A General Framework for Greedy Routing in Mobile Ad-hoc Networks

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***Abstract*—This paper introduces the notion of a reliable and efficient greedy routing provisioning (RGRS) in mobile ad hoc networks. The proposed RGRS constructed of two mechanisms in the context of improving and enhancing greedy routing. These mechanisms are Dynamic Beaconing Update Mechanism (DBUM), and Dynamic and Reactive Reliability Estimation with Selective Metrics (DRESM). The building structure of DRESM is based on the notion of multi-criteria next relay node selection using fuzzy weighted logic multi-objectives. To efficiently track node's status, DRESM is supported with a dynamic and effective updating DBUM scheme. In this work, and to show the performance of the proposed RGRS detailed experiments in simulated environments are executed. The simulation results show that RGRS is quite reliable and efficient and superior to the traditional greedy forwarding strategy (GFS). Moreover, the results reveal that RGRS can be used as a standalone routing protocol without the aid of any recovery mode. RGRS outperforms GFS in terms of the packet delivery ratio. Moreover, RGRS achieves high level of accuracy in terms of nodes' information and can find routs between communicating nodes whose cost is close to the optimum.**

Keywords- Adaptive beaconing approach; Greedy routing; Multi-criteria; Multi-objectives

I. INTRODUCTION

The interest in Mobile Ad hoc Networks (MANETs) has grown immensely over the last decade. MANETs constructed of a group of wireless mobile nodes (MNs) [1]. The MANET is very flexible network and appropriate for applications such as conferences, battlefield communications, and disaster rescues. As a new environment, and because of its' new features, MANET gains numerous new challenges issues [2]. Those issues must be resolved before it can be efficiently deployed within different areas. Among these issues, routing is one of the most fundamental yet challenging problems for MANETs.

In the last ten years, the packet forwarding strategies for position-based routing in MANET have become one of the main subjects of research. Greedy forwarding (GFS) is a hop-by-hop forwarding fashion that seems to be the method of choice [3]. With the standard of the greedy algorithm, source node forwards the packet to its neighbor whose distance to the destination is the smallest through applying geometric calculation [1]. Therefore, greedy is simple, incurs relatively low overhead, and usually results in optimal or near-optimal paths [3]. However, Greedy success is attributable to two unrealistic suppositions for routing a packet using shortest path [4]. The former assumption is that the network is always connected. The latter assumption, that the nodes' neighbors list remains stable and accurate during beacon interval time. Due adopting one routing objective and MANETs' constrains, these assumptions are invalid in any realistic deployment [3].

Regarding to the first assumption, and owing of the GFS algorithm functionality, certain nodes at the center of the network may be required to forward packets more often than others. On other words the shortest path adoption (as the only objective) makes GFS algorithm cannot fairly distribute the routing load among mobile nodes and result in a hot spot phenomenon at the center of the network Thus, the participants at the center of MANET will become very soon the most congested nodes, and the least of battery power (Hole nodes) [5]. These "Hole" nodes seem to be died fast; due to out of battery power, thus, a node's connectivity degree is unstable. Additionally; any considerable difference of relative velocity (speed and direction) between source and next relay node shows a fluctuation of the link life-time between them that makes routes out-of-date and hence incorrect [2]. Therefore, the unreality of the first assumption combined with the shortest path adoption can easily results in a disconnected network. To make the first assumption more realistic; neighbors' condition and mobility attribute of a node's should be considered in the selection process (multi-objectives).

For latter assumption, we believe that nodes' movement will cause unpredictable change in MANET topology. Accordingly, the position information in the nodes' neighbors' list might include some stale information for neighbor nodes. As a consequence, if the next selected node is one of those with inaccurate position, then the packet will be incorrectly forwarded to the next relay node and the packet will be dropped. Thereafter, to make the second assumption more realistic, an effective and efficient beaconing update should be adopted.

To conclude, this paper focuses on providing a suitable solution for greedy failure in MANET. The noble goal of this work is to enhance and improve the GFS and to make it as standalone routing scheme. It presents a new model of a reliable and efficient greedy routing provisioning in MANETs RGFS. The RGFS algorithm is a distributed and localized algorithm for practical MANET. After the

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introduction above the reminder of this paper is as following. The related work is presented in Section II, followed by the proposed model in Section III. The functionality of RGRS in MANET presented in Section IV. The performance analysis of the proposed RGRS presented in Section V, and lastly Section VI conclude this work.

II. Related Works

As it alluded in the previous section greedy 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 face two ends. The former end incurs forwarded packet to be dropped. The latter end results that the forwarded packet to enter a recovery mode to reach the destination via an alternative route. Although several recovery strategies have been proposed to deal with such hot spot events, the system performance is inevitably degraded as a result of the additional processes required to route the packet around the afflicted node.

To prevent forwarded packet to be dropped, many efforts have been done in the state of the art that can mainly classified into three main categories. First category is the Supportive Recovery Strategies with Greedy Failure (RESR), as in Greedy Perimeter Stateless Routing (GPSR) [6], Partial-partition Avoiding Geographic Routing-Mobile (PAGER-M) [7], Geographic Routing Algorithm (GRA) [8], and Stateless Extension of Greedy Routing (GR (K)) [9]. Second category is the Supportive Enhancement for Greedy Forwarding (EGARS), as in Directional Greedy Routing Protocol (DGRP) [10] Beacon-based Cooperative Forwarding (BCF) [11], Dynamic Route Maintenance algorithm (DRM) [12], Adaptive Position Update (APU) [13], Velocity-Assisted Predictive routing (VAR) [14], and the Reliable and Efficient Forwarding mechanism (REEF) [15]. The third category is the Enhancing GFS as Standalone Routing Protocol (EGSR), as in Mobility-based Adaptive Greedy Forwarding (MAGF) [16], Greedy Virtual Coordinates scheme (GSpring) in [17], and Position-based Opportunistic Routing (POR) [18].

In RESR category, once the packet faces the routing hole, the recovery phase should be executed for routing the packet around the dead end. In EGARS, each approach is executed with its embedded enhancement (as one objective besides geometric calculation). Later, as the dead end occurs, the recovery operation should be executed. On the other hand, the proactive schemes EGSR solve the dead-end problems by detecting the routing holes in advance, or by using carry and forward mechanisms.

Due to limited allowed pages, our discussion is constrained for one protocol of each category. We select them regarding to their appearance date i.e. GPSR, DGRP, MAGF, and POR. Also, same protocols are used for comparison sake.

B. Karp and H. T. Kung proposed the GPSR protocol. GPSR is one of earliest proposed protocol to solve the greedy failure. In GPSR, a packet is normally routed in greedy forwarding mode, and the algorithm switches to perimeter forwarding when a packet reaches a Hole. With the recovery mode in GPSR, packets are routed by using un-optimal path that consumes more energy and incurs more end-to-end delay.

R. Kumar and S. Rao proposed the DGRP protocol. DGRP belongs to the EGARS category. DGRP uses the position of participating nodes, and their movement characteristics (speed and direction) to make the forwarding decision besides distance. DGRP also uses the two forwarding strategies, greedy and perimeter mode.

However, DGRP have three main drawbacks; firstly, it still relaying on recovery mode, secondly, packet loss possibility is increased with weak link stability between the forwarding node and its neighbors. Lastly, in high mobility environment where inaccurate position information and path disruptions are often, DGRP suffers from low throughput and high overhead.

J. Li and S. Shatz proposed the MAGF protocol. 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 in making forwarding decision. MAGF solve the dead-end problems by detecting the routing holes in advance.

S. Yang, et al., proposed a novel Routing protocol POR. In POR, the authors addressed the problem of reliable data delivery in highly dynamic MANET. To solve the problem in hand, the proposed POR was designed in a manner to benefit from the stateless property of geographic routing and broadcast nature of the wireless medium. In such case, besides selected next-optimal relay node, candidate nodes can hear the sent packet and can forward the intended packet in behalf of the optimal node in case it failed to do its mission. If the Hole appears during communication, the authors proposed a Virtual Destination-based Void Handling (VDVH) to work together with POR to avoid it.

The authors argued that, simulation results show that POR under high mobility performs current routing protocol for MANET in terms of packet delivery ratio, and end to end delay with acceptable extra overhead. However, in proposed POR, the communication Hole still occurs while communication, and needs for more computational procedure to escape away from it that incurs more delay and drains more power. Moreover, with POR, the selection of the next relay node was just based on distance as main criterion, and it did not take into account any other important criteria to solve traditional greedy forwarding failure.

III. Proposed model

From the works in [6-18], it is concluded that the proper operation of GFS function can be affected by three major and very critical issues. Ignorance of considering these issues while making forwarding decision consider as the main reason behind greedy failure. Specifically, these issues revolved around the conditions of participating nodes, their mobility attributes, and the accuracy of their position information.

This paper comes to introduce the notion of a reliable and efficient greedy routing provisioning (RGRS) in MANETs. A schematic illustration of the RGRS model architecture is shown in Fig1.

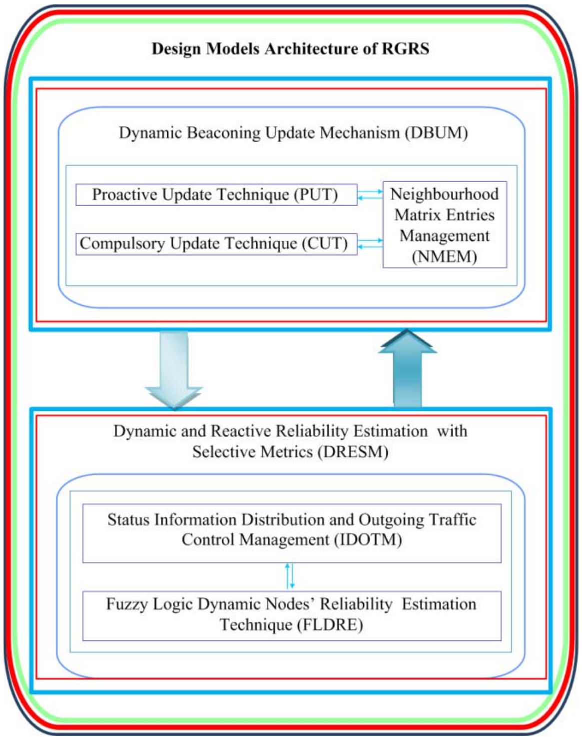


Figure 1. The Reliable Greedy Routing Strategy (RGRS) model architecture

This work is conducted to introduce the notion of multi-criteria next relay node selection using fuzzy weighted logic multi-objectives DRESM. DRESM combines mobility attributes, and conditions of participating nodes as other deciding factors in addition to distance, and modify them to have a new mechanizes depending on the proposed metrics. Moreover, in order to make suitable routing decisions and high accurate network topology, greedy routing strategy requires being modified to have an efficient and scalable beaconing mechanizes DBUM. DBUM is proposed to track nodes status and to improve the accuracy of a node's neighbor information in its neighbors list. Finally, the two mechanisms were integrated in the traditional GFS strategy and dubbed as "Reliable Greedy Routing Strategy" RGRS.

The overall aim of this work is to enhance traditional greedy forwarding policy to make it more reliable and efficient to satisfy various MANET applications. RGRS is a standalone geographic routing scheme that uses fresh up to-date participating nodes' information and fuzzy logic to make forwarding decisions. As with most geographic routing scheme, RGRS is localized in the sense that it does not need information about the entire MANET. Instead, RGRS was designed to keep track of neighbors within direct communication range, thus adding a level of resilience to dynamic network behavior. As it is obvious in Fig1, the main building block of RGRS is constructed of two main modules. The proposed modules in the system model are as follows.

A. Module 1: DBUM mechanism

The DBUM mechanism is primarily responsible for providing a node with fresh information about its neighbor nodes. DBUM was designed in a manner to track up-to-date information for each self-node and its neighbors. To fulfil this task, DBUM consists of three major components; (i) Proactive update technique (PUT), (ii) Compulsory Update Technique (CUT), and (iii) Neighborhood Matrix Entries Management (NMEM).

PUT technique was adopted to proactively distribute the node's information for all its neighbors, through using Fixed Beacon Message (FBM). At the same time, CUT was designed to be initiated by the node that exceeds a pre-specified tolerance deviation distance, from its most recent FBM. CUT beaconing technique generates an urgent message called (UBM) when required. Moreover, both update techniques incorporate with the Neighborhood Matrix Entries Management (NMEM) to ensure the refreshment of entries of node's neighbors' matrix. Through using NMEM, a node can estimate its neighbors' residual link lifetime and thus determine when a neighbor will move out of its transmission range and exclude it from its neighbors' matrix.

B. Module 2: DRESM mechanism

The DRESM mechanism is primarily responsible to alleviate the hot spot problem. DRESM was proposed to explore the unused system resources and to distribute the traffic load among all nodes. With DRESM, the enhancement of GFS routing protocol is accomplished in terms of the nodes status information that is been used to take routing decisions. And thus, a multiple criteria approach that can optimize several metrics simultaneously was formulated.

The DRESM is constructed of two coherent techniques; (i) Status Information Distribution and Outgoing Traffic Control Management (IDOTM) supported with destination prediction DPS, and (ii) Fuzzy Logic Dynamic Nodes' Reliability Estimation (FLDRE) technique. IDOTM technique is used to reactively and efficiently allocate and distribute the participating nodes' status information by using the four handshaking messages RTF\CTF\DATA\ACK. As a consequence, every node in the network can reactively get comprehensive and accurate information about its neighbors. With FLDRE technique a node applied a fuzzy logic weighted multi-criteria, to dynamically evaluate the reliability index of its candidate nodes depending on five proposed metrics.

IV. THE FUNCTIONALITY OF RGRS IN MANET

A node periodically broadcasts the FBM message to its one hop neighbors with constant frequency. This period of time is called Long Beacon Packet Interval Time (LBPIT). As a node transmitted FBM, it resets the timer for transmitting the next FBM.

Each node in MANET should perform CUT functionality within the adopted LBPIT interval time to generate UBM. Transmitting UBM is specified by two related conditions. Firstly, a neighbor node should estimates the check time by using fuzzy logic dynamic check time (FLDCT). And a checker node finds that it has deviated a tolerance deviation distance.

Each node receives FBM or UBM updates its neighbors' matrix (NLM) with new neighbor's information. Moreover, besides essential fields NLM contains two additional information fields. These fields are the residual link lifetime (RLT) between the sender of FBM or UBM and the receiver node. The latter on is the neighbor's entry life time (ELT).

By using NMEM, the RLT is estimated based on the relative velocity (speed and direction) between a node and its neighbors. Basing on RLT a node runs an intelligent dynamic fuzzy logic controller refreshment period of entries in neighborhood matrix (IFPE) technique to estimate the neighbor ELT and added it as another part of the entry for this neighbor in its NLM.

A node that has DATA packet to be sent should perform IDOTM and FLDRE technique. With IDOTM all nodes apply the four handshaking messages RTF/CTF/DATA/ACK at the MAC layer. These messages are used by the nodes to collect\ distribute their status. Moreover, these messages are used to forward DATA packets and to send back acknowledgement messages to the source node.

For the sake of sending DATA packets, every node in the network should have another matrix besides NLM matrix. This matrix is used to list a node's neighbors' index. The new matrix is called Reliability Index of Candidate Neighbors (RICN) matrix. The RICN matrix should be empty as the node enters the network area. The containment of this matrix is shaped after maintaining and updating NLM matrix, and after a node runs FLDRE technique to find the reliability index of the neighbors.

Every time a sender node receives a CTF message after it sent RTF message, it updates the reliability value associated to the neighbor sent the beacon. As the sender node finished executing FLDRE and selects next relay nodes, it appends the information of the optimal node and sub-optimal nodes in the header of the DATA packet and sends it for just only the optimal next relay node. A node receives the DATA packet will follow the same procedure to forward the packet to the next hop in case it is not the destination node.

V. Performance Analysis of the Proposed RGRS

A. *Simulation Environment*

The simulations were conducted using Ns2 version 2.33. The simulation network area is rectangle of 2500 m × 2000 m, with 250m nodes' transmission range. We use the MAC layer protocol 802.11 DCF RTS/CTS. The GPSR protocol is utilized as the underlying routing protocol. Both GPSR [6] and POR [18] protocols use the fixed beacon packet interval time (FBPIT) and the entry lifetime (ELT) which set to 3s and 9s (3*FBPIT) respectively. The nodes move according to the Boundless mobility model. The fuzzy logic system has been coded using C++. All simulation results have been averaged over 10 simulation runs and include 95 percent confidence interval data.

B. *Simulation scenarios*

In our simulation environment, we compare the performance of RGRS versus two other routing protocols. To demonstrate the robustness of the proposed algorithm we investigate three scenarios. In the first scenario, we deploy 50 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 25, 50, 75, 100, 125, 150, 175, and 200. Finally, we deploy 50 nodes with fixed nodes speed to 20 m\s and vary the number of data traffics to 5, 10, 15, 20, 25, and 30 flows. The source and destination nodes were randomly selected among the nodes in the simulation scenario.

For comparison sake we selected the Greedy perimeter stateless routing protocol GPSR and the Position-based Opportunistic Routing POR protocol.

C. *Performance Evaluation Metrics*

Based on the proposed mechanisms to improve greedy, the performance evaluation metrics were carefully derived these metrics are.

- Packet Delivery Ratio
- Routing Stretch Measurement

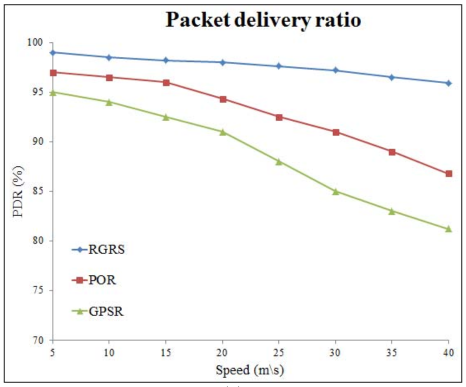
D. *Simulation Results*

1) *Packet delivery ratio*

Fig.2 (a) shows the performance analysis of the achieved packet delivery ratio as a function of node moving speed for the GPSR, POR and RGRS. The result clearly shows that RGRS is much better than the both protocols. Under increasing mobility's topology change, and because of using FBPIT with both GPSR and POR, the position information of the neighbors in a node's NLM matrix becomes stale very fast. Thus, link breakages become more frequently. On the other hand, as the node's mobility increases, DBUM scheme in RGRS maintains an accurate position information of the neighbors in a node's NLM.

Fig. 2(b) shows the performance analysis of the achieved packet delivery ratio as a function of the number of nodes. The figure shows that RGRS is much better than both protocols and GPSR is the worst. For both GPSR and POR, as the sender's degree increases the number of outdated neighbors in its NLM increases too. On the other hand, through using IFPE with RGRS the neighbors' ELT in the node's neighbors' matrix is adaptively and dynamically update regardless of the sender's degree. Moreover, using FLDRE in RGRS guarantees that hot spot problem to not appear.

Fig.2 (c) shows the performance analysis of the achieved packet delivery ratio as a function of data traffics. For GPSR and POR since both of them use the shortest path, the increment in the traffic results collision, congestion, and more link breakage at the center of the network that increases the probability of packet loss. On the other hand, while using RGRS, and through using DRESM and FLDRE algorithms the information of the neighbors in any node's NLM is always accurate. And thus, RGRS protocol achieves the highest packet delivery ratio.



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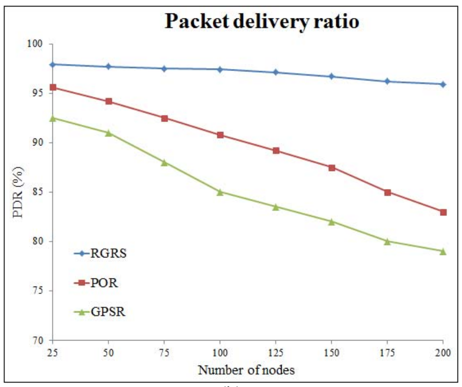

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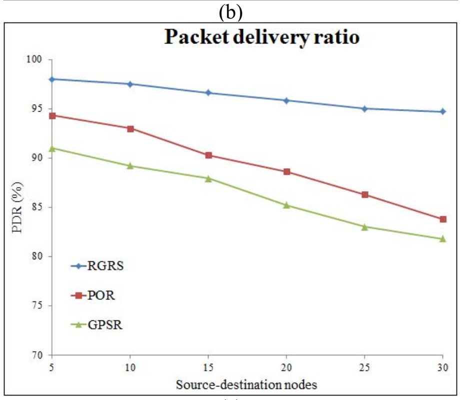


(c)

Figure 2. Packet delivery ratio via (a) node speed, (b) number of nodes (c) number of data traffics

2) Routing Stretch Measurement

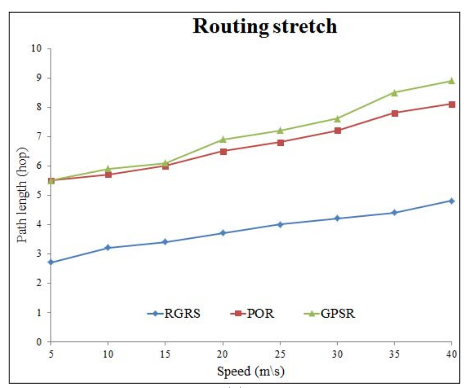
Fig. 3(a) shows results for average hop count in GPSR, POR and RGRS protocols as a function of node speed in the network. The results show that under increasing the nodes' mobility, and with fixed FBPIT, GPSR and POR consumed more hop counts. This is due to the increasing in use stale position information of neighboring nodes in the senders' neighbors matrix. The sender node may pick outdated neighbor node from its NLM to route the data packets. While RGRS scheme actually shortened the route and come close to optimum one. This is because RGRS approach explicitly considers node mobility. On the other hand, RGRS strategy performs less hop counts route comparing with GPSR and POR protocols. This is due to the high network topology maintains achieved by using CUT and NMEM that maintain up to date neighbors information in a node's NLM. This incurs to select more suitable next routing neigbour from the sender NLM.

Fig. 3(b) shows results for average hop count in GPSR, POR and RGRS protocols as a function of number of nodes in the network. It is obvious that for all protocols when network density increases, the average hop count for each route decreases. Also the rout length is decrease and come close to optimum. For GPSR, this is because it can forward packet without the need for using recovery mode and relay on greedy mode to forward the packets. With POR, also there is no need to use virtual destination scheme very often and only use greedy approach.

However, using RGRS strategy achieves better improvement in number of travelled hops compared with conventional GPSR. This is due to high network topology maintains achieved by using CUT and NMEM that maintain up to date neighbors information in a node's NLM.

Fig.3(c) shows results for average hop count in GPSR, POR and RGRS protocols as a function of number of data traffics in the network. For all strategies, as the number of data traffics increase, the hop count increases this is due to more source-destination pairs involves in the routing process which yields to more packets to be forwarded.

Again thanks CUT and NMEM that maintain up to date neighbors information in a node's NLM in RGRS strategy. This incurs to select more suitable next routing neigbour from the sender NLM. Compared to the two other protocols RGRS achieves better improvement in number of travelled hops. On the other hand GPSR is the worst compared to POR.



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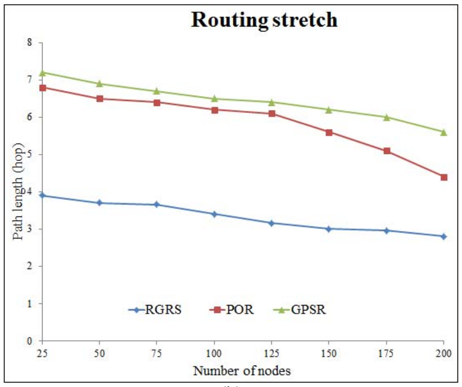

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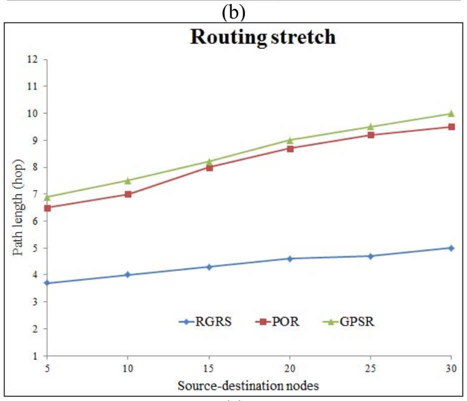

(c)

Figure 3. Routing stretch via (a) node speed, (b) number of nodes (c) number of data traffics

VI. CONCLUSIONS

In this paper, we proposed the RGRS architecture which makes use of two new proposed mechanisms in position-based routing protocols. Unlike conventional position-based routing protocols, RGRS select the next relay node in terms of multi-metrics instead of using one objective. Moreover, RGRS uses an adaptive updating scheme to be sure of the correctness of neighbor information in a node's neighbor's matrix. And finally RGRS does not route packets in a recovery mode towards the destination if not possible but uses the carry and move method. RGRS performs superior to GPSR and POR in various scenarios and routes packets over paths that are 50% and shorter than of GPSR and POR. Compared to GPSR and POR, RGRS has to maintain a small extra routing matrix at nodes limited to some hundred bytes only. Also at high mobility rate few additional control packets are transmitted to keep position information up to date. The RGRS architecture is designed such that the individual protocols could be replaced with relative small costs. Instead of using GFS combined with recovery strategy RGRS as a standalone position-based routing protocol in MANET.

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