Content-Oriented Disaster Network Utilizing Named Node Routing and Field Experiment Evaluation

Xin QU, Zheng WEN, Student Members, Keping YU†††, Member, Kazunori MURATA†††, Kouichi SHIBATA†††, Nonmembers, and Takuro SATO††, Fellow

SUMMARY Low Power Wide Area Network (LPWAN) is designed for low-bandwidth, low-power, long-distance, large-scale connected IoT applications and realistic for networking in an emergency or restricted situation, so it has been proposed as an attractive communication technology to handle unexpected situations that occur during and/or after a disaster. However, the traditional LPWAN with its default protocol will reduce the communication efficiency in disaster situation because a large number of users will send and receive emergency information result in communication jams and soaring error rates. In this paper, we proposed a LPWAN based decentralized network structure as an extension of our previous Disaster Information Sharing System (DISS). Our network structure is powered by Named Node Networking (3N) which is based on the Information-Centric Networking (ICN). This network structure optimizes the excessive useless packet forwarding and path optimization problems with node name routing (NNR). To verify our proposal, we conduct a field experiment to evaluate the efficiency of packet path forwarding between 3N+LPWA structure and ICN+LPWA structure. Experimental results confirm that the load of the entire data transmission network is significantly reduced after NNR optimized the transmission path.

key words: disaster network, information-centric networking, named node networking, low bandwidth wide area network

1. Introduction

With increasing frequency and intensity of natural disasters, the impact of various disasters on large urban areas is rising, so it is essential to focus on the critical issue of facilitating communications during and after the disaster. In the aftermath of a disaster, communication networks became more and more stressed. It is due to the heavier traffic and potential capacity loss due to infrastructure damage. However, in the event of such a disaster, communications problems should be provided to deliver emergency information, such as real-time evacuation information and SOS message, to the first responder or government authorities [1]. It is now feasible to provide low-cost, low-powered networks that can cover a wide range of areas, such as Low Power Wide Area Network (LPWAN) [2], [3]. These technologies allow the deployment and management of sensors using low-power wide-area clients, and the sensor network’s test link can operate up to 25 kilometers [4]. However, the required type of communication in a destructive disaster scenario is primarily information-centric in nature, such as the rapid propagation of warnings and evacuation plans, or the critical content from legitimate authorities to reach all users timely. It is important to shift the focus on disaster communication from being an afterthought to being a first class citizen, exploiting emerging network architectures [5]. The need for information-centric coupled with the inherent support for mobility, security, and in-network opportunistic caching provided by the Information Center Network (ICN) paradigm make it a natural fit for communications in disaster network scenarios [6].

ICN introduced a paradigm shift from a host-centric communication model for the future of the Internet architecture. It supports the retrieval of specific content regardless of the physical location of the content. In our previous studies, a ICN based content-oriented network architecture named-node networking (3N) [7] was proposed. 3N focuses on content distribution and ensuring low delay and higher network bandwidth efficiency than other current generation network. Emergency networks in disaster situations present significant challenges to ICN deployment. With the functions provided by ICN architecture, especially regarding mobility support, caching and interrupt recovery capabilities, ICN based LPWAN for disaster system has particular advantages in network traffic solutions, where multiple subscribers need the same content, by substituting host-centric principle with content-centric principle. The problem is that tracking the final position of people becomes more difficult because ICN network only focuses on the content name but ignore the physical content location. However, tracking the position of people is also very vital when a disaster happens. To address this issue, we proposed a Named Node Networking (3N) architecture for LPWAN in a disaster scenario.

The previous studies were based on static network architecture, whereas during disaster evacuation, people move randomly. Our proposed system is the extension for DISS (Disaster Information Sharing System), which based on LPWAN and 3N. The contributions of this paper are listed as follows.

a) We designed a 3N based LPWA network as the extended version of DISS. This brings ICN features into the disaster network as well as 3N NNR routing.

b) NNR can optimize the NNST (node name signature table) and reduce the network load. Especially, with SO

Copyright © 2019 The Institute of Electronics, Information and Communication Engineers
(source only) and DU (dual unit) PDUs (protocol data units) in 3N, the nodes can effectively forward the data.

c) We applied object detection in the camera nodes to detect and generate categorized contents, so the small size data can be transmitting in the low bandwidth network such as LPWA network.

The remaining of this paper is organized as follows. Section 2 presents our previous studies including LPWAN, ICN, 3N, object recognition and their application in disaster. In Sect. 3, we have proposed our content-oriented disaster network, which utilize node name routing. Moreover, in Sect. 4, we have designed and evaluated a field experiment held in a sea side city. In the end, we have concluded our proposal with some scope of the future work.

2. Related Work

2.1 LPWAN

The development of LPWAN has benefited from the rapid development of the Internet of Things (IoT) in recent years (Standards by different organizations shown in Fig. 1). In comparison to LPWAN, Wi-Fi module’s current cost is also very low, but the communication range is not wide enough, cellular network module is too expensive which it provides wide range coverage. LPWAN module is in the middle between Wi-Fi and cellular network so it is an ideal low-cost, low-power consume and long-distance communication device which is suitable for “IoT private network”. LPWAN is used in several applications, including disaster monitoring and recovery communicating. LPWAN sensors can capture data bits and transmit them via dedicated gateways, then send them to the public network.

LPWAN has three physical features: 1. “long-distance communication”, 2. “low-rate data transmission,” and 3. “low power consumption” so it is very suitable for IoT applications like the disaster scenario that requires long-distance transmission, less communication data, and long-term duration. Most IoT applications usually only need to transmit a very small amount of data. For example, the sensors that control the switches in the industrial production plant only generate data when the switch is abnormal. These devices generally consume low power and can be powered by batteries for a long time. Although cellular networks can also be applied, it cannot solve the problem of high power consumption.

The LPWA communication module we used in this paper is IM920 [8], a 920MHz communication module which transmission rate at 50kbps, range at 400m and consumes power at 25mW. Unlike cellular networks, the 920MHz LPWAN is license free. There is already an IM920 based LPWA mesh network deployed in Minami-cho, Tokushima, Japan [9], to perform field experiment for our proposed network architecture. This LPWA module uses its special communication format that combines packet header and user data. The received packet header contains node number, received signal strength indication (RSSI), sequence number, etc. This packet header can cooperate with our previous proposed Named-node networking (3N) to realize the Information-centric networking (ICN) implementation.

2.2 CCN and 3N

As one of the famous ICN solutions, the Content-Centric Network (CCN) was designed by Palo Alto Research Center (PARC) [10]. It relies on the concept of publish/subscribe paradigm (Fig. 2) as an alternative to the typical send/receive model [11]. A subscriber sends an interest message which she/he is interested in, and the interest message is only identified by the content name and routed to the publisher based on the content name. Once interest has arrived, the content message sent by the publisher will be returned to the subscriber in response and a copy of the content will be stored in each crossed router. Therefore, other subscribers can obtain this content based on the content name from the nearest router which has stored this copy instead of re-acquiring it from the publisher. Therefore, CCN proposed a thorough revision of the Internet architecture from naming hosts to naming content. On the IoT side, contents are ephemeral, short-lived, small and fresh, different priorities and from various locations [12]. Also, CCN provides the primary mechanisms for content integrity and authentication veri-

![Fig. 1](parameters_of_LPWAs.png)  
**Fig. 1** Parameters of LPWA standards.

![Fig. 2](ICN_overview.png)  
**Fig. 2** ICN overview.
fication. During the entire message transmission, the content is addressable, routable, and certifiable, regardless of its physical location [13].

The main idea behind CCN is to allow a network device to obtain specified content from a content producer (publisher) regardless of the physical location of the content producer (publisher) or from any other device that has cached the same content. The network uses some key elements to share the contents, which are Content Store (CS), Pending Interest Table (PIT) and Forwarding Interest Base (FIB), as shown and described with the working mechanism in Fig. 2. Therefore, network devices (subscribers) communicate based on content names rather than IP addresses. It makes content locations transparent to network devices and simplifies content access. Second, a copy of the named content can be cached on every intermediate node from the publisher to the subscriber. This can increase device mobility, low power operation, and content availability under intermittent connection conditions. Third, self-contained content security can be provided in the CCN. The security of content depends on the content itself, not the protection of end-to-end communication channels via IPsec or SSL.

Content name is the only identifier for content distribution in CCN. Every content’s name prefix structures like URIs using “/” characters to separate different components. The first and second part of the content name provides global routing information and organizational routing information for packet routing. The last part of the name contains the segmentation functionality and the versioning, basing on the principle, one content can be fragmented into multiple segments and still be addressable [10].

In the CCN network, all data packets are forwarded hop-by-hop, while the routers maintain three basic data structures, PIT, FIB and CS. The CS serves as a local content cache for contents that passed through. The FIB helps to map content names to the output interface to reach the appropriate publisher. The PIT helps to track the incoming pending interest message interface. Once a packet reaches an interface, a longest matchmaking is performed based on its content name, and further action will be taken based on that result.

However, because the standard CCN network lacks accounting capabilities, there are doubts about controlling, managing and connecting. The lack of accounting has the unintended side issue of unable to ensure reliability in the low delay and high user mobility scenarios. In order to solve the issue, we proposed named-node networking (3N) [7], a network architecture that is an alternative to TCP/IP, as a host-centric extended solution for ICN. We aimed for efficient and flexible content sharing in environments where users are basically mobile. 3N introduces a new node namespace into basic content-centric network architecture. 3N uses a network naming scheme described by Dr. Saltzer in RFC 1498 [14], which contained separated, unique node and content namespaces. Particularly, the node namespace is managed with a topological structure designed for enrolling and dis-enrolling in the 3N network. 3N defines two kinds of protocol data units (PDUs), mechanism PDUs and data transmission PDUs, as shown in Fig. 3. We also introduced node name signature table (NNST) as a routing table managed by node names. The PDUs and NNST affect the network configuration by offering 3N names to the nodes and using node name based routing strategy to deliver data packets.

### 2.3 3N PDU and NNR

The 3N architecture and 3N PDUs, as mentioned in the previous section, use known procedures of packet-switching networks. 3N still concentrates standard ICN content sharing mechanisms to decrease the server’s load on particular content producers and ensure low network latency and higher network bandwidth efficiency. The naming for the nodes in 3N network ensures those types of scenarios can be managed clear and efficient. In this paper, we mainly discuss the utilization of the data transmission PDUs, source only (SO) packet and dual unit (DU) packet, in the LPWAN. The SO and DU qualified LPWAN packet architecture can be found in Figs. 4 and 5.

Data transmission PDUs are designed to transmit content using 3N names. The use of 3N data transmission PDUs...
requires the node to have a 3N node name. By satisfying this condition, the node can route the 3N packet with NNR (node name routing). In [15], NNR has been proofed to be valuable for use in disaster areas. The study evaluated the NNR strategy to compare with the OLSR (optimized link state routing protocol) and the DSR (dynamic source routing) strategy, and the results showed that NNR performs better regarding packet delivery, routing cost in a substantial number of users.

When a node receives a SO packet, it will first process the 3N header which contains the source node’s 3N name, then process with standard ICN protocol to satisfy the requested content delivery. If a standard ICN interest packet reaches a 3N node, the node will ignore the 3N header process and deal it in standard 3N. When a DU packet is being delivered to its subscriber node, any router node will process the 3N header and trace the PIT to forward the packet through the correct interface. If a standard ICN content packet reaches a router node, the standard ICN process will be performed.

With NNR implemented in the LPWAN, a self-organized network can be set up very quickly when a disaster occurs. NNR can make sure to always forward packets to the nearest data source, because NNR can flood the network, using RSSI and delivery hops information to compare the distance and route health among all nodes, and select the best path to route data packets. This is very valuable in emergency network conditions, where users can send alarm information to the nearest area for rescue. Thus, NNR can reduce the broadcast packets compare to ICN flooding and release the network pressure.

2.4 M2M Network and Disaster

In recent years, the IoT network benefits from the rapid machine to machine (M2M) network development. In a disaster network, people worked hard on technological details for no-disconnection network and disaster information sharing system (DISS).

Recently, some studies were also proposed on disaster networks based on ICN as well as IoT networks based on ICN. Arshad et al. [12] developed an ICN based hybrid naming scheme for IoT based smart campus. They aim to update categorization of IoT applications, operate to assign names to contents and better request satisfaction rate for IoT smart campus. Chen et al. [5] developed a notification service for managing disasters, which can significantly reduce network load, network latency, and benefits from the simplified operation, security and appropriate prioritization. Yagyu et al. [16] proposed a demo to show the integrated framework of push and pull type ICN communication and applied it in a disaster scenario. Hannan et al. [17] designed the ICN and IoT based disaster management system and showed its effectiveness of scalability and ICN infrastructure. They also proposed push support in the system with simulation results.

There are also some ICN based disaster network proposed related to our previous works. Shibata [9] organize and performed the experiment of ICN based LPWA network to demonstrate the evacuation and alarm information sharing system. Wen et al. [15], [18] developed an ICN based ad-hoc content sharing network and the extended version of using NNR to solve the multiple-name problems in both 3N ad-hoc networks and TCP/IP ad-hoc network. My previous work [6] proposed a content-oriented surveillance network architecture, and evaluate the system’s performance on reducing the network load by generating named contents using object detection.

While in a content-oriented network, the content name is a vital element to the whole data delivery system. Who/what is naming the contents becomes an important part of the system. In this paper, we used tensorflow platform [20] and region-based convolutional neural network (RCNN) [19] to detect objects, categorize the generated contents and name them. Figure 6 is the example of human detection in the experiment. This down resolution image is authorized by MIC.

3. Content-Oriented Disaster Network Utilizing Node Name Routing

3.1 System Overall

Our proposed disaster network architecture is a combination of several parts, the LPWA mesh communication network, and the DISS Box units. The LPWA network was deployed in the field experiment area in Minami-cho, Tokushima, Japan. In the experiment area, there were many LPWA forwarding nodes, working on the same frequency (LPWA channel), covering the place. The mesh network automatically repeats the packets and broadcast them to every receiver by default. However, we managed to implement the nodes with 3N basic functions to recognize the ICN packets and the ability to maintain the routing table with NNR, which will be discussed in the next subsection. The LPWA nodes formed a mesh network and can be managed as one information distribution platform.
A Disaster Information Sharing System Box (DISS Box) is assembled with several components: a central processing platform powered by a compute stick [21], an image capturing unit powered by a camera, wireless communication modules and a battery module (topology shown in Fig. 7). The high performance compute stick provides the real-time image processing power to generate useful information based on the captured image, which includes people count information and intercepted images of interested objects. The Wi-Fi and Bluetooth module included in the compute stick provides the connectivity to the client users for disaster information publishment, and Bluetooth tag for evacuating individual tagging, which was used in the previous experiment [9].

### 3.2 Node Name Routing

In the LPWAN communication protocol, a node name (serial number) is utilized in the packet header of each sent packet. In this paper, we proposed a node name protocol to combine the LPWA’s device name with the 3N’s node name, in order to implement 3N NNR mechanism in the network, optimizing the packet routing efficiency for the entire network. To achieve this goal, we formatted the LPWA packet structure into 3N qualified structure (related 3N qualified SO and DU packets are shown in Figs. 4 and 5). Using this packaging format, we can utilize NNR mechanism to maintain the network and optimize the traffic routing actively during the data transmission.

NNR is a routing strategy which maintained by node names. In the packet transmission of the network, the DISS content name prefix is organized in a hierarchical URI style similar to the CCN standard style. DISS uses a name prefix by combining Message Type, Geographical Names and Coordinates. For instance, Fig. 8 presents an example of the name prefix. When a user wants to generate a name prefix, the GPS device generates a GPS coordinate and the node performs geographical information look up with the reverse geocoder, powered by small size offline database of the region. Then the node combines the enriched geographical information with the GPS coordinate to generate the named content. The coordinates information can be found from a database like Open Street Map (OSM).

In a general 3N network, there are enrollment procedures for nodes (fixed or mobile) that do not have a preset name. In our experiment below, we pre-assigned node name to each node. During the initialization of the network, the
system would flood the network with 3N SO packets and retrieve the DU packets. The nodes would update and maintain its NNST, tracing the last and the next hop to determine the best route. The NNR routing strategy is designed to find the best route between the subscriber and the publisher. Like the DSR (dynamic source routing) and AODV (Ad-Hoc on-demand distance vector) methods in TCP/IP, NNR show more advantages in optimizing routing table in ICN network [15].

The forwarding mechanism in Fig. 9 represents the packet forwarding mechanism. When a node receives a source only (SO) packet, it will first check its Content Store (CS) to see if there is already matching content stored. If there is no cached content, it will check Pending Interest Table (PIT) if there is already an entry in PIT, then the node will add a new entry or update an existing one. At last, if no existing PIT entry found, then the node will log the information in Forwarding Interest Base (FIB) and continue flooding the SO packet to the other nodes. The DU packet will help the node tracing the last hop.

4. Evaluation

In this section, we performed a series of field experiments to evaluate the actual performance of NNR in the LPWAN. We have taken the experiment in Minami-cho, Tokushima, Japan, in Dec. 13th, 2017. As a matter of fact, this place very much values the disaster precaution and emergency response. The experiment is an extension of the previous LPWA IoT system experiment for tsunami disaster prevention [9], which performed an evacuation drill authorized by MIC. There were approximately 40 people observed from the street view, during the experiment. The experiment took place for 4 hours in the day, with the powered of rechargeable batteries. Figure 10 shows the node distribution map. We have set DISS Boxes at node 41 through 46, marked red in the figure. Based on the map of our experiment area, the city is surrounded by water by the south and east side. So, during a tsunami evacuation, people will have to move in the direction of the northwest. The yellow roads on the map represent for the main road of the city, which are also the life-lines during a disaster. In general, node 44 and 45 represent the evacuation locations, a hospital and a government building with a school next to it. Node 21 is also a high-altitude tower, the emergency control center, which can be a shelter, but it lacks accessible life-lines. Because of this patent, we can generate experiment database on the camera nodes in the main roads. We aimed to compare the network load between ICN routing and 3N node name routing, which didn’t need to perform large scale of evacuation drill, which also needs complicated application and preparation. The contents were generated from street view, in order to protect public privacy, unauthorized image data wouldn’t be stored.

4.1 Field Experiment

In the field experiment, we extended the previous ICN based LPWAN network [9] to a 3N based LPWAN network. The experiment aimed to measure the performance between ICN routing and 3N node name routing, rather than a real-life evacuation drill. Around this region, we have arranged 40 DISS nodes, at the lamp posts in the streets and main roads (location details are shown in Fig. 10 and experiment parameter are shown in Fig. 11). The DISS nodes were embedded with ICN and 3N stack [23] in order to forward communication packets, and they use LPWA network to communicate. Additional 6 DISS Boxes were distributed on the main roads, and the nodes 41–46 were on the main road of the city. In the experiment, people would take the main road and captured by the camera nodes eventually, ensuring that
the collected tracking data was accurate on the evacuation route from the previous experiment.

The experiment uses an IoT platform with data processing capabilities. For ICN routing we used CCNx 0.8.2 in the 6 DISS Boxes, and for 3N NNR routing we used 3N application version 0.1. During the experiment, the nodes along the street actively collect data to obtain useful information by machine learning during the experiment. By using node names, it is possible to push to the disaster prevention center’s server or terminals of affected people. In the disaster scenario, the nodes also have a built-in HTTP server to output the real-time human recognition processed image visually.

When the tsunami evacuation alarm is in effect, the residents will take refuge in the places safe on high grounds. The general evacuation route is to move from the streets to the roads and finally upon the high-altitude shelters. The DISS Boxes are on the roads of the evacuation routes. The nodes identify the evacuating people individually and generate related information and send it to the client or evacuation command center, and the command center is assumed allocated at node 21, on top of a hill. We use this scenario to generate contents and let the LPWAN to forward them to the command center with NNR and with ICN routing strategy.

### 4.2 Results

Figures 12 and 13 are the network traffic heat-maps using normal ICN flooding routing and NNR routing. Figure 13 also contains a delivery route topology, indicating a content delivery route used in the network. The delivery topology shows how the packets are forwarded in the network. Because the LPWA connection might be lost and reconnected, the 3N nodes might need to reflode the network to create a new forwarding route. The system had generated approximately 13230 packets and we verified and compared 3N with standard ICN in packet transmission efficiency. From these two heat-maps, we can see that 3N network consumes less network resource than standard ICN network. Based on the traffic data gathered in the experiment, we were able to calculate the overall traffic ratio is at 40.58%, compares 3N to ICN. The overall packet ratio received at the emergency control center is 5.29% and 2.15%, in 3N and ICN. The network consumption in 3N network is significantly smaller compared with that in ICN network when the same size packet is transmitted. The difference between the two figures is that based on LPWA mesh network topology, the ICN flooding routing method will broadcast interest packet to every node possibly containing content and then when the content packet is being transmitted, the packet will follow the PIT entry to be delivered to every node. The ICN flooding routing causes waste data traffic in the mesh network, and this leads to multiplied bandwidth consumption and in the figure the whole area in high traffic load. Instead of blindly flooding packets to mesh network nodes, NNR actively updates the NNST in the nodes and finds the best route for the content delivery. This method means only the related nodes in the path of the content delivery route consume network bandwidth, the excluded part of the nodes will remain in low traffic consumption because only SO packet will be flooded in the whole network to determine the best route.
From the two heat-maps, we can see that 3N network consumes less network resource.

In Fig. 14, there is the traffic comparison of NNR and ICN forwarding mechanism. In the experiment, the emergency control center requires named content from the network. When a matched content is found, the content will be forwarded to the control center. Together with the heat-map above the compare of our proposed NNR and the ICN mechanism we can notice the difference in those nodes excluded in the optimized routes of the whole content delivery topology. In the ICN mechanism, those nodes were flooded with the packets and this caused almost all the bandwidth of the LPWAN system and unnecessary traffic load to them. On the other hand, our NNR system optimized the content delivery mechanism and only utilized the best delivery route, based on the number of hops and RSS information, to handle the packets. This is very important for LPWAN to deliver most valuable information out of least costly communication network as more valid information can be distributed, and the rescue power can be deployed most effectively.

5. Conclusions

An NNR-based LPWA disaster network is proposed in this paper. By applying NNR, the low bandwidth utilization problem in LPWAN is solved with its optimized routing ability. Field experiment results demonstrate that NNR expresses a better performance regarding the overall network bandwidth usage and content deliver efficiency. This is very valuable in the disaster area where mainstream networks are down, by using LPWAN+NNR based self-optimized network an emergency network can take place. However, future practical solutions require practical experience. Future research and experiment are required because we need more result data for further inspection to conclude more solutions.

Acknowledgments

I appreciate the support from “Disaster reduction promotion project to protect lives using no disconnection network” by MIC. This paper used some parts of results of 3N developed by “Establishment of high efficient and secured IoT data collection and control technologies for distribution network” supported by MIC. I also would like to present acknowledgement for MIC. This work also was supported by JSPS KAKENHI Grant Number JP18K18044.

References

[1] E. Monticelli, B.M. Schubert, M. Arumaitthurai, X. Fu, and K.K. Ramakrishnan, “An information centric approach for communications in disaster situations,” IEEE Local & Metropolitan Area Networks, USA, May 2014.
[2] X. Xiong, K. Zheg, R. Xu, W. Xiang, and P. Chatzimisios, “Low power wide area machine-to-machine networks: Key techniques and prototype,” IEEE Commun. Mag., vol. 53, no. 9, pp. 64–71, 2015.
[3] J. Petijäärvi, K. Mihaylov, M. Hämäläinen, and J. Finatti, “Evaluation of LoRa LPWAN technology for remote health and wellbeing monitoring,” 2016 10th International Symposium on Medical Information and Communication Technology (ISMICT), pp. 1–5, 2016.
[4] K.E. Nolan, W. Guibene, and M.Y. Kelly, “An evaluation of low power wide area network technologies for the Internet of Things,” 2016 International Wireless Communications and Mobile Computing (IWCMC), pp. 439–444, 2016.
[5] J. Chen, M. Arumaitthurai, X. Fu, and K.K. Ramakrishnan, “CNS: Content-oriented notification service for managing disasters,” Proc. 3rd ACM Conference on Information-Centric Networking (ACM-ICN’16), pp. 122–131, 2016. DOI:https://doi.org/10.1145/2984356.2984368
[6] X. Qi, Z. Wen, T. Tsuda, W. Kameyama, K. Shibata, J. Katto, and T. Sato, “Content oriented surveillance system based on information-centric network,” 2016 IEEE Globecom Workshops (GC Wkshps), Washington, DC, pp. 1–6, 2016.
[7] J. López and T. Sato, “Seamless mobility in ICN for mobile consumers with mobile producers,” IEICE Trans. Commun., vol. E100-B, no. 10, pp. 1827–1836, Oct. 2017.
[8] LPWA communication module, module IM920 by interplan. [Online]. Available: http://www.interplan.co.jp/solution/wireless/im920.php
[9] K. Shibata, “ICN autonomous distributed communication for IoT devices and its experimental system for Tsunami disaster prevention,” 2018 IEICE Society Conference, Tokyo, BT-2-4, 2018.
[10] V. Jacobson, D.K. Smetters, J.D. Thornton, M.F. Plass, N.H. Briggs, and R.L. Braynard, “Networking named content,” Proc. ACM 5th
S. Arshad, M.A. Azam, S.H. Ahmed, and J. Loo, “Towards information-centric networking (ICN) naming for Internet of Things (IoT): The case of smart campus,” Proc. International Conference on Future Networks and Distributed Systems, 6 pages, 2017, DOI: https://doi.org/10.1145/3102304.3102345

K. Yu, M. Arifuzzaman, Z. Wen, D. Zhang, and T. Sato, “A key management scheme for secure communications of information-centric advanced metering infrastructure in smart grid,” IEEE Trans. Instrum. Meas., vol.64, no.8, pp.2072–2085, Aug. 2015.

J.H. Saltzer, “On the naming and binding of network destinations,” RFC 1498, Aug. 1993.

Z. Wen, D. Zhang, K. Yu, and T. Sato, “Node name routing in information-centric ad-hoc network,” IEICE Trans. Fundamentals, vol.E100-A, no.2, pp.680–687, Feb. 2017.

T. Yagyu, K. Nakamura, T. Asami, K. Sugiyama, A. Tagami, T. Hasegawa, and M. Arumaithurai, “Demo: Content-based push/pull message dissemination for disaster message board,” Proc. 2nd ACM Conference on Information-Centric Networking, pp.205–206, 2015, DOI:https://doi.org/10.1145/2810156.2812609

A. Hannan, S. Arshad, M.A. Azam, J. Loo, S.H. Ahmed, M.F. Majeeed, and S.C. Shah, “Disaster management system aided by named data network of things: Architecture, design, and analysis,” Sensors, vol.18, no.8, 20 pages, 2018, DOI:https://doi.org/10.3390/s18082431

Z. Wen, D. Zhang, K. Yu, and T. Sato, “Information-centric networking for disaster information sharing services,” IEICE Trans. Fundamentals, vol.E98-A, no.8, pp.1610–1617, Aug. 2015.

D. Nozaki, K. Okamoto, T. Mochida, X. Qi, Z. Wen, S.H. Myint, K. Tokuda, T. Sato, K. Tamesue, “AI management system to prevent accidents in construction zones using 4K cameras based on 5G network,” Wireless Personal Multimedia Communications 2018, Chiang Rai, Thailand, 2018.

M. Abadi, A. Agarwal, P. Barham, E. Brevdo, Z. Chen, C. Citro, G.S. Corrado, A. Davis, J. Dean, M. Devin, S. Ghemawat, I. Goodfellow, A. Harp, G. Irving, M. Isard, Y. Jia, R. Jozefowicz, L. Kaiser, M. Kudlur, J. Levenberg, D. Mane, R. Monga, S. Moore, D. Murray, C. Olah, M. Schuster, J. Shlens, B. Steiner, I. Sutskever, K. Talwar, P. Tucker, V. Vanhoucke, V. Vasudevan, F. Viégas, O. Vinyals, P. Warden, M. Wattenberg, M. Wicke, Y. Yu, and X. Zheng, “TensorFlow: Large-scale machine learning on heterogeneous distributed systems,” arXiv preprint arXiv:1603.04467 (2016).

Intel Compute Stick, module STK2mv64CC by Intel. [Online]. Available: https://ark.intel.com/products/91979/Intel-Compute-Stick-STK2mv64CC

Map data and location provider: Microsoft Bing, Zenrin.

Q. Xin, Z. Wen, J. López, K. Yu, T. Sato, et al. “Named-node networking (3N) implementation approach,” IEICE 9th ICN Workshop, Tokyo, Japan, 2016.

Kouichi Shibata received M.E. degree in electrical and electronic engineering from Nagoya University, JP in 1988. From 1988, he worked for Central Research Lab. HITACHI Ltd. on Digital Signal Processing and Communication. He was visiting scholar at Columbia University, Center for Telecommunication Research (1996–1997). He worked for HITACHI Ltd., HITACHI Consulting, HITACHI Solutions, JP (1997–2015) and currently working on Distributed Autonomous Communication Technology, in Skeed Co. Ltd., JP from 2015.

Kazunori Murata had graduated from Shibuya Makuhari high school, JP, in 2013 and received a B.S. degree from Waseda University, JP, in 2018. His research interests include LPWA network.

Zheng Wen received B.E. degrees in Computer Science and Technology from Wuhan University, China in 2005 and 2009 and a M.Sc. degree from Waseda University, JP in 2015. Now he is a Ph.D. candidate at Waseda University, JP. His research interests include ICN/CCN for next-generation communication systems.

Xin Qi received B.E. degrees in Computer Science and Technology from Hangzhou Dianzi University, China in 2013 and a M.E. degree from Waseda University, JP in 2016. Now he is a Ph.D. candidate at Waseda University, JP. His research interests include ICN and 3N for next-generation communication systems.
Takuro Sato was born in Niigata Prefecture, Japan, on January 16, 1950. He received the B.E. and Ph.D. degrees in electronics engineering from Niigata University. He was a member of Research and Development Laboratories, Oki Electric Industry Co., Ltd., in Tokyo Japan, where he worked on PCM transmission equipment, mobile telephone and standardization of mobile data transmission and CDMA system for international standardization committee. During 1977–1978 Sato developed AT&T AMPS (EIA/TIA-553) cellular phone equipment in Oki Electric Industry, Co. He developed high speed cellular MODEM on AMPS cellular system in USA in 1983. This technology was proposed to be standardized in the CClTTT (now ITU) SG17. In 1990, he developed the data transmission system on digital cellular. He developed W-CDMA system named IS-665 in TIA for next generation cellular system. In 1990 the T1P1/TIA Joint Technical Committee (JTC) was organized to evaluate proposed 2nd generation, 1.9 GHz, Personal Communications Systems. He proposed W-CDMA and passed the evaluation tests and became TIA Standard IS-665 and T1P1 Standard J-STD-015 in 1996. He became a Professor in the Department of Information and Electronics Engineering, Niigata Institute of Technology in 1995. He contributed to the standardization process in IEEE 802.11a. He established the venture company Key Stream to provide LSI integrated circuits to 802.11 wireless LAN systems. In 2004, He became a Professor in Faculty of Science Engineering at Waseda University. Recently he is interested in smart grid technologies cooperated with ICT system including wireless communication. He is also interested in mobile edge computing technologies based on ICN (Information Centric Network) to apply for 5G mobile communication network. He is fellow member of IEICE, fellow member of IEEE and fellow member of JSST.