

# CMP: A Context Information-based Routing Scheme with Energy-based Message Prioritization for Delay Tolerant Networks

Regin Cabacas and In-Ho Ra

Department of Information and Telecommunication Engineering, Kunsan National University, Kunsan, Korea



## Abstract

Communication infrastructure supports wide variety of mobile services such as photo and file sharing, location tracking, social network services and instant messaging. However, instances like power-loss and natural disasters disrupt these communication infrastructures unable to render support to these mobile services. Delay-tolerant networks (DTNs) offer a solution to these problems at hand. By utilizing mobility and opportunistic contacts among mobile devices, a plausible communication network can be establish and enable support to mobile applications. This paper presents an energy-efficient, reliable message delivery routing scheme with message prioritization rules for DTN. It uses the context information of nodes (mobile devices) such as the contact history (location and time of contact), speed/velocity, moving direction to determine the best forwarders among nodes in the network. The remaining energy of the nodes is also used to determine the message types a node can deliver successfully. The simulation results show that proposed approach outperforms Epidemic and Prophet routing schemes in terms of delivery ratio, overhead ratio, delivered messages per types and remaining energy.

**Keywords:** Context-information-based routing, Context-aware routing, Message prioritization, Delay tolerant networks

## 1. Introduction

Delay Tolerant Network (DTN) is an emerging area of networking that addresses challenges in disconnected, disrupted networks and commonly without end-to-end connection [1]. DTN provides communication infrastructure for environments with intermittent connectivity, long or variable delays, asymmetric data rates, high error rates and ambiguous mobility patterns [2]. Mobility of nodes is a valuable factor for routing in DTN [3, 4] and is an important feature that makes opportunistic contacts occurs. Mobility is innate among mobile device carriers (such as smartphone users, vehicles with access points) which can be utilized in DTN to assist message transmission.

With nodes' mobility and dynamic movement pattern, several context information can be extracted. Context information has been very useful for location-aware systems that have been implemented in various discipline like disaster response, recommender systems, mobile social networks and environmental monitoring and forecasting. According to Schilit et al. [5] context information may refer to an entity's (person, place, or object) location, identities, nearby people and objects, and changes to those entities. It is also viewed as any information

Received: Nov. 7, 2014  
Revised : Nov. 25, 2014  
Accepted: Dec. 2, 2014

Correspondence to: In-Ho Ra  
(ihra@kunsan.ac.kr)  
©The Korean Institute of Intelligent Systems

© This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/3.0/>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

that can be used to characterize the situation of an entity that is considered relevant to the interaction between a user and an application, including the application themselves. The availability of this information and its dynamic nature are the promising aspects why several applications have benefited from using it.

The main contribution of this paper is the context-information based routing algorithm that evaluates each message's probability of delivery if given to an intermediate node (IN) in contact with the source node (SN). The proposed routing approach involves estimating the nodes position and determining if the IN would encounter the message's destination node (DN). Most of the concepts of selecting the best forwarder for message delivery are adopted from the equations of a straight line involving the slope and y-intercept [6]. The concept of considering the differentiation of messages is commonly neglected in designing routing protocols where another contribution of this paper is the energy-based message prioritization rule that makes sure important messages are given the utmost attention for delivery.

The remainder of this paper is structured as follows: section 2 discusses the motivation and objectives. Section 3 explains in detail the proposed approach and section 4 presents the simulation settings and scenarios. The results of the simulation and discussion are depicted in section 5 and lastly, section 6 concludes this paper.

## 2. Motivation and Objectives

From the observation made on the works in [7, 8], over replication is both an advantage and a disadvantage in routing protocols for DTN. This routing strategy helps several protocols like Spray and Wait [9] at the cost of giving burden to the storage and energy capacity of the node. With this problem, the proposed routing scheme is made to control over-replication in a sense that it only chooses the best forwarder for messages that has higher possibility of contact with the destination. Thus, this results to less relayed messages without compromising success of delivery.

Localization schemes in wireless sensor network (WSN) using RSSI (received signal strength indicator) through anchors have also motivated this study to utilized context-information and geometric relationship of nodes for routing in DTN [10]. Localization scheme brings forth an oracle assessment of where the nodes are and can be exploited in extent of message transmission, especially in helping to choose the best forwarder [11]. When the geographic placement of the message destination is known, certain criteria like (link quality, distance, energy con-

sumption) can be used as metric to evaluate if nodes are capable of delivering the messages.

Energy-efficiency is one desirable characteristic routing protocols should possess and most of the time protocol designs fail to embody it. Moreover, most routing protocols in literature treat each message equally resulting to inadequacy to consider prioritization of messages, especially in low energy level situations [12]. However, some applications like military networks and disaster response systems need to consider differentiation of messages priority levels and recognize important messages that needs faster delivery.

One of the main objective of using context information is to ensure balance in the performance of the routing scheme particularly in delivery ratio, overhead ratio, latency or delay and message prioritization. The use of context information for routing and choosing the best node forwarder aims to avoid unnecessary message copies that causes bottleneck and message congestion within the nodes.

## 3. Proposed Approach

In this section, we present in detail the context information-based routing with energy-based message prioritization rule for Delay Tolerant Networks called CMP. CMP belongs to the context-based routing category that falls under the deterministic routing protocols for DTN. In particular, the routing scheme is partially deterministic as it estimates the position of the destination at the current contact period and at a particular point in time. One of the peculiar characteristic of CMP is its strict selection of the node forwarder for message delivery by evaluating if the intermediate node (IN) has higher possibility of meeting the destination node (DN) than the source node (SN). The SN and IN's trajectory and position is calculated and is compared that of the DN. The following subsections further elaborate this process.

### 3.1 Routing Components

The routing scheme implemented essential components, which includes the Contacts, Connection Message Tables, and energy-based message prioritization rule, and are described as follows.

#### 3.1.1 Contacts Table (CT)

During encounters, nodes exchange several valuable information for message delivery. This information includes the summary vectors (list of messages currently on nodes storage) [13]

Node Id	PosX	PosY	STime	ETime	VelX	VelY
---------	------	------	-------	-------	------	------

Figure 1. Node’s contacts table format.

and routing table. For the proposed approach, we implemented a Contacts Table (CT) to record the context information of nodes during contact. The CT format is illustrated in Figure 1.

### 3.1.2 Message Connection Table (MCT)

This table records the updated context information of the message destinations (DNs) currently in SN’s storage. It also records all IN who has been given shared responsibility of delivering the message to the destination, which includes the destination information (ID, context information), elapsed time (ET), and node Id of the IN selected as forwarder. For all the SN’s messages evaluated to be transmitted to an IN, this table also stores a temporary list of those messages. These messages will then be retrieved to undergone checking by the energy based-message prioritization rule.

### 3.1.3 Energy-based Message Prioritization

The energy-based message prioritization rule decides what type of messages can be transmitted and has higher chance of delivery to the destination. The deciding factor of the prioritization rule is the remaining energy of the IN in contact. This message prioritization rule is adopted from the work in [14], which prioritizes important packets in a body sensor network (BSN) for patient monitoring. The delivery capability of the IN is particularly dependent on its remaining energy and as node energy decreases; its communication capability also decreases. Therefore, when node reaches low energy level it must only consume its energy to the messages that are of great importance to the application.

This message prioritization rule is called out after every message has been evaluated to be transmitted to the IN. The message prioritization pseudocode is shown in Figure 2.

## 3.2 Routing Phases

The proposed routing scheme is divided into three (3) routing phases namely CT exchange and update, connection message table update, and forwarder node selection. The notations pre-

```

if IN energy is greater than or equal to 50%
    accept All messages
else if IN energy is less than 50% of initial energy and greater than 25%
    accept MT3 to MT5 messages
else if IN energy is less than 25% of initial energy and greater than 15%
    accept MT4 and MT5 messages
else if IN energy is less than 15% of initial energy
    only Accept MT5 messages
    
```

Figure 2. Message prioritization rule used for message transmission.

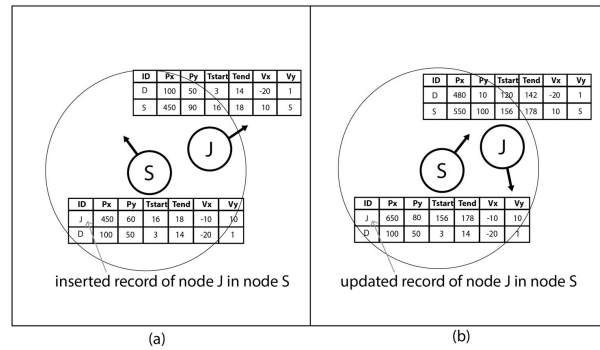


Figure 3. (a) Adding of a new record in the CT during T=16, nodes S and J first contact (b) updating of record in the CT during T=156, nodes S and J second contact.

sented in Table 1 are used in routing algorithm of proposed scheme. The routing phases are describe in detail in the following subsections.

### 3.2.1 Contacts Table Exchange and Update

The routing phase starts with the context information exchange after the nodes establish the connection. The Contacts Table (CT) described in previous section holds information about each node’s contact of other nodes in the network. CMP makes use of the CT to obtain information for every message destination that SN currently have in its storage.

When both nodes encounter each other for the first time, SN and IN puts a new record of the contact in the CT and an update of the contact record happens when there is already a previous record of the nodes meeting each other.

Figure 3 describes the CT adding and updating scenario when nodes S and J encounter each other for several times at different periods. This means that the CT of nodes are updated through encounters and technically contains the recent context information of nodes in the network.

Table 1. Notations and description for the routing algorithm

Symbol	Description
$E_T$	Elapsed time from the last encounter
$C_T$	Current time at node encounter
$LC_T$	Last contact time of DN
$N_T$	Needed time to reach the intersection point
$D_{VelX}$	x-axis velocity of DN
$D_{VelY}$	y-axis velocity of DN
$D_{PosX}$	Previous x-axis position of DN
$D_{PosY}$	Previous y-axis position of DN
$DE_{PosX}$	Estimated x-axis position of DN at current time
$DE_{PosY}$	Estimated y-axis position of DN at current time
$D_{Slope}$	Calculated slope of DN
$DY_{Intercept}$	Calculated y-intercept of DN
$DE_{IntPosX}$	DN's estimated x-axis intersection point with IN/SN
$DE_{IntPosY}$	DN's estimated y-axis intersection point with IN/SN
$N_{PosX}$	IN/SN current x-axis position
$N_{PosY}$	IN/SN current y-axis position
$N_{VelX}$	x-axis velocity of IN/SN
$N_{VelY}$	y-axis velocity of IN/SN
$NE_{PosX}$	Estimated x-axis position of DN
$NE_{PosY}$	Estimated y-axis position of DN
$N_{Slope}$	Calculated slope of IN/SN
$NY_{Intercept}$	Calculated y-intercept of IN/SN
$NI_{PosX}$	SN/IN's estimated x-axis intersection point with DN
$NI_{PosY}$	SN/IN's estimated y-axis intersection point with DN
$D_{Final}$	Distance between IN/SN and DN after reaching the intersection point

### 3.2.2 Connection Message Table Update

After the context information exchanged, the routing scheme performs a connection message update for every message destination in the SN's storage. This phase retrieves the recent context information of the message destinations from the IN's Contacts Table. Figure 4 shows the encounter scenario of nodes S, I and J and the updating of context information of node D.

$$E_T = C_T - LC_T \quad (1)$$

### 3.2.3 Forwarder Node Selection

The forwarder node selection is the very core aspect of CMP. This is where a node is determine if it will be a reliable forwarder to deliver the message to the destination. From the

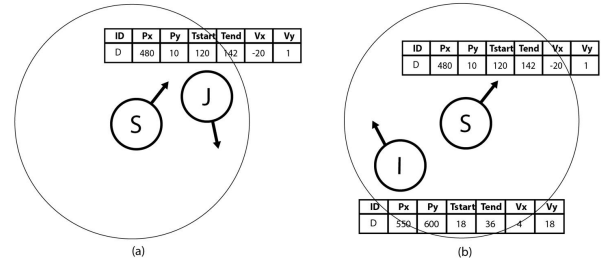


Figure 4. Updating of Connection Message Table in SN (node S).

updated connection message table, the routing scheme performs a comparison of the distance of the SN and IN to the DN based on their moving direction, velocity and current position. The concepts applied here are adopted from the equations of a straight line [6]. In general, a straight line is the shortest path from one point to another, thus, it is reasonable to assume that nodes under general conditions will follow a straight path trajectory. This routing phase is subdivided into series of steps:

#### 1) DN Position Estimation

The next step after getting the recent context information of every message destination in SN is the calculation of the estimated position of DN at current contact time. This method is taken from the concept of determining the velocity of a moving object,  $v = \Delta d / \Delta t$ , where  $v$  is the velocity (speed with direction) of the object,  $d$  is the distance and  $t$  is the time. Eq. (2) shows how to calculate DN's estimated position.

$$\begin{aligned} DE_{PosX} &= (D_{VelX} \times E_T) + D_{PosX} \\ DE_{PosY} &= (D_{VelY} \times E_T) + D_{PosY} \end{aligned} \quad (2)$$

#### 2) Determine the Trajectory of the DN

To determine the trajectory of the destination, we should define the equation of the line representing its trajectory using the slope-intercept form ( $y=mx+b$ ), where  $m$  is the slope and  $b$  is the y-intercept. To solve for the slope, we use the the change of the value of the y coordinates over the change of value in x coordinates ( $m = \Delta y / \Delta x$ ), and since x and y position of the node is available, the y-intercept should be calculated as  $b=y-mx$ . The estimated position of the DN calculated from the previous step is the first coordinate and the second coordinate is the DN's last known position that is further used to determine the slope and y-intercept. Eq. (3) shows the formula to calculate

the slope and y-intercept of the DN.

$$D_{Slope} = \frac{DE_{PosY} - D_{PosY}}{DE_{PosX} - D_{PosX}} \tag{3}$$

$$D_{YIntercept} = D_{PosY} - (D_{Slope} \times D_{PosX})$$

**3) Determine the Trajectory of the IN/SN**

In order to determine if the IN will move towards the DN’s position, its trajectory is also determine using the same set of equations in determining the DN’s estimated position. Eqs. (4) and (5) show the calculation for the trajectory of the IN/SN. In this case, unlike the DN’s position that has been determined using the elapsed time (ET), we utilized a time interval of four to estimate its position at a particular time. The time interval has little effect on the trajectory of nodes since the primary factor that dictates it is its velocity.

$$NE_{PosX} = (N_{VelX} \times 4) + N_{PosX} \tag{4}$$

$$NE_{PosY} = (N_{VelY} \times 4) + N_{PosY}$$

$$N_{Slope} = \frac{NE_{PosY} - N_{PosY}}{NE_{PosX} - N_{PosX}} \tag{5}$$

$$N_{YIntercept} = N_{PosY} - (N_{Slope} \times N_{PosX})$$

**4) Calculate for the Intersection point of the IN/SN and the DN**

When the trajectories of the nodes are determine, the routing scheme identifies the possible intersection point of IN/SN with the DN. To calculate for the intersection point, the calculated y-intercepts and the slopes in the previous steps are used as shown in Eq. (6). The primary goal of this step is to determine at what specific location point the nodes will intersect each other within a certain radius of transmission range.

$$NI_{PosX} = \frac{N_{YIntercept} - D_{YIntercept}}{D_{Slope} - N_{Slope}} \tag{6}$$

$$NI_{PosY} = (D_{Slope} \times NI_{PosX}) + D_{YIntercept}$$

**5) Compute for the needed time for IN/SN to reach the Intersection Point and Estimate the DN’s position by the time the IN to reach the Intersection point**

This step ensures that the selected IN will have the shortest time to reach the estimated intersection point. This step will also verify if the IN will deliver the message at the best possible time. Since the velocity ( $v = \Delta d / \Delta t$ ) of the IN/SN is available, the time interval  $t$  or the needed time for an object to reach a specific point can be determine. Using the calculated intersection point of the nodes (IN/SN and DN) in the previous step the calculated

needed time for the node to reach it is shown in Eq. (7) below.

$$N_T = (NI_{PosX} - N_{PosX}) \div N_{VelX} \tag{7}$$

The calculated position of the destination on the first routing phase denotes its current location at the time of contact of the SN and IN. In contrast, this particular step determines the estimated position of the destination when the IN reaches the calculated intersection point Eq. (8) shows how to solve this. Furthermore, this step checks if both the DN and IN will be inside each other’s transmission range to be able to transmit messages.

$$DEInt_{PosX} = (D_{VelX} \times N_T) + D_{PosX} \tag{8}$$

$$DEInt_{PosY} = (D_{VelY} \times N_T) + D_{PosY}$$

**6) Calculate the distance between IN and DN at the time IN reach the intersection point**

Lastly, and the most important step that will determine if a message will be given to the IN from the SN is to determine the distance between the DN and IN/SN using the calculated intersection points from step 3 and 6. In Eq. (9), using the Pythagorean Theorem, the distance between the IN/SN and the DN when it reached the intersection point is determine.

$$D_{Final} = \sqrt{\frac{(NI_{PosX} - NI_{PosY})^2 + (DEInt_{PosX} - DEInt_{PosY})^2}{}} \tag{9}$$

The final distance ( $D_{Final}$ ) calculated for both IN and SN is compared, wherein, if the calculated distance of the IN to the DN is lesser than the SN, the message will be added to the SN’s queue to be sent to the IN. This assumption simply states the SN’s which evaluate other node it contacts with, are either the original source of message or an IN which had been given shared responsibility of delivering message to the destination. In addition, this means that while the IN is on its way to the destination and meet other nodes, it will evaluate other node as suitable forwarders.

The final distance ( $D_{Final}$ ), node ID of IN and the elapsed time (ET) are recorded in the message connections table as the best connection for each message. In DTN, since nodes store messages with different destination in their buffer for a certain period, our proposed scheme exhibit the restriction of sending messages to the IN when it has low possibility of meeting the destination compared with the SN. The routing scheme also suggests that only few messages are given to an IN. In particular, the messages that are only evaluated are those whose destination

might have the possibility of meeting the IN.

When all messages have been evaluated and added on the SN's queue, the energy based prioritization rule will check all these messages and allow only the message types according to message prioritization rules.

## 4. Simulation Settings

### 4.1 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 [15]. We utilized the Epidemic [16] and Prophet [17] routing schemes available in ONE for comparison.

### 4.2 Simulation Settings and Scenarios

The following simulation settings and scenarios are used to evaluate the performance of CMP, Epidemic and Prophet.

#### 4.2.1 Mobile Urban Setting

This simulation scenario involves mobile carriers in an urban area. We used the Helsinki area to emulate a daily routine of moving people, cars and trams. Vehicles (cars and trams) have map route movement that can be set using mapRoute-File in ONE. The energy settings are listed in Table 2 and the simulation settings is depicted in Table 3, respectively.

#### 4.2.2 Random Initial Energy

This simulation scenario involves nodes with random initial energy for the start of the simulation. The initial energy of the nodes are set to be in the range of 3600mAh (75% from the initial energy) to a full 4800mAh battery level. This scenario meant to replicate a real world scenario where mobile devices are not of the same energy levels when using a particular mobile service supported by DTN. The number of messages created on this scenario is set to 250.

### 4.3 Performance Metrics

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

**Delivery Ratio.** Delivery ratio is defined as the ratio of number of messages received by destination nodes to the number of messages created.

Table 2. Energy settings for the simulation

Parameter	Value
Initial Energy	4800 mAh
Scan Energy	0.1
Transmit Energy	0.1
Scan Response Energy	0.1
Idle Energy	0.01

Table 3. Environment settings for simulation

Parameter	Value
Simulation time	43200 sec/ 12 hours
Simulation area	4500 x 3400 m
Total number of nodes	126
Number of groups	6
Buffer size	5MB
Number of messages	1225
Message size	500KB–1MB
Movement model	Shortest Path Map-based Movement

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

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

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

**Delivered Messages per Message Types.** This describes the number of messages delivered for each message types. This metric will also verify if messages with higher degree of importance has more successful deliveries than those that are not.

## 5. Results and Discussion

### 5.1 Mobile Urban Setting

The mobile urban setting is comprised of heterogeneous DTN nodes (pedestrians, cars, trams) with different speed and buffer spaces have yielded results in favor of CMP. Figure 5 to 9 show the results for the performance of the first simulation scenario. The success of delivery for CMP is about 20% higher compared to the Epidemic and Prophet as shown in Figure 5.

We observed that the speed variation and the map-based movement have effect on these results. A high difference in terms of overhead ratio is seen in Figure 6. The number of



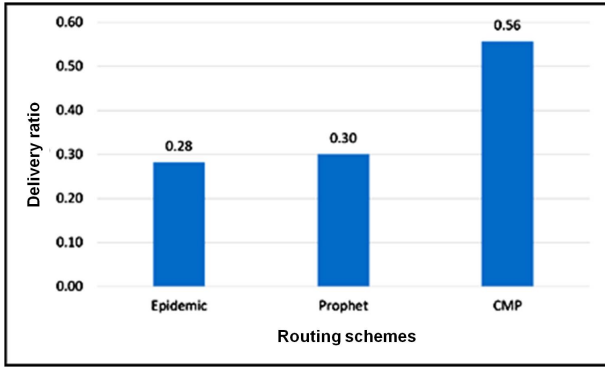


Figure 5. Delivery ratio of routing schemes for mobile urban scenario.

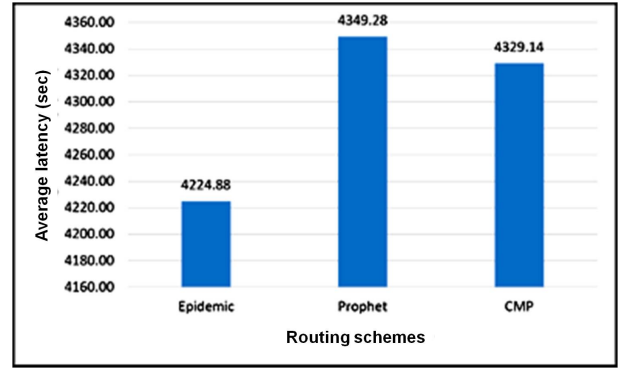


Figure 7. Average latency of routing schemes for mobile urban scenario.

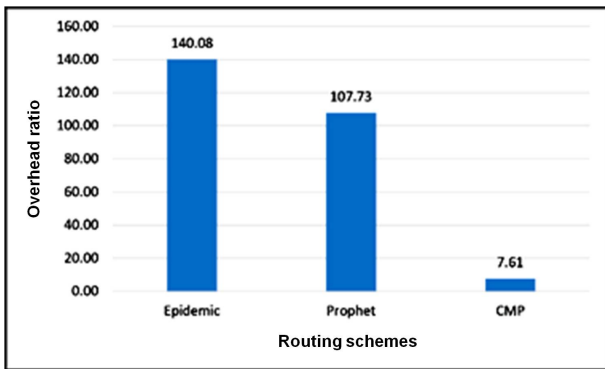


Figure 6. Overhead ratio of routing schemes for mobile urban scenario.

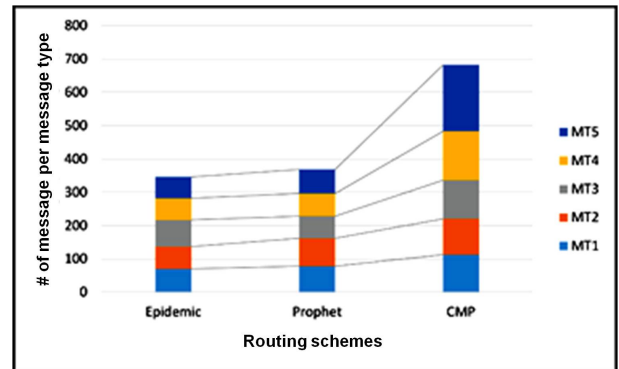


Figure 8. Delivered messages per type of routing schemes for mobile urban scenario.

relayed messages of CMP is minimal as the routing algorithm finely selects the best forwarder for each message. However, a small difference is seen for the average delay of CMP compare to Prophet in Figure 7. This figure also shows that with the different speed of nodes a faster delivery of messages can be achieved.

For this scenario, all routing protocols have a good mix of message types delivered to the destination but CMP clearly prioritizes message types MT4 and MT5 as it energy becomes low. We observed a fairness of delivery for all message types during high energy level even if the messages are queued based on their message type and size as shown in Figure 8. Figure 9 shows the average remaining energy of nodes at the end of the simulation. The remaining energy of nodes using CMP is higher compared to the other two (2) routing schemes as shown in Figure 9.

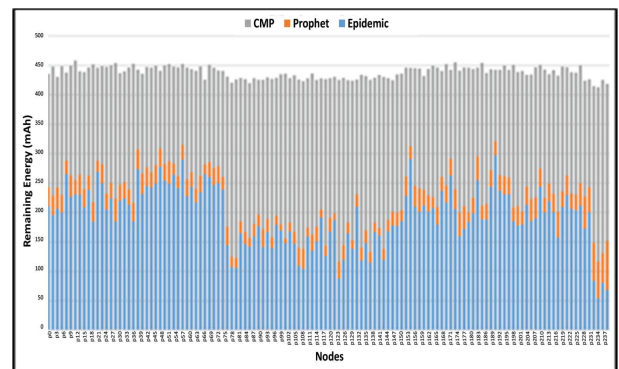


Figure 9. Remaining energy of nodes for mobile urban scenario.

### 5.2 Random Initial Energy

This particular scenario emulates what might be the situation of a publish-subscribe mobile application platform at the start of the day. Users have different battery levels, which uses the application service. From the results of the simulation

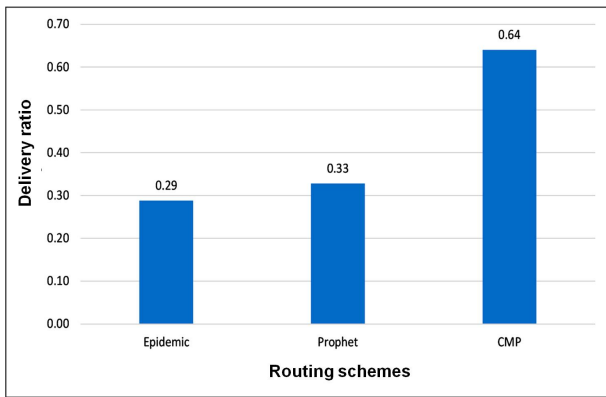


Figure 10. Delivery ratio of routing schemes for random initial energy.

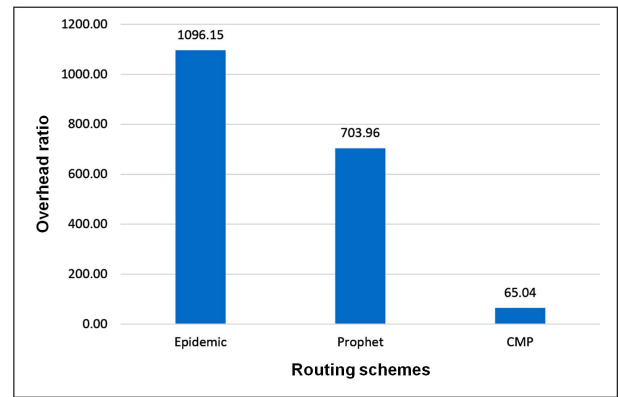


Figure 12. Average latency of routing schemes for random initial energy.

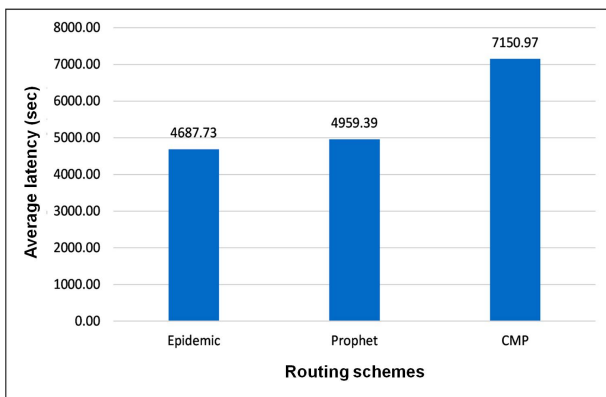


Figure 11. Overhead ratio of routing schemes for random initial energy.

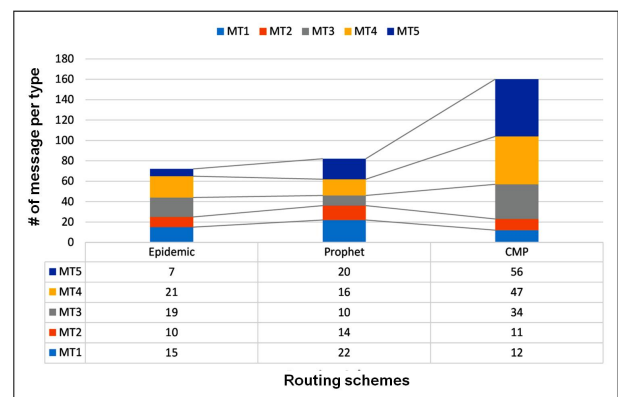


Figure 13. Delivered messages per type of routing schemes for random initial energy.

shown in Figures 10 to 14, CMP still outperforms Epidemic and Prophet in terms of message delivery and energy-efficiency. With all other simulation scenarios, the delivery ratio in Figure 10 reached 60% as the number of created messages is set to 250.

In Figure 12, we observed that the average latency was high compare to the previous scenarios, which is a direct trade-off of the achieved low overhead ratio in Figure 11 and result of the unacceptance of other messages for delivery because of low energy. The number of nodes chosen as the forwarder of messages becomes lesser, resulting to fewer message transmission or relay.

The result in shown in Figure 13 clearly shows the advantage of CMP in transmitting MT3 to MT5 types of messages. Due to the random starting energy level of nodes, a higher number of important messages are already prioritized as soon as node's energy level reaches the 50% and 25%. This also results to

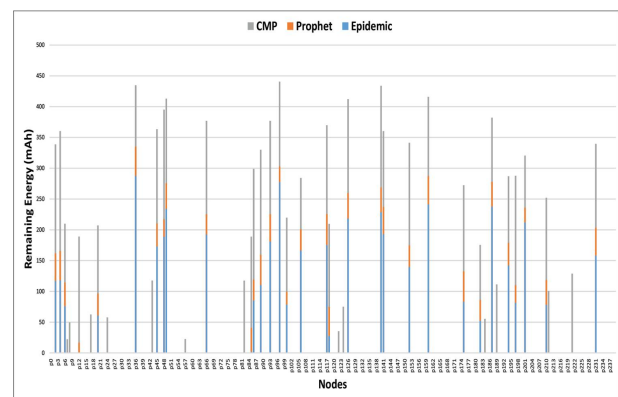


Figure 14. Remaining energy of nodes for random initial energy.

more number of dead nodes at the end of the simulation as depicted in Figure 14.



## 6. Conclusions

In this paper, we presented an energy-efficient context-information based-routing scheme with energy-based message prioritization for Delay Tolerant Networks. The scheme is comprised of several components to perform effective routing of messages to reach destination. It involves making use of other nodes as anchor nodes that holds contact record of the message destinations. Estimation of the destination node position and calculation of the possibility of the intermediate node (IN) to make contact is mostly done using the formulas from equations of a line. An energy-based message transmission rule was also implemented to efficiently use node's energy in accepting messages (prioritizing important ones) during low energy level.

The performance of the proposed approach (CMP) was compared with two (2) existing routing protocols Epidemic and Prophet by extending the ONE simulator. We performed two (2) different simulation scenarios in order to investigate in detail the performance of the proposed approach. The first scenario includes heterogeneous setting of mobile devices in an urban environment; the second scenario involves random starting energy levels that proved the energy efficiency and the effectiveness of the message prioritization rule. Most of the results yield better performance in all aspects (especially delivery ratio) for the proposed approach. However, the proposed scheme made certain trade-offs like slightly higher latency and buffer time occupancy in exchange for a low overhead and high number of important messages delivered. These trade-offs seems inevitable but are observed well-balanced compare to the performance of other routing schemes.

To further validate the effectiveness of the proposed approach, a more intensive simulation should be done with consideration of the contact time and contact frequency and changing speed of the nodes. A comparison with an existing context-information based routing scheme similar to the proposed approach would also give insights on its insufficiencies and limitations. Lastly, other context information should be investigated to improve the routing performance of the proposed approach.

## References

- [1] Vasilikos, A., Zhang, Y., Spyropoulos, T., "Delay Tolerant Networks: Protocols and Applications," CRC Press, 2011.
- [2] Al-Fagih, A., Hassanein, H., "Routing Schemes for Delay-Tolerant Networks - An Applications Perspective," *Technical Report*, Telecommunications Research Lab (TRL), School of Computing, Queen's University, Canada, 2012.
- [3] Tumar, I., Sehgal, A., Schönwälder, J., "Impact of Mobility Patterns on the Performance of a Disruption Tolerant Network with Multi-radio Energy Conservation," *IEEE International Conference on Advanced Information Networking and Applications (AINA)*, pp. 69-76, 2011.
- [4] Mayer, C., "Hybrid Routing in Delay Tolerant Networks," KIT Scientific Publishing, 2011.
- [5] Schilit, B., Theimer, M., "Disseminating Active Map in Formation to Mobile Hosts," *IEEE Network*, vol. 8, no. 5, pp. 22-32, 1994
- [6] Bird, J., "Basic Engineering Mathematics," Routledge Publishing, 6th Edition, 2014.
- [7] Cabacas, R., Nakamura, H., Ra, I., "Performance Evaluation of Routing Protocols in Delay Tolerant Networks in terms of Energy Consumption," *International Journal of Software Engineering and Its Applications (IJSEIA)*, vol. 8. no. 2, pp. 1-10, 2014.
- [8] Cabacas, R., Ra, I., "Reducing Message Overhead using Community-based Message Transmission for Delay Tolerant Networks," in *Proceedings of International Conference on Convergence Content (ICCC2014)*, pp. 61-62, 2014.
- [9] Spyropoulos, T., Psounis, K., Raghavendra. C. S., "Spray and Wait: An efficient routing scheme for intermittently connected mobile networks," in *Proceedings of the 2005 ACM SIGCOMM Workshop on Delay-Tolerant Networking (WDTN'05)*, pp. 252-259, 2005.
- [10] Karl, H., Willig, A., "Protocols and Architectures for Wireless Sensor Networks," Wiley Publishing, 2005.
- [11] Li, W., Hu, Y., Fu, X., Lu, S., Chen, D., "Cooperative Positioning and Tracking in Disruption Tolerant Networks," *IEEE Transactions on Parallel and Distributed Systems*, no. 99, pp. 1-13, 2013.
- [12] Joe, I., Kim, S., "A Message Priority Routing Protocol for Delay Tolerant Networks (DTN) in Disaster Areas,"

*Future Generation Information Technology, Springer*, vol. 6485, pp. 727 – 737, 2010.

- [13] de Oliveira, E. C. R. , de Albuquerque, C. V. N, “NECTAR: A DTN Routing Protocol Based on Neighbourhood Contact History,” in *Proceedings of the 2009 ACM symposium on Applied Computing*, pp. 40-46, 2009.
- [14] Encarnacion, N., “Transmission Priority Decision Scheme Based on Remaining Energy for Body Sensor Networks,” Master’s Dissertation, Kunsan National University, 2013.
- [15] Keranen, A., Ott, J., Karkkainen, T., “The ONE Simulator for DTN Protocol Evaluation,” in *Proceedings of the 2nd International Conference on Simulation Tools and Techniques*, Article no. 55, 2009.
- [16] Vahdat, A., Becker, D., “Epidemic routing for partially connected ad hoc networks,” *Technical Report CS-200006*, Duke University, 2000
- [17] Lindgren, A., Doria, A., Schelen, O. “Probabilistic routing in intermittently connected networks,” in *The First International Workshop on Service Assurance with Partial and Intermittent Resources (SAPIR)*, 2004.



**Regin Cabacas** received the B.S. degree in Information Technology from West Visayas State University, Iloilo, Philippines, in 2010. He is currently working toward the Master’s degree with the Department of Information and Telecommunications Engineering, Kunsan National University, Kunsan, Korea. His research interests include energy efficient routing in delay tolerant networks, social network analysis, recommender systems, mobile opportunistic sensor networks and integration of sensor networks and social networks.



**In-Ho Ra** received the M.S. and Ph.D. degrees in computer engineering from Chung-Ang University, Seoul, Korea, in 1991 and 1995, respectively. He is currently a Professor with the Department of Information and Telecommunication Engineering, Kunsan National University, Kunsan, Korea. From 2007 to 2008, he was a Visiting Scholar with the University of South Tampa, Florida, USA. His research interests include mobile wireless communication networks, sensor networks, middleware design, cross-layer design, quality-of-service management integration of sensor networks and social networks.