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Routing Problems and Solutions for Location-Based Routing in MANETs

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Abstract: In MANET, to form a multi-hop network, autonomous nodes act as a traffic originators and forwarders. In this, out-of-range nodes are reached by routing process. Due to constraints on battery power and bandwidth consumption, routing is considered to be a challenging task. To avoid complex route discovery and maintenance, stateless location-based routing schemes have been proposed, in which nodes makes routing decision solely on knowledge about its own, neighbour(s) and destination's location. Such prerequisite in natural routing scheme suffers from local maxima or loop problems. We mitigate these problems by proposing randomized routing algorithms in this paper. It outperforms others in terms of packet delivery ratio and throughput.

Keywords: MANET, PGR, GeRaF, hidden node, topology.

I. INTRODUCTION

Usually wireless environment is vulnerable to environmental changes and susceptible to interference. It is difficult to characterize propagation characteristics of wireless nodes because of their unpredictability and dependence on many pinpoint factors [2].

We found few fundamental issues that need to get solved by effective communication techniques:

ISSUES OF LOCATION-BASED ROUTING IN MANETS

***The absence of infrastructure*:** Nodes in ad-hoc networks need to serve as the traffic originators and forwarder as there is no central control or preexisting infrastructure. This fact makes network management more challenging and keeps more burdens on nodes.

***Dynamic network topologies*:** In this, nodes move frequently and unpredictably. This leads to network partitioning, change in routes, packet drop at a reasonable price. [8,6].

***Constrained resources*:** In this, nodes operations are performed with the help of limited resource budget (in most cases with the battery power). As energy utilization is crucial and besides that if one wish to gain better throughput, then implementing better mechanisms are desirable.

***Heterogeneous nodes and links*:** Nodes normally possess different capabilities with variety in software and hardware configuration.
Many times, node may be equipped with many transceivers with varying capacities. In turn, you may find out asymmetric link in network topology. All these facts make routing a tedious task and needs adaptation to ever changing conditions [3].

***Scalability*:** Scalability becomes challenging issue when there is large network (e.g. sensor network) which goes on adding number of nodes into it. It becomes really difficult to manage routing and locations of nodes in resource constrained network.

***The hidden and exposed terminal problem*:** Fig 1a shows hidden terminal problem [2] in which node A communicates with node B. As node C is outside of node A's radio range, it is unaware of A and B's communication. Node C suspects that medium is free to use and sends message to its neighbor B which results in collision. From fig 2.1, it can be understood that all hidden nodes for A are located in C-(A\C). The exposed terminal problem (illustrated in fig 1b) is called so because it prevents nodes from transmitting packets in safe communication way in certain situations. For example, A wish to communicate with B and C has packets for D. Now upon hearing communication between A and B, C will stay silent. Thus it is called hidden and exposed terminal phenomenon. Terminal problem leads to wastage of resources because of collision and exposed problem leads to lower throughput because of unused resources.

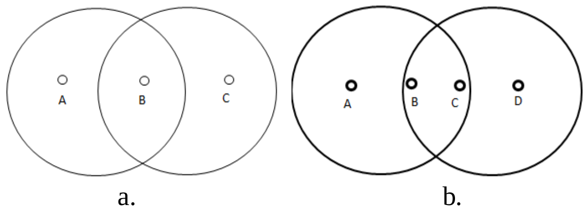

Figure 1: Hidden and exposed terminal phenomenon [2]

II. THE PROBLEM DEFINITION AND NETWORK MODEL

We formally describe MANET as a set V of N nodes placed in 2- or 3-dimensional Euclidean space. In location based schemes, it is expected that each node has knowledge about its location, which is expressed as Cartesian coordinates (x, y) or (x, y, z). Here we make an assumption that transmission range of all nodes is the same and equal to R. To confirm the communication between two nodes, their Euclidean distance must need to be at mot R. Edge between corresponding nodes represents ability of their communication.

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So resulting graph G= (V, E), is the topology of network. G is varied depending on presence and absence of the links among nodes.

2.1 Channel Model

In simulations we assume the shadowing propagation model [7] with the path loss at distance *d* being

PL(*d*)[*dB*] = *PL*(*d*0)+10□log(*d* / *d*0)+*X*□

where *PL*(*d*0) is the path loss at the reference distance *d*0, □□is the path loss exponent, and *X*□□is a zero-mean Gaussian distributed random variable with standard deviation □. The antenna gain is included in *PL*(*d*)[*dB*],

PL(*d*0) = 20log(4□*d*0 / □□)

where □□is the wavelength. The received power is expressed as

Pr[*dBm*] = *Pt* [*dBm*]−*PL*(*d*)[*dB*]

where *Pt* is the transmission power.

The signal could not be correctly received, if received power is less than threshold power *Pth* [4]. In our simulations, □□and □□are 3 and 8 respectively. The reference distance is 1m, the transmit power is 25dBm, and the threshold is -95dBm and □□corresponds to 2.4 GHz.

We choose these parameters based on simulation results, where we assumed that network is connected and with moderate power and range nodes are communicating with each other. These parameters are consistent with associated standard values used in related work.

2.2 Energy Model

The energy model is the same as in [8], which coincides with the one used in ns-2 [4]. A node loses *Pxmit* × *ttransmit* amount of energy, where *ttransmit* is the transmission time. Also, when receiving a packet, the energy loss is *Precv* × *treceive*. If we wish to measure performance analysis of network lifetime then we need to update the remaining energy.

2.3 Antenna Model

A protocol uses a smart switched-beam antenna with multiple predefined directional beams [11]. Omni-directional and directional are considered as two modes of operations with one node being active at a time. The size of the main lobe in *Directional Location-based Selection (DLS)* [5] is □/3; the side lobes (deemed insignificant) are approximated into a (single) sphere. The *Probabilistic Geographic Routing (PGR)* [12] protocol in particular also starts with this main lobe, but increases it up to □.

2.4 Mobility Model

We use random waypoint model, when mobility is stimulated, whereby each node chooses a uniformly distributed random location from a rectangular area and moves there at a constant speed selected at random from [0, Vmax]. Once node reaches to new location, it stays there for a pause time. Node repeats the process until end of simulation run. In our simulation, pause time is constant 30sec and Vmax is 10m/s. We choose these parameters based on simulation results.

2.5 Traffic Model

The uniform traffic model adopted in our simulations makes sure that the destination of a packet is at least two hops away from the source. The most sophisticated way to implement such a model is to generate the destination first (uniformly from all nodes), and then select a random source, uniformly among all nodes except destination as well as its neighbours. In the case of biased traffic, we assumed that the endpoints are located on the edges (specifically the bottom and upper edge of the grid), while the interior nodes act exclusively as routers.

2.6 Performance Measures

During experiment we collect following performance measures.

- Packet delivery ratio: the ratio of the total number of packets successfully received by the destination to the total number of packets originated at the source.
- Path length: the number of hops taken by a packet to reach the destination in case of a successful packet delivery. The path length is an indicator of delay performance.
- Network lifetime: the average number of successful routing tasks before the first node in the network has lost all its energy.
- Throughput: the maximum number of bits per unit of time that were successfully received. In all cases, we drove the networks to saturation to see how the schemes perform under extreme loads.

III. OUR PROPOSED ROUTING PROTOCOLS

Directional Location-based Selection (DLS), Forward-Backward with Ranking (FBR), and Forward with Selection out of Two (FST) [5, 10], could avoid local maxima and loops by exploiting the random next neighbor selection. Unlike random walk, GeRaF, or PGR they could also control their path length by introducing weight to the randomized neighbor selection, where the weight could be determined based on various criteria such as remaining distances, angles etc. Indeed, they could also balance load by avoiding congested nodes on their way to the destination.

IV. PROPOSED PROTOCOL DEFINITIONS

In this section we present our proposed protocols. We first define our notation. Suppose that the current routing node, the next-hop node, the destination, and the number of neighbours of j are j, x, k, and n, respectively. The Euclidean distance between two nodes j and k is denoted by djk. Let θxi = ∠kjxi be the angle formed between j, k and one of the neighbours of j, xi. Erexi represents the residual energy of a neighbour xi.

Algorithm 1: Directional Location-based Selection (DLS) (j, k, □)

1: for i ← 1 to n do

2: Assign rank P(*xi*) ← Ere_{xi} to the neighbour *xi* of the routing node *j*.

3: Assign weight W(*xi*) ← 1 / (Ere_{xi} +*c*0(*n*−1 / 2□□) $□_{xi}$)

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to the neighbour *xi* of the routing node *j*.
4: for end
5: Define a sector *O* of size □ around the routing node *j* towards the destination *k*.
6: Select the candidate next nodes, *cnn*, from inside the sector *O*.
7: if *cnn* ! = NULL then
8: Select next node *x* out of *cnn* proportional to the rank P(*x*).
9: else
10: Select next node *x* out of *n* proportional to the weight W(*x*).
11: if end

In DLS, the sector size □ is chosen as π/3 so that with high probability j may have neighbours inside the sector, which will also be close to the direction of k compared to the remaining neighbours. The closer the direction the better the chance that the protocol follows a shorter route to the destination. In case of empty sector, weight is assigned to the neighbours according to their angles so that a neighbour with smaller angle may get higher priority to be chosen as the next node x. Assuming that the traffic load and the mobility of nodes are uniform across the network, then we may expect that the energy depletion is approximately the same across all nodes. Therefore, if nodes start with the same energy reserves, they may approximately have equal reserves at a later point. Hence, even though the weight biases in favour of nodes with less energy, a suitable choice of constant c0 can amplify the impact of the angle to be dominant over the smaller differences we expect in terms of the energy across nodes.

Algorithm 2 Forward with Selection out of Two (FST) (j, k, □)

1: for i ← 1 to n do
2: Assign weight W(*xi*) ← *djxi* × |cos θ *xi* | to the neighbour *xi* of the routing node *j*.
3: for end
4: Define a sector *O* of size □ around the routing node *j* towards the destination *k*.
5: Select the candidate next nodes, *cnn*, from inside the sector *O*.
6: if *cnn* ! = NULL then
7: Rank neighbours from inside *O* in terms of maximizing W(*xi*).
8: Select first two such neighbours, *x1* and *x2*, with highest rank.
9: Select next node *x* at random between *x1* and *x2* uniformly.
10: else
11: Drop the packet.
12: if end

The sector size □ is chosen as π /2 and p in case of FST-90 and FST-180, respectively. FST initially considers two neighbours that ensures highest progress towards the destination. Then select one of them uniformly at random as the next node to balance the load and to avoid creating congestion to the best candidate on the way to a destination.

Algorithm 3 Forward-Backward with Rank (FBR) (j, k, □)

1: for *i* ← 1 to *n* do
2: Assign weight FW(*xi*) ← *djxi* × |cos□□□*xi* | to the neighbour *xi* of the routing node *j*.
3: Assign weight BW(*xi*) ← *dxi k* ×|□*xi* | to the neighbour *xi* of the routing node *j*.
4: for end
5: Define a sector *O* of size □□around the routing node *j* towards the destination *k*.
6: Select the candidate next nodes, *cnn*, from inside the sector *O*.
7: if *cnn* ! = NULL then
8: Select next node x out of *cnn* such that FW(*x*) is maximum.
9: else
10: Select next node x out of n such that BW(*x*) is minimum.
11: if end

The sector size □ is p for FBR. It selects the next node from inside the sector O that maximizes the progress towards the destination. However, instead of dropping the packet in case of empty sector (unlike Greedy, Compass, GeRaF, and PGR do) FBR considers remaining neighbours to forward packets to the destination. Thus it may follow a suboptimal route but may able to reach destination with high success rate compared to the other schemes. In a nutshell, we proposed a new set of location-based routing protocols that are designed as a compromise between the packet delivery ratio, the path length, the loop freedom, the network lifetime, and the throughput. Indeed we explore the impact of different load conditions and network topologies on the performance of these proposed protocols

V. PERFORMANCE COMPARISON OF DLS IN 2D

The packet delivery rate of DLS vs PGR and Greedy is shown in Table 1.

Table 1: The average packet delivery rate in 2D space

Nodes\Algo ->		Greedy	DLS	PGR
Node=50	Avg	69.50	82.90	68.30
	Dev	19.86	16.26	19.97
Node=70	Avg	91.90	91.90	90.10
	Dev	11.23	12.78	13.09
Node=90	Avg	96.80	99.30	97.50
	Dev	4.89	2.21	3.87
Node=110	Avg	98.30	99.50	98.00
	Dev	2.71	0.85	2.21
Node=130	Avg	99.40	99.70	99.40
	Dev	1.90	0.95	1.58

Note that the packet delivery rate of DLS is higher than in the other protocols. This is because DLS increases the choice of alternative paths and thus reduces the packet dropping rate. The performance of Greedy and PGR is very close. PGR can reach the destination as long as it finds eligible forwarding nodes inside the sector. Greedy may drop packets due to local maxima, even though the chance of facing local maxima is less in dense networks. As the number of nodes increases, all the protocols exhibit

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better performance due to high node density. For example, the chance of facing a local maximum by Greedy is reduced, which tends to increase the packet delivery rate. In PGR, the chance of having more forwarding nodes inside the sector increases with the increasing node density, which also pushes up the delivery rate. Also in DLS, the delivery rate is slightly improved owing to the reduced probability of reaching the threshold.

The performance of the three routing strategies in 2D in terms of the network lifetime is shown in Table 2, with PGR being the winner. This is because PGR considers residual energy of nodes and link reliability to balance the energy utilization among the nodes. The next protocol is Greedy, which does not confine routing to a narrow sector, which gives it more flexibility to distribute the energy utilization among the neighbours of a routing node. Finally, DLS has the worst performance in terms of the network lifetime. In DLS, a packet may bounce back and forth, possibly several times, before arriving at the destination, which may increase overall energy usage by involving more nodes than necessary. With fewer nodes in the network, Greedy performs better than PGR. The probable explanation is that PGR has fewer choices for next-hop nodes, due to its dependence on the link reliability and the sector size. The Greedy protocol retains a relatively large choice for balancing energy, even within a relatively sparse network. This advantage disappears with increased node density, as the choice for PGR becomes relevant and discriminating. Similarly, the performance of DLS also improves with the increasing node density as the likelihood of "bouncing" a packet is reduced.

Table 2: The average network lifetime in 2D space

Nodes\Algo ->		Greedy	DLS	PGR
Node=50	Avg	51.20	15.30	46.50
	Dev	16.82	8.41	15.09
Node=70	Avg	62.90	36.00	70.10
	Dev	15.43	24.44	14.74
Node=90	Avg	89.90	47.90	90.60
	Dev	29.17	23.48	26.97
Node=110	Avg	103.40	76.20	106.60
	Dev	24.17	33.63	33.51
Node=130	Avg	134.80	80.30	156.80
	Dev	26.73	44.61	73.11

Table 3 shows the performance of three routing schemes in terms of the average path length. Greedy is the winner here, followed by PGR and then DLS. This result was expected as minimizing the distance towards destination is Greedy's primary objective. Both PGR and DLS may traverse a longer route due to the (biased) randomization. Then, in DLS, packets may occasionally travel backwards, which can never happen in PGR. As the number of nodes increases, the path length of Greedy decreases slightly. In DLS, the likelihood of a backward "bounce" decreases, and so does the average path length. PGR, however, may need to traverse a few extra hops in such circumstances, as it always prefers shorter links with high reliability. Hence, the path length of PGR tends to increase as the network becomes denser.

In summary, DLS's enhanced packet delivery rates comes at increased energy cost.

Table 3: The average number of hops in 2D space

Nodes\Algo ->		Greedy	DLS	PGR
Node=50	Avg	3.67	9.71	3.83
	Dev	0.32	1.42	0.44
Node=70	Avg	3.97	7.97	4.40
	Dev	0.17	4.00	0.20
Node=90	Avg	3.85	6.93	4.25
	Dev	0.39	3.36	0.31
Node=110	Avg	3.80	5.52	4.51
	Dev	0.29	1.31	0.41
Node=130	Avg	3.65	4.71	4.40
	Dev	0.17	0.41	0.39

VI. CONCLUSION

The main objective of DLS is to avoid local maxima and loops and provide high percentage of packets delivery. DLS does not easily "give up" forwarding packets, in that it is willing to divert packets away from the path to the destination and play the odds that at some later time the packet will be eventually pushed in the right direction. In FST and FBR we avoided relying on one type of network topology only. Instead we considered regular (grid) as well as random topologies. Likewise, we considered uniform and non-uniform traffic. Some of our intuitions, like "routing randomization works well with random networks" proved to be wrong. In addition, we established that, yes, randomized routing protocols could deal with random environments but one has to be weary of the additional cost that randomization will place on path lengths and therefore congestion.

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