디지털산업정보학회 논문지 제14권 제3호-2018년 9월
http://dx.doi.org/10.17662/ksdim.2018.14.3.029

COS LoRa 기반의 임베디드 시스템 설계*

홍 선 학** · 조 경 순*** · 윤진섭****

Embedded System Design with COS LoRa technology

Hong Seonhack · Cho Kyungsoon · Yoon Jinseob

<Abstract>

It is the approach of embedded system design that analyzes COS(Cut Out Switch) failure in the power distribution and an instantaneous breakdown of power distribution supply could cause the weakness of industrial competence and therefore we need to feed the stable power distribution with developing the technology of open-source embedded system. In this paper, we apply the LoRa technology which is the Internet of Things(IoT) protocol for low data rate, low power, low cost and long range sensor applications. We designed the hardware and software architecture setup and experimented the embedded system with network architecture and COS monitoring system including accelerometer for detecting the failure of distribution line and sensing the failure of its fuse holder by recognizing the variation and collision and afterwards sending the information to a gateway. With experimenting we designed the embedded platform for sensing the variation and collision according to the COS failure, monitoring its fuse holder status and transferring the information of states with LoRa technology.

Key Words : COS(Cut Out Switch), LoRa, Open Source Platform, Embedded System, IoT

Ⅰ. 서론

It is indispensible for high quality of power distribution to compete with the advanced information society of occupying the stable performance in the industry and daily lives. The instantaneous breakdown of power distribution supply could cause the weakness of market competence of industry fields and therefore we need to feed the stable power distribution with developing the technology of distribution power system. The electric utility system is usually divided into three categories that are generation, transmission and distribution.

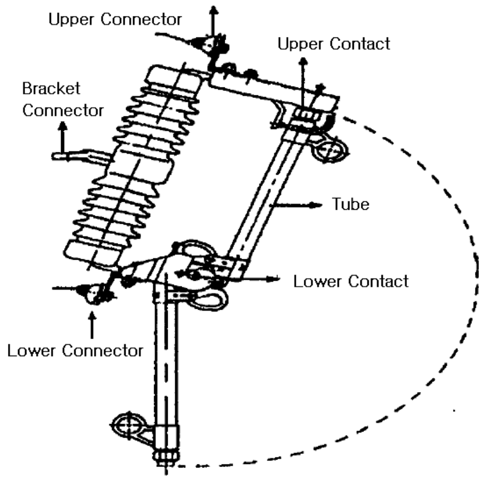
The distribution system consists of a much

* 본 연구는 2018년 서일대학교 교내학술연구비 지원으로 수행되었음.
** 서일대학교 컴퓨터응용전자과 교수
*** 서일대학교 컴퓨터응용전자과 교수
**** 서일대학교 컴퓨터응용전자과 교수

wider variety of components, loads and interconnection devices[1]. A primary distribution feeder is connected with various equipments such as fuses, distribution transformers, reclosers and switches. The system is exposed to many interruption possibilities, the most important of which are those due to primary overhead or underground cable failure or transformer failure. The feeder utilize cut-out switch (COS) to restrict the interruption caused by failures of overhead transformer and secondary loads.

<Figure 1> shows the COS that is consisted with porcelain body, steel connector and fuse cartridge. The fuse cartridge has fuse links its inside that includes short fusible element section to sense the overcurrent. Attached to this there is a long conductor, commonly called a fuse leader which connected with the rest of the fuse hardware. It begins to substitute the porcelain body with polymer but the rest part of COS having porcelain body.

Fuses are the most effective and fusible protectiondevices. COS is the typical expulsion fusing device that the most basic and efficient type of overcurrent sensing device presently being used by the utility industry. That is also one of the most reliable devices that they can provide their function for over 30 years with essentially no maintenance[2]. Its main function is current interruption. What they actually do is setup a high dielectric environment that prevents the arc from re-establishing when the fault current passes through a current zero.



<Fig 1> Structure of cut-out switch

When the fault current flows, the fusing element will melt making an arc inside the fuse cartridge. The produced arc will rapidly create gases from vulcanized fiber located in close proximity to the fuse element[3]. The gases generated by the fiber is to deionize and remove arc generated ionized gases and allow a rapid buildup of dielectric strength that can withstand the transient recovery voltage and steady state power system voltage. The porcelain body should sustain the fuse cartridge with enough mechanical strength during service period[4].

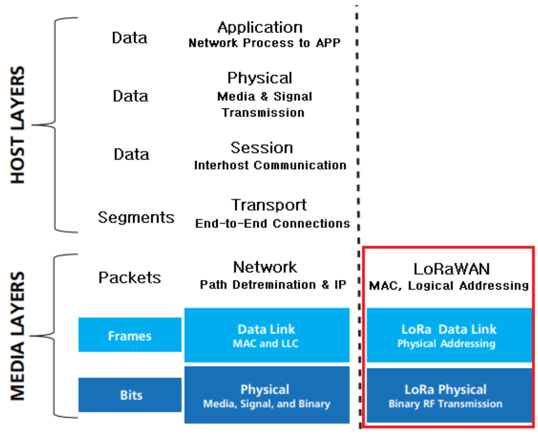
In this paper, we apply the LoRa technology which is the Internet of Things(IoT) protocol for low data rate, low power, low cost and long range sensor applications in a variety of global markets. Especially there are thousands of LoRa end-nodes[5] connected to gateways around the world. We provide a high-level overview of COS failure detection technology[6] with LoRa modulation open protocol and network topology, and experiment the major steps necessary to convert an accelerometer which measures the specific acceleration. Being the acceleration or rate of change of velocity in a body in its own instantaneous rest frame is not the same as coordinate acceleration, comparing to the acceleration in a fixed coordinate system.

II. LoRa Technology

LoRa(short for long range)[7] is a spread spectrum modulation technique derived from Chirp Spread Spectrum(CSS) technology. It offers a trad-off of sensitivity versus data rate and bandwidth and it uses orthogonal spreading factors which allow the network to make adaptive optimizations of an individual end-node's power level and data rates with a goal of preserving end-node battery life.

In this paper, a sensor of accelerometer which detected the failure of COS located to a gateway should be transmitted at a low spreading factor since very little budget is needed. Embedded system which had an accelerometer including COS located several miles from a gateway will need to transmit with a much higher spreading factor as the increased spreading factor will provide increased processing gain resulting in higher RX sensitivity, but at a lower data rate.

LoRa itself is purely a physical layer implementation as defined by the OSI 7 Layer Network Model in <Figure 2>.

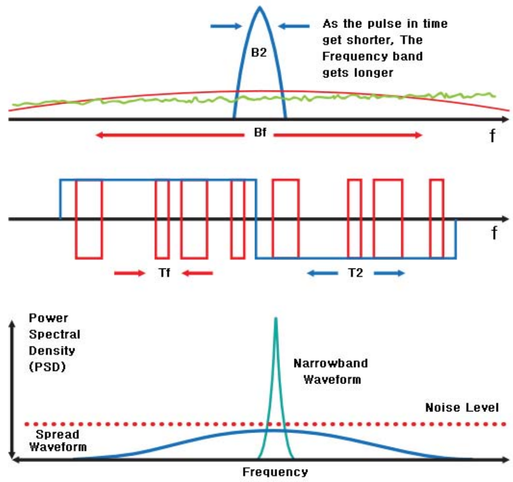


<Fig 2> OSI 7 Layer Network Model

Instead of a cable, the air is used as a medium to transmit the LoRa radio waves from an RF transmitter in an embedded system including COS to an RF receiver in a gateway and vice versa.

In a traditional LoRa system[8], the carrier phase of the transmitted signal changes according to a code sequence as shown in <Figure 3>. When multiplying the data signal with a pre-defined bit pattern at a much higher rate, also known as a spreading code (or chip sequence), a faster signal is created that has higher frequency components than the original data signal and as such, spreads the signal bandwidth beyond the bandwidth of the original signal.

In RF terminology, the bits of the code sequence are called chips, in order to distinguish between the longer un-coded bits of the original data signal. When the transmitted signal arrives at the RF receiver, it is multiplied with an identical copy of the spreading code used the RF transmitter, resulting in a replica of the original data signal.



<Fig 3> LoRa Modulation

In LoRa terminology, the amount of spreading code applied to the original data signal is called the spreading factor(SF). There are a total of six spreading factors defined in LoRa Modulation: [SF7....SF12], A signal modulated with a larger spreading factor will be able to travel a longer distance and still be received without errors by the RF receiver compared to a signal with a lower spreading factor.

<Table 1> LoRa spreading factor

Spreading Factor (for UL at 125KHz)	Bit Rate	Range (dependent on terrain conditions)	Time on Air for an 11-byte payload
SF10	980 bps	8 km	371 ms
SF9	1760 bps	6 km	185 ms
SF8	3125 bps	4 km	103 ms
SF7	5470 bps	2 km	61 ms

<Table 1> shows the four different spreading factors that can be used for uplink(UL) messages on a 125KHz channel. Downlink messages use 500KHz channels that can use all six available spreading factors. it shows the equivalent bit rate as well as the estimated range[9]. It also shows the time-on-air(TOA) values for payload for each of the four spreading factors.

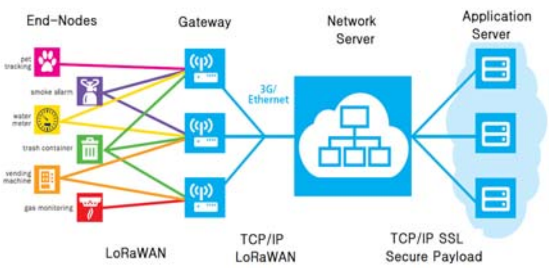
Ⅲ. Embedded System Architecture

We experimented the embedded system with network architecture and COS including accelerometer for detecting the failure of distribution line. Therefore, we designed the embedded platform for sensing the variation and collision according to the COS failure, monitoring its fuse holder status and for transferring the information of its states with LoRa technology.

3.1 Network Architecture

In this paper, we used star topology for LoRa network as shown in <Figure 4>. Unlike a mesh topology, a star topology is ideal for power constrained (i.e., battery operated) end-nodes because it only has to transmit its own messages[10] of COS status and does not waste battery capacity transferring messages from other end-nodes.

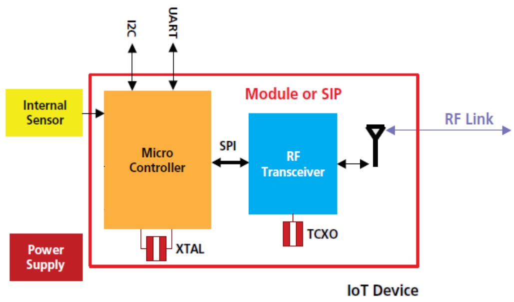
A LoRa network consists of one or more LoRa gateways that are all connected to one central network coordinator, or so called network server[11]. Unlike cellular base stations which have a high complexity of hardware and software, and therefore a high cost needed. Each gateway received a Loa modulated radio message from end-nodes within radio distance. Gateways can be connected to the Network server over Wi-Fi, hard-wired ethernet or even a cellular connection. In essence, Gateway is a bridge between LoRa and IP frame.



<Fig 4> LoRa Star Network Topology

3.2 Hardware Setup

In this paper, Embedded platform have some components as depicted in <Figure 5>.



<Fig 5> Embedded Platform Block Diagram

We used an internal battery though an external power source which could a small solar cell connected to a re-chargeable battery. Since one of the main objectives of LoRa technology is to use sensors that can operates on the same battery for years, it is crucial to estimate the battery life for the particular sensor design. There are five particular power consumption modes of the hardware must be determined.

- ▣ OFF/SLEEP mode : all electronics are turned off or in some kind of sleep mode.
- ▣ IDLE mode : radio, sensor. all of other components turn off except for the microcontroller
- ▣ RUNNING : Platform is operational (no RF transmission)
- ▣ LoRa TX : Device is sending data over the LoRa Radio TX output
- ▣ LoRa RX : Device is receiving data over the LoRa Radio RX input.

The next step is to calculate how much current the device will consume in each of these modes. Then, one has to estimate how long the device will be in each of these modes per hour, day or week. We used the internal sensor, accelerometer which is detected the variation and collision strength of COS fuse holder caused by failure of distribution system. The accuracies of accelerometer are the variation of ±90°,±1g, the collision strength of ±12g in this paper.

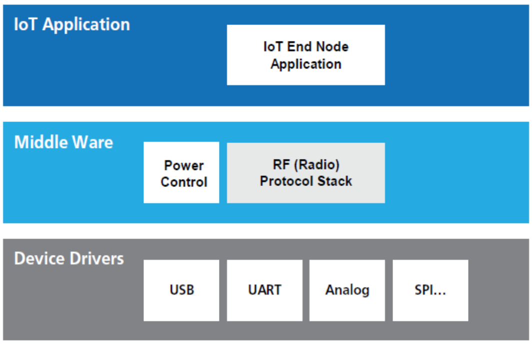
Microcontroller runs the software in order to control the end-node; sampling of the sensor data, formatting of the sensor data into the transmission protocol's payload format, scheduling of radio messages to some kind of gateway, communication with the network controller[12].

Antenna is a key component for reaching the maximum distance in the wireless communication link between Embedded platform and LoRa gateway it will connect to. The goal of an antenna is to transform electrical signals into RF electromagnetic waves, propagating into free space(TX mode) and to transmit RF electromagnetic waves into electrical signals(RX mode)[13].

There are five kinds of antenna which are wire type, PCB type, Chip type, Coil and External type in the electronic circuits. We used the wire type antenna which is took up a fraction of the board space compared to a PCB trace antenna, but will add bill of material and assembly cost[14,15].

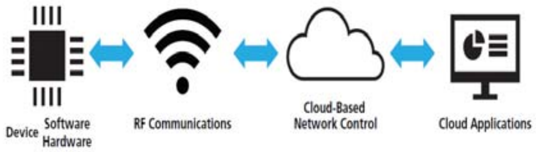
3.3 Software Setup

We configured the software design architecture as depicted in <Figure 6>. First there will be an assortment of lower level device drivers to connect to USB, UART, analog or digital interfaces, in essence of providing a hardware abstraction layer to the middleware.



<Fig 6> Device Software Architecture

The middleware layer implements any communication protocol type functions. Finally, the application layer contains the code that implements the device functionality and behaviour. The scope of the software development will depend on the implementation of the hardware architecture of the LoRa end-nodes. typically, the software development in a LoRa device conversion will involve replacing the current communication protocol stack with a LoRa protocol. In this paper, We have completed a high-level LoRa protocol and network procedure as shown in <Figure 7>, and theres are four key steps to IoT solution. and therefore, we have the device hardware and this would be some kind of end-node with embedded platform[16].



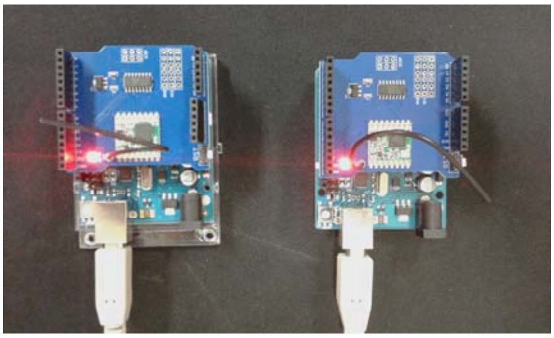
<Fig 7> End-Node technology Stack

Ⅳ. Experimenting Procedure

The LoRa Shield is a long range transceiver on a open source shield and based on open source library. The LoRa Shield[17] allows the user to send data and reach extremely long ranges at low dat rates. It provides ultra-long range spread spectrum communication and high interference immunity whilst minimizing current consumption.

Using LoRa modulation technique, the LoRa Shield can achieve a sensitivity of over -148dBm using a low cost crystal and bill of materials. The high sensitivity combined with the integrated +20 dBm power amplifier yields industry leading link budget making it optimal for any application requiring range or robustness. LoRa also provides significant advantages in both blocking and selectivity over conventional modulation techniques, solving the traditional design compromise between range, interference immunity and energy consumption.

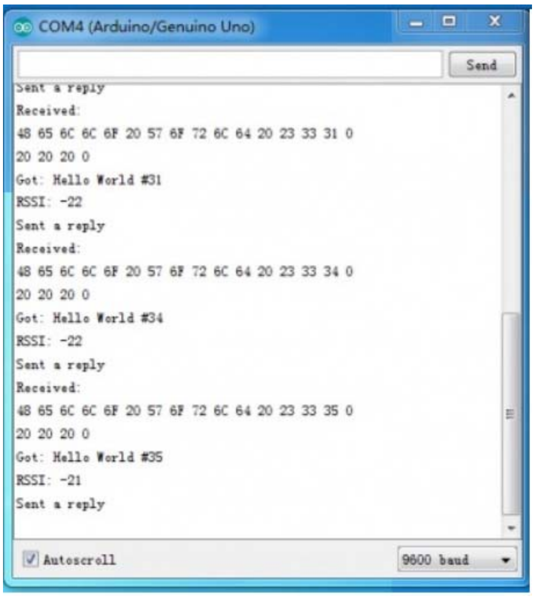
In this paper, we used two LoRa Shields to transmit and receive signal, there are some API library in the RadioHead Library[18], the operation is shown like the <Figure 8>. Connect two Lora Shields with open source board and connect them to computer via the USB cable[19].



<Fig 8> End-Node technology Stack

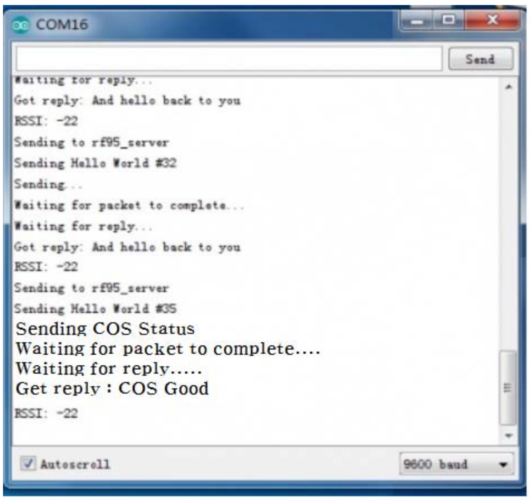
We used the Lora Shield and open source platform board as the server to transmit signal and the other Lora shield and open source platform as the client to receive signal here[20].

In each serial monitor window, we'll need to set the baud rate to 9600 and we can see them communicating well. The <Figure 9> shows the result of server side message in order to transmit data with LoRa technology[21].



<Fig 9> Server side message

The <Figure 10> shows the result of client side message in order to receive data with LoRa technology.



<Fig 10> Client side message

Ⅴ. Conclusion

In this paper, we implemented the Embedded platform with LoRa communication and COS failure in the distribution system. Failure analysis of COS caused electricity outage in distribution system and the majority causes are burned down of fuse cartridge and fractured porcelain body. Especially we experimentally designed the embedded system and made hardware platform. At this point we acknowledged a certain level of LoRa communication technology. Afterwards, we would enhance the performance of LoRa embedded platform with adapting various technologies of monitoring the COS failures in these fields.

참고문헌

[1] Jongman Joung, Dong-Myeong Kim & Myung-Ho Choi, "Failure Analysis of COS used in Distribution System," Journal of International Council on Electrical Engineering, JICEE, 2011.010.3, pp.264-268.

[2] Tinder, Richard F. Relativistic Flight Mechanics and Space Travel: A Primer for Students, Engineers and Scientists. Morgan & Claypool Publishers, ISBN 978-1-59829-130-8, pp.33-42.

[3] 심판섭, "수변전 설비에서 변압기 보호용 COS에 관한 연구," 호서대학교 대학원, 안전공학과 전기안전전공 박사학위 논문, 2003.

[4] 이홍용, "22.9kV 배전용 COS 품질 향상에 관한 연구," 대전산업대학교, 산업대학원, 2000.5.

[5] http://en.wikipedia.org/wiki/LoRa

[6] 황유섭, "흡음장치를 내장한 하이브리드형 COS 연구," 충주대학교 제어계측공학과, 2011.12.

[7] LoRa Mote User;s Guide, Microchip, 2015.

[8] Migrating an Internet of Things(IoT) Sensor Design to LoRaWAN, Sementech White Paper, 2018,05.

[9] Enabling Wide Area IoT Solutions with machineQ, A Comcast Service, machineQ., 2017.

[10] Hong Seon Hack and Choi Young Woo, Opensource MongoDB with studying Node.js. SungAnDang Pub. 2016. 03.

[11] Hong Seon Hack, "Mobile Embedded USN platform Design," Korea Institure of Communications and Information Sciences, 37, 4th, 08. 2012.

[12] Oh Il Suk, Computer Vision – From Basic to Recent Mobile Application, Hanbit Media, 07. 2014.

[13] Hong Seon Hack, Cho Kyung Soon, "Computer Vision Platform Design with MEAN Stack," Korea Society of Digital Industry and Information Management. 09. 2015. pp.79-87.

[14] Hong Seon Hack, "Mobile Arduino Embedded Platform Design," Korea Society of Digital Industry and Information Management. 4th, 12. 2013, pp.33-41.

[15] Hong Seon Hack, "Real Time Linux System Design," Korea Society of Digital Industry and Information Management. 10th, 06. 2014, pp.13-20.

[16] Hong Seon Hack, Cho Kyung Soon. "3D Scanning Embedded System Design," Korea Society of Digital Industry and Information Management. 13th, 12. 2017, pp.49-56.

[17] Jeff Dickey, "Write Modern Web Apps with the MEAN Stack," PEACHPIT PRESS, 2015.

[18] Sei-Hyun Lee, Doo-Kee Park, Kyung-Wan Koo, Sang-Ok Han, Dept. of Electrical Eng. Chunnam National University, "Analysis of Electrical Field Distribution in an Insulator of COS using FEM," 12, 1996.

[19] Dominique D.Guinard and Vlad M. Trifa, "building the Web of things with examples in Node.js and Raspberry Pi," Manning Publisher, 2016.

[20] 이리나, 이가람, 김호원, "LoRa 기술 분석," 2017년 한국통신학회 하계종합학술발표회, 부산대학교, 2017.

[21] Patrick Mulder and Kelsey Breseman, "Node.js for Embedded Systems," O'REILLY, 10. 2016.

■ 저자소개 ■

홍 선 학
(Hong Seonhack)

1992년~현재
서일대학 컴퓨터응용전자과 교수
1994년 광운대학교 대학원 박사 졸업

관심분야 : 제어응용, 임베디드 리눅스 설계
E-Mail : hongsh@seoil.ac.kr

조 경 순
(Cho Kyoungsoon)

1998년~현재
서일대학 컴퓨터응용전자과 교수
2008년 광운대학교 대학원 박사 졸업

관심분야 : 전기전자 재료응용
E-mail : kscho@seoil.ac.kr

윤 진 섭
(Yoon Jinseob)

1991년~현재
서일대학 컴퓨터응용전자과 교수
2002년 동국대학교 대학원 박사 졸업.

관심분야 : 정보기술, 반도체 설계
E-Mail : js22y@seoil.ac.kr

논문접수일 : 2018년 08월 16일
수 정 일 : 2018년 08월 28일
게재확정일 : 2018년 09월 11일