AUTONOMOUS CONFIGURATION WITH THE SHORT-RANGE INFORMATION SHARING SYSTEM NAMI

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ABSTRACT

SHONAN, an advanced system harmonizing human capabilities and information technology (IT), was introduced in light of the COVID-19 pandemic, which prompted the shift of office workers and school students to online platforms. In addition, a specific application of SHONAN, referred to as the narrow area communication system (NAMI), was previously implemented, exclusively sharing text-based information. Further, NAMI uses Bluetooth low energy (BLE) to exchange messages; however, it is difficult to exchange large data, and therefore, we have confirmed that it is possible to exchange large data using Wi-Fi. Thus far, all experimental systems have been designed on paper in advance. This is insufficient for actual dynamic systems. In this paper, we considered a method that can allow NAMI functions to continue to be used even when devices and edges move and the network configuration changes dynamically. Further, we implemented and confirmed the functions in the prototype.

KEYWORDS

IoT, Sustainable System, Multimedia Data, Autonomous Configuration, Ad Hoc Network

1. INTRODUCTION

The COVID-19 pandemic necessitated a widespread shift towards online lifestyles. Initially perceived as advantageous for IT professionals, eliminating the need for commuting to physical offices and offering students the ability to attend classes remotely did not unfold as seamlessly as anticipated. Challenges stem from an underdeveloped state of IT infrastructure and systems, coupled with a general lack of awareness of the profound impact of this paradigm shift on individual capabilities. Despite the value of online resources for knowledge acquisition, certain facets of learning and interaction are only uniquely attainable through in-person engagement. Furthermore, not all tasks can be optimally executed by IT-based systems, with human proficiency often surpassing that of automated counterparts.

Network and internet technologies have contributed to shortening distances between spaces, thereby enabling face-to-face conversations with people from the other side of the world. However, few services focus on people who are close to each other.

If people can experience things in their immediate vicinity that cannot be achieved with network technology, the functions of network technology can be complemented in such scenarios. For example, authentication mechanisms can be simplified or eliminated. New services that go beyond the conventional framework can be provided by understanding the system as a whole,

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including information and communications technology (ICT) and functions provided by the people who use it.

We previously proposed a sustainable system based on harmony between human capabilities and IT (SHONAN). This novel framework extends the functionality of existing IT systems by harmonizing human capabilities with technological interfaces [1]. SHONAN represents an exemplary case favoring human-centric solutions over exclusively IT-driven approaches (Figure 1). Adopting such a sustainable system offers the prospect of substantial reduction in unnecessary IT development and resource utilization, thereby mitigating the imperative to perpetually expand the IT domain.

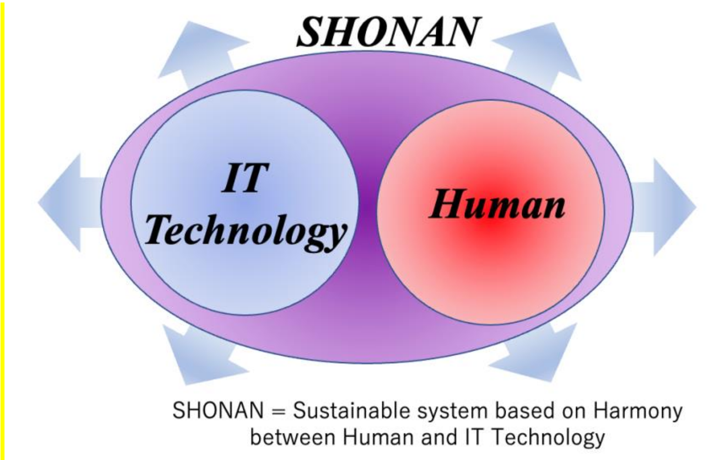

Figure 1. Proposed sustainable system: SHONAN

In a previous study, a messaging system called the neighborhood communication system (NAMI) was implemented as a specific application of SHONAN. NAMI facilitates message exchange within confined geographical areas. The details of NAMI are discussed in a previous study [1]. Sharing only textual information is feasible because it uses BLE. Social networking site (SNS) applications involve the exchange of images and videos, and therefore, we considered developing a sustainable system such as NAMI that can avoid unnecessary distribution or storage of data, while simultaneously accommodating the exchange of images and videos when required. Previous research showed that large amounts of data such as photos and videos can be shared using Wi-Fi communication via access points [2].

Thus far, all implementations were performed by determining the paper configuration in advance and manually setting it for each device. However, in actual use, devices move, and therefore, connections change constantly and dynamically. In addition, the edge was assumed to be a mobile notebook PC and therefore moved dynamically, similar to a device. It is not always possible to connect communication channels. Therefore, functions that can withstand dynamic changes in networks and nodes are necessary to operate in real-world scenarios.

In this study, we investigated the ability of the NAMI system to withstand dynamic changes and verified its operation using a prototype system.

In Chapter 2, we will discuss related researches. Chapter 3 provides an overview of NAMI. In Section 4, we propose an algorithm for dynamic configuration in NAMI. Chapter 5 describes the implementation method of the experimental system and the execution results. Chapter 6 provides the conclusion.

2. RELATED RESEARCHES

NAMI is generally classified as a mobile ad hoc network (MANET)because it consists of moving mobile devices, the network is not fixed, and there is no infrastructure network[3][4].In MANET, the routing protocol is one of the challenges because the network configuration changes dynamically [5].In NAMI, messages are broadcast to all nearby nodes, so there is no need to search for the destination node, but neighborhood detection is important when unconnected nodes approach each other. There are a couple of neighborhood detection algorithms such as HELLO, PRR and their improved versions [6][7][8]. Recently, routing protocols using AI technology have also appeared[9][10].

As described above, various routing protocols have been proposed for mobile ad hoc networks, but most of them have been implemented only through theoretical studies or demonstration experiments [11]. NAMI proposed a method with higher feasibility by implementing it on existing smartphones and operating systems.

3. OVERVIEW OF NAMI

NAMI facilitates information exchange among nearby individuals, fostering direct communication in school classrooms, community-center meetings, or exhibitions. The system eliminates the need for pre-registering IDs and addresses privacy concerns by enabling information exchange based solely on the physical presence of individuals. NAMI restricts the scope of information provision to a localized area for a brief duration to prevent the global dissemination of information, thereby contributing to a sense of security for users (Figure 2).

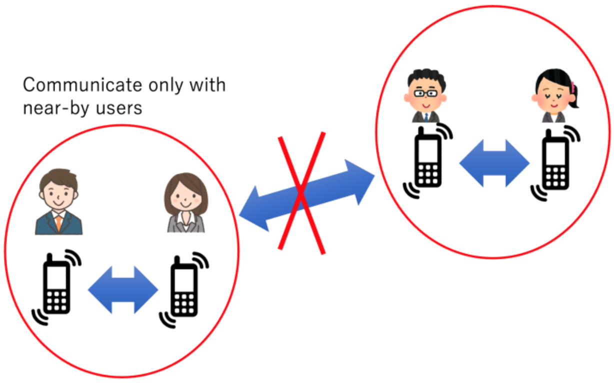

Figure 2. NAMI system

NAMI comprises only mobile devices (i.e., smartphones), which use the BLE function to detect nearby devices and exchange messages one-on-one. NAMI ensures that the same devices are not connected for a certain period, and therefore, the messages are exchanged between multiple devices. All devices are mobile, and therefore, they can exchange messages with new and different devices as they move. Subsequently, the message is conveyed through the next device to yet another device. The message included an ID, and therefore, it is not sent twice to the same device. The message has no destination and spreads to nearby devices; there is no guarantee that a message will reach a specific device. The scope of transmission is limited by the number of transmissions and time of message generation; therefore, the messages were not transmitted everywhere.

NAMI uses BLE for communication, and therefore, the transfer speed is slow (~2 Mb/s [12]). There is no problem with transferring text because it becomes difficult to share large amounts of data, such as photos and videos. The system was expanded to send large amounts of data, and Wi-Fi was used to connect the devices to the edges. We created a three-layered network comprising devices, edge servers, and cloud servers to exchange large amounts of data (Figure 3).

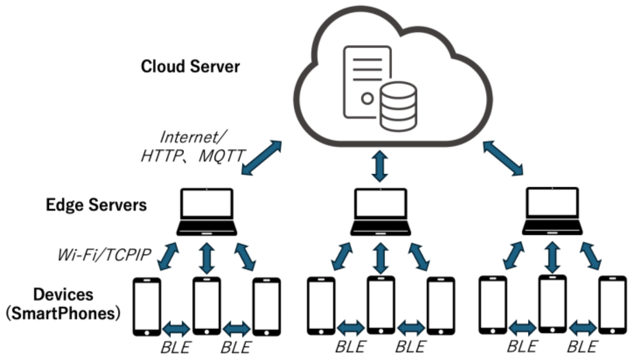

Figure 3. Proposed network configuration

A cloud server exists on the internet and can be accessed via a URL, which is similar to a regular internet site. Edge servers are moving nodes (usually notebook PCs) that can connect to the internet. The edge servers can access a cloud server when connected to the internet, and they have Wi-Fi access-point functions. We assume that this is a small, portable access point. The edge servers connect to their access point (Figure 4), are equipped with a traditional BLE communication function, and can communicate with devices.

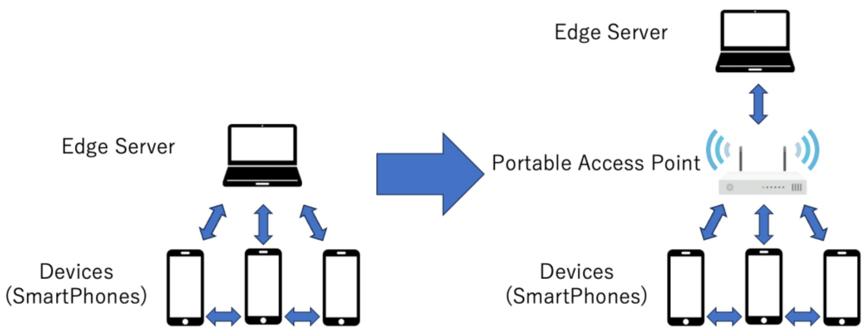

Figure 4. Portable Wi-Fi access point

Devices can communicate with the edge servers via Wi-Fi using an access point attached to the edge server. In this configuration, a normal text information exchange was achieved using a conventional BLE network. When sharing large amounts of data such as photos and videos, they are sent to a three-layer network via the edges. Only photo or video files were sent to the three-layer network, and the ID of these files were transferred via BLE. The IDs can be used to download the data to the user’s own device when accessing these files.

Thus, information can be exchanged via a three-layered network using Wi-Fi for large amounts of data and a BLE network for text messages. In our previous research, we configured BLE and three-layered networks in an experimental system, and we confirmed that information-sharing functions could be realized. In these experimental systems, the network configuration was designed in advance, and each device was individually configured manually to confirm its operation.

We manually changed their configurations and confirmed their operation for the movement of devices. We did not address the dynamic changes in the configuration caused by the actual movement of devices and edges although we verified the operation in each hypothetical scenario. Therefore, there is a need for extensions that can accommodate dynamic changes in actual usage.

4. Dynamic Configuration for the NAMI System

System configuration changes that need to be addressed are as follows:

1) Install applications when you need them (This is excluded in this paper).
2) Communication with a new device or edge is initiated when a device or edge is moved, or communication with a disconnected device or edge is automatically stopped.

Even if these events occur in combination, the system must continue operation without any special operations performed by the user. These functions should be realized using existing functions. We used an iPhone as the device, Mac as the edge, and an Ubuntu server as the cloud. We considered implementation methods that can be solved using this combination.

4.1. General Technique

1) Mobile Ad Hoc Network

NAMI is a type of mobile ad hoc network because devices and edges are movable, and the network configuration changes dynamically [13]. One method (OSPF protocol) for route detection in ad hoc networks uses hello messages [14]; each device communicates its presence to surrounding devices by periodically sending hello messages. Each device repeatedly sends and receives hello messages, thereby allowing the devices to learn about each other's existence as a whole. The hello message can efficiently propagate information over a wider range of areas by including not only information about yourself but also information about nearby devices. Thus, all devices have the same functionality. However, the OSPF protocol is not normally implemented in iPhones.

2) BLE

In BLE, each device is divided into peripheral and central devices. The center detects peripherals by receiving advertisement signals sent by them, and there are two types of BLE devices.

3) Wi-Fi

With Wi-Fi, devices can detect access points by listening to beacon signals transmitted by the access points [6]. However, authentication information–generally an SSID or password–is required to connect to an access point.

Thus, it is possible to detect nearby nodes without dividing their roles using the OSPF protocol of a mobile ad hoc network. However, it is necessary to separate the roles of the nodes, such as sender and receiver, when using BLE or Wi-Fi (Figure 5).

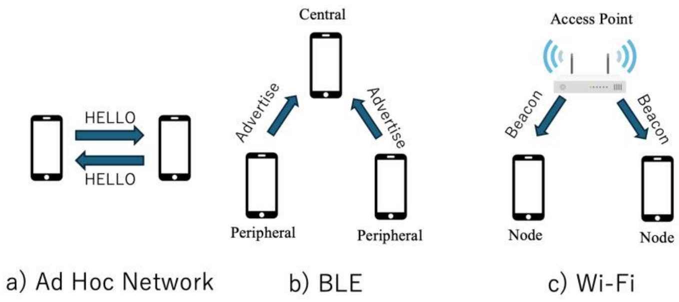

Figure 5. Device detection.

4.2. NAMI Case

Message communication using BLE is a basic function and Wi-Fi communication is a supplementary function in NAMI. Therefore, we need to ensure communication between devices using BLE. We implemented a simple method in which a device periodically switches its role to peripheral or central using BLE communication, which allows a device to detect new devices. Once communication is enabled using BLE, Wi-Fi authentication information can be transmitted from the edge to the peripheral device using BLE communication.

1) Device Discovery with BLE

NAMI alternates the role of each device in the peripheral and central functions. The switching time is randomly set between 5 and 8 min. The two devices cannot detect each other or exchange messages when they operate in the same mode. Even if the two devices are in the same mode, randomly changing the switching time can change the devices into different modes after waiting for a while. The experimental system demonstrated that messages could be exchanged within ~15 min in many cases.

2) Edge Server Detection

Edge servers have the same message exchange system as the devices. If the device and edge are nearby, they can exchange messages using BLE. Edge servers have their own portable Wi-Fi access points as peripheral devices; the edge and access points move simultaneously. The devices can communicate with the edge servers by connecting to that access point because the edges are connected to their own access points. Devices need the SSID and passwords of the access point to access the access point. The SSID and password are transmitted to nearby devices via the BLE. The TCP/IP communication with the edge becomes possible when the device connects to the Wi-Fi access point using the transmitted SSID and password.

This type of mechanism enables NAMI to detect each other and secure a communication channel between moving devices and moving edges (Figure 6).

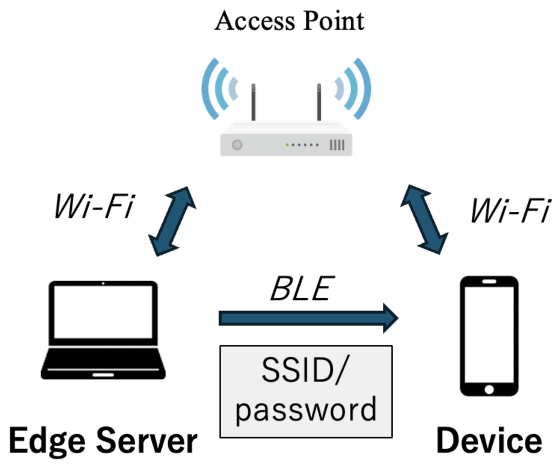

Figure. 6. Edge server detection

3) Task Management

Users execute tasks regardless of the network connection status. Tasks executed while not connected to the network may not have been completed. The system must detect tasks that have not been completed and re-execute tasks that can be re-executed. It may be difficult to re-execute all tasks completely. Therefore, we categorize tasks and select those that can be re-executed. normal operations need to be organized to categorize the tasks.

4) Normal Case

The user captures a photo (or video, hereafter referred to as a photo) using a device. The user selects a photo to be shared and uploads it to an edge, which creates a file ID for the uploaded photograph and returns it to the device. The edge has a unique edgeID, and the fileID includes an edgeID, which makes the file ID unique. The device shares the file ID and accompanying information, such as a description of nearby devices, using BLE.

If a device that receives a file ID wants to download the file, it sends a download request to the edge to which it is connected. The edge where the file is uploaded and the edge that receives the download request may have different edges because the devices are movable. When an edge receives a request, it downloads it to the device if the edge has the corresponding file. When the edge does not contain a file, it sends a request to the cloud. After the download from the cloud is completed, the edge downloads it to the device.

Similarly, the cloud that receives the request downloads the corresponding file to the edge, if it holds it. If the cloud does not have a file, it sends a file request to the corresponding edge because the edge ID is included in the file ID. The edge that receives the file request should have a relevant file, and therefore, it will be uploaded to the cloud. This is the flow of processing when all networks are connected (Figure 7).

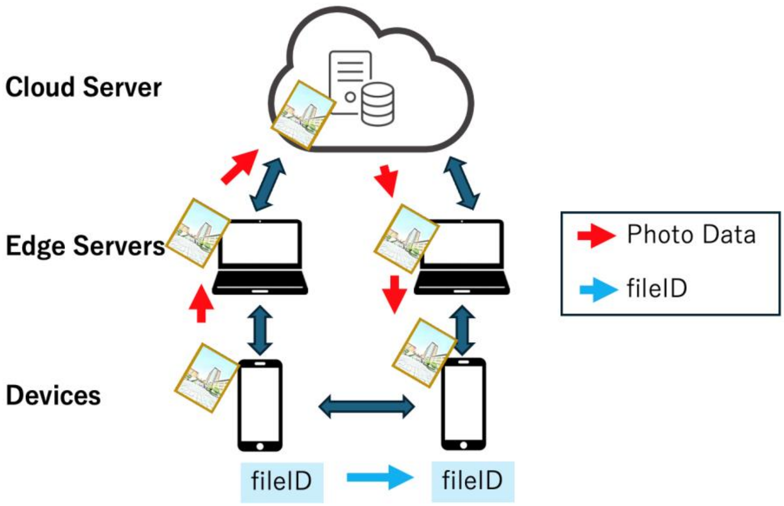

Figure 7. File transfer operation: Normal case

5) Error Case

The processing flow fails when there is no connection. The system retries the process if success is possible. An error is displayed to the user if the number of retries exceed the preset limit.

6) Error Case: Download

Based on whether the file exists, there are download requests from the device to the edge and from the edge to the cloud, and upload requests from the cloud to the edge.

a) Request from the Device to the Edge

In this case, no edges can be connected to the device, which can be detected because the request API fails immediately. This failed request is added to the list of pending tasks. Pending tasks are re-executed when the connection to a new edge is successful (Connecting to a new edge means connecting to a new Wi-Fi application). This process is executed when Wi-Fi information is transmitted to the device via BLE such that it can be detected on the device side.

b) Request from the Edge to the Cloud

This is the case when the edge is not connected to the internet or cannot connect to the cloud for some reason. The system does not specify how the edge, which is a notebook PC, connects to the internet. In many cases, Wi-Fi or wired LAN were used. In this case, detection was possible because the request failed immediately. The only option is to wait and try again because the cause of failure is unknown. At this point, we did not incorporate retries at this level into the system.

c) Upload Request from the Cloud to the Edge

In NAMI, an edge is a device that does not have a global IP, and therefore, an edge cannot be specified by the IP address on the cloud. We used the MQTT protocol to send requests from the cloud to the edge instead of the IP address. The cloud uses “MQTT to publish” and requests a file that the cloud does not own from the edge that holds that file. The edge can receive the request by waiting with “MQTT subscribe.” When an edge receives a request, it uploads the file to a cloud web server. With MQTT, it is impossible to check whether a message has been transmitted to an edge. The cloud determines whether a process is successful by checking whether a file has been uploaded after a certain amount of time.

If the upload process from the edge was incomplete within a certain amount of time, it was considered an error. The reason for this error was unknown, and therefore, no retrieval was performed.

7) Error Case: Upload

When a device uploads a photo to an edge, a file ID, including the edge ID, is returned from the edge. The file ID is used as an index for the corresponding photo and is transmitted to nearby devices via BLE communication. There is no communication between the edge and the cloud. Therefore, if communication between the device and the edge is possible, this process is completed. This process fails only when the device cannot connect to an edge.

In NAMI, BLE communication is the main method and multimedia data are transmitted via a three-layer network. Communication on the side of the BLE should be successful even when the device cannot connect to an edge. In this case, multimedia data will not be uploaded. We aim to perform an upload process when the connection to an edge is successful.

8) Error Case: Summary

The entire processes is designed as explained below.

a) When the device cannot connect to an edge, it creates a pseudo-unique file ID on the device and transmits it via BLE communication.
b) All unfinished files are uploaded as soon as the device can connect to some edge.
c) The file ID does not contain an edge ID because the edge information is unknown at the time of its creation. Even after the file is uploaded, the edgeID cannot be obtained from the fileID.
d) The file ID and the corresponding edge ID information are uploaded to the cloud when the file is uploaded to an edge.
e) The cloud retains the fileIDs and edge ID information. Even if a file request reaches the cloud with the corresponding file ID, the edge ID to which the request should be sent can be determined.

Through this process, even if communication from the device to the edge fails when uploading a file, it will be possible to obtain information about the edge that contains the file with the corresponding file ID.

However, the request fails because edge information does not exist in the cloud when a request from another device reaches the cloud before this information is stored.

5. Prototype Implementation and Operation Confirmation

We implemented a prototype system using this method and verified its operation. The prototype system consists of the equipment listed in Table 1.

Table 1. System equipment.

Device	iPhone
Edge	Macbook
Wi-Fi access point	GL-iNet travel router
Cloud	Linux server

We reproduced the normal and error cases and confirmed that the prototype system worked as expected. Two typical cases are shown below along with screenshots.

The normal case, where each device is connected to an edge, is explainedbelow (Figure 8).

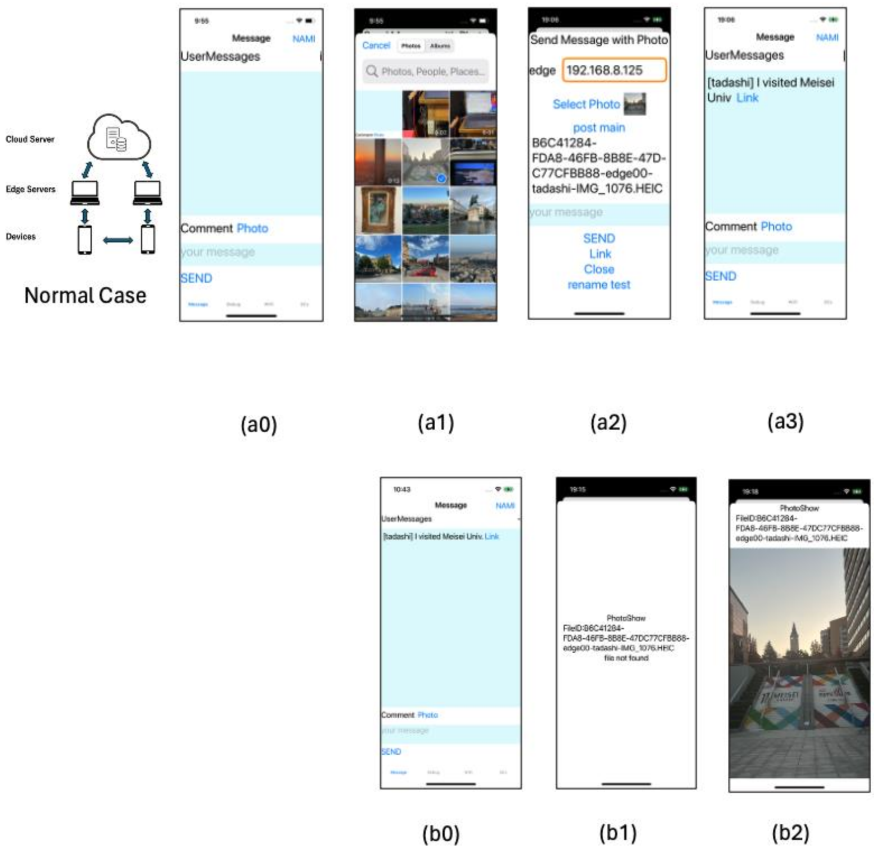

Figure 8. Results: Normal case

(a0) shows the initial screen for NAMI. (a2) shows that the photo is selected by tapping the Photo Button.

When the selected photo is uploaded to the edge (a2), the fileID is returned. The file ID includes the edgeID as edge00. After you add a text message and send it, the message, including the file is shared using BLE. T display screen on the first device is shown in (a3). The same message was displayed on the other device (b0). In (b0), the user can request a file download by tapping the link. At this point, the file is still on another edge, and therefore, at first, the error message is displayed such that there is no file, as indicated in (b1); however, at the same time, a request is sent to the cloud. After waiting for a while, the download is completed, and the photo is displayed, as shown in (b2).

We considered an error case in which the device was not connected to the edge (Figure 9), as indicated below.

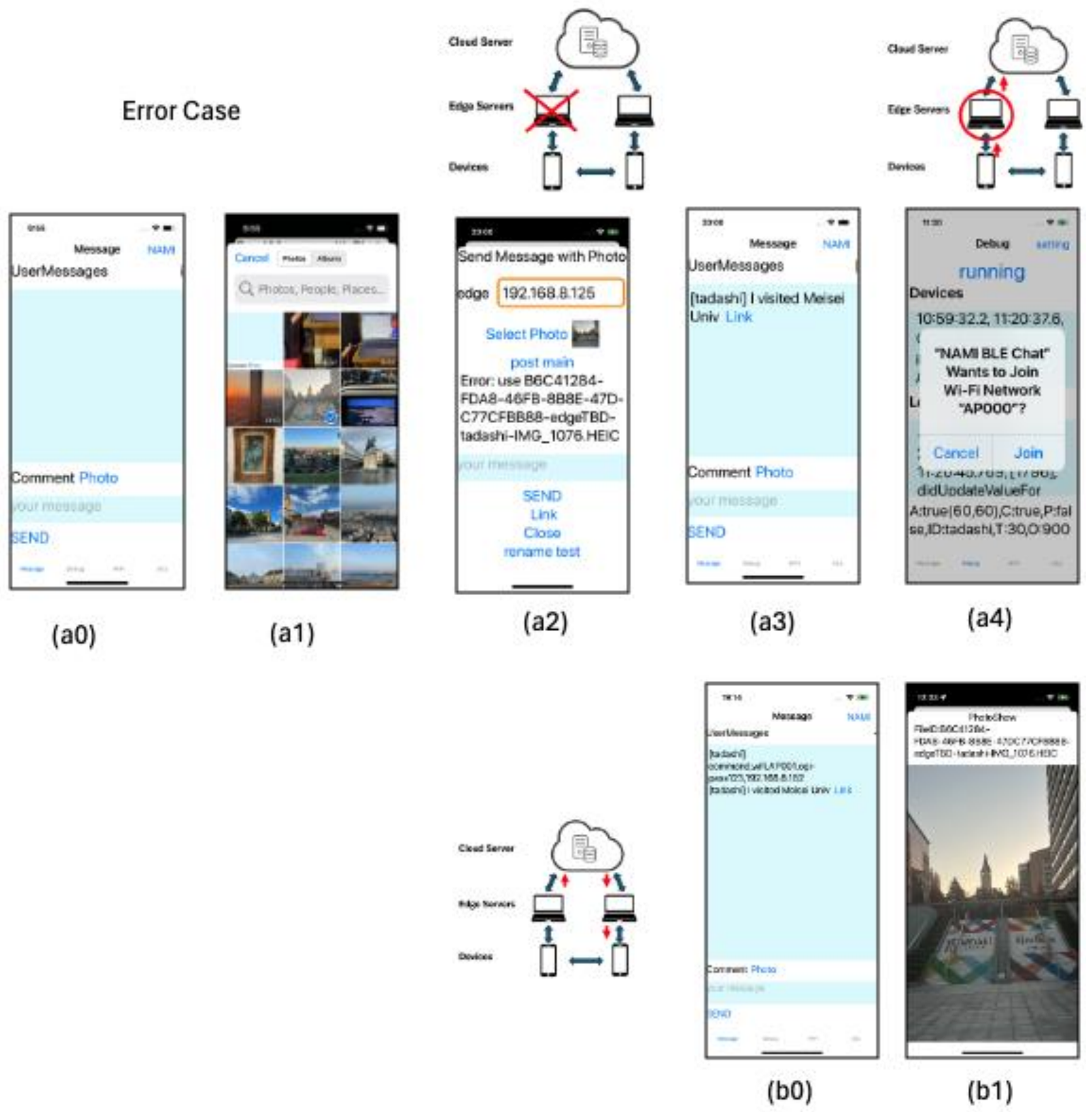

Figure 9. Results: Error case

The process of selecting photos (a0) and (a1) was the same as that in the normal case. If you attempt to upload a photo, the upload will fail because the device is not connected to the edge. Therefore, a fileID is generated that does not include an edgeID but includes the temporary name edgeTBD (a2). The text can be shared with this fileID using BLE (a3). Subsequently, communication with the edges is established. You can connect to a new Wi-Fi access point; however, a confirmation screen will be displayed to the user to ensure security, as shown in (a4). These are the specifications of an iPhone. At this point, the photo is automatically uploaded to the edge, and the fileID is uploaded to the cloud.

A request was sent to the cloud when a link displayed on another device was tapped. The edge information can be obtained from the cloud. This edge sends the corresponding photo through the cloud and displays it on another device (b1).

6. CONCLUSIONS

When text and multimedia data were shared with NAMI, the system could autonomously respond even if the network environment or system environment changed dynamically as the user moved, thereby reducing the burden on the user. We considered a method for allowing the process to continue without giving any user supports. Further, we implemented a prototype and confirmed that it worked correctly, as designed.

Complete autonomous operation was not possible without user intervention because the goal was to implement it in an existing product given the specification limitations. This topic will be considered for future research. In future, we plan to expand this system to include an applied system that envisions more specific scenarios.

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