, IoT technologies facilitate the monitoring, control, and end-to-end management of systems with complex structures consisting of many different physical subsystems or located in hard-to-reach points, IoT system and application architecture design was first used in the energy sector before areas such as smart city and smart building, where the uncertainty and complexity of system components is high (GOREN, ALATAS et al. 2018). Many electricity companies have started to use Automatic Meter Reading systems (OSOS) in their customers' meters. An automatic meter reading system has many advantages over manual reading systems, like lower budget, quick response, online control, etc.

LoRa as “LoRa (Long Range) technology is an unlicensed RF (radio frequency) communication at 483 MHz and 868 MHz bands. LoRa Alliance(2002) defined the LoRaWAN® network architecture as “LoRaWAN® network architecture is deployed in a star-of-stars topology in which gateways relay messages between end-devices and a central network server.”(Alliance 2022).

The designed system architecture has figured at Figure 1.1.

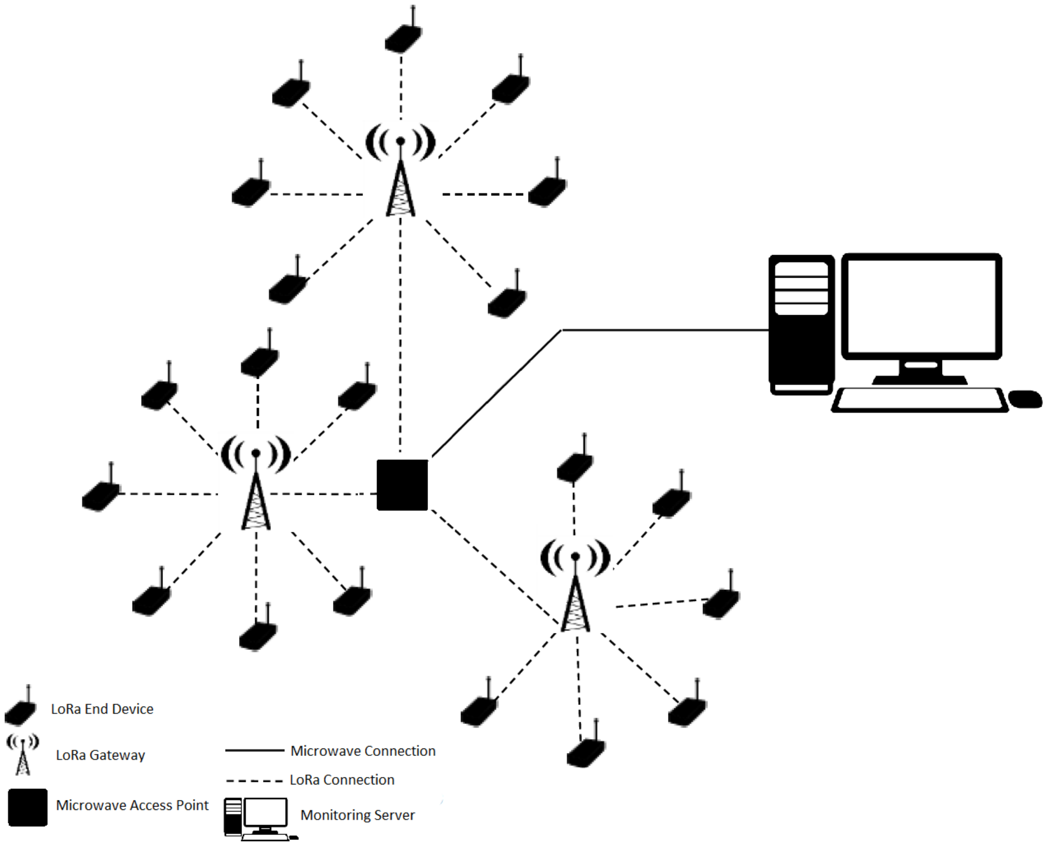

Figure 1.1 Designed system architecture diagram of study

1.2 Previous Studies

LoRa technology has 10 years history. So, this technology is considered new and some studies about it as below;

Authors has been drawn performance measurements for LoRaWAN end nodes and this study shows that only one LoRaWAN gateway can support a few billions end nodes (Toussaint J., et al ,2016).

In this study, LoRa is compared with WiFi multi-interface communicatin module and in real life tests were maden at 6 km , 15 km , 20 km. The results of RSSI and data speed show that WiFi data rates are better than LoRa but LoRa uses lower energy (Pulpito M., et al,2018). Also same authors designed the open source and low-cost LoRaWAN devices because of existing LoRaWAN devices (end device and gateway) are generally closed-source and proprietary in their study. In additionally, they performed tests such as energy consumption and packet loss rate of these device kits (Pulpito M., et al,2018).

Experiments on moving nodes have shown that at speeds greater than 40 km/h, communication performance deteriorates due to the Doppler effect (Petajajarvi J. et al , 2017), (Sanchez-Iborra R. et al, 2018).

The author discusses the scalability of a LoRa network, which shows through simulations that interference can have a very strong impact on network performance. It also shows that increasing gateways can help reduce this problem and that this process is more efficient than using directional antennas in gateways (Voigt T. et al, 2016).

1.3 Outline of Thesis

In this thesis, it is aimed to implement the application of collecting the data of electricity meters by using LoRa wireless communication at data transfer node and transmit this data to Data Collecting and Process Center by microwave (MW).

The following chapters of the thesis are organized as follows. In Chapter 2, concepts and characteristics of some communication systems, literature review of LoRa communication, Microwave communication, and serial communication protocols. In Chapter 3, methodology of designed system is introduced, also infrastructure of electricity meter with reading data of electricity meter, sending data which is read by using LoRa communication and transformation communication protocols from serial communication to HTTP protocol by using prepared software for Arduino development board. Also, results are discussed in Chapter 3. Conclusions are given in Chapter 4 which is the last chapter.

CHAPTER TWO

CONCEPTS AND CHARACTERISTICS OF SOME COMMUNICATION SYSTEMS

2.1 What is LoRa Communication

LoRa is a spread spectrum modulation at the physical layer or the wireless modulation utilized to create the long-range communication link. Lora Alliance said that “many legacies wireless systems use frequency shifting keying (FSK) modulation as the physical layer because it is a very efficient modulation for achieving low power. LoRa is based on spread spectrum modulation which is derivate Chirp Spread Spectrum modulation (CSS) which keeps the same low power characteristics as FSK modulation but significantly increases the communication range.” (Lora Alliance, 2015).

Medium access control (MAC) protocol stack of the LoRa is implemented over LoRa modulation (PHY). The figure draws the corresponding concept in Figure 2.1.

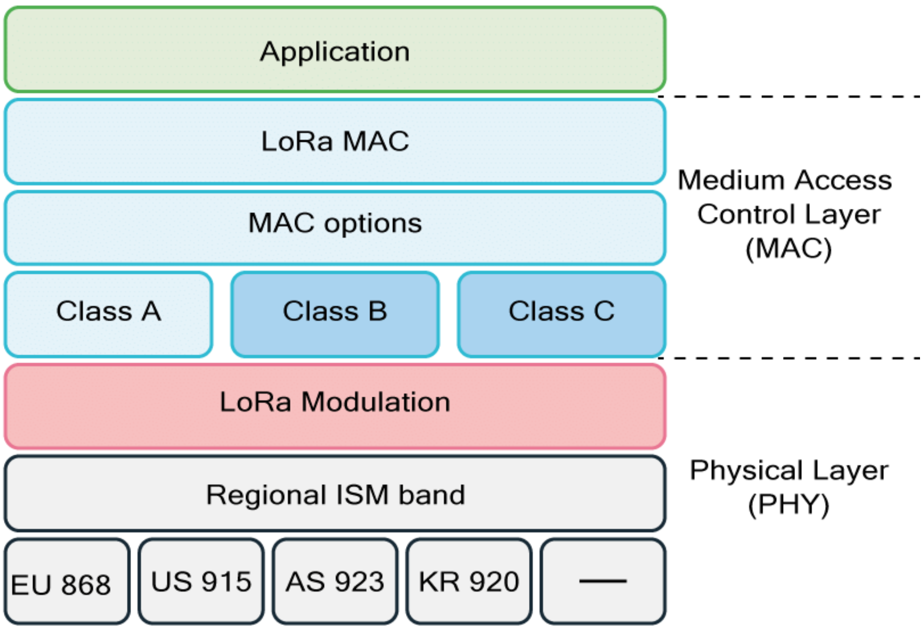

Figure 2.1 (MAC) protocol stack of the LoRaWAN is implemented over the LoRa modulation (PHY) (Lora Alliance, 2015)

The presented Spread Spectrum rules are extended by LoRa modulation for reducing the required energy to send bits on the channel. The Rate of Data (DR) in an achievable communication is able to compute from the bandwidth BW , Spreading Factor, and Coding Rate (CR). Rate of Symbol (RS), bandwidth (BW), and the factor of spreading can be seen in Equation (1) (Semtech Corporation, 2015).

It describes the rate of data transmission and relation between SF, Rate of Symbol (RS), and bandwidth (BW).

$$RS = \frac{BW}{2^{SF}} \tag{2.1}$$

According to equation 2.1, the RS of SF values are shown in Table 2.1 in some cases.

Table 2.1 LoRa SF values (Semtech Corporation, 2015).

Spread Factor(SF)	Chirps/Symbol 2^{SF}
7	128
8	256
9	512
10	1024
11	2048
12	4096

2.2 Shannon – Hartley Theorem

Shannon–Hartley theorem tells the maximum rate at which information can be transmitted over a communications channel of a specified bandwidth in the presence of noise at the information theory (Semtech Corporation, 2015).

Shannon's channel capacity defines the maximum data rate that can be transmitted within a specified bandwidth in the presence of additive white Gaussian noise (Semtech Corporation, 2015);

$$C = B \log_2 \left(1 + \frac{S}{N}\right) \tag{2.2}$$

C is the channel capasity (bit/s)

B is the channel Bandwidth(Hz)

S is the signal power (Watts)

N is the noise power (Watts)

S/N is the signal to noise ratio (SNR)

2.3 LoRaWAN – Classes

There are three main channel access strategies groups at LoRaWAN. They are the Class A, B and C. Class A is needed and all end devices have to implement protocol description defined by (Lora Alliance, 2015). Table 2.2 presents a brief information about the classes.

Table 2.2 The LoRaWAN class comparison (Lora Alliance,2015)

Class	Battery Consumption	Description
A	Most energy efficient	Must be supported by all the End-Nodes. DL after TX
B	Efficient by controlled DL	Slotted communication synchronized with the beacon frames
C	Least energy efficient	Devices listen continuously. DL without latency.

2.4 What is Microwave Communication

Microwave link is the information transmission by electromagnetic waves with microwavelengths. (“Microwave transmission” ,2022)

Microwave is a line-of-sight wireless communication technology that uses high frequency to provide high speed wireless connections.

Radio frequencies such as microwaves and millimeter waves occupy the region of the electromagnetic spectrum below 300GHz.It is shown in Figure 2.2.

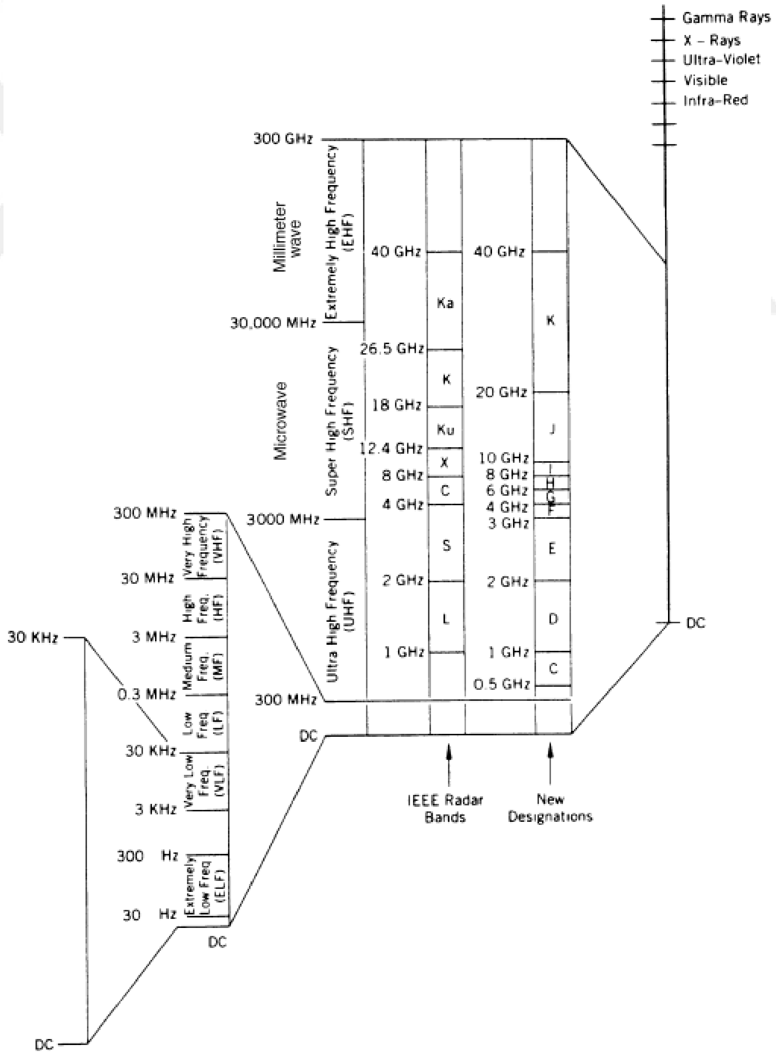

Figure 2.2 Electromagnetic Spectrum (Chang K. ,2000)

2.5 Modern Commercial Microwave Links

Recent Microwave Links can transmit up to 400Mbps in a 56MHz channel. The modulation is 256 QAM.

Operating Distances for microwave links are defined by the antenna size (gain), link capacity, and frequency band. The accessibility of clear Line of Sight is crucial for Microwave links for which the Earth’s curvature has to be allowed.

Nowadays, microwave links are cost effective and more useful then past. So, everybody can use this links for their private applications. For example, a people who is from Mexico installed a private microwave link which is in Figure 2.3 to speed up his internet access.

Figure 2.3 Connecting a Remote Home Application, (Cambium Networks, 2019)

2.6 Serial Communications

Serial communication is the process of sending data one bit at a time.

2.6.1 RS-232 Protocol

RS-232 is defined as the single-ended standards, which has much characteristic, such as more communication distance in a low-speed serial communications, moderate price and good practicality of the system, so it is most appropriate to be a communication port. The new generation computer has a 9-pin connector (DB9) to connect with the RS-232 communication port. In order to achieve reliable and real time transmission, the system adopt a three-wire connection technique that is to say that the GND pin, RXD pin and TXD pin of RS-232 port is connected with the external port, it is shown in Figure 2.4. (Han, X. et al 2010)

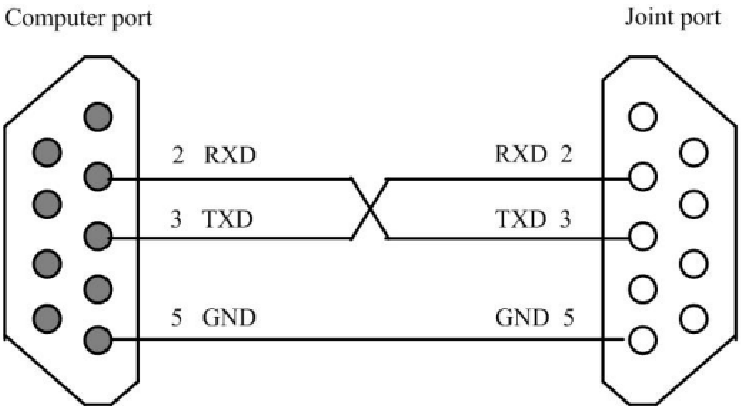

Figure 2.4 The RS-232 Port

One start bit is sent first, followed by the 8-bit data information and one bit stop bit in final at RS232 asynchronous communication. It is figured in Figure 2.5.

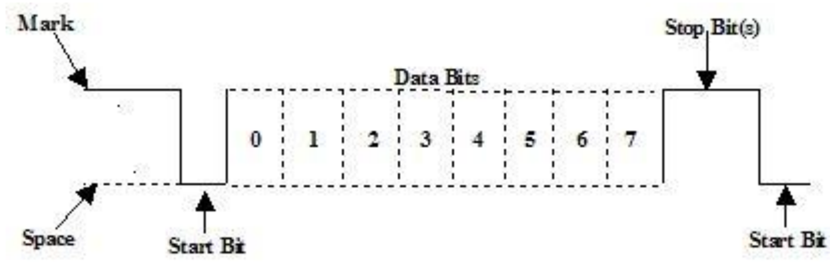

Figure 2.5 RS-232 serial communication data 8-bits

Baud rate represents the number of bits sent per second. It varies between 50-500k depending on the speeds supported by the devices. Generally, 9600 bps is used.

2.6.2 RS-485 Protocol

RS-485 is known as most common wired serial communication protocol in the industrial automation. RS-485 interface can support distance of maximum 1200 meters with multiple devices (up to 32 devices) on the same bus.

Modbus is a server-client based protocol that can provide communication between different devices. Therefore, it is a network system where data can be received from devices and gathered in a data center. It is an open protocol. Manufacturers can use it without any charge. There can be 247 Slave devices with 1 Master in the Modbus network. A sample diagram is figured in Figure 2.6.

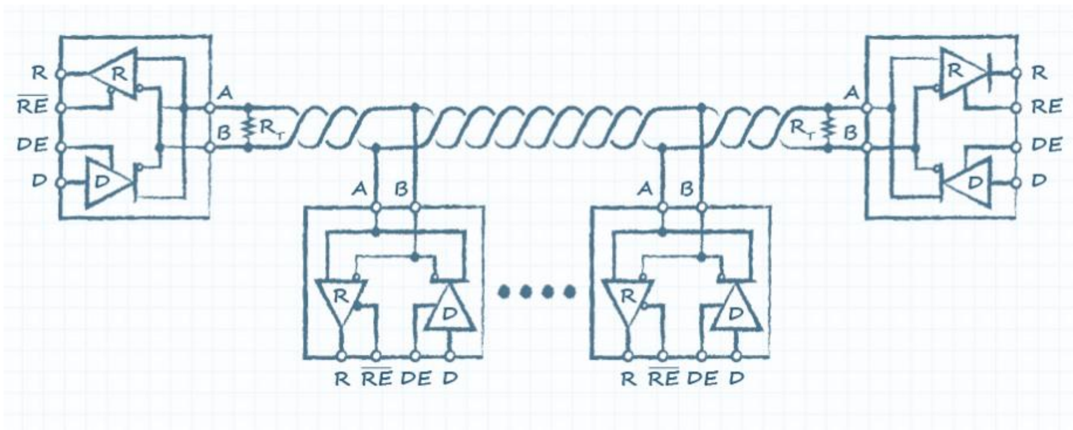

Figure 2.6 Typical RS-485 network topology

The master device can also manage the slave devices according to the data it receives from the slave devices, it can receive data from the slave devices and write data to the devices. RS232 serial communication standard is used for short distance connections and RS485 serial communication standard is used for long connections at Modbus. Universal asynchronous receiver-transmitter (UART) is a hardware for serial data transmitter. RS-485 protocol can be used with UART for especially microcontrollers. Simple diagram of RS-485 to UART conversion is figure in Figure 2.7.

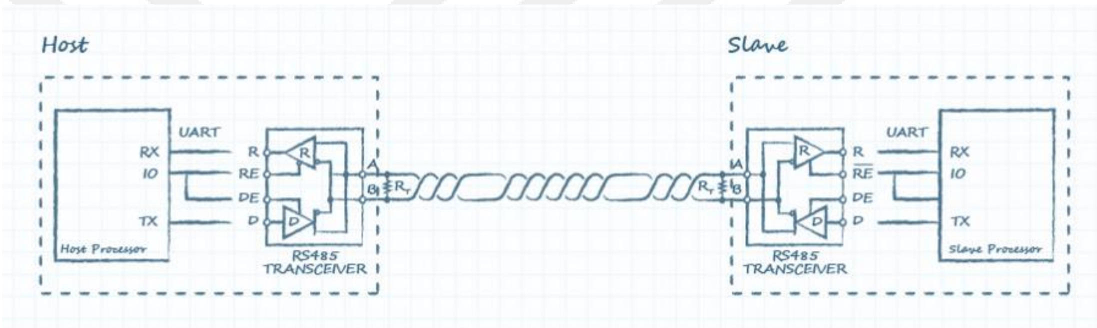

Figure 2.7 Common use of UART to RS-485

CHAPTER THREE
METHODOLOGY

In general, the components of the remote meter reading system consist of three parts: the digital electricity meter with electronic reading feature, the communication system for remote access, and the central management unit.

LoRa technology is new, so it is developing rapidly, and new networks are being established. Lora has low cost and low power consumption features. Compared with other solutions, this method has advantages such as low cost, wide coverage, low power consumption, and etc.

3.1 Reading Electricity Meter Data

Electricity meter is a device to measure the amount of electric energy consumed by an electrically powered device or a residence. Simple electricity meter devices which is shown in Figure 3.1 have a few main parts as display, power supply, measurement unit, memory unit, security unit, timing unit and microcontroller unit.

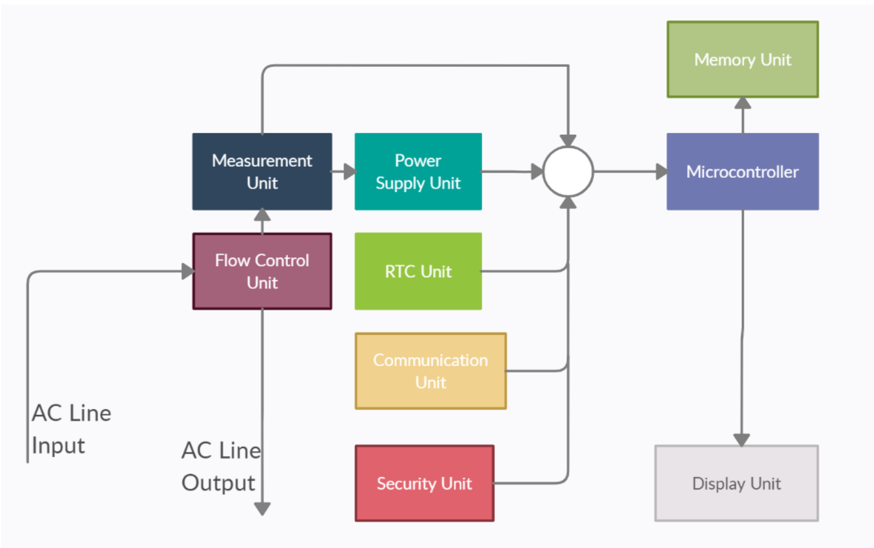

Figure 3.1 Electronic Electricity Meter Infrastructure

These units can be explained as below;

Power Supply Unit: It is the unit that supplies power to the circuit.

Measuring Unit: This unit differs in electricity meters, water meters and gas meters. There are many measuring techniques used in meters. In electricity meter, this unit measures voltage and current than it calculates the power consumption.

Display Unit: This unit forms the display of the Counter. All information about the meter can be displayed here. This unit usually consists of module LCDs or glass LCDs.

Flow Control Unit: It is the unit that provides control of the flow. It enables flow cutting and opening operations. For example, circuit breakers fulfill this job in electricity meters.

Security Unit: It is the unit that detects outside intervention to the meter. This unit consists of several switches and these switches create alarms.

Memory Unit: It is the unit where the information of the meter is kept. This unit holds everything related to the counter. Even if the meter is broken, this information can be obtained from the meter circuit. This unit consists of EEPROM.

RTC: Unit Real time clock unit. It allows to control the standard works done depending on the time.

Na Wu et al. (2016) defined the alternating current and voltage on the load at time t are as follows;

$$u(t) = U_m \sin \omega t = \sqrt{2} U \sin \omega t \tag{3.1}$$

$$i(t) = I_m \sin(\omega t - \varphi) = \sqrt{2} U \sin(\omega t - \varphi) \tag{3.2}$$

$u(t)$: instantaneous value of voltage at time t

$i(t)$: instantaneous value of current at time t

U_m : peak of voltage

I_m : peak of current

U : effective value of voltage

I : effective value of current

φ : phase difference between voltage and current

ω : angular frequency

Based on above equations, the average active power P for a period is as follows;

$$P = \frac{1}{T}\int_0^T u(t)i(t)dt = \frac{1}{T}\int_0^T U_m \sin \omega t I_m(\omega t - \varphi)\, dt = \frac{1}{T}\int_0^T UI[-\cos(2\omega t + \varphi) + \cos \varphi]dt = UI \cos \varphi \tag{3.3}$$

The electric energy W for a period is as follows;

$$W = \int_0^T u(t)i(t)dt = TUI \cos \varphi \tag{3.4}$$

Microcontroller Unit: It is a central unit that manages other units and controls all operations of the meter. This unit consists of a microcontroller. Generally used microprocessors are microcontrollers with 8 bits, flash rom and ram and embedded in many peripheral units (UART, SPI, I2C, timer, ADC....).

Electronic electricity meters have TS EN 62056-21 communication protocol. EN 62056-21 standard allows data exchange for electricity meters at local. This standard describes protocol and hardware properties for the local meter data exchange. International equivalent is DIN EN 62056-21-EQV.

Electronic Meter Specification Standards describe the common minimum coding structure (OBİS) for all electricity meters.

OBİS codes which is important for our application in Table 3.1.

Table 3.1 Basic OBİS Codes for the introduced system

0.0.0	Serial Number
0.9.1	Clock
0.9.2	Date
0.9.5	Weekday
96.1.3	Production Date
96.2.5	Calibration Date
96.6.1	Battery Status
96.70	Body Opening Alarm Time
31.7.0	R-Phase Current
32.7.0	R-Phase Voltage
1.8.0	Total Active Power
96.7.1	First Phase Interrupted Error Warning Counter

Based on electricity meter reading protocol, communication should be started with 300 baud rate and security unit allows to communicate when read command has been sent to meter. Then the electricity communication unit starts to communicate with 9600 baud rate and send all memory data via RS-485.We used in this study Makel M600 which is shown in Figure 3.2.

Figure 3.2 Makel Monophase M600 Electronic Electricity Meter (Personal Archive,2022)

3.2 Sending Electricity Meter Data via LoRa

In this study, Four-Faith F8L10T LoRa terminal which is shown in Figure 3.3 is used for LoRa communication. F8L10T terminal has RS232 and RS485 interface to connect directly to the serial device.

Figure 3.3 Four-Faith F8L10T Lora Terminal (Personal Archive,2022)

F8L10T LoRa terminal supports both gateway configuration and end node configuration as figured in Figure 3.4.

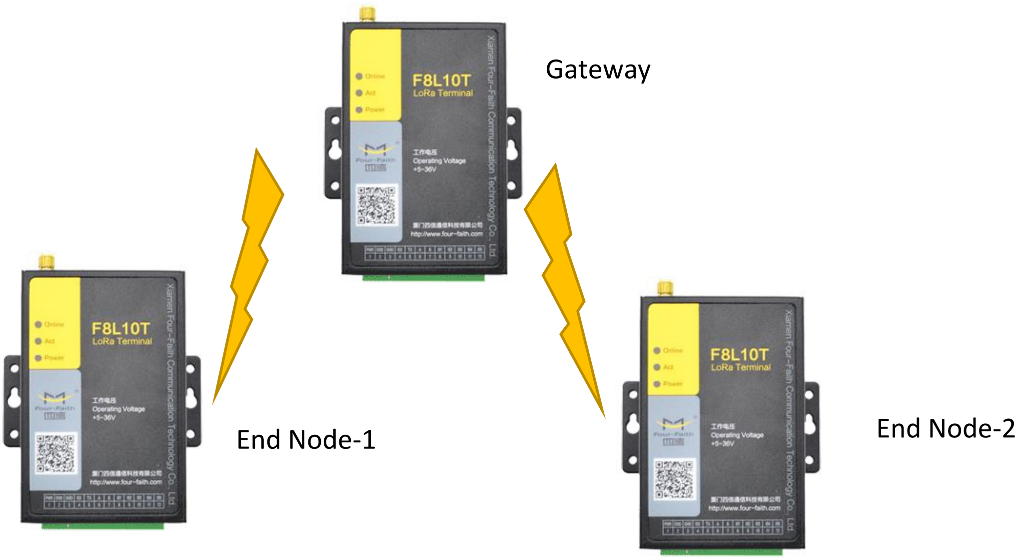

Figure 3.4 Simple LoRa Network Structure

3.3 Sending LoRa Data via Microwave

The Cambium Networks ePMP 1000 Integrated Radio offers more than 150 Mbps of real user throughput. Using 2x2 MIMO-OFDM technologies, the ePMP deployments attain industry leading data rates.

The ePMP 1000 Integrated Radio which is shown in Figure 3.5 can be designed as an unsynchronized Access Point, a Subscriber Module, or a Backhaul radio. This radio will operate as a client to an ePMP GPS Synchronized Radio in either a PTP or PMP deployment forming a GPS Synchronized solution.

Figure 3.5 Cambium ePMP 1000 Integrated Radio(Cambium,2019)

The ePMP 2000 System shown in Figure 3.6 involves a novel compressed high-performance Sector Antenna and a well-functioning, GPS-Synchronized Access Point (AP) Radio with Smart Filtering. The ePMP 2000 maintains up to 120 simultaneously active Subscriber Modules without any accomplishment degradation.

Figure 3.6 Cambium ePMP 2000 Radio with Sector Antenna(Cambium,2019)

Basic features of ePMP devices is detailed in Table 3.2.

Table 3.2 Basic Features of ePMP 1000 and ePMP 2000

CHANNEL SPACING	Configurable on 5 MHz increment
FREQUENCY RANGE	5 GHz: 4910 – 5970 MHz (exact frequencies as allowed by local regulations)
Channel Width	5 , 10 , 20 , 40 MHz
ETHERNET INTERFACE	100 BaseT
Network Management	HTTPs, SNMPv2c, SSH

3.4 Conversation Data Communication Protocols

Electronic electricity meter has RS-485 and we need to convert this protocol into RS-232 for LoRa terminal for sending correct reading codes to electricity meter. So, we add an Arduino development board.

We have developed a software to run on the Arduino board so that it can be used in both RS232 and RS485 protocols. However, we used an RS485 to TTL converter between the electricity meter and the Arduino board to make the hardware connection and for the software to work correctly. This system diagram is figured in Figure 3.7.

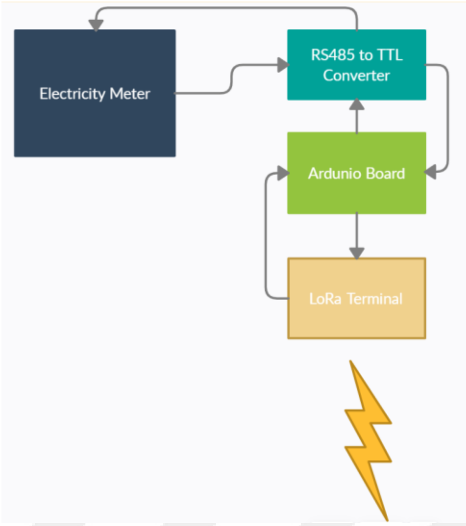

Figure 3.7 The Introduced System Diagram of Electricity Meter Side

Since the incoming data from the Data collect gateway node is transferred via RS232 over the Lora terminal, we had to make a protocol change here as well. For this reason, at this point, we have prepared a software to run on Arduino and converted the data to TCP/IP protocol. We transferred it to the microwave over HTTP and transmitted it to the center. This system diagram is figured in Figure 3.8.

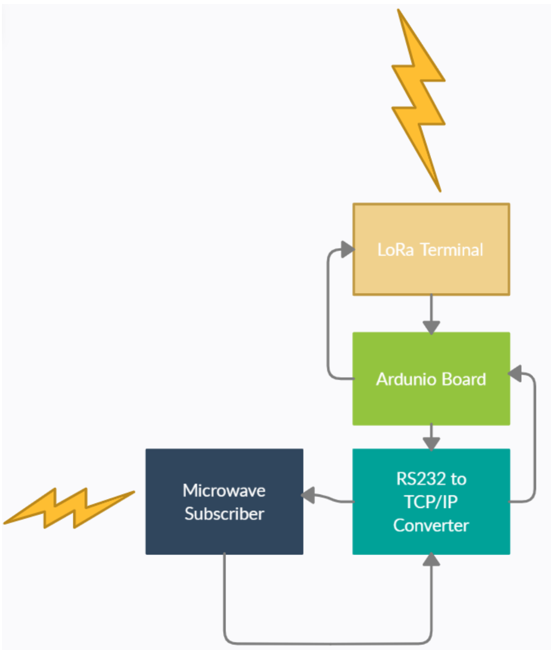

Figure 3.8 The Introduced System Figured Diagram of Data Collection Gateway Node

We read the data coming to the central point by microwave over HTTP as figured in Figure 3.9.

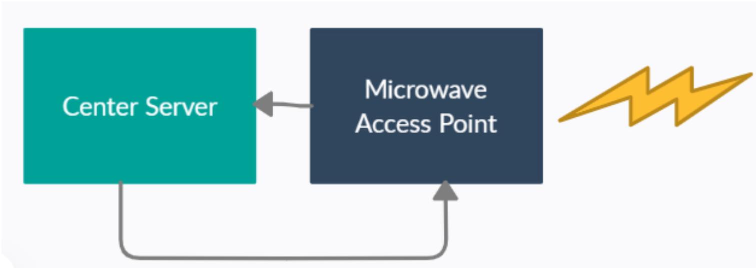

Figure 3.9 The Introduced System Figured Diagram of Center

Physical connection of Figure 3.3 is shown in Figure 3.10.

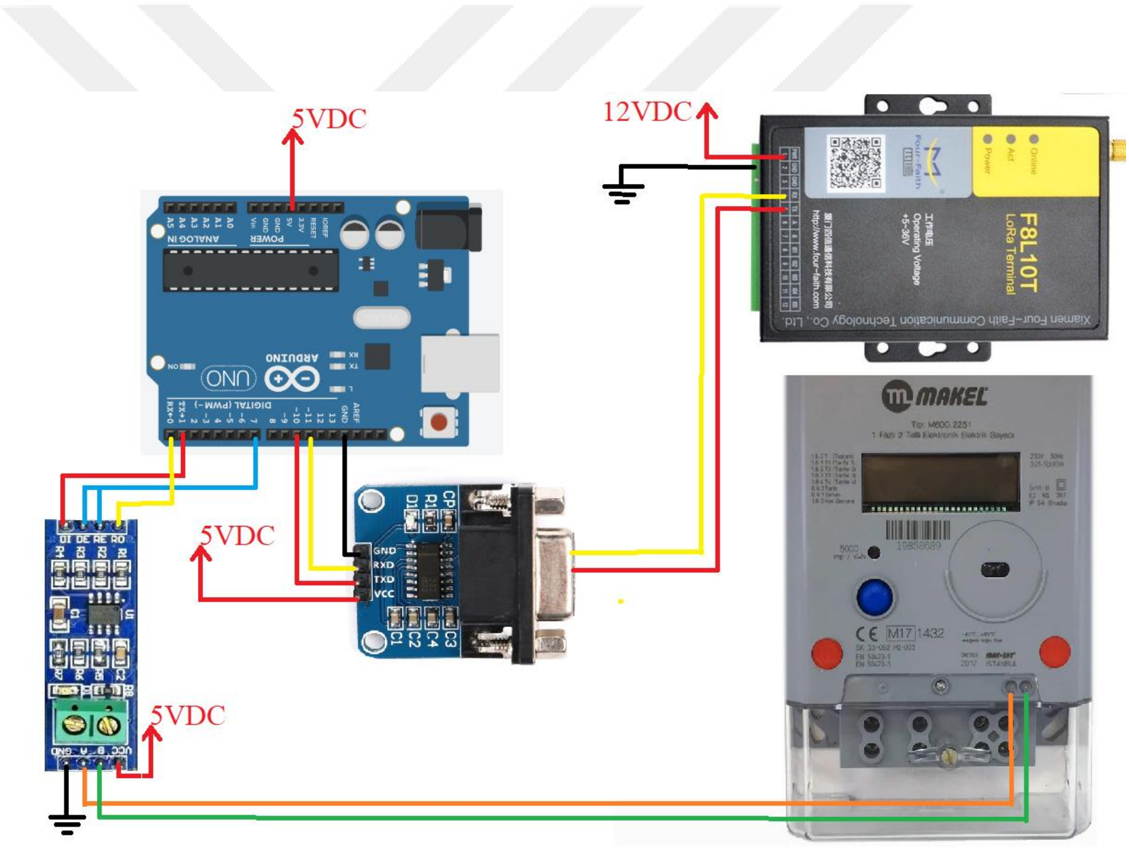

Figure 3.10 Connection Diagram of The Introduced System Figured

3.5 Commands of Electricity Meter

There are same commands for electricity meters based on TS EN 62056-21 Mod-C. These commands as like below ;

- 0 Long Reading Mode (All Info)
- 1 Programming Mode
- 6 Short Reading Mode
- 7 Past Information Mode
- 8 Alarm Mode
- 9 Outage Records Package

The information requested from the meters will be sent encoded with ASCII characters.

A data block involves a series of data lines, separated by LF (line feed) and CR (carriage return) characters. A data row can contain one or more data sets. A data set generally consists of an address identification number, value, unit and boundary characters. A data line cannot exceed 78 characters, including border characters.

Communication request message is shown in Table 3.4 based on TS EN 62056-21

Table 3.3 Request Message based on TS EN 62056-21

/	?	Device Address	!	CR	LF

/ : Start Character

? : Communication Request Character

! : End Character

CR+LF : Finish Character ("Carriage Return" and "Line Feed")

The device address is an optional field. It is a number given by the manufacturer and consists of a maximum of thirty-two characters. Characters can be "space", numbers from 0 to 9, lowercase and uppercase letters A to Z. The "0" characters at the beginning of the address are ignored. Even when no device address is sent, the sent devices respond to the command [IEC, 2006].

Protocol Mode C provides bidirectional data transmission with communication speed variation. Data transmission may include data reading, programming and special modes specified by the manufacturer. Communication starts at 300 bps, a confirmation message is sent to the counter according to the identification message. Communication starts according to the communication speed specified in this confirmation message [IEC, 2006].

3.6 Arduino Development Board Software

In the study, we have provided the necessary data transfer by changing the communication protocols in the transfer of data by using the software which we have prepared.

Each device has different communication protocol and interface so, we have to covert communication interfaces. Based on this necessity , we have prepared software for both side Arduino boards, accordingly communication protocols have been changed.

3.6.1 RS-485 to RS-232 Conversion

LoRa terminal supports transparent communications. When the Arduino get the commands from LoRa then it send the necessary commands to electricity meter via RS-485.

When the program on the Arduino starts, we first read to check that the data is coming from LoRa with the RS232 protocol. In order for Arduino to do this, we open the serial port and switch it to listening mode at a baud rate of 9600. Meanwhile, we start our communication with the converter we use to connect the counter with RS485 at a rate of 300 baud. Thus, we check whether there is a data request from the electricity meter by reading the incoming data, and if the message is to communicate with the electricity meter than we send the meter reading command to the electricity meter with the RX and TX pins of the Arduino.

Pin 7 of Ardunio is defined as control pin for the RS-485 port to determine the status at the time of sending and receiving. When this pin is HIGH, the communication is in the transmit direction, when it is LOW, the communication is in the receive direction.

In addition, the serial communication pins that we have defined as 10 and 11 pins, are assigned for RS-232 and create RX and TX channels by using software serial method.

When we send a command to the electricity meter, we can observe the working status with the leds which we connected to pins 13 and 8 of Arduino and they are for control purposes.

If the data coming from the LoRa terminal is to read the data from the electricity meter, with the written function, we first send a read command to the electricity meter at 300 baud rate and immediately change our serial port to 9600 baud rate and read the data from the electricity meter and assign it to the string we have defined. We transfer this string with LoRa by transferring it to the serial port which we have defined with LoRa.

You can find the flow chart of this software at Figure 3.11

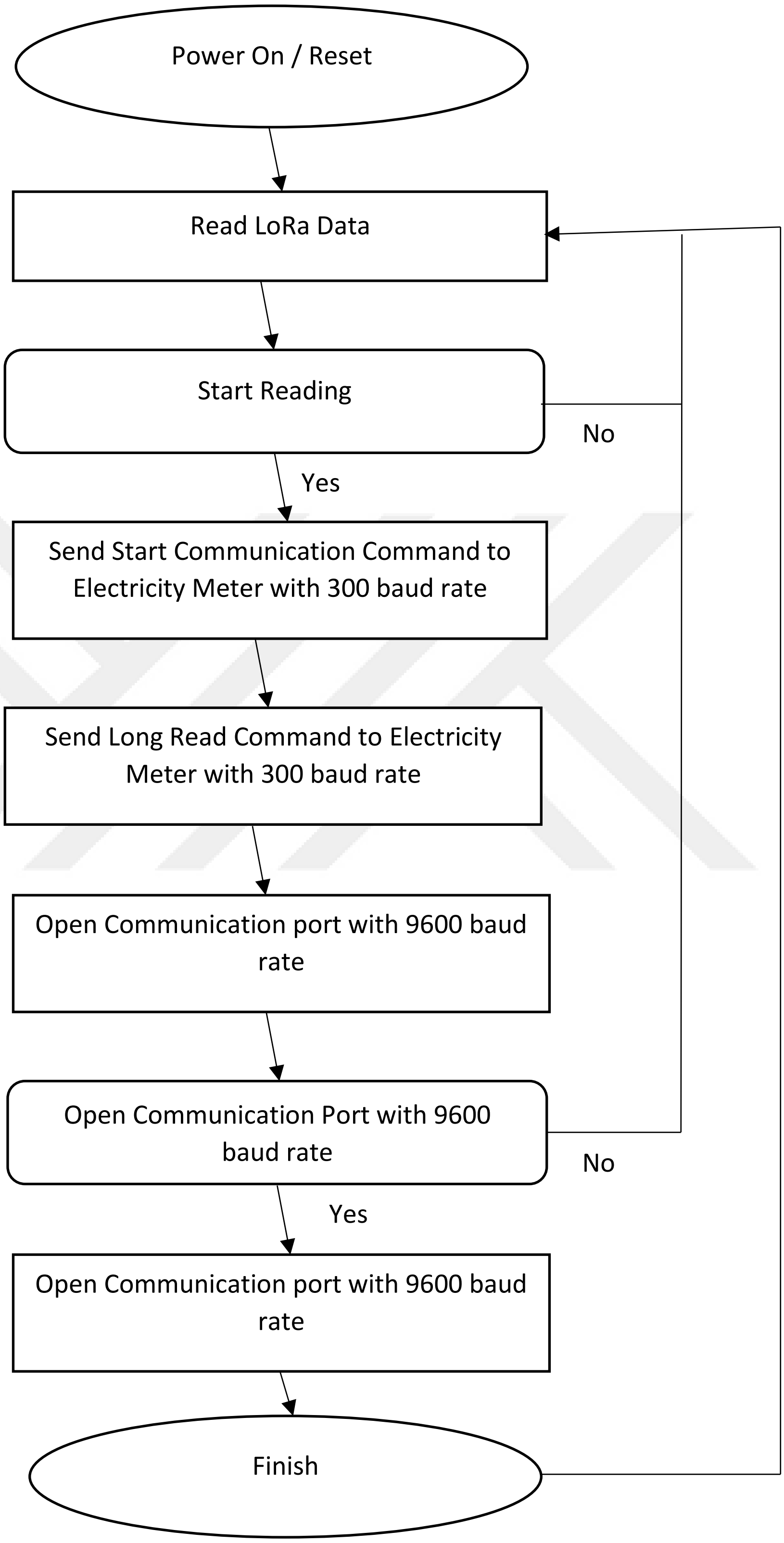

Figure 3.11 Algorithms of Arduino Software Electricity Meter Side

```
#include <SoftwareSerial.h>
SoftwareSerial mySerial(10, 11); //LoRa TX, RX // (Send and Receive)
#define RxTxControl 7  //RS485 Direction control
#define RS485Transmit    HIGH //RS485 activation when RS485 is transmit mode
#define RS485Receive     LOW //RS485 activation when RS485 is receive mode
#define LEDPin      13       //Data control LED
#define KPin        8       //Data control LED
unsigned long simdiki_zaman;
unsigned long eski_zaman;
unsigned long simdiki_zaman1;
unsigned long eski_zaman1;
int i;
String_serino=" ";
String inputString = " ";         // string structure to keep incoming data
bool string_Complete = false;  // the string structure is complete or not
void setup()
{
pin_Mode(RxTxControl, OUTPUT);//Control pin for RS485
pin_Mode(LEDPin,OUTPUT);
pin_Mode(KPin,OUTPUT);
Serial.begin(300,SERIAL_7E1);//change serial config of power meter
mySerial.begin(9600);
serino.reserve(200);
```

```
inputString.reserve(300);
digitalWrite(RxTxControl,RS485Transmit);///Ardunio transmit mode & RS485 receive mode
}
void loop()
{
   while(mySerial.available())
  {//When RS485 or LoRa connection avaliable
   digitalWrite(RxTxControl,RS485Transmit);///Ardunio transmit mode & RS485 receive mode
   Serial.end();
   Serial.begin(300,SERIAL_7E1);//change serial config of power meter
   digitalWrite(LEDPin, HIGH);
   digitalWrite(KPin, HIGH);
   delay(5);
   String merkezden_gelen1 = mySerial.readString();//Read LoRa
   String serino_oku = "Seri No Oku";//Start to read serial no command
   String sayac_oku = "Sayac Oku";//Start to read information command
   if(merkezden_gelen1==serino_oku)//If request is that reading power meter
      {
         digitalWrite(RxTxControl,RS485Transmit);///Ardunio transmit mode & RS485 receive mode
         delay(5);
         Serial.println("/?!"); //Send reading start command to power meter
```

```
          delay(500);
          digitalWrite(KPin, HIGH);
          digitalWrite(LEDPin, LOW);
          delay(5);
          digitalWrite(RxTxControl, RS485Receive);//Ardunio receive mode &
RS485 transmit mode
          delay(1);
              void serialEvent();
          for(i=0 ; i<1 ; i++)
          {
          String merkezden_gelen2 = mySerial.readString();//Read LoRa
            if(merkezden_gelen2==sayac_oku)
              {
                digitalWrite(KPin, LOW);
                digitalWrite(LEDPin, HIGH);
                digitalWrite(RxTxControl,RS485Transmit);///Ardunio transmit
mode & RS485 receive mode
                delay(5);
                Serial.print(0x6,HEX); //Send ACK begining of start command to
power meter
                Serial.println("050"); //Send reading start command to power meter
                delay(500);
                digitalWrite(RxTxControl, RS485Receive);//Ardunio receive mode
& RS485 transmit mode
                delay(1);
```

```
                    Serial.end();

                    Serial.begin(9600,SERIAL_7E1);

                      void serialEvent();

                      inputString="";

                      merkezden_gelen2 ="";

                  }

               }

            }

    }

}

void serialEvent()

{

  digitalWrite(LEDPin, LOW);

  digitalWrite(KPin, LOW);

  while (Serial.available())

     {

      // obtain new byte:

      char in_Char = (char)Serial.read();

      // adding with inputString:

      inputString += in_Char;

      // if the incoming character is a newline, set a flag so the main loop can

      // do something about it:

      if (in_Char == '\n')
```

```
      {
          string_Complete = true;
      }
    if (string_Complete==true)
      {
          simdiki_zaman=millis();
          eski_zaman=millis();
          while(simdiki_zaman-eski_zaman <2)
            {
              simdiki_zaman=millis();
              mySerial.print(inputString);
              inputString = "";
              digitalWrite(LEDPin, LOW);
              digitalWrite(KPin, LOW);
              delay(5);
              string_Complete = false;
            }
      }
  }
}
```

3.6.2 RS-485 to TCP/IP HTTPs Conversion

When the LoRa gateway get the data from electricity meter side, it should send the data via MW to center. But MW has TCP/IP protocol HTTPs interface. So, we must convert the data to ethernet protocol by using another Arduino and ethernet shield. We can use ready WebClient codes for this conversation.

At the LoRa gateway node, we need to transfer the data from the meter via microwave, and for this we need to combine LoRa and microwave.

For this reason, we have provided conversions over Arduino, which we use here, in order to take the communication protocols with RS232 and convert them to IP. First of all, we made our definitions by assigning a static IP to Arduino. Afterwards, we set the baud rate to 9600 for the data which we will receive via the serial port.

We ensured that the information we received from the serial port was transmitted directly to the server side via the microwave with the ethernet port.

On the server side, we reach the Arduino by reaching the IP address with a remote microwave and we ensure that the commands we want are transmitted to the electricity meter side.

During this process, we provide 2 different wireless communication connections by connecting 2 different technologies.

3.7 Experimental Results of Tests

In our tests, we saw that LoRa is sending electricity meter data at 500 meters which is shown in Figure 3.12, 800 meters which is shown in Figure 3.13 and 1700 meters which is shown in Figure 3.14 without any data loss. This distance can be upgradeable up to 3 kilometers by a line of sight and signal level. But this distance is not enough to collect all regional electricity subscribers in a city. So, the structure of the study design is based on LoRa gateway with microwave nodes. These nodes will send the collected data to the center via point-to-multipoint microwaves (Figure 1.1).

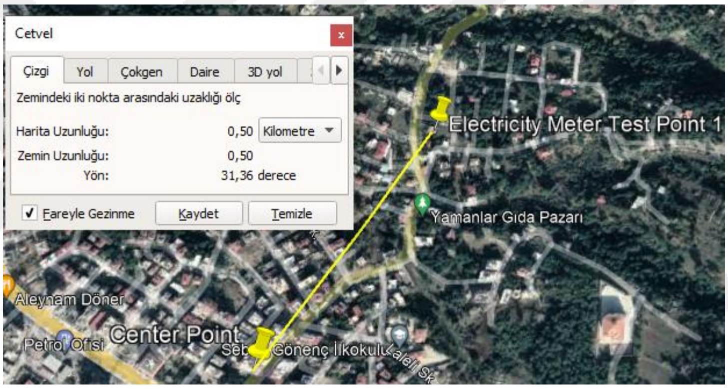

Figure 3.12 LoRa Test Point 1 and Center Point

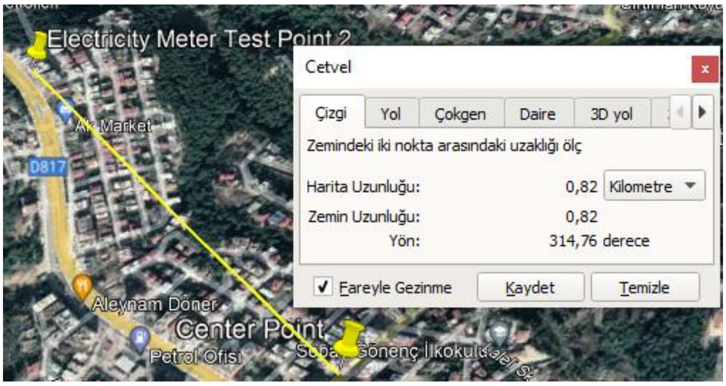

Figure 3.13 LoRa Test Point 2 and Center Point

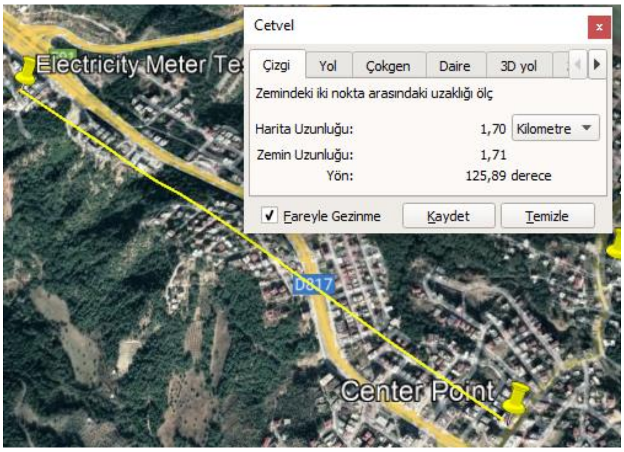

Figure 3.14 LoRa Test Point 3 and Center Point

We have been successful at data transmission in our microwave test which was at a 9 km distance. The LoRa data collection gateway node which we call the central point had LoRa coverage area of approximately 1.7 km. The data of the electricity meter which was in the coverage area was received with LoRa and transmitted to the point 9 km away by using a microwave link which is shown in Figure 3.11.

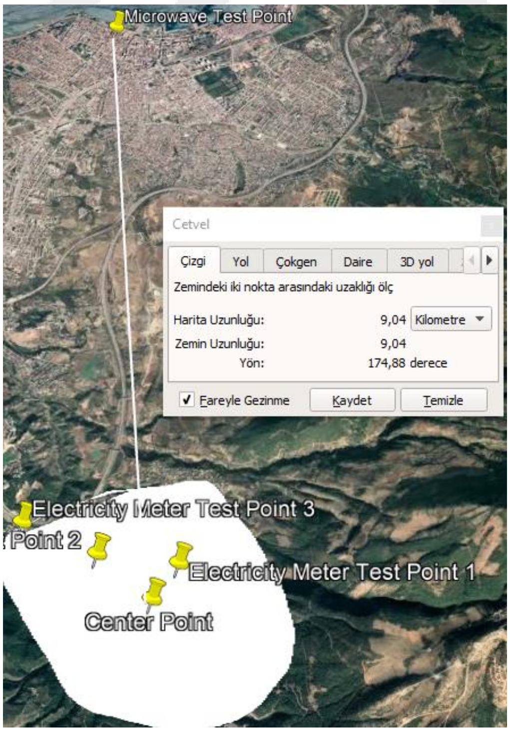

Figure 3.15 LoRa Test Coverage and Microwave Test Distance

CHAPTER FOUR
CONCLUSION

So far many electricity subscribers who accommodate remote electricity meter reading systems, transmit the collecting data through Global System for Mobile Communications(GSM). That means an extra monthly cost. Long Range Area (LoRa) communication allows low energy, low cost, long-distance, and free communication. With all these advantages, Long Range Area (LoRa) technology also has some disadvantages. These are, having low data capacity, being a new technology, and not having enough applications until now. A lot of wireless communication companies have been working on developing LoRa. LoRa is the future of many IoT applications.

In this study, we combined the LoRa and microwave link because of the ability to send more data and to longer distances. It has been shown that this transmission is possible by using long-range area network and microwave link together. With the wide-ranging application of current work in the country's electricity sector, especially in the regional electricity, a big step will be taken to build an intelligent grid for meter readings. Due to the effective result of the study, it is possible to combine two unlicensed band wireless communication technologies, this platform will have many posts, and a large novel intelligent grid for reading the electricity meter readings.

The most difficulties of the study were the combination of the communication protocols and interfaces. Especially, sending the correct command and getting the correct data from the electricity meter was challenging. So, Arduino development boards were used to solve this problem. By using software developed at Arduino, we could get commands which provided by LoRa via serial communication RS-232 interface and sends data to the electricity meter via RS-485 interface.

On the other side of the communication part, which is used to combine LoRa and microwave link, is converted to TCP/IP protocol via the Arduino development board. By the software on the Arduino, the Arduino is acted as a web client and transferred the LoRa data via the microwave link with its IP address. In this software, remote access is provided with a fixed IP address. The operator in the center can access the electricity meter at the endpoint and reach the desired data with remote access.

In this application, 2 different wireless communication technologies were combined, preventing data loss and providing transmission over longer distances. The most effective part used in combining 2 different wireless communications is the conversion of communication protocols to each other as a software part.

In performed tests, it is seen that LoRa is sending electricity meter data at 500 meters, 800 meters, and 1700 meters without any data loss. This distance can be upgradeable up to 3 kilometers by a line of sight signal. But this distance is not enough to collect all regional electricity subscribers in a city. So, the structure of the study design is based on LoRa gateway with microwave nodes. These nodes will send the collected data to the center via a point-to-multipoint microwaves link.

While the LoRa and microwave technologies used to have a longer range and lower power consumption than Zig-bee, Wi-Fi, and Bluetooth technologies, it also has less cost than the Global System for Mobile Communications (GSM) system. Because LoRa and microwave link, which serve in the unlicensed band, serve long distance, low power consumption, and free license band.

For future works can install a LoRa network to reduce the costs and frequency capacity availability by removing the microwave from the system. It’s possible to use existing LoRa networks for example Helium networks. Helium's Technology permits anyone to build out cost-effective, massive wireless infrastructures in an entirely novel business model that aids everyone. The network aims to offer connectivity to the IoT sensor devices in areas where wireless or mobile coverage is minimum or needs too much power.

Also, for this application, it’s possible to replace the Arduino with other development boards for example, Raspberry, Beagle bone, STM32, etc. If the software will be designed for the other boards it can be allowed to us for removing some hardware from the system.

This designed and introduced system can be used in many IoT applications such as smart home, energy monitoring, sensor control, etc.

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