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MULTIMEDIA DATA SHARING AND 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. In this paper, we have confirmed that it is possible to exchange large data using Wi-Fi under a preliminary experiment.At first, an experimental system was designed on paper in advance. This is insufficient for actual dynamic systems. So, after the preliminary experiment, 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, including information and communications technology (ICT) and functions provided by the people who use it.

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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.

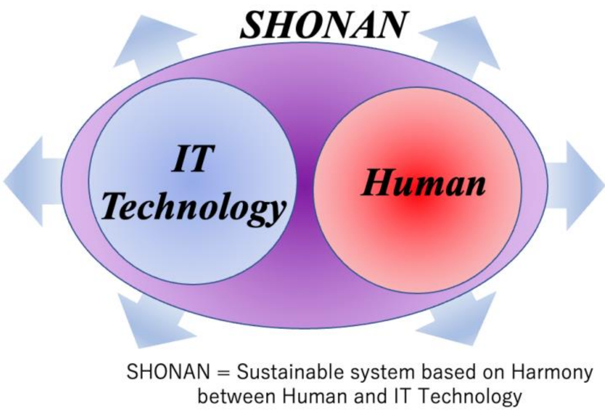

Figure 1. Proposed sustainable system: SHONAN

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.

At first, the preliminary experiment shows that large amounts of data such as photos and videos can be shared using Wi-Fi communication via access points [2].

The preliminary implementation was 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 is 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 the second half of this paper, we investigated the ability of the NAMI system to withstand dynamic changes and verified its operation using a prototype system [3].

In Chapter 2, we will discuss related researches. Chapter 3 provides an overview of NAMI. In Chapter4,a preliminary experiment on data exchange using Wi-F will be shown. In Section 5, we propose an algorithm for dynamic configuration in NAMI. Chapter 6 describes the implementation method of the experimental system and the execution results. Chapter 7 provides the conclusion.

2. RELATED RESEARCHES

IT systems have continually augmented functions to cater to an expanding user base, aligning with technological advancements and broadening the application scope of the technology. SHONAN took a distinctive approach, striving to establish a sustainable system by streamlining provided functions and restricting user access—a departure from the conventional pursuit of inclusivity.

In data distribution, existing studies have explored the content-caching function on the Internet [4]. This method entails placing a copy of the content near the user to alleviate the load and latency associated with video distribution services. However, it involves placing multiple data pieces, contradicting the sustainability concept. Our research diverges by aspiring to create a sustainable system by minimizing data placement.

Furthermore, edge computing, which introduces a computational edge between the cloud and devices, processes data stored on the device at the edge, leveraging higher CPU power for tasks like artificial intelligence (AI) and 3D processing [5]. These technologies presuppose high-speed data transfer, posing challenges for direct application to our current proposal, which predominantly relies on low-speed, short-distance communication methods.

Systems using Twitter [6] and social media [7] have been devised for disaster information sharing, requiring Internet connectivity. However, our system can function seamlessly by exchanging data between nearby users even without Internet connectivity during a disaster.

Next, the perspective of automatic configurationis explained.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[8][9]. In MANET, the routing protocol is one of the challenges because the network configuration changes dynamically [10].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 [11][12][13]. Recently, routing protocols using AI technology have also appeared[14][15].

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 [16]. 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).

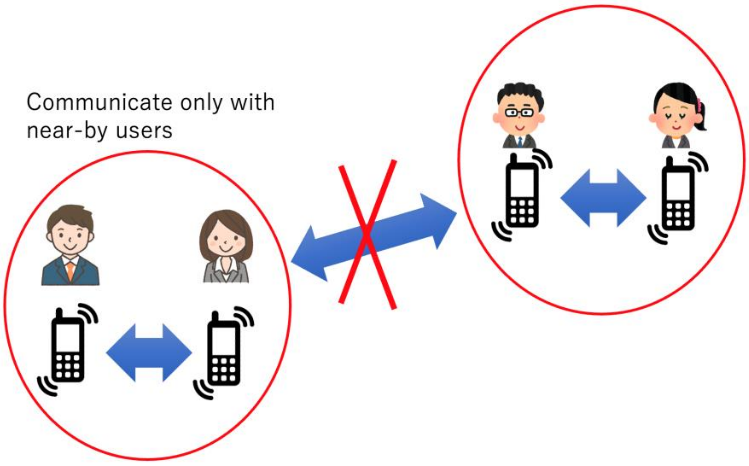

Figure 2. NAMI system

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.

4. Preliminary experiment to use Multimedia Data with NAMI

4.1. Problems with NAMI

Smartphones have evolved to encompass high-definition photos and videos in the current social media landscape. However, the existing NAMI framework only supports text sharing. Thispreliminary experiment addresses the feasibility of integrating multimedia data into the NAMI system.

NAMI employs BLE as a shared channel with other devices. Nevertheless, BLE has a short packet length (standard 256 bytes for BLE5) and slow communication speed (maximum 2 Mbps for BLE5), rendering the sharing of large files impractical. Therefore, we considered a method compatible with commercially available smartphones. Wi-Fi emerges as an alternative to BLE for communication. Therefore, we considered methods to integrate Wi-Fi seamlessly into the NAMI concept.

4.2. Communication Speed

First, we measured and compared the communication speeds of BLE and Wi-Fi. We transferred a JPEG file between two smartphones (iPhone) using BLE and Wi-Fi, with Wi-Fi tested through a direct device-to-device connection and an indirect connection via a Wi-Fi access point (Figure 3).

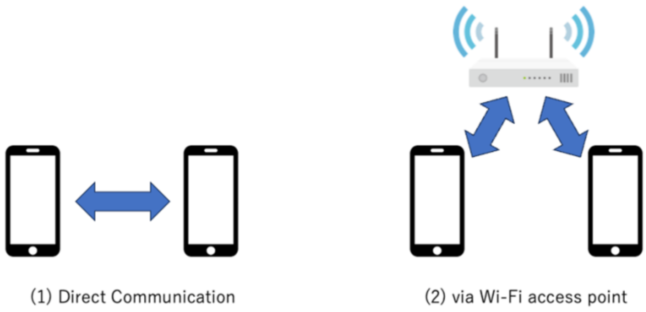

Figure 3. Communication methods using Wi-Fi

4.2.1. Measurement Details

Equipment: Two iPhone SEs
Transfer file: JPEG file (4.24 MB) and MOV file (21.73 MB)

A custom measurement program was developed using Xcode for each method. The procedure involved transferring a specified JPEG file from one iPhone to another and measuring the time to receive the data, encompassing the writing time to the internal memory. No special parameter tuning was applied to enhance transfer speed.

4.2.2. Result

The outcomes are presented in Table. 1.

Table. 1. Communication Speed

	PDF file (4.24MB)		MOV file (21.73MB)	
	average time (seconds)	average speed (B/s)	average time (seconds)	average speed (B/s)
BLE	151.0	28.1K	773.9	28.1K
Wi-Fi (via access point)	0.569	7.45M	1.533	14.2M
Wi-Fi (direct)	0.382	11.1M	1.361	16.0M

Though the fastest method involves a direct connection between devices via Wi-Fi, Wi-Fi through an access point, including video transfer, is deemed practical for everyday use.

Establishing a direct Wi-Fi connection necessitates a specialized function. This system used a “Bonjour” feature provided by Apple [17]. Although Wi-Fi via an access point requires additional hardware, the Wi-Fi function is approximately ubiquitous, facilitating straightforward system development. Considering potential system expansions, the design proceeded with the assumption of Wi-Fi via an access point.

4.3. System Configuration

We used BLE for text-based information exchange, which was subsequently expanded to enable the exchange of images and videos via Wi-Fi.

Images and videos were not distributed unconditionally to circumvent unnecessary large data transmission and accumulation; information on obtaining them was shared. The information, termed FileID, was text-based and continued to be shared via BLE. Users seeking images and videos use the FileID to request data.

Given the resource-intensive nature of managing images and videos on a single device, they were stored on a server, and the server also processed data requests.

Device-server communication occurred via Wi-Fi. The server had a hierarchical structure comprising edge servers, accessible by the devices via Wi-Fi, and a cloud server linked to the edge servers through the Internet, consolidating all information. An edge server can relocate using a laptop or high-performance smartphone and connect to the cloud through the Internet when Internet access is available. The cloud, residing within the Internet, aggregates multimedia data from multiple edges.

These components are illustrated below in Figure 4.

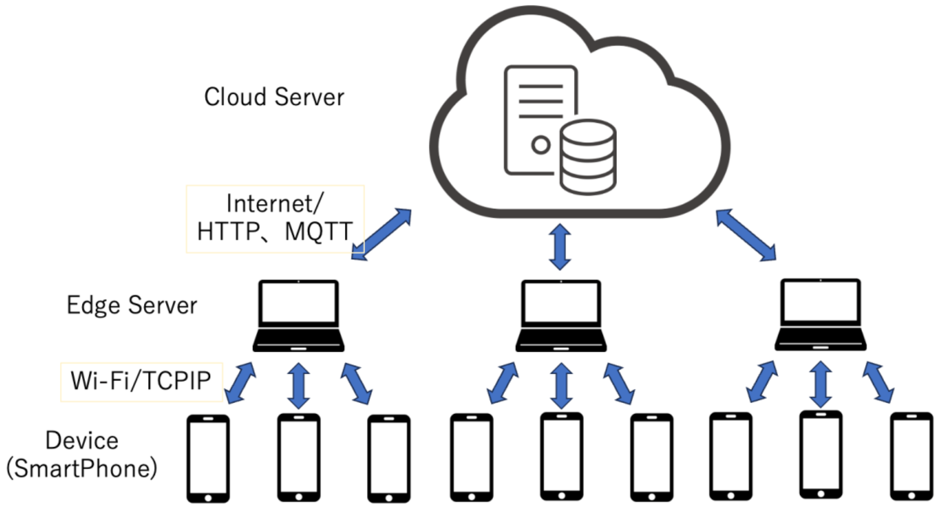

Figure 4. System configuration

4.4. System Processing

The device uploaded photos and videos to nearby edge servers. The edge server assigned a unique ID (FileID) to the uploaded content and replied to the originating device. Simultaneously, the FileID was transmitted to the cloud.

The device shared its FileID with nearby devices, accompanied by text information about the photo or video.

If a different device required data corresponding to the shared FileID, it would request it from the FileID at a nearby edge. Given the mobility of the device, the edge serving as the point of requirement and the edge where the photo was uploaded initially may or may not coincide. Consequently, the FileID data may not reside on the same edge. If the edge server contains the data, it transmits it to the requesting device. In cases where the edge server lacks the required data, it solicits data from the cloud.

All FileID information is centralized in the cloud (distributed management of multiple clouds is a viable option). Furthermore, copies of previously requested data may exist in the cloud. If the cloud retains a copy of the requested data, it forwards it to the requesting edge.

If the cloud lacks a copy of the requested data, it seeks the data from the edge containing the relevant information. The edge server does not maintain continuous Internet connectivity; data requests from the cloud to the edge server are facilitated using the MQTT protocol.

4.5. Implementation

We implemented the proposed system to confirm its functionality using iPhones as devices, MacBooks as edges, and the cloud.

4.5.1. NAMI Application

An iPhone application was developed using Xcode. This involved integrating the proposed functionalities into the original text-only NAMI application. Communication with the web server of the edge server was implemented through HTTP communication.

4.5.2. Edge, Cloud Applications

The systems on the edge and cloud servers were implemented as web servers using FASTAPI.
The edge server, a MacBook, connects to the Internet as needed and possesses a local IP but not a global IP. However, a cloud server, another MacBook, is permanently installed on the Internet and can be accessed using a URL.

Communication between the iPhone and the edge server, as well as between the edge server and the cloud server, was achieved through REST applications on a FastAPI web server. The edge and cloud servers used MONGODB for data management.

If the cloud server requests data that does not exist, the cloud server must seek the data from the edge server. However, the edge server, possessing only a local IP, cannot receive HTTP requests from the cloud server. Therefore, the MQTT protocol was employed for requests from the cloud server to the edge server. The cloud server with the global IP functions as the MQTT broker and becomes the MQTT publisher. The edge server serves as a subscriber, relaying requests from the cloud server to the specified edge server. The edge server responds to these requests by uploading files to a cloud web server.

4.5.3. Results

The operating screen of the application is shown in Figure 5. (a) Initial screen of the tadashi user. Tapping a photo on this screen navigates to the photo selection screen (b).

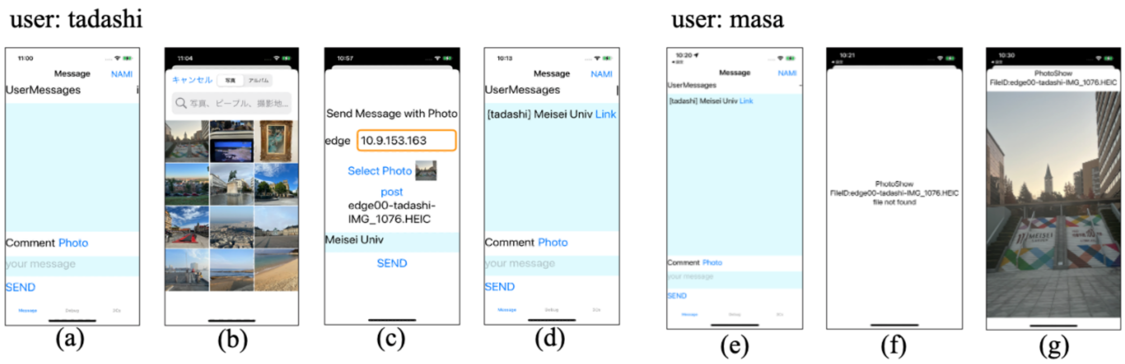

Figure 5. Screenshots of the application NAMI

Choosing a photo leads to a photo upload screen (c) displaying a thumbnail of the selected photo. Tapping “POST” triggers uploading the photo to the edge via its IP. The returned File ID (edge00-tadashi-IMG_1076. HEIC) is displayed. Inputting the desired text for sharing (in this case, "MeiseUniv") and tapping “SEND” facilitates text sharing. Subsequently, the user is redirected to the message display screen where the shared text is exhibited (d).

Subsequently, the text is displayed on the screen of a nearby user masa (e). Tap the link to view the photograph. The corresponding photo has not yet been downloaded to the masa’s terminal, resulting in a notification that the file cannot be found (f). Simultaneously, a photograph request is dispatched from the background to the edge. The requested photo is displayed on the terminal of the mask (g).

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.

5. 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.

5.1. 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 [18]. One method (OSPF protocol) for route detection in ad hoc networks uses hello messages [19]; 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 [20]. 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 6).

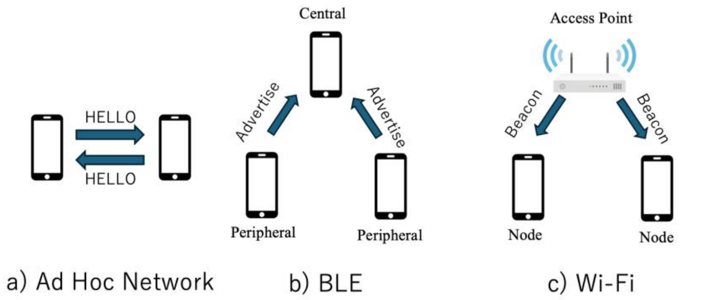

Figure6. Device detection.

5.2. 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 7).

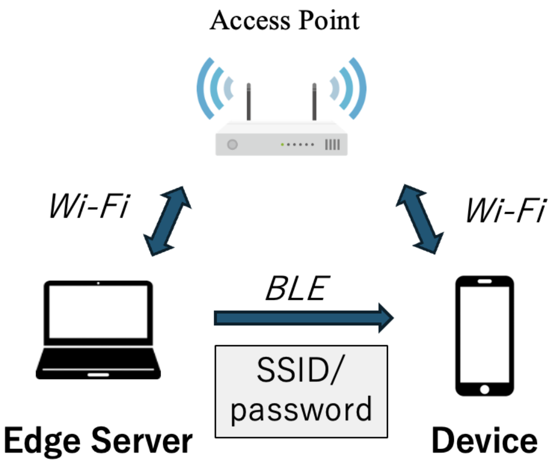

Figure. 7. Edge server detection

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 8).

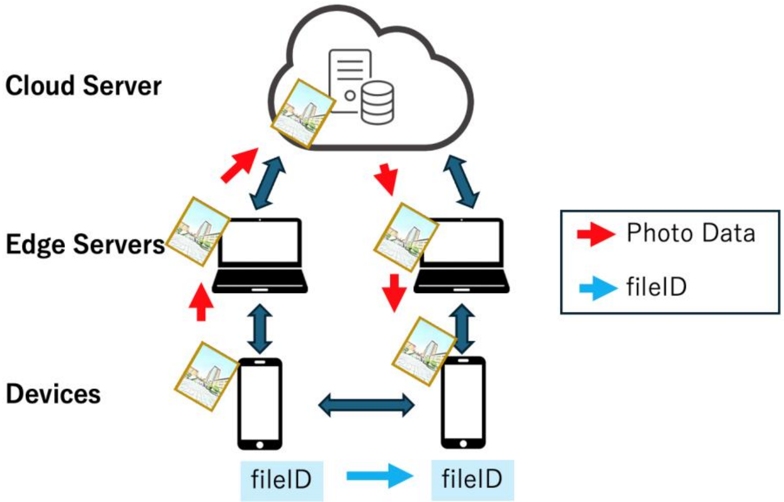

Figure8. File transfer operation: Normal case

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.

6. 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 2.

Table 2. 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 (Figure9).

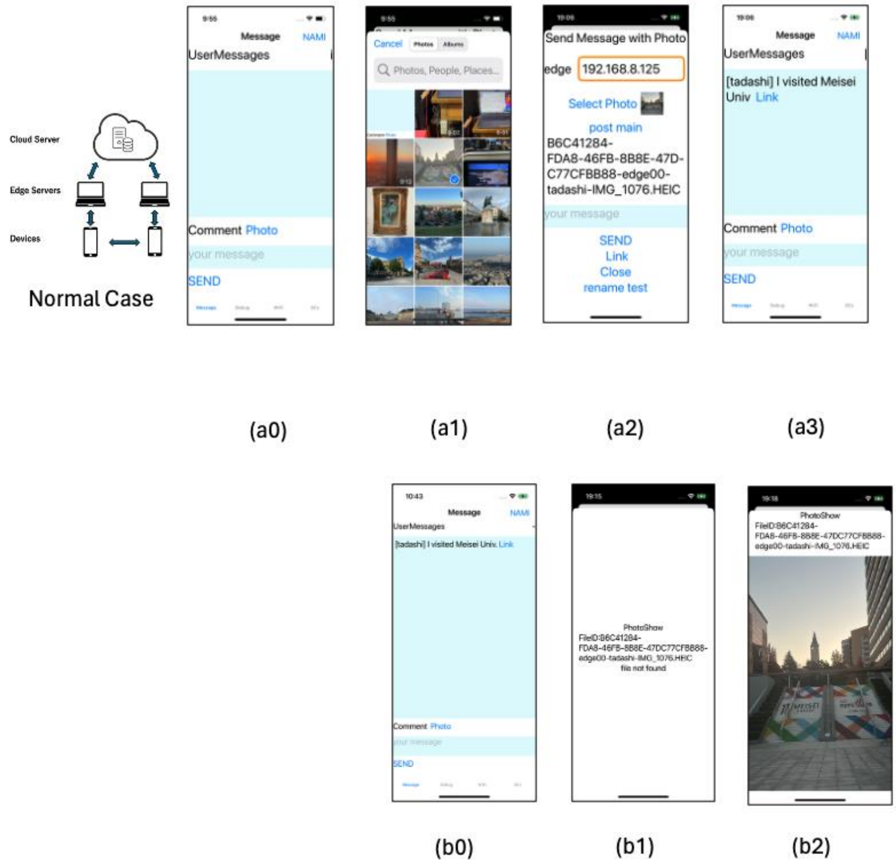

Figure9. Results: Normal case

(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 (Figure10), as indicated below.

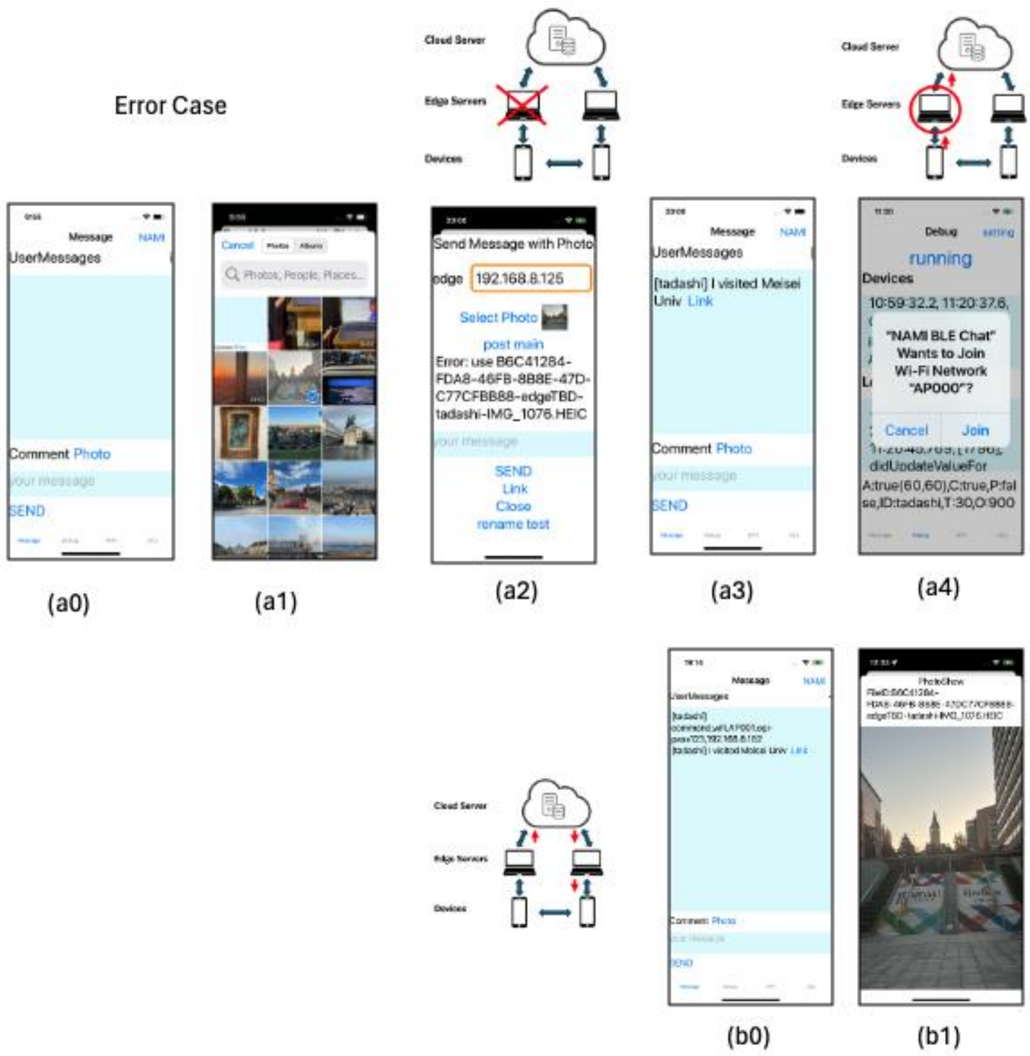

Figure10. Results: Error case

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).

7. CONCLUSIONS

This study proposes a method for handling multimedia data, such as images and videos, in NAMI—an information-sharing system using short-range communication while adhering to the core principles of NAMI. The main parts of the proposed method were successfully implemented, demonstrating the feasibility of sharing images and videos through Wi-Fi data sharing.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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REFERENCES

[1] T. Ogino, (2022) “Proposal of a sustainable system based on harmony between human and information technology,”*International Journal of Computer Theory and Engineering*, vol. 14, no. 3, pp. 135–140.

[2] T. Ogino, (2024) “Multimedia data sharing with the NAMI short-range information sharing System,” *Proceedings of the 7th International Conference on Information and Computer*, pp.3-13.

[3] T.Ogino, (2024)“Autonomous Configuration with the Short-range Information Sharing System NAMI,” *Proceedings of*5th *Intl. Conf. on Big Data & IoT.*

[4] D. Prerna, R. Tekchandani, N. Kumar, (2020) "Device-to-device content caching techniques in 5G: A taxonomy, solutions, and challenges," *Computer Communications*, vol. 153, 2020, pp. 48-84.

[5] J. Ren, D. Zhang, S. He, Y. Zhang, T. Li, (2019) "A Survey on End-Edge-Cloud Orchestrated Network Computing Paradigms: Transparent Computing, Mobile Edge Computing, Fog Computing, and Cloudlet," *ACM Computing Surveys*, vol. 52, Issue 6, Oct. 2019, Article No.125, pp. 1-36.

[6] M. Kosugi et al., (2019) "A Twitter-Based Disaster Information Sharing System," *2019 IEEE 4th International Conference on Computer and Communication Systems (ICCCS)*, Singapore, 2019, pp. 395-399,

[7] M. Karimiziarani, K. Jafarzadegan, R. Abbaszadeh, W. Shao, H. Maradkhani, (2022) "Hazard risk awareness and disaster management: Extracting the information content of Twitter data," *Sustainable Cities and Society*, vol.77, 2022.

[8] D. Ramphull, A. Mungur, S. Armoogum and S. Pudaruth, (2021) "A Review of Mobile Ad hoc NETwork (MANET) Protocols and their Applications," *2021 5th International Conference on Intelligent Computing and Control Systems (ICICCS)*, Madurai, India, 2021, pp. 204-211.

[9] Reeya Agrawal, Neetu Faujdar, Carlos Andres Tavera Romero, Oshin Sharma, Ghadia Muttashar Abdulsahib, Osama Ibrahim Khalaf, Romany F Mansoor, Osama A. Ghoneim,(2023) “Classification and comparison of ad hoc networks: A review,” *Egyptian Informatics Journal*,Volume 24, Issue 1,Pages 1-25.

[10] K. Kaur and S. Kaur, (2021) "Mobile Ad-Hoc Network Routing Protocols: A Comparative Study," *2021 10th International Conference on Internet of Everything, Microwave Engineering, Communication and Networks (IEMECON)*, Jaipur, India, 2021, pp. 1-4.

[11] Ben Hamida, E., Chelius, G., Busson, A., & Fleury, E. (2008) “Neighbor discovery in multi-hop wireless networks: Evaluation and dimensioning with interference considerations,”*Discrete Mathematics Theoretical Computer Science DMTCS*, 10(2), 87–114.

[12] Mcglynn, M. J., &Borbash, S. A. (2001) “Birthday protocols for low energy deployment and flexible neighbor discovery in ad hoc wireless networks,”*In Proceedings of the 2nd ACM international symposium on mobile ad hoc networking computing*, pp. 137–145.

[13] Jose Vicente Sorribes, Lourdes Peñalver, Carlos Tavares Calafate, and Jaime Lloret (2021) “Randomized neighbor discovery protocols with collision detection for static multi-hop wireless ad hoc networks,”*Telecommun. Syst.* 77, 3, 577–596.

[14] Abir Mchergui, Tarek Moulahi, SheraliZeadally, (2022) “Survey on Artificial Intelligence (AI) techniques for Vehicular Ad-hoc Networks (VANETs),” *Vehicular Communications*, Volume 34.

[15] F. Safari, I. Savić, H. Kunze, J. Ernst and D. Gillis, (2023) "A Review of AI-based MANET Routing Protocols," *2023 19th International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob)*, Montreal, QC, Canada, pp. 43-50.

[16] Susumu MATSUI, (2018) “The Application Trends to the Real Systems of an Ad Hoc Network(Telecommunications for Critical Use),”*The Journal of Reliability Engineering Association of Japan*, 2012, Volume 34, Issue 8, Pages 532-539, Released on J-STAGE January 31, 2018.

[17] Apple Inc., [Online] “Bonjour.” https://developer.apple.com/bonjour/(accessed Nov.23, 2023)

[18] W. Kiess and M. Mauve, (2007) “A survey on real-world implementations of mobile ad-hoc networks,” *Ad Hoc Networks*, vol. 5, no. 3, pp. 324–339.

[19] J. Shakir, (2008) “Ospf extensions for mobile ad-hoc networks,” Washington University in St. Louis.

[20] 802.11b specification [Online]. Available: https://standards.ieee.org/ieee/802.11b/1166/

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