Name-Based Dynamic Routing in Ad-Hoc Networks

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***Abstract*—The ad-hoc network technology is an indispensable infrastructure for the digital society, and an IP-based routing scheme for ad-hoc networks is important to integrate with the Internet. Ad-hoc networks can work in the same routing scheme as the Internet using AutoIP and mDNS. However, they cause excessive power consumption and delay before establishing communication. In order to address these issues, we propose a new method of name-based dynamic routing based on Intentional Naming System (INS) and InterPlanetary Network (IPN.) In this paper, we show that our routing scheme is feasible through some simulation experiments.**

Keywords*—*ad-hoc networks; routing; naming

I. Introduction

Wireless mobile communication devices, such as laptops or smartphones, are increasingly used in every day communication. Recently, ad-hoc networks, which are composed of such devices, called nodes, have attracted increased attention [1]. In ad-hoc networks, communication between nodes is realized by multihop message forwarding, so that it does not require any infrastructure such as base stations or access points. For this reason, ad-hoc communication is used in various fields. The most important feature of ad-hoc networks is their dynamic topology. Most nodes have mobility and a possibility of disconnection because of their battery shortage, so the network topology changes continuously. Therefore, ad-hoc networks have problems in routing schemes and power consumption.

Ad-hoc networks can work in the same routing scheme as the Internet using AutoIP and multicast DNS (mDNS) [2]. AutoIP assigns an IP address to a node automatically, and mDNS realizes name resolution without Domain Name System (DNS). Using AutoIP, each node obtains an IP address when joining the ad-hoc network. Using mDNS, when each node communicates with each other, it requests name resolution to all nodes in the network as follows:

1) A node sends a request packet containing a name to be resolved to all the other nodes in the network.
2) The destination node sends back its IP address to the requesting node, when it receives the packet whose name matches its own.
3) The requesting node communicates with the destination node using the IP address obtained in 2.

However, this method causes some problems:

- Increase of traffic in the network,
- Delay before establishing communication,
- Excessive power consumption.

These problems are caused by the routing scheme that many packets are exchanged among the requesting node and the other nodes.

In order to address these issues, we propose a new scheme, name-based dynamic routing. Our proposal applies Intentional Naming System (INS), which was proposed for the Internet, and realizes routing without resolving a name of a node to its IP address. Additionally, in order to realize the dynamically adaptive routing corresponding to the change of network topology, we use the step-by-step routing scheme proposed in InterPlanetary Network (IPN). It does not require any name resolution. Our proposal aims at realizing reduction of traffic load and suppression of power consumption, as well as avoidance of delay before establishing communication.

Over time, there have been various naming schemes proposed for Wireless Sensor Networks (WSNs,) Delay Tolerant Networks (DTNs,) and so on. For example, Amoretti et al. [3] proposed a method based on tree-structured networks for WSNs. Bovet et al. [4] proposed a name resolution method for networks in smart buildings. Schildt et al. [5] proposed a name-based routing method based on Chord [6] for DTNs. Our routing scheme focuses on small ad-hoc networks, and this is a preliminary study to realize a routing scheme which replaces AutoIP and mDNS in a dynamic manner.

We built a simulator which makes virtual ad-hoc networks on a single computer, and we verified the effectiveness of our proposal through some experiments. The results confirmed that our name-based dynamic routing could work on ad-hoc networks, and our routing scheme reduced power consumption and delay.

This paper is organized as follows: we summarize some related works in Section 2. In Section 3, we describe our proposed method. Subsequently, we evaluate our method through some simulation experiments in Section 4. Finally, Section 5 contains some concluding remarks and future work.

II. Related work

In this section, we summarize some related works: INS and the routing scheme in IPN.

A. INS

INS is a resource discovery and service location system for dynamic and mobile networks of devices and computers [7]. Communication between nodes in INS is realized using a name of service without performing name resolution.

INS realizes routing without name resolution by introducing nodes called Intentional Name Resolvers (INRs) in a

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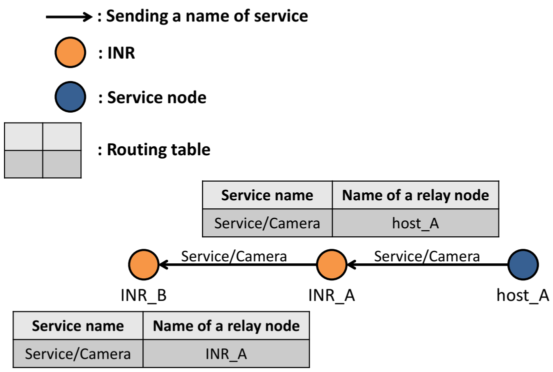

Figure 1. Registration of service.

network. INRs manage a routing table in which the following contents are kept.

- The name of service (called service name)
- The name of a relay node

In this manner, INS realizes suppression of traffic on a network and reduction of delay before establishing communication. This is because there is no need of resolving names by communicating with name resolution nodes such as DNS.

INS is implemented in two processes called registration of service and searching of service. The registration of service means that INRs update their routing tables, and the searching of service means that any nodes searches a node which provides service.

Here we describe registration of service. The following operation is repeatedly performed (Figure 1).

1) Any node which provides service (called a service node) sends a service name to a near INR.
2) Upon receiving the above message, the INR writes the service name and a name of a relay node in its routing table.
3) The INR transfers the name information to neighboring INRs.

In this manner, the INRs manage routing information for reaching any node which provides service.

Next, we describe searching of service. Communicating between a requesting node and a service node is realized by the request node simply sending a service name to any INR. Searching of service has a variety of features, as follows, that are different from the ones for the Internet.

- No node must convert a name of a destination node to an IP address.
- Relay nodes do not tell location information of the service node to the requesting node.

In this manner, INS eliminates the use of IP addresses.

B. Routing scheme in IPN

IPN aimed at implementing reliable communication between a node on a planet and a node on another planet through satellites. The issue was that it takes an enormous amount of time to perform communication, and the destination node often moves elsewhere during communication. Moreover, delay before establishing communication causes communication failure. Therefore, a step-by-step routing scheme using a hierarchical naming was introduced in order to address the issue [8].

TABLE I. Example of a routing table managed by each node.

Name of a destination node	Name of a relay node
Earth, host_A	host_A
Earth, host_B	host_B
Mars	host_C

A hierarchical name is assigned to each node and the name is a combination of two names as follows.

- *Region* : the name of a range in which node exists.
- *Region-specific-part* : the name which has been given to a node from the beginning.

For example, the name "Earth, host_A" is assigned to the node if the node has the name "host_A" and is placed on the Earth.

Now we describe the step-by-step routing scheme. Each node has a routing table as shown in Table I. First, a node sends a request packet toward a destination node. When a relay node receives the packet, the node checks the *region* of the destination node. On this step, there can be two scenarios: one is the case in which the *region* of the destination node is the same as the *region* where the requesting node is placed, and the other is the case in which the *region* of the destination node is different from the *region* where the requesting node is placed.

1) The first case: The node checks the *region-specific-part* of the destination node, and sends the packet to a relay node.

2) The second case: The node checks only the *region* of the destination node and sends the packet to a relay node. If the packet reaches the *region* where the destination node is placed, the node that received the packet checks the *region-specific-part* of the destination node, and sends the packet to a relay node.

In this way, each node sends a packet to a relay node closer to a destination node gradually. The routing scheme in IPN overcomes failures in the communication in an ever-changing and unreliable network.

III. Proposed Method

As described in Section I, this study introduces INS-based name-based dynamic routing, and also IPN-based step-by-step name-based routing to ad-hoc networks. More specifically, we perform registration of service and searching of service similar to INS, and step-by-step routing similar to IPN. This is to handle dynamic changes of a network topology and to improve communication availability.

However, it is difficult to apply the INS scheme to ad-hoc networks as they are. Most nodes in ad-hoc networks have mobility, so it is difficult to arrange stable nodes to behave as INRs. Therefore, it is necessary to select nodes to manage a routing table in place of INRs. Moreover, it is necessary to configure *regions* on a network and each node must belong to any *region*. Below is our proposal to address the above two issues.

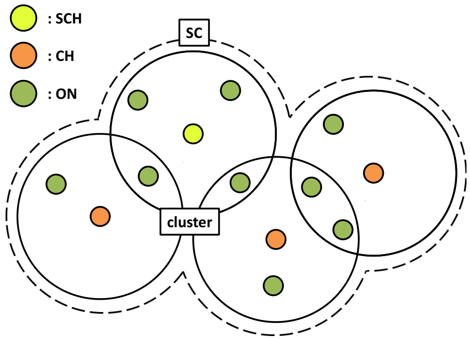

Figure 2. Example of a SC and a cluster.

TABLE II. Example of a routing table managed by each CH.

Name of a destination node	Name of a relay node
SC_A/Cluster_A/host_A	host_A
SC_A/Cluster_A/host_B	host_B
SC_A/Cluster_B	host_C
SC_B	host_D

A. Selection of nodes which manage a routing table in place of INRs

We configure clusters and super-clusters (SCs), which are aggregations of some clusters shown in Figure 2. Cluster-Heads (CHs) and SC-Heads (SCHs) manage routing tables respectively: a CH is a representative of a cluster, and an SCH is a representative of an SC. Routing information as below is written in a routing table. Example of a routing table is shown in Table II.

1) Information on a relay node to reach another cluster or another SC
2) Information on a relay node to reach another node belonging to the same cluster

B. Setting of regions

The name of each *region* is the name of a cluster or an SC. The name of each node is concatenation of "the name of its SC, the name of its cluster, and the name of itself".

C. Participation in a region

Participation of each node except for SCHs in any *regions* is realized with the following procedure (Figure 3).

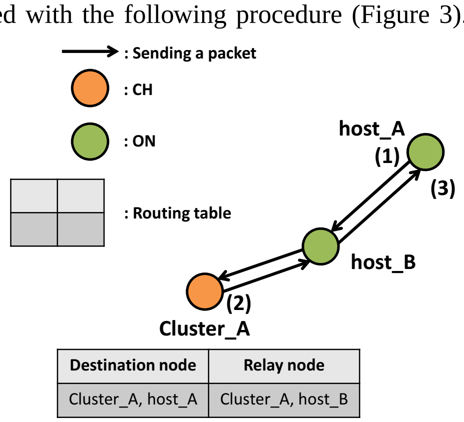

Figure 3. Participation in a *region* and creation of a routing table.

1) A node sends a packet to neighboring nodes when the node joins the network.
2) When a CH or an SCH receives the packet, it replies with a packet to the request node and updates its routing table.
3) The requesting node joins the *region* when the node receives the reply packet, and the node is named based on the name of the *region* where the node joins.

D. Searching a node

When a node communicates with a destination node, the node sends a packet called query packet to its CH or SCH. The CH or SCH which receives the query packet checks its routing table and transfers the packet to a relay node.

Something to be investigated is that the difference of contents in the routing tables affects the searching cost. Therefore, we consider four candidates based on the difference of contents and compare the four. After the comparative experiments, we will recommend one approach which achieves the best result.

E. Four candidates

We describe contents written in the routing table in detail, and four method candidates searching a node.

1) First approach: This is the simplest approach which does not consider congestion. This approach is designed so that routing information in the table is minimal.

In particular, SCHs manage two pieces of routing information: one is information on a relay node to reach each cluster in the same SC, and the other is information on a relay node to reach other SCs. CHs manage routing information on a relay node to reach a SCH of the SC it belongs. Nodes except for the CHs and SCHs, which are called ordinary nodes (ONs,)

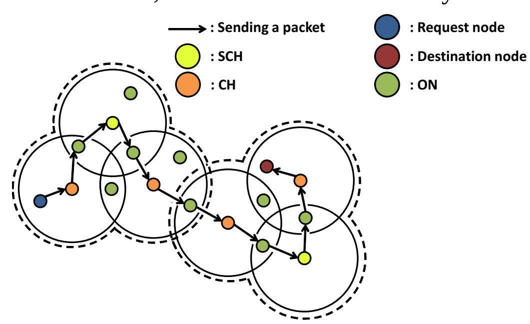

Figure 4. A communication path in the first approach.

Require: ON, CH, SCH, DEST
  while DEST does not receive the packet **do**
    if ON receives the packet **then**
      ON sends the packet to CH or SCH
    else if CH receives the packet **then**
      if DEST belongs to the CH's cluster **then**
        CH sends the packet to DEST
      else
        CH sends the packet to the relay node to reach SCH
      end if
    else if SCH receives the packet **then**
      SCH sends the packet to the relay node to reach DEST
    end if
  end while

Figure 5. Pseudo code of the first approach

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have routing information to reach the CH of the cluster they belong.

In this approach, searching a node is performed as shown in Figure 4 and 5. Communication between SCs or clusters is realized via SCHs.

2) Second approach: This is an approach which aims at suppressing congestion of the network, although it increases load of the CHs. The amount of routing information in the table is larger than the one in the first approach. In particular, the CHs manage routing information on a relay node to reach each cluster in its SC in addition to the CHs' in the first approach.

In this approach, searching a node is performed as shown in Figure 6 and 7. Communication between clusters in the same SC is realized without the SCHs.

3) Third approach: This is an approach which aims an suppressing congestion of the network by removing distinction between SCHs and CHs. In particular, CHs manage routing information on a relay node to reach each SC in addition to CHs' in the second approach. Therefore, routing information managed by SCHs and CHs are the same.

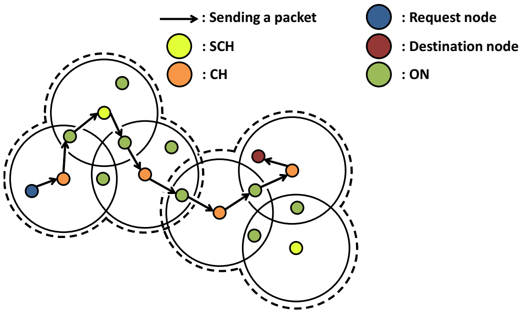

Figure 6. A communication path in the second approach.

Require: ON, CH, SCH, DEST
while DEST does not receive the packet **do**
if ON receives the packet **then**
ON sends the packet to CH or SCH
else if CH receives the packet **then**
if DEST belongs to the CH's cluster **then**
CH sends the packet to DEST
else if DEST and CH belong to same SC **then**
CH sends the packet to the relay node to reach DEST
else
CH sends the packet to the relay node to reach SCH
end if
else if SCH receives the packet **then**
SCH sends the packet to the relay node to reach DEST
end if
end while

Figure 7. Pseudo code of the second approach

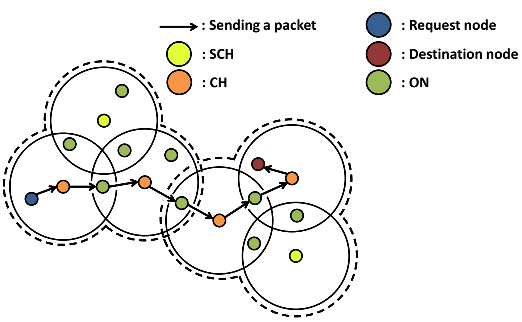

Figure 8. A communication path in the third approach.

Require: ON, CH, SCH, DEST
while DEST does not receive the packet **do**
if ON receives the packet **then**
ON sends the packet to CH or SCH
else if CH or SCH receives the packet **then**
if DEST and the CH (SCH) belong to the same cluster **then**
CH (SCH) sends the packet to DEST
else
CH (SCH) sends the packet to the relay node to reach DEST
end if
end if
end while

Figure 9. Pseudo code of the third approach

In this approach, searching a node is performed as shown in Figure 8 and 9. Communication between SCs is realized without SCHs.

4) Fourth approach: This is an approach which aims at suppressing congestion of the network by adding routing information managed by ONs.

In ad-hoc networks, broadcast communication is performed when a node communicates to any node. In short, each node sends a packet to all nodes which exist in its wireless communication range and all nodes except for a relay node discard the packet. Therefore, ONs can obtain routing information towards neighboring ONs by these packets.

In this approach, searching a node is performed as shown in Figure 10 and 11. Communication between a node and a

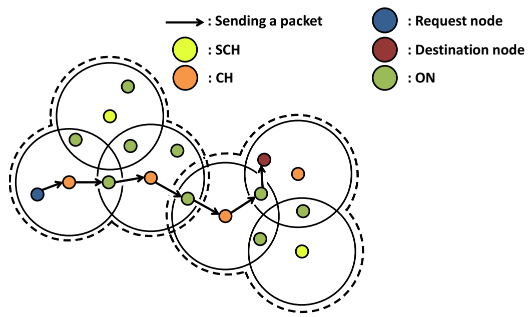

Figure 10. A communication path in the fourth approach.

Require: ON, CH, SCH, DEST
while DEST does not receive the packet **do**
if ON receives the packet **then**
if ON has a routing information to reach DEST **then**
ON sends the packet to DEST
else
ON sends the packet to CH or SCH
end if
else if CH or SCH receives the packet **then**
if DEST and the CH (SCH) belong to the same cluster **then**
CH (SCH) sends the packet to DEST
else
CH (SCH) sends the packet to the relay node to reach DEST
end if
end if
end while

Figure 11. Pseudo code of the fourth approach

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destination node is realized without the CH.

F. Loop elimination

Our routing scheme takes measures to loop of packets. Each packet has a unique identifier (ID), and if a node receives the packet with the same ID twice, the node discards the second one.

IV. Evaluation

We implemented a simulator in Java and built a virtual ad-hoc network on a single computer. In simulation-based experiments, we examined and compared the effectiveness of the four method candidates and mDNS.

- The average number of packets which each node processes
- The average number of hops
- The success rate of searching

The environment of the simulation is shown in Table III.

In mDNS, the following operation is repeatedly performed. When the simulator creates 300 query packets, the simulation is completed.

1) 50 query packets are created, and each packet is given to a node respectively.
2) Each node sends the query packet $P1$ toward a destination node.
3) When the destination node receives $P1$, the node replies the packet $R1$ to the request node.
4) When the request node receives $R1$, the node sends a packet $P2$ to the destination node again.
5) When the destination node receives $P2$, the node replies the packet $R2$ to the request node.
6) When all packets on the network are processed, each node moves elsewhere.

In the proposed method, the following operation is repeatedly performed in a single simulation. When the simulator creates 300 packets, the simulation is completed.

1) CHs and SCHs are selected at random out of nodes, and clusters and SCs are formed in the network. (This operation is performed only once in one simulation.)
2) 50 query packets are created, and each packet is given to a node respectively.
3) Each node sends the query packet $P1$ toward a destination node.
4) When the destination node receives $P1$, the node replies the packet $R1$ to the request node.
5) When all packets on the network are processed, each node moves elsewhere. (And CHs and SCHs send control messages to update their routing tables.)

TABLE III. Environment of the simulation

Parameter	Value
Number of nodes	500
Number of query packets	300
Time to live of a query packet	20
Communication range	150
Experimental area	1000*1000
Number of the simulation	10

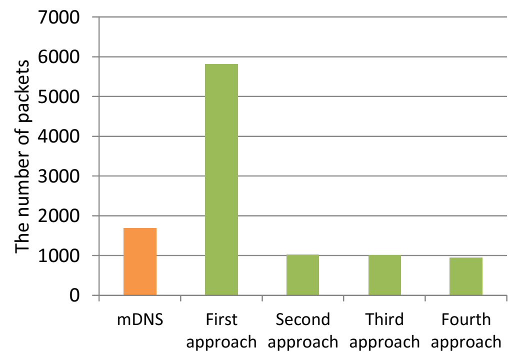

Figure 12. The the average number of packets which each node has processed.

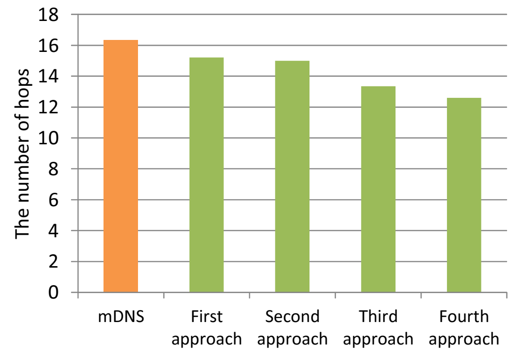

Figure 13. The average number of hops.

A. The average number of packets which each node processes

The result of the experiment is shown in Figure 12. The proposed approaches, except for the first approach, improved the number of packets compared to mDNS. In the first approach, each node must send a query packet to SCHs many times. We consider that the number of packets increases consequently. Therefore, the candidate approaches except for the first one will realize suppression of traffic in the network and power consumption.

B. The average of number of hops

The result of the experiment is shown in Figure 13. All the proposed method improved the number of hops compared to mDNS. In mDNS, each node must send a packet to a destination node twice. However, in the proposed method, each node must send a packet to a destination node only once. We consider that the number of hops decreases consequently. Therefore, all the proposed method will realize suppression of delay before establishing communication.

C. The success rate of searching

The success rate of searching is expressed in the following equation.

The success rate of searching $= \frac{NUM_{RP}}{NUM_{SP}} * 100$

NUM_{RP} represents the number of nodes which receive a packet from a destination node, and NUM_{SP} represents the number of nodes which sent a query packet. The result of the experiment is shown in Figure 14. The success rate of searching of the proposed methods is worse than mDNS. We consider that some clusters may be isolated to each other in the experiment.

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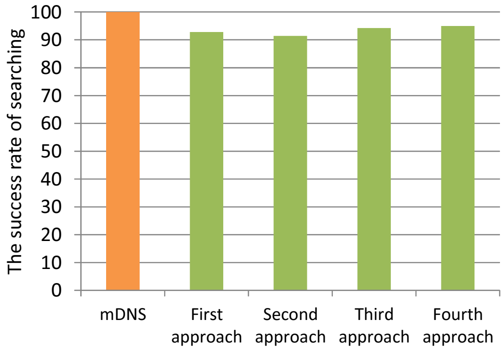

Figure 14. The success rate of searching.

V. Conclusion and Future work

Ad-hoc networks can use the same routing scheme as the Internet with such technologies as AutoIP and mDNS. However, using these technologies will cause delay before establishing communication and excessive power consumption. In this study, we aimed at introducing name-based dynamic routing based INS and IPN in order to address these issues. The result of the experiment proves that name-based dynamic routing can be realized on ad-hoc networks. It is also confirmed that our routing scheme, especially the fourth approach, can achieve the best result.

Issues to address in further studies are as follows.

1. Reselection of CHs and SCHs

CHs and SCHs consume more power than ONs because these nodes often become a relay node. Moreover, in a real world network, CHs or SCHs may be disconnected from the network due to movement or failure. Therefore, it is necessary to add a mechanism to reselect them to the proposed method.

2. Measures to duplication of a node name

In this study, we assume that each node is assigned a unique name. However, the name of any node may conflicte to each other in a real network. Therefore, it is necessary to take measures on duplication of the node name.

3. Selection of the routing scheme

In this study, it is revealed that the fourth approach is better than the other approaches. However, the size of a routing table managed by each node in the fourth approach is larger than the other's. The fourth approach can not be realized if the performance of each node on the network is poor. Therefore, it is necessary to select one of the four proposed approaches based on the performance of each node.

4. Application to Content Centric Networking

Recently, a content-oriented architecture has attracted increased attentions for a next-generation Internet [9]. Especially, Content Centric Networking (CCN) [10], which realizes routing using the name of contents only, is expected to solve some problems of the current Internet. We are now investigating relevance and applicability of our routing scheme to such architectures.

References

[1] C. K. Toh, “Ad-hoc mobile wireless network —protocol and system—”, Kyoritsu Publisher, 2003.

[2] Multicast DNS, http://www.multicastdns.org/, 2016.

[3] M. Amoretti, O. Alphand, G. Ferrari, F. Rousseau, and A. Duda, “DINAS: a DIstributed NAming Service for All-IP Wireless Sensor Networks”, Proceedings IEEE Wireless Communications and Networking Conference, 2014, pp. 2781–2786.

[4] G. Bovet and J. Hennebert, “A Distributed Web-based Naming System for Smart Buildings”, Proceedings 2014 IEEE 15th International Symposium on a WoWMoM, 2014, pp. 1–6.

[5] S. Schildt, W-B. Pottner, O. Ohneiser, and L. Wolf, “NASDI - Naming and Service Discovery for DTNs in Internet Backbones”, Proceedings Mobilware 5th International Conference, 2012, pp. 108–121.

[6] I. Stoica, R. Morris, D. Liben-Nowell, D. R. Karger, M. F. Kaashoek, F. Dabek, and H. C. Balakrishnan, “Chord: A Scalable Peer-to-peer Lookup Service for Internet Applications”, Proceedings of the 2001 Conference on Applications, Technologies, Architectures, and Protocols for Computer Communications, 2001, pp. 149–160.

[7] W. A. Winoto, E. Schwartz, H. Balakrishnan, and J. Lilley, “The design and implementation of an intentional naming system”, 17th ACM Symposium on Operating Systems Principles, 1999, pp. 186–201.

[8] L. Clare and S. Burleigh, “Endpoint Naming for Space Delay / Disruption Tolerant Networking”, Aerospace Conference, 2010, pp. 1–10.

[9] A. A. Barakabitze, T. Xiaoheng, and G. Tan, “A Survey on Naming, Name Resolution and Data Routing in Information Centric Networking (ICN)”, International Journal of Advanced Research in Computer and Communication Engineering, 2014, pp. 8322–8330.

[10] V. Jacobson, D.K. Smetters, J.D. Thornton, M.F. Plasee, N. Briggs, and R. Braynard, “Networking named content”, Proceedings of the 5th ACM Int. Conf. on Emerging Networking Experiments and Technologies, 2009, pp. 1–12.