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Coverage Comparison of LoRa and APRS

Abstract

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<https://docs.google.com/document/d/1SholShRExXLCmzu9jXzBOb05KF8RPzGBn4Qy4qiX28A/edit#>

**Thesis Purpose: Feasibility of Networking Technology for Smart Farm : LoRa vs APRS**

1. **INTRODUCTION - Chaehee , Lydia**

* 스마트 팜의 도입과 요즘 뜬다
  + 요즘 실태 어떤지
  + 저예산, 보안, 배터리 등 요소가 중요함
    - 증거 (Farmer’s survey)
* LoRa 와 APRS 기술의 특징 및 이래서 얘네를 써보고자 한다
  + 참고문헌
  + 증거
* 어떤게 스마트팜에 더 어울릴까?
  + 그래서 비교 테스트를 할거다

Abstract: Smart Farm IoT 관련 얘기 추가

Smart Farms and IoT(Internet of Things) have an inseparable relationship. Sensors, gateways, servers, databases, and web based application are all connected in smart farms. Hence, the decision of the networking technology is very vital when running a smart farm. LoRa(Long Range) has been the most suggested candidate for smart farms. Theoretically APRS((Automatic Packet Reporting System) can communicate in far more distance than LoRa. However, there weren’t any papers that studied about APRS in smart farms. Therefore, we conducted tests that compared the distance coverage of the networking technologies in Purdue Agronomy Center for Research and Education, a corn farm. As a result, LoRa had more distance than APRS. Therefore, we concluded that LoRa was more feasible than APRS.

Key words: Smart Farm, IoT, LoRa, APRS, distance comparison

With the fourth industrial revolution and the advancement of IoT technology, ICT (Information and Communication Technologies) has been integrated into agriculture and increased not only the quantity and quality of products but also convenience for the farmers.

In IoT-based smart farming, data from weather condition, light, soil moisture or crop’s growth progress is collected by IoT device sensors. With the data, farmers can monitor the field conditions from anywhere with smart devices. Also, irrigation systems are automated so that the water will be used more efficiently and the yields will be improved.

In recent years, research on solutions to increase the performance and productivity of the smart farm while lowering the cost has become very popular.

In previous studies, the main technologies of IoT based smart farming are network technologies, security, and IoT agriculture applications.

(A Survey on the Role of IoT in Agriculture for the Implementation of Smart Farming)

To be more specific with the networks, there are numerous network technologies for wireless connection of the sensors and actuators for IoT. The network technologies focus on providing scalability, extended coverage, low cost, and energy efficiency for the end user devices.

(Ericsson, “Cellular Networks for Massive IoT,” White paper, 2016)

Since the IoT agricultural network helps to monitor agriculture data and facilitate the transmission and reception of agriculture data, it is one of the vital elements of IoT in agriculture.

(A Survey on the Role of IoT in Agriculture for the Implementation of Smart Farming)

Although many researches focus on implementing an IoT system with suitable communication network for smart farming, little attention has been given to comparing communication systems to decide the better network technology. Therefore, this study focuses on two network technologies, LoRa and APRS, for the smart farm IoT system. The objective of this paper is to question the feasibility of LoRa and APRS in smart farm IoT system and to propose a better network technology that is more suitable for smart farm. In this paper, we experiment the distance coverage of LoRa and APRS network at Purdue Agronomy Center for Research and Education.

The next section describes IoT communication protocols. Section 2 gives an overview of the LoRa and APRS. Section 3 provides the results of our test conducted in the Purdue University’s corn farm and Section 4 concludes the paper.

1. **RELATED WORK - Lydia**

**Related Work**

In this section we discuss existing IoT communication protocols, explaining why we particularly chose LoRa and APRS for this study.

1. ***LoRa***

As this study focuses on IoT devices for smart farms, protocol selection was made within Low-Power Wide Area Networks (LPWANs). Two main factors should be considered when developing smart farm IoT devices: 1) wide area coverage; 2) long battery life. Therefore, short-range communication protocols like Bluetooth or ZigBee are not likely used for IoT devices that require long-range communication and wide area coverage. LPWAN, on the other hand, provides long-range connections with low data transmission rates. Hence, LPWAN should be used for low power IoT devices that transmit a small amount of data and require battery efficiency. Smart farm IoT devices suite these descriptions; comparatively small data collected by sensors transmitted for long-range communication.

LoRa, NB-IoT, Sigfox, Weightless are some of the leading LPWAN technologies. This study specifically tests LoRa as it is known to provide long-range communication, long battery life on a low budget. LoRa’s advantages are evidently shown in many studies. Ji et al.[] successfully transmitted image data using LoRa technology. Kodali et al. was able to implement an irrigation system in smart farm through web interface.

***2. APRS***

Automatic Packet Reporting System (APRS), also known as ‘amateur radio’ or ‘ham radio’, was designed by Bob Bruninga about 25 years ago. APRS enables real-time information exchange between multiple nodes and processed data are visualized on APRS-Internet Service (APRS-IS) websites as the APRS infrastructure. (As an RF network, APRS range coverage depends on the RF propagation.) APRS is transmitted on a shared local VHF frequency, depending on the country. North America uses 144.39mHz. Although APRS was designed for large local areas, easy digipeating with callsigns allows fast global communications. Due to these characteristics, APRS has been used for real-time tactical, emergent situations.

There are many attempts like Hajdarevic et al.[ ] on building low-cost, low-energy APRS transceivers on microcontrollers or single-board computers such as Arduino and Raspberry Pi. Despite the increasing interest in building low-cost APRS transceivers (and APRS characteristics suitable for IoT devices), there was no research that solely used or tested APRS as an IoT communication protocol. This raised the question of why APRS is not applied in the IoT field. Therefore, this study ultimately aims to answer the question of the feasibility of APRS for long-range IoT device communications.

1. **RESULT**

혜원:For the feasibility test of LoRa and APRS, we have conducted several tests outside in the Purdue University’s corn farm. This section, we mention our testing environment, multiple test results, and final experiment, which was conducted after fixing the errors we have done in the previous experiments.

**3-0. 테스트 환경**

The distance comparison test between LoRa and APRS was conducted at the Purdue Agronomy Center for Research and Education. The tests were conducted by placing the receiver antenna at the weather station of the Purdue Agronomy Center. The receiver antenna of LoRa and the receiver antenna of APRS were installed on a same bar, but on different height. The receiver antenna of LoRa was 4.0 meters high from the ground, 6.4 meters high for APRS. Transmitters were on the move, checking if the data were properly received at the receiving end, the weather station. Both transmitters were carried in a car, and the transmitter antenna of APRS were securely attached to the roof of the car, while LoRa’s antenna was held at the same height as the transmitter antenna of APRS, 2.35 m. The location of the transmitting points were all saved on Google Maps, which was later used to calculate the distance from the weather station to the transmitter. To minimize radio interference during testing, LoRa and APRS were tested alternately. Also, cell phone calls were banned and at least 30 seconds of waiting time was ensured to prevent possible errors due to the movement of the transmitters. If the data were consecutively received, the transmitters were moved forward for further distance. If not, the transmitters moved back to shorten the distance. This process was repeated to find the last transmitting point where data were successfully transmitted. All of the following distance results were derived by calculating the distance between the weather station and the last transmitting point using Google Maps. (((((((((To minimize radio interference, LoRa and APRS were tested separately, did not make cell phone calls while checking for data coming, and waited for about 30 seconds after moving a certain distance to prevent possible communication errors while the car was moving, before checking five signals. If any of the signals were transmitted, we would continue to move forward and if no signals were transmitted, we would move backward and repeat this process to find the last location where the data could be transmitted. ))))))))

**3-1. Trials**

|  |  |  |
| --- | --- | --- |
|  | APRS | LoRa |
| 1차 | 1.30km | 0.16km |
| 2차 | 0.70km | 4.2km |
| 3차 | 0.86km | N/A |

1, 2, 3차 결과

|  |  |  |  |
| --- | --- | --- | --- |
|  | 1차 | 2차 | 3차 |
| transmitter antenna gain | 2.14 dBi | 2.14 dBi | 1.17 dBi |
| transmitter antenna output power | 15 dBm | 20 dBm | 24 dBm |
| receiver antenna gain | 6 dBi | 6 dBi | 6 dBi |

1, 2, 3차 실험 조건 - APRS

리시버 안테나는 변화 없고

트랜스미터 아웃풋 조금씩 늘려갔으며 (트랜지스터랑 50옴 케이블)

트랜스미터 안테나는 2-3차 사이에 케이블 불량으로 교체 !

위에는 정리된 표이고 아래 내용 정리되어 있음 !

|  |  |  |  |
| --- | --- | --- | --- |
| LoRa | 1차 | 2차 | 3차 |
| transmitter antenna gain | 2.14 dBi | 9 dBi | 9 dBi |
| transmitter antenna output power | 16 dBm | 16 dBm | 16 dBm |
| receiver antenna gain | 2.14 dBi | 6 dBi | 6 dBi |

1. 1차 테스트 (9/27)

The transmitter and receiver of LoRa consist of Arduino and LoRa Shield v1.4. The antenna gain for the both transmitting and receiving ends are 2.14 dBi. Both antennas were held by hand on about 1 m above ground. The output power of the transmitter antenna measured by the spec analyzer was 16 dBm. Due to weather conditions, the receiver antenna was inside the weather station. The maximum distance coverage was 160 m.

APRS used Arduino and HX1 transmitter while the antenna was connected using jumper cables. Software Defined Radio (SDR), powered by a laptop and an antenna was used as the receiver for APRS. The gain of the transmitter antenna for APRS was 2.14 dBi, where the output power was 15 dBm. For the receiver, the antenna gain was 6 dBi. At that time, the maximum distance was 1.3 km. Transmitting and receiving conditions were generally good, although some of the data were missed from time to time.

1. 2차 테스트 (11/8)

In the second test, the transmitter of APRS was the same as for the first test and additionally the transistor was used to amplify the output power of the transmitter. Receiver was also the same as for the first test.

The gain of transmitter antenna in the APRS was 2.14dBi, output power was 20dBm with transistor and the height of installation was 2.35m. For the receiver, the antenna gain was 6dBi and the installation height was 6.4m.

In this case, the test result in the farm was 670m in the same environment as in the first test without transistor and when using transistor was 700m.

Although the test was conducted in the same conditions as the first test, the result was worse than the first test. The reason was the antenna cable connection was bad. (안테나 접지가 잘 안되어 있었다, 안테나가 뽑혔다를 표현하고 싶었음)

LoRa changed both transmitter and receiver antenna. Previously, the antenna gain for both antennas were 2.14 dBi. With the new antennas, the transmitter antenna had 9 dBi gain and the receiver antenna had 6 dBi gain. The transmitter antenna was attached on the car roof at about 1.8 meters above ground. With the new antenna specifications, LoRa was able to cover 4.2 km, successfully receiving data.

For APRS, the setup for both sides were =the same as before, except for a transistor. A transistor was added to amplify the output power of the transmitter. While the transmitter antenna gain was identical to 2.14 dBi, the output power increased to 20 dBm by using the transistor. Two tests were conducted on this second test: 1) without transistor; 2) with transistor. APRS covered 670 m without using the transistor, while it covered 700 m using the transistor. The result was significantly different to the first test due to the open circuit problem inside the antenna.

**3-2. Final setup and test**

APRS 셋업 어케했는지 (스펙 등 - 라파/ 안테나/쉴드) : Gowoon / Arthur

|  |  |  |
| --- | --- | --- |
| H/W |  |  |
| Radiometrix HX1-144.390-3 | USRP b200 USB software defined radio |
|  |  |
| Arduino UNO | X2200A Dualband Base/Repeater |
|
|  |  |
| Genuine Nagoya UT-72 |  |

1. **transmitter**

The hardware used :

* Arduino Uno
* radiometrix HX1-144.390-3
* Tram 144MHz/430MHz Dual-Band Magnet Antenna
* Genuine Nagoya UT-72

For transmitting APRS packet at 144.390kHz, we used Arduino and HX1 chip. In general, HX1 can control easily with RadioShild of Argent Data Systems. But we control HX1 chip directly for using transmit power efficiently. And the antenna that we used for transmitting is 1.17 dBi gain and can be used 144-148MHz for APRS. Transmit antenna output power measured by spec analyzer is 24dBm. When we connect the antenna to HX1 chip, we used the 50 ohm cable to amplify the output power.

Arduino Uno and HX1 chip was used to transmit APRS packets at 144.390MHz. Since the lack of radio shield for APRS, HX1 was directly controlled to transmit power efficiently. The transmitter antenna was suitable for 144-148MHz frequency, with 1.17 dBi gain. The transmitter antenna’s output power measured by the spectrum analyzer was 24 dBm. 50 ohm cable was used to connect the antenna and the HX1 transmitter to amplify the output power. To receive APRS data packets, GNU radio was used with USRP b200 on Ubuntu. The receiver antenna had 6 dBi gain.

1. **receiver**

The hardware used :

* USRP b200 USB software defined radio
* X2200A Dualband Base/Repeater

For receiving APRS packet, we installed GNU radio and connected USRP b200 on Ubuntu. And the antenna that we used for receiving is 6 dBi gain and can be used 144MHz for APRS.

3-2 LoRa 셋업 어케했는지 (스펙 등 - 라파/ 안테나/쉴드) : Miran / DJ

|  |  |  |
| --- | --- | --- |
| H/W |  |  |
| Arduino Uno | Arduino LoRa/GPS Shield v1.3 |
|  |  |
| wlaniot 900MHZ 1900MHz Antenna | 824-960 MHz 6 dBi 900 MHz Omni Antenna |

* Arduino UNO
* Dragino LoRa/GPS Shield v1.3

<https://wiki.dragino.com/index.php?title=Lora/GPS_Shield>

* Transmitter antenna gain: 9dBi (850~960/1710~2170)

<https://www.amazon.com/wlaniot-Magnetic-Extension-Wireless-Repeater/dp/B07NRYTDL6/ref=sr_1_2?keywords=915mhz+9dbi+antenna&qid=1576104042&sr=8-2>

* Receiver antenna gain: 6dBi

<https://www.altelix.com/900-MHz-6-dBi-SCADA-WiFi-Omni-Antenna-p/au09g6-nf.htm>

In the LoRa test, we used the Arduino Uno as the controller for the transmitter and receiver. To facilitate the use of LoRa networks, we used the LoRa/GPS shield that can be attached to the Arduino. The transmitter's antenna used 9 dBi to match the LoRa frequency of 915mhz. The receiver's antenna used 6dBi also can be used 915mhz. Transmit antenna’s output power measured by spec analyzer is 16dBm.

To facilitate the use of LoRa network, LoRa/GPS shield attachable to the Arduino was used. The antennas used for both transmitter and receiver supported 915MHz, which is the LoRa frequency in North America. Transmitter antenna and receiver antenna had 9 dBi and 6 dBi gain. The output power of the transmit antenna measured by the spectrum analyzer was 16 dBm.

* 거리 비교 테스트 :

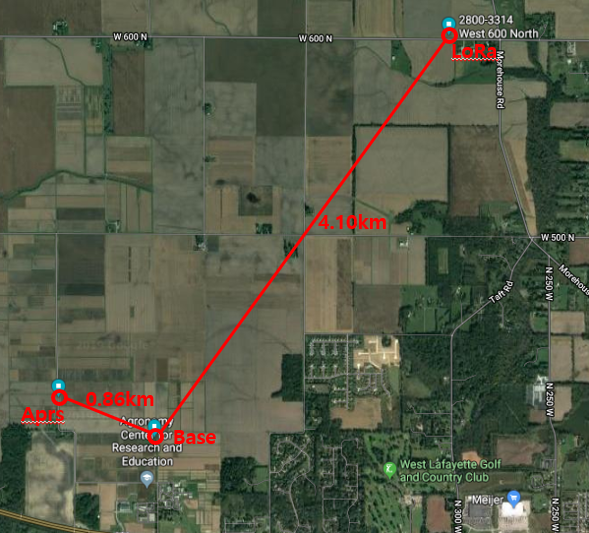
APRS을 이용한 회로에서 신호 감쇄를 줄이기 위해 HX1과 안테나를 연결하는 선을 점퍼 케이블 대신 50옴 도선을 사용했다. 50옴 도선으로 바꿈으로써 HX1에서 나오는 신호의 세기가 더 세졌고, transistor을 제거하고 spec analyzer로 측정했을 때 transmit power가 24 dBm이 나왔다. HX1이 수용할 수 있는 신호의 세기는 최대 24.7 dBm이므로 회로에서 사용하던 transistor를 제거하기로 결정했다. 그리고 gain이 1.17 dBi인 새로운 transmitter 안테나를 사용했다. 새로 바꾼 APRS 회로와 안테나를 가지고 다시 테스트를 진행했고 최종 결과 LoRa는 4.2km까지 도달했고, APRS는 0.86km까지 도달했다.

To reduce signal attenuation in the circuit using the APRS, 50 ohm cable was used instead of the jumper cable when connecting HX1 and the antenna.0 By switching to the 50 ohm cable, the signal from the HX1 was stronger, and when the transistor was removed and measured with the Spec Analyzer, the transmit power was 24 dBm. It was decided to remove the transistor used in the circuit, since the strength of the signal that the HX1 can accommodate is up to 24.7 dBm. And a new transmitter antenna with a gain of 1.17 dBi was used. The test was conducted again with the newly changed APRS circuit and antenna, and the final result was that LoRa reached 4.2 km, and the APRS reached 0.86 km.

To reduce the signal attenuation in APRS circuit system, 50 ohm cable was used instead of the jumper cable to connect HX1 and the transmitter antenna. By doing so, the output signal from the HX1 got stronger, and the transmitting power measured by the spectrum analyzer was 24 dBm without the transistor. Since HX1 can handle signal power up to 24.7 dBm, the transistor was removed from the circuit. APRS also changed the transmitter antenna after the second test. The new transmitter antenna had 1.17 dBi gain. With the newly alternated APRS circuit and antenna, APRS was able to cover 0.86 km.

LoRa used identical specifications for the entire transmitter, receiver system. The results were also identical as the second test, covering 4.2 km as shown in Fig. 1.

Fig. 1 shows the final transmitting points of LoRa and APRS



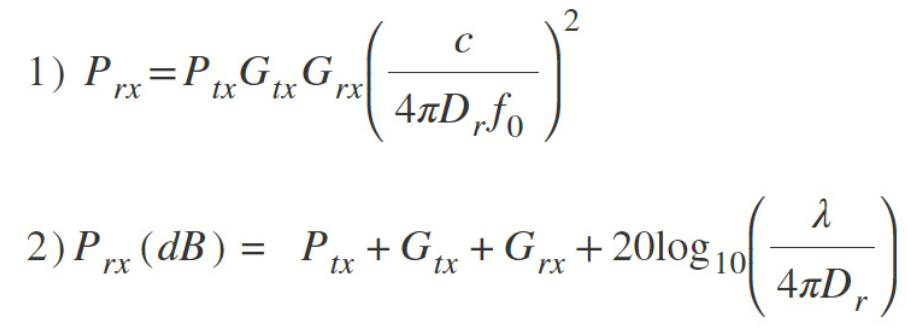
**3-4 Result Evaluation - Hye Won**

|  |  |  |
| --- | --- | --- |
|  | LoRa | APRS |
| Transmit Power | 16 dBm | 24 dBm |
| Transmit Gain | 9 dBi | 1.17 dBi |
| Receiver Gain | 6 dBi | 6 dBi |
| Theoretical Distance | 9.3 km | 59.7 km |
| Fresnel Zone Radius | 27.79 m | 176.02 m |
| 80% of Fresnel Zone Radius | 22.23 m | 140.82 m |
| Tested Distance | 4.2 km | 0.86 km |
| Efficiency constrained by height | 45.16 % | 1.44 % |

With the antenna specifications that were used for the final test, Friss transmission formula was used to review the final distance coverage results.

“The **Friis Transmission** formula is a basic equation used to calculate the received power of a basic receiver at a fixed distance from a transmitting system.”

Equation:



Transmitter Power (Ptx), Transmission Gain (dBi) (Gtx), Frequency (f0), Distance (Dr), Receiver Gain (dBi) (Grx)

According to the Friis Transmission formula, theoretically APRS should have covered longer distance than LoRa as shown in Table 5. However, according to the final results, APRS distance was much shorter than LoRa. In order to understand the reasoning of the final test results, the Fresnel Zone Radius was calculated.

The definition of Fresnel Zone is the size of the elliptically-shaped area of RF propagation between a transmit and receive antenna. “Objects within the area of the Fresnel zone can reflect radio waves and induce multi-path propagation issues between the transmitter and receiver, where direct path line-of-sight radio waves and the reflected path radio waves are received out of phase from one another.” Therefore, in order to have no interference, it is important to have no obstacles in the Fresnel Zone. This zone could be calculated by a Fresnel Zone Calculator. The antennas must be located within the 80% of the radius obtained through the Fresnel Zone Calculator, shown in Table 5, for seamless communication.

The antennas must be

Equation:

Radius(m)=

The result of the Fresnel Zone Radius indicated that in order to communicate around the theoretical 59.7 km, the theoretical distance, away using APRS, the antennas for both transceiver and receiver antenna must be at least 140m above the ground. However, the testing for the antennas were installed approximately 4.0 m above the ground.

Also in order to calculate the efficiency constrained by height, the tested distance was divided by the theoretical distance. LoRa was 45.16%, while APRS was 1.44%, as shown in Table 5.

1. **CONCLUSION -Hye Won**

This study was proposed to determine whether LoRa or APRS is more adequate for the networking technology in Smart Farms. The location of the experiment for the distance coverage of both networks was at Purdue Agronomy Center for Research and

Education. According to the test results, LoRa’s final distance coverage was 4.2 km, when the transmitter gain was 9 dBi and the receiver gain was 6 dBi. While APRS distance coverage was 0.84 km, with 1.17 dBi of transmitter gain and 6 dBi of receiver gain.

Also, both transceiver and receiver antenna must be above 190 m from the ground in order to communicate the theoretical distance for the antenna specification as shown in Table 5, we conducted our tests. However, the testing for the antennas were installed approximately 4.0 m and 6.4 m above the ground, LoRa and APRS correspondingly. The calculation result of the efficiency constrained by height was 45.16% and 1.44% for LoRa and APRS, as shown in Table 5. Also, APRS needs to be installed in very high altitudes, which the majority of the smart farms can not meet the circumstances. Therefore, LoRa would be a better candidate to use for the networking technology in a Smart Farm rather than APRS.

The efficiency constrained by height from the final test results was 45.16% for LoRa and 1.44% for APRS. Both of the estimated antenna installation heights calculated from the Fresnel Zone Radius are high altitudes, which the majority of the smart farm system cannot meet the circumstances. When comparing the installation possibility of the two networking technologies, LoRa’s theoretical distance was more achievable than APRS. Therefore, the result indicates that LoRa is more feasible than APRS for the networking technology in smart farms.

However, there are limitations to our test experiment. First, the antenna specification was different for LoRa and APRS. Even though, we used two antennas that had the same dBi of 3, when running the frequency (APRS frequency) for the APRS the dBi was measured to be 1.17 dBi. Second,the testing was done after the corns were all harvested. Hence, there could be different results when there are obstacles between the transceiver and receiver antennas.

Future testing will be done by using the same antennas gains for LoRa and APRS. Also, the transmitter and receiver antennas will be installed at much higher altitudes.