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Performance Analysis of the Gossip-Based Ad Hoc Routing Using Received Signal Strength of AODV

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ABSTRACT

In Mobile Ad hoc Networks (MANETs), congestion control is a critical issue in controlling the degradation of network performance. During the route discovery process, the MANET routing protocol floods control packets to discover routes which may cause congestion. Currently, routing protocols take the shortest path with the minimum number of hops to reach the destination without considering the effects of Received Signal Strength (RSS). During the route discovery process, each node of MANET should not blindly broadcast without considering RSS to avoid link breakage. This causes excess energy consumption in rediscovering new routes and a greater likelihood of network partition. This paper suggests a modification of the rebroadcasting procedure for Received Requests (RREQ) in AODV using RSS on Gossip algorithm (AODV-RG). The performance of the protocol is measured based on different scenarios through metrics such as packet delivery ratio, throughput and, end-to-end delay using Network Simulator (NS 3.24.1). Experimental results show that thee AODV-RG protocol outperforms that of AODV with gossip probability *p*=0.66 by minimizing RREQ rebroadcasting messages during route discovery process.
The Ad hoc mobile networks are suffering from the scarce power in the nodes. To decrease the amount of power consumption the AODV has been developed by many researchers by introducing the GOSSIP probability to alter the flow of RREQ. The advantage of this scheme is to decrease the overheads and the busy time of the node by detecting the RSS of the receiving node. When RSS is more than the threshold, then the RREQ is forwarded. If RSS is less than the threshold value, then RREQ is ignored. We need to test if the GOSSIP use has affected positively the quality of performance parameters such as utilization, packet delay ratio and throughput of the RREQ rebroadcasting and the end-to-end delay.

Keywords*: GOSSIP, RSS, RREQ, AODV and MANET*

1. INTRODUCTION

GOSSIP is a powerful technique to build highly scalable, flexible and, easily managed robust applications. Traditionally, GOSSIP has been applied in wired networks [1]. Recently GOSSIP protocols have been applied to wireless *ad hoc* networks [2][3][4].

In the GOSSIP technique, each node communicates with small subsets of other nodes in a probabilistic manner to propagate small amounts of information. The information receiving nodes in turn forwarded to other subset of nodes. Thus, information is disseminated by the majority of the nodes in the network by some probabilistic randomized mechanism.

Mobile Ad hoc networks (MANET) have dynamic topologies which are prone to interference from different sources, which may cause the network to be highly instable. Furthermore, mobility of nodes causes severe link breakage during communication between the nodes. In addition, there is no centralized system to control the activities of nodes [5].

Many ad hoc routing protocols do not use Global Positioning System (GPS). Together with few optimizations, new routes are discovered between the nodes by means of flooding techniques. In regard of optimization, many routing messages are propagated. Owing to this fact, it creates a large number of redundant packets, collision of packets, additional energy consumption and network congestion.

In recent years, many researchers have focussed on the optimization of routing protocol from different point of view. Some of the proposed solutions try to implement congestion avoidance rather than congestion detection technique. Finally, by means of probabilistic approach, many routing overheads has been diminished [6]. However, during routing discovery process, factor such as Received Signal Strength (RSS) is not taken into account which may cause the linkage to break rapidly and the discovered route life span will be short.

To alleviate these challenges, flooding mechanism based on GOSSIP algorithm exploiting cross layer technique of RSS value in PHY/MAC layer for Ad hoc On Demand Distance Vector (AODV), a reactive protocol works in network layer is proposed in this paper. The proposed technique minimizes the route message forwarding which is guided by RSS to establish strong link.

The rest of the paper is organized as follows. Section II briefly discusses about the GOSSIP algorithm in mobile ad hoc networks and its implementation. Section III discuss the route discovery process in AODV and how RSS based GOSSIP can be implemented in AODV. Section IV shows the simulation setup performed for this research. Section V analyses and discusses the simulation results for four different scenarios. Section VI concludes the paper.

2. BACKGROUND

GOSSIP protocols take inspiration from rumour dissemination and disease epidemics to important computer algorithm. Various types of GOSSIPs are found in literature [7]. GOSSIP protocols are considered as decentralized, message-passing in which 1) small information are exchanged between the nodes; and, 2) exchanges are probabilistic in nature.

Consider a source node S wants to send packets to destination D. According to GOSSIP algorithm, the route discovery can be performed by following steps:

1. If the source node is current node, then by using routing protocol list of neighbours N is collected.
2. From the list of N neighbours, randomly K number of neighbours are selected where K<=N.
3. First node in K is chosen and GOSSIP message is forwarded.
4. GOSSIP messages for remaining nodes are scheduled for interval I.
5. Each member of K will become current node and GOSSIP with its neighbour and step is repeated. The process is continued until the destination is reached.

6. When member of K nodes receive the GOSSIP message and if it is destination, then it will send the reply to Source. Otherwise, it will proceed to step 5.

In short, every node in the wireless network forwards broadcasting packets with the same probability. This probabilistic scheme is called as GOSSIP. In this scheme, the source node sends Receive Request (RREQ) packets with the probability p and discards it with probability 1-p. This scheme is called as GOSSIP (p) [8][9].

GOSSIP1 (p, k) [9], an improved version of GOSSIP in which source broadcast GOSSIP message with the probability of p=1 for the first k hops. This guarantee certain connectivity up to a distance of k hops from the source node. However, the main predicament in GOSSIP1 is establishing optimal forwarding probability for given scenario.

[9] Found that optimal probability for GOSSIP1 is between [0.65, 0.75] where number of nodes is less than 1000. Likewise, the author [9] suggests that probability for rectangular layout containing 150 nodes is 0.5.

Another important issue is fixing the k value. For more than 1000 nodes with distance up to 45 hops, the authors [9] suggests for fixing the value of k = 4. However, reference [10] fixed the value as k=1 for 150 nodes when GOSSIP was implemented with AODV.

[11] Found that for the nodes less than 100, the optimum gossiping forward probability (p) is between 0.4 and 0.5. On the other hand, in highly congestion area, the forward probability is as low as 0.1 is achieved to reach all nodes implemented in IEEE 802.11 MAC layer [12].

GOSSIP algorithm is implemented by [13,14] in geographical protocols. In this protocol, neighbouring nodes are identified by their location and packets are forwarded in greedy manner using coordinates. Thus, comprehensive network information is not required to choose subsequent hop selections in dynamically changing topology for MANET and therefore it is not scalable.

[15] Proposed probabilistic based routing protocol based on neighbour coverage. By using neighbour coverage, the number of neighbours to receive RREQ message is determined. The rebroadcast probability is calculated using unearth neighbours, connectivity metrics and local node density. The proposed protocol alleviates the collision and network contention to increase the packet delivery ratio and decrease the average end-to-end delay.

Hybrid Location based Ad hoc routing protocol (HLAR) is proposed to mitigate the routing overhead caused due to link breakage [16]. The location information provided by geographical routing is effectively used to reduce routing overhead. However, the reactive routing mechanism is used when location information is inaccurate. RREQ is forwarded to the neighbours who are closer to the destination. Otherwise, RREQ is forwarded to all other nodes. HLAR performed better than AODV without affecting network performance in terms of throughput, packet delivery ratio and end-to-end delay.

Estimated Distance based Routing Protocol (EDRP) proposed by [17] consists of two components namely: Estimated Geometrical Distance (EGD) and, Estimated Topological Distance (ETD). EGD measures geometrical distance between two nodes if there is fluctuation in their RSS value when two nodes move apart. ETD facilitates EGD if erroneous assessment of distance is made. RREQ is propagated with the help of EGD and ETD which significantly improves the routing performance by reducing the routing overhead.

[18] Suggested Hybrid Flooding scheme to reduce outburst of route message during simple flooding. Derived from distance to the neighbour and neighbourhood node denseness, each node adjusts its forwarding probability. The RREQ are broadcast with minimal probability in intense area whereas in non dense area to condense the redundancy of broadcasting messages, RREQs are propagated with elevated probability. In forwarding zone, RREQ forwarding is restricted for the nodes located inside the zone. The RREQs forwarding are prohibited to the nodes lying beyond the zone. The routing overhead of hybrid flooding scheme is less while compared to other flooding techniques when energy utilization in packed network is minimal.

[19] Proposed GOSSIP Based Battery Usage (GBBU) routing protocol. The battery capacity and node degree of individual node is considered during implementation of gossiping probability. This probability outperforms traditional AODV in terms of packet delivery fraction, energy utilization per packet delivered, delay and network life time.

[20] Implemented GOSSIP algorithm in AODV using RSS(RSS-GOSSIP AODV). In this protocol, RSS is utilized to select the best path than shortest path. However, in this research, the proposed protocol is analysed based on varied sending data only.

It does not account for other consequences such as mobility and flow nosiness.

This work has been motivated by the experiments performed in [20]. However, those results are expanded further by initiating three new network scenarios, high traffic packets and in advance simulation tool. First, three new network scenarios are analysed designated as school field trip, rescue operation and archaeological field trip respectively. The fourth scenario is in analogous with [19]. They are intended to test and compare the proposed routing protocol with existing protocol with realistic parameters. Second, numbers of packets are enhanced to understand the performance under traffic flow. Final, the advanced simulation tools are adopted to take into account updated models, attribute system and improved tracing techniques, which append to the pragmatism of the latter scenarios.

3. INCORPORATING RSS BASED GOSSIP IN AODV

The GOSSIP technique implementation in routing protocol AODV using RSS threshold is as follows:

A. AODV

In MANET, each node behaves as router in forwarding RREQ messages to the neighbouring nodes. Based on route discovery process, MANET routing protocols can be classified as Proactive (table-driven), Reactive (on-demand) and Hybrid (mixed of both).

Proactive routing protocols such as Destination Sequenced distance Vector (DSDV) and Optimized Link State Routing (OLSR) exchange routing information periodically irrespective of usage routes for packet transfer. In contrast, reactive protocols such as AODV discover route on demand when source nodes requires route to destination. The review of literature shows that AODV is much efficient and most studied protocol among other MANET routing protocols.

In AODV, an expanding-ring search process is employed to discover route. Firstly, it floods Route Request (RREQ) packets to neighbour nodes located within its transmission range. It is then progressively extended to large radius to retrieve the location of neighbours. So, AODV parameters play a crucial role in the propagation of RREQ.

When a node obtain RREQ packets, in case, it has destination information in its routing table, it dispatch Route Reply (RREP) message to the originating node. If any node is malfunctioned on the route, it send Route Error (RERR) message to originating node. On acceptance of RERR messages by originating node, it purges the route information from its routing table.

B. RSS based GOSSIP

RSS varies inversely to the square of distance between sender and receiver [20]. For this research, Friis propagation model [21] is used to calculate RSS using the formula:

$$RSS = Tx + 10 \log(\lambda^2 / [(4 * \pi * d)^2 * L])$$

where Tx is the transmitting power, λ is the wavelength, d is the distance between receiver and transmitter and L is the system loss. The wavelength (λ) is calculated using the formula:

$$\lambda = C / f$$

Where C is speed of light in vacuum and f is the carrier frequency (in Hz) at which RREQ is propagated.

Due to periodic discrepancy in the attributes of wireless factors, the received signal strength at all times oscillate. Two nodes can exchange packets if the RSS of receiving node is beyond convinced threshold values.

Currently, in AODV, the route discovery mechanism is based on number of hops between source and destination to find the shortest path. If many paths exist between source and destination, then AODV chooses the shortest path. While forwarding RREQ message to neighbouring nodes, quality of link is not contemplated.

Thus, there is a chance of choosing weak node for new route. As a consequence, newly discovered route may soon split and be inoperative for sending the data. In this ill case scenario, RREP forward by destination under no circumstances accessed by the source since the intermediate nodes would have moved out of its route path resulting in link breakage.

Due to this fact, efforts taken for RREQ forwarding become wasted result in rediscovering the new route once again by the source node. If this happens to all nodes, it increases network congestion, packet delay and consumption of node energy which ultimately reduce the battery life time of nodes. Thus, it is essential to discover the best path instead of shortest path.
To alleviate this issue, the variant of AODV termed as AODV-RG is proposed. In the proposed algorithm, RREQ forwarding is guided by RSS based on GOSSIP probabilistic concept.

As suggested by [2], GOSSIP3 (0.65,1,m) is implemented in AODV-RG where ‘m’ is RSS value. During expanding-ring search of AODV_RG, after 1-hop, the RSS of the receiving node is validated with threshold value of RSS. While the node having RSS value above the threshold value is allowed for normal flooding of RREQ, the node below the threshold value implements GOSSIP algorithm for rebroadcasting.

In short, an intermediate node forwards RREQ only if it receives the RSS of the packet within the threshold value, else it performs GOSSIPs with probability p=0.65. Thus, AODV-RG precludes the discovery of weak paths by reducing the RREQ packets forwarding only to ensure best path instead of shortest path.

The experiment is conducted to investigate threshold value of RSS. With constant topology model, the throughput is checked for RSS by Fixed RSS propagation model in the range between -102 dBm and -80 dBm for the communication between two nodes. The experiment was repeated for DSS1Mbps, DSS2Mbps, DSS5_5Mbps and DSS11Mbps.

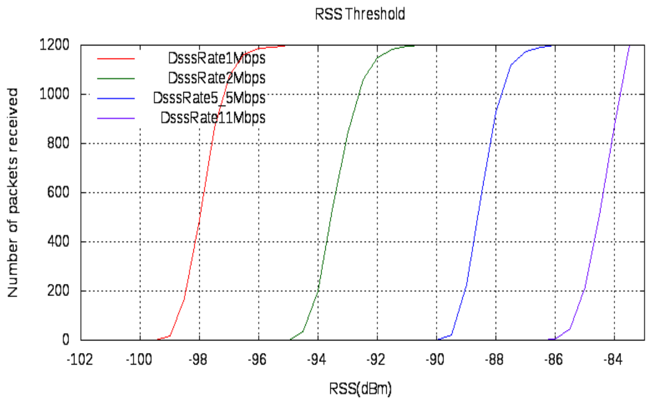

Figure 1 RSS Threshold

The result (Fig1) shows that threshold values are -94 dBm for DSS1Mbps, -89 dBm for DSS2Mbps, -85 dBm for DSS5_5Mbps and -83 dBm for DSS11Mbps respectively. These threshold values are supported by [20] and it is applied for GOSSIP probability in the experiment.

4. SIMULATION

The simulation study was conducted in the Network Simulator (NS3) version 3.24.1 over IEEE 802.11 MAC/PHY layer protocol. The simulations were performed on laptop equipped with 2.5 GHz (Intel Core i5) processor with 6GB of RAM running on Ubuntu Linux version 14.04 LTS. The performance of AODV-RG is evaluated against AODV. The radio propagation model is propagation model developed by [21]. The packet size of application is 512 bytes. The transfer data rate is 1024 Kbps.

For mobility, random-way point is chosen in a rectangular field [22]. The uniform mobility speed of 5 m/sec is maintained, to thwart mobility from being stationary.

In a grid of 2000 x 2000 m, 25 nodes are randomly placed. There is a flow from first node to last node, generating traffic of $1 * 10^7$ packets. This represents a worst-case assessment on the functioning of MANET using gossiping.

The simulation time is 100 seconds. On 40th second, the traffic is injected. At uniform speed from 1 to max speed m/s, the nodes moves randomly. The pause time is set to zero. To maintain even-handedness, identical mobility and traffic scenarios are exercised for both AODV and AODV-RG.

On average, each data point symbolizes 30 numbers of runs of simulation. As reported by [2], the timeout period of AODV-RG gossiping is set as 5 * NODE TRAVERSAL TIME. The GOSSIP timeout is determined by AODVs NODE TRAVERSAL TIME parameter. The threshold value of RSS as mentioned in the Section III.

The performance of simulation is studied with the following three metrics which were studied by [20]:

1. The *Packet Delivery Ratio* is the ratio of the number of data packets successfully delivered to the number of data packets generated by the source.
2. The *Average End-To-End Delay* of data packets includes all possible delays to reach the destination from source which are caused by buffering during interface queuing, route discovery, propagation, transfer time and retransmission at the MAC layer.
3. The *Throughput* is the average rate of successful message delivery over a communication channel.

5. SIMULATION RESULTS

In order to investigate how the routing protocols perform, three scenarios were designed and simulated. The simulation results are discussed with Scenarios.

A. Scenario 1

During the school field trip to mountain range where more obstacles prevails, throughput and delay is controlled by the amount of sent and received traffic by the participants. The traffic is affected by the factors such as packet interval (inter arrival time between the packets). Thus, the packet interval is defined as time interval between two successive packets which plays a crucial role in the simulation. Due to this fact, the simulation is conducted for packet interval in the range between 0.01 seconds to 0.20 seconds.

Fig2,3&4 shows that AODV-RG delivers better network performance than AODV in terms of throughput, packet delivery ratio and end-to-end delay. At initial stage, congestion is not reduced and does not have much impact on packet interval. Once it reaches saturation point at the packet interval=0.5 seconds, congestion started to decline and thus throughput and packet delivery ratio of AODV-RG inclined abruptly.

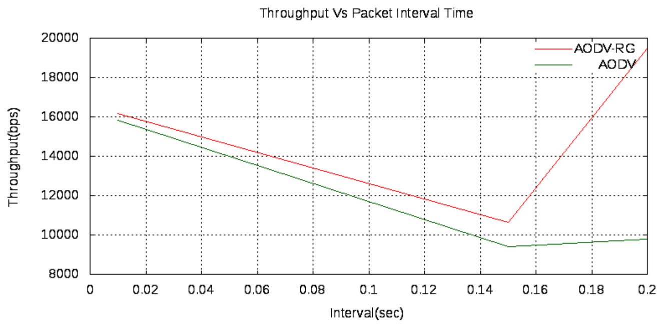

Figure 2 Throughput as a function of packet interval

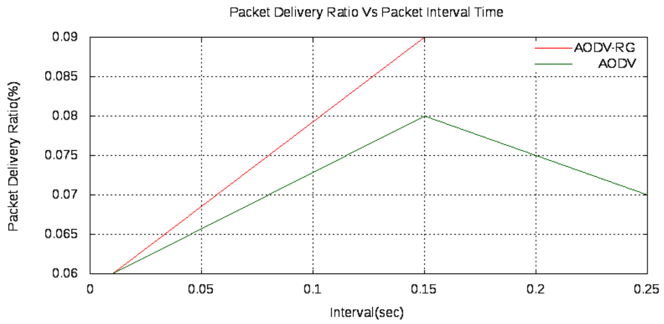

Figure 3 PDR as a function of packet interval

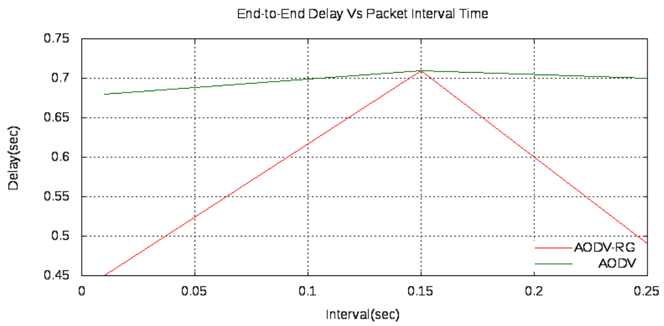

Figure 4 End-to-End Delay as a function of packet interval

The average end-to-end delay in AODV is larger than AODV-RG. For the reason that in AODV, due to elevated probability of channel contention, queue delay and packet collisions triggered by repeated retransmissions disproportionately and flooding, the majority of the RREQ messages not succeed in reaching their destinations. Thus the amount of time essential for the packets to be broadcasted between source and destination is amplified.

B. Scenario 2

In rescue operation where earthquake occurs in mountain region, the missing person will be searched by the rescue team. The rescue team will search in certain area of 2500 X 2500 m^2 at every face. The team may move with Random mobility model. During the operation, team members can interact with other rescue members by files, text or voice messages with data rate is 1024 kbps. They may move at the various speeds to search for missing persons. Thus, Simulation is run for various speeds from 1 m/s to 5 m/s.

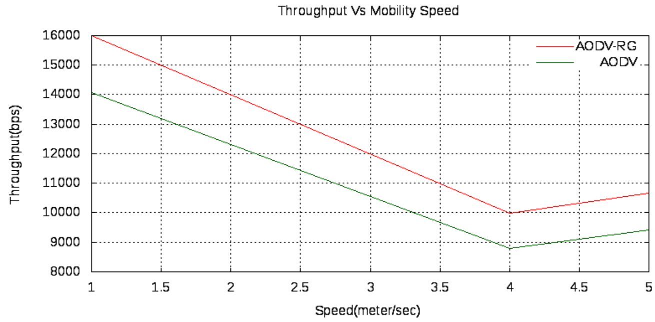

Figure 5 Throughput as a function of mobility

With an offered load of 10^7 packets, the maximum throughput approximately is 16000 bps. Throughput and packet delivery (Fig 5&6) decreases with increased mobility on AODV-RG and AODV. This is due to difficulties in finding routes when mobility increases. This is clear from Fig 5, where the throughput drops about 10 percent at high mobility for AODV than AODV-RG.

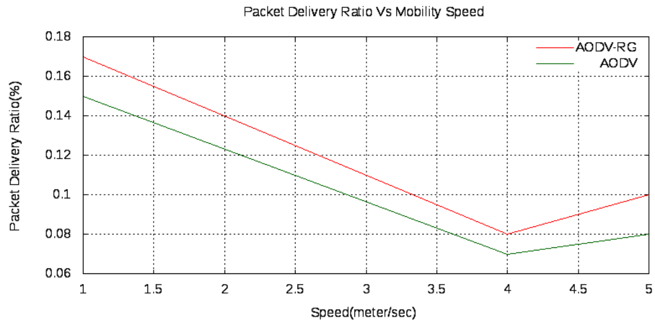

Figure 6 PDR as a function of mobility

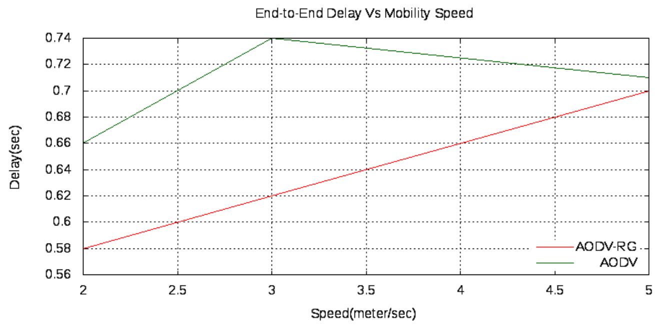

Figure 7 End-to-End Delay as a function of mobility

The average packet delivery increases with mobility (Fig 7). However, AODV has higher delay than AODV-RG due to weak link and much time was spent on new route discovery. On the other hand, AODV-RG uses strong link compared to AODV due to implementation of RSS in GOSSIP algorithm.

C. Scenario 3

In the museum where Wi-Fi spots unavailable, the handheld devices such as handsets are the primary exhibit to communicate with other tourist team members. The team members form a Manet with each member moving with a constant speed. They can communicate with heavy multimedia files. The simulation is conducted with number of packets being send which affects the communication.

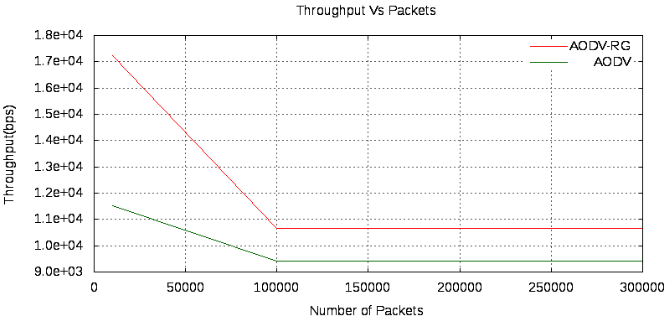

Figure 8 Throughput as a function of Number of Packets

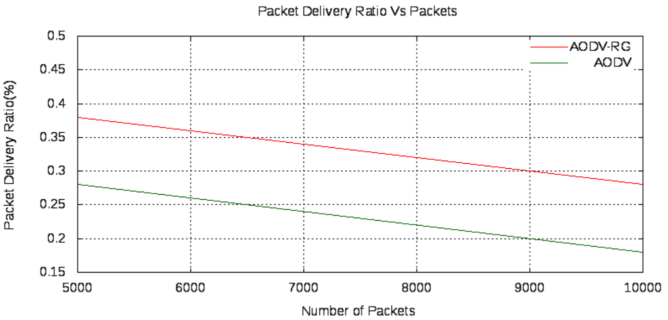

Figure 9 PDR as a function of Number of Packets

Fig 8, 9 & 10 shows that AODV-RG delivers better network performance than AODV in terms of throughput, packet delivery ratio than AODV protocol. This is because AODV-RG chooses GOSSIP algorithm below the threshold value of RSS and thus reduces the weak link.

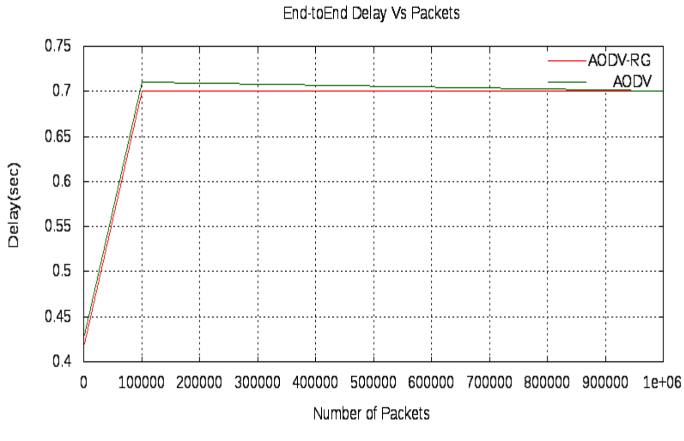

Figure 10 End-to-End Delay as a function of Number of Packets

However, when both the routing protocols reach saturation limit (10^6 packets), all three metrics namely throughput, packet delivery ratio and delay is maintained steadily. This is owing to the fact that by increasing number of packets, the congestion condition remains unaltered.

D. Scenario 4

In this scenario, the impact of varied sending data rate from 32 kbps to 1024 kbps is studied on proposed AODV-RG protocol and traditional AODV protocol.

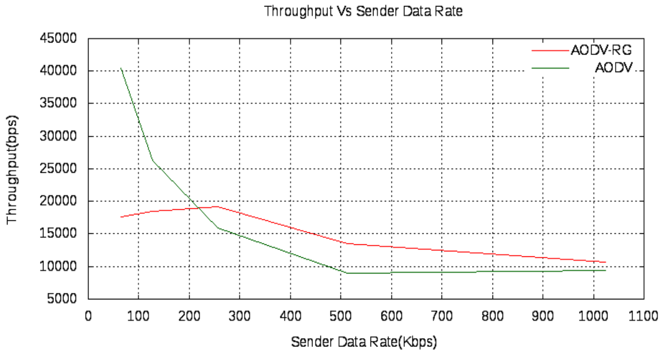

Figure 11 Throughput as a function of Sender Data Rate

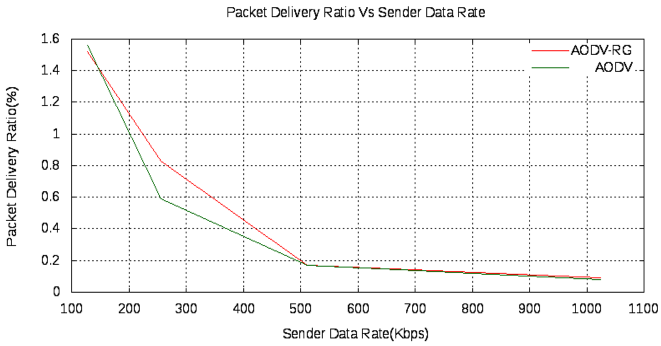

Figure 12 PDR as a function of Sender Data Rate

As in the Fig 11, 12 &13, sender data upsurge further than the saturation limit, AODV-RG outperforms conventional AODV. At 250 Kbps, network congestion begins and thus channel bandwidth is freed due to reduction in number of RREQs. And also, the route selected is based on threshold level of RSS due to gossiping algorithm. These facilitate increase in throughput and packet delivery ratio.

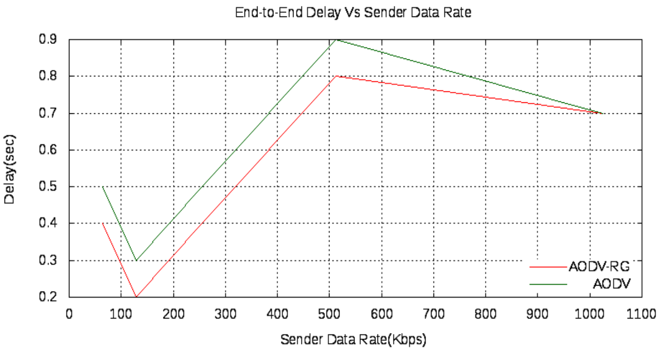

Figure 13 End-to-End Delay as a function of Sender Data Rate

However, beyond 500 Kbps, the network congestion increases slowly and steadily. Consequently, RREQ broadcast is increased because of new route discovery and network performance degrades.

6. CONCLUSIONS

Despite the various optimizations on MANET routing protocol such as AODV, many routing messages (RREQ) are propagated unnecessarily. GOSSIP has various approaches such as fixed probability and adaptive scheme. In this research, fixed probabilistic scheme is adopted were probability p=0.66 which is fixed until the end of the propagation.

The proposed scheme exploit the channel quality at the physical layer and attempts to get good route to reach destination from the source by plummeting RREQ broadcasting along the weak links to enhance network performance and linking lifetime.

The realistic scenarios were examined to get an understanding on how the protocols would behave in realistic environment. The performance of routing protocol is checked with variation in packet interval, mobility, number of packets and data rate by measuring throughput, packet delivery ratio and end-to-end delay.

The simulation result clearly indicates that proposed AODV-RG is superior to traditional AODV protocol. In all aforementioned scenarios, the principle of implementing GOSSIP algorithm to below RSS threshold value seems to be excellent. On the whole, proposed AODV-RG over performed AODV in terms of throughput, packet delivery ratio and delay. On the basis of this study, AODV-RG should be considered suitable for mobile ad-hoc networks with small networks.

7. FUTURE WORK

The work presented is the first of a series of simulation studies within the area of mobile ad hoc networking. These studies should include

- Interfacing MANET with wired networks
- Experiment for large networks with multiple traffic flow
- Optimization of the power consumption and the processing cost along with received signal strength
- Inclusion of QoS mechanism for real-time and no real-time traffic

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