Integration of LoRa-Cellular: Design and Implementation of Data Communication in Vehicle Tracking Systems

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Abstract. The development of communication technology has improved efficient communication in tracking mobile objects. Several types of communication links are available for the tracking systems. Among them, cellular is the most widely used communication network for tracking inter-city areas. However, the implementation of IoT using cellular network requires the availability of communication network from network service providers. The communication will be lost for the area which is not covered by the cellular network. To overcome this problem, in this paper we proposed the Integration of LoRa-Cellular (ILC) using hybrid communications: LoRa network and the cellular network to trace a vehicle position. The decision which network used for communication is decided based on the level of RSSI. The energy consumption is also a parameter in the communication link selection. The transition process uses soft-handover to maintain the availability of communication links and reduce data loss. Our experiments show that the threshold of LoRa RSSI level uses -120 dBm and the threshold of cellular RSSI level uses -85 dBm. Energy consumption of Lora and cellular while sending data has a significant difference. Lora consumption is 292 mW and cellular consumption is 497 mW.

1. Introduction

The mobile object tracking system is a system designed for remote observation, security, and the location of objects while cruising away. It involves tracking humans [1], animals [2], and vehicles [3] as shown in a recent study. Location information, transmission media, and storage media are the main parameters for location accuracy and real-time monitoring [4].

The mobile object tracking system with various transmission media and communication network was developed by researchers. This communication network is cellular [5], Zigbee [6], and LoRa [7]. Several aspects considered in recent studies for the development of tracking systems. These aspects are the area of coverage, power consumption, and implementation costs. The focus in developing tracking systems is to create powerful tracking with low cost [8].

Every network in the communication system has their own drawback. As with the cellular network, the tracking area relies heavily on the network infrastructure of the service provider. A problem arises when a region is not covered by network service in some tracking areas (blank spot area) such as in suburban areas and mountain areas. Another example such as LoRa network, The Lora network has limited area coverage, expansion of coverage requires additional infrastructure and more costs. The...
implementation of the Lora network on vehicle tracking has constraints on unlimited mobility and large tracking areas. These problems need costs to expand the coverage area. Example case, the application of the Lora network consists of node and gateway. It provides long-distance communication, around 10 km [9]. If the tracking area is more than 10 km, a new gateway is needed.

Muhammad et al in his research made a Vehicle Tracking System and history recorder of vehicle journey using GSM (Cellular) as a communication network, but the tracking area depends on the availability of the GSM network around the tracking area [10]. Another study by Kim et al. Used the LoRa as a communication link on vehicle tracking systems. The proposed system does not depend on the availability of the network service provider [7]. Next research by Team et al developed an energy-efficient and low-cost vehicle tracking system using LoRa as a communication system [9]. Next research by ham develops IoT system to track and monitor patients with mental disorders using Lora as a communication link. This research evaluates the performance of Lora in the conditions of Line of Sight (LoS), Non-Line of Sight (N-LoS), and the "crowded area" [11].

A good object tracking system is a tracking system with communication networks available anytime and anywhere, but every communication system has their own limitations in providing network service. Therefore, in this research, we developed a tracking system that provides an alternative to track vehicles in areas not covered by cellular networks. The alternative is the Lora network, our system is Integration of LoRa-Cellular (ILC). ILC design has two communication network services. Lora and Seluler are integrated to expand the coverage area and always provide network services during the monitoring process. Not only that, the system that we propose can also be implemented in other cases that require a backup of communication.

2. Architecture and Design of System

2.1. Tracking architecture

Figure 1 shows an overview of the vehicle tracking architecture. The main parts of the development are Node-ILC and Lora-Gateway, Node-ILC is the transmitter of the location obtained from GPS via one of the Lora networks or cellular networks, and Lora-Gateway is the recipient of data from Nodes-ILCs and bridges to connect to the internet.

![Figure 1. Tracking Architecture on ILC](image)

2.2. Data delivery scheme

The proposed system has two different communication links with the same destination from Node-ILC to the internet. First destination: Node-ILC → LoRa-Gateway → Cellular BTS → internet. Second destination: Node-ILC → Cellular BTS → internet. The process of sending location data from the
Node-ILC to Users starts from the device selects communication link to be used according to the available network, if the device chooses LoRa, the location data will be sent to the LoRa-Gateway then forwarded to the Internet, if the Node-ILC selects Cellular, the location data will be sent to the BTS then forwarded to the internet.

3. Suggestion Method
This chapter discusses case studies and methodologies for the proposed system. Figure 2 shows the transition scenario of the communication link between LoRa network and cellular network. Area A and area B are cellular network coverage and area C is blank spot area. Assume that Lora-Gateway will be installed on Area C as an alternative data transmission. If a vehicle in either area A or area B, Node-ILC will use cellular services. But when a vehicle crosses an area where there is no cellular network available, the Node-ILC will use Lora to send data. In another case, when a vehicle crosses an area covered by both the cellular network and the Lora network (A-C / C-B), ILC Node measures RSSI level. ILC will use RSSI level measurements as a reference for the choice of the communication link in accordance with RSSI level measurements in table V. Transitions Service are carried out when the vehicle is between the area A-C / C-B.

The type of handover on ILC is soft-handover, the soft-handover steps on ILC are as follows:
- Measurement step, the first step is to measure the signal strength of the cellular network and LoRa network.
- Decision step, the measurement results are compared with the RSSI Level threshold in table V as a reference for the handover process.
- Execution step, execution of the handover will take place at this step

4. Hardware and Software Implementation

4.1. Hardware
In the design of hardware, the hardware part is divided into two functional parts, namely Node-ILC and LoRa-Gateway. Components of the Node-ILC are Arduino Mega, GPS Module NEO-6M, 915Mhz Dragino LoRa Shield, external antenna 3 dBi and SIM900 Mini V4.0. Node-ILC voltage source is a power bank. For components of the LoRa-Gateway are Arduino Uno, Dragino LoRa Shield 915Mhz, Ground Plane Antenna FPV Telemetry, SIM900 Mini V4.0 and a voltage source using a power bank.
4.2. Software implementation

Figure 3 shows the flowchart of the proposed system. Part A is Node-ILC software and part B is LoRa-Gateway software. The Node-ILC software is designed to send the location to LoRa-Gateway or cellular BTS. The LoRa-Gateway software is designed to forward the packet from the Node-ILC to the internet.

We use the Arduino Integrated Development Environment (Arduino-IDE) to develop the proposed tracking system. We use RadioHead library and TinyGPS++ library.

![Flowchart of the proposed system](image)

**Figure 3.** Flowchart of the proposed system

5. Experiment and Result

5.1. Experiment scenario

We conducted some experiments to obtain the RSSI level, packet delivery ratio, and energy consumption. The following are the experimental step of RSSI level and packet delivery ratio:

- The Node-ILC is installed on the vehicle.
- Vehicles will move away from LoRa-Gateway (if using LoRa) or cellular base transceiver station (if using cellular)
- The Node-ILC measures RSSI levels and acquires the current location from the GPS module
• Next process, the Node-ILC combines several data such as current location, RSSI levels and the current time.
• The Node-ILC sends packet periodically, each packet has a serial number for the packet identifier.
• We get the packet delivery ratio from the number of packets received

Details of the packets sent are the location of the vehicle, the current time and RSSI level (LoRa and cellular) with a total size of 50 bytes. The location experiment of LoRa network was on Malino street, Borongloe, Bontomarannu, Gowa Regency, South Sulawesi (Faculty of Engineering, Hasanuddin University). The location experiment of the cellular network was on Inspeksi PAM street, Manggala, Makassar City, South Sulawesi. Table 1 shows the LoRa configuration.

The measurement of energy consumption in LoRa and cellular (Sim900A) uses Adafruit INA219 Current Sensor Breakout in two conditions. The conditions are transmission and standby.

Table 1. Lora configuration

| Lora Configuration | Setting Value |
|--------------------|---------------|
| Bandwidth          | 125 kHz       |
| Preamble Length    | 8             |
| Coding Rate        | 4/5           |
| Spreading Factor   | 7             |
| TX Power           | 13 dBm        |

5.2. Analyzing performance

This chapter discusses transmission performance on LoRa network and cellular network based on RSSI Level. The results of the experiments are in table 2 and table 3. A good RSSI level is RSSI level near 0. For example, the signal strength of -120 dBm is better than the signal strength of -100 dBm. The lowest RSSI level of LoRa is between -120 dBm to -130 dBm with packet delivery ratio of 67%. The lowest RSSI level of Cellular is between -80 dBm and -90 dBm with packet delivery ratio of 76%. The both lowest RSSI level is the threshold for reference in the handover process.

Table 2. Lora Performance

| Packet Detail | -100 ≤ X < -90 | -110 ≤ X < -100 | -120 ≤ X < -110 | -120 ≤ X < -130 |
|---------------|----------------|-----------------|-----------------|-----------------|
| Send Packet   | 100            | 100             | 100             | 100             |
| Received Packet | 98             | 93              | 80              | 67              |
| Lost Packet   | 2              | 7               | 20              | 37              |
| Received Rate | 98%            | 93%             | 80%             | 67%             |

Table 3. Cellular (Sim900A) Performance

| Packet Detail | -60 ≤ X < -50 | -70 ≤ X < -60 | -80 ≤ X < -70 | -90 ≤ X < -80 |
|---------------|---------------|---------------|---------------|---------------|
| Send Packet   | 50            | 50            | 50            | 50            |
| Received Packet | 49            | 46            | 43            | 38            |
| Lost Packet   | 1             | 4             | 7             | 12            |
| Received Rate | 98%           | 92%           | 86%           | 76%           |
5.3. Comparison energy consumption

Energy consumption is an additional parameter for choosing a communication link. Table 4 shows energy consumption on Sim900 (cellular) and LoRa.

| Device | Current (mA) | Power (mW) |
|--------|--------------|------------|
| Cellular | Standby | 55 | 247 |
| | Send Packet | 107 | 497 |
| LoRa | Standby | 6 | 21 |
| | Send Packet | 85 | 292 |

5.4. Communication link selection

The results of the experiment provide information about the proper condition of the RSSI level to send data. Table 5 shows the threshold of RSSI level. It is the reference for the communication link selection. When the LoRa RSSI level is greater than -120 dBm, the LoRa network will become the communication link. While the cellular network becomes a communication link when the RSSI level is greater than -85 dBm and the RSSI LoRa is smaller at -120 dBm.

| RSSI | Seluler (dBm) |
|------|---------------|
| LoRa (dBm) | ≥ -120 | ≤ -120 |
| | LoRa | Seluler | LoRa |

5.5. Implementation results of ILC

This section explains the results of implementing the ILC. Experiment results can be seen in table 5. The experimental results show the service transition process. The first transition occurs on line 10. The LoRa network and cellular network do not reach the threshold so that the communication link uses the default option (LoRa network). Next transitions occur on line 12. Cellular networks reach the threshold requirements and LoRa network does not reach the threshold requirement so communication links use the cellular network. Next, on line 15, RSSI level of Lora network reach the threshold so that the communication link uses the LoRa network.

| No | Longitude | Latitude | Cellular RSSI | Lora RSSI | Time Node-ILC | Description |
|----|-----------|----------|---------------|-----------|--------------|-------------|
| 1  | -5.124391 | 119.54945 | -90          | 0         | 06/30/2018-08:09:32 | Cellular    |
| 2  | -5.124383 | 119.54945 | -90          | 0         | 06/30/2018-08:09:36 | Cellular    |
| 3  | -5.124378 | 119.54945 | -90          | 0         | 06/30/2018-08:09:42 | Cellular    |
| 4  | -5.124376 | 119.54945 | -90          | 0         | 06/30/2018-08:09:45 | Cellular    |
| 5  | -5.124369 | 119.54944 | -90          | 0         | 06/30/2018-08:09:52 | Cellular    |
| 6  | -5.12437  | 119.54945 | -90          | 0         | 06/30/2018-08:09:57 | Cellular    |
6. Conclusion
The availability of communication networks is an important part of the object tracking system. Integration of LoRa-Cellular is one of the studies to keep the availability of communication network. The focus on LoRa-Cellular Integration is to overcome the problem in the tracking system, like is a blank spot area and data loss.

The communication link selections use two parameters. The parameters are RSSI level and energy consumption. The threshold of LoRa RSSI level uses -120 dBm and the threshold of Cellular RSSI level uses -85 dBm. RSSI levels of both communication link use a threshold of -120 dBm and -85 dBm to form an intersection between LoRa coverage and cellular coverage. Table 4 shows energy consumption. LoRa uses low power than Cellular, so the communication link accentuates the LoRa network.

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