An Energy-Efficient Routing Protocol for CCN-based MANETs

Geunhyung Lee, Longzhe Han, Yunhui Park, Jung-Been Lee,
Juwon Kim and Hoh Peter In*

College of Information and Communications, Korea University
Seoul, Republic of Korea
{skypepper, lzhan, ssocoori, jungbini, xacti2, hoh_in}@korea.ac.kr

Abstract

The content-centric network (CCN) paradigm is well suited to mobile ad-hoc networks (MANETs), because MANET scenarios are data-centric in nature. CCN-based MANETs implement named-data routing, in-network caching, and receiver-driven data dissemination. However, because resources such as energy are limited, this network faces many challenges, such as reduced lifetime of the entire network. Therefore controlling energy consumption is important for effective communication in MANETs. If popular contents are transferred repeatedly in the same routing path, each node is down by short of energy. Then node carrying data packet may fail and energy imbalance occurs in entire network. To solve these problems, using added residual energy and frequency of node usage as routing parameters, we propose an energy-efficient routing protocol for CCN-based MANETs and evaluate the energy consumption of routing protocols.

Keywords: *Mobile ad-hoc networks (MANETs), Content-Centric Network (CCN), Energy, Routing protocol*

1. Introduction

A mobile ad-hoc network (MANET) is composed of mobile nodes without any fixed infrastructure. These mobile nodes that are connected by wireless links are free to move and organize themselves in a random manner. They also act as routers to communicate other node without propagation range. Application scenarios include battlefield, disaster, emergency, etc. [1]. This design faces two basic issues. First, managing IP address of moving nodes is difficult, because IP address built with infrastructure support, such as a central DHCP server. Second, conventional routing protocols are designed for wired network. Third, assigning IP address is increasingly infeasible by increasing number of computing devices most of which are mobile [2, 3, 4].

Content-centric networking (CCN) is an emerging communication paradigm proposed by the Palo Alto Research Center (PARC), the purpose of which is to change host-to-host based communication to content based communication. The CCN paradigm is well suited to MANETs, because MANET scenarios are data-centric in nature. CCN provides new opportunities to facilitate the performance of MANETs [2, 3, 4].

CCN-based MANETs, implement named-data routing, in-network caching, and receiver-driven data dissemination [5, 6]. However, because of its limitations related to energy, this network faces many challenges, a major one of which is the potentially reduced lifetime of the entire network. Therefore, controlling energy consumption is important for effective communication in MANETs. Further, if popular contents are transferred in the same routing

* Corresponding Author

path, each node is down by short of energy. Then node carrying data packet may fail and energy imbalance occurs in entire network. To increase the lifetime of MANETs, a ratio of energy consumption for each node should be kept constant by equally. In this paper, using added residual energy and frequency of node usage as routing parameters, we propose an energy-efficient routing protocol for CCN-based MANETs and evaluate the energy consumption of routing protocols.

2. Related Work

2.1. Routing Protocols

Researchers have been studying various protocol layers to find ways to reduce energy consumption in MANETs. Table 1 shows study on energy consumption in each protocol layer. Current routing protocols communicate data packets by the shortest route. Therefore, if data packet communication has occurred in some node, this node has consumed more energy than other nodes. Thus, if some nodes are used repeatedly, entire network energy imbalance can be occurred.

Table 1. Studying on Energy Consumption in Each Protocol Layer

Layer	Studying energy consumption
Link layer	- Prevent unnecessary retransmission - Reduce collision of data packet in accessing channel - Receive node operates as standby mode - Allocation continuous slot for receive node - If node is not receive status, power off
Network layer	- Considering routing path overhead - When routing path choose, considering energy - Reduce frequency of control message usage - Reduce header size of control packet - Efficient routing path reconfiguration
Transmission layer	- Reduce retransmission - Handling packet loss between included nodes of path - Using low-power, error restore technology

The routing protocols for MANETs are typically divided into two main categories: proactive (OLSR, DSDV, etc.), and reactive (AODV, DSR, etc.) [7, 8].

Proactive routing protocols find routing path between each source and destination in advance. Therefore, when data need to be transmitted, a route discovery process is not required. As a result, data latency is low. When there is a change in the network topology, these protocols propagate updated routing information throughout the network in order to maintain a consistent network topology. The advantage of this strategy is that routing path to any destination are always available, without incurring the overhead of the routing path discovery procedure. However, proactive routing protocols can cause substantial routing overhead, thus affecting bandwidth utilization and, throughput, as well as energy usage, because the routing information has to be maintained. Moreover, these protocols cannot perform efficiently when the mobility rate of the network is high or when the number of nodes in the network is large.

Reactive routing protocols are characterized by a routing path discovery mechanism that is initiated when a source needs to communicate with a destination, the routing path to which it does not know. Routing path discovery is usually carried out in the form of query flooding. In general, reactive routing protocols incur fewer routing and control traffic overheads than table-driven routing does. However, they cause a routing path discovery delay whenever a new path is needed.

These most routing protocols in MANETs focus on the method of data communication using the shortest route without fixed infrastructure support. However these routing protocols do not focus on the entire network energy or energy consumption economy

2.2. Content-centric Network (CCN)

The principle and architecture of today's Internet were conceived in the 1960s and 70s. Rapid developments in Internet technology have made; various Internet services ranging from Web pages to mass data, available. However, today's Internet is not suitable for many services because it supports host-to-host-based communication. Users value the Internet for its content. Therefore, for today's Internet services, a new and efficient networking paradigm has been proposed, namely, the content-centric network (CCN). A CCN accesses and delivers resources (e.g., data and services) efficiently by focusing on the needs of the user rather than the location of the content. Users request resources using a data name as an address, instead of an IP address. Further, because the CCN router has a cache function, requested data can be disseminated [5, 6]. Thus, a CCN manages network resources efficiently by reducing the network traffic.

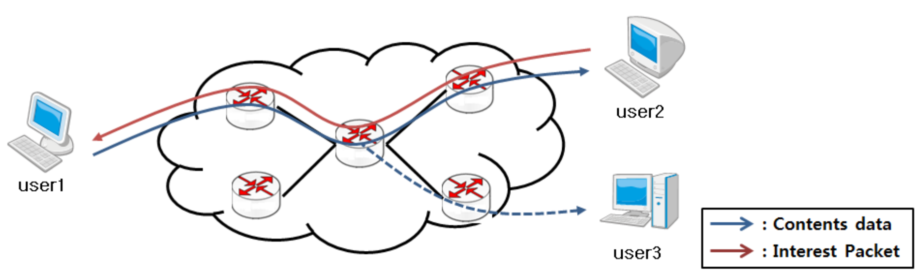


Figure 1. Communication in Content-Centric Architecture

There are two packet types: interest packet and data packet. Interest packet is used for request data. Then the users that receive the interest packet compare the data name in the content table and in the interest packet. If the data name is the same, the data are sent back to the request node via the path created by interest packet.

3. An Energy Efficient Routing Protocol for CCN-based MANETs

3.1. Routing Parameters

In general, routing path reconfiguration occurs in a MANET when a node leaves its routing path by moving its location, and, because of battery exhaustion, the node does not communicate. It can also happen that, because the network traffic is excessive, a node does not participate in the network. This paper does not discuss node mobility and link instability, but focuses rather on stable network topology. Energy consumption per node is maintained uniformly to maximize the lifetime of the entire network. In order to achieve uniform energy consumption, the possibility of a critical node occurring is suppressed to the highest possible degree. If a specific node is used repeatedly by a data communication, the residual energy of the nodes in the route decreases more quickly than in other nodes. Therefore in this study, to restrain occurrence of a critical node, when a route is configured, the residual energy and frequency of node usage are considered. The frequency of nodes usage is used to discriminate between a critical and a normal node.

$$E_i = (E_{curr(i)} / E_{init(i)}) \times 100$$

E_i : Energy rate of node (N_i)
$E_{curr(i)}$: Residual energy
$E_{init(i)}$: Initial energy

Figure 2. Residual Energy Circulation as Routing Parameter

The residual energy capacity of a node is calculated, as shown in Figure 2, by dividing the current energy divided by the initial energy, and $0 < E_n < 100$. This study assumes residual energy (E_n) of node (N_i) in time. Because the initial energy capacity differs according to the device, in this paper, residual energy is expressed as a rate as shown in Figure 2.

Node		Energy (%)	Node usage
Current	Next		
A	B	50	2

Figure 3. Interest Packet for Energy Efficient Routing Protocol

Information on the residual energy and frequency of node usage is added to the interest packet as shown in Figure 3, to provide an energy-efficient routing protocol for a CCN-based MANET.

3.2. Routing Protocol Scenario

Proposed model adopt routing path discovery mechanism as reactive routing protocols that is initiated when a source needs to communicate with a destination, the routing path to which it does not know.

When a routing path is configured in a proposed model, a node broadcasts an interest packet to neighboring nodes within propagation range. Each node saves the information about the route such as, the residual energy of node and frequency of the node usage. Before communication, request node compares the added routing parameters of neighboring node. First, residual energy is compared with neighboring nodes for configuring routing path. Then if residual energy of neighboring nodes is identical, frequency of node usage is compared in second. If node is below threshold that is used for preventing down of node, node does not participate in the network communication.

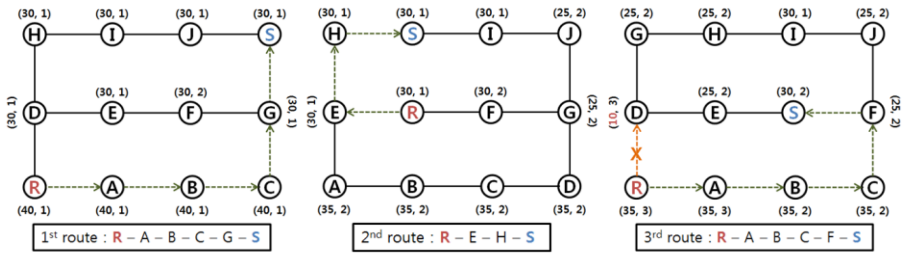


Figure 4. Routing Protocol Scenarios

Figure 4 shows energy efficient routing protocol scenarios. In bracket of Figure 4, each value is residual energy and frequency of node usage respectively. In first route, request node (R) detects node A and node D within propagation range. In this case, because frequency of node A and node D usage is same, request node (R) compare residual energy of each node. Then residual energy of node A is higher than it of node D. According to comparing route parameters, request node (R) sends interest packet to source node (S) as arrowed line. And according to created route information from interest packet, request node (R) receives data from source node (S). Then intermediate nodes (A, B, C, G) cache and disseminate data to neighboring node. In second route, request node (R) detects node E and node F within propagation range. In this case, because residual energy of node E and node F is same, request node (R) compare frequency of each node usage. Then frequency of node E' usage is lower than it of node F. According to comparing route parameters, request node (R) sends interest packet to source node (S) as arrowed line. In third route, request node (R) detects node D and node A within propagation range. In this case, because residual energy of node D is lower than threshold such as 10%, node D does not participate in the network communication. Therefore, according to three case of routing protocol scenarios proposed model operate for energy consumption economy.

4. Experiment

4.1. Calculation of Energy Consumption

Since energy is a limited resource in MANETs, energy-efficient routing protocol design is a key issue. The performance analysis of such protocols requires proper modeling for the measurement of energy consumption. Four possible energy consumption states are identified: transmit, receive, idle and sleep. The transmit, and receive states are when the node is transmitting and receiving packets respectively, the idle state is when the node is waiting for any packet transfers, and the sleep state is a very low power state where the node can neither receive nor transmit [9]. This paper use a transaction based model. It is that the total energy is calculated by adding up the consumption incurred by all equipment used to deliver a service [10].

Total consumed energy of CCN consists of two parts such as transport energy and caching energy. This study use Feeney's result for calculation transport energy. The cost for a node to communicate is modeled. There is a fixed cost associated with channel acquisition and an incremental cost proportional to the size of the packet [9].

$$\text{Transport cost} = m \times \text{size} + b$$

Caching energy is calculated as follows [11, 12]

$$\text{Caching cost} = n \times \text{size} \times \text{power of caching in router}$$

4.2. Result and Discussion

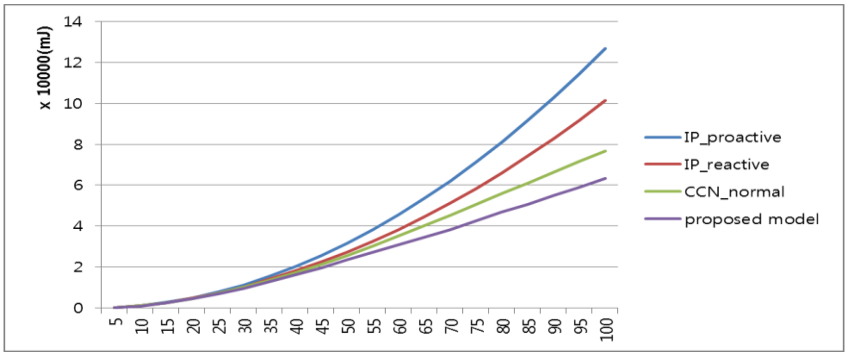


Figure 5. Total energy consumption by the number of packets

Figure 5 shows total energy consumption by the number of packets. Proactive routing protocols incur more transport cost than reactive routing protocols by routing path configuration of entire network in advance. Thus, the total energy consumption by the number of packets in proactive routing protocols is higher than that in reactive routing protocols. When the number of packets is a little, there is less difference of total energy consumption. However, larger the number of packet is, the bigger total energy consumption is difference by caching between IP- and CCN-based MANET. Proposed model distribute network traffic into all of the nodes equally. And because of link fail is a little by terminated node, control packet such as interest packet, is low for router configuration in proposed model. Therefore, proposed model is more energy efficient rather than others as shown in Figure 5.

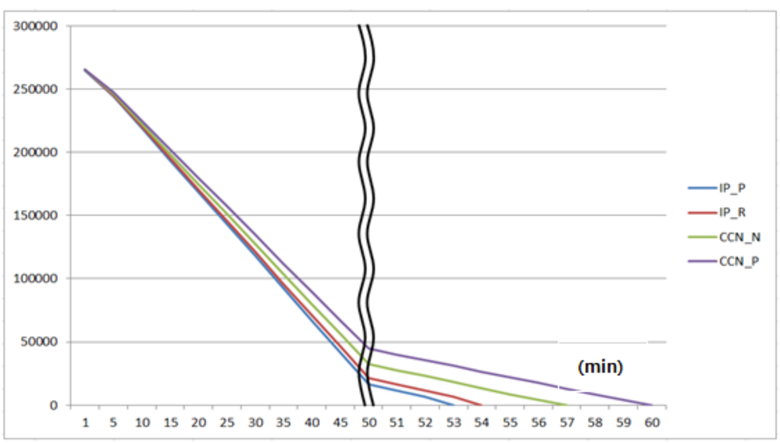


Figure 6. Total Energy Consumption by Time

Figure 6 shows total energy consumption by time. According to the energy consumed by the packets from each node, we analyze how long entire network is maintained. To analyze the total energy consumption by time, the number of nodes is 9 and the energy of each node, is 1800mAh. The less energy consumption by Packet is, the longer total energy in network is maintained.

5. Conclusion

Because of limited energy in MANETs, controlling energy consumption is very important issue. For overcoming this problem, using residual energy and frequency of node usage, this study proposes an energy efficient routing protocol for CCN-based MANETs. Considering transport and caching energy, it measures energy consumption between current and proposed model. In this paper proposed model is more energy efficient than other routing protocols by equally distributing network traffic into all of the nodes. As future work, we intend to analyze energy consumption exactly, through simulations, considering various parameters, such as mobility, linkage, etc.

Acknowledgements

This research was supported funded by the R&BD Support Center of Seoul Development Institute and the South Korean government (WR080951), Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education, Science and Technology (2012R1A1A2009021), and the MKE(The Ministry of Knowledge Economy), Korea, under the ITRC(Information Technology Research Center) support program supervised by the NIPA(National IT Industry Promotion Agency"(NIPA-2012-(H0301-12-3004)))

References

[1] I. Chalamtac, M. Conti and J. -N. Liu, “Mobile ad hoc networking: imperatives and challenges”, Ad Hoc Networks, vol. 1, no. 1, **(2003)** January-March, pp. 13-64.

[2] M. Varvello, I. Rimac, U. Lee, L. Greenwald and V. Hilt, “On the Design of Content-Centric MANETs”, 2011 Eighth International Conference on Wireless On-Demand Networks Systems and Services, **(2011)** January 26-28; Bardonecchia, Italy.

[3] M. Meisel, V. Pappas and L. Zhang, “Ad Hoc Networking via Named Data”, MobiArch’10, **(2010)** September 24; Chicago, Illinois, USA.

[4] S. Y. Oh, D. Lau and M. Gerla, “Content Centric Networking in Tactical and Emergency MANETs”, IFTP Wireless Days 2010, **(2010)** October 20-22; Venice, Italy.

[5] V. Jacobson, D. K. Smetters, J. D. Thornton, M. F. Plass, N. H. Briggs and R. L. Braynard, “Networking Named Content”, CoNEXT’09, **(2009)** December 1-4; Rome, Italy.

[6] S. Arianfar, P. Nikander and J. ott, “On Content-Centric Router Design and Implications”, ACM ReArch 2010, **(2010)** November 30; Philadelphia, USA.

[7] S. Buruhanudeen, M. Othman, M. Othman and B. M. Ali, “Existing MANET Routing Protocols and Metrics used Towards the Efficiency and Reliability-An Overview”, Proceeding of the 2007 IEEE International Conference on Telecommunications and Malaysia International Conference on Communications, **(2007)** May 14-17; Penang, Malaysia.

[8] J. H. Zhang, H. Peng and F. J. Shao, “Energy Consumption Analysis of MANET Routing Protocols based on Mobility Models”, 2011 Eighth International Conference on Fuzzy Systems and Knowledge Discovery (FSKD), **(2011)** July 26-28; Shanghai, China.

[9] G. Allard, P. Minet, D. Q. Nguyen and N. Shrestha, “Evaluation of the Energy Consumption in MANET”, ADHOC-NOW 2006, **(2006)** August 17-19; Ottawa, Canada.

[10] J. Baliga, R. Ayre, K. Hinton and R. S. Tucker, “Architectures for Energy-Efficient IPTV Networks”, Optical Fiber Communication Conference, **(2009)** March 22-26; San Diego, USA.

[11] U. lee, I. Rimac and V. Hilt, “Greening the Internet with Content-Centric Networking”, E-Energy ’10, **(2010)** April 13-15; University of Passau, Germany.

[12] K. Guan, G. Atkinson and D. C. Kilper, “On the Energy Efficiency of Content Delivery Architecture”, Communications Workshops (ICC), 2011 IEEE International Conference, **(2011)** June 5-9; Kyoto, Japan.

Authors

Geunhyung Lee

He is a M.S candidate in the College of Information and Communication, Korea University, Seoul, South Korea. He received the B.S. degree in computer science from Sangmyung University, in 2011. His research interests are green network, and embedded software engineering.

Longzhe Han

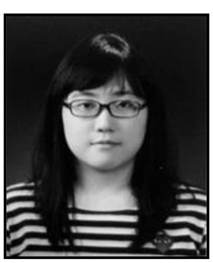
He is a Ph.D. candidate in the Dept. of Computer Science at Korea University, Seoul, South Korea. He received the M.S. degree in computer software from Myongji University, in 2006. His research interests are multimedia communications, wireless networks and embedded software engineering.

Yunhui Park

She is a M.S candidate with the College of Information and Communication, Korea University. Her research interests include network routing, ubiquitous computing. She received her B.S. degree in multimedia communication from Gachon University in 2010.

Jung-Been Lee

He is a Ph.D. Student in the Department of Computer Science at Korea University in Seoul Korea. He received the M.S. degree in Computer Science from Korea University, in 2011. His main research area is data mining for finding of relationships between static analysis of source code and behavior data of developer. Other research interests are Lawful interception handover for 3G IP multimedia subsystems (IMS) and software architecture evaluation.



Juwon Kim

She is a M.S candidate in the College of Information and Communication, Korea University, Seoul, South Korea. She received the B.S. degree in computer and information science from Korea University, in 2011. Her research interests are ubiquitous, and embedded system.

Hoh Peter In (*Corresponding Author)

He is an Associate Professor in the Dept. of Computer Science at Korea University at Seoul, South Korea. His primary research interests are embedded software engineering, social media platform and service, and software security management. He earned the most influential paper award for 10 years in ICRE 2006. He published over 100 research papers. He was an Assistant Professor at Texas A&M University. He received his Ph.D. in Computer Science from University of Southern California (USC).