Journal of Information Technology Management

Print ISSN: 2008-5893

Online ISSN: 2423-5059

Hybrid Algorithm for Efficient node and Path in Opportunistic IoT Network

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Abstract

Opportunistic networks in the Internet of Things (IoT) scenario, also known as OppIoT, espouse IoT devices interactions opportunistically in order to improve connectivity, the lifetime of the network, and network reliability. An increase in opportunistic utilization is fostered by IoT applications to find communication opportunities whenever possible to route and deliver data efficiently. In this opportunistic scenario, devising an efficient path for data delivery is a challenging work due to uncertainty in the connection between the nodes and the selection of intermediate forwarder nodes for data delivery towards the destination. Considering the scenario of uncertainty in device location and exploiting IoT devices opportunistically, this paper propounds a routing algorithm for OppIoT called Hybrid Multi-Copy Routing Algorithm (HMCRA). The proposed algorithm finds potential forwarder nodes by using fuzzy logic wherein residual energy, distance, and speed of the nodes are considered as input values while preparing fuzzy rules. Genetic Algorithm (GA) is considered along with fuzzy logic to select an efficient path for data delivery. In GA, the delay is taken as the fitness function to select a reliable path for data delivery. Simulation results of the proposed algorithm perform well in contrast with relative existing routing algorithms with respect to latency, overhead ratio, delivery probability, and hop count. The work uniqueness lies in the selection of potential nodes and finding path having less hop count in an opportunistic IoT network scenario.

Keywords: Boundary, Fitness function, Fuzzy logic, Genetic algorithm, IoT, Multi-copy routing.

DOI: 10.22059/jitm.2021.80618

Introduction

The rapid increase of smart devices, which helps in daily activities, such as phablets, smartwatches, smartphones, and tablets, links directly to the Internet all over the world, enabling devices to collect, process, and communicate data without the assistance of the human is called as IoT. An increase in devices connecting to the internet leads to high traffic over cellular networks. At the end of 2017, global cellular data traffic reached approximately 11.5 exabytes per month, and by 2022 it is expected to grow to 77 exabytes per month (Fixed, V. G. 2016 and Ippisch, A., et al 2018). Traffic growth gives rise to challenge networks and Internet providers to cater to the high demand for traffic (Jia, B., Li, W., & Zhou, T. 2017). On the other hand, due to limited network coverage, mobile users will not have Internet access while during emergencies (e.g., LTE or 3G). To address these challenges, a reliable communication model termed Opportunistic Networks has been devised. Opportunistic networks are challenged networks (Boldrini, C., et al 2007), termed as OppNets, which is an expansion of Delay-tolerant networks (DTNs). In an OppNet, connectivity is sporadic, and there will be no direct path to communicate between two nodes(Sharma, D. K., et al., 2007), hence the store-carry and forward paradigm, as shown in Figure 1, is used for message transmission. Each node in a network will contain a buffer with a fixed size to store and carry a message. Whenever it gets the opportunity to interact with a more desirable carrier, then it forwards the message, and the medium like Bluetooth, Cellular networks, WiFi, to name a few (Burgess, J., et al., 2007 and Makhlouta, J., et al., 2011) are used to communicate the information among the nodes.

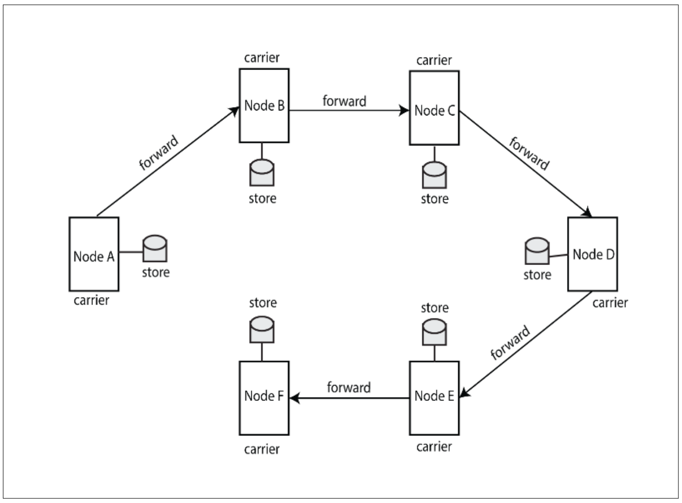


Figure 1. Store-carry and Forward mechanism in OppNets

Due to the Opportunistic nature and the randomness of the node, the nodes in the network will have the partial information about the network topology (Ott, J., et al., 2011) and the best technique used for this type of network in routing is flooding and this result in high resource consumption and also the congestion in the network (Park, J., et al 2016). OppNets can have mobile nodes like fixed nodes, vehicles and pedestrian users (Ahmad, K., et al., 2017) and prodigiously applied on the applications (Zadeh, L. A. 1965) like Wildlife monitoring, Underwater Sensor Networks (USNs), Mobile Social Networks (MSNs), Military Ad Hoc Networks (MANs), etc.

The message transfer in opportunistic routing protocols occurs in two categories viz. single-copy and multi-copy. In single-copy routing, the whole network will have only one message copy, and whenever the node carrying message fails, then the destination will not receive the message. Whereas flooding of messages to the whole network happens in case of multi-copy, and multiple copies of the same message are maintained in order to increase delivery probability. Routing in Multi-copy is categorized into 2 subclasses viz. limited and unlimited routing protocols. In a limited protocol, messages are transmitted based on probability so that copies of messages can be configured and limits the copies of unnecessary messages, whereas, in unlimited routing, the message is disseminated to the whole network.

A. Motivation

Proposed work motivation includes the following: (1) Delivering data towards the destination in an opportunistic IoT network is a challenging task due to the finding of intermediate forwarder nodes in dynamic routing. (2) Excess overhead on the resources of IoT network during delivery of messages due to the use of multicopy while routing of data. (3) Finding the reliable path between source and destination during the multipath scenario.

B. Contribution of the paper includes the following

1. Use of fuzzy logic rules to select potential forwarder nodes to deliver messages. Rules of fuzzy logic are formulated using energy, distance, and speed.

2. Use of GA to select reliable paths among multipath.

3. Various parameters optimization of IoT network in an opportunistic scenario.

The following are the sections considered in the paper. In Section II, related routing protocols for OppNets are reviewed. Section III, presents the problem statement of this work. In Section IV, provides a description of the system. Section V, the proposed HMCRA is described. VI provides the simulation results, and Section VII, summarizes the paper.

Literature Review

The Epidemic Theory-based H + 1 hop Forwarding (Lilien, L., et al., 2007) technique combines the multi-hop and 2 hops forwarding based on the epidemic theory. It uses a multicopy technique for forwarding the messages, and for forwarding, it calculates the equilibrium point by the SIR model of the basic epidemic theory. It has a better efficiency in delay and message delivery. The DiPRoPHET (Srinidhi, N. N., et al., 2019) is an improved version of PRoPHET. An additional parameter called distance is added to the PRoPHET to produce better efficiency in the delivery predictability, delay, and overhead. The MaxProp (Srinidhi, N. N., et al., 2019) is an improved version of the Epidemic protocol designed with the aim to improvise the latency rate and delivery rate of a message, and it was modeled for vehicle-based DTNs. This protocol forwards the message to the highest probability node, which is capable of transferring the message towards the destination and gives the high priority to new messages to prevent the duplication in the network. The priorities for the message are given on the basis of a head start for new messages, historical data, acknowledgment, hop count, and previous intermediary nodes.

Adaptive fuzzy Spray and Wait protocol (Sok, P., et al., 2013) is an improvised spray kind of routing scheme that considers the management of buffer and network overhead policy into an adaptive type of protocol to estimate parameters locally. This method clearly differentiates between dissemination and forwarding strategies. If the small message numbers are higher than then, large messages will be delayed. If every message in the network is of the same size, then a constant indicator to represent size will be considered instead of a priority. If the buffer is full, then older messages will be deleted.

The authors propounded the HCMM model (Nelson, S. C., et al., 2009) to control the delay and also to balance the traffic in the OppNet. In this HCMM model, artificial bee colony optimization is applied, and the bee's behavior is related to OppNets to achieve the objective. But this technique failed to optimize the network parameters because of the frequently changing mobility behavior. ORBOPH (Kumar, S. D., & Kumar, B. V. 2008, December) is an enhancement of Epidemic protocol; it finds the optimal path by selecting the neighboring nodes which are moving towards the destination. In this protocol, it controls the message replication by forwarding a copy of the message to the nodes which are moving in the direction to the destination. If the node's direction is not towards the destination, then the node stops the replication. When ORBOPH is compared with the epidemic, it has a higher buffer time, and that results in delay, but in case of overhead ratio, it is reduced.

GD-CAR (Borah, S. J., et al., 2017), various genetic operations are applied to the network in order to find the next best hop by using the context information to find the optimal route. When compared with Prophet, the number of hops is less and delivers the message faster, but the overhead ratio is high. Jia et al. (Dhurandher, S. K., et al., 2013) use a markovian model to maximize the delivery ratio. This markovian model is applied to Spray and Wait for the protocol to improve the delivery probability of the message. But this protocol has many delays because the node which is carrying the message has to wait until it gets the opportunity to find the best forwarder node to spray the message. The GT-ACR (Dhurandher, S. K., et al., 2018,) uses a game theory concept for finding the best next hop for forwarding the packets to the destination. An encounter and distance parameters are used to form the best strategy to select the best next forwarder using the technique non-zero-sum cooperative. It yields better performance in hopcount, average latency, delivery probability, etc. Because of context-based behavior, it performs poorly in message delivery probability when compared to PRoWait.

Problem Statement

Selection of potential forwarder node and finding a reliable path having fewer hop count in order to disseminate messages towards the destination with optimized hop number, latency, and overhead is the problem statement of the proposed work.

Proposed Algorithm for Optimal Path

In this section, we apply the fuzzy rule to find the potential nodes to disseminate the message and GA to find the optimal path.

A. Notations

Various notations used in the paper will be shown in the Table 1.

Table 1. Notations used in Proposed Algorithm

Symbols	Description
e_c	Consuming Energy of each node in a Network
e_{tx}	Individual node consumed energy for transmitting a message in network
e_{rx}	Individual node consumed energy for receiving a message in network
e_{init}	Initial energy
e_{res}	Remaining energy
m	neighboring nodes in the network
β	Potential nodes.
T_s	Sojourn time
c	frequently contacted.
$\bar{M}$	Mean number of nodes within the boundary
$\bar{m}$	Mean number of nodes with the message inside the boundary
$\bar{n}$	Mean number of nodes without message inside the boundary
N_{mr}	Number of messages received
X	Probability of message transferred successfully.

B. Assumptions

- The propound HMCRA protocol assumes an OppIoT network composed of N mobile nodes; each node will store all the context information with sufficient buffer.

- The message creation is done at the source node, and it also selects the destination node to forward the message.
- And no nodes will act maliciously in the network, and selected potential nodes1 will be allowed to forward the message till it reaches the destination.

C. System Model

Consider there is N number of mobile nodes in the OppIoT network model which are being carried by users with N = {n1, n2, ..., nn}, and these nodes will have Bluetooth/WiFi as their wireless medium interface having range R as depicted in Figure 2. The message generated by the nodes at any point in time will be forwarded to the intended nodes within its boundary. Nodes in OppNets will have a fewer amount of contact time between nodes; hence, these nodes will have a buffer to store these messages for an extended period of time. Let's consider message set M which will be forwarded to potential nodes within the boundary, and each of these messages will have time-to-live (TTL) in the network.

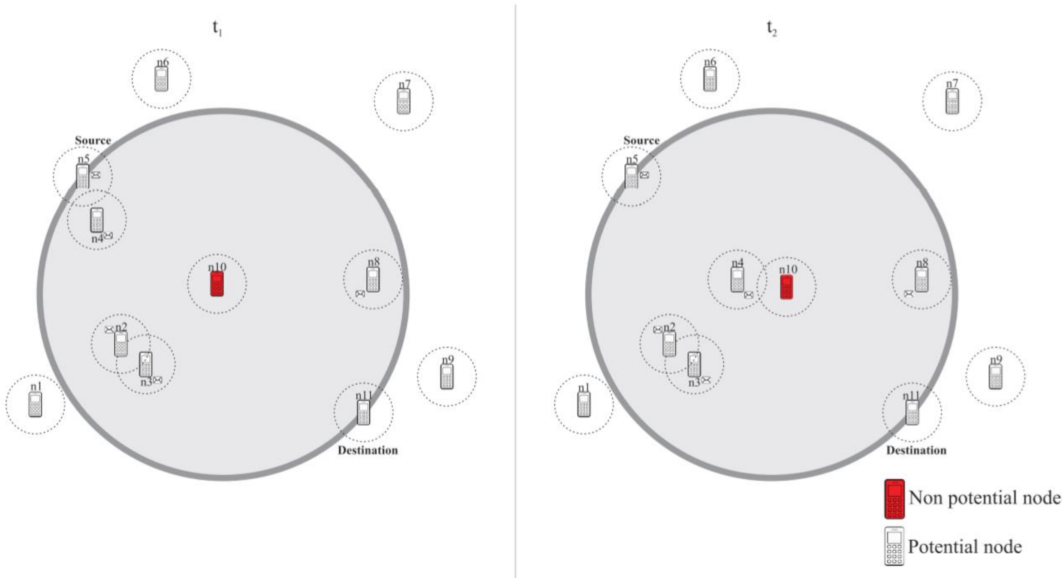


Figure 2. Node n5 located at (x, y), creates the message and chooses the destination node and makes the boundary. At time t1, the source node n5 forwards the copy of the message to n4. But at time t2, the node n4 will not forward the message to n10, which is within the boundary because the node is not a potential node.

In Figure 2, the forwarding of messages in the network is briefed. Let's assume node n1ϵN has mϵM message will come in contact with node n2ϵN, which doesn't consider message m in the buffer then the n1node checks the nodes n2 position if it is within the boundary then it again checks for reliability if the node n2is potential then node n1 sends a message to it. After receiving the message, the hop count field of node n2 is incremented by 1, and it is added to β. Where variable β stores, the nodes are carrying messages.

Overview of the Proposed Work

A. Boundary

In OppNets, there will be no direct connection from the source to the destination. If the connection exists, then transfer the message to the destination or else find the (x, y) coordinates of the source node and destination node using location id through GPS[1]. Let $S\ (x, y)$ and $D\ (x', y')$ be the coordinates of source and destination, are also two points on the circle. The midpoint of the line segment $SD\left(\frac{x+x\prime}{2}, \frac{y+y\prime}{2}\right)$, which represents the center of the circle and $\frac{1}{2}$SD is the circle representation where $\frac{1}{2}\sqrt{[(x-x')^2+(y-y')^2]}$. Consider the circle equation having a center at (h, k) and radius equal to $r(x-h)^2+(y-k)^2=r^2$; therefore, the equation of the required circle is:

$$\frac{1}{2}\sqrt{[(x-x')^2+(y-y')^2]} \tag{1}$$

Nodes in the network are carried by a human; hence nodes may be stable and dynamic. If the source and destination nodes are stable, then the boundary will be fixed. If the nodes are dynamic, then the boundary will be changed according to the distance of the source and destination.

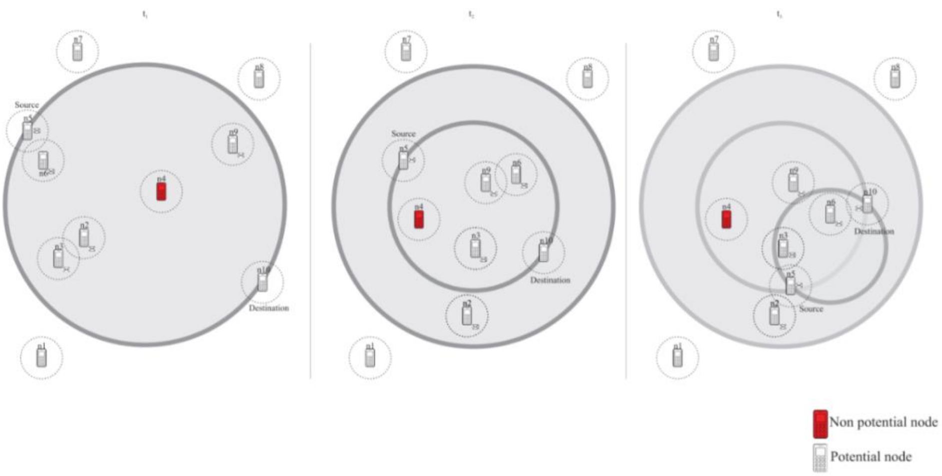


Figure 3. When the source and destination node moves, at time t1 node n5 is located at (x, y) and the destination is at(x', y'); when the source or destination moves close, the boundary will also become small at time t2, at time t3 the boundary become smaller when source and destination moved to close.

1. smart mobile devices are enabled with GPS and capable of capturing, storing location information.

The Figure 3 shows the example of dynamic nodes at the time t_1, where the source node is located at $S\ (x, y)$ and the destination node at $D\ (x', y')$. Due to the dynamic nature, the nodes move closer to the destination, and meantime the boundary also becomes smaller at time t_2. At the time t_3 source node moves closer to the destination, and the boundary becomes smaller than the boundary as is in t_1 & t_2. If the source and destination move far from each other than the boundary becomes bigger.

Theorem 5.1 *(Message availability):* By Little's law and balanced equation for node density. Where $B \geq\geq r$, at the criticality condition.

$$\bar{M} T_s c \geq 1 \tag{2}$$

is satisfied, the mean number of nodes in the boundary with the message $\bar{m}$ is given by

$$\bar{m} = M - \frac{1}{T_s c X}$$

The mean number of nodes without a message, denoted with $\bar{n}$, is

$$\bar{n} = \frac{1}{T_s c X} \tag{3}$$

Proof: By using the balance equations, we find the mean number of nodes. The mean number of nodes in the nodes, which is having the message that leaves the boundary and also the nodes which are not having the message and contact with the nodes having a message and successfully exchanging it. The mean sojourn time in the boundary is T_s and assume the nodes with a message are distributed uniformly within the boundary then $\frac{m(t)}{T}$ will be nodes with message leaving the boundary at time t. The nodes can exchange/acquire the message within the boundary, and it is determined by the frequent encounter of a node with a message and a node without a message. The mean rate of encounter of a node within the boundary is given by c (the mean rate of two nodes comes in contact), and inside the boundary, it is multiplied with the number of pair nodes at time t is $\frac{M(t)(M(t)-1)}{2}$. For these contacts, which increase $m(t)$ are the two nodes (only one node of the two has the message) which contact each other and exchange message successfully. As $p_m(t) = \frac{m(t)}{M(t)}$ the fraction of nodes having a message in the boundary and X is the probability of a message successfully transferred. The mean rate when $m(t)$increases at t are given by

$$2p - m(t)\big(1 - pm(t)\big)X\frac{M(t)(M(t)-1)}{2}c \quad (4)$$

Since $M(t) \gg 1$, can be approximate with the Equation (4) with $cm(t)n(t)X. hence\ we\ have$

$$c\overline{mn}X - \frac{\overline{m}}{T_S} = 0 \quad (5)$$

Over time, *n* increases because of the arrival of new nodes into the boundary; when the nodes leave the boundary without a message, then *n* decreases, and if nodes come into the boundary without a message and contact the node, which is having a message. Hence by Little's law and balance equation, we get (3). Hence proved.

$$\lambda - c\overline{mn}X - \frac{\overline{n}}{T_S} = 0 \quad (6)$$

Optimal Multicopy Scheme (OMS)**:** HMCRA is an optimal multi-copy scheme, if a node generates a message *m*, it also selects the destination node and creates a boundary *B*. Similarly, if a node contacts another node within the boundary, a message is replicated only if it is a potential node. Let *r* be the replication range, *B* is the Boundary, and *P* is the potential node shown in Algorithm 1.

Algorithm 1:	Replication of Message by node $n_i\ to\ n_j$
Input:	M_i Messages carried by the node n_i
Output:	Message Replication decision

for $m \in M_i$ do

if *j == Potential_node && r ≤ B* **then**

Replicate m to j

Else

No Replication

Theorem 5.2: The Performance of Floating Content (Sisodiya, S., et al., 2017) with replication range *r* and availability range a does not exceed that of OMS with *r ≤ B* where *B* is a Boundary.

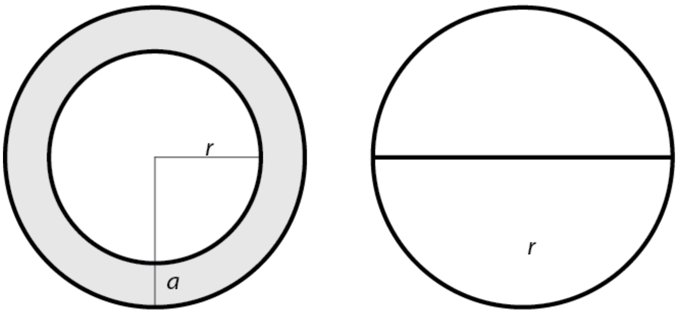


Figure 4. a) Floating Content, b) Proposed model

Proof: Let us consider the Floating Content that divides the locality into two regions viz., a region with white circular $r$and annular region grey radii r and a. Replication of contents happen automatically within the r and probabilistically within a. But OMS has only one region, as shown in Figure 4.b, and contents are replicated probabilistically in the white circular region r.

At any time interval t, let $n_r(t)$ and $n_a(t)$ be users number within circular and annular regions, respectively. The user's number within locality received concerned messages whenever OMS is considered and given by $p * n_r(t)$. But in the Floating content case, this gives $n_r(t) + P * n_a(t)$. The OMS and Floating Content difference at time t is given by, $\Delta(t) = (1 - p) * n_r(t) + P * n_a(t) \geq 0$

B. Selecting the potential nodes by fuzzy logic

Fuzzy set theory is an efficient method in case of input uncertainty. Fuzzy firstly introduced by Zadeh (Srinidhi, N. N., et al., 2019); after considering fuzzy logic into the network, a set of crisp values and fuzzy values are used to provide precise results. In an opportunistic network, uncertainty is the key aspect; hence probabilistic theory is applied. Select all the nodes which are inside the boundary and apply fuzzy rules to find the potential nodes, as shown in Algorithm 2. The table will get updates at a regular instant time with the information respect to the node, as potential or not, as shown in Table 2 & 3. Here Table 2 & 3, is identical to the message forwarding scenario shown in Figure 2.

Table 2. Fuzzy updation table at time t_1

Nodes	Value
n_5	Potential
n_4	Potential
n_2	Potential
n_3	Potential
n_{10}	Non-potential
n_8	Potential
n_{11}	Potential

Table 3. Fuzzy updation table at time t_2

Nodes	Value
n_5	Potential
n_4	Potential
n_2	Potential
n_7	Potential
n_3	Potential
n_{10}	non potential
n_8	Potential
n_9	non potential
n_{11}	Potential

The fuzzy model with three linguistic input variables is applied within the boundary to find the potential nodes, and it is accomplished in four steps, as shown below.

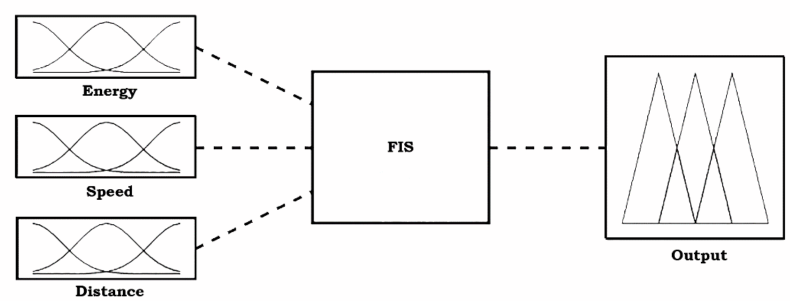


Figure 5. FIS

Linguistic Inputs

The model with three inputs, which are based on energy, speed, and distance, are applied to select the potential nodes, as depicted in Figure 5.

- *Node's energy:* The first fuzzy input shown in Figure 6 is energy; in the network, each node will consume energy for scan, transfer, and to receive the message. Where *(e_c)* is energy consumption, and it is calculated by adding e_s, which scans the *(t_x)* message transmission and *(r_x)* message receiving **node(n_i)* is the consumption of energy by a particular node. Hence the node's residual energy is given by (8)

$$e_s = (e_s + e_{tx} + e_{rx}) * n_i \quad (7)$$

$$Energy = e_{init} - e_c \quad (8)$$

where, e_{init} is the initial energy. The node's energy is deliberated at an instant time to update the residual energy.

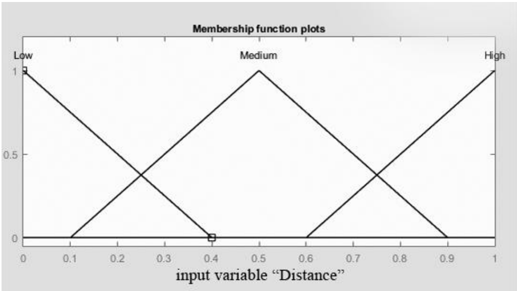


Figure 6. Energy

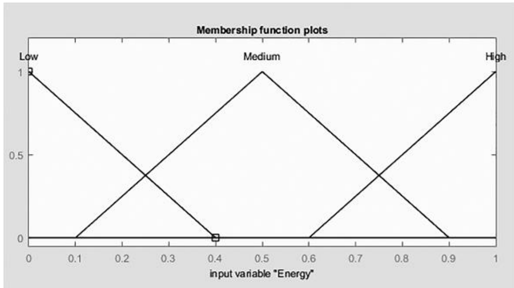


Figure 7. Distance

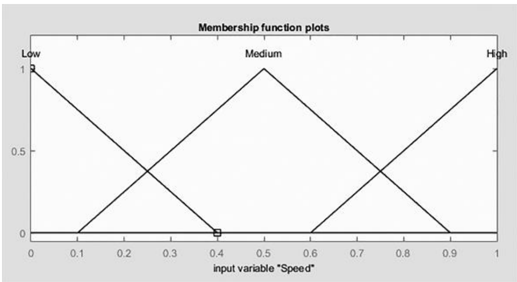


Figure 8. Speed

- *Node’s distance:* The second fuzzy input is shown in Figure 7 is the distance, here Euclidean distance is applied to find the distance between two nodes, and it is calculated by using the Equation (9)

$$D(n_i, n_j) = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (9)$$

Where n_i is the source node, and n_j is a neighboring node.

- *Node’s speed:* The third fuzzy input shown in Figure 8 is speed, and it is obtained by Equation (10). Nodes in OppIoT are dynamic and moves in various directions, also with waffling speed. The nodes which are moving in over speed are discarded for message transfer, and it is treated as unstable nodes. In order to find these types of nodes, the mean speed is compared with the moving speed. If nodes speed is higher than that of mean speed, then those nodes are rejected for delivering the data. The speed of the node is calculated as follows.

$$speed - factor = average - speed - current - speed \quad (10)$$

If a negative value is generated by speed_factor, then it is considered that node as crossed the average speed, and it is moving in over speed, which makes the node not pertinent for delivery of a message. Hence speed is also an important factor in selecting a potential node.

1) *Fuzzification Process:* The process of transformation of a crisp value into a fuzzy value is known as the fuzzification process. Here three input linguistic variables are connected with the AND operator. Triangular and trapezoidal are the membership functions used in the proposed method to map crisp values to fuzzy sets. The less, average, and more are considered as fuzzy values. Equation (11) provides a membership function for more and is represented as

$$M_{more}(x) = \begin{Bmatrix} 0, & x < l_1 \\ \frac{x - l_1}{l_2 - l_1}, & l_1 \leq x \leq l_2 \\ 1, & x > l_2 \end{Bmatrix} \quad (11)$$

Equation (12) provides a membership function for average and is represented as

$$M_{average}(x) = \begin{Bmatrix} 0, & x < m_1 \\ \frac{x - m_1}{m_2 - m_1}, & m_1 < x \leq m_2 \\ \frac{m_3 - x}{m_3 - m_2}, & m_2 < x < m_3 \\ 0, & x \geq m_3 \end{Bmatrix} \quad (12)$$

Equation (13) provides a membership function for less and is represented as

$$M_{less}(x) = \begin{Bmatrix} 0, & x > n_1 \\ \frac{n_1 - x}{n_1 - n_2}, & n_2 \leq x \leq n_1 \\ 1, & x < n_2 \end{Bmatrix} \quad (13)$$

2) *Fuzzy Interference Rule-Base:* The FIS is a decision-making system that takes the inputs and produces the outputs based on the interference rule. Mamdani FIS is used, and the internal processing is based on fuzzy rules and fuzzy arithmetic. Equation (14) shows the first input's inference rule.

$$\text{“}If\ Energy\ is\ less\ AND\ Speed\ is\ less\ AND\ Distance\ is\ less\ then\ Output\ is\ less.\text{”} \quad (14)$$

Here three variables are taken as input, and each variable has three input values. Therefore, 27 different rules will be there for all combinations of inputs as delineated in TABLE 4.

Table 4. Fuzzy Rules

Sets	Energy	Speed	Distance	Output
1	L	L	L	L
2	L	L	A	L
3	L	L	M	L
4	L	A	L	L
5	L	M	L	L
6	L	A	M	L
7	L	A	A	L
8	L	M	M	L
9	L	M	A	L
10	A	A	L	A
11	A	M	L	L
12	A	L	L	A
13	A	L	A	M
14	A	L	M	M
15	A	A	M	A
16	A	A	A	A
17	A	M	A	A
18	A	M	M	A
19	M	A	L	A
20	M	M	L	L
21	M	L	L	A
22	M	L	A	M
23	M	L	M	M
24	M	A	A	A
25	M	A	M	A
26	M	M	A	A
27	M	M	M	A

Where L = Less, A = Average, M = More.

3) Defuzzification: The final step after fuzzification is defuzzification. Equation (15) is used to get the best crisp values based on the fuzzy sets using the mathematical method. There are many types of defuzzifiers like the Centroid of Area (COA), Mean of Maxima (MeOM), and many more. Among them, COA is considered for defuzzification. The defuzzification z_C is given by

$$z_c = \frac{\int_z \mu_A(z) z dz}{\int \mu_A(z) dz} \tag{15}$$

Where, $\mu_A(z)$, is the aggregated output membership function.

C. Genetic Algorithm for Optimal Path

The genetic algorithm (GA's) have been successfully and widely used to solve the constrained optimization problems based on the laws of natural evolution and genetics (Srinidhi and et al., 2017). The proposed algorithm uses the following function to apply a genetic algorithm.

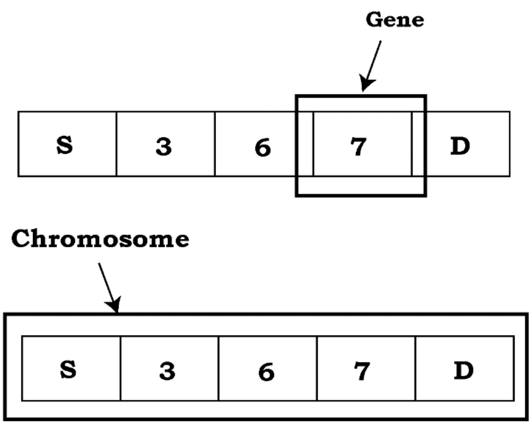
$$D(hopcount) = \begin{cases} 0, & if\ hopcount = 1 \\ 1, & if\ hopcount > 1 \end{cases} \quad (16)$$

Equation (16) explains if D (hop count) > 1where destination D receives a message with more than one hop count, ensuingly GA is used. If D (hop count) = 1, then no need to apply the GA, and it is considered as optimal path as shown in Algorithm 3.

A. Chromosome Initialization

The initial population is created by selecting all the potential nodes which are updated in the β, and it is generated randomly. In the proposed work nodes are treated as gene, and the route from source to destination is called a chromosome. A set of chromosomes is called a population. Here intermediate nodes will differ during message transfer towards the destination while keeping source and destination as constant. In each generation, the fitness function is applied to the chromosome to evaluate and find a suitable chromosome for the next generation. The population of resultant generations is devised by selecting and altering the suitable prior chromosomes. Only the suitable chromosomes are selected from the population, and the rest of the chromosomes are discarded. In Figure 9, the chromosomeS-3-6-7-D. Where S is the source, D is the destination and 3,6,7 are the intermediate nodes.

Figure 9. Chromosome Representation and Initialization



B. Fitness Function

The core of the genetic algorithm is a fitness function and is also referred to as an objective function. In other words, the fitness function is applied and evaluated on each chromosome to remove the poor chromosome. In the proposed genetic algorithm, delay is selected as a fitness function; hence the path which is having fewer delay is elected.

$$fitness\ function\ (Delay) = \frac{Sum * t_{ij}}{N_{mr}} \tag{17}$$

C. Parents Selection

The selection of parents is carried out randomly; it is selected according to their best value of fitness function, and parents who are best fitted are selected for crossover. In rank-based, the chromosomes are selected on the basis of the fitness function. Chromosome, which is having the highest fitness value, is selected as a parent.

D. Crossing Over

Crossover is a technique to merge two best chromosomes to generate new offspring. The concept behind crossover is that the offspring will be finer than the parents because it takes only the best characteristics from each of the parents. Here the best-fitted parents are selected and applied the single-point crossover method to produce offspring.

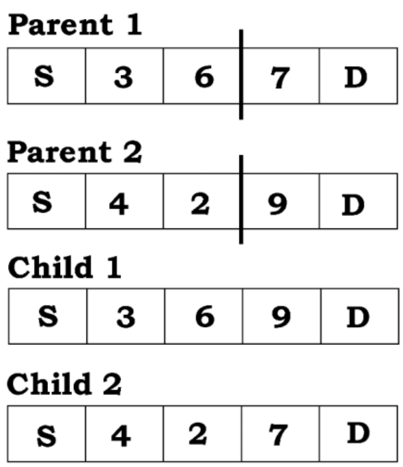


Figure 10. Single-Point Crossover

E. Mutation

The flipping of a random bit and changing the information of the chromosome is referred to as a mutation. It is always applied to the offspring by checking the following four conditions. The mutation is applied to the resulting offspring, and it is carried out on the following conditions

- Case 1: If the size of the chromosome is three, then only the middle node of the chromosome is changed with the missing node.

- Case 2: If duplicate nodes are present in the chromosome, then flip the repeating nodes with new nodes.

- Case 3: If there are no repeating or missing nodes in the chromosome, then select any two nodes randomly and move them.
- Case 4: If the new offspring is smaller when compared with the average fitness of the previously generated chromosome, then the node x of the chromosome y can be changed.

Algorithm 3: Genetic Algorithm to Find Optimal Path

Input: Select all the nodes which are in β
Output: To find the optimal path
if *hop count == 1* then
it is an optimal path
else
$hop\ count\ \geq\ 1$
Select all the nodes in β
Randomly initialize the chromosome
Apply the $fitness\ Function\ (Delay) = \frac{Sum*t_{ij}}{N_{mr}}$
Parents selection on rank base
Single Point cross over
Mutation
Optimal Path

Simulation and Results

A. Simulation Settings

This part of the section provides the evaluation of the proposed HMCRA, and the proposed work is simulated using ONE simulator (Guan, X., Chen, M., &Ohtsuki, T. 2012). The different parameters employed during simulation are represented in TABLE V. Here, the proposed HMCRA performance has been compared with Epidemic (Lilien, L., et al., 2007), Prophet (Srinidhi, et al., 2019), and GTACR (Dhurandher, S. K., et al., 2018) routing protocols, with changing TTL values from100 to 300 seconds, nodes number from 51 to 198, and interval of message creation from 25 to35 seconds.

B. Simulation results and performance analysis

This section provides the proposed algorithm performance in comparison to probability of delivery, time in the buffer, hop count, overhead ratio, and latency in par with relative algorithms.

Table 5. Simulation Parameters

Parameters	Value
Area Considered	(4,300 x 3,500) sq. m
Nodes Considered	198
Nodes Group	6
Pedestrians Group	3
Pedestrian's Walking Speed	0.5 – 1.5 km/h
Buffer size of pedestrian	15 Mb
Trams Group	3
Nodes Number in each trams group	2
Tram Speed	6.5 Km/h
Transmitting speed of Bluetooth	250 K
Range of Bluetooth	20 meters
TTL for each message in group	100 minutes
Interval of message	25 - 35 seconds
Size of the message	500Kb - 1Mb
Mobility model	Shortage path map-based movement model
Time allocated for simulation	100000 seconds

Figure 11, Figure 12, and Figure 13 compares the average latency of various algorithms when the nodes number, TTL, and interval of message generation is varied accordingly. HMCRA average latency is lesser in contrast with all other relative routing algorithms, which is resultant of efficient routing of data in a path with less number of hops obtained after applying HMCRA. Hence, HMCRA minimizes latency during routing of data from source to destination.

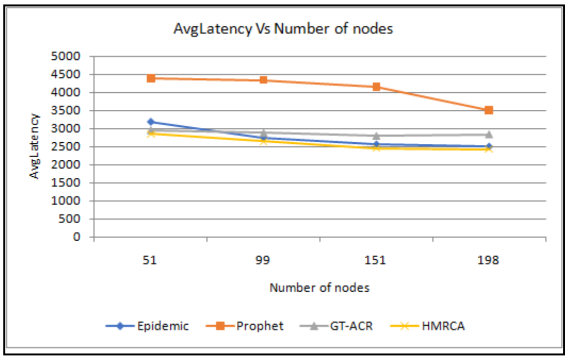


Figure 11. Average vs nodes number

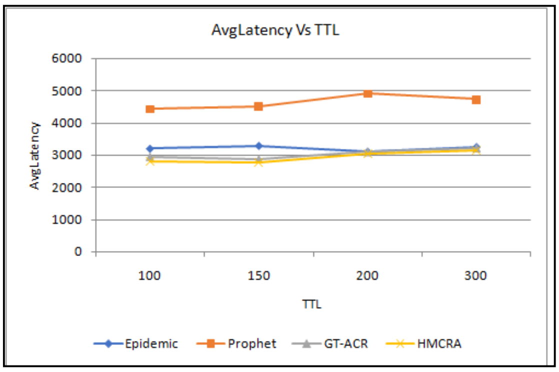


Figure 12. Average latency vs TTL

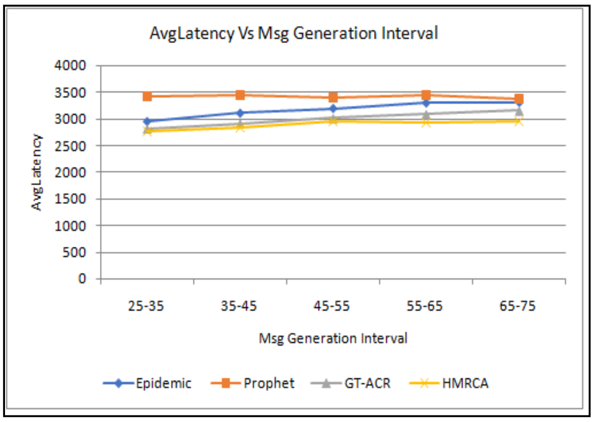


Figure 13. Average latency vs interval of message generation

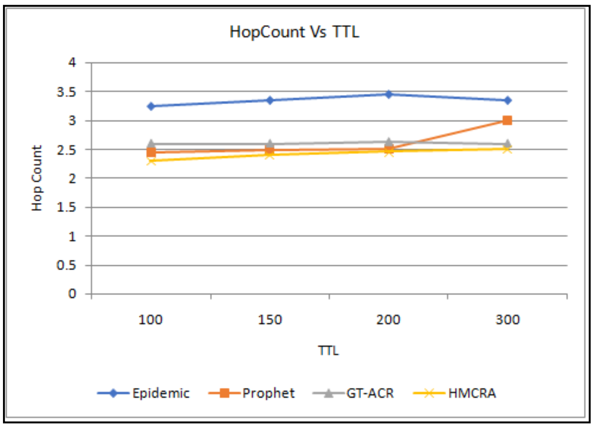


Figure 14. Hop count vs TTL

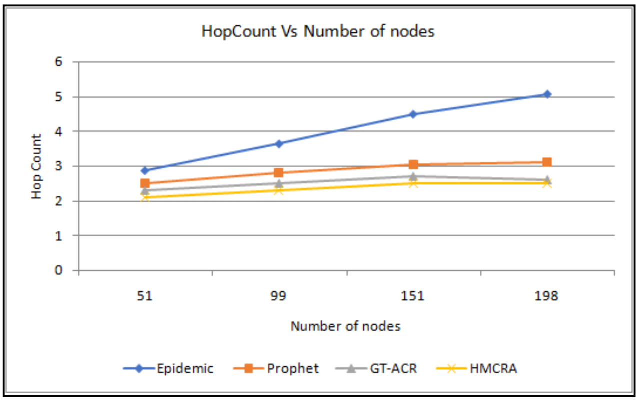


Figure 15. Hop count vs nodes number

Figure 14, Figure 15, and Figure 16 provide an effect on hop count when the nodes number, TTL, and interval of message generation is varied accordingly in par with relative algorithms. HMCRA uses fewer hops in forwarding order data from source to destination when compared to other similar routing algorithms HMCRA takes a fewer amount of hop count while delivering data towards the destination on par with relative algorithms. HMCRA algorithm selects potential nodes by making use of fuzzy rules. Here node having a higher value in fuzzy will be taken into consideration. These nodes data will be forwarded in the reliable path having fewer hops obtained after applying GA. GA provides a path with a fewer number of hops after doing mutation and crossover. Finally, data is forwarded from efficient nodes in a reliable path obtained after applying fuzzy logic and GA.

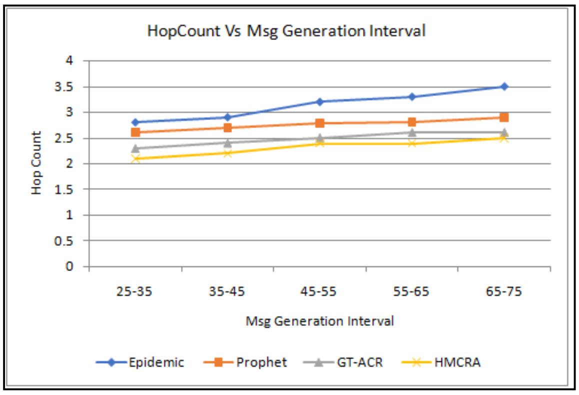


Figure 16. Comparison of the hop count vs message generation

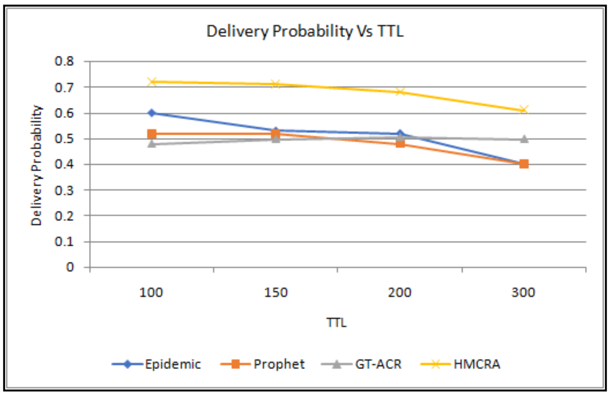


Figure 17. Delivery probability vs TTL

Figure 17, Figure 18, and Figure 19 provide the probability of delivering packets when the nodes number, TTL, and generation of messages interval is changed respectively, and it is compared along with relative algorithms considered. The HMCRA better performs than the various considered algorithms with respect to the probability of delivering messages towards the destination as the proposed HMCRA selects only nodes having optimal value with respect to distance, speed, and energy, which are considered as parameters. These selected nodes aids in delivering data towards a reliable path selected using the proposed algorithm for longer time results in an increased probability of message delivery.

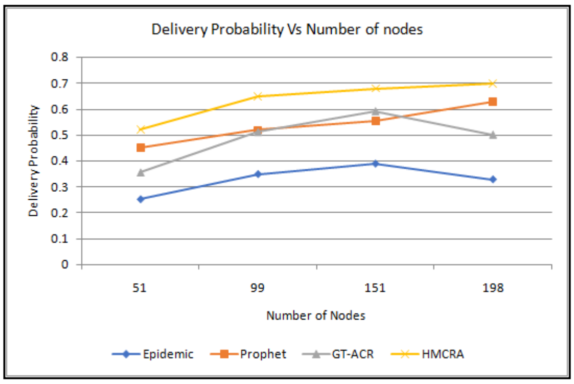


Figure 18. Delivery probability vs nodes number

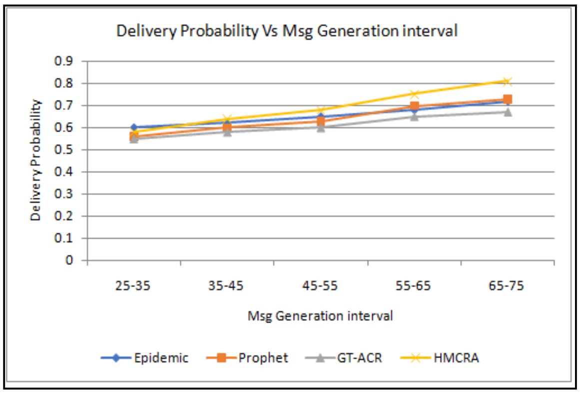


Figure 19. Delivery probability vs message generation

Figure 20 provides an overhead graph when compared with the interval of generating the message, and results are compared with considered algorithm types. HMCRA has a less overhead ratio in comparison to various other types of considered algorithms is due to the forwarding of data in the reliable path having less number of hops and this less amount of hops will reduce network overhead. The selection of reliable nodes using the proposed algorithm will help prolong nodes' lifetime which reduces overhead in selecting nodes for forwarding of data towards the destination.

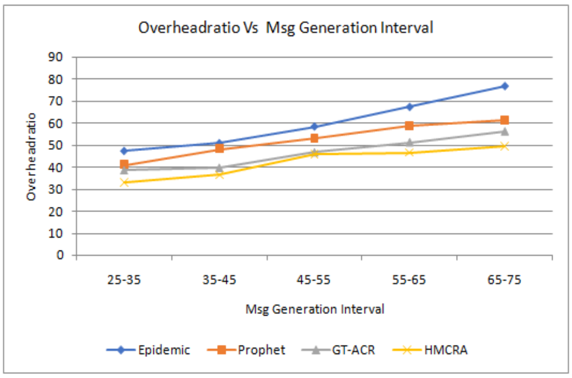


Figure 20. Comparison of the overhead ratio vs interval of message generation

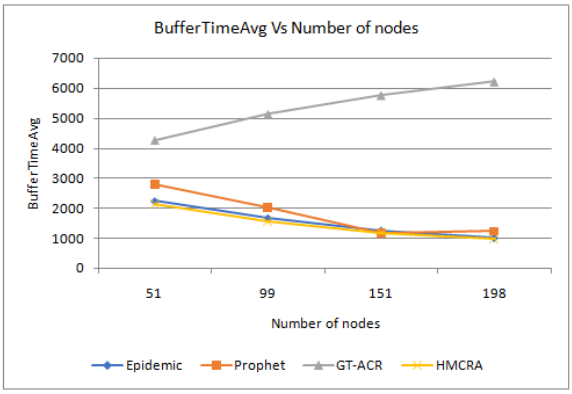


Figure 21. Comparison of the average buffer time vs nodes number

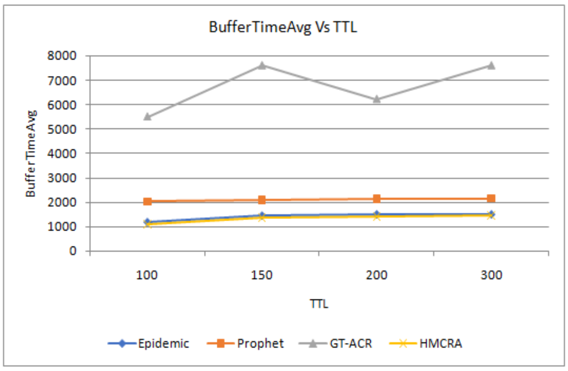


Figure 22. Comparison of the buffer time average vs TTL

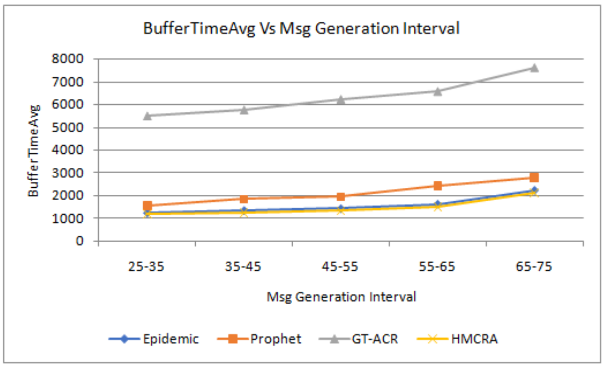


Figure 23. Comparison of the buffer time average vs interval of message generation

Figure 21, Figure 22 and Figure 23 delineate the effect on average buffer time when the nodes number, TTL, and Interval of Message Generation is varied accordingly and compared with various similar algorithms. HMCRA has almost similar average buffer time compared to Epidemic routing because of time spent in finding potential next forwarder node with high delivery probability keeps message for an extended period of time than the normal, and when the nodes number increases, the amount of time taken in order to find potential forwarder nodes also increases. In contrast, the average buffer time taken is slightly lesser than the Epidemic. Increased TTL will also have a similar impact as the message stays longer time in the buffer space of the node without being forwarded. The proposed algorithm average buffer time is almost similar to that of epidemic routing.

Conclusion and Future Work

Improving the performance of the IoT network in an opportunistic scenario is very much important due to the frequent change in the movement of nodes and the non-availability of the fixed routing paths. In order to address these challenges, HMCRA, which is a multi-copy routing algorithm, is propounded, which uses fuzzy logic rules to select potential nodes and provides a reliable path for forwarding data towards destination using GA. The results obtained after evaluating the proposed method using simulation concludes the following (i) During the selection process of nodes, the proposed method differentiates nodes into potential and non-potential nodes based on the rules of fuzzy logic to forward the data and to reduce the nodes failure rate while data forwarding towards the destination. (ii) HMCRA uses GA in order to selectreliable path among various other available path with the help of carrying mutation and crossover on the obtained resultant set. (iii) Proposed algorithm result outperforms in terms of various network parameters in par with similar considered algorithms, while average buffer time remains almost similar to Epidemic routing algorithm. Further to this solution the algorithm can be made more efficient by minimizing nodes selection time which has negative impact on overall message time in the buffer and also it could be made more efficient by considering energy conserving solution while routing of data towards the destination.

Acknowledgements

SERB-DST has funded this work with Project File No. EEQ/2017/000681.

References

Fixed, V. G. (2016). Mobile Internet Traffic Forecasts. *URL: https://www. cisco. com/c/en/us/solutions/service-provider/visualnetworking-index-vni/index. html*, *328*.

Ippisch, A., Sati, S., &Graffi, K. (2018, May). Optimal replication based on optimal path hops for opportunistic networks. In *2018 IEEE 32nd International Conference on Advanced Information Networking and Applications (AINA)* (pp. 251-258). IEEE.

Jia, B., Li, W., & Zhou, T. (2017, July). A novel P2P service discovery algorithm based on Markov in internet of things. In *2017 IEEE International Conference on Computational Science and Engineering (CSE) and IEEE International Conference on Embedded and Ubiquitous Computing (EUC)* (Vol. 2, pp. 26-31). IEEE.

Boldrini, C., Conti, M., Jacopini, J., &Passarella, A. (2007, June). Hibop: a history based routing protocol for opportunistic networks. In *2007 IEEE international Symposium on a world of wireless, mobile and multimedia networks* (pp. 1-12). IEEE.

Sharma, D. K., Dhurandher, S. K., Woungang, I., Bansal, A., & Gupta, A. (2017, August). GD-CAR: a genetic algorithm based dynamic context aware routing protocol for opportunistic networks. In *International Conference on Network-Based Information Systems* (pp. 611-622). Springer, Cham.

Burgess, J., Gallagher, B., Jensen, D. D., & Levine, B. N. (2006, April). MaxProp: Routing for Vehicle-Based Disruption-Tolerant Networks. In *Infocom* (Vol. 6).

Makhlouta, J., Harkous, H., Hutayt, F., &Artail, H. (2011, October). Adaptive fuzzy spray and wait: Efficient routing for opportunistic networks. In *2011 international conference on selected topics in mobile and wireless networking (iCOST)* (pp. 64-69). IEEE.

Ott, J., Hyytiä, E., Lassila, P., Vaegs, T., &Kangasharju, J. (2011, March). Floating content: Information sharing in urban areas. In *2011 IEEE International Conference on Pervasive Computing and Communications (PerCom)* (pp. 136-146). IEEE.

Park, J., Lee, J., Kim, S. K., Jang, K., & Yang, S. B. (2016). A forwarding scheme based on swarm intelligence and percolation centrality in opportunistic networks. *Wireless Networks*, *22*(8), 2511-2521.

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.

Zadeh, L. A. (1965). Information and control. *Fuzzy sets*, *8*(3), 338-353.

Lilien, L., Gupta, A., & Yang, Z. (2007, April). Opportunistic networks for emergency applications and their standard implementation framework. In *2007 IEEE International Performance, Computing, and Communications Conference* (pp. 588-593). IEEE.

Srinidhi, N. N., Sagar, C. S., Chethan, S. D., Shreyas, J., & Kumar, S. D. (2019, December). Machine Learning Based Efficient Multi-copy Routing for OppIoT Networks. In *International Conference on Computational Intelligence, Security and Internet of Things* (pp. 288-302). Springer, Singapore.

Srinidhi, N. N., Nagarjun, E., & Kumar, S. D. (2019, November). HMCRA: Hybrid Multi-Copy Routing Algorithm for Opportunistic IoT Network. In *2019 International Conference on Smart Systems and Inventive Technology (ICSSIT)* (pp. 370-375). IEEE.

Sok, P., Tan, S., & Kim, K. (2013, November). PRoPHET routing protocol based on neighbor node distance using a community mobility model in delay tolerant networks. In *2013 IEEE 10th International Conference on High Performance Computing and Communications & 2013 IEEE International Conference on Embedded and Ubiquitous Computing* (pp. 1233-1240). IEEE.

Nelson, S. C., Bakht, M., &Kravets, R. (2009, April). Encounter-based routing in DTNs. In *IEEE INFOCOM 2009* (pp. 846-854). IEEE.

Kumar, S. D., & Kumar, B. V. (2008, December). Energy-aware multicast routing in MANETs based on genetic algorithms. In *2008 16th IEEE International Conference on Networks* (pp. 1-5). IEEE.

Borah, S. J., Dhurandher, S. K., Woungang, I., & Kumar, V. (2017). A game theoretic context-based routing protocol for opportunistic networks in an IoT scenario. *Computer Networks*, *129*, 572-584.

Dhurandher, S. K., Sharma, D. K., &Woungang, I. (2013). Energy-based Performance Evaluation of Various Routing Protocols in Infrastructure-less Opportunistic Networks. *J. Internet Serv. Inf. Secur.*, *3*(1/2), 37-48.

Dhurandher, S. K., Borah, S. J., Woungang, I., Tibarewal, S., &Barolli, L. (2018). DEEP: distance and encounter based energy-efficient protocol for opportunistic networks. *Journal of High Speed Networks*, *24*(2), 119-131.

Sisodiya, S., Sharma, P., & Tiwari, S. K. (2017, February). A new modified spray and wait routing algorithm for heterogeneous delay tolerant network. In *2017 International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud)(I-SMAC)* (pp. 843-848). IEEE.

Srinidhi, N. N., Sunitha, G. P., Nagarjun, E., Shreyas, J., & Kumar, S. D. (2019, November). Lifetime Maximization of IoT Network by Optimizing Routing Energy. In *2019 IEEE International WIE Conference on Electrical and Computer Engineering (WIECON-ECE)* (pp. 1-4). IEEE.

Srinidhi, N. N., Kumar, S. D., &Banu, R. (2017, December). Internet of things for neophytes: A survey. In 2017 International Conference on Electrical, Electronics, Communication, Computer, and Optimization Techniques (ICEECCOT) (pp. 234-242). IEEE.

Guan, X., Chen, M., &Ohtsuki, T. (2012). Epidemic theory based H+ 1 hop forwarding for intermittently connected mobile ad hoc networks. *EURASIP Journal on Wireless Communications and Networking*, 2012(1), 1-10.

Bibliographic information of this paper for citing:

Srinidhi, N. N.; Nagarjun, E. & Dilip Kumar, S. M. (2021). Hybrid Algorithm for Efficient node and Path in Opportunistic IoT Network. *Journal of Information Technology Management*, Special Issue, 68-91.