Demand Collection System using LPWA for Senior Transportation with Volunteer

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***Abstract*—Recently, the transportation means of the elderly have been insufficient due to aging and depopulation, therefore, the area volunteers have provided the demand-responsive transport (DRT) for seniors such as senior transportation service and demand bus. However, the demands collection via telephone or mobile applications has problems: the telephone call imposes a heavy burden on volunteers, and the mobile applications hinder the elderly who are not using or familiar with smartphone from using the service. In this paper, we propose a pick-up demand collection system that easily collects the demands from the elderly and makes them visible to the transportation manager. To collect demands, we designed the demand transmission device having LPWA (Low Power Wide Area) and a user interface for the elderly. As a result of asking the elderly to operate our prototype demand transmission device, it was found that the operability was better for the elderly than the existing input interface with the smartphone. In addition, we confirmed that the transmission device can transmit the demands through repeater devices with multihop communication by LPWA even if the demand request is not directly reachable to gateway due to the influence of radio shielding objects.**

***Index Terms*—senior volunteer transportation, aging society, lpwa**

I. Introduction

Population aging and depopulation are major social problems. In the region with small population, the continuation of bus service is difficult, and the decrease of the services or the abolishment of the route is evitable. In addition, the number of traffic accidents caused by the elderly is increasing due to the decline in exercise capacity caused by aging, and many people return their licenses. Because of these reasons, lack of transportation means for the elderly has become a problem. On the other hand, many volunteer staff and organizations voluntarily support going out for the elderly in order to secure the transportation means [1] [2]. However, in many cases, the manager has trouble in managing the service efficiently because s/he collects the pick-up demand by telephone and creates the pick-up schedule manually. As a result of our interviews with volunteer staff in the Shikanodai area of Nara Prefecture, Japan, where the transportation service for the elderly is actually provided, it turned out that transportation management is a heavy burden because tasks such as collecting demands, creating a transportation schedule, and coordinating volunteer staff to transport are concentrated on one volunteer staff. As the elderly in need of transport will increase further in the future, current telephone coordination and management will make it impossible for volunteers to support transportation. Therefore, systematization is necessary for efficient operation.

A demand-responsive transport (DRT) system is an example of an existing system that provides transportation. The Smart Access Vehicle System (SAVS) developed by Hirata et al. [3] does not have a fixed route and immediately dispatches a vehicle in response to a user's call. At this time, if the passenger who has boarded or another passenger who is going to board allow and the arrival time is within the desired time, carpool occurs. In other words, it is a transportation system that combines both conventional taxi and bus services. However, in SAVS, since the transmission of the pick-up demand and the receipt of the dispatch result is performed by an application installed in the smartphone, the elderly who do not have a mobile terminal such as a smartphone or is unfamiliar with the operation of the application have trouble. In addition, since an Internet connection is required to use the application, building a communication environment can be an additional burden.

In this paper, we propose a demand collection system to support community volunteer staffs who provide outgo support services for the elderly. The proposed system constructs a dynamic mesh network in the volunteer area by the communication devices implementing the LPWA (Low Power Wide Area) module and collects the pick-up demands from the dedicated demand transmission devices for the elderly. The demand transmission device is used for transmitting the date and time and destination information desired by the elderly, and it is assumed to be installed in the elderly's home. We adopted a key input device in which the elderly are accustomed to the operation as the input interface for the demand transmission device instead of the touch interface of a smartphone application that the existing DRT services utilize to collect the demands. In addition, since the device implements the LPWA module that enables the long-range communication without communication contract, the elderly can use the service without the monthly payment for communication, and the construction of communication environments by their hand. The pick-up demands from the devices are transmitted to server through area gateway. Since the volunteer transportation managers, who have collected demand for each one by telephone call so far, can collectively confirm these demands on the server, the proposed system can remove their burden for demand collection.

We conducted two types of experiments to realize the proposed system. The first is UI evaluation of the pick-up demand transmission device developed in this study. We asked 8 elderly people over 70 years old to operate two kinds of devices we developed and existing information input application. As a result, all of them evaluated that our device was the easiest to operate, so we confirmed that our device is more suitable to the elderly. The second is a survey of the communication range by LPWA. As a result of the investigation in the residential area where the volunteer carried out the pickup service, it was proven that the whole area could not be covered by LPWA. Therefore, we developed a repeater and adopted multi-hop communication, and finally succeeded in expanding the LPWA coverage area.

II. Related Work

A. Transportation System

Various studies and services are being conducted to solve the shortage of transportation. Conventional public transport (CPT) with fixed routes and schedules is an important transportation means, especially in urban areas where there are many users. On the other hand, CPT also has some inefficiencies, and there is a growing demand for DRT that operates according to demand. Kashani et al. [4] compared DRT and CPT by incorporating a dynamic routing algorithm into an agent-based traffic simulation. As a result, it was shown that by replacing CPT with DRT, passengers could shorten their perceived travel time and improve their mobility without extra cost. In other words, DRT is a useful transportation system in terms of providing passengers with efficient transportation. The ride-sharing service Uber [5] is also a DRT system that provides a pick-up service in cooperation with taxi companies and individual drivers. In such a system, the collection of pick-up demands and the creation of pick-up schedules are performed automatically, so efficient pick-up management can be performed. However, the elderly who do not have a mobile terminal such as a smartphone or are unfamiliar with the operation of the application have trouble using the services because the transmission of pick-up demands and receipt of the dispatch result are performed by the application installed on the smartphone. In addition, since it is necessary to connect to the Internet to use the application, building a communication environment is an additional burden. In Japan, “Koko Demand Bus” [6], which is a kind of DRT, automatically dispatch cars according to the user’s pick-up demand. However, this system requires labor costs because the operator is responsible for reservation and operation management. In addition, since taxis and bus companies are responsible for pick-up, a commission fee for each transportation is also required. From this aspect,

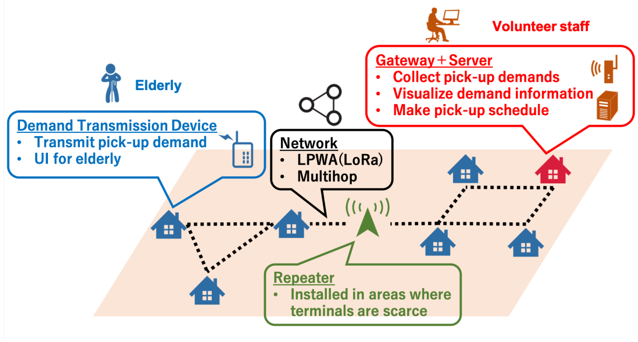

Fig. 1. System Configuration

the problem with the existing pick-up management system is that it does not consider the elderly in collecting pick-up demands, and the operation cost is high.

In this study, we aim to create an environment that allows users who are not familiar with the application to easily use the pick-up service by designing a device for transmitting pick-up demands for the elderly. In addition, the device is pre-installed with LPWA communication functions that can communicate at low cost, so there is no communication cost to maintain the proposed system.

B. LPWA Communication

With the spread of IoT (Internet of Things), LPWA, which enables a wide range of communication at low cost, is attracting attention, and various researches such as evaluation of communication capacity and scalability are being conducted [7] [8]. The LPWA technology is gradually being applied, and new systems are being developed for indoor and outdoor use, such as indoor position measurement [9] and air quality monitoring [10]. Oliveira et al. [11] also showed that the maximum communication range differs between urban and rural areas even in the same outdoor environment, which shows that the configuration of the system and the network can greatly change according to the scenario. Honda et al. [12] developed a system for monitoring the daily activities of the elderly living in a depopulated area using LPWA communication, and confirmed that the communication was possible. Since there are few buildings and houses that block communication in this area, the wide communication range compared with the urban area can be a factor of the success of communication.

Therefore, we investigated whether the operation of the system was possible in the environment with many shields by constructing the LPWA network in the residential area (Intermediate between urban and rural areas) where many elderly people live.

III. Proposed System

To clarify the problems of the existing pick-up service, as a result of interview surveys with users and providers of the pick-up service operated by local volunteers and managers, it was found that there are many elderly people who do not have an Internet environment at home and do not have a

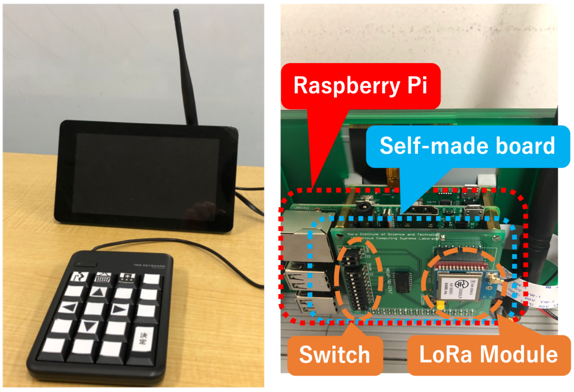

Fig. 2. Demand Transmission Device(Left:Front, Right:Back)

PC or smartphone, and the collection of pick-up demands by telephone is a burden on the administrator. From this result, we confirmed that there is a need for a device that allows the elderly to easily send pick-up requests, and a system that automatically aggregates demands to managers. In this paper, we propose a pick-up demand collection system that makes it easy for the elderly who are not familiar with smartphones and smartphone applications to send pick-up demands easily. Figure 1 shows the configuration of the proposed system. This system consists of a demand transmission device installed at the elderly's home, a repeater installed to expand the communication range, a gateway that transfers the pick-up demands to the Internet, and a server that visualizes the pick-up demands to the volunteer staff. The elderly input pick-up demands using the demand transmission device developed in this study. Pick-up demands are collected on a server connected to the Internet via LPWA communication and visualized to volunteer staff.

A. Demand Transmission Device

A preliminary interview with volunteer staff who picked up the elderly revealed that many elderly do not have smartphones and do not have an Internet environment at home. Systems that require new contracts for smartphones and Internet connections, application installations and the construction of Wi-Fi environments are not suitable for the elderly because of the heavy burden. Therefore, the elderly need a device that works just by placing it at home. The elderly feel confused about operations such as launching applications, accessing websites, logging in, and inputting and sending information in smartphone applications and web services. Furthermore, the touch interface is unsuitable as an input method because it is not familiar to the elderly. In this study, we have newly developed a demand transmission device as shown in Fig. 2, which does not require a contract with a smartphone or an Internet line and can transmit a demand to a transport service manager by a simple key operation.

Configuration of Demand Transmission Device: Figure 3 shows the configuration of the demand transmission device. The demand transmission device consists of a RaspberryPi that performs processing, a numeric keypad as a key-type input device, a display that performs visualization, and a self-made board including a LoRa module [13] that performs communication and a switch that sets the device ID. The elderly inputs the pick-up demand information using the numeric keypad while checking the display. The information input by the numeric keypad is reflected in the display, and the input information is transmitted by the LoRa module when the transmission key is pressed. The prototype device in Figure 2 was developed using the Raspberry Pi 3 Model B, the Elecom wired keyboard TK-TCM011BK (Key Pitch: 19 mm), and the EASEL LoRa module ES 920 LR (Technology Certification). Section III-D describes the ES920LR specs and the LoRa environment implementation method.

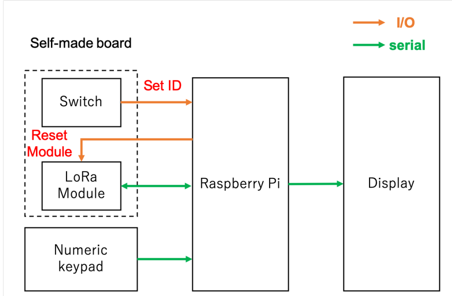

Fig. 3. Configuration Diagram of Demand Transmission Device

Fig. 4. Input Screen for Pick-up Demand

Device Operation: Figure 4 shows the screen displayed to the elderly when entering a pick-up demand. The elderly input destination and desired time information while viewing this screen. Date and time information is displayed at the top of the screen and destination information is displayed at the bottom of the screen, indicating that items with a red triangle on the screen are currently settable items. As an example, in the case of Fig. 4, the time can be changed.

Input Interface and Design: We assumed that the existing smartphone application-based pick-up service is difficult to use for the elderly who are not familiar with the touch interface therefore we adopted the physical keys as the input interface. As for actual input devices, we adopted numeric keypad which can directly input numerical values, has a sufficient number of keys for the input of pick-up demands, and is large enough for the elderly to press. However, with the commercially numeric keypad, the elderly have a possibility of unreadable the characters of keys because the character size is small. Therefore, we created stickers printed illustrations with elderly readable and pasted to the top for each key. At the design of

Fig. 5. Key Design (Left: Cursor Type, Right: Numeric Type)

the key stickers, we considered two types of input methods shown in 5 for the input of pick-up demand: cursor type and number type. In the cursor type, the up and down arrow keys express the increase and decrease of the numerical value, and the left and right arrow keys express the change of the selected item. For example, in the case of Fig. 4, pushing the upper arrow key changes to 20 minutes (here, 5-minute unit), and the left arrow key switches the cursor to the hour setting. The advantage of the cursor type is that there are just six key types: up, down, left, right arrow keys, and the enter and back key. Therefore, the cursor type is possible elderly to input easy without the trouble of finding or understanding keys. On the other hand, the disadvantage of the cursor type is that the number of key presses increases depending on the input information. For example, if setting a schedule for two weeks later, the elderly have to press key 14 times, but the numeric type requires only 1 or 2 times. Therefore, the cursor type can be said less efficient than the numeric type. The numeric type is a method of directly pressing the number assigned to the key. Unlike the cursor type, the required time can be shortened because the information can be entered directly. Against the cursor type, the numeric type has the disadvantage that requires to use more types of keys: 10 numbers, forward, and back keys, which is a total of 12 types. Three illustrations shown in the top of both the cursor type and the numeric type indicate the destination category. The elderly easily input the destination information by pressing a specific key. The categories represent the representative destination on the volunteer transportation service in the Shikano-dai area in Nara, Japan. For other destinations, the elderly can choose from the destination list shown in the bottom part of the input screen in Fig. 4.

B. Repeater

Although LPWA communication has the feature that the coverage area is wide, it seems that the coverage area can be narrow because there are many shielding objects such as houses and trees in the residential area. Therefore, we thought that the coverage area could be expanded by adopting multi-hop communication. To perform multi-hop communication, a device with a communication function is required in addition to the demand transmission device. Therefore, in this study, we developed a new repeater that repeats the information transmitted by the demand transmission device. The repeater

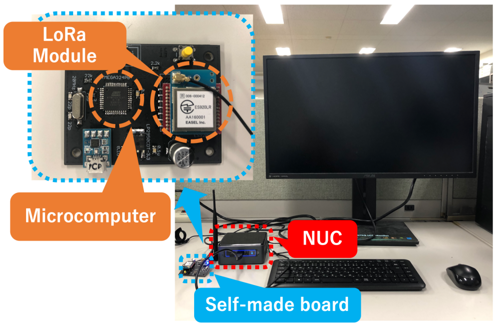

Fig. 6. Gateway

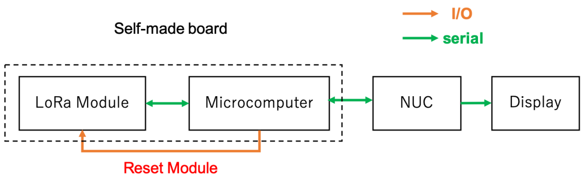

Fig. 7. Configuration Diagram of Gateway

uses the same board as the demand transmission device. On the other hand, it does not require an input/output interface such as a numeric keypad or a display, so it can be installed at a lower cost than a demand transmissioion device.

C. Gateway

We have developed a gateway that receives pick-up demands transmitted by the elderly. Figure 6 shows the developed gateway. Pick-up demand information received by the gateway is visualized on the administrator's display via the server.

Configuration of Gateway: Figure 7 shows the gateway configuration. The gateway consists of a NUC (small PC) that performs processing, a display that performs visualization, and a self-made board including a LoRa module and a microcomputer for controlling it. As with the demand transmission device, LoRa environment of the gateway is described in section III-D.

Visualization of Demand Information: To reduce the burden on volunteer staff, who collect demands and create transport schedules, we propose a system that visualizes collected pick-up demand information. In the proposed system, collected pick-up demand information is visualized to reduce the burden on volunteer staff, who collect demands and create transport schedules. The transportation manager can check the list of demand information only by accessing the server, so the burden of collecting demands by telephone is reduced and the manager can create schedule smoothly. The collected demand information is aggregated into a table for each item such as user, desired date and time, destination, etc., as in the output example shown in Fig. 8.

D. Implementation of Communication Functions using LPWA

In this study, LPWA is used for communication between devices such as demand transmission devices and repeaters.

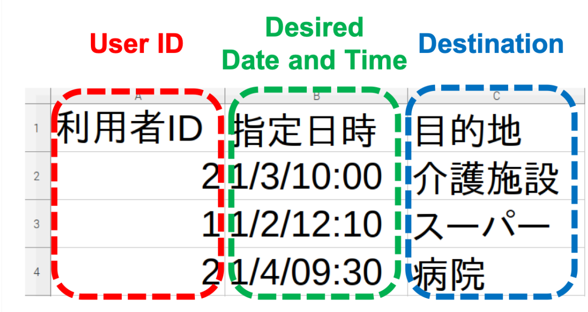

Fig. 8. List of Pick-up Demand Information

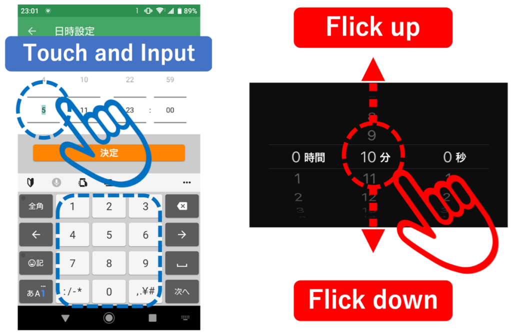

Fig. 9. Existing Interface(Left: Touch Interface, Right: Flick Interface)

Among LPWA, we adopted LoRa, which has a long communication distance and is widely used. Table I shows the specifications of the ES920LR used in this system.

ES920LR needs to restart the module to apply the setting change such as changing the destination. At this time, the Raspberry Pi in the demand transmission device can be controlled by GPIO, but the NUC in the gateway does not have a digital pin, so the ES920LR is controlled via a microcomputer. This allows the NUC to send a command to control the microcomputer's digital pins and restart the module. ES920LR is included in the self-made board, and is connected via a USB cable at the gateway and as a Raspberry Pi shield at the demand transmission device. Regarding the communication method, the demand transmission device broadcasts the demand information to all devices, and the repeater repeats the broadcast, and finally, the gateway receives the information. In this way, by setting not to create a fixed communication path, the administrator can easily add or delete devices and can build a flexible network. To prevent the same demand from looping, each device records a log of the received demand information and does not receive the same demand.

IV. Experiment

To realize the proposed system, we conducted two types of experiments. The first is the UI evaluation of the pick-up demand transmission device developed in this study. By asking the elderly to compare the two types of devices developed in this study with the existing information input application, we verify that our device is a better UI for the elderly. The second is a communication experiment using LPWA. We verify that the proposed system can be operated in the area where the pick-up service is provided by using the communication devices we developed. This experiment was conducted with the cooperation of volunteer staff groups and the service users in the Shikanodai area, Nara Prefecture, which provides the pick-up service.

TABLE I
Spec of ES920LR

Item	Setting
Communication Distance	30km(When using an external antenna)
Interface	UART
Frequency	920.6 - 928.0MHz
Bandwidth	62.5kHz - 500kHz
Diffusion Rate	7 - 12
Transmission Speed	146bps - 22kbps
Transmit Power	Less than 13dBm
Receive Sensitivity	-118dBm - -142dBm
Data	Up to 50byte(Any ASKII code)

A. UI evaluation

To verify the validity of the UI of the pick-up demand transmission device, the information input interface developed in this study was compared with the interface of the existing application.

Experiment Contents: The elderly subjects were asked to operate 4 types of input interfaces: cursor type, number type, touch type (left in Fig. IV-A), and flick type (right in Fig. IV-A), and to select the interface that was easiest to operate. The subjects were eight elderly people (1 female in their 70s, 6 females in their 80s, 1 female in their 90s) who used the pick-up service.

Experiment Result: When the subjects were asked about the interface that was easiest to operate, all subjects selected the two types developed in this study. Seven of the subjects selected the numeric type and one selected the cursor type. The reason for selecting the numeric type was that it was easy to operate intuitively and it was possible to input quickly. The reason for selecting the cursor type was that it was also easy to operate intuitively. On the other hand, the touch type and flick type often did not react with the fingers of the elderly, causing malfunctions.

Analysis: Since many subjects chose the numeric type, it became clear that operational efficiency was an important factor in evaluating the UI. Another reason why many elderly choose the numeric type is similar to the UI that they have used so far, like a telephone. The reason why the elderly's fingers were not recognized maybe that the fingertips of the elderly are less watery or that they are not used to the operation.

B. Communication Experiment

Assuming the actual operation of the proposed system, we conducted a communication experiment in the Shikanodai

Fig. 10. Location of Communication Devices

area, Nara Prefecture, Japan to verify whether LPWA communication is possible in a residential area where pick-up service is provided.

Experiment Contents: Since the demand transmission device used in the proposed system is assumed to be installed at the elderly's home, this experiment also verifies whether the communication device can be installed and communicated in the area where the pick-up service is provided. Figure. 10 shows the location of the communication device. B is a point one block away from point A across the road and houses, and C is a point two blocks away. First, communication was performed at points A and B, and then communication was performed at points A and C.

Experiment Result: As a result of communication at points B and C starting from point A, it was possible to communicate at point B but not at point C. In other words, it was found that when communicating between houses, communication was possible up to one block, but communication was difficult after two blocks.

Multi-Hop Communication: Since it is difficult to operate the pick-up service when the device's communicable range is up to one block ahead, we attempted to expand the coverage area by performing multi-hop communication using a repeater. When a repeater was installed at point B of Figure. 10 and communication was performed between points A and C, communication was successful.

Analysis: LPWA is originally capable of long-distance communication, but in residential areas, it has been limited to communication up to one block ahead, so it is considered that houses etc. have blocked communication. Therefore, as it was done in this experiment when communication is difficult, a wider range of networks can be constructed by installing a repeater around it. We are considering the location of the repeater in the home of volunteer staff participating in the transportation service and public facilities such as parks in the area.

V. Conclusion

In this study, we constructed a system to automatically collect pick-up demands from the elderly in a transportation service provided by local volunteer staff. In realizing the system, we worked on (a) development of a pick-up demand transmission device, (b) construction of a communication environment using LPWA, and (c) visualization of pick-up demand information. When we asked the elderly to use the device developed in this study, we were able to obtain a higher evaluation than existing information input applications. In addition, as a result of investigating the communication range by LPWA, it was found that even in LPWA that can be used for long-distance communication, the communication range was shortened due to the influence of houses and natural objects. Therefore, we confirmed that the coverage area could be expanded by newly developing a repeater and adopting multi-hop communication. As prospects, we will improve the demand transmission device and UI for demand information visualization by operating the proposed system in the long term. We will also verify the scalability of the network by installing devices in more homes.

Acknowledgment

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