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Performance Comparison of Position-Based Routing Protocols in the Context of Solving Greedy Failure

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***Abstract*—In Mobile Ad-hoc Networks (MANETs), greedy forwarding strategy (GFS) seems to be the method of choice for position-based routing protocols. During the last decade GFS has become the subject of research. However, with greedy routing there is no guarantee that a node could always find a suitable next-relay hop to forward its packet. Of such situation, forwarded packets might be ends at a concave (Hole) node that result in the forwarded packet to be dropped. This "Hole" node might be out of battery power, full congested or does not have neighbor(s) in the direction of ultimate destination, etc. Accordingly; this Hole is considered as vital section of the whole network which results that the whole MANET fails. Considering the problem of greedy failure at the network holes, several works have been proposed in the state. In this paper, we present these works in new classification with two categories. Moreover, an investigation of the proposed routing protocols corresponding to each category is conducted. Thus, besides the new classification, this paper presents an overview and a qualitative comparison of the existing position based routing protocols that tried to solve greedy failure. The noble goal of this classification and investigation is to conclude the most important features to be considered in rebuilding GFS to make it as standalone position based routing protocol.as future research efforts. Hopefully that GFS with the new features becomes more reliable and efficient that satisfies most MANET's applications**

Keywords-MANET; GFS; position-based routing

I. INTRODUCTION

Mobile Ad-hoc Network (MANET) is a self-organizing, self-routing multi-hop network. MANET constructed of mobile nodes connected via wireless links. The nodes are free to move randomly and organize themselves arbitrarily. MANET topology may change rapidly and unpredictably. Thus, one of the most challenges in MANET is to design an efficient routing protocol that is compatible with the new characteristics of such network [1].

A MANET needs an appropriate multi-hop routing protocol to perform the communication between the participating nodes. Such protocol should sustain efficiency and scalability with both sparse and dense network. Moreover, it should quickly respond to the regular continual MANET topology change and adaptively consider its resources constrain [2]. Accordingly, the efficiency of the underlying used routing algorithm is a sign of the performance and reliability of mobile nodes communication.

Due to its implementation simplicity, and efficiency, greedy forwarding scheme (GFS) [3] is considered as the basic mechanistic building block in the geographic routing. In greedy, the source node forward the packet via a path composed of a group of relay node sequences. The only deciding factor for a neighbor to be elected as a member of this route is to achieve most progress towards the destination. However, this selection process is not feasible since GFS is unable to fully address the unique characteristics of MANET (mobility, limited resources, and lack of static topology). Hence, GFS may not always succeed, and it may fail due to several issues; especially in high dynamic and sparse networks.

To address greedy failure, Greedy algorithm has been enhanced by several researchers' efforts. For the clarity sake this paper introduces these efforts in two new main categories. Moreover, it held a performance comparison between selected protocols of each category. Section II provides a quick review of the current effort to enhance greedy routing categories in new classification. Section III gives a general review of the selected routing protocols. Section IV presents the simulation environment. In Section V the results of simulations are presented and discussed. Section VI concludes the paper and provides recommendations for future work.

II. CURRENT STATE OF THE ART IN SOLVING GREEDY FAILURE

As it alluded earlier, GFS may fail repeatedly due to hot spot problem or inaccurate position information. Whenever a packet forwarded to inaccurate position or encounters the routing Hole, it may be dropped or enter a recovery mode to reach the destination via an alternative route. To prevent packet to be dropped, several solutions have been proposed in the state. These approaches came with additional processes that required in routing the packet around the afflicted node.

In this paper we classify the proposed efforts that have been done in the state of the art to solve greedy failure into two categories. We broadly divided them into; Recovery

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Strategies to Handle GFS Failure (RSGF), and Supportive Enhancement for GFS (SEGF). In RSGF, once GFS fails due to dead-end problem, the recovery phase should be executed to continue routing the stuck packet around the void. With SEGF, GFS is enhanced by adopting other metrics besides distance metric to achieve other objectives besides shortest path objective. With SEGF all proposed solution is still in need to the recovery mode to be executed as GFS fails due to dead-end problem.

Greedy Perimeter Stateless Routing protocol (GPSR) [4], Partial-partition Avoiding Geographic Routing-Mobile (PAGER-M) [5], Geographic Routing Algorithm (GRA) [6], and Stateless Extension of Greedy Routing (GR (K)) [7] are prominent examples of the first category.

The Directional Greedy Routing Protocol (DGRP) [8], Beacon-based Cooperative Forwarding (BCF) [9], Dynamic Route Maintenance algorithm (DRM) [10], Adaptive Position Update (APU) [11], Velocity-Assisted Predictive routing (VAR) [12], Reliable and Efficient Forwarding (REEF) [13], Mobility-based Adaptive Greedy Forwarding (MAGF) [14], and Reliable Directional Greedy Routing (PDGR) protocol [15], are prominent examples of the second category.

III. Review of the Selected Routing Protocols

A. *Greedy Perimeter Stateless Routing*

Greedy Perimeter Stateless Routing (GPSR) proposed by B. Karp and H. Kung. GPSR is one of the earlier routing protocols that combine greedy routing and a variant of face routing to escape from the concave problems. In the basic algorithm, the current forwarder node always selects the neighbor farthest from it in the direction of the destination as the next relay. However, when the current forwarder node fails to find a neighbor closer to the destination than itself, it marks the packet as the recovery algorithm and records the location at which greedy forwarding failed. With the recovery algorithms, the node selects a vertex from the graph using a right-hand rule to escape from the concave. Afterwards, the next hop is sequentially a counter clockwise node for the previous node until the packet reaches a mode conversion node where the packet's mode is returned back to the greedy mode.

B. *Directional Greedy Routing Protocol*

Directional Greedy Routing Protocol (DGRP) is another position-based routing approach proposed by R. Kumar and S. Rao. DGRP uses the position of participating nodes, and their movement characteristics (speed and direction). They deployed this information to predict the accurate position of the neighbors within the beacon interval, later; this information is used to make the selection decision at the time of forwarding. DGRP uses the two forwarding strategies greedy and perimeter.

C. *Mobility-based Adaptive Greedy Forwarding*

J. Li and S. M. Shatz, proposed Mobility-based Adaptive Greedy Forwarding (MAGF). MAGF is a method to handle a potential dead end. It takes advantage of the motion potential that combines the node mobility patterns with the node position to help make forwarding decisions. MAGF solves the dead-end problems by detecting the routing holes in advance. In MAGF algorithm the nodes repositioned within the holes. This mechanism helps the packets to be more smoothly routed through the void. Using MAGF mechanism nodes propagate and update the information of the observed void node in order to reduce the probability of encountering the void problem. In MAGF, by default, the message is forwarded to a node from the progressive region. In case there is no node in the progressive region, the message is passed to one of the nodes from the potential region. The node for which the motion potential is the highest is chosen as the relay.

D. *Predictive Directional Greedy Routing*

Jiayu Gong et al. proposed Predictive Directional Greedy Routing (PDGR). With PDGR, the routing selection decision is made depending on a weighted score algorithm. Weighted score is calculated from two methods namely, Position First Forwarding (PFF) and Direction First Forwarding (DFF). The weighted score is calculated not only for the source\forwarder and its current neighbors but also for its possible future neighbors in very near future. The information can be collected using beacon messages. With PDGR current and future predicted mobility information are hired to make a decision to select the next-relay hop for forwarding packets. The case of unavailability of such neighbor, the source node carries the packet until it finds its neighbor which has higher weighted score than itself.

IV. The Simulation Study

A. *Simulation Set-up*

To investigate the performance of the selected routing protocols, we use the network simulator 2 version 2.33 [16]. For this simulation sake, we used the default settings of Greedy Perimeter Stateless Routing GPSR as the form of geographic routing protocol.

The simulation network area is 2500 m x 2000 m rectangle with 250m nodes' transmission range. We use the MAC layer protocol 802.11 DCF RTS/CTS. Bandwidth (*Bw*) set to standard value of 2 mbps. Traffic model uses Continuous Bit Rate (CBR) traffic sources. Traffic sources transmit data at a fixed data rate of 5 packets/s. Data's packet size set to standard values 512 bytes and beacon packet size is 64 bytes. Node's queue size set to standard size of 50 packets, and node's queue uses First-In-First-Out (FIFO) policy. The simulation for each scenario is executed in a period of 1200, seconds, and to avoid the effect of initializing and ending; we only gather the data between 800s – 1000s.

B. *Mobility Model Set-up*

Table I summarizes the main simulation parameters and their values used in this paper that is relevant to Boundless Mobility Model.

TABLE I. BOUNDLESS MOBILITY MODEL VALUES

Boundless Mobility Model	Description	Value	Unit
	Maximum speed (v_{max})	40	m/s
	Maximum acceleration (A_{max})	10	m/s^2
	Maximum angular (α)	90	*degree*
	Updating time steps (Δt)	1000	*ms*

C. Performance Evaluation Metrics

For the simulation results, and to compare the selected routing protocols, we consider the following performance metrics:

- Packet Delivery Ratio (PDR): This ratio represents the number of data packets successfully received by the destination to the total number of packets sent to destination.
- End-To-End Delay (E-2-E D): This metric represents the difference between the time a data packet is received by the destination and the time the data packet is generated by the source.
- Routing overhead (ROH): This metric represents the ratio between the numbers of beacon packets transmitted for every data packet sent.

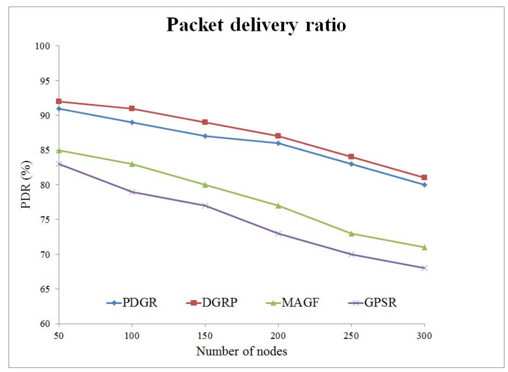
D. Simulation scenarios

In our simulation environment, we compare the performance of the selected position based routing protocols. To demonstrate the robustness of each protocol algorithm we investigate them in two scenarios. In the first scenario, we deploy 100 nodes with fixed number of 5 flows and vary the nodes speed to 5, 10, 15, 20, 25, 30, 35, and 40 m/s. In the second scenario, the speed and flows are fixed to 20 m\s and 5 flows respectively, and vary the deployed number of nodes to 50, 100, 150, 200, 250, and 300.

V. SIMULATION EVALUATION

A. Simulation Results with Different Number of nodes

With the first scenario, we measure the three performance metrics as a function of number of nodes. Fig.1. (a) shows the ratio of total number of received packets by GPSR, DGRP, MAGF, and PDGR protocols. The figure shows that .as the number of nodes increases the packet delivery ratio decreases. The increment of number of nodes increases the transmitted control packet in the network, that increases the collision opportunity to be occurred which incurs more packet loss. As the figure reveals, PDGR and MAGEF relatively achieved the same PDR ratio, and outperform the other two protocols, where GPSR shows the worst PDR ratio. Fig.1. (b) shows the average end-to-end delay in GPSR, DGRP, MAGF, and PDGR protocols. The chart reveals that as the number of nodes increases, the required time to rout the data packet is increases too. This comes as a result of hot spot problem at the center of the network which incurs more congestion and collision that incurs packet to be dropped. Dropped packet need to be retransmitted that incurs more delay. Moreover, since GPSR and DGRP use recovery mode to handle the void problem both result in more end-to-end delay. On the other hand PDGR uses carry and move and MAGF can detect the void node in advance thus they outperform GPSR and DGRP. Again MAGF is superior to the other protocols, and GPSR shows the highest end-to-end delay. Fig.1. (c) shows the total number of beacon packets exchanged by GPSR, DGRP, MAGF, and PDGR protocols. For all protocols, the number of beacon packets sent by nodes increases when the number of nodes increases since we have more nodes at the network to send beacon packets. MAGF achieves the lowest overhead and GPSR suffers from the highest control packets overhead.



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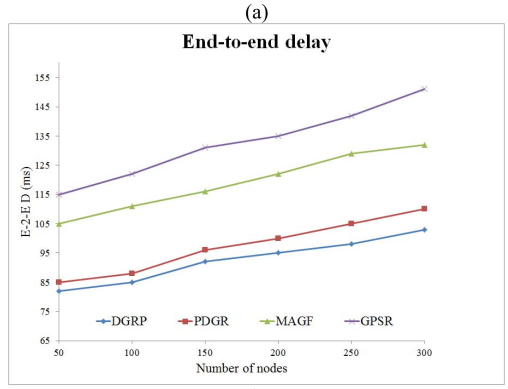

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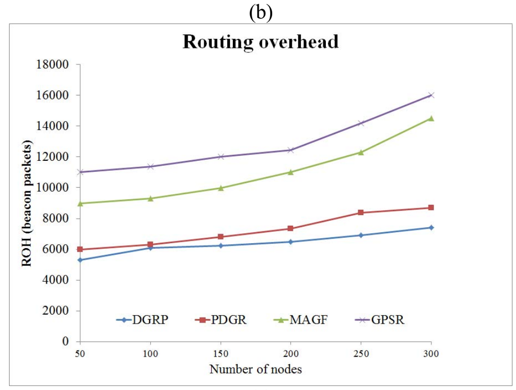


(c)

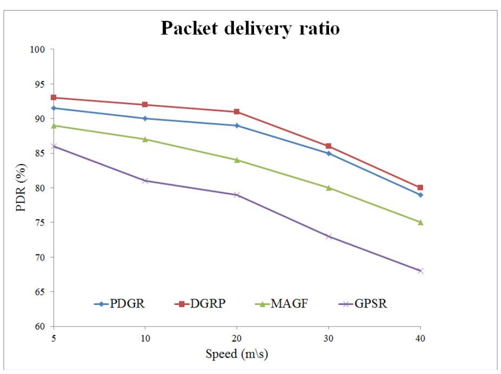
Figure 1. Performance metrics with different number of nodes.

B. *Simulation Results with Different Nodes' mobility*

With the second scenario, we measure the three performance metrics as a function of node speed. Fig.2. (a) shows the ratio of total number of received packets by GPSR, DGRP, MAGF, and PDGR protocols. The chart reveals that the packet delivery ratio decreases as the node velocity increases. MAGF shows an increment in the delivery rate when nodes moved faster compared with the other protocols. This is due to using node mobility when making forwarding decisions, and detecting void node before making forwarding decision. The second order is PDGR because it has no restriction on the routing path and employs direction probing in routing. Moreover it employs carry and move method as the forwarded packet fall in dead end. Packet delivery ratio of DGRP decreases because the accuracy of the location prediction decreases as speed increases. MAGF and PDGR show same PDR ratio like. GPSR is the worst in terms of PDR ratio.

Fig.1. (b) shows the average end-to-end delay in GPSR, DGRP, MAGF, and PDGR protocols. The figure shows that end-to-end delay increases as the node speed increases. MAGF shows the superiority of having the least end-to-end delay, and GPSR shows the highest end-to-end delay.

Fig.1. (c) shows the total number of beacon packets exchanged by GPSR, DGRP, MAGF, and PDGR protocols. The chart reveals that the control packets for all protocols increases as the node speed increases. GPSR has the highest control overhead compared with the other protocols, and MAGF is the least.



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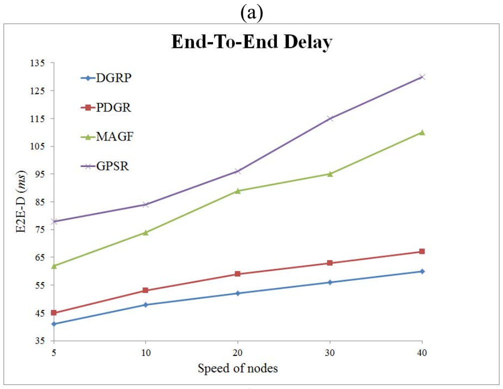

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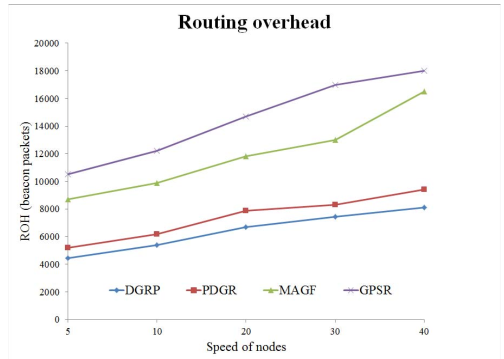

(c)

Figure 2. Performance metrics with various mobility values.

VI. CONCLUSION AND FUTURE WORKS

The results revealed that with the increasing of network density, delay and overhead, are increased quickly. On the other hand, the increasing in nodes mobility resulted in increasing on delay and overhead. For both scenarios the packet delivery ratio is decreased. Also we can notice that the conventional routing protocols that only relaying on recovery strategies i.e. GPSR, have the worst performance. This supports the idea of considering the other category when designing new routing protocol for MANET.

GPSR is the worst compared with other protocols. The main weakness of GPSR, which represents the RSGF category, is that the recovery mode is executed after the existence of the Holes. Thus, even with the usage of such recovery mode the core problem still occurs. Moreover, such recovery strategies gave up to the idea that greedy forwarding strategy could be fixed to overcome its shortcomings during its performing. Through using RSGF category and due to using the recovery mode the packet delivery increases in the expense of more delay. Moreover, with the recovery mode the forwarded packet reaches the destination through long path this result of more delay and exhausted the nodes in terms of their energy.

MAGF has three main drawbacks; firstly, it still relaying on recovery mode, secondly, packet loss possibility increased with weak link stability between the forwarding node and its neighbor. And the last weakness appeared in the high mobility environment where inaccurate position information and path disruptions are often leads to high overhead.

DGRP and PDGR protocols represent examples of SEGF class to solve greedy failure. As it seems from the results both protocols did not give full solution to the greedy failure and still have many drawbacks. Also, both did not pay attention to the environmental issue and nodes' condition. Adding, both did not use effective periodic routing updates and full multi-objective routing protocol. And thus, in this class of routing protocols, to guarantee high delivery ratio this is accomplished in the expense of more delay and long bath compared to the optimum.

However, the results revealed that the second category is the superior of the first one. This result also enhanced our idea that greedy can be used as standalone routing protocol if some enhancement is done to release the gaps existed in the third class. Table II shows the advantages and disadvantages of each category.

TABLE II. COMPARISON BETWEEN PROPOSED CATEGORIES

Category	Advantages	Disadvantages
RSGF	-Solve greedy failure at Hole nodes -Guarantee delivery	-Hole problem still occurs -Flooding inefficient in terms of resource utilization, incurs congestion, collision, more packet loss The other approaches incur more overhead, long routing path, more delay, consume more bandwidth and energy. Adding network partition problem may occur with sparse and high dynamic networks.
SEGF	-Solve greedy failure at Hole nodes -Guarantee delivery based on the used recovery strategy -mitigate using recovery mode due to adopting other routing metrics that may achieve extra objective besides shortest path	- Holes still occurs at any time this is followed by all drawbacks as in RSGF enhancement mode -All approaches incur non-optimal rout, that result in more delay, and more energy consumption

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