Journal of Korean Institute of Intelligent Systems, Vol. 23, No. 6, December 2013, pp. 571-576
http://dx.doi.org/10.5391/JKIIS.2013.23.6.571

Pocket Witched Network 라우팅 프로토콜의 메시지 전송 및 에너지 소비 분석

Message Delivery and Energy Consumption Analysis on Pocket Switched Network Routing Protocols

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요 약

인터넷 기술의 발전과 사용범위 및 영역이 지속적으로 확장되고 있지만 아직도 네트워크 연결성을 제공할 수 없는 원격 지역과 상황들이 상당히 존재한다. Pocket Switched Network(PSN)은 모바일 송수신 장치를 휴대한 사람이 제공하는 이동성을 활용하여 인터넷을 사용할 수 없는 지역에서도 데이터 전송을 가능케 하는 네트워크로서 PSN에서는 노드의 이동성, 링크 고장, 배터리 방전 등의 문제점을 고려하여 데이터 전송을 위한 네트워크 연결성을 계속적으로 유지해 주는 것이 매우 중요하다. 본 논문에서는 현재까지 제안된 주요 PSN 라우팅 기법들을 살펴보고 이것들의 성능을 분석하기 위해 네트워크 노드 수를 증가시키면서 전송 확률, 오버헤드 비율, 평균 전송지연, 평균 잔여에너지양의 변화를 실험을 통해 비교한다. 또한, 실험 결과를 통해 데이터 전송을 최대화하면서 에너지 소비는 최소화하여 네트워크 수명을 연장할 수 있는 기법을 제시한다.

키워드 : Pocket 교환망, 성능분석, 지연허용네트워크, 에너지소비

Abstract

Despite the development of the Internet, both in terms of technology and coverage, there are still remote areas and scenarios where connectivity is very difficult to achieve. Pocket Switched Network is a network paradigm that takes the advantage of human mobility to disseminate data. Factors such as mobility of nodes, link failures, discharged batteries, are among the challenges that may compromise connectivity in these networks. This paper presents a performance analysis of existing routing schemes for PSN in terms of delivery probability, overhead ratio, average latency and average residual energy when the number of nodes is increased. We seek to identify a scheme that maximizes data delivery while minimizing communication overhead and thus extending the network lifetime.

Key Words : Pocket Switched Network, Performance Analysis, Delay Tolerant Network, Energy Consumption

1. Introduction

Pocket Switched Networks (PSNs) are networks that consist of mobile smartphones or handheld devices, exploiting human mobility to distribute data across users [1]. PSN is an emerging category under Delay Tolerant Network (DTN) or Challenged Networks. In such environments, disconnections are frequent making traditional design routing protocols based on end-to-end communication paradigm inapplicable. PSN works using the opportunistic encounters between people carrying mobile devices during their daily lives.

Several challenges such as mobility, link failures, energy and resource constraints (e.g. bandwidth buffer size) are identified as they can compromise the connectivity of nodes in the network. Once a node is disconnected, it is difficult to predict when it will be available again [2]. Since PSNs depend on the availability of its nodes to perform routing from source to a destina-

접수일자: 2013년 9월 1일
심사(수정)일자: 2013년 9월 7일
게재확정일자 : 2013년 11월 26일
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본 논문은 한국연구재단 연구자지원사업(2013054460)에서 지원하여 연구하였음.

tion node, it is necessary to maximize the availability of the nodes in order to increase routing success and message delivery rate [3].

A routing protocol design for wireless networks is often guided by two essential requirements: minimize energy cost and maximize network throughput [4]. As the search for neighbouring nodes is mainly responsible for the energy consumption of the nodes, new routing protocol design whose strategy is based only on the reduction of messages exchanged, may have little impact in terms of actual network performance [3]. Previous researches on routing protocols utilize multi-replica or flooding based transmission schemes in PSNs and DTN in general. But for a PSN whose resources are usually limited, too many duplicate messages will dramatically increase traffic overhead and overall delays and drain each mobile node's battery faster. Therefore, an efficient routing scheme for PSN that could maximize data delivery ratio while minimizing communication overhead is highly needed.

This paper evaluates the performance of several existing routing protocols used in PSN, where details are discussed in section 2. The simulation setup is presented in section 3. Section 4 shows the result of the simulation with the performance metrics such as Delivery Probability, Overhead Ratio, Average Latency and Nodes Average Residual Energy. Finally, section 5 presents the conclusion.

2. Pocket Switched Network

The goal of PSN is to utilize of a huge number of devices carried by humans and exploit their inherent mobility to find more and more communication opportunities. Forwarding is the key challenge in opportunistic networking, as the use of PSN is strongly correlated with the number of messages that reach their destination [5]. The following are the categories and various routing protocols used in message forwarding for PSN. We choose four routing protocols briefly discussed in section 2.2, due to their energy expenditure nature and is summarized in Table 1.

2.1 Routing Protocol Categories

Routing protocols in PSN are categorized as Encounter-Based and Prediction based [2].

A. Encounter-based

In encounter-based schemes, nodes forward messages randomly hop by hop with the expectation of eventual delivery, but with no guarantees. Generally, messages are exchanged only when two nodes meet at the same place, and multiple copies of the same message are flooded in the network to increase the probability of message delivery.

B. Prediction-based

In prediction-based schemes, routing protocols make relay selection by estimating metrics relative to successful delivery, such as delivery probability or expected delay based on a history of observations. Other network properties such as social relations, trust weight, community and centrality are also use in several routing protocol designs [2].

2.2 Routing Protocols

A. Epidemic Routing

It is a routing protocol that whenever two nodes encounter one another they will exchange all the messages they currently carry with each other. Wherein, at the end of the encounter both nodes will possess the same set of messages [6]. As this process continues, every node will be able to send information to every other node. The messages are basically flood-ed through the network much like the spread of a virus in epidemiology.

B. Spray and Wait

It is a routing protocol which provides an improvement to the Epidemic routing protocol by controlling the level of message flooding [7]. It has two phases: the Spray phase and the Wait phase. In Spray phase, every message originating at the source node is passed to distinct relays in the network. While, in the Wait phase, if the destination was not found in the Spray phase, each relay node having a copy of the message performs the direct transmission of the message to the destination.

C. ProPHET(Probabilistic Routing Protocol using History of Encounters and Transitivity)

It is a routing protocol where each node calculates a probabilistic metric called Delivery Predictability for each known destination before sending a message [8]. This metric indicates the probability of successful delivery of a message from the source node to the destination node. The Delivery Predictability is calculated on the basis of history of encounters between the nodes or the history of their visits to certain locations.

D. MaxProp

It is a routing protocol that does not assume any prior knowledge about the network connectivity. It uses the local information, mobility of nodes to select the next best-hop for message delivery. It forwards the message to any node in the network having maximum probability of delivery of the message towards the destination. It is based on prioritizing the schedule of the packets sent to other nodes, and the schedule of the packets to be deleted from the buffer.

Table 1. Characteristics of PSN routing categories

Characteristic	Encounter based	Prediction based
Forwarding Method	Flooding /Reactive	Reactive
Type of Nodes	Homogeneous	Homogeneous
Delay	Low	High
Message Replication	Every Node Encounter	Criteria based
Retain Encounter Information	No	Yes

3. Simulation Environment

3.1 The ONE Simulator

Opportunistic Network Environment (ONE) is used for the simulation. ONE is a Java based simulation environment that combines movement modelling, routing simulation, visualization and reporting in one program[9].

3.2 Simulation Settings

We have simulated with 3 groups of nodes; pedestrians, cyclists and people riding vehicles; all are assumed mobile in nature and carrying mobile devices with different moving speed and waiting time as shown in Table 2. We apply the shortest path map based movement model [9] where nodes move on a path defined in the form of maps, and then chooses the shortest path from the source to destination. For the simulation, Helsinki map (shown in Figure 1) and trace file in the ONE simulator are used. Table 3 and 4 present the simulation environment settings and energy settings, respectively.

Table 2. Mobility Settings

Parameter	Group 1	Group 2	Group 3
Movement Speed	2-10kmh	10-50kmh	30-80kmh
Wait Time	5-10min	3-5min	5-10min

Table 3. Simulation Environment Settings

Parameter	Value
Simulation Area	4500m x 3400m
Interface	Bluetooth
Interface Data Rate	2 Mbps
Radio Range	10 m
Number of Groups	3
Message TTL	3 hours
Message Interval	25-35 sec
Simulation Time	12h (43200 sec)

Table 4. Energy Settings

Parameter	Value (units)
Initial Energy	4800
Scan Energy	0.1
Transmit Energy	0.2
Scan Response Energy	0.1
Idle Energy	0.01

3.3 Metrics

The following subsection presents the metrics used in the performance evaluation of routing protocols.

A. Delivery Probability

This routing metric is calculated as the number of delivered messages divided by the number of unique messages created.

B. Overhead Ratio

Overhead ratio is computed as the difference of relayed and delivered messages divided by the number of delivered messages.

C. Average Latency

Average latency is a fundamental performance metric representing the average delivery time from source node to destination.

D. Average Residual Energy

It represents the average remaining energy values of the nodes when the simulation ends.

Fig. 1. Node paths of Helsinki Map used in the simulation

4. Simulation Results

Increase in the number of nodes of the network affects the overall performance of various routing schemes. Figure 2 to figure 8 show the results of the simulation.

A. Delivered and Relayed Messages

Figure 2 shows that the number of messages created and delivered is higher in case of MaxProp and Spray and Wait. Increasing in network nodes positively affects the number of messages delivered. However, Figure 3 depicts that the number of messages relayed is lowest in case of Spray and Wait compared to the other 3 protocols. This implies that the delivered and relayed messages are proportional, thus making lower overhead as shown in Figure 5. Furthermore, protocols with high number of messages relayed and delivered may actually be applicable for emergency applications where message flooding is considered essential and practical.

B. Delivery Probability

Figure 4 shows that when the network has more nodes, the delivery probability for both Spray and Wait and MaxProp is increased. This suggests that successful delivery of messages is optimized in these two routing protocols as network size is scaled. However, Prophet and Epidemic show poor delivery probability resulting to approximately 20% chance of delivery probability when network nodes are increased in the network. This implies that the flooding nature of Epidemic does not guarantee high percentage of successful delivery but are costly in terms of energy consumption.

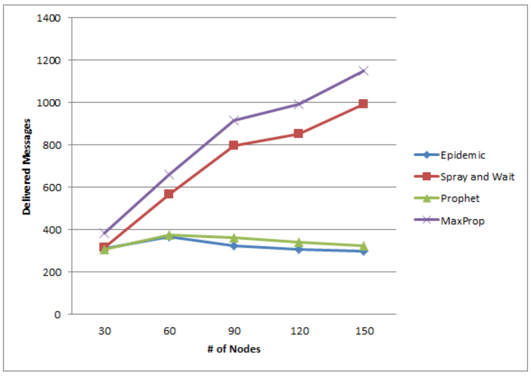

Fig. 2. Delivered Messages vs Number of Nodes

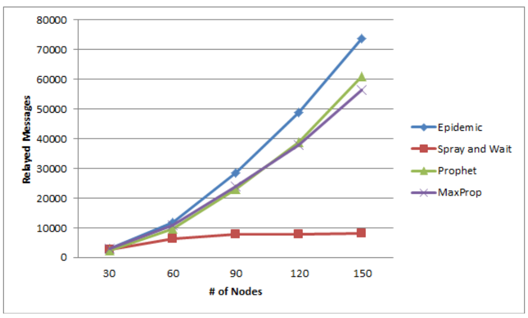

Fig. 3. Relayed Messages vs Number of Nodes

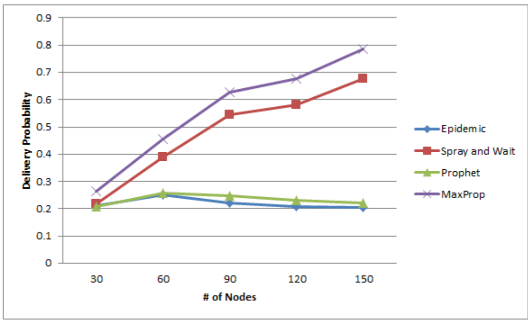

Fig. 4. Delivery Probability vs Number of Nodes

C. Overhead Ratio

Figure 5 shows that the increase in nodes in the network is directly proportional to the increase in overhead ratio of Epidemic and ProPHET. However MaxProp and Spray and Wait result in the lowest Overhead Ratio. The ratio of messages created and transmitted is greater in case of Spray and Wait, and it remains stable with the lower overhead compared to other protocols. This is due to the controlled flooding nature of Spray and Wait. The number of messages being replicated in the network is limited to a certain number (e.g. 6 copies in this simulation) thus balancing the message delivery and energy consumption. Another factor that contributes to the Overhead Ratio result of Spray and Wait is the Shortest Path Map-based Movement model which makes nodes visit almost all areas of the simulation map given the shortest path possible that consume less energy.

D. Average Latency

Average latency is in unit of second. In literature, high latency means longer time for the message to be delivered from source to destination. In Figure 6, a decrease in latency is observed in all routing protocols as the number of nodes is increased in the network. MaxProp has the highest average latency compared to other 3 protocols. Use of multi-copy based schemes as in Epidemic and Spray and Wait results in lower latency due to their flooding nature.

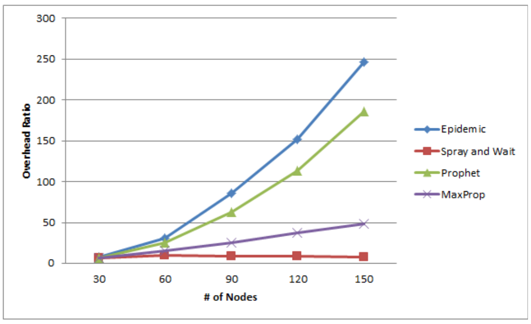

Fig. 5. Overhead Ratio vs Number of Nodes

E. Average Residual Energy

It is shown in Figure 7 that as the number of nodes increases, the average remaining energy of nodes decreases.

Increase in the number of nodes also makes the number of delivered messages increased, so that it results in more transmits and scans of nodes. Spray & Wait has the highest average remaining energy among all the protocols. This is because in Spray & Wait other nodes have to wait and deliver the message after the source node has not found the destination. Thus, a small number of scans and transmits with other nodes take place which results in low energy consumption and less number of dead nodes in the network as shown in Figure 8.

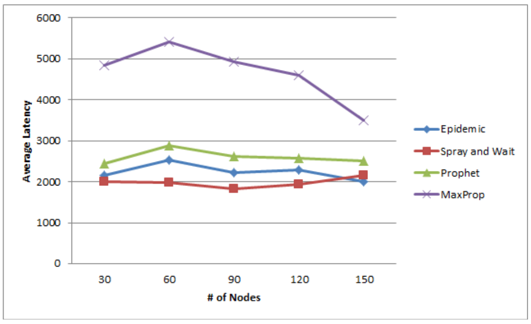

Fig. 6. Average latency vs Number of Nodes

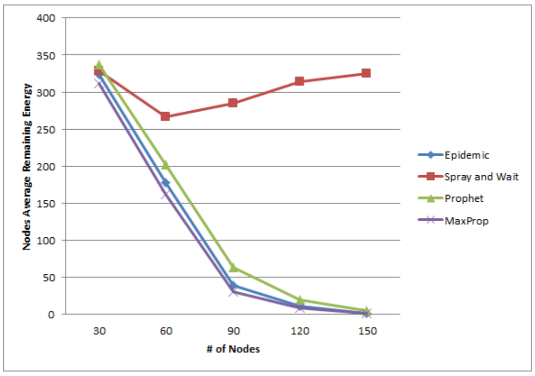

Fig. 7. Average Residual Energy vs Number of Nodes

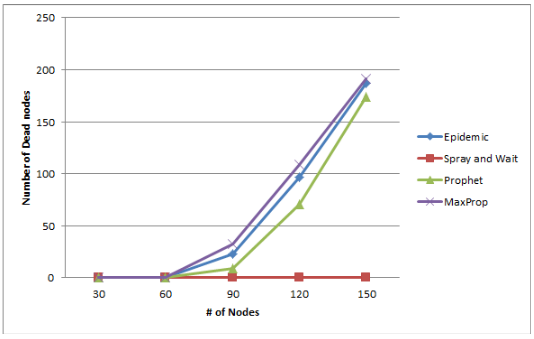

Fig. 8. Number of Dead Nodes vs Number of Nodes

5. Conclusion

Network scalability and energy consumption in PSN have less consideration in designing new routing protocols. In this paper we evaluated several PSN routing protocols in terms of message delivery and energy consumption performance. With the observation and analysis, we conclude that: (1) increase in the number of nodes takes a significant influence on the network settings of PSN regardless of the routing protocols being used, Spray and Wait has shown better results in most of the metrics used in this paper (2) Spray and Wait is deemed to illustrate low energy consumption compared to the other routing protocols. Thus most of network nodes are still available after completing the simulation. In the future, we seek to implement a routing scheme for PSN that addresses scalability, and resource constraints (battery, bandwidth and buffer size) incorporating with the simulation results.

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