International Journal of Future Generation Communication and Networking
Vol. 13, No. 4, (2020), pp. 3284–3303

Contact Prediction based Routing for Opportunistic Networks

Syed, M, Rabiya.[1], *Ramalakshmi,R.[2]

[1]*Department of Computer Science and Engineering, syedrabiya.m@klu.ac.in*

[2]*Department of Computer Science and Engineering, rama@klu.ac.in*

[1,2]*Kalasalingam Academy of Research and Education, Anand Nagar, Krishnankoil, INDIA.*

Abstract

As nodes experience intermittent connectivity, Opportunistic Mobile Social Networks (OMSN) forward messages via opportunistic contacts. Observed that considering social and contact expectation together would improve an accuracy of prediction, we propose a novel approach called Contact Prediction based Routing (CPR), a quota copy-based routing strategy, it utilizes contact and inter-contact duration to assess the delivery predictability. First, nodes are divided into several communities according to their social similarities. While contact occurs, nodes exchange multiple copies of a message based on their predicted community encounters. This distribution will happen until the remaining copies of the message become one. Then, unlike the traditional routing where each message is stamped with a single forwarder address, the proposed paper augments each message with multiple probable forwarders. The potential forwarders are prioritized based on the remaining-inter contact time between two nodes. Consequently, one of the most possible forwarders decides dynamically to act as a next relay while suppressing others using an acknowledgement scheme. Thus, a heap of retransmission is diminished. The proposed system is implemented in Opportunistic Network Environment (ONE) simulator and performance is analyzed in terms of delivery rate, delay, overhead. The simulation results show that the proposed system diminishes overhead by 85% and the composite metric is increased by 38% as compared to the other routing schemes.

Keywords: Routing in Opportunistic Mobile Social Network, Meeting duration, Inter-meeting duration, Remaining inter-meeting duration, quota-based routing, Potential Forwarders

1. Introduction

Mobile Social networks play an important role in establishing a communication or sharing information between intended ones through mobile Internet. However, in some challenged environments due to short radio coverage, intermittent connection, insufficient bandwidth or damaged infrastructure, the conventional routing which requires multi-hop connected path, is not efficient and sometimes not opt either. Such a kind of challenged environments created a need to develop a new routing paradigm to cope with the absence of connected path. Hence, the recent research concentrates on developing an opportunistic routing approach which benefits from the mobility and opportunistic contacts among the nodes. It is obvious that the mobile devices such as smart phone, laptop, tablet etc have become an essential part of our life style and they make us do things with ease. The enhancement of mobile devices and their incredible increase lead to develop a novel networking called Opportunistic Mobile Social Network (OMSN), a specialization of Mobile Ad Hoc Network. OMSN, which consists of mobile devices with wireless technology such as 802.11, WiFi, Bluetooth, etc, makes communication between two nodes possible even when there is no connected path between any pair of nodes at the time of message transmission, under the cooperation of opportunistic contacts (two nodes are in contact when they both comes within the direct transmission range of each other).

To confront with the intermittent connectivity and partitioned networks, OMSN adopts the store-carry-forward mechanism that means whenever a node wants to send a message to other nodes, it carries the message, until it detects contact with some other node and forwards the message to the encountered

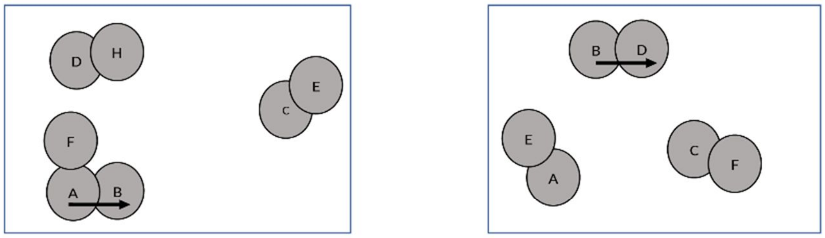
ISSN: 2233-7857 IJFGCN

node only if the encountered node is more likely to meet the destination [1-2]. For instance, fig. 1 represents a simple network with 7 nodes which have an intermittent connection. Node A has a message to D and it meets B and F at time t. Then, it forwards the packet to B as its delivery utility towards the destination is higher than itself. Node B, then carries the message, after some time (t+Δt) B meets D and delivers the message. In addition, as the efficiency of the opportunistic routing is dependent on relay selection, the selection of incapable relay will lead to poor performance, a great amount of overhead, and high latency. Consequently, the mobile devices go dead as they have limited energy and the life span of the network is diminished. So, the relay selection strategy has a great impact on the delivery and latency of the message.

Opportunistic routing protocols are classified into: forwarding based protocol, replication based protocol and hybrid-based protocol [3]. The forwarding based protocol works as follows: The forwarding based protocols select the best relay node from its immediate neighbors and send the message to the selected neighbor. Although consumes fewer amounts of network resources, it incurs a high delivery delay and low delivery rate because it allows only one copy of the message to be present at any point of time in the network. If the intermediate node fails due to resource scarcity, then it will affect the delivery rate. The replication based protocol works as follows: Each node with a packet creates a copy of the message and forward it to the neighbor nodes whenever it encounters. Since it creates a huge amount of replicas, it achieves a higher delivery rate over forwarding based protocol, but it incurs a high overhead and network resource consumption. The hybrid based protocol mixes both forwarding and replication based protocol techniques to limit the replicas. The replication and hybrid-based protocols allow the node to replicate the message to improve the delivery ratio and shorten the delivery delay. The shortcoming of the conventional routing methods is that they create multiple copies of the message to achieve a high delivery rate in an error-prone wireless environment. In addition, each message is addressed to single forwarder, each corrupted transmission needs retransmission and it affects the routing performance and incurs high resource consumption even though multiple nodes can receive the transmission at the same time. Hence, there is a need to develop a routing protocol which provides a tradeoff between routing performance and resource consumption.

The paper proposes a novel approach named Contact Prediction based Routing (CPR) which represents multiple candidates to act as a relay node instead of selecting a single relay. *CPR* implements an idea of allowing each message custodian to select a set of its neighbors from its first hop neighbors, whose average meeting duration with the destination is greater than or equal to the time required to transmit the message. Then, it assigns priority to each node based on their expected remaining inter-meeting time to destination. It allows only one of the candidate nodes to forward the message according to their priority and the received packet status level; a node with the least expected remaining inter-meeting time receives the highest priority. The higher priority node takes the chance of forwarding the message only if the highest priority node fails to receive the message packet due to error-prone wireless links or resource scarcity. As CPR selects multiple candidate nodes instead of selecting a single relay node, it compensates the error-prone wireless links and provides robust routing. It achieves a low resource consumption as forwarding based method and a high delivery rate as replication based methods. It would extract the benefits of both single-copy and multi-copy based protocols to provide a tradeoff between routing performance and resource consumption.

ISSN: 2233-7857 IJFGCN



a) Message forwarding from A to B b) Message forwarding from B to D

Fig 1. Opportunistic Routing

The major contribution of the paper is given below.

- Partition the nodes which have similar interest into community. Some interest can be common to more than one community. For example, one community could visit mall, stadium and restaurant, and another community could visit club, stadium and theatre
- Each node maintains a record of community id, contact-time, inter contact-time, and last contact time with the nodes which had met before.
- Defining the formula to distribute a ratio of the message copies to the encounters
- Defining the formula to find out the RICT between two nodes based on their routine activity and time frame of the day.
- Prioritize all potential forwarders based on their RICT to the destination and add the list with the message header.
- Demonstrating that the proposed paper achieves a great goodput and reduces a huge amount of overhead and showing that these improvements have a great influence on overall performance of the system.

The organization of the proposed paper is given as follows. The related works are explained in section 2. System model is described in section 3. The proposed work is given in detail in section 4. Simulation parameters and result analysis is presented in section 5. Section 6 concludes the proposed work and highlights the future enhancement.

2. Related Works

An opportunistic contact in OMSN is considered an important factor in delivering messages to the intended destination. The Intermittent connection and nodes' mobility generate complexity in message routing. The OMSN routing protocols, which adopt store-carry-forward paradigm, have emerged as a dynamic research issue.

2.1 Single copy-based routing algorithm

ISSN: 2233-7857 IJFGCN

As its name implies, single copy-based protocols hold just only one copy of a message at any point of time to lessen a network overhead. In Direct delivery, source does not forward a message to intermediate nodes but destination [3]. First contact allows message holders only to forward a message to a first encounter [3]; as a result, it avoids a high resource utilization, but it provokes a low delivery rate. In mobispace routing, an optimum path between source and destinations is detected, based on the prediction of minimum delay between a pair of nodes, which experience a repetitive and a cyclic mobility [4]. CAR estimates the next hop exploiting Kalman Filter algorithm and the utility functions, in which the prediction techniques do not require nodes to keep track of historical encounter information and avoids stale route problems [5]. PER, on the other hand, makes nodes to keep a record of landmark transition and the time to visit the same to improve the prediction performance; thus, it tends to find an optimal routing decision considering both the contact frequency and the time of contact [6]. Moreover, in [7], the reference paper highlights that transient contact prediction could choose a suitable relay node by separating the contacts which would occur at different periods of a day. It also establishes subnets, in which nodes have transient connectivity, and forwards packets from one subnet to others by predicting the transient mobility pattern of encounters. Time sensitive utility-based routing algorithm is adopted in the paper [8], which considers the message's benefit, transmission cost and utility value which is calculated by deducting the cost from the benefit of the message. Thus, the message with a high benefit is delivered successfully. However, the resource friendly single copy-based algorithms enforce the accurate prediction technique in order to achieve a great performance.

3.1 Multi-copy based routing algorithm

In this section, multi copy based algorithm which leverages utility value estimated by spatial and temporal attributes are given. In this sort of algorithm, the message holder decides whether to forward the message to encounter based on the knowledge it has. Epidemic [9] is a known multi copy routing algorithm which achieves the highest delivery rate by replicating the message whenever the message holder encounters another node which has no message. But it consumes a lot of buffer and energy and also generates high overhead as it fails to utilize the utility value towards the destination. PRoPHET [10] calculates the delivery predictability towards the destination using its past contacts. The message is only forwarded to encounter which has higher delivery predictability than the message holder. It achieves the same delivery rate as Epidemic with less overhead, but it takes a long time to reach the destination compared to Epidemic [9]. MaxProp [11] calculates the delivery probability for each packet and schedules them based on the delivery probability. It achieves a high packet delivery ratio and a less latency, but it creates more replicas. Fuzzy-PRoPHET [12] selects the best forwarder applying the fuzzy logic membership function as it states the degree of utility value. In the worst and best case scenarios the PROPHET suffers from low delivery rate and high overhead. To overcome these problems, Replica Reduced Routing [13] selects a set of forwarders in an increasing order of delivery predictability compared to the last selected forwarder. Super node routing [14] divides the network into clusters or cells and designated node called super node takes the packet from one cell to another in the direction of destination cell. It controls the message flooding. Relay Erlang [15] selects proper relay node considering delivery probability, buffer status and delivery time together.

As mobile devices are carried by human beings, OMSN utilizes community structure the mobile holder belongs to and the interaction among the nodes in order to take forwarding decision. SimBet[16] forwards the message to encounter which has a higher utility value calculated in terms of social similarity and centrality. Bubble rap [17] is a social attribute-based protocol which selects relay nodes based on the centrality and community metric. It achieves a low buffer and energy consumption. People rang algorithm [18] considers a person who has more centrality values as a famous person. Cosine similarity based

ISSN: 2233-7857 IJFGCN

routing [19] decides to forward the packet based on degree of cosine similarity between two nodes by assigning weight to data set. Multi attribute based routing [20] has proposed a Point of interest aware routing which decides to forward the packet comparing the probability to visit the destination PoI. Privacy preserving routing [21] constructs an optimal path between source and destination. An effective positive transmission [22] involves only nodes which have a strong social connection in forwarding process in order to avoid malicious nodes. In addition, this paper [23] shows that opportunistic routing improves the transmission reliability and gains the throughput by utilizing the potential benefits offered by the broadcast nature of wireless transmission. ExOR [24] transmits the packet to the neighbours and one which is very near to the destination receives the highest priority and forwards the packet.

2.3. Quota based routing algorithm

Quota-based technique provides a balance between network performance and resource utilization, and controls overhead by allowing a fixed number of message copies to be presented in the network. Spray and Wait is a quota-based routing scheme, which replicates a fixed number of copies of each message during spray phase [25]. A node with a single replica of the message enters into the Wait phase, in which it does not select any relay nodes until it meets the destination, thus, it reduces redundancy but incurs a high delivery delay. Spray and Focus [26], an extension of Spray and Wait, follows the same spray phase as in [26]. Once the residual replica becomes one, a node moves to focus phase, in which the message gets forwarded to encounter only if its utility value is greater than the message holder. In sharing spray and wait [27], message replicas are sprayed to encounters based on their delivery capability. Encounter-based routing (EBR) distributes message copies to encounter in proportion to contacts that the encountering node will meet in the future [28], and it implies that the encounters are likely to meet the destination with a high probability. Since message's TTL determines the message validity, Contact-based routing considers expiration time for each message while predicting the encounter value; each node distributes the message copies to encounter in proportion to the expected encounters that the node will meet before the packet lifetime gets expired. When a node has a single copy of the message, it predicts an average meeting delay between any pair of nodes [29]. Geospray [30], as its names implies, predicts forwarding capability of nodes in accordance with the geographical information, which integrates both single and multi-copy forwarding techniques as a hybrid routing. In AMRT [31], various replicas are generated for each message, which depends on the existence of the congestion around the sender's neighbor. Similarly, the paper [32] decides the number of copies to be sprayed to encounter nodes in accordance with the chance of contacting the destination. Thus, the quota-based protocol balances a routing performance and network overhead with high computational cost and drop ratio.

According to the survey, in a single copy based technique, just only one node moves the packet towards the destination at any point of time. Since the failure of packet holder affects the routing performance, it is not a robust technique. In addition, it incurs long delay and less packet delivery rate. But it consumes less amount of resources which leads to long lifespan of the network. In the case of muti-copy technique, since more than one node involves in packet forwarding towards the destination at any point of time, it achieves a greater packet delivery rate at the cost of high resource consumption. The idea of developing a new routing technique by combining the benefits of both single and multi-copy based techniques ensure the results such as high packet delivery rate, low resource consumption, less delay and robustness. In this paper, a novel strategy called 'Contact Prediction based Routing (CPR)' is proposed, which consumes less resources like a single copy protocol and achieves a greater delivery rate , robustness and less delivery delay like multi copy routing protocols. Totally, the proposed work provides a tradeoff between delivery rate and overhead utilizing the advantages of potentials offered by the broadcast nature of wireless medium.

3. System model

ISSN: 2233-7857 IJFGCN

We consider an Opportunistic network which consists of N nodes. Let R denote the transmission range of nodes. Two nodes *i* and *j* can communicate with each other if they both come under the direct transmission range of each other, that is $|X_i(t) - X_j(t)| \leq R$, where $X_i(t)$ and $X_j(t)$ denote the position of *i* and *j* at a time 't' respectively.

The Eq. 1 and Eq. 2 represent the meeting and leaving time between node 'i' and 'j'. The meeting (contact) and inter-meeting (inter-contact) durations between two nodes are calculated using the Eq. 3 and Eq. 4. Each node calculates average meeting duration, inter-meeting duration and expected remaining inter-meeting time as in Eq. 5, Eq. 6 and Eq. 7 respectively. For easy reading, the corresponding notations used in this paper are listed in Table 1. Fig 2 represents the sequence of meeting and inter-meeting durations between node 'i and 'j'. The related calculations are given below to make understanding the proposed paper easy.

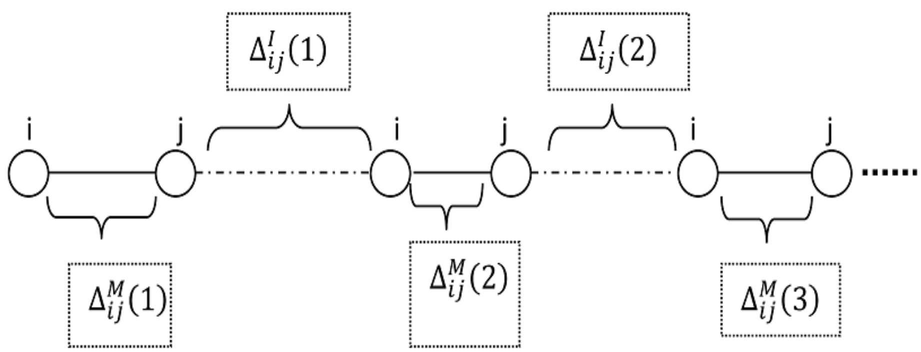


Fig 2. Meeting and Inter-meeting duration between node 'i' and 'j'

Table 1 Notations

Notation	Description
$N=\{v_1,v_2,\ldots,v_N\}$	Set of nodes in the network
$M_{ij}(k)$	k^th^ Meeting time between nodes *i* and *j*
$M=\{M_1,M_2,\ldots,M_k\}$	Set of messages
$L_{ij}(k)$	k^th^ Leaving time between nodes *i* and *j*
$\Delta_{ij}^M(k)$	k^th^ Meeting duration between nodes *i* and *j*
$\Delta_{ij}^I(k)$	k^th^ Inter-meeting duration between nodes *i* and *j*
μ_{ij}^M	Average Meeting duration between nodes *i* and *j*

ISSN: 2233-7857 IJFGCN

μ_{ij}^{I}	Average Inter-meeting duration between nodes *i* and *j*
$ERMD_{ij}^{t}$	Expected Remaining Inter-meeting duration between nodes i and *j*
M_r	Message transmission time
$H_i(t)$	One-hop Neighborhood of node i at time t
$C_i(t)$	Candidate set selected by node i from $H_i(t)$
RTT	Round-trip time
ACK	Acknowledgment packet
Index(*v*)	Index value of node *v;* index value = 0,1 2 ,…..

3.1 Related calculation

Meeting time: The Meeting time between two nodes i and j is defined as the point of time at which they both come under the direct transmission range of each other. K^{th} meeting time is defined as follows.

$$M_{ij}(k) \triangleq \{t > L_{ij}(k-1): |X_i(t) - X_j(t)| \leq R\} \quad \text{Eq. 1}$$

Leaving time: The Leaving time between two nodes i and j denotes the time at which they both go out of their direct transmission range of each other. K^{th} leaving time is defined as follows.

$$L_{ij}(k) \triangleq \{t > M_{ij}(k): |X_i(t) - X_j(t)| > R\} \quad \text{Eq. 2}$$

Meeting duration: The meeting duration is the period of time during which two nodes i and j remain in contact until they move away from contact again as in figure 2. K^{th} meeting duration is defined as follows

$$\Delta_{ij}^{M}(k) = L_{ij}(k) - M_{ij}(k) \quad \text{Eq. 3}$$

Inter-Meeting duration: The inter-meeting duration between two nodes i and j is the length of the time these two nodes remain out of contact before getting in contact with each other again as in figure 2.

$$\Delta_{ij}^{I}(k) = M_{ij}(k) - L_{ij}(k-1) \quad \text{Eq. 4}$$

Average Meeting duration (μ_{ij}^{M}): Let T_{ij}^{M} be the total number of meeting duration between nodes i and j.

$$\mu_{ij}^{M} = \begin{cases} +\infty, & T_{ij}^{M} = 0 \\ \frac{1}{T_{ij}^{M}} \sum_{k=1}^{T_{ij}^{M}} \Delta_{ij}^{M}(k), & T_{ij}^{M} > 0 \end{cases} \quad \text{Eq. 5}$$

Average Inter-meeting duration (μ_{ij}^{I}): Let T_{ij}^{I} be the total number of recorded inter-meeting duration.

ISSN: 2233-7857 IJFGCN

$$\mu_{ij}^{I} = \begin{cases} +\infty, \ T_{ij}^{I} = 0 \\ \frac{1}{T_{ij}^{I}} \sum_{k=1}^{T_{ij}^{I}} \Delta_{ij}^{I}(k), \ T_{ij}^{I} > 0 \end{cases} \quad \text{Eq. 6}$$

Expected Remaining Inter-meeting duration (ERMD): For a pair of nodes, how long it will take to meet each other again at time t. Let two nodes say i and j encounters periodically every μ_{ij}^{I} and the last encounter occurred between them is at time t_0^{ij}. At time t (t>t_0^{ij}), the elapsed time since the last contact occurred between two nodes (E_{ij}^{t}) is t-t_0^{ij}. Thus, the expected remaining inter-meeting duration between i and j is at time t:

$$ERMD_{ij}^{t} = \mu_{ij}^{I} - E_{ij}^{t} \quad \text{Eq. 7}$$

Message transmission time (M_r): It is defined as the amount of time required to transmit a message from beginning to end of a message. Let node v_i holds a message with B_m KB and the transmitting rate is T_r KBps.

$$M_r = B_m \ / \ T_r \quad \text{Eq. 8}$$

4. Contact Prediction based Routing (CPR)

In this section, the proposed paper CPR is described in detail. The CPR contains 3 phases: message distribution, potential forwarder selection and message forwarding. The nodes with same kinds of interest are divided into community and each community has unique ID. Since the previous paper has remarked that the movement observations can make accurate predictions [33][34] , each nodes make a contact expectations based on its past contact history. In accordance with the node's past contact pattern, it can anticipate future contact data between itself and any other node which had met before. Each node predicts contact information such expected community, meeting time, inter-meeting time, and remaining inter-meeting time using their past contact history. The expected communities are used in message distribution phase. The Eq. 1 and Eq. 2 represent the meeting and leaving time between node 'i' and 'j'. The meeting and inter-meeting durations between two nodes are calculated using the Eq. 3 and Eq. 4. Each node calculates average meeting duration, inter-meeting duration and expected remaining inter-meeting time as in Eq. 5, Eq. 6 and Eq. 7 respectively.

4.1 Message distribution

To increase packet delivery ratio in an intermittent connection, opportunistic routing algorithm creates a message with a fixed number of copies and distributes over the network and the message is considered as delivered successfully if any one of the copies gets to the destination before its Time to live becomes invalid. So, to get high message delivery ratio, an efficient routing strategy forwards λ copies of each message to λ different nodes [25-29].

The proposed work creates a message with λ *(λ=8)* copies and distributes them to encountering nodes according to the ratio of expected number of communities before message's TTL gets invalid. For example, let us assume node *i* with M_k copies ($M_k > 1$) of the message meets *j* which has no copy. After exchanging contact history, node *i* will distribute the following ratio of message copies to j.

$$\left| M_k \cdot \frac{j's\ expected\ Communities\ before\ m's\ TTL\ expired}{i's\ expected\ Communities\ before\ m's\ TTL\ expired + j's\ expected\ Communities\ before\ m's\ TTL\ expired} \right|$$

ISSN: 2233-7857 IJFGCN

In general, a copy of the message is forwarded during contacts and the relevant number of copies is mentioned along with the message as a property. This process will be continued until the message holder keeps a single copy. Once message distribution got over, each message holder takes the forwarding decision based on the utility value of itself and encounters towards the destination.

.1 Candidate selection

Suppose a node *i* with a single copy of message *m,* wants to send it to D. Node *i* calculates Expected Remaining Meeting Duration (ERMD) with the destination. When node *i* encounters multiple contacts, they all exchange their average contact duration (μ_{jd}^{M}) and ERMD towards the destination with *i*. The node *'i'* selects candidates from its immediate neighbors as follows.

$$C_i(t) = \{j | j \in H_i(t),\ \mu_{jd}^{M} \geq M_r \ \ \&\& \ \ ERMD_{jd}^{t} < ERMD_{id}^{t} \} \qquad \text{Eq.9}$$

According to the eq. 9, node $'i'$ selects a set of candidates $C_i(t)$ from its current contacts such that the candidate's average contact duration with the destination D is great enough to transmit the packet ($\mu_{jd}^{M} \geq M_r$). Also, the candidate's expected inter-meeting duration with the destination D is less than $'i'$. The candidate with the least expected remaining inter-meeting duration with D in $C_i(t)$ gets the highest priority over another candidates. The new field named 'potential forwarder list' is included in the message header. The addresses of the potential candidate nodes are stored in the potential forwarder list in the order of their priority as in fig 3. The address of the highest priority candidate which has the least RICT to the destination occupies an array index 1 and the next higher priority node takes index 2 and so on. The procedure of the candidate selection algorithm is given in Algorithm 1.

Ethernet Header			
Version	Flags	Header length	Payload length
Potential forwarder list			
Checksum			
Payload			

Fig.3 CPR Packet Header

Fig 3 shows CPR packet header format. The Ethernet header is followed by CPR header, and is followed the data. The version field represents the current version of the CPR . The header length indicates the length of the CPR packet header and payload length denotes size of the payload. The potential forwarder list includes a copy of the potential candidates selected by the message holder.

ISSN: 2233-7857 IJFGCN

Algorithm 1. Forward Node Selection and Message Forwarding

nput: Node *i* selects candidate set. Node *v* receives a message *m* from node *i*.

Output: Forward or drop of m

1. for j = 1 to $|H_i(t)|$
2. $C_i(t) = \{ j \mid j \in H_i(t),\ \mu_{jd}^{M} \geq M_r$ && $ERMD_{jd}^{t} < ERMD_{id}^{t} \}$
3. end for
4. if (node *v* receives message m from node *i*)
5. if ($v \in C_i(t)$)
6. k= index(v) in $C_i(t)$ // retrieving an index value of node v
7. Wait (k-1) * t_{ACK} to send an ACK
8. if ACK is not received until (k-1) * t_{ACK} gets expired
9. Send ACK // v act as a next relay
10. Go to step 1
11. else // if the ACK is received for m
12. Drop the message *m*
13. end if
14. end if
15. end if

Example 1: Let us assume that source node S wants to send a packet m to destination D, which needs the transmission time of 20s. Table 2 contains an average meeting and inter-meeting duration between S and D. Fig 4 shows that node S encounters six nodes named E1, E2, E3, E4, E5, and E6 at a time 't'. The average meeting duration and $ERMD^t_{E_i d}$ are given in Table 3. S selects E2, E3, E5, and E6 according to their average meeting duration as shown in Fig 5. Then, S selects E3, E5, and E6 as candidates because they have lesser $ERMD^t_{E_i d}$ than S. This is illustrated in Fig 6. E6 receives the highest priority because it has the least $ERMD^t_{E_i d}$. If the highest priority candidate fails to receive the packet, then the next higher priority candidate node takes the chance of acting as a relay. The selected candidates are included in the message header. The selected candidates are included in the message header as a potential forwarder list as shown in Fig 3.

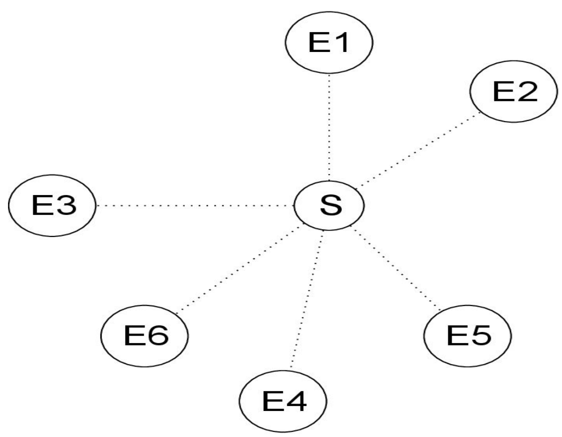


Fig 4 One-hop neighbors of node S

Table 2 Record of past contact data between S and D

Node Id	μ^M_{Sd} (seconds)	$ERMD^t_{Sd}$ (seconds)
S	32s	250s

Table 3 Record of past contact data between neighboring nodes of S and D

ISSN: 2233-7857 IJFGCN

International Journal of Future Generation Communication and Networking
Vol. 13, No. 4, (2020), pp. 3284–3303

Node Id	$\mu^{M}_{E_i d}$ (seconds)	$ERMD^{t}_{E_i d}$ (seconds)
E1	10s	160s
E2	26s	280s
	28s	
	15s	
	40s	
	30s	

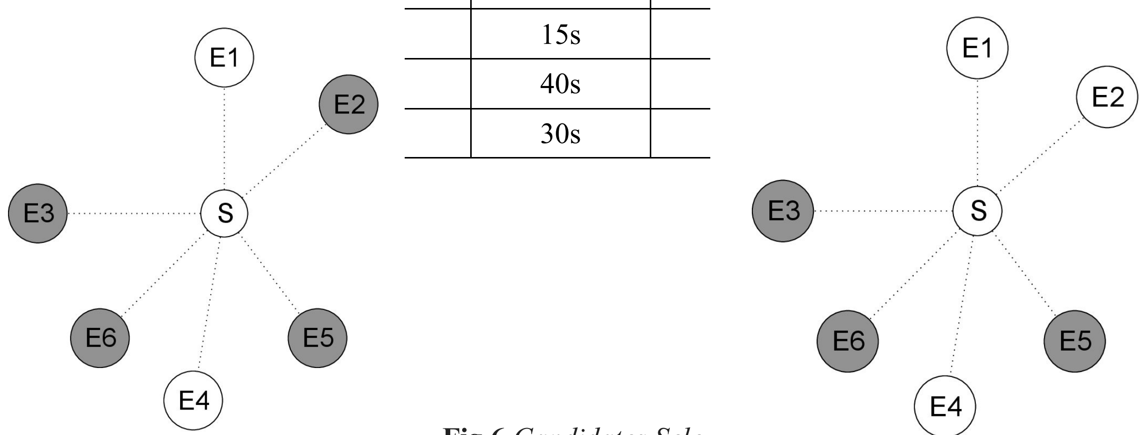


Fig 6 *Candidates Selec*

5. SIMULATION

In this section, the performance of the CPR is evaluated in terms of delivery ratio, overhead, goodput, latency, and relayed copies. As well as, the overall performance of the proposed system is assessed by measuring the composite metric. The proposed system is implemented in ONE simulator [10] and compared with the existing routing protocols of Opportunistic Networks. The metrics used in performance assessment are defined as follows. The simulation parameters are given in table 4.

Table 4 Simulation Parameters

Simulation Parameters	
Number of nodes	25, 50, 75, 100
Transmission Range	100m
Movement Speed	0..20 m/s
Pause Time	0,5s

ISSN: 2233-7857 IJFGCN

Simulation Time	4500s
Antenna	Omni Directional Antenna
Mobility Model	Random Waypoint Movement
Packet sending Rate	2KBps
Buffer size	200 k
Packet Size	25KB-50KB
Time To Live (TTL)	10m
Simulation Area	1500 x 300

Delivery ratio: The ratio of successfully delivered messages out of a total number of generated messages.

Latency: Latency indicates how long it takes for a message to travel from source to destination.

*Overhe*ad: It is the ratio of the total number of relayed messages to the number of created messages.

*Goodpu*t: It is defined as the ratio of the total number of successfully delivered messages out of relayed messages.

As the given protocol is not stable in terms of various metrics such as delivery rate, delay, and overhead, a composite metric is also obtained to assess the overall performance of the given system [6][7]. The composite metric which involves delivery ratio, goodput, and latency, is defined as follows.

$$Composite\ metric = (Delivery\,ratio\ x\ Goodput)/Latency$$

To analyze the efficiency of the proposed system CPR, we compare with Epidemic [9], PRoPHET[10], MaxProp[11], Spray and Wait[25] and CAR[29]. Figure 7-12 exhibits the performance comparison between CPR and the others in terms of relayed messages, overhead, delivery ratio, delay, goodput, and composite metric.

ISSN: 2233-7857 IJFGCN

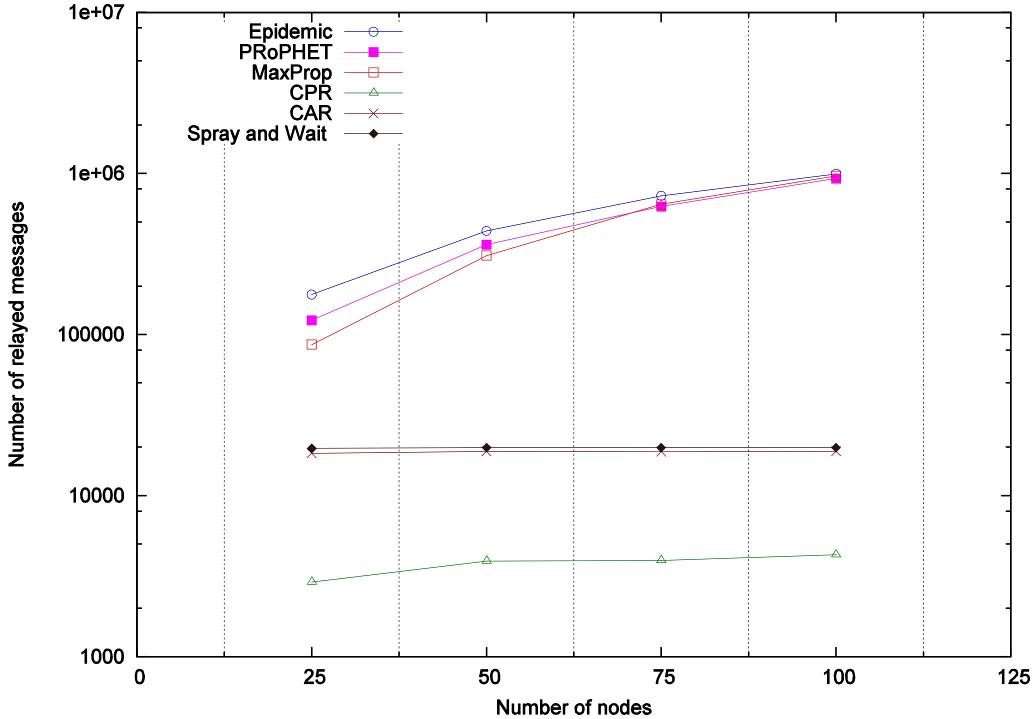
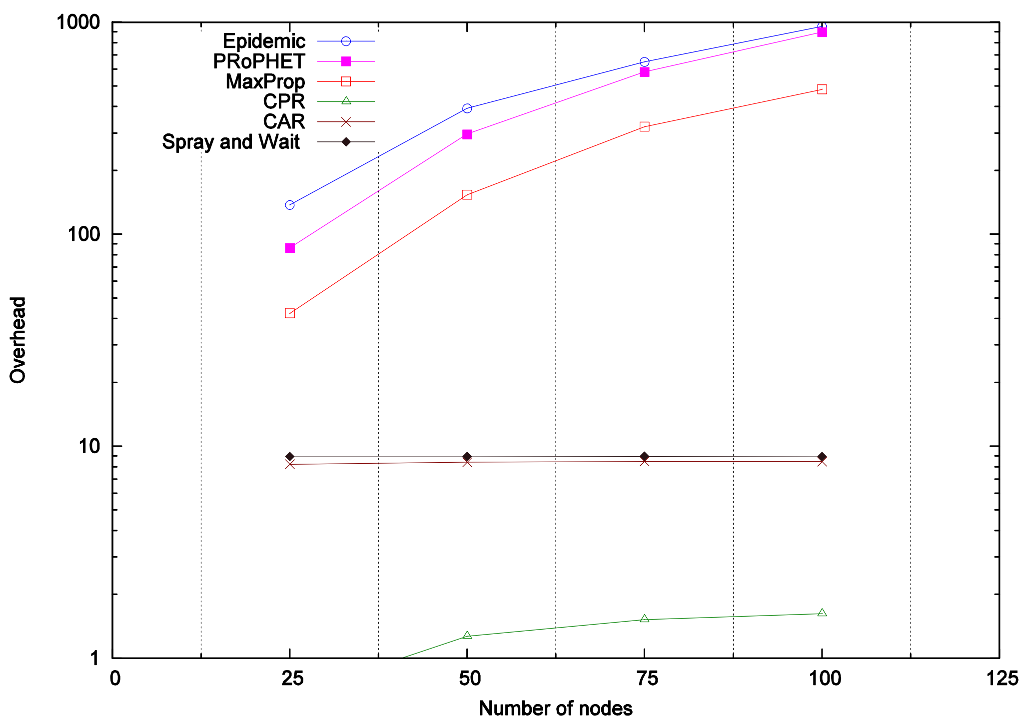


Fig 7 Relayed Messages

In Fig 7, CPR relays very less amount of messages even though the network size gets increased. As it applies a single copy based routing, it avoids transferring huge amount of replicas. As Epidemic is a replication based protocol, it creates the highest amount of replicas.



ISSN: 2233-7857 IJFGCN

Fig 8 Overhead

As Fig 7 shows that as the CPR creates less amount of replicas, it incurs the least amount of overhead compared to all other existing protocols. Fig 8 implies that an appending an extra field in the packet header and ACK packet does not create much overhead compared to redundant data retransmission. As CPR reduces a huge amount of replicas, it directly reduces congestion and resource consumption. PRoPHET and MaxProp produce lower overhead than Epidemic.

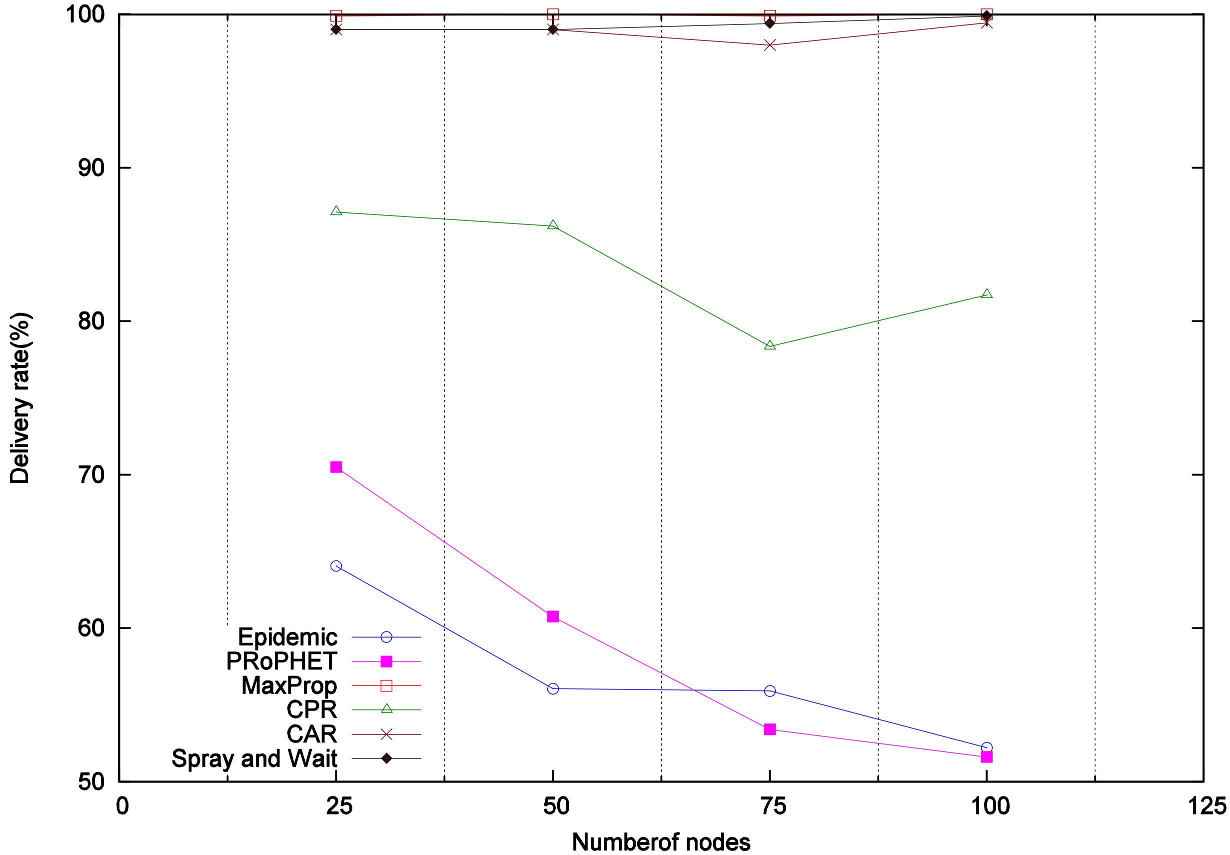


Fig 9 Delivery rate

In Fig 9, MaxProp achieves the highest amount of delivery rate as it schedules the packets according to their Delivery probability. CAR and Spray and Wait protocols also achieve better delivery ratio as both are replication based protocols.

ISSN: 2233-7857 IJFGCN

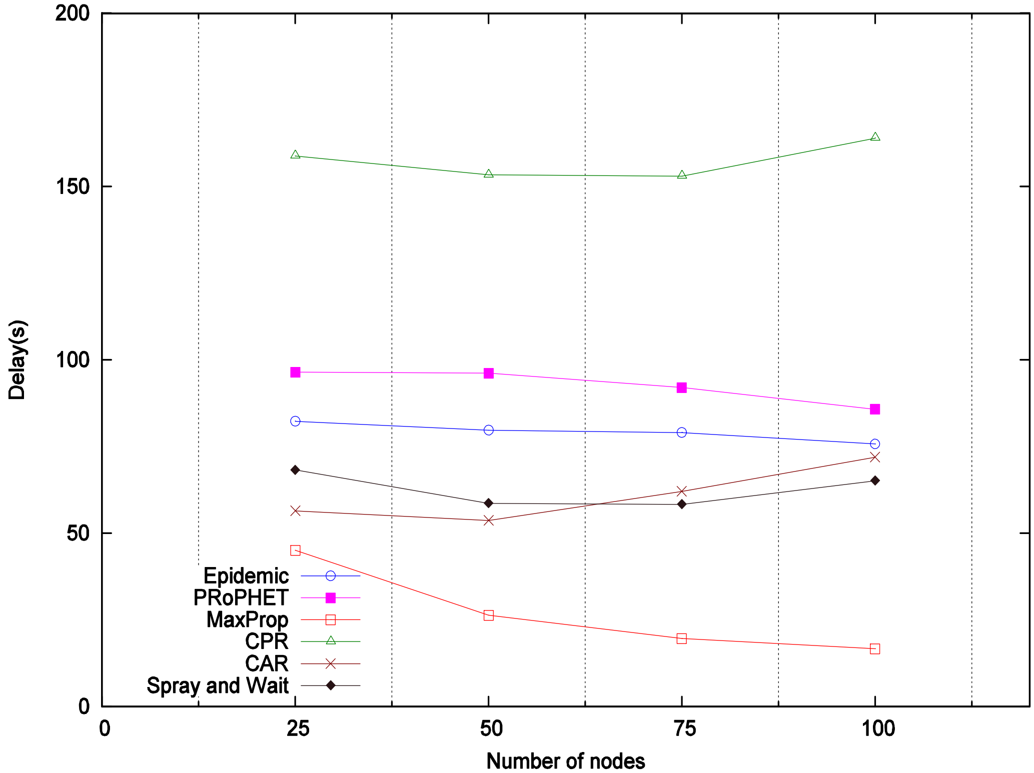


Fig 10 Delay

Fig 10 shows that MaxProb achieves the lowest delay since it considers the TTL of packets and schedules them. As CPR routing is a single copy based routing it experience a little bit delay in message delivery compared to the existing protocols. Spray and Wait and Car protocols yields lower delivery delay than CPR because Both Spray and Wait blindly spray copies during spray phrase and CAR protocol distribute a portion of copies according to the number of expected encounter the node visits in future.

ISSN: 2233-7857 IJFGCN

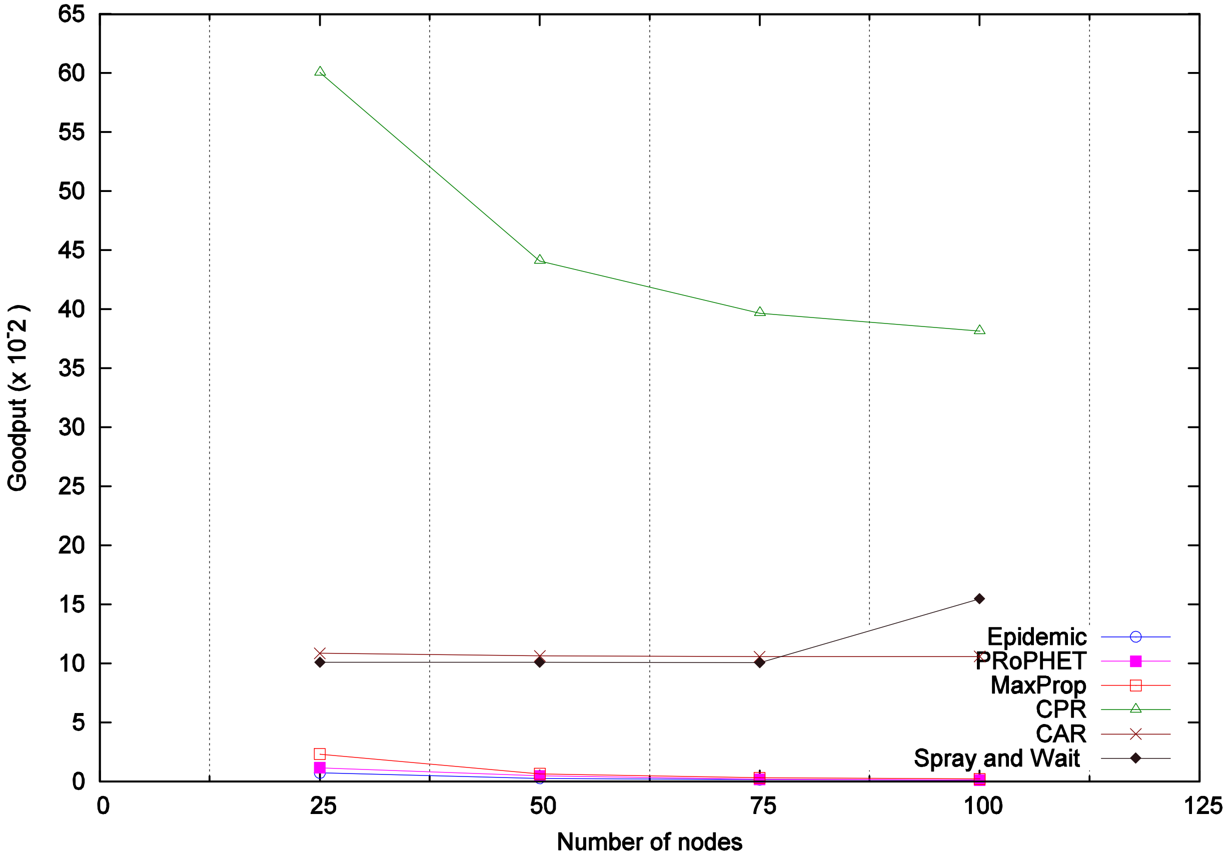


Fig 11 Goodput

ISSN: 2233-7857 IJFGCN

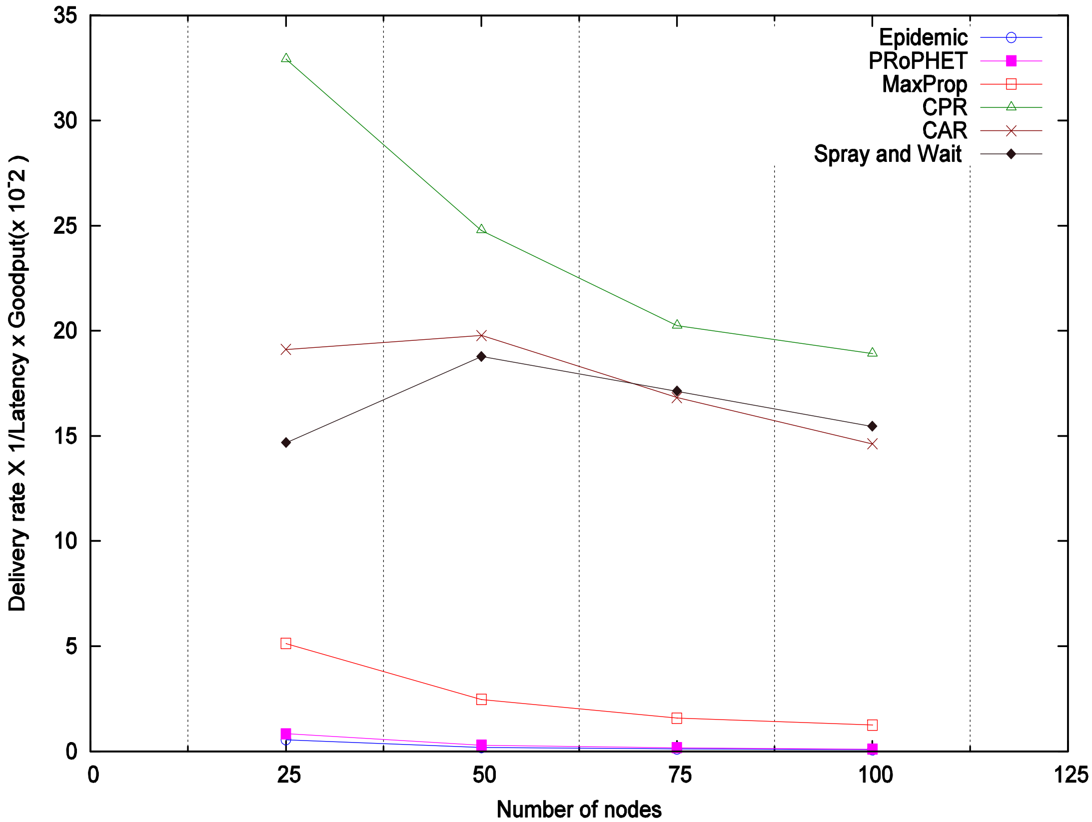


Fig 12 Composite metric

Fig 11-12 show that the proposed system outperforms over all other protocols in terms of goodput and composite metric. In the proposed system, representing multiple candidate nodes for each hop transmission compensate for the packet reception failure by the node. In addition, as CPR allows only one of the selected candidate to forward the packet, it reduces a huge amount of replicas without affecting the routing performance, which results in low consumption of resources such buffer and energy. CPR decreases packet dropped rate and thus, increases goodput. Fig12 exhibits that the proposed system diminishes overhead by 85% and the composite metric is increased by 38% than the existing systems.

6. CONCLUSION

In this paper, we propose a Contact Prediction based Routing (CPR) which has 3 phases namely message distribution, candidate selection and message forwarding. During message distribution, it distributes a ratio of message copies between encounters according to their expected communities. When a node has a single copy of the message, CPR selects a list of potential forwarders by comparing the Remaining inter-meeting duration to the destination and attach with the message header. An Ack from a higher priority node prevents a lower priority node from duplicate retransmission. An absence of ACK from the higher priority nodes allows the lower priority node to act as a next relay for further message forwarding. We evaluate the performance of the proposed paper in the ONE simulator under various parameters and performance metrics to exhibit its effectiveness. In future work, fuzzy logic can be applied to solve an uncertainty in relay selection to optimize the search process.

ISSN: 2233-7857 IJFGCN

References

1. Cerf, V., Burleigh, S., Hooke, A., Torgerson, L., Durst, R., Scott, K., ... & Weiss, H. (2007). Delay-tolerant networking architecture.
2. Fal, K. (2003). A delay—tolerant network architecture for challenged internets [C]. In *Proc of ACM SIGCOMM* (Vol. 3, pp. 27-34).
3. Keränen, A., Ott, J., & Kärkkäinen, T. (2009, March). The ONE simulator for DTN protocol evaluation. In *Proceedings of the 2nd international conference on simulation tools and techniques* (pp. 1-10).
4. Liu, C., & Wu, J. (2008, May). Routing in a cyclic mobispace. In *Proceedings of the 9th ACM international symposium on Mobile ad hoc networking and computing* (pp. 351-360).
5. Musolesi, M., & Mascolo, C. (2008). CAR: Context-aware adaptive routing for delay-tolerant mobile networks. *IEEE Transactions on Mobile Computing*, *8*(2), 246-260.
6. Yuan, Q., Cardei, I., & Wu, J. (2009, May). Predict and relay: an efficient routing in disruption-tolerant networks. In *Proceedings of the tenth ACM international symposium on Mobile ad hoc networking and computing* (pp. 95-104).
7. Gao, W., & Cao, G. (2010, October). On exploiting transient contact patterns for data forwarding in delay tolerant networks. In *The 18th IEEE International Conference on Network Protocols* (pp. 193-202). IEEE.
8. Xiao, M., Wu, J., Liu, C., & Huang, L. (2013, April). Tour: time-sensitive opportunistic utility-based routing in delay tolerant networks. In *2013 Proceedings IEEE INFOCOM* (pp. 2085-2091). IEEE.
9. Vahdat, A., & Becker, D. (2000). Epidemic routing for partially connected ad hoc networks. In Technical ReportCS-200006, Duke University (pp. 1–14).
10. Lindgren, A., Davies, E., Grasic, S., & Doria, A. (2012). Probabilistic routing protocol for intermittently connected networks. In Proceedings of ACM MobiHoc (pp. 19–20). ACM.
11. Burgess, J., Gallagher, B., Jensen, D. D., & Levine, B. N. (2006, April). MaxProp: Routing for Vehicle-Based Disruption-Tolerant Networks. In *Infocom* (Vol. 6, pp. 1-11).
12. Ahmad, K., Fathima, M., Jain, V., & Fathima, A. (2017). FUZZY-PRoPHET: a novel routing protocol for opportunistic network. *International Journal of Information Technology*, *9*(2), 121-127.
13. Rabiya, M. S., & Ramalakshmi, R. (2019). Replica Reduced Routing Protocol for Intermittent Connected Networks in Emergency Scenarios. *International Journal of Distributed Systems and Technologies (IJDST)*, *10*(2), 84-109.
14. Sharma, D. K., Kukreja, D., Chugh, S., & Kumaram, S. (2019). Supernode routing: a grid-based message passing scheme for sparse opportunistic networks. *Journal of Ambient Intelligence and Humanized Computing*, *10*(4), 1307-1324.
15. Derakhshanfard, N. (2020). Erlang Based Buffer Management and Routing in Opportunistic Networks. *Wireless Personal Communications*, *110*(4), 2165-2177.
16. Daly, E. M., & Haahr, M. (2007, September). Social network analysis for routing in disconnected delay-tolerant Manets. In *Proceedings of the 8th ACM international symposium on Mobile ad hoc networking and computing* (pp. 32-40). ACM.
17. Hui, P., Crowcroft, J., & Yoneki, E. (2010). Bubble rap: Social-based forwarding in delay-tolerant networks. *IEEE Transactions on Mobile Computing*, *10*(11), 1576-1589.
18. Mtibaa, A., May, M., Diot, C., & Ammar, M. (2010, March). Peoplerank: Social opportunistic forwarding. In *2010 Proceedings IEEE INFOCOM* (pp. 1-5). IEEE.
19. Lin, Y., Chen, Z., Wu, J., & Wang, L. (2018). An Opportunistic Network Routing Algorithm Based on Cosine Similarity of Data Packets between Nodes. *Algorithms*, *11*(8), 119.

ISSN: 2233-7857 IJFGCN

20. Rabiya, S. M., & Ramar, R. (2020). Multiattribute-based routing for lifetime maximization in opportunistic mobile social networks. *INTERNATIONAL JOURNAL OF COMMUNICATION SYSTEMS*.
21. Rashidibajgan, S., & Doss, R. (2019). Privacy-preserving history-based routing in Opportunistic Networks. *Computers & Security*, *84*, 244-255.
22. Zheng, P., Fei, H., & Yan, Y. (2020). An effective positive transmission routing algorithm based on social relationships in opportunistic social networks. *Peer-to-Peer Networking and Applications*, *13*(1), 269-286.
23. Kabaou, M. O., & Hamouda, H. (2020). Implementation and Evaluation of Opportunistic Routing Protocols for Wireless and New Generation Communication Networks. *Wireless Personal Communications*, 1-19.
24. Zeng, K., Lou, W., Yang, J., & Brown, D. R. (2007). On throughput efficiency of geographic opportunistic routing in multihop wireless networks. *Mobile Networks and Applications*, *12*(5-6), 347-357.
25. Spyropoulos, T., Psounis, K., & Raghavendra, C. S. (2005, August). Spray and wait: an efficient routing scheme for intermittently connected mobile networks. In *Proceedings of the 2005 ACM SIGCOMM workshop on Delay-tolerant networking* (pp. 252-259).
26. Spyropoulos, T., Psounis, K., & Raghavendra, C. S. (2007, March). Spray and focus: Efficient mobility-assisted routing for heterogeneous and correlated mobility. In *Fifth Annual IEEE International Conference on Pervasive Computing and Communications Workshops (PerComW'07)* (pp. 79-85). IEEE.
27. Derakhshanfard, N., Sabaei, M., & Rahmani, A. M. (2016). Sharing spray and wait routing algorithm in opportunistic networks. *Wireless Networks*, *22*(7), 2403-2414.
28. Nelson, S. C., Bakht, M., & Kravets, R. (2009, April). Encounter-based routing in DTNs. In *IEEE INFOCOM 2009* (pp. 846-854). IEEE.
29. Chen, H., & Lou, W. (2016). Contact expectation based routing for delay tolerant networks. *Ad Hoc Networks*, *36*, 244-257.
30. Soares, V. N., Rodrigues, J. J., & Farahmand, F. (2014). GeoSpray: A geographic routing protocol for vehicular delay-tolerant networks. *Information Fusion*, *15*, 102-113.
31. Iranmanesh, S., & Saadati, M. (2018). A novel congestion control technique in delay tolerant networks. *International Journal of Interdisciplinary Telecommunications and Networking (IJITN)*, *10*(1), 20-35.
32. Wang, H., Song, L., Zhang, G., & Chen, H. (2018). Timetable-aware opportunistic DTN routing for vehicular communications in battlefield environments. *Future Generation Computer Systems*, *83*, 95-103.
33. Jones, E. P., Li, L., Schmidtke, J. K., & Ward, P. A. (2007). Practical routing in delay-tolerant networks. *IEEE Transactions on Mobile Computing*, *6*(8), 943-959.
34. Song, L., Kotz, D., Jain, R., & He, X. (2004, March). Evaluating location predictors with extensive Wi-Fi mobility data. In *Ieee Infocom 2004* (Vol. 2, pp. 1414-1424). IEEE.

ISSN: 2233-7857 IJFGCN