Emergency Network을 위한
목적지 기반 라우팅과 경로 기반 라우팅*

조은상[O], 한진영, 고동일, 장덕현, 권태경, 최양희
서울대학교 컴퓨터공학부
{escho[O], jyhan, diko, dhchang}@mmlab.snu.ac.kr, {tkkwon, yhchoi}@snu.ac.kr

Destination Based Routing and Path Based Routing for the Challenged Emergency Network

Eunsang Cho[O], Jinyoung Han, Dong-il "Diko" Ko, Dukhyun Chang, Taekyoung Kwon, Yanghee Choi
School of Computer Science and Engineering, Seoul National University

요 약

지진이나 토네이도 등의 위급상황에서는 infrastructure의 파괴로 인해 통신시스템이 제 역할을 하지 못한다. 그러나 통신은 인명구조나 복구에 있어서 매우 중요한 역할을 담당해야 한다. 이러한 emergency network 환경에서는 delay-tolerant network (DTN)이 중요한 역할을 할 수 있는데, emergency network의 제한된 통신 환경이 DTN의 특성, 즉 infrastructure의 부재, 통신의 우연적 경향 등과 유사하기 때문이다. DTN과 유사하게 Emergency network에서는 전송 신뢰도 향상, 지연시간 감소, 통신 오버헤드 감소 등이 중요한 요소가 된다. 본 논문에서는 emergency network을 위한 두 가지 라우팅 프로토콜, Destination Based Routing (DBR)과 Path Based Routing (PBR)을 제안한다. Emergency 환경에서는 network source들이 보통 병원이나 구조본부 등의 제한된 수의 destination을 사용한다. 또 패킷을 전달하는 노드들도 DakNet의 mobile access points (MAPs)처럼 특정 경로들을 따라 매우 주기적으로 움직인다. 라우팅 성능을 향상시키기 위해 DBR과 PBR은 이러한 emergency network 환경의 특징을 최대한 활용하였다. 그리고 시뮬레이션을 통해 제안한 프로토콜의 성능을 입증하였다.

Abstract

In the emergency situation such as earthquakes, tornadoes, etc, communication systems are usually out of order due to the wide devastation of the infrastructure. However, the normal communication should do the very important role in rescue operations and restorations. In the emergency network environments, delay-tolerant network (DTN) can play an important role because the limitations of communication environment in the emergency network are similar to the characteristics of DTN: lack of infrastructures and the opportunistic communication manner. It means that enhancing transfer reliability, reducing delay, and reducing communication overhead – these factors are important in the emergency network, as they are in DTN. In this paper, we propose novel routing protocols for emergency networks: Destination Based Routing (DBR) and Path Based Routing (PBR). In emergency environment, network sources usually have a limited number of destinations: such as hospitals, rescue headquarters and so on. The relaying nodes, which transfer network packets, move some specific paths very routinely as mobile access points (MAPs) of DakNet do. To enhance the routing capabilities, DBR and PBR leverage those properties of the emergency network environments. We evaluate the performance of proposed protocols through simulations.

* 본 연구는 지식경제부 및 정보통신연구진흥원의 IT신성장동력핵심기술개발사업의 일환으로 수행하였음 [2007-F-038-02, 미래 인터넷 핵심기술 연구]. 이 연구를 위해 연구장비를 지원하고 공간을 제공한 서울대학교 컴퓨터연구소에 감사 드립니다.

This work was supported by the IT R&D program of MKE/IITA [2007-F-038-02, Fundamental Technologies for the Future Internet]. The ICT at Seoul National University provides research facilities for this study.

1. Introduction

Recently, disasters are everywhere: earthquakes in China and Japan, tornadoes, hurricanes, volcanoes and so on. Under the situations of emergency, communication systems are usually out of order due to the wide devastation of the infrastructure. However, the normal communication should do the very important role in rescue operations and restorations.

In the emergency situations, the challenged network or the delay-tolerant network (DTN) can play an important role because the communication environment has a lot of limitations; the occasional communication opportunity is very limited, connections are established very opportunistically and it usually accompanies long end to end delay.

There are many examples of applications over DTN environment, usually in the place of the network environment is very challenging. ZebraNet [1] is a project at Princeton University which monitors wildlife animals. ZebraNet is planned to be deployed in the vast savanna area of Kenya. Zebras in the deployment area wear special collars – which is the name ZebraNet come from. It focuses on tracking wild species to deeply investigate their behavior and understand the interactions and influences on each other, as well as their reaction to ecosystem changes [2].

DakNet [3] is another interesting project. DakNet is a project that is trying to provide Internet connectivity rural and developing areas in India. According to the DakNet project, kiosks are built up in villages and equipped with digital storage and short-range wireless communications. Periodically, mobile access points (MAPs) mounted on buses, motorcycles, or even bicycles pass by the village kiosks and exchange data with them wirelessly [2].

We have noticed that the characteristics - lack of infrastructures and the opportunistic communication manner - of those examples of DTN are very similar to those of the emergency network environment. It means that enhancing transfer reliability, reducing delay, and reducing communication overhead – these factors are important in the emergency network, as they are in DTN.

In this paper, we propose novel routing protocols for emergency networks: Destination Based Routing (DBR) and Path Based Routing (PBR). In emergency environment, network sources usually have a limited number of destinations: such as hospitals, rescue headquarters and so on. The relaying nodes, which transfer network packets, move like MAPs of DakNet, thus they move some specific paths very routinely. To enhance the routing capabilities, DBR and PBR leverage those properties of the emergency network environments.

2. Background

2.1 Epidemic Routing

In this paper, we choose two routing mechanism of DTN as our target reference: the Epidemic routing mechanism and Spray and Wait mechanism. Epidemic routing mechanism [4] is introduced by A. Vahdat and D. Becker in 2000. It is very simple and brute-force mechanism. In epidemic routing, messages diffuse in the network similarly to diseases or viruses by means of pair-wise contacts between individuals/nodes.

When a node has a message to deliver to the destination, it transfers the message to the other nodes with contacting the other nodes. A lot of copies of the original message are created and flooded in the network until it reaches the destination. Epidemic routing is very easy to achieve reliability; however, it is easy to see that there comes a lot of redundancy due to the infinite number of message copies.

2.2 Spray and Wait

In SIGCOMM 2005, T. Spyropoulos et al. proposed Spray and Wait mechanism (SnW) [5]. In SnW, the possibility of infinite number of message copies of epidemic routing is reduced to the moderate 'L' number of copies.

SnW is a two-phase routing mechanism: the spray phase and wait phase. In spray phase, for every message originating at a source node, L messages copies are initially spread to L distinct "relays" For every relay, the half of the L message copies (1/2 of L) are transferred to the other nodes. After the L copies reduce to the 1 copy, the wait phase starts. In wait phase, if the destination is not found in the spraying phase, each of the L nodes carrying a message copy performs direct transmission (i.e. will forward the message only to its destination). When it comes to the destination, the routing procedure is terminated.

3. Routing Protocols using Geographical Location Information

As we mentioned in chapter 2, the most popular algorithms which are proposed in DTN are Epidemic and SnW. These are kind of flooding-based message passing mechanism and they perform well in random situations. However, there need some more proper algorithms in Emergency Network that nodes move routinely with special

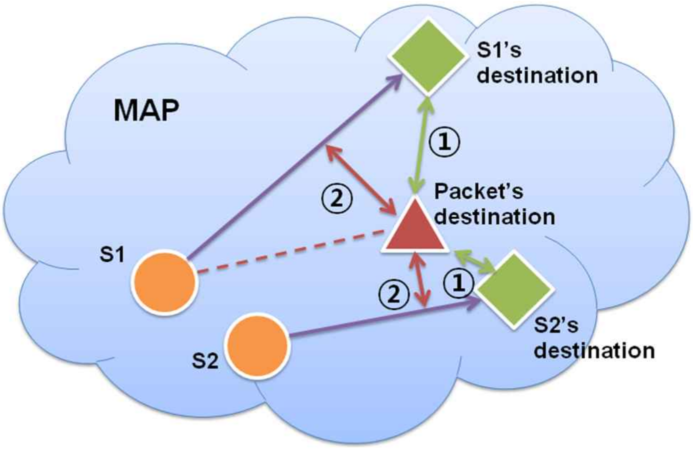

Figure 1: Destination Based Routing (DBR, ①) and Path Based Routing (PBR, ②)

purposes and data should be transferred to the specific spots such as police stations and hospitals. In this network, we can improve performances by using geographical location information from GPS or Navigation System.

In SnW algorithm, the node transfers L/2 copies of a message when it meets a new node. This algorithm can decrease the number of messages in overall network than other flooding-based algorithms. However, whenever the node finds a new node, it transfers copies unconditionally, and we think that it is not quite effective because it does not consider any node's geographical information. Therefore we would like to propose novel message distribution protocol using geographical information to improve performance.

3.1 Destination Based Routing (DBR)

In this chapter, we propose Destination Based Routing (DBR) which considers node's destination information when a node meets a new node. That is, when a node S1 meets S2, S1 gets S2's destination location information and calculates the distance between S2's and packet's destination, and then compares it with the distance between S1's and packet's destination. If a new node S2's distance is closer than S1's, S1 transfers L copies to S1, otherwise S1 keep those copies. Figure 1 shows the DBR briefly.

3.2 Path Based Routing (PBR)

In this chapter, we propose Path Based Routing (PBR) which considers node's path information when a node meets a new node. As we can see in Figure 1, when a node S1 meets S2, S1 gets S2's destination location information. And S1 draws the line from S2 to S2's destination and then calculates the distance between the lines and packet's destination. After then, S1 compares it with the distance of S1. If S2's distance is smaller than S1's, S1 transfers L copies to S1, otherwise S1 keep those copies. DBR considers only node's destination location, but PBR can also consider the behavior or trajectory of node.

Table 1: Simulation Settings

Map Size (m)		4500 * 3400
Simulation time		3000
Transmission range (m)		20
Number of nodes		110, 210, 310
Number of destination nodes		1(fixed point)
Number of sources		10
Node Speed (m/s)		5 ~ 25
Movement model	**Relay Node**	Circulation, Map-Route Movement
	Source Node	Random-Way point

4. Evaluation

4.1 Simulation Settings

We evaluate the performance of our proposals on The Opportunistic Network Environment simulator (The ONE) developed by Helsinki University of Technology, Finland. We compare three metrics Delivery Probability (or reliability), Average Latency and Overhead Ratio (the ratio of packets to be relayed other than delivered). Table 1 shows simulation settings of our experiment.

Our simulation scenario is as follows.

- Source Node: There are 10 nodes to send help message like SOS. They move randomly and generate messages and then try to distribute their help messages
- Relay Node: There are circulating nodes to get help messages from sources and relay nodes. These nodes are like police cars or fire trucks with special purposes. They circulate in routine path and collect SOS messages and then deliver it to the destination through several relay.
- Destination Node: There is one destination node which operates emergency situations such as a police station or a fire station. The location of this node is fixed.

4.2 Simulation Results

Following figures show the average results from 5 simulation runs in the emergency scenario. At first, we investigate the delivery probabilities of our protocols and references, shown in Figure 2. In the figure, DBR outperforms other protocols in 110 and 210 nodes, and PBR is almost the same with SnW except 210 nodes. DBR

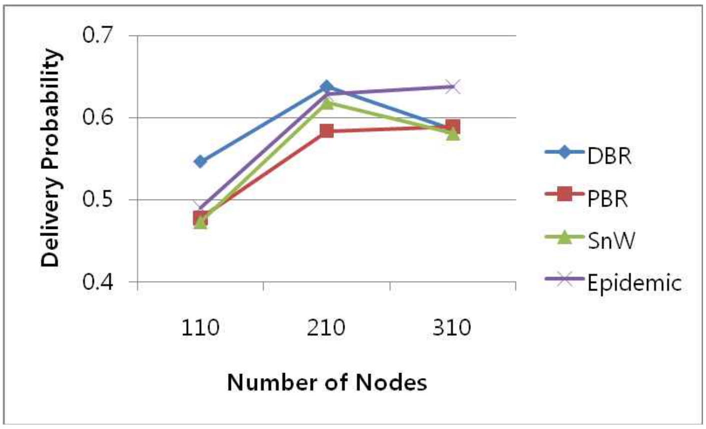

Figure 2: Delivery Probability

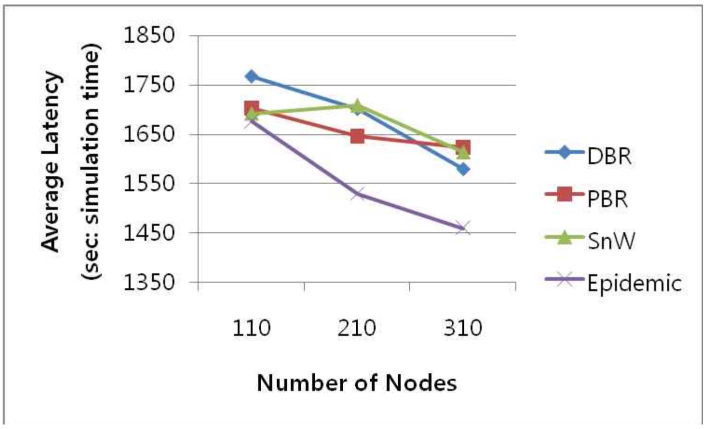

Figure 3: Average Latency

shows about 14% higher probability than SnW in 110 nodes and this performance gap is getting smaller as number of nodes grows, which implies that geographic information is more meaningful to decide next relay node as node density is sparser.

Epidemic routing shows extremely high delivery probability in 310 nodes and it is slightly better than SnW in other cases. Interestingly its delivery probability is lower than DBR's in sparse node density, although it is working as an indication of upper limit in flooding-based mechanisms. This also means that geographic information is more useful than basic flooding scheme in sparse node density.

Figure 3 shows the average latency of the delivered packets. In this figure, PBR has little bit better latency than SnW, but DBR does not. But these three show almost the same results. Therefore average latency of DBR and PBR is acceptable in comparison with SnW. Epidemic routing shows the best latency, but it is a tradeoff with overhead ratio, shown in Figure 4.

Finally, we have checked the overhead ratio, shown in Figure 4. In this figure, DBR shows the best result of all,

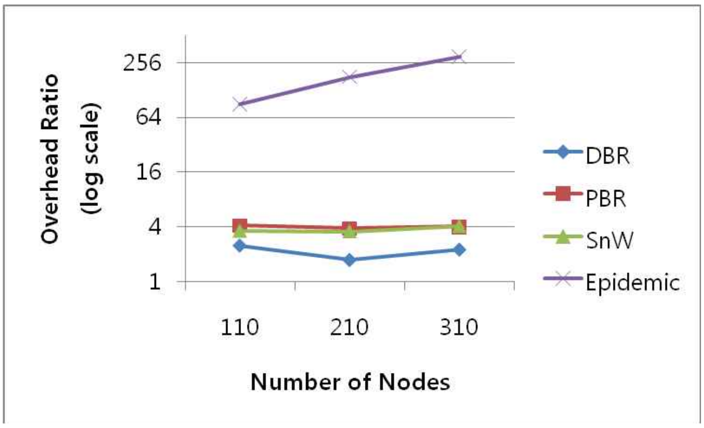

Figure 4: Overhead Ratio

and SnW follows. Actually PBR shows almost the same overhead ratio with SnW. Epidemic routing is the worst protocol in this point of view; its overhead ratio shows that the delivered packet travels all the nodes reachable and then finally delivers.

Even though Epidemic routing shows the best latency and relatively good delivery probability among four protocols, its overhead ratio - shown in Figure 4 - are very poor. Therefore average latency and delivery probability of DBR, PBR, and even SnW are acceptable in overall performance.

5. Conclusion

In this paper we have proposed two novel routing protocols for the emergency network. DBR and PBR use geographical information to achieve a reliable transfer in the emergency situation such as broken infrastructure. Simulation results show that in the emergency scenario, DBR and PBR show better performance than SnW or Epidemic routing. Furthermore DBR is the best protocol of all, in the overall performance and the delivery probability which implies high reliability. Based on simulation results, DBR takes advantage of delivery probability and overhead ratio, and PBR has relatively low latency. Thus it is a good direction of future works; mixing advantages of two protocols and making a hybrid protocol.

References

[1] P. Juang, H. Oki, Y. Wang, M. Martonosi, L. S. Peh and D. Rubenstein, "Energy-Efficient Computing for Wildlife Tracking: Design Trade-Offs and Early Experiences with ZebraNet," ACM SIGPLAN Notices, vol. 37, pp. 96–107, 2002.

[2] L. Pelusi, A. Passarella and M. Conti, "Opportunistic Networking: Data Forwarding in Disconnected Mobile

Ad Hoc Networks," IEEE Communications Magazine, November 2006.

[3] A. Pentland, R. Fletcher, and A. Hasson, "DakNet: Rethinking Connectivity in Developing Nations," IEEE Computer, vol. 37, no. 1, pp. 78–83, January 2004.

[4] A. Vahdat and D. Becker, "Epidemic routing for partially connected ad hoc networks," Tech. Rep. CS-2000-06, Department of Computer Science, Duke University, Durham, NC, USA, 2000.

[5] T. Spyropoulos, K. Psounis and C. S. Raghavendra, "Spray and Wait: An Efficient Routing Scheme for Intermitterntly Connected Mobile Networks," Proceedings of the 2005 ACM SIGCOMM workshop on Delay-tolerant networking, Philadelphia, Pennsylvania, USA: ACM, pp. 252-259, 2005.