A New Routing Protocol for Mobile Ad Hoc Networks

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Abstract. Mobile Adhoc Networks (MANETs) is a wireless infrastructure-less network, where nodes are free to move independently in any direction. The nodes have limited battery power; hence we require energy efficient routing protocols to optimize network performance. This paper aims to develop a new routing algorithm based on the energy status of the node. In this paper, it has been proposed a new Protocol for Mobile Adhoc Networks which is expected to achieve energy efficiency and reliability. The gossiping probability of a node is determined by the throughput. Differently from other proposals no external location service support, e.g., via GPS, is not required. Rather, the throughput is estimated from the ''inside'' of the network using feedback factor through the node propagation to the destination and the value of gossiping probability is adaptively adjusted. This results in less energy consumption and more reliability in the network.

Keywords: Ad hoc Networks, Throughput, Delivery Ratio, Energy Consumption, Reliability.

1 Introduction

A mobile ad-hoc network (MANET) is a collection of many mobile nodes with no infrastructure. To form a network over radio links, the mobile nodes are self-organized. Extending mobility into the self-organized, mobile and wireless domains is the main objective of MANETs where a set of nodes form the network routing infrastructure in an ad-hoc fashion. MANETs are used in those areas where wired network is unavailable and where rapid deployment and dynamic reconfiguration are necessary. These include military battlefields, emergency search, rescue sites, classrooms and conventions, where the participants share information dynamically using their mobile devices [1].Generally the existing routing protocols are classified as Table-driven (proactive) routing protocol ,On-demand (reactive) routing protocol ,Hybrid routing protocol and Geographic routing protocol.

1.1 Proactive MANET Protocol (PMP)

A proactive MANET protocol (PMP) detects the layout of the network which is active. PMP maintains a routing table at every node. From the routing table, with minimal

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delay, a route can be determined. The PMP can provide good reliability and low latency. This protocol cannot update the route information immediately for a node moving with high speed. Also for a node moving occasionally, updating the unchanged entry continuously in the routing table results in much traffic overhead and wastage of network resources. PMP is not appropriate for large scale MANETs [2]. PMP is used in DSDV [11], OLSR [14].

1.2 Reactive MANET Protocol (RMP)

In Reactive MANET protocol (RMP) when the source node requests communicate with the other node, only then a route between a pair of nodes is found. For nodes with high mobility and for nodes which transmit data occasionally, this on-demand approach is quite suitable. But in RMP, the source node broadcasts route requests throughout the network and has to wait for the response which is a disadvantage. This route discovery procedure results in a major delay [2]. RMP is used in, DSR[12], AODV [13] and TORA[15].

1.3 Hybrid Routing Protocol

It is distinct that both PMP and RMP have their own merits and drawbacks [2]. It is hence natural to consider a hybrid approach that integrates the merits of PMP and RMP. Zone routing protocol (ZRP) [2] common characteristic is that the association of nodes with zones is generally deterministic, i.e., each node must be in a specific zone. The intra-zone routing protocol is proactive while the inter-zone routing is performed by the reactive approach.

1.4 Geographic Routing Protocol

Geographic routing uses nodes' locations as their addresses, and forwards packets (when possible) in a greedy manner towards the destination. One of the key challenges in geographic routing is how to deal with dead-ends, where greedy routing fails because a node has no neighbor closer to the destination (*GPSR*) [18].

1.5 Gossip Routing Protocol

For location discovery or for secure routing applications, most ad hoc routing algorithms depend on broadcast flooding. Though flooding is a robust algorithm, because of its extreme redundancy, it is unfeasible in dense networks. The use of flooding algorithms may lead to broadcast storms in large wireless networks where the number of collisions is so high it could cause system failure. Since the packet retransmission is based on the outcome of coin tosses, Gossip [3] is a probabilistic algorithm. The main objective of gossip is to minimize the number of retransmissions, while maintaining the main benefits of flooding.

The paper is organized as follows. In Section 2 we summarize related works. Section 3 presents an analytical performance model of the gossip protocol. Section 4 describes an implementation of the algorithm which exploits throughput as feedback; simulation results are provided in Section 5 and concluding remarks in section 6.

2 Related Work

Xiaobing Hou and David Tipper [3] propose the Gossip-based Sleep Protocol (GSP). With GSP, each node randomly goes to sleep for some time with gossip sleep probability p. When the value of p is small enough, the network stays connected. Mike Burmester et al. [4] consider ways to reduce the number of redundant transmissions in flooding while guaranteeing security. They present several new gossip protocols which automatically correct all faults and guarantee delivery. Yuval Shavitt and Amir Shay [5] introduce the Gossip Network model where travelers can obtain information about the state of dynamic networks by gossiping with peer travelers using ad-hoc communication. Travelers then use the gossip information to re-choose their path and find the shortest path to destination. Zhongmin Shi and Hong Shen [6] Gossip-based techniques recently adopted in mobile ad hoc network (MANET) system have achieved significant improvement on network overhead, routing efficiency and reliability. Zygmunt J. et al. [7], propose a gossiping-based approach, where each node forwards a message with some probability, to reduce the overhead of the routing protocols. With less number of executions maximum of nodes get the message that depends on the gossiping probability and the topology of the network. Hany Morcos et al. [8] propose a new approach - by control-theoretic adaptations similar to those widely used in the Internet, e.g. additive-increase multiplicative-decrease (AIMD) of TCP for reacting to congestion conditions. Cigdem Sengul Indranil Gupta et al. [9] propose networking protocols for multi-hop wireless sensor networks (WSNs) which are required to simultaneously minimize resource usage as well as optimize performance metrics such as latency and reliability. They explore the energy-latency-reliability trade-off for broadcast in multi-hop WSNs, by presenting a new protocol called PBBF (Probability-Based Broadcast Forwarding). Xiang-yang li et al.[10] used Gossip based routing method and re-checked to reduce the number of messages in both wired networks and wireless ad hoc networks.

3 Gossip Routing in Adhoc Networks

A message is normally transmitted as a broadcast rather than a unicast communication in adhoc networks. So the message is received by the entire nodes one hop away from the sender. Since wireless resources are expensive, we use this physical-layer broadcasting feature of the radio transmission. In the gossiping protocol, we control the probability with which this physical-layer broadcast is sent [7].The basic gossiping protocol is simple. A source sends a route request with probability 1. When a node first receives a route request, with probability p it broadcasts the request to its neighbors and with probability 1-p it discards the request; if the node receives the same route request again, it is discarded. Thus, a node broadcasts a given route request at most once [6]. Thus, in almost all executions of the algorithm, either scarcely any nodes receive the message, or most of them do. Ideally, we could make less number of executions where the gossip dies out relatively low while also keeping the gossip probability low, to reduce the message overhead [7].

The gossip routing protocol satisfies the following conditions:

- The main portion of the protocol involves periodic, pairwise, inter-process communications.
- During these communications the information exchanged is of bounded size. Agents interact, just to intimate the change in the state of the other agent.
- A gossip communication does not occur when A pings B, to compute the response time, as this does not involve the transmission between agents.
- Reliable communication is not implicit.
- The protocol costs are insignificant since the frequency of the communications is low compared to classic message latencies.

Since the current ad hoc network routing protocols require all the nodes to be awake and keep listening wastes a lot of energy.

4 A New Proposed Routing Protocol

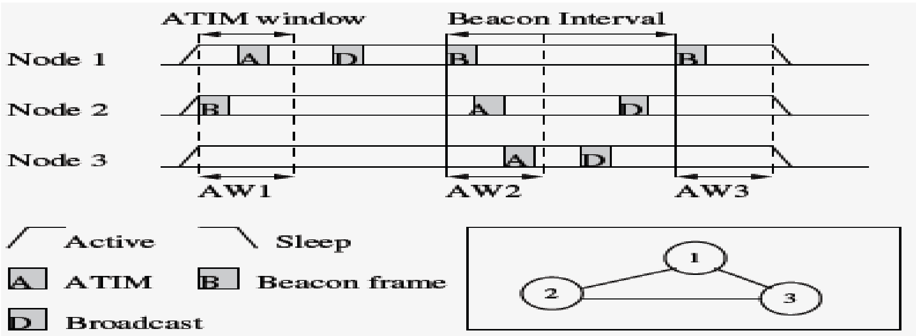
Our observation is that if gossiping can make all the nodes receive a message, then the nodes forwarding the message are connected at least by the paths the message passes through. Therefore, in a static network without mobility (e.g., a sensor network), with certain probability p', gossiping protocols [7] can make almost all nodes in the network receive the message. Then if all nodes go to sleep with probability p = (1-p'), almost all the awake nodes stay connected. Thus, we can safely put a percentage (p) of the nodes in sleep mode without losing network connectivity. We term p the gossip sleep probability.

Let us assume that every node in the ad hoc network chooses an equally distributed random time interval, known as gossip interval. When the time is up, the node will immediately choose another random interval independently. To make it possible, we assume the feasible maximum gossip interval is much smaller than the lifetime of the network. Each node independently generates a random time interval and chooses either going to sleep with probability p or staying awake with probability 1-p for the interval. Every sleeping node wakes up at the end of its interval. Every node repeats the above process for every random interval independently.

4.1 Sleep Scheduling Mechanisms

There are two main MAC-layer approaches to reduce energy consumption in Adhoc Networks. The first approach is to use an active-sleep cycle, which lets nodes sleep periodically. The second approach involves using an additional low-power wake-up radio to wake up nodes. However, since this approach requires an extra hardware component on the sensor node, the remainder of the paper focuses on only the active-sleep cycle approach.

The basic idea of introducing an active-sleep cycle to a contention-based protocol is to divide time into frames. Each frame is divided into an active time and a sleep time. During the sleep time, a node puts its radio in sleep mode to save energy. During the active time, a node can send and receive messages. For instance, the IEEE 802.11 protocol [IEEE 802.11 1999] provides such a power-save mode (PSM), which requires nodes to be time-synchronized and follow the same active sleep schedule. In IEEE 802.11 PSM active and sleep times are fixed.



(a) Broadcast in IEEE 802.11 PSM.

Since the focus of this paper is broadcast, we next discuss the behavior of these sleep scheduling mechanisms for this communication pattern. Fig.1 shows where nodes are synchronized to wake up at the beginning of every beacon interval. Pending traffic is announced via ATIMs (Adhoc Traffic Indication Messages) in an ATIM window. In the example, Node 1 announces a broadcast ATIM for which all one-hop nodes (or neighbors) (e.g., Node 2 and Node 3) should stay awake to receive the message after the ATIM window.

An immediate observation is that to rebroadcast the message, a node must wait for the next ATIM window to guarantee that each neighbor receives the ATIM advertising the broadcast. This increases latency. A second observation is that when, say, Node 2 retransmits the broadcast message, Node 1 and Node 3 receives redundant packets. Furthermore, due to redundant broadcast packets, nodes stay awake the entire beacon interval more often, mostly listening on the channel. This increases energy consumption.

Hence, broadcast traffic does not increase the energy spent in idling; however, energy consumption still increases due to redundancy. Additionally, nodes that follow more than one schedule add to redundancy since these nodes typically transmit a broadcast message multiple times to guarantee the neighbors with different schedules receive the message. However the broadcast redundancy problem remains as all nodes send the message once to IEEE 802.11 PSM. For each broadcast packet, nodes need to send and receive a preamble at least as long as the check interval. Hence, the energy spent for listening increases with redundant packets. Therefore, the sleep scheduling mechanisms for Adhoc networks display similar disadvantages in the presence of broadcast traffic. Motivated by these observations, we propose a new Routing Gossip Routing Protocol which allows achieving less energy consumption and more reliability.

A node (which wants to communicate) maintains a control variable called C which represents the active number of neighbors. The rest of the nodes in the network will be in either p or 1-p state. The higher - C is the more power the node uses to send packets and thus the communication is more reliable. When node X needs to broadcast a data packet, X looks up its neighbor list for the distance between itself and its neighbors numbered C. X then calculates the amount of power needed to send the packet to that neighbor. Every node initializes C to one. This means that a node initially broadcasts data packets only to its closest neighbor, thus requiring the least power. After sending data packet, node X waits for a feedback from destination. While receiving packets at the destination, the throughput D is calculated and it will be sent as a feedback to the source. If X hears a feedback D for the data packet below a reliability threshold RT, X increases the value of C there by increasing the probability of number of active nodes. This assures the increased throughput. When D becomes greater than or equal to RT, the value of C is decreased adaptively to decrease the number of forwarding nodes and there by decrease the probability of number of active nodes. This process continues until either X hears a feedback for the packet or the value of C reaches reliability threshold RT, which is determined by the total number of neighbors. Upon receiving a feedback, X starts to decrease the value of C (after a certain number of acknowledged data packets) to a minimum value of one.

Algorithm

1. Let sleep probability P(s) = p and awake probability A(s) = 1-p.
2. Let initial value of C=1.
3. X broadcasts data packets to Y.
4. At Y, calculate throughput D,
   D= Number of packets received /Number of packets sent
5. Y sends D as a feedback to X.
6. At X, If D<RT then,
   6.1. C = C+ δ, where δ is the additive factor.
   6.2. Repeat from 3.
7. End
8. Else. If D >= RT, then,
   7.1. If C>1, then,
      7.1.1. C=C-δ
      7.1.2. Repeat from 3.
   7.2. End If
9. End If
10. End.

After some beacon interval of time, from the step 3, algorithm will be repeated.

To summarize, new routing protocol has the following salient features:

- Unlike existing routing schemes, new protocol is neither single-path nor multi-path; rather each node exploits the multiplicity of paths based on its observed loss conditions.
- In new protocol, only for low packet delivery ratios, a node uses high-power transmissions to reach farther neighbors. For high packet delivery ratios, a node adapts to low-power transmissions. Thus, new protocol sensibly consumes power based on local error conditions, which maximizes the lifetime of the network and minimizes the cost of the power consumed per successfully delivered data.
- Thus new protocol aggressively probes for possible routes to deliver data packets, thus reacting quickly within unreliable areas of the network.

5 Simulation Results

5.1 Simulation Model and Parameters

NS2 is used to simulate the proposed algorithm. In our simulation, the channel capacity of mobile hosts is set to the value: 2 Mbps. For the MAC layer protocol the distributed coordination function (DCF) of IEEE 802.11 is used. It has the functionality to notify the network layer about link breakage.In the simulation, mobile nodes move in a 800 meter x 400 meter region for 50 seconds simulation time. The number of mobile nodes is kept as 40. We assume each node moves independently with the same average speed. All nodes have the same transmission range of 250 meters. In our simulation, the speed is set as 10m/s. The simulated traffic is Constant Bit Rate (CBR). The pause time of the mobile node is kept as 10 sec.

5.2 Performance Metrics

Our proposed a new Routing protocol is compared with existing Probability Based Broadcast Forwarding GSP [9] protocol. The evaluation is mainly based on performance according to the following metrics:

Throughput: It is the number of packets received successfully.

Average Energy: It is the average amount of energy consumption of all nodes in sending, receiving and forward operations expressed in Joules.

Drop: It is the number of packets dropped.

Packet Delivery Fraction: It is the ratio of the fraction of packets received successfully to the total number of packets sent.

5.3 Results

1. Based on number of neighbor nodes

In our initial simulation, we vary the number of flows as 1, 2, 3 and 4.

As we can see from the figure, the throughput is more in the case of new protocol than existing protocol.

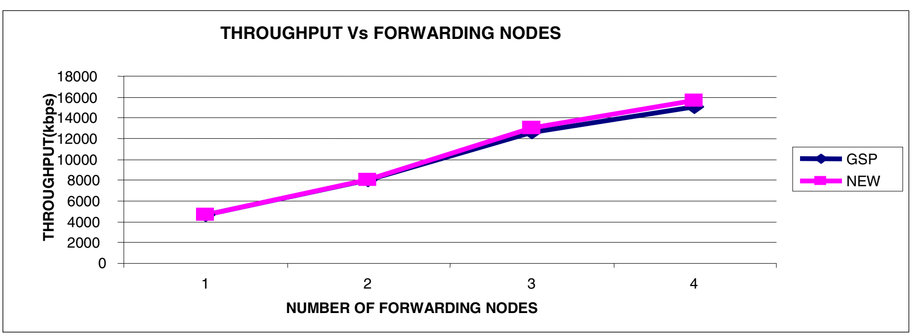


Fig. 1. Throughput of protocols when the number of flow is increased

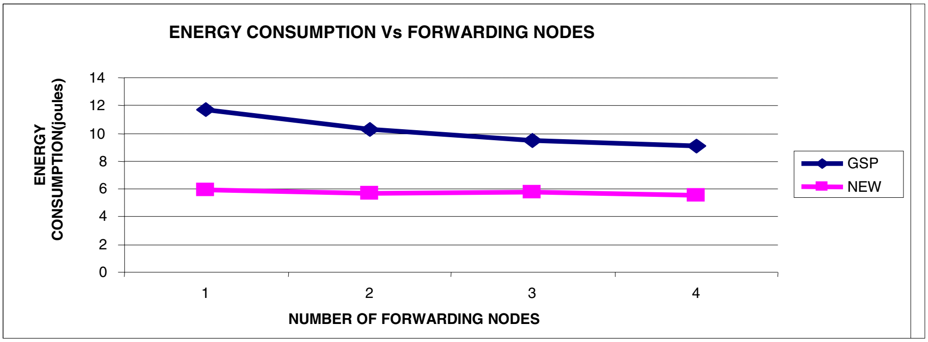


Fig. 2. Energy consumption for varying number of nodes

From the results, we can see that propose scheme has less energy than existing scheme, since it has the energy efficient routing.

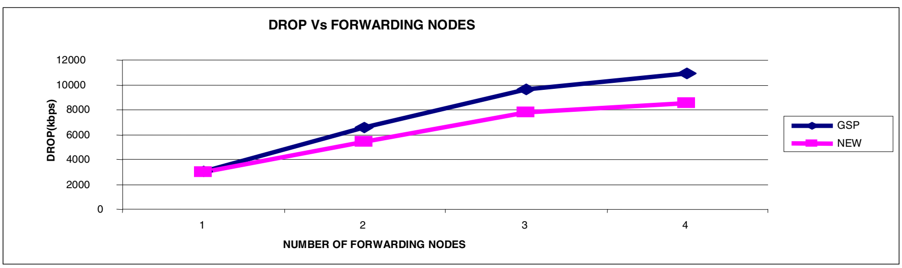


Fig. 3. Packets drop with forwarding number number of nodes

From the figure we can show that the packets dropped are less for proposed protocol when compared with existing protocol.

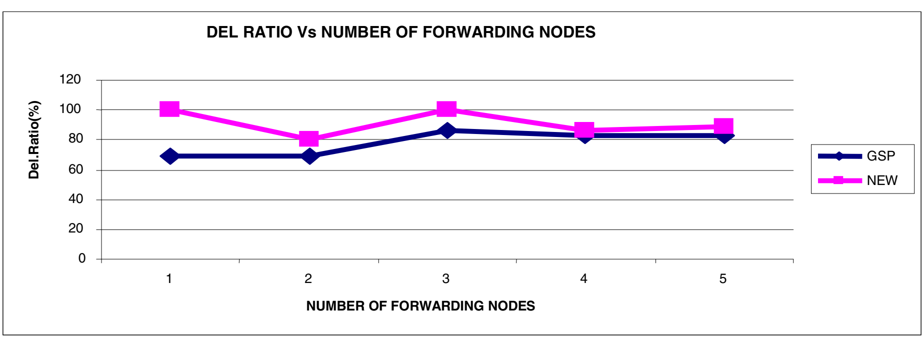


Fig. 4. Packet delivery ratio with forwarding nodes

This Figure gives the comparison for both the protocols. Since the packet drop is less and the throughput is more, proposed scheme achieves good delivery ratio, compared to existing scheme.

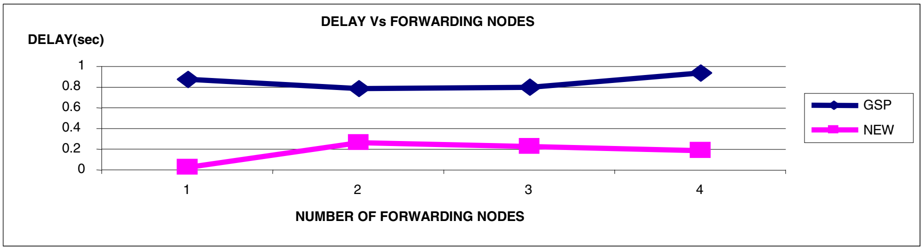


Fig. 5. Delay with forwarding nodes

From the figure, the number of packet dropped are less in new protocol compared to existing protocol.

2. Based on Probability Value

In the second simulation experiment, we vary the probability values as 0.0, 0.1, 0.2, 0.3 and 0.4.

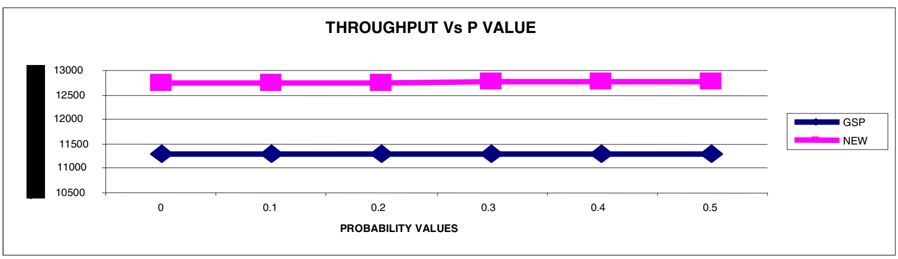


Fig. 6. Throughput for varying number of active nodes

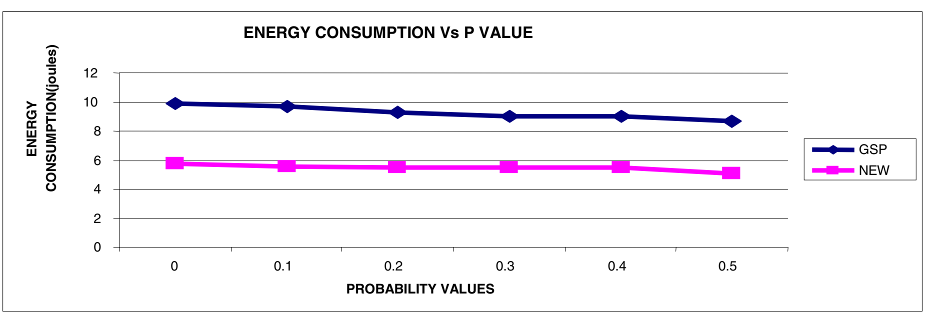


Fig. 7. Energy consumption (Joules) for varying probability values

Figure gives the throughput of both the protocols when the number of Probability values is increased. As we can see from the figure, the throughput is more in the case of proposed scheme than existing scheme.

Figure shows the results of energy consumption for the number of p values as 0.0, 0.1, 0.2, 0.3 and 0.4. From the results, we can see that propose scheme has less energy consumption than existing scheme, since it has the energy efficient routing.

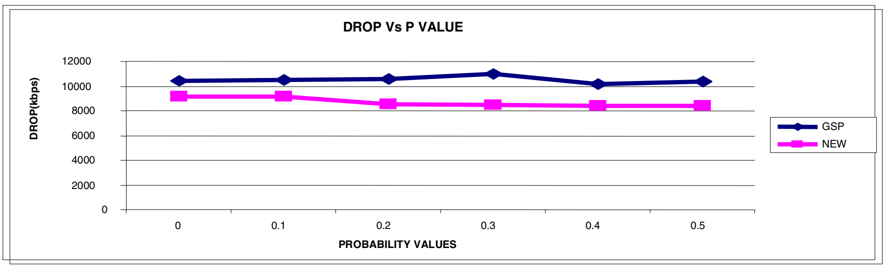


Fig. 8. Number of packets dropped with increasing probability values

We can ensure that the packets dropped are less for proposed protocol when compared with existing protocol.

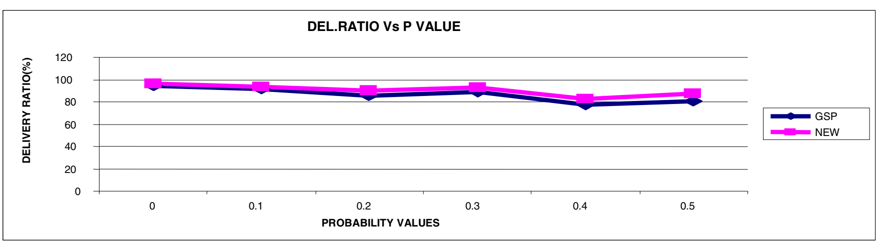


Fig. 9. Delivery Ratio for varying number of active nodes

This figure presents the packet delivery ratio of both the protocols. Since the drop is less and the throughput is more, proposed scheme achieves better delivery ratio, compared to existing protocol.

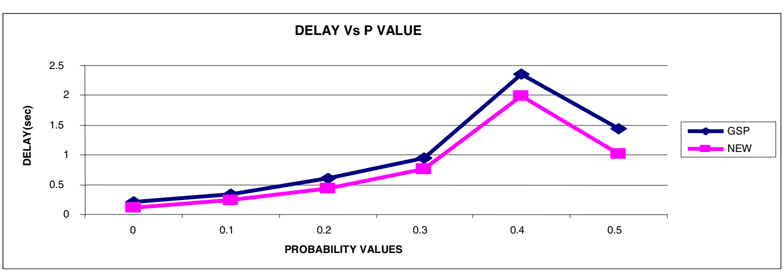


Fig. 10. Delay for varying probability values

Figure shows the results of dropped packets for varying number of probability values as 0.0, 0.1, 0.2, 0.3 and 0.4. From the results, we can see that proposed scheme has less delay than existing scheme, since it has the efficient routing.

6 Based on Rate

In the third simulation experiment, we vary the data sending rate as 100, 200, 300, 400 and 500 kbps.

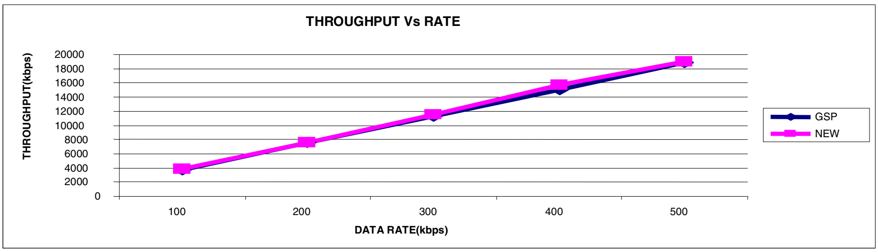


Fig. 11. Throughput for varying data rates

Figure gives the throughput of both the protocols when the number of flow is increased. As we can see from the figure, the throughput is more in the case of proposed protocol than existing protocol.

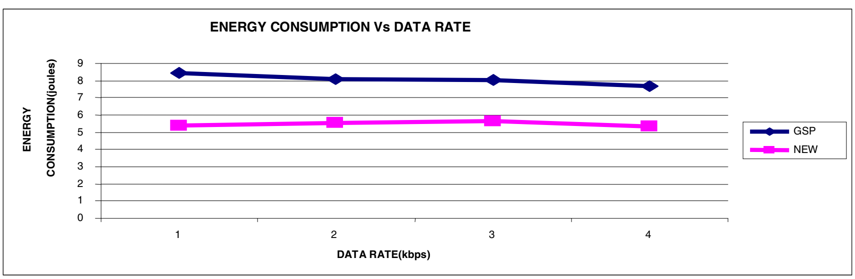


Fig. 12. Energy consumption for varying data rates

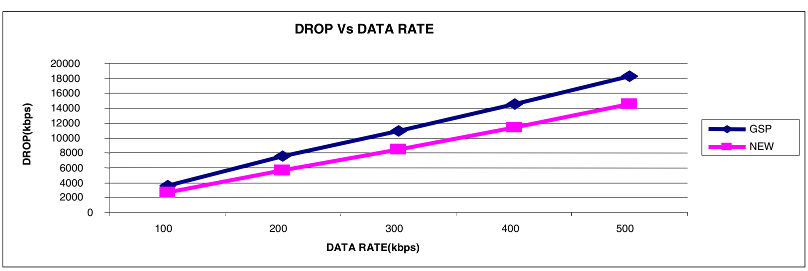


Fig. 13. Packets dropped for varying data rates in kbps

Figure shows the results of energy consumption for different varying data rates. From the results, we can see that proposed scheme has less energy consumption than existing scheme, since it has the energy efficient routing.

We can ensure that the packets dropped are less for proposed scheme when compared with existing scheme.

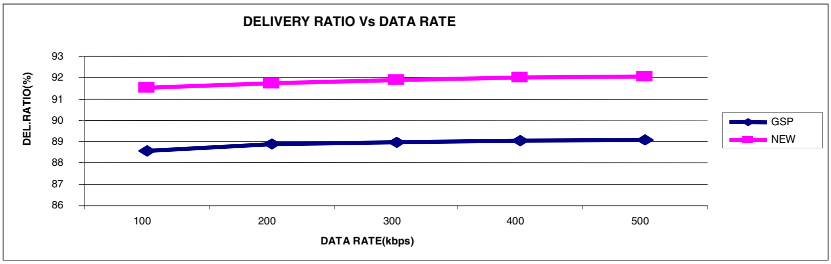


Fig. 14. Packets delivery Ratio for varying data rates

Figure presents the packet delivery ratio of both the protocols. Since the packet drop is less and the throughput is more, proposed could able to achieve good delivery ratio, compared to existing protocol.

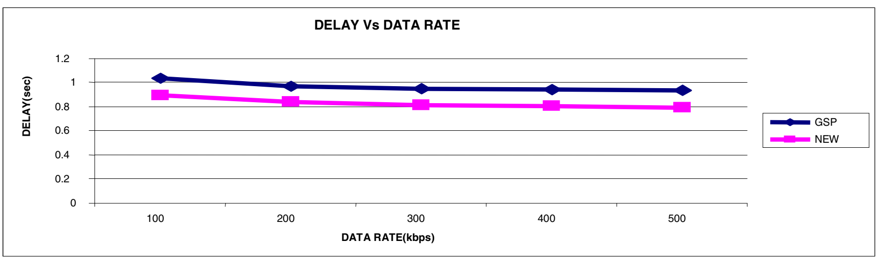


Fig. 15. Packets delay for varying data rates

7 Conclusion

This paper introduces a new class of gossip algorithms designed to direct the gossip process towards a specific polarizing node in the network. The algorithm has been adaptive in Gossip. While in the classical gossip algorithm each node forwards a message with the same probability, our proposal is characterized by a variable gossiping probability-based on the throughput, which is high enough only for sustaining the spreading process towards the polarizing node. An important application of the algorithm is when used for path discovery in MANET. We have shown by simulations the protocol allows saving up to 80% of energy efficiency compared to a pure flooding, while 60% of nodes have to process a requesting packet.

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