Shared Geolocation Gateway LoRa Network: An Alternative Smart Farm Deployment Strategic Infrastructure

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ABSTRACT

Smart farm solutions have been partially applied to vinyl greenhouses but hardly used for outdoor culture. Low battery consumption devices and geolocation technologies are technological bottlenecks for the outdoor smart farm deployment while low market affordability of local farms are economical bottlenecks. The shared geolocation gateway LoRa network is the alternative strategic smart farm deployment infrastructure. The technological bottlenecks are addressed by the geolocation gateway networks. The two times of field test verify the enhanced technical feasibility of the solutions. The sharing economy model of private networks was also proposed with conceptual framework. The sharing economy of inter-operable private networks can decrease the cost of the network installation and operation among participating individual farms. The smart farm sharing model can also extend to partner with other public and private LoRa networks to sharply decrease the network costs to ensure scale and scope economy.

Keywords: Smart farm, geolocation gateway, low battery consumption, private network inter-operation, sharing economy

INTRODUCTION

Old and new agricultural challenges can be addressed by digital technologies and even small holders can be benefited (OECD, 2019). The overall cost of agriculture production can be reduced and precise control of water, fertilizer and light leads to higher production from the same amount of area while smart technologies with remote monitoring enable farming on smaller and more distributed lands (Chandler, 2019). They also have potentials to create value both upstream and downstream (OECD, 2019). Upstream of the farm includes new services to customize services to farmers, research and development, or finance, while downstream feeds into food processors, wholesalers, retailers, or government, for traceability in line with evolving consumer preferences.

Successful deployment of smart farm system requires an access to enabling basic connectivity infrastructure (OECD, 2019). The challenges of a smart agriculture system inevitably cover the integration of the sensors and connecting the sensor data to the data analytics (Chandler, 2019), which sets up a communications network integrating a limited number of sensors across a large area of farmland and requires a private network consisting of access points and uplinks to a private backhaul network with third-party network.

As for the outdoor cultivation, positioning of sensors is important since the production area is more extensive than indoor vinyl houses. The wireless connection of sensors can be sustained only with low battery consumption. Two technologies of positioning and low battery consumption are key components of the smart farm network infrastructure. Chandler (2019) distinguishes the specific requirements for the large and traditional farming and smaller indoor farming as follows;
For large-area, more traditional farming, sensors placed within the ground may record real-time data on soil moisture, temperature and pH, while environmental sensors may record sun exposure, rainfall, wind speed, air temperature and humidity. Aerial drones may also be used for surveillance of crops and pests.

For smaller, indoor farming, LED lighting, precise control of photo period, and soil and environmental sensors can reduce the cost of energy and increase yields.

The private smart farm networks can be established for individual farms through contract with Telcos and utility providers which provide public commercial IoT network services. The Korean SKT is the first global IoT service provider in the world with LoRa technologies while the Chinese Huawei is promoting its NB IoT network with focus on 5G technologies. Such a rental network, whether LoRa or NB IoT, is expensive to deploy in market mechanism. An alternative solution and network deployment strategy is necessary to utilize the potential benefits of the digital technologies in agricultural production, by which the variety of IoT capabilities which can improve farming production and deliver new monitoring capabilities (Chandler, 2019) can be available to individual farms.

This paper proposes the shared geolocation LoRa gateway as an alternative strategic infrastructure for the deployment of outdoor smart farms. In the following chapter, the strategic infrastructure of smart farms will be detailed with core technological components of LoRa network, geolocation technology and shared network, which was followed by technical field test results of the proposed system. And sustainable business model of the network infrastructure will be conceptualized in the last chapter. The model is based on the sharing economy by which individual farms can decrease the cost of the network installation and operation with their inter-operable private networks. The smart farm sharing model can also extend to partner with other public and private LoRa networks to sharply decrease the network costs to ensure scale and scope economy.

**SHARED GEOLOCATION GATEWAY LORA NETWORK**

The shared geolocation gateway LoRa network is the alternative strategic smart farm deployment infrastructure. This chapter examines the technological requirement of the smart farm infrastructure. The two technological requirements for outdoor smart farms are positioning and low battery consumption technologies. The paper argues that the geolocation gateway LoRa networks can manage them.

**LoRa Network**

Personal smart farm networks can be created with the LoRa network (Figure 1). Data such as soil humidity and nutrition level from smart farm sensors can be concentrated into gateways, which transmit the received data to network servers. The network server, which also manages the entire LoRa network, then delivers data to target applications. The saved data in individual application servers can be monitored and the smart farm LoRa devices can be controlled through diverse user interfaces of web or mobile apps.
There are three competing IoT network technologies; LAN, LPWAN and Cellular. The LAN (Local Area Network) is good for a system with short range and high battery consumption, which is not fit for the outdoor cultivation. For a long range system, LPWAN (Low Power Wide Area Network) and cellular are possibilities. Cellular or NB-IoT is only good for high battery consumption devices. Technologically LPWAN is the only option for outdoor cultivation which requires wide area service and low battery consumption (Figure 2). LoRa (Long Range) is the core technology to configure the LPWAN. The data for smart farm do not require high data rate which is only available from LAN or cellular technologies.

ABI Research and LoRa Alliance (2019) defines the LoRa and NB-IoT as follows;
LoRa is the modulation technique used in the physical layer that enables long-range low-power communications by using Chirp Spread Spectrum (CSS) modulation, which spreads the narrowband signals across a wider channel allowing greater interference resilience and low signal-to-noise ratio levels. NB-IoT, on the other hand, operates in the licensed spectrum, and like LTE, uses Frequency Division Multiple Access (FDMA) in the uplink, Orthogonal FDMA (OFDMA) in the downlink, and Quadrature Phase Shift Keying (QPSK) modulation.
Geolocation Gateway

The outdoor smart farm also requires the positioning of the smart farm sensors. This is enabled by the TDOA (Time Difference of Arrival) technologies of geolocation gateways. TDOA based location is calculated with signals of ToA (Time of Arrival) from more than 3 gateways (Figure 3). End node (device) transmits messages and gateway (AP0, AP1, AP2, AP3) receives them. Each gateway records arrival time and transmits it to network server. Time synchronization of gateways is the crucial part of the geolocation gateways.

The development of Gateway 2.1 enhances location accuracy, which enables nano sec time measurement. TDOA measurement incurs 300,000m radio distance error by 1 msec and 300 m by 1 μsec. More than 3 GW ToA values create values of more than 2 TDOA by which locations are calculated through Multilateration Algorithm.
Technical Field Tests

The two times of field test verify the enhanced technical feasibility of the solutions (Table 1 and Figure 1). After the first test, following three are modified for the second test; LTE router based backhaul connection, Device ADR function turned off (SF11~SF12) and more than three GW uplink confirmation before collos api identification.

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Comparison of collos api geolocation data and real location data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Tongjeong-Ri Seokmun-myeon Dangjin-si Chungcheong Nam-do (reclaimed-land near Seokmun seawall)</td>
</tr>
<tr>
<td>Date</td>
<td>2019-07-18 (first test), 2019-08-27 (second test)</td>
</tr>
<tr>
<td>Procedure</td>
<td>- Seven gateways at four coordinates (GW1~GW7)</td>
</tr>
<tr>
<td></td>
<td>- Measurement of LoRa devices locations with collos api at twenty one reference points (pt1~pt21)</td>
</tr>
<tr>
<td></td>
<td>- Comparison of GPS/real data and collos geolocation data</td>
</tr>
</tbody>
</table>

Figure 4. Field test map
For the two tests, average distance errors are less than 200 meters compared with GPS and real locations when the network server received signals from four gateways (Table 2), which is a success criteria for geolocation gateways. For TDOA, 20-200m accuracy is the allowed distance error range depending on conditions. For the second modified test, the results are critically improved.

Table 2. Geolocation distance error

<table>
<thead>
<tr>
<th># of GW of which server received signal</th>
<th>Average distance error between GPS and collos (m)</th>
<th>Average distance error between real location and collos (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>first</td>
<td>second</td>
</tr>
<tr>
<td>1</td>
<td>1221.7</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>870.9</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>338.8</td>
<td>256.1</td>
</tr>
<tr>
<td>4</td>
<td>168.3</td>
<td>156.1</td>
</tr>
</tbody>
</table>

SHARING ECONOMY: SUSTAINABLE BUSINESS MODEL OF THE NETWORK INFRASTRUCTURE

In this chapter the sharing economy model of private smart farm networks will be proposed with conceptual framework. The sharing economy of inter-operable private networks can decrease the cost of the network installation and operation. The smart farm sharing model can also extend to partner with other public and private LoRa networks to sharply decrease the network costs to ensure scale and scope economy.

LoRaWAN as a low cost solution

In previous chapter the LPWAN is identified as a most relevant solution for outdoor smart farms. LPWAN or LoRaWAN is the lowest cost solution among alternative IoT networks (Figure 4). This also has the longest battery life use cases. The accuracy for RSSI (received signal strength indicator) is 1,000-2,000 meters while TDOA 20 to 200 meters.

WiFi is relatively cost efficient for outdoor and indoor solutions. The accuracy increases with hotspot density which requires a BLE (Bluetooth Low Energy) beaconing indoor solution. GPS (Global Positioning System) is most accurate but most expensive and power consuming solutions. One GPS adds $5 to $10 on the BOM (Bill of Material). AGPS (Assisted GPS) improves battery consumption slightly.

![Figure 5. Comparison of LoRaWAN with WiFi and GPS](Source: LoRa Alliance ®)

Shared Gateway LoRa Network

LoRa network is still expensive for outdoor cultivation though it is the lowest cost IoT solution (ABI research and LoRa Alliance, 2019). It is estimated that the registration fee per device is around 5 USD
to 20 USD per year for commercial IoT services. Instead of renting IoT networks, it is more feasible to build private LoRa IoT networks for smart farms. The private networks can be utilized for further cost reduction and revenue generation.

The private gateways can be shared to decrease the cost since it is reported around ninety percent of the capacities are not used but available for sharing. The sensors can send data to any gateways around them and the most efficient and effective data are transmitted to the network server (Figure 6). The gateway sharing will also allow for additional revenue creation for the gateway providers. The registration fee sensor owners or service users pay for their services will be shared among the gateway providers, which incentivize more gateway providers to join the network partnership. Gateway sharing cost reduction and revenue sharing can be enabled by blockchain technologies which provide a transparent transaction platform. Then the cost of smart farm network can be sharply decreased.

The LoRa IoT network can also be deployed by the strategic partnership with large public and private stakeholders. Local governments can build their own private LoRa networks for their various public service management which includes environment monitoring, asset tracking for the disabled and the socially neglected and others. And large private and public companies need their private LoRa networks for smart metering and watering, road and traffic management and others. The public and public, public or private and private LoRa network alliance can create a comprehensive LoRa IoT network. The network can function as a public network infrastructure on which smart farm devices and solutions can be deployed in market mechanism with almost zero network cost.

Figure 7 depicts the expected outcome of nationwide LoRa network creation with the sharing economy model. The SKT has created its own commercial LoRa IoT network across the country of Korea with 16,000 gateways. The gateway alliance model will create more comprehensive nationwide LoRa IoT network with 20,000 gateways, which can extend smart farm services across the country more efficiently and effectively.
CONCLUSION AND POLICY RECOMMENDATIONS

The paper has conceptualized the technological and economic framework of the strategic infrastructure of LoRa IoT network for outdoor smart farm deployment. It comprises of long range and low battery consumption technologies of the incumbent LoRa network solution. The solution provides the most economical solution among alternative IoT network solutions. The paper also argues that the sharing economy model of the available gateway capacities can create more comprehensive IoT network which can provide an almost zero cost network for smart farm.

The initial investment of the public sectors on LoRa IoT network where private technology companies can lead the network installation and service deployment is strongly recommended with permissive regulation changes. The network as an strategic infrastructure can accommodate various device and solution service providers to create smart ecosystem. The domestic ecosystem enabled by the policy intervention can generate innovation dynamics to explore overseas market collectively.

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