Proposal for Japan's Community Bus Location System Using Blockchain

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Abstract. In recent years, Japan's regional public transportation systems, particularly in rural areas, have been affected by population decline and aging. The expansion of areas with no public transportation due to the abolition or reduction of bus routes has become a serious problem. To address this issue, many local governments have introduced community buses. However, operating these services efficiently within limited budgets and human resources remains a challenge. Meanwhile, advancements in information and communication technology (ICT) have led to the development of new methods for improving the convenience of public transportation. Digital technologies that use standard formats, such as general transit feed specifications, are currently in progress. However, their use in regional public transportation remains limited. In this study, we developed and supported the implementation of ICT-based bus location system (BLS) and passenger counting system (PCS) to address regional public transportation issues. The BLS tracks real-time vehicle locations using mobile applications, providing passengers and operations with up-to-date information to improve convenience. The PCS enables drivers to record the number of passengers on and off through an application and analyze the data to optimize operation routes and timetables. These systems improve the convenience of regional public transportation and streamline local governments' operational management. However, to ensure data management and prevent tampering, certain issues must be addressed when implementing such systems. In particular, because public-transport data, such as general transit feed specifications (GTFS), are directly linked to passenger-movement information, there are concerns about the risk of unauthorized access and tampering. In this study, we improve the data reliability and strengthen tamper resistance by storing some GTFS data in a blockchain. Blockchain is

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distributed ledger technology that enables highly transparent data management while preventing data tampering. The proposed system was tested in a real-world operational environment to verify its effectiveness. The results demonstrated that introducing a blockchain improved the reliability of GTFS data and reduced the risk of unauthorized data modification. However, adding or updating data takes time due to the blockchain feature. In this study, we analyze the current challenges of regional public transportation in Japan and explain the proposed BLS and PCS in detail. In addition, we discuss data management methods that utilize blockchain technology and verify their effectiveness through system evaluation. Finally, we propose a sustainable development model for regional public transportation based on the results of this research.

Keywords: Blockchain · Community Bus · Regional Public Transportation · Bus Location

1 Introduction

In recent years, the quality of public transportation in Japan has become a significant issue. In urban areas, public transportation, such as trains and buses, is well developed, and many people can enjoy convenient means of transport. However, in rural areas, a decline in population and the aging of society have reduced revenue, making public transportation difficult to maintain. In particular, in depopulated areas, main bus routes are being closed or reduced because of unprofitability, increasing the number of areas with no public transportation. In this situation, local governments are increasingly implementing community buses to ensure that residents have a means of transportation. However, these services face significant challenges, such as limited budgets and human resources. There is a need for a system to facilitate efficient operation management and use.

However, with the advancement of information and communication technology (ICT), new methods to improve the convenience of public transportation are gaining traction. In particular, the widespread use of smartphones has made it easier to search for and use transportation information. The use of real-time operational information is becoming increasingly common. Many public transportation organizations are responding to these trends by using standard formats, such as general transit feed specifications (GTFS), to provide operational details [1]. However, the use of such digital technology in regional public transport is lagging, and issues such as the inability to grasp the operational status of buses, failure to find bus stops, and reliance on manual record-keeping by bus crew members remain.

To address these challenges, we examined two areas of support for regional public transport using ICT: the bus location system (BLS), which uses location information from mobile device applications, and the passenger counting system (PCS), which uses mobile device applications. The BLS collects real-time location information on buses in operation and provides it to passengers and opera-

tion managers, thereby improving convenience and streamlining operations. The PCS is used by drivers to record the number of passengers on and off the bus. The collected data are then analyzed to optimize bus routes and timetables. These systems can improve the convenience of regional public transportation and make the operation management of local governments more efficient.

However, data management and security are significant challenges when implementing these systems. In particular, public-transport data, such as GTFS, contain essential information directly linked to passengers' movement, and the risk of unauthorized access and tampering must be considered. Conventional centralized database management remains vulnerable to server administrator errors or cyberattacks, which requires measures to ensure safety. In this study, we propose a method to strengthen data reliability and tamper resistance using blockchain technology. Blockchain is distributed ledger technology (DLT) that enables highly transparent management while preventing data tampering. Based on these, we construct a system that improves safety by storing part of the GTFS on a blockchain to ensure the accuracy of the operation information.

We summarize the current situation and issues of regional public transportation in Japan and introduce initiatives to support regional public transit. We detail the proposed BLS and PCS, highlighting how blockchain technology can improve safety and reliability. Finally, we evaluate the proposed system by verifying its effectiveness and demonstrating a new approach to contributing to the sustainable development of regional public transportation.

2 State of Regional Public Transportation

Regional public transportation is a public transportation service operated by local governments, such as railways, fixed-route buses, passenger ships, community buses, demand-response transportation, and passenger taxis [2,3]. In Japan, many regions, including major cities such as Tokyo and Osaka, have large-scale bus services operated by municipalities with ample funds or by companies that operate railways that form significant transportation arteries. However, outside city centers, population declines and aging have significantly impacted public transportation. Major railway and bus routes sometimes withdraw because of unprofitability. As a result, an increasing number of areas with no public transportation are becoming a problem [4]. Those without private vehicles cannot use public transport, thereby reducing their quality of life. Therefore, ensuring transport for residents is a significant issue. To solve this problem, municipal governments have taken the lead in operating regional public transport, such as small-scale community buses [5–7]. This allows residents to travel to their destinations without using cars. Regional public transportation is particularly important for people with difficulty moving around, such as the elderly and disabled because it enables them to participate in society. Local governments that operate them are also considered an essential part that contributes to the sustainable development of local communities and the improvement of mobility by incorporating them into urban planning and transport policy through regional public-transport planning [8–11].

In recent years, checking the means of transport and routes to your destination and then using websites or smartphone map apps to get there has become common. To include route information and other data in map apps, it is necessary to support GTFS, and more regional public-transport services are doing so, creating an environment that is easy to use for residents and visitors from outside the area. In addition, technologically advanced services, such as electronic payments and the ability to pay fares using IC cards, are also being developed. Many public transportation services are linked to other transport services at railway stations and bus terminals, providing more effective mobility. However, in many cases, regional public-transport services continue to operate with limited budgets, human resources, and equipment. In addition, GTFS and other systems are not yet fully developed. This means that the operation status is unknown to anyone other than residents, the location of bus stops is unknown, and operation records are written manually.

3 A System to Provide Support

Therefore, our research group has been supporting regional public transport to local governments in Fukuoka Prefecture, Japan, where we are based [12–16]. We focus on two main areas: support for developing regional public-transport data and regional public transport using ICT.

3.1 Support for Developing Regional Public-Transport Data

GTFS is a standard format for providing public-transport operation information, including timetables, routes, and bus stops. It is an essential format for standardizing public-transport data and enabling developers and service providers to handle data efficiently. It is also used to improve transit information and traffic system optimization. It is designed to be easily used by developers and systems and is particularly useful for transportation applications and related services. To date, we have provided support to 15 local governments. This support includes the development of GTFS and a standard bus information format (GTFS-JP) [17]. In particular, we create and validate the necessary files for GTFS or GTFS-JP and send them to companies that provide map applications, such as Google Maps, which are used to publish route information.

3.2 Support for Regional Public Transport Using ICT

We have supported 11 local governments, including questionnaire surveys using tablets, BLSs using mobile positioning data, passenger count surveys using mobile device applications, guidance display systems using in-vehicle monitors, and digital signage using monitors installed at major bus stops. These supports are made possible by the ACE system, comprising applications that run on the mobile devices and various servers we have built in our laboratory.

This study examines the BLS, which uses location information from mobile device applications, and the survey to track the number of passengers on and off using mobile device applications to support regional public transportation using ICT.

4 A System to Provide Support

This study introduces a system for implementing a BLS using location information from mobile device applications and a survey to track the number of passengers on and off. The system configuration is shown in Fig. 1.

The server provides two services for managers: booking and vehicle operation status for demand transportation. For community bus drivers, a service called passenger count records was also provided. For passengers using local buses, two services are provided: a simplified questionnaire survey and an on-board information display. For passengers waiting for local buses, two services are provided: display timetable/operation status and provision of vehicle location (bus location). Regional governments can access services that display operation history and geographic information system data. The infrastructure system was hosted on two physical servers running Apache and Cron, and the services were mainly developed in PHP.

We developed the SHINGU application (Fig. 2) to send bus location information and track the number of passengers on and off the bus. The application has a bus location function that sends location information to the cloud and records the number of passengers on and off the bus for each bus route. Smartphones with the SHINGU application installed are placed on the community bus to collect location information. The devices are powered by USB from inside the community bus. However, to conserve the battery during off-hours, such as during nighttime, the power is automatically turned off outside business hours. To collect the location information, the operator ID and bus number are configured in the application settings (Fig. 3). Once the application is activated, it transmits the current time, operator ID, bus number, battery level, and GPS coordinates to the cloud every three seconds. To count the number of passengers on and off the bus, the driver selects the operating route within the application and records the number of passengers on and off the bus on a dedicated screen. The application requests a list of routes that will begin operating approximately 30 min before the current time from the server, displaying the option to assist in route selection. This route information is based on GTFS data stored in the server database. The GTFS is often published as open data and is not confidential. However, when used in a way directly linked to operations, as in our system, threats of data tampering due to unauthorized access or server administrator errors remain. Therefore, we propose using the blockchain as a secure database that can track changes to store GTFS.

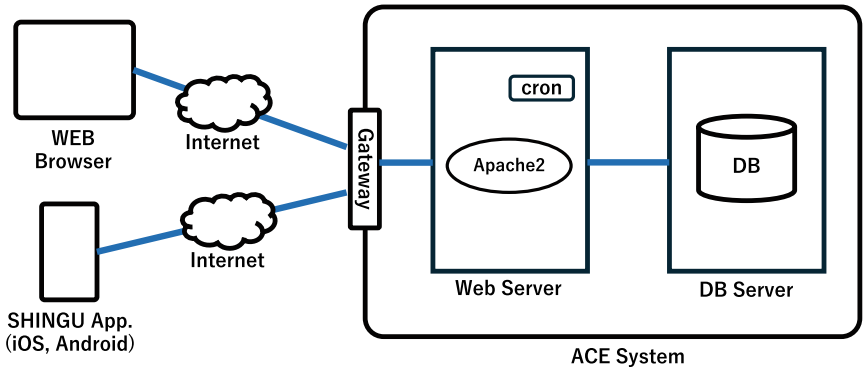

Fig. 1. ACE System Components.

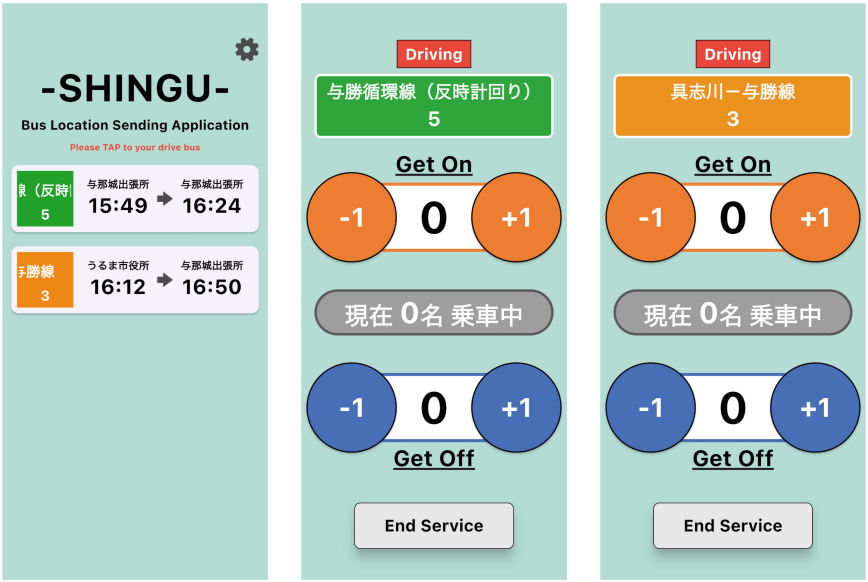

Fig. 2. SHINGU Application

5 Strengthening Through Blockchain

Blockchain is a DLT for securely managing data and recording transactions transparently and tamperproof [18]. As shown in Fig. 4, a blockchain is made up of blocks, which are the basic unit, a chain connecting these blocks in sequence, a distributed network comprising multiple nodes that store blockchain data, verify transactions, add new blocks on computers within the network, and smart contracts that are executed automatically when certain conditions are met. The system configuration enhanced by blockchain technology is shown in Fig. 5. In

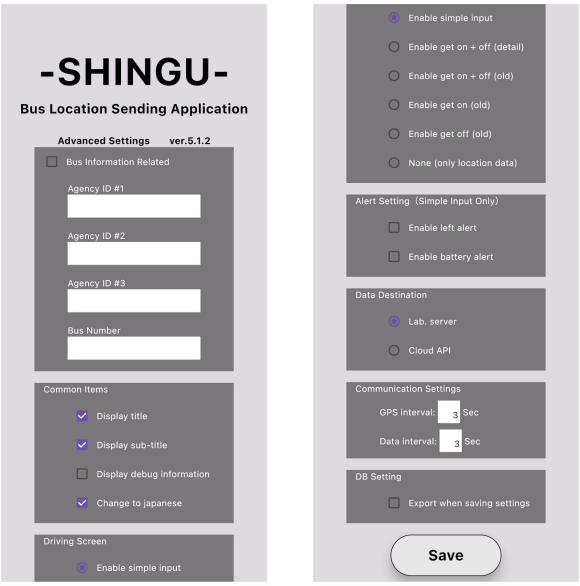

Fig. 3. SHINGU Application Settings

addition to a conventional database, the proposed system includes a blockchain with three nodes. Only a portion of the database data can be moved to the blockchain. The GTFS comprises nine different files (Table 1). The data that significantly impact operations due to tampering, such as agency, routes, shapes, stops, and trips, are stored in the blockchain. Only the server administrator can add, change, or delete this data.

Changes that were previously made directly in the database are now processed using the smart contract of the blockchain, which generates and connects a block to complete the storage process. Therefore, this method takes time to add, change, or delete data.

6 Verification and Discussion

We verify the proposed method for managing GTFS data using blockchain technology by constructing and evaluating an actual system. Blockchain provides resistance to data tampering and enhance transparency. This study improved the accuracy of operational information and ensured data safety. In addition, we tested BLS and PCS, which were developed in collaboration with local governments in Fukuoka Prefecture, in a real-world operating environment. Specifically, we stored some of the GTFS data (routes, stops, trips, etc.) on the blockchain and evaluated the impact of adding, updating, and deleting data compared to conventional database management.

The implementation environment was entirely built using Amazon web services. The web server and blockchain nodes were built using EC2 virtual

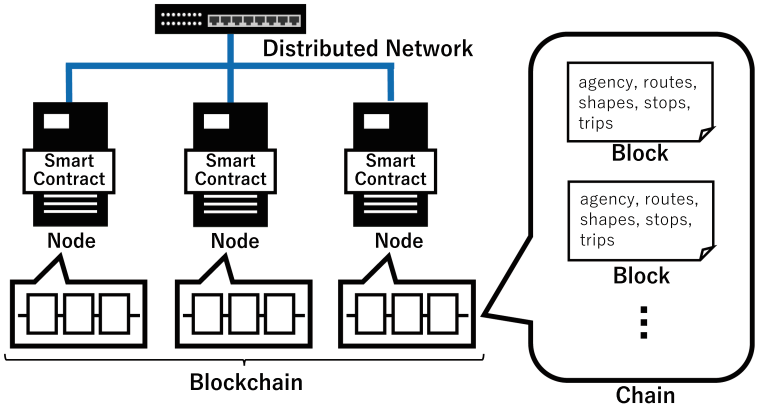

Fig. 4. Blockchain Construction

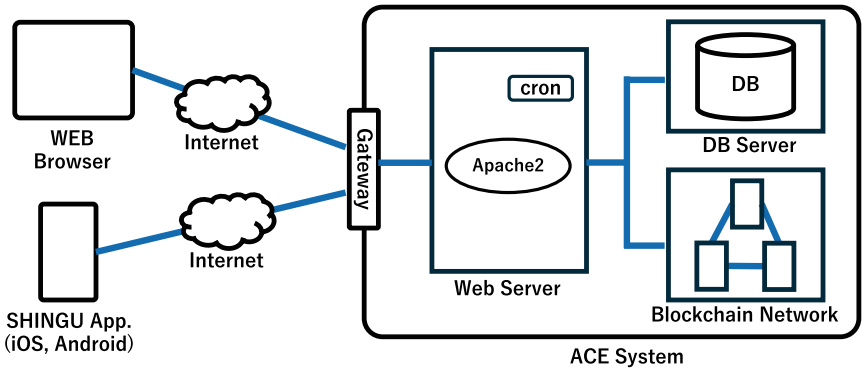

Fig. 5. System Strengthened by the Blockchain

machines. The web server configuration is t2 micro, memory, and 30 GB storage. The blockchain node configuration is t 3 medium, Memory, and 20 GB Storage. Figure 6 illustrates the data flow from the moment the web server requests the GTFS data to the time it is returned. We measured the time from data request to data return for the old system (without blockchain) and the new system (with blockchain). We ran each simulation 20 times, and the average results are shown in Fig. 7. The old system took an average of 15.5 ms, whereas the new system took an average of 283.4 ms. Moving to blockchain improves reliability and processing time.

The old system is vulnerable to data tampering due to administrator errors or unauthorized access. In contrast, the proposed system records all past data histories in the blockchain, which makes it easier to detect unauthorized changes. However, we observed that the time required to add and update data increased because data processing via smart contracts is required. We also examined the system's operational speed, data integrity, and tamper resistance. One of the

Table 1. GTFS Components

agency.txt	Contains information about the transit agencies, such as The agency's name, URL, and timezone
stops.txt	Contains information about the stops, including the stop's name, location (latitude and longitude), and time-zone
routes.txt	Contains information about the routes, including route names, route IDs, and types (e.g., bus, subway, etc.)
trips.txt	Contains information about trips, such as trip IDs, associated routes and service IDs
stop_times.txt	Contains detailed stop times for each trip, including arrival and departure times at each stop
calendar.txt	Defines the operating days for each service, including start and end dates and the days of the week on which the service operates
calendar_dates.txt	Provides exceptions to the service calendar, such as holidays or special operating days
fare_attributes.txt	Contains information about fare attributes, including fare types, price, and currency
fare_rules.txt	Defines the fare rules, mapping fares to specific routes or fare attributes

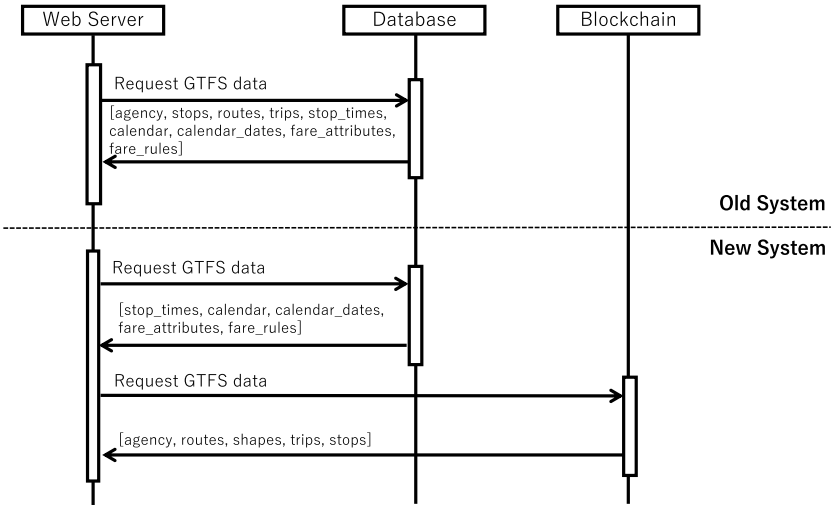

Fig. 6. Flow of a GTFS Data Request

advantages of implementing blockchain technology is its ability to prevent unauthorized data modifications because the history of changes is recorded on it. The recording of changes in operational information allows local governments and residents to check the validity of the data. In addition, the decentralized management approach reduces the risk of data loss due to server failures or admin-

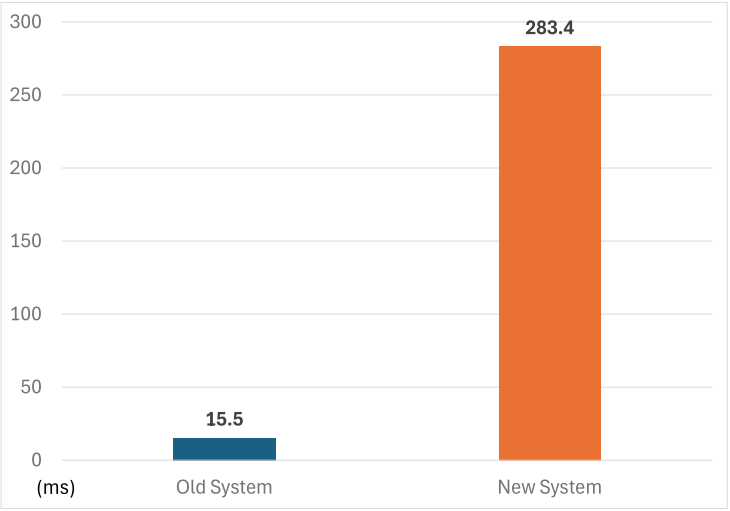

Fig. 7. Comparison results

istrator errors. However, reduced data processing speed was observed because data writing to the blockchain takes longer than immediate updates in traditional databases. This latency must be considered when implementing a real-time processing system. Although we achieved specific results in improving data reliability, we also identified issues such as delays in real-time processing and operating costs. In future work, we plan to consider hybrid operations that combine blockchain storage for critical operational data with traditional databases and methods to improve processing speed.

7 Conclusion

In this study, we developed BLS and PCS that use ICT to address the issues faced by regional public transportation in Japan. To improve data reliability and prevent tampering, we implemented blockchain technology to manage GTFS data. To ensure the safety of public transportation data, we stored key components of GTFS data on a blockchain. Blockchain technology allows us to manage data history and improve reliability transparently; conventional databases are vulnerable to tampering due to unauthorized access or management errors. However, blockchain takes a longer time to add and update data.

Our comparative analysis between the proposed system and conventional approaches demonstrates significant improvement in the convenience of regional public transportation and streamlining operations. However, the inherent latency in blockchain processing should be addressed in future work. In particular, to solve the problem of delays in data management using blockchain, a hybrid operation method that manages large real-time data and data essential for historical management separately is necessary.

In the future, we will collaborate with more local governments to expand the implementation of this system. We will also improve the technology to contribute to the sustainable development of regional public transportation. These efforts will advance the digital transformation of regional public transit while promoting the safety and comfortable movement of residents.

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