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Geographical Routing in Intermittently Connected MANETs with Guaranteed Delivery at Void Locations

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Abstract— **The major challenges in MANETs are finding the destination, routing and robust communication dealing with constant topology change. When there is no end to end path at any given time between source and destination via intermediate peers then it forms partitions in the network. It is said to be intermittently connected network. LAROD is the geographical routing protocol designed for such type of networks. Basically greedy approach is followed in any of the routing protocol to forward the packets. LAROD-LoDiS is also based on greedy packet forwarding along with store carry forward principle. But it works until greedy forwarding is possible. When greedy forwarding fails then the protocol has to follow some other recovery strategy to move the packets from void areas. The areas where nodes do not travel are void areas. In this paper, we propose a Timer Based DFS recovery technique to handle void in LAROD-LoDiS protocol (TBD-LAROD)[1]. Our main aim is to improve it in terms of delivery ratio. We also calculate the timer function to find the next optimal node considering forwarding area, void flag and load balancing. Simulation is done in ns2. Results show that new routing protocol outperforms existing one by improving delivery ratio.**

Index Terms - ***Geographic Routing; LAROD-LoDiS; TBD-LAROD; VOID HANDLING;Depth First Search***

I. INTRODUCTION

Mobile adhoc networks (MANETs) has evolved as one of the hot research topic in the wireless communication. There has been a tremendous change in the wireless technologies since the evolution of the mobile devices such as cellular phones, Laptops etc. There are two different approaches for enabling the wireless communication between two nodes. One is by maintaining the centralized administration or fixed infrastructure and the other is infrastructure less communication. An Adhoc network contains the group of nodes participating in the data communication without fixed infrastructure. Each node in the network acts both as router and host. Due to the node mobility there is a frequent topology change in the network, thus routing becomes more challenging. A routing protocol is needed to route the packets to the destination through intermediate nodes without packet loss. In MANETs there is an end-to-end path assumed between source and destination. But in the real world scenario, this case is not valid that means routing protocol must handle intermittent connectivity due to absence of end-to-end path.

Geographic routing or position based routing has been adopted as basic routing primitive for designing communication protocols in MANETs due to its scalability, robustness and simplicity. It mainly relies on an extremely simple geographic greedy-forwarding strategy at every hop to move a data packet to a locally optimal next-hop node with a positive progress towards the destination node. But Greedy forwarding may fail at some point such as in LAROD-LoDiS. This is called local minima or void area or dead end. If there are areas where nodes (e.g. UAVs) never travel then packet should be routed around these areas. There are many protocols developed to handle void problem for geographic routing in MANETs requires that network is fully connected. Examples of protocols include GPSR [5], face routing etc. But these methods are not applicable to the intermittently connected MANETs(IC-MANETS) due to absence of end-to-end path at any given time . Disaster area scenarios and military operations are two application areas for IC-MANETs [1].This paper discusses about void handling in military reconnaissance operations using swarming UAVs (unmanned aerial vehicles) which monitor the selected areas and report the activities within areas [1].

In this paper, we propose a Timer based DFS technique for intermittently connected MANETs based on the concept of contention based forwarding [10] with beaconless routing [9]. It uses a novel void handling or void avoiding mechanism. It is also scalable and fully distribute. When ever a node finds itself approaching stuck areas or trapped in, it raises a void flag. This flag is a local variable maintained at each node. The flag information is piggybacked with data forwarding communication to broadcasting nodes. The next hop node can be located using the single back-off function called timer function. This function is integrated with void handling, forwarding area determination and load balancing. Our

1 LAROD-LoDiS with void handling or Timer based DFS- LAROD (TBD-LAROD) protocols are same names used for proposed protocol.

technique delivers packets to the destination along paths that are near optimal in the depth first search sense. In this paper we compare our technique with LAROD-LoDiS protocol without void handling. Our simulation results show that timer based DFS- LAROD has superior performance compared to LAROD-LoDiS in terms of total packets delivered, reducing transmissions per data packet and choosing best node to forward a packet.

II. Related Work

Basic elements in the protocol defined irrespective of categories of the geographical routing protocol are:

1) Forwarding area determination: Forwarding area contains a set of nodes called tentative custodians, one of which will be selected as a custodian (packet holder).

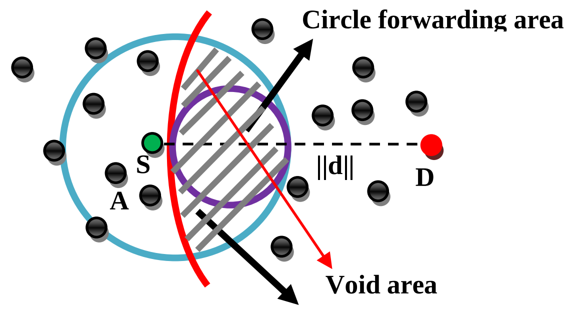

Fig. 1 Forwarding areas in geographical routing

Above figure shows the forwarding areas adopted by existing protocols. Besides these we have 60◦ circle sector, a Reuleaux triangle (not shown in fig 1). In fig. area with gray crossed lines is void area (no nodes). Within radio range of custodian S, Each sub area with same color is forwarding area. This area is chosen so that loop should not be formed and there should be positive delivery progress towards destination D can be made at each hop.

2) Timer function to find Next hop: This is the back-off function used for locating next hop from tentative custodians. It can be built based on the location information to minimize distance a packet travels from source to destination D or to best node location.

3) Void avoidance/detection: Communication void occurs when the nodes does not travel in the forwarding areas. This reduces the delivery ratio if we do not follow some other strategy for routing packet to D. Different strategies in [3,5,7] like face routing, GPSR, flooding and increasing transmission power are used to handle communication void.

GPSR [5] routing protocol uses beaconing based on greedy forwarding. It uses face routing when greedy forwarding fails at void locations to relay packets hop by hop. Right hand rule strategy is used to recover from void areas. Some of the beacon-less routing protocols are IGF [3], GeRaf [4], PSGR [7] and SIF [8] based on contention based forwarding. They are not used as the void handling is not properly defined in these protocols. TENT rule is not suitable for beaconless CGR based routing. This protocol requires node to collect 1-hop information to identify void.

BOUNDHOLE with Restricted Flooding [6] is the hybrid void handling technique where one technique fails to handle voids then other is used. It cannot handle a void if the destination is inside the hole, because it is possible that all the nodes in the hole are not closer to the destination than the void node is. So it uses Restricted Flooding (RF) to guarantee the delivery of packets to destination. But it is not suitable for clustered networks such as IC-MANETs and DTNs.

III. Proposed Protocol

A. Assumptions

For implementing this protocol we have made the following assumptions for IC-MANETs:

- Each mobile node has radio range RR and unique ID.
- Mobile nodes (UAVs) have been deployed within two dimensional coordinate system.
- Nodes can communicate with other nodes only at distance less than RR.
- Each node is aware of its location through GPS or some localization algorithms [11].
- At the boundaries there are regions where greedy routing is possible.

B. Timer Based Depth First Search technique

This section explains the proposed protocol for handling void in IC-MANETs based on distributed Depth First Search approach.

Terminologies used in this technique:

- *Distance of node* is the Euclidean distance from custodian to destination node.
- *Progress of the node* is the difference between distances from destination to the custodian and to the neighboring nodes.
- *Void Flag* is the local variable maintained at each node. It indicates whether the node is virtual dead end or real dead-end.

Protocol works as follows:

At each hop custodian broadcasts an ReTF (Request-To-Forward) message to its neighbors to hire the next best node; once receiving the ReTF message, each neighbor first evaluates a timer function based on the node's progress, and void flag value, and sets a corresponding competing timer; when the timer expires, the nodes responds the custodian with an RsTF (Response-To-Forward) message to notify its willingness to be the next hop. The tentative custodians cancel their timers after overhearing the RsTF message from new custodian. Retransmission may take place until the new

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custodian is found with low void flag value. The details of void flag updation and function to locate new custodian is given in C and D sections.

Below Figures gives a simple example depicting how a data packet is delivered from a source S to a destination D in TBD-LAROD at some instance. Gray nodes in 2(a)-2(c) represent the custodian, an arrow between two nodes represents an effective data transmission and dotted lines represent movements by custodians when packet could not be transmitted. Other nodes not participating in the data transmission are not shown in the figure. The numbers besides nodes are the void Flag. 2(a)-2(c) also show how the void Flag value in nodes involved in a successful data delivery are locally maintained. Node X is identified as a dead-end at 2(a). Fig. 2(c) shows that a new path will be found for a new data packet based on void Flag obtained in previous stages.

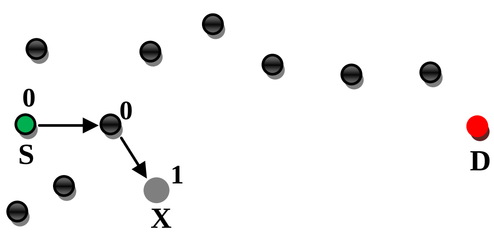

Fig. (a)

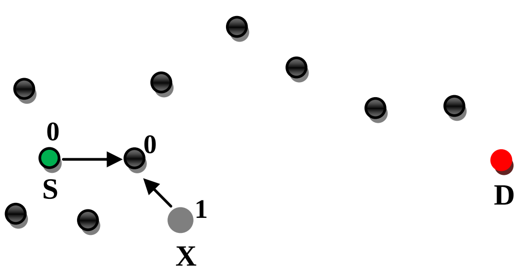

Fig. (b)

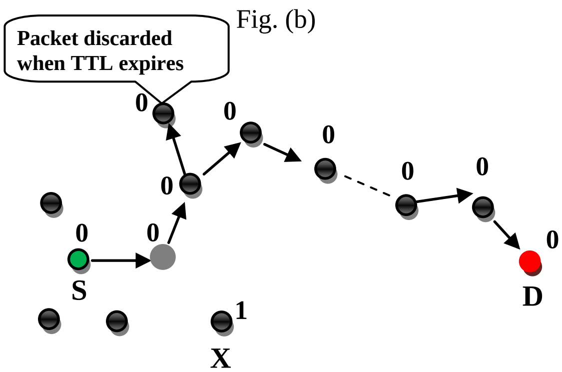

Fig. (c)

Fig. 2 Example of packet forwarding by TBD-LAROD technique

C. Locating next hop using back-off function

Here we use Depth First method to find the next custodian during data delivery. When tentative custodians receive ReTF message from custodian, each node evaluates the timer function to determine back-off time before responding to custodian. This timer function F_{NH} is used to select the next custodian in the DFS manner.
The criteria to determine next custodian is that:

- for every broadcast the data packets should be forwarded to node which is nearest to destination
- Nodes which are in void regions should be penalized.

In this function we combine issues such as forwarding area determination, load balancing[2] and void handling in the single integrated function. Before defining F_{NH}, let ||x, y|| be Euclidean distance between two nodes x and y. voidFlag (x) be the void flag of node x. Let B, A, D be Custodian, Neighbor to B, Destination respectively:

If the Euclidean distance between nodes A, D is less than B, D then F_{NH} is defined as:

$$F_{NH} = [c_1 (1-\Delta d/RR) + c_2 (1-E_r/E_i) + c_3 U + K (1+ \Delta VF)] \rho \qquad - (1)$$

Otherwise the function F_{NH} is defined as

$$F_{NH} = [c_1 (1-\Delta d/RR) + c_2 (2-E_r/E_i) + c_3 (U+1) + K(1+ \Delta VF)] \rho \qquad - (2)$$

where from equations (1) and (2)

VF-void flag

$\Delta VF = VF(A) - VF(B)$ and $(\Delta VF \geq -1)$[3]

$\Delta d = ||AD|| - ||BD||$

$c_1 + c_2 + c_3 = 1$, $c_1, c_2, c_3 > 0$

F_{NH} – function to find next hop.

U is random number between [0, 1]

RR-nominal radio range

E_r – Remaining energy in node

E_i – Initial energy in node

ρ- Parameter based on node density to reduce collisions

K- Constant used to select node with less void flag value.

Lemma: For custodian, necessary condition to choose next hop with zero void flag the constant 'K' should be greater than or equal to 2. (for proof refer appendix 1)

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[2] Load balancing is not discussed in this paper, we have used $E_i=E_r$ for evaluation purposes.

[3] If VF(A)=VF(B)=0 or VF(B)-VF(A) < -1, we set ΔVF =-1 so that additional packet delay is avoided.

D. Void Flag(VF) Updation

1) Initially set VF=0.
2) Custodian includes 'VF' value and its ID in broadcast ReTF message.
3) Neighbors respond with RsTF message with its' VF' value and distance to destination.
4) Custodian after receiving RsTF message from node X:
   i) if X is not closer to destination than itself (custodian is dead end) it increments VF to VF_{RsTF}+1, VF_{RsTF} is VF value from node X embedded in RsTF message.
   ii) otherwise
   Replaces VF value with VF_{RsTF}.
   iii) For handling situation when there is no path between source and destination, if current VF value exceeds threshold, it is set to 0.
5) For adapting to highly dynamic network VF is set to 0 periodically.

IV. Results and Performance Evaluation

In this section we evaluate performance of our proposed routing protocol through simulations. It has been implemented in ns-2 simulator [12] using Random way point mobility model. The two main evaluation metrics used are delivery ratio and transmissions generated per data packet (overhead).Delivery ratio is important metric because it determines quality of service perceived by application. Transmissions generated per data packet is also important because lean protocols will allow either higher throughput or low power consumption by nodes. In each run, a network is randomly deployed within a 2000m by 2000m rectangle area. The basic simulation parameters are summarized in table 1.

Table 1 Basic Simulation Parameters

Parameter	ns-2
Reconnaissance area	2000x2000m
Radio Range	250m
Node density	20 nodes/km^2
Node Speed	1.4m/s
Packet Life Time(TTL)	1000s
Data Generation rate	36 pkt/hour/uav
Constants -(c_1,c_2,c_3,K)	(0.5,0.4,0.1,2)

For our simulation in ns-2 we have used default ns-2 radio range. For Random waypoint mobility model [13] we have used the constant speed setting of 1.4m/s. The node speed used in our simulations might seem low compared to the node speeds in other MANET papers, but it is actually close to the average speed used in most simulations. The speed presented in most papers is the top speed for the random waypoint mobility model. According to the equations in [2] for a top speed of 20 m/s and minimum speed of 0.1 m/s with no pause time 49.8% of the nodes would move slower than 1.4 m/s. Adding the fact that most simulations use pause times this means that they have large number of relatively stable nodes that can be used to create stable routes.
The performance has been tested in the scenario of data transmission involving communication voids. In this we create an empty circular area in the network in which a source and a destination are selected at the two opposite sides of this area. The number of nodes (UAVs) in the network is 95.
Simulation results are shown in Fig.1 and Fig.2 (XGraphs in ns-2). The data points taken in the evaluations below are the average result of ten simulations. In Fig. 1 we see the impact of the packet lifetime on the delivery ratio. The Red curve in figures shows LAROD-LoDiS without void handling and Green curve shows LAROD-LoDiS-with-VOID HANDLING. Both the metrics has been calculated by increasing the packet life time as 200s, 300s, 400s, 600s, 800s and 1000s.The LAROD-LoDiS-with-VOID HANDLING (TBD-LAROD) outperforms the existing LAROD-LoDiS protocol in terms of delivery ratio. It has been increased up to nearly 100% by increasing the packet life time. Also we have seen that how Void Flag value is used to avoid the packets approaching the void areas there by reducing the packet drops and choosing optimal node based on function, F_{NH}. The improvement with high node density results from the initial distribution of the packet taking less time. LAROD actively tries to forward a packet toward the destination through wireless forwards, and with increased node density so the forwarding opportunities are increased. The overheads in the two protocols, as presented in Fig. 2, illustrate what is expected from the protocol design showing overhead for node density of 95 under Random Way Point mobility. In LAROD–LoDiS, the overhead increases with a decreased node density as delivery latency increases, and more packets exist in the network for their maximum lifetime (TTL). For LAROD-LoDiS with void handling technique, the overhead is reduced to some extent. Void Flag value plays an important role to select the node with less value there by reducing the path length to all nodes. Collisions may occur during request response which chooses bad neighbor as next hop, so we can adjust the ρ parameter and use existing scheduling mechanism to handle this situation.

The impact of network performance greatly depends on the system parameters and mobility model being chosen. So for convenience and comparison purposes of our protocol we have used Random Way Point mobility model.

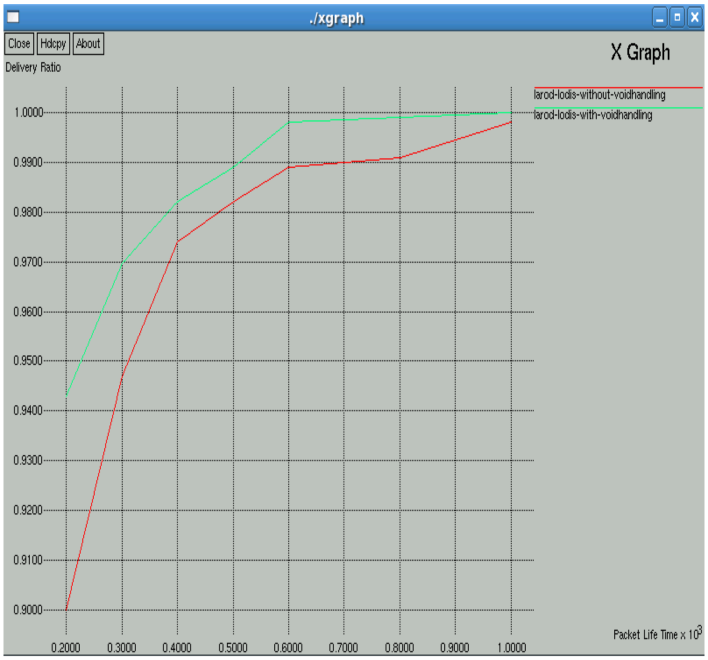

Fig. 3 Packet Life Time with Delivery ratios

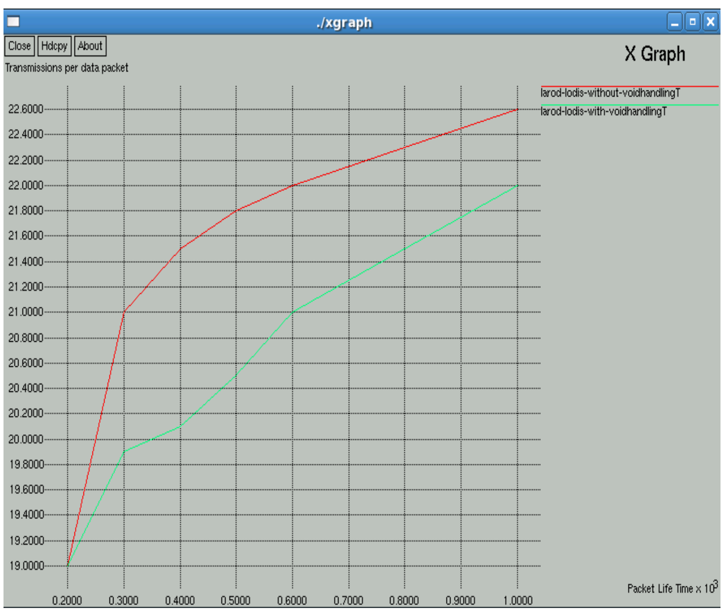

Fig. 4 Packet Life Time with Transmissions per data packet

V. Conclusion and Future work

In MANETs constraints on resources and capability limitation of nodes make it inconvenient and not scalable to design state-based routing protocols. Periodical beaconing makes use of high bandwidth and energy wastage in high density networks. In this paper, we have proposed a beaconless technique to handle void based on Depth First Search approach. We have also defined a timer function for choosing next hop that includes forwarding area determination, void handling and load balancing for geographical forwarding. Load balancing is not addressed in this paper, as we have used same energy level throughout the simulations. But void handling has been addressed clearly based on void flag updation. Simulation results show that TBD-LAROD has better performance than LAROD-LoDiS.

Our future work includes comparisons with other mobility models, finding the boundary regions where greedy forwarding is possible and calculating the energy levels of nodes to make routing more efficient.

Appendix

Choosing Parameter 'K'

Now let us discuss how to choose 'K' so that DFS method works correctly. To avoid choosing stucked or void node again, we have to choose the node with low Void Flag than that node to be next hop.

Since $\Delta d \leq RR$, for given Constant K, ΔVF and ρ

$\boldsymbol{F_{NH}} \geq K\,(1+\Delta VF)\,\rho$ - (3) and

$\boldsymbol{F_{NH}} \leq (2+K\,(1-\Delta VF))\,\rho$ - (4)

Consider nodes X be void node, Y be next node to be selected.

Denoting $\boldsymbol{F_{NHX}}$ as for node X and ΔVF_X ,

$\boldsymbol{F_{NHY}}$ as for node Y and ΔVF_Y

From (3) $\boldsymbol{F_{NHX}} \geq K\,(1+\Delta VF_X)\,\rho$ - (5)

From (4) $\boldsymbol{F_{NHY}} \leq 2+ (K\,(1+\Delta VF_Y))\,\rho$ - (6)

i) If $\Delta VF_X \geq \Delta VF_Y + 1$, then we have

$\boldsymbol{F_{NHY}} \leq (2+K^*\Delta VFx)\,\rho$ - (7)

From (5) and (7), we have

$\boldsymbol{F_{NHX}} - \boldsymbol{F_{NHY}} \geq (K\text{-}2)\,\rho$ - (8)

From (8), we get that if $\boldsymbol{F_{NHX}} \geq \boldsymbol{F_{NHY}} +1$ if $K \geq 2$,

then $\boldsymbol{F_{NHX}} \geq \boldsymbol{F_{NHY}}$, which means Node Y, has Void Flag less than X, so Y is selected as next hop.

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