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Breadth Fixed Gossip: a Route Discovery Mechanism in Ad Hoc Network

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Abstract – *The lack of information from a root node to neighbors becomes a particular constraint in a message delivery. While the transmission range of node needs to be considered also for ensuring a delivered packet message to them. Therefore, a route discovery mechanism is a good start to make a reliable path in an unknown environment. The objective of this study is to explore the implementation of Breadth First Search, fixed radius model, and gossip algorithms (Breadth Fixed Gossip) on the ad hoc network. Simulations were conducted to obtain the value of three metrics i.e. saved retransmission, transmission failure, and hop counts. These results were compared with Depth First Search and Gossip performance. It indicates that saved retransmission metric Breadth Fixed Gossip has a 58 times better performance, reduces transmission failure by 20%, and requires 50% more hops at transmission range below 15 than Depth First Search and Gossip.* ***Copyright © 2016 Praise Worthy Prize S.r.l. - All rights reserved.***

***Keywords**: Route Discovery, Breadth First Search, Gossip, Fixed Radius, Wireless, Ad Hoc Network*

Nomenclature

g	Gossip function
p	Forwarding probability
p_c	Critical probability
$G = (V,E)$	Graph model with node set V and edge set E
$O(b^d)$	Time complexity of depth d
r	A node range transmission
$m \times n$	Simulation area
l_{ij}	Link between node i and node j
D_i	Distance of node i
x_i	Coordinate of x at node i
x_0	Coordinate of x at initial or root node
y_i	Coordinate of y at node i
y_0	Coordinate of y at initial or root node
t_i	Number of retransmission at route i
h_i	Number of hop at route i
p_s	Number of successful in transmitting a packet message from a root node
n_i	Node i
$p_{flooding}$	Probability of flooding
$l_{r,16}$	Link between a root node and node 16
Tx	Transmission range

I. Introduction

A network is a group of people, a system or organization that aims at achieving the purpose of exchanging information through a wire or wireless media.

Given the increasing need for data communication and the lack of infrastructure availability, a wireless ad hoc network is an option to overcome the obstacles that spontaneously occur. The ad hoc network issue is a route discovery process, i.e. to establish and select the shortest route of messages/information distribution that is included in a routing protocol. To select a route, a root (source) node should identify, recognize, and record the neighbor nodes as a reference to select appropriate nodes which could relay the packet data to the destination. Moreover, a routing protocol can identify and prevent the attacks [1], such as geographic routing approaches, which investigated the similarities and differences based on design attributes and attack protection [2].

The discovery process is a complex issue when it is coupled with node mobility where each node moves arbitrarily moves to join or leave a group. Recently, several techniques related to route discovery have been proposed. To minimize and optimize a route rediscovery process, an attempt is offered based on cluster and compared with the existing routing protocols such as AODV. Referring to simulation results, the effectiveness and network performance of Quality of Service (QoS) improved [3]. Likewise QoS-DSR considers bandwidth constraint in MANET to select the appropriate route [4]. Also, [5] offers a routing method to minimize energy consumption to enhance the network life time. Ref. [6] presents Routing-IP model as an advance investigation to reduce energy consumption of each node in network. Moreover, it compared QoS performance with other models. Meanwhile, [7] it proposes a route selection

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based on fuzzy logic with hybrid optimization of Genetic Algorithm and Hill Climbing algorithm.

The availability of a communication network provided by ad hoc network is slightly reliable than the existing network infrastructure. Moreover, this network has dynamic movement, topology, limitation of energy resources for communication and computation. Therefore, the algorithm for this network should be robust against network dynamics and utilize minimum energy resources. This situation and requirements lead us to Gossip algorithm. It is a part of the mechanisms that has been proposed in routing protocols. This protocol evolved in combination with the existing method that offers probability technique to determine routes for information delivery. Gossip algorithm is a particular method for probabilistic broadcast on flooding technique [8]. Implementing this algorithm in ad hoc network is described as follows. It starts from a root node and conducts a searching process Depth First Search (DFS) algorithm, followed by computing the probability of the links among nodes [9]. The objective of DFS is looking for a destination on a deep branch.

In the large-sized network, the connection among the nodes becomes complex. Knowledge of members of the network's nodes is required. With DFS search, the possibility of one branch from a root node can be infinite, therefore, the chosen route may not be guaranteed as an optimal route. When compare with DFS, BFS is easy to implement, because it finds out first the solution at the same level, if not then it will be searched in a higher level.

Another problem arises when a node is selected as relay node by the previous node, so it must ensure that the relay node must be in the transmission range. Therefore, the authors propose the BFS search techniques combined with a fixed radius model and probabilistic broadcast. Fig. 1 depicts the route from the root to destination (node 25), through 5 relay nodes.

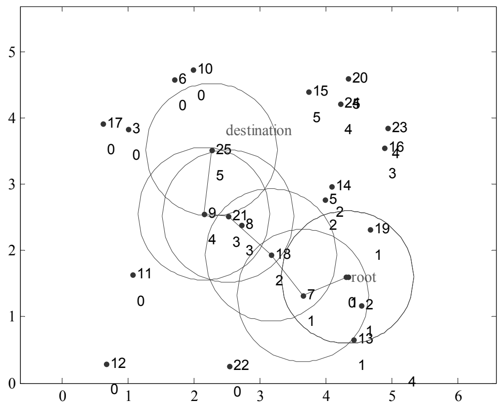


Fig. 1. A route discovery from root to destination node

The objective of this work is to propose a simple mechanism of route discovery in order to select an appropriate node as a relay node to disseminate information from source to destination in ad hoc network by combining Breadth First Search, fixed radius model, and Gossip algorithm. Our contributions in this work are:

1. Discovering a route that is available for source node to transmit the packet information
2. Selecting the appropriate the relay node when out of transmission range, and
3. Performing evaluation of the proposed a route discovery mechanism in metrics of transmission failure, hop counts, and saved retransmission.

The remainder of the paper is organized as follows: in Section 2, we present related work in particular development of Gossip algorithm and DFS. Meanwhile, in Section 3, Breadth Fixed Gossip (BFG) as the proposed route discovery mechanism is described in details. Simulation and results are presented in Section 4. And the last, Section 5 presents the conclusions of this study.

II. Related Work

This section describes the existing route discovery mechanisms based on Gossip algorithm and Depth First Search. Also, it denotes the benefit and drawback of both algorithms.

II.1 Gossip Algorithm

For the realization of topology in MANET, there are some models in random graphs. Fixed radius model is one of the models in which some points are placed randomly and which correspond to percolation theory. A key aspect in ad hoc network in disseminating information is random mobility in particular when nodes have partial knowledge of the network (e.g. route history, node location and schedule, mobility pattern) and nodes are outside of the transmission range. This situation forced the root node in network to select the appropriate node that is able to disseminate information to destination nodes or to other network members. Many attempts to achieve better performance by combining several algorithms are proposed, since it will affect other matters in performance metric, i.e. end-to-end delay or energy consumption. Therefore, selecting the appropriate node and a route discovery in the proposed mechanism should be simple and reliable.

The term Gossip, first stated by Demers et al. in 1987, has been implemented for distributed system [10]. The idea of Gossip was used for the implementation of updates distribution of databases replica in a distributed system, which evolved into the algorithm. Therefore, the information exchange randomly occurs when a node selects other members randomly.

The benefit of Gossip has been used and developed into a protocol that was implemented in sensor networks. Some research areas that become trending topics are data dissemination and reliable broadcast. Gossip routing protocol consists of a probability function of the input parameters [11]:

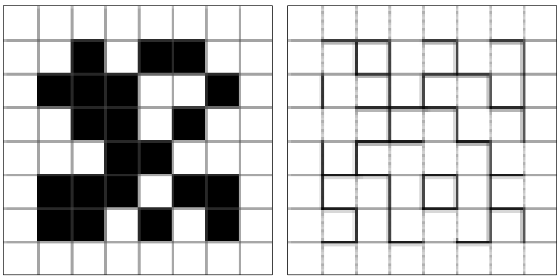
$$g(...) = p \quad (1)$$

$$g(...) \rightarrow [0,1] \quad (2)$$

The value of Gossip function (g) lies in 0 and 1. Generally, the Gossip function known as Gossip probability is based on percolation theory and random graphs.

Ref. [12] introduced percolation theory that learns geographic connectivity. It means that two locations are connected if they are near each other, and unconnected other than that. In a square lattice, a cluster is shown as a collection of occupied (nearest) neighboring sites, marked with the black dot [12]. This theory describes two models in the two-dimension square lattice, i.e. site and bond percolation [13].

In site percolation, it is considered that a lattice site is open (marked in black) with probability p and closed with probability $(1 — p)$. Fig. 2(a) illustrates site percolation. Meanwhile, in bond percolation model (Fig. 2(b)), each open edge of a lattice (marked in bold) is a probability p_c. p_c is the value of probability that allows a node to reach its neighbors. Based on previous studies, p_c value is ≈ 0.583 [14] – [16].



(a) Site percolation (b)Bond percolation

Figs. 2. Site and bond percolation [14]

The objective of Gossip algorithm as a broadcast technique is to achieve reliability in scalable group communication. Many applications used this technique in ad hoc networks and developed as Gossip protocol. Some recent works on applying Gossip algorithm in ad hoc networks and their achievements are discussed here.

Haas, Halpern and Li [17] showed that Gossip protocol improved performance up to 35% to obtain fewer messages than flooding in large network. For future work, they recommended Gossip protocol could be combined with optimization approach to achieve the better performance.

Li et. al [18] proposed regional Gossip routing that reduced overhead of generated message up to 94% than simple flooding.

Shi and Shen [19] proposed Adaptive Gossip Ad hoc Routing. Compared with AODV+G, it has reduced routing load by 29.2% and delay by 54.5%. Moreover, the throughput increased up to 2.7%.

Dimakis et al. [20] developed routing protocol based on Gossip and geographic information. This algorithm intended to improve energy consumption in the distributed nodes.

Dwivedi, Sharma and Sharma [21] investigated the variant of Gossip based Sleep Protocol (GSP) i.e. Adaptive GSP, Traffic-aware GSP and Battery-aware GSP in energy conservation.

Other studies are Gossip protocols involving a fuzzy method [22] and considering the adaptation of failures and network topology changes [23].

In previous studies, Gossip routing protocol has evolved to many applications and various methods to achieve better performances in ad hoc network. The advantages of Gossip algorithm can be listed as follows [24]:

- Gossip is easy to implement and selects the first partner to submit the information.
- It converges in rapid speed and can automatically adjust to the network.
- Gossip is a robust algorithm from changes and failures in the network.

Meanwhile, the drawback of Gossip algorithm is that it cannot estimate the size of a network in practice, therefore, we did not know how many rounds are needed to run the algorithm to approach the real value [25].

II.2 Depth First Search

A route discovery begins with searching algorithm because of unknown state in ad hoc networks. A searching algorithm is able to know the connection among members of the network and finds the shortest path to the desired node. DFS is one of the search algorithms used for graphs and trees.

It explores a branch (from a root) as deep as possible and uses stack data-structure. It allows the algorithm to be applied in both iterative and recursive forms.

The graph in a network can be modeled as $G = (V,E)$, where V denotes the set of nodes (vertices) and E denotes the set of edges. Fig. 3 depicts the DFS algorithm, which starts from 0 (as root) and the red arrows indicate the search order [26].

The obvious advantages of DFS are shown as follows [27]:

- The memory requirement is linear to graph search, because it needs to store a stack of nodes from the root to the current node.
- Time complexity of depth d is $O(b^d)$, i.e. DFS is time-limited rather than space-limited.
- When DFS finds solutions without deeply exploring a path, time and space are smaller.

The disadvantage of DFS is the possibility that the infinite graph can generate an infinite tree. Therefore, to solve this problem, depth d must be limited, but if d is too small, it may fail to find a solution. Also, DFS does not guarantee to find a solution if more than one solution exists [27].

Algorithm 1 Depth First Search

```
Input: Graph G = (V,E)
Output: DFS tree

Mark each vertex in V with 0 as a mark of being "unvisited"
count ← 0
for each vertex v in V do
    if v is marked with 0
        dfs(v)

dfs(v)
count ← count + 1
Mark v with count
For each vertex w in V adjacent to v do
    If w is marked with 0
        dfs(w)
```

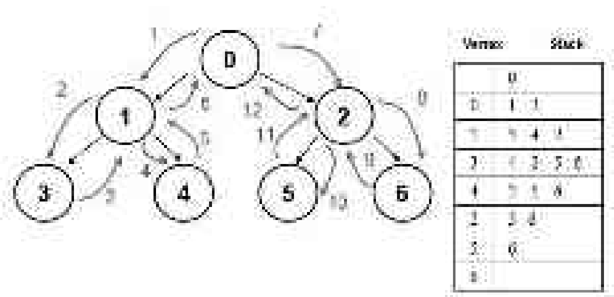


Fig. 3. DFS Visualization

III. Breadth Fixed Gossip Mechanism

This section proposes Breadth Fixed Gossip (BFG) mechanism for route discovery in ad hoc network. BFG is an approach that considers search algorithm and fixed radius model as an initial step and Gossip algorithm as a last determination step. The objective of this mechanism is achieving a route discovery and make successful delivery of a message from a root to a destination.

Breadth First Search (BFS) is a graph searching technique, which analyzes semantic graphs, decides the relationship of two vertices in a graph, and looks for the shortest path. Moreover, BFS could find paths between two vertices in a certain range [28]. The previous study shows that BFS is a search strategy with efficient memory usage and preventing node regeneration being it easy to implement [29].

BFS is used to illustrate the node graph in a network and their relationship. The objective of this graph is to determine how to reach the goal.

BFS starts a search from a single root assigned to level 0, continues to visit the neighbors sequentially on the right side first, i.e. 13, 14, and 5 assigning them as level 1 (see Fig. 4). Then, it proceeds to the next level, i.e. 4, 10, 2, and 11 as level 2. The process continues until the last level, i.e. 15 and 3 as level 3, node 9 and 8 as level 4, node 12 as level 5. This is illustrated in Fig. 4. Furthermore, it creates a list that records the entire nodes connectivity in a network [30]. This property is a significant matter for network routing, because the shortest path from root to destination can constructed and detected.

Thus, the implementation of BFS in wireless ad hoc networks becomes challenging because:

- Network size, number of members, and their connectivity are unknown.
- It overcomes DFS problem i.e. ensuring a minimal solution if some solutions exist that meet requirements such as relay node in transmission range, the shortest path, minimum hop count, and successful transmission exist.

How BSF can select one of the several solutions is described in detail using Fig. 4. First, a root searches the connectivity between the members of entire network and determines the level for each node. After locating the destination, the root knows that there are some relay nodes (node 13, 14, and 5) in its transmission range (fixed radius model). BFS can handle this situation and select node 13 as relay node because it is on the shortest path to node 4 (destination).

Algorithm 2 Breadth First Search [31]

```
Input: Graph G = (V,E)
Output: BFS tree

count ← 0
mark each vertex in V with 0
for each vertex v ∈ V do
    if v is marked with 0
        bfs(v)

bfs(v)
count ← count + 1
mark v with count
initialize queue with v
while queue is not empty do
    a ← front of queue
    for each vertex w in V adjacent to a do
        If w is marked with 0
            count ← count+1
            mark w with count
            add w to the end of the queue
    Remove a from the front of the queue
```

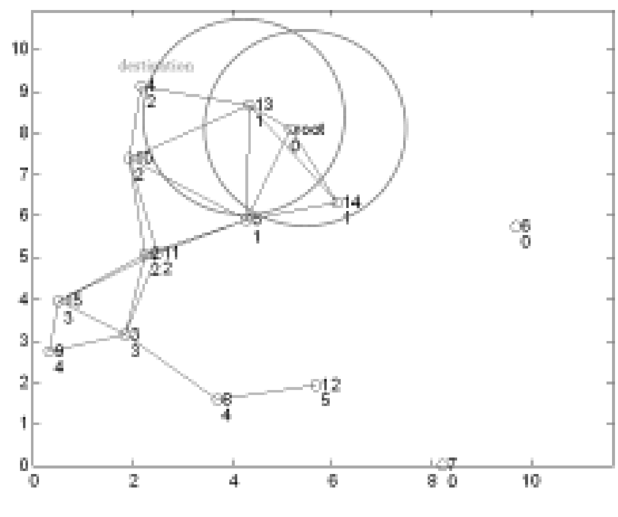


Fig. 4. Selected route of network members in envSize 10×10

In the fixed radius model, r indicates a node's communication range and scattered in $m \times n$ areas. A link between node i and j, denoted as link l_{ij}, has been added to the graph when it is smaller or equal to r, like $l_{1,4}$ in Fig. 5.

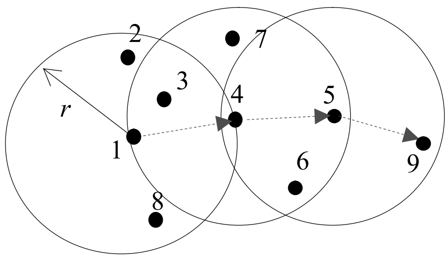


Fig. 5. Fixed radius model

Two kinds of neighbors should be considered, i.e. reachable and unreachable neighbors where nodes are located in fixed position. The distance of reachable neighbors per root is defined as:

$$D_i = \sqrt{\left(x_i - x_0\right)^2 + \left(y_i - y_0\right)^2} \leq r \quad (3)$$

D_i denotes distance to node i, x_0 and y_0 are x and y coordinates of the root looking for the relay node in its transmission range.

Figs. 6 show the flowchart of BFG mechanism. The flowchart consist of the main flowchart (Fig. 6(a)), the subroutine BFS (Fig. 6(b)), and the subroutine Gossip (Fig. 6(c)).

IV. Simulation and Results

Simulations are performed five times each in Matlab 7.10 to evaluate the performance of BFG, then the average of five running simulations was determined.

To prove BFG's significant performance, the simulation results have been compared with the performance of DFS+Gossip. Simulations were conducted following three metrics:

- Saved retransmission (*SR*): the number of transmission that could be saved when a link probability is higher than its flooding probability.

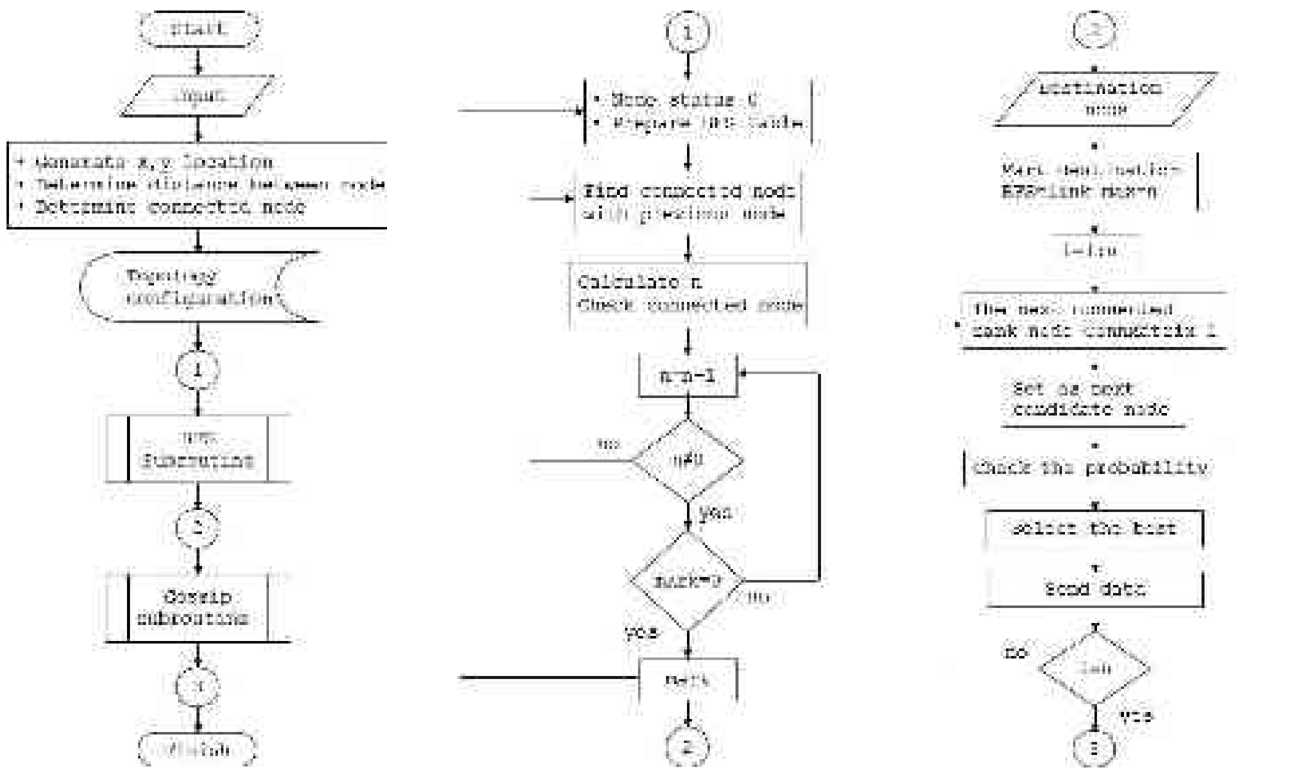
$$SR = \sum_{i=1}^{n} t_i \quad (4)$$

where t_i = number of retransmission at route i, i = 1,2,...,n

- Hop counts (*HC*): the number of hops from a root node to a destination node:

$$HC = \sum_{i=1}^{n} h_i \quad (5)$$

where h_i = hop route i, i = 1,2,...,n.



(a) Main flowchart of BFG (b) BFS Subroutine (c) Gossip Subroutine

Figs. 6. Flowchart of BFG mechanism

- Transmission failure (*TF*): a percentage of failure in transmitting a packet message from a source node to its neighbors in the network.

$$TF = 100\% - \frac{p_s}{(n-1)} \quad (6)$$

where p_s denotes a number of successful transmissions of a packet message from a root node and n as a number of nodes in network. The complete set of simulation parameters are shown in Table I.

TABLE I
SIMULATION PARAMETERS

Simulation Parameters	Values
Number of nodes	15 – 200
Transmission range	1 – 70
Environment size	10×10, 50×50, 100×100

At the beginning of the simulation, 15 nodes are generated in 10×10 field with transmission (Tx) range = 3. Node 1 is the root which has role as the source node. Then, BFS works to determine the level of each node in the entire network. First, BFS determines the 0 level and 1 starts from node 1 (Fig. 7). Note that 0 level means that node is the root itself or it is unreachable from the root. Then, node 8 and 15 are indicated as level 2 (Fig. 8).

Finally, level 3 is determined at node 9, 7 and 14 (Fig. 9(a)), and level 4 at node 2 (Fig. 9(b)). After BFS finishes its searching, the next step is specifying the relay node to distribute the packet message.

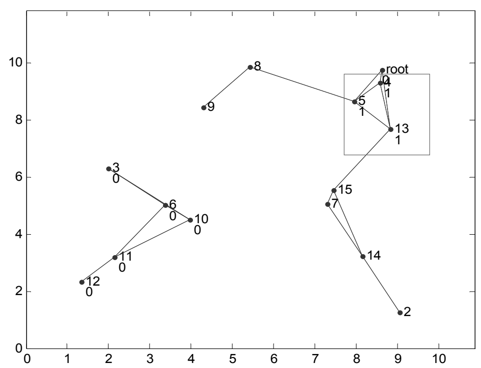


Fig. 7. Selected node for Level 0 and 1

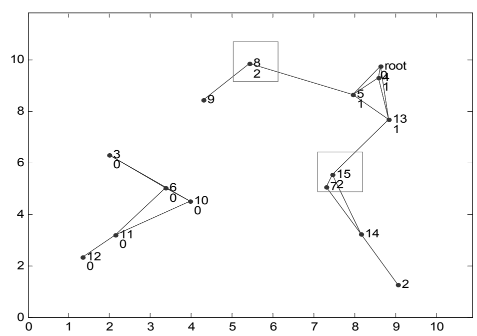
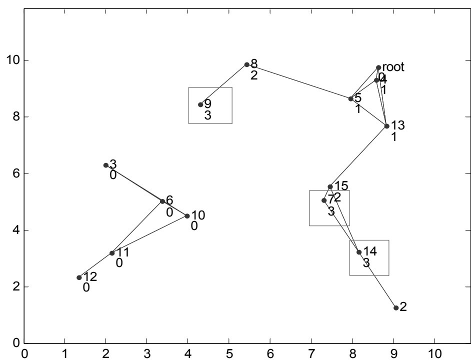
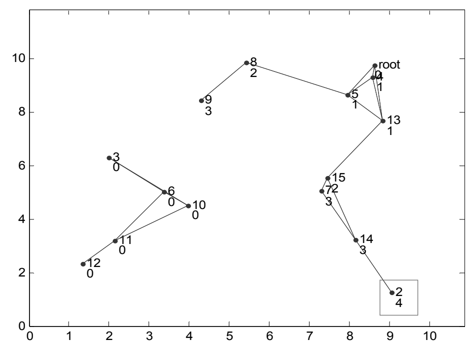


Fig. 8. Selected node for level 2



(a) Selected node for level 3



(b) Selected node for level 4

Figs. 9. Selected node of BFS technique

Considering that the destination is node 10, it can be determined that delivering packet message results in a failure because node 10 is level 0, which means unconnected. In this case, a fixed radius model has been implemented to support BFS, however, node 10 is outside of root's transmission range (Fig. 10).

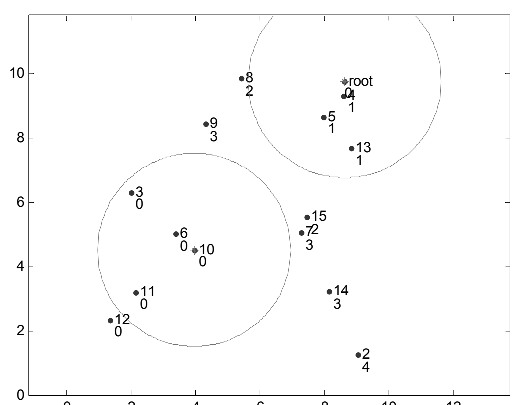


Fig. 10. Unconnected link between root and destination

Meanwhile, when the packet message is delivered to node 2 (destination), based on BFS algorithm and fixed radius model, the root will be connected to node 2 through node 13, 15, and 14 (Fig. 11). In other words, the root will send packet message in 4 hops to node 2.

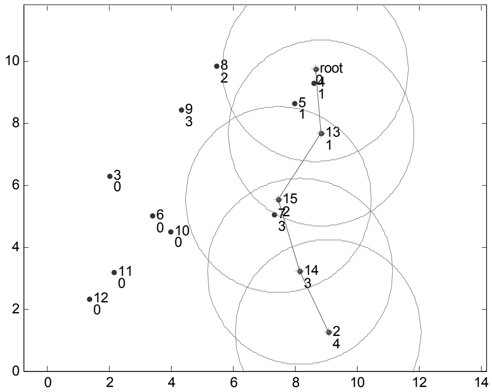
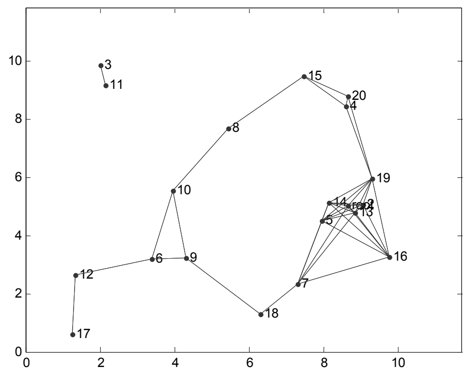


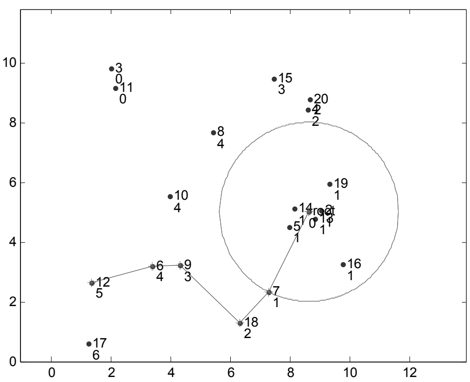
Fig. 11. Selected route between root and node 2

When the number of node is 20 in the same size of field with Tx range = 3, the connection is different. Suppose the destination is node 12. To determine relay nodes to reach node 12, there are several route options (Fig. 12(a)). Node 2, 5, 7, 13, 14, 16, and 19 are the nodes within the root's Tx range. To select one of these nodes, the requirement of Eq. (3) must be met and the link must have the higher probability than p_c.

Consider that links $l_{1,2}$, $l_{1,5}$, $l_{1,7}$, $l_{1,13}$, $l_{1,14}$, $l_{1,16}$, and $l_{1,19}$ are at the same level. Gossip algorithm compares their probabilities with p_c, then selects the highest link probability. A selected route is displayed in Fig. 12(b).



(a) Connected route of a network



(b) Selected route between root to node 12

Figs. 12. Network topology of 20 nodes

IV.1 Saved Retransmission

This subsection discusses the calculation of saved retransmission (SR) metric. This metric aims at reducing retransmission of message delivery to neighbors to save node's power. Fig. 13 shows the graph of BFG saved retransmission in transmission range (Tx) up to 5. It shows the maximum number of SR increases as the number of nodes rises in a larger transmission range. At Tx range 5, the number of SR is the highest than others. It can be explained that when there are many nodes within the transmission range, BFG selects the highest probability and farthest node to retransmit. Therefore, the other nodes are not obliged to retransmit. Referring Figs. 12 and Table II, 20 nodes at environment size 50×50, at Tx range = 20, there are four levels to distribute the packet message to the entire network. Thus, SR has been counted when nodes are at level 3 and 4.

TABLE II
BFG MAXIMUM SAVED RETRANSMISSION

Tx Range	Environment Size 50×50								Number of Nodes			
	15	20	30	40	50	60	70	80	90	100	150	200
1	x	x	x	x	0	x	x	x	x	0	x	0
5	0	0	0	0	0	0	0	1	1	3	1	8
10	0	1	0	4	7	6	12	23	34	35	73	105
20	2	7	9	22	25	30	42	52	68	75	112	168
30	5	12	17	26	23	40	54	62	72	79	131	180
40	7	15	23	31	31	47	57	67	78	89	142	163
50	9	17	25	33	37	53	61	71	81	95	145	192

Tx Range	Environment Size 100×100								Number of Nodes			
	15	20	30	40	50	60	70	80	90	100	150	200
1	x	x	x	x	0	x	x	x	x	0	x	0
5	0	0	0	0	0	0	0	0	0	0	x	0
10	0	0	0	0	0	0	0	1	1	3	1	18
20	0	1	0	4	5	2	3	14	24	14	61	105
30	0	3	4	17	9	8	13	19	43	25	64	159
40	2	7	9	22	25	30	42	52	68	75	112	165
50	1	13	9	27	26	36	45	60	70	80	120	177

x = there is no connected node

Some important points correspond to Table II:

- No connected nodes at Tx range = 1 although the number of nodes is up to 200.
- Considering Tx range = 40, the increasing node density (envSize vs nodes) in network, a number of SR is greater. Because of the increasing number of nodes in a Tx range, many nodes do not need to transmit the same message.
- While the environment size of network is getting bigger, a number of SR is getting smaller. This can be explained as follows: the number of nodes in network is fixed, but they spread in a larger area, therefore nodes are few in Tx range and SR becomes less.
- At envSize 50×50, SR is available from 80 nodes (Tx range = 5). Meanwhile, at 100×100, SR is available from 80 nodes at Tx range = 10.

The results indicate that the node density and Tx range increase, while the SR decreases.

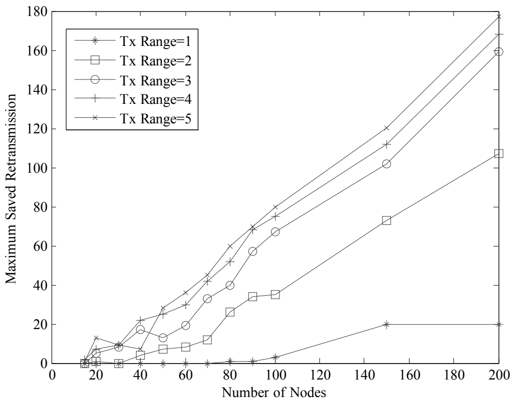


Fig. 13. Saved Retransmission at envSize 10×10

Consider 20 nodes at envSize 100×100, Tx range = 30, and the destination is node 17. The neighbors node are 2, 5, 7, 13, 14, 16, and 19 at level 1. Based on Gossip, a root calculate the link probability of neighbors. First, a root visited node 2, node 2 was initially set to 0 becomes 1. Because of $p_{flooding}$ = 0.625 and $p_{l_{1,2}}$ = 0.7117, thus $p_{l_{1,2}} \geq p_{flooding}$, and there is no need to retransmit (i.e. saved retransmission). Second, a root visited node 5, $p_{flooding}$ = 0.625, it is still constant and $p_{l_{1,5}}$ = 0.7837. Because $p_{l_{1,5}} \geq p_{flooding}$, then node 5 no need to retransmit (second saved retransmission). Third, a root visited node 7, $p_{flooding}$ is still constant (0.625), but $p_{l_{1,7}}$ = 0.3871. Because $p_{l_{1,7}} \leq p_{flooding}$, then node 7 retransmits the message. Fourth, node 7 visited node 18, $p_{flooding}$ = 1.6667 and $p_{l_{7,18}}$ = 0.4638. Because of $p_{l_{7,18}} \leq p_{flooding}$, node 18 retransmit. The process will continue until reaching a destination node. The topology configuration is shown in Fig. 14.

Table III shows the maximum SR of DFS+Gossip in various node density and Tx range. Table III shows no correlation between the number of nodes and Tx range. At Tx range 20 up to 40, the maximum SR is constant. Moreover, at Tx range = 50, the maximum SR is 1. But, at Tx range = 5, the maximum SR is up to 15. These results would seem to be contradicted with Table II, for the increasing number of nodes and Tx range. This occurs on a particular node within Tx range, because DFS does not perform the probability calculation for all links connected to a destination. Therefore, it can not select a link that has great potential to reach a destination. This way, the maximum SR is smaller than BFG. Figs. 15 compare and illustrate maximum saved retransmission in BFG and DFS+Gossip. Overall BFG has a better SR than DFS+Gossip, except at Tx range = 5, DFS+Gossip shows a better result. Referring to both results, BFG saved retransmission is 5 up to 58 times better than DFS+Gossip in various node densities and Tx ranges.

TABLE III
DFS+GOSSIP MAXIMUM SAVED RETRANSMISSION

Tx Range	Environment Size 50×50						Number of Nodes					
	15	20	30	40	50	60	70	80	90	100	150	200
1	x	x	x	x	1	x	x	x	x	1	x	1
5	1	1	2	1	1	1	1	3	6	2	5	15
10	1	2	4	4	3	7	6	3	6	6	5	7
20	2	3	3	2	3	2	2	2	3	2	2	4
30	2	2	2	2	2	2	2	2	2	2	2	3
40	2	2	2	2	2	2	2	2	2	2	2	2
50	2	1	1	1	1	1	1	1	1	1	1	2

x = there is no connected node

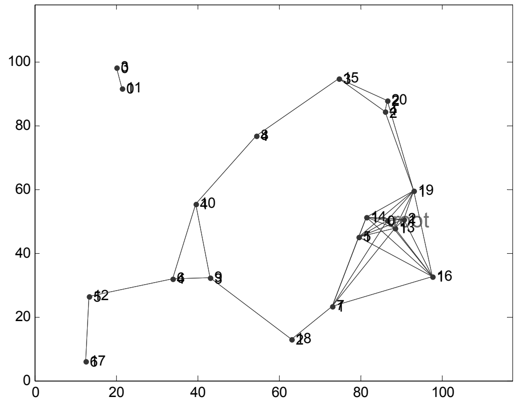


Fig. 14. Tolopogy 20 nodes at envSize 100×100

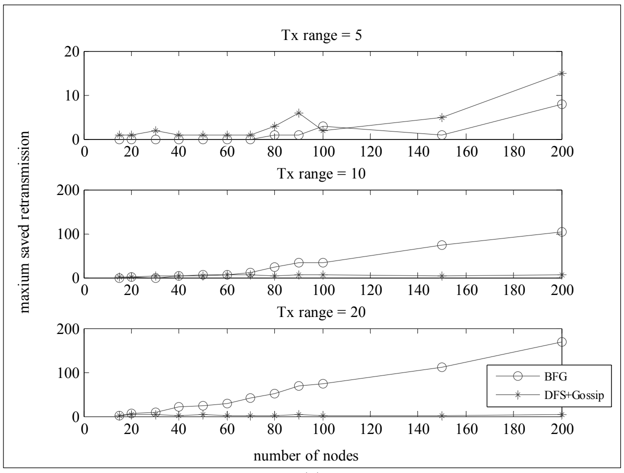
IV.2 Transmission Failure

This subsection describes transmission failure (TF) metric in various numbers of nodes, Tx ranges, and envSize to investigate the performance of BFG. The results of TF is shown in Table IV. TF metric calculate the transmitting failure from a root to neighbors.

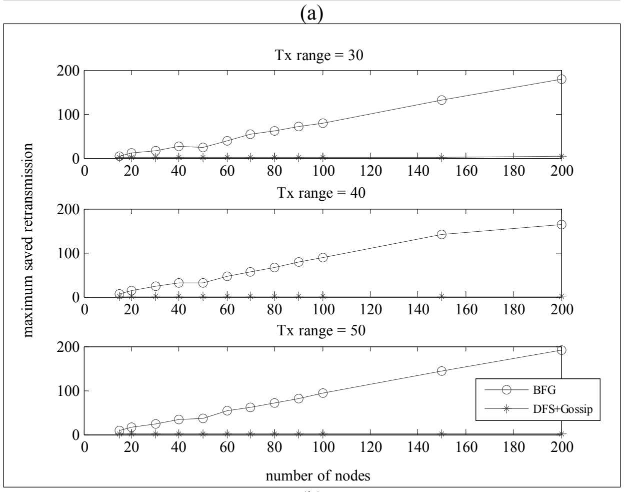
Referring to results of Table IV, we can summarize the points of the investigation.

- Consider Tx range = 1, TF occurs in all envSize because the neighbor nodes are outside of a root's Tx range. Hence, there is no node which can retransmit a packet message to the destination.
- TF decreased as the number of nodes and Tx range increased.
- There is no TF in Tx range below 20 and 40 at envSize 50×50 and 100×100. This happens because nodes are generated randomly, spread in environment region, and have limited transmission range to connect other nodes.

Table V shows transmission failure of DFS+Gossip in various node densities and Tx ranges. This table indicates that for Tx range up to 5, almost 100% transmissions fail. Meanwhile, from Tx range = 10 up to 20, the increasing number of nodes causes TF decreases. And no TF at Tx range = 20 in all number of nodes. At Tx range 10 and 15, some nodes get TF up to 95%. Means some nodes outside of coverage although it retransmitted by another node. In other words, DFS+Gossip still unable to ensure zero TF although the number of nodes becomes enlarged.



(a)



(b)

Figs. 15. BFG vs DFS+Gossip at envSize 50×50

TABLE IV
BFG TRANMISSION FAILURE (%)

Tx Range	Environment Size 50×50							Number of Nodes				
	15	20	30	40	50	60	70	80	90	100	150	200
1	100	100	100	100	98	100	100	100	100	98	100	99
5	86	74	90	90	95	95	93	72	47	66	72	0
10	79	68	34	8	0	0	0	0	0	0	0	0
15	36	11	3	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0

Tx Range	Environment Size 100×100							Number of Nodes				
	15	20	30	40	50	60	70	80	90	100	150	200
1	100	100	100	100	98	100	100	100	100	99	100	100
5	93	89	100	97	98	100	100	99	98	96	100	97
10	86	75	90	90	76	95	93	72	47	66	72	0
20	79	68	34	8	0	0	0	0	0	0	0	0
30	36	11	3	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0

Table IV compared with Table V (envSize 50×50) indicates some points as follow:

- At Tx range =1, both methods show 100% TF in a various number of nodes, because the Tx range of a root does not cover its neighbors.
- Both methods indicate no TF at Tx range = 20, which means that all members of nodes within the network can receive the message.
- Overall BFG shows better TF at some Tx ranges, considering values over Tx range = 5, TF decreases as a number of nodes increases.
- BFG can reduce TF up to 20% from transmission failure of DFS + Gossip.

TABLE V
DFS+GOSSIP TRANMISSION FAILURE (%)

Tx Range	Environment Size 50×50							Number of Nodes				
	15	20	30	40	50	60	70	80	90	100	150	200
1	100	100	100	100	100	100	100	100	100	100	100	100
5	100	100	100	97	96	97	97	97	94	95	97	94
10	85	89	0-80	0-95	0-94	0-91	0-94	0	0	0	0	0
15	75	0-89	0-75	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0

x=no node is connected

IV.3 Hop Counts

This subsection describe hop count (HC) metric that used for determining the number of hops of a root node to reach destination. HC calculation based on the highest probability of connected links within the network. This metric is related with many involved nodes, so a lot of energy resource is required to retransmit. Implementation of BFS does indeed makes it easier and more efficient to determine the number of hops of nodes required to establish a route (Table VI). Table VI shows the maximum hop count BFG in various node density and Tx range.

TABLE VI
BFG MAXIMUM HOP COUNTS

Tx Range	Environment Size 50×50							Number of Nodes				
	15	20	30	40	50	60	70	80	90	100	150	200
1	x	x	x	x	1	x	x	x	x	1	x	0
5	2	2	2	2	6	2	2	9	12	12	11	18
10	2	2	5	9	8	7	7	7	7	7	6	8
15	4	6	4	4	5	4	4	4	5	4	4	5
20	4	4	4	3	4	3	3	3	4	3	3	4
30	3	2	3	2	2	2	2	2	2	2	2	3
40	2	2	2	2	2	2	2	2	2	2	2	2
50	2	1	2	1	2	1	1	1	2	1	1	2

Tx Range	Environment Size 100×100							Number of Nodes				
	15	20	30	40	50	60	70	80	90	100	150	200
1	x	x	x	x	1	x	x	x	x	1	x	0
5	1	1	0	1	1	0	0	1	2	2	x	3
10	2	2	2	2	6	2	2	9	12	12	11	18
15	2	1	3	4	5	7	6	11	11	9	8	10
20	2	2	5	9	8	7	7	7	7	7	6	8
30	4	6	4	4	5	4	4	4	5	4	4	5
40	4	4	4	3	4	3	3	3	4	3	3	4
50	3	2	3	2	3	2	3	2	3	2	2	3
60	3	2	3	2	2	2	2	2	2	2	2	3
70	2	2	2	2	2	2	2	2	2	2	2	2

x=no node is connected

There are several points that can be inferred from Table VI:

- Overall calculation of hops begins at Tx range = 5, because below Tx range = 5, most all nodes are unconnected to a root node.
- When the number of nodes and Tx range increases, HC decreases. This relates to the node density, when the node density is increasing, it is only requiring several HC to reach all the member's nodes of network.
- When the number of nodes increases at a certain Tx range, HC almost decreases.
- As Tx range 5 and 10, the number of HC is the highest at envSize 50×50 and 100×100.

Considering envSize 50×50, at Tx range = 5, the maximum HC is obtained where the number of nodes is 200. Meanwhile, at Tx range = 15, up to 200 nodes, average is 4 HC. Meanwhile at envSize 50×50, maximum HC require 4 to reach all members of the network at Tx range = 20. Likewise, when Tx range increases two times, it requires HC from 4 till 2 hops only, thus a reduction up to 50% (Table VI).

Table VII shows the maximum HC of DFS+Gossip in various node densities and Tx ranges. There are some points that can inferred from Table VII:

- Generally, the greater the Tx range, the fewer the number of hops that can reach all network's member.
- Over Tx range = 20, all number of nodes have a maximum two hops to reach all network members. As range transmission increases, a node can reach longer distances. So, a root node need fewer relay nodes to send a packet message to destination.
- Hop count calculation starts at Tx range = 5, because at Tx range = 1, all nodes within network unconnected.
- Maximum hops is 12, which means that a root node can send a message to all members of the network with 12 hops.
- At Tx range = 50, a maximum of 2 hops can reach all members of network.

TABLE VII
DFS+Gossip Maximum Hop Counts

Tx Range	Environment Size 50×50						Number of Nodes					
	15	20	30	40	50	60	70	80	90	100	150	200
1	x	x	x	x	x	x	x	x	x	x	x	x
5	2	2	2	1	2	2	2	2	5	5	5	12
10	2	2	5	2	8	5	4	7	6	7	5	5
15	3	5	4	3	4	3	4	5	5	4	4	4
20	4	3	4	3	4	3	3	3	4	3	3	3
30	3	2	3	2	2	2	2	2	2	2	2	3
40	2	2	2	2	2	2	2	2	2	2	2	2
50	2	1	2	1	2	1	1	1	1	1	1	1

From Tables VI and VII (envSize 50×50), it can inferred some points:

- Maximum hops with DFS+Gossip is 12, meanwhile BFG has 18 hops. It indicates BFG needs much time and node relay to reach all member network with the same topology configuration.
- At Tx range = 5, BFG requires more hops compared with DFS+Gossip, which may require extra energy. BFG expect efficient resource. However, it needs further investigation.
- Over Tx range = 15, the number of hops in the two methods are similar. Meanwhile, DFS+Gossip has the number of hops fewer than BFG in below Tx range = 15.

V. Conclusion

BFG is a route discovery mechanism in ad hoc network that applies BFS, fixed radius model and Gossip algorithms aiming at establishing a link to deliver a packet message to the desired destination. This route discovery mechanism focuses on the observed parameter i.e. the number of nodes, Tx range, and node area distribution. The measurement metrics for performance evaluation are transmission failure, hop count, and saved retransmission. Based on the simulation, it is proved that a route discovery is affected by the number of nodes that spread across the network. When the number of nodes increases, the possibility of the establishment of a route to a destination is greater but undeniable that Tx range has an important role, because it limits the ability of each node to send a packet message. Another important finding is that BFG shows the better performance in metric saved retransmission and transmission failure, and a similar number of hops needed at Tx range above 15 than DFS+Gossip. Meanwhile, when Tx range below 15, a number of hops need to pay attention, because BFG require hops more up to 50%.

This study has conducted a preliminary mechanism as a basic for next proposed routing protocol in wireless ad hoc network which associated optimization method in artificial intelligence.

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