Adaptive Energy Conserve Routing protocol for Mobile Ad hoc Network

S.RAJESWARI[1] , Y.VENKATARAMANI[2]
Associate professor[1], Dept. of ECE, *Dean(R & D)* [2],
Saranathan college of Engineering, Affiliated to Anna University- Chennai,
Venkateswara Nagar,Panjapur,Trichy,Tamilnadu.
India-620012
rajee_ravi@sify.com1, diracads.sce@gmail.com2,http:www.saranathan.ac.in

ABSTRACT: Protocols are required to optimize network performance based on energy resource due to limited battery power in Mobile Ad hoc NETwork (MANET) nodes. This paper proposes a modified Protocol for MANET to achieve energy efficiency and reliability. The probability for a sleep node is determined by the parameter metric of Packet Delivery Ratio at the destination node. The probability value can be adaptively adjusted by Radio Activated Switch (RAS) which is embedded in each node. This results in less amount of energy consumption and more reliability in Mobile Ad hoc network. User Datagram Protocol and Transport Control Protocol based traffic models are used to analyze the performance of this protocol and NS-2 simulator is used.

Key-Words: MANET, Routing Protocol, Delivery Ratio, Energy Consumption, Reliability.

1 Introduction

Mobile ad hoc network is formed by a collection of dynamic wireless mobile nodes. It results in a temporary network and it is established without the aid of any established infrastructure or centralized administration. The configuration of the ad hoc network depends on the transmission power of the nodes and the location of the mobile nodes, which may change with time [1]. The primary objectives of MANET routing protocols include: maximizing network throughput, maximizing network lifetime and minimizing delay. Network efficiency is usually measured by life time, packet delivery ratio and energy consumption. Energy consumption is measured in joules. Energy consumption varies with number of packets transmitted. It measures the amount of energy consumed for the transmission of all the packets which includes both control and information exchange packets. A major challenge that a routing protocol designed for ad hoc wireless network faces is resource constraints.

In wireless networks, energy consumption occurs due to three main events other than the usual operation of transmission and reception. The first event results due to overhear (due to flooding technique) in which a node receives traffic not meant for it. The second event occurs due to collision. Collisions are due to retransmissions and hence result in an increase in energy consumption.

The third event - the key idea of this paper - is idle listening. It does not involve any active participation like transmission or reception. Idle listening means that a node continues to be a part of the network, but it is inactive at that time. The node consumes small amount of energy for being part of the network. When a wireless interface is in an idle state (that is neither transmitting nor receiving), as per the Lucent's 915 MHz Wave LAN card specifications, it consumes 1.15W when idling, 1.2W while receiving and 1.6W while transmitting [2]. Observations have shown that depending on the network loading situations, even this idle listening can consume up to 50-100% of energy required for receiving.

This paper proposes a modified protocol that reduces energy consumption due to idle listening by implementing an Adaptive Awake-Sleep scheduling algorithm. In a network, nodes must be synchronized, so that they can turn their interface off during the sleep section of the synchronized schedule. They communicate during the awaken section of the schedule. By introducing sleep mode into the network, the total energy consumption of the network can be reduced and the network lifetime can be prolonged. But the problem is that packets may go through longer paths if the nodes are sleeping on the shortest paths between source and destination nodes, resulting in more energy consumption in the network. Also, paths will be broken more often due to mode change of the nodes. Therefore, more overhead is generated to overcome the path failures and this will consume some extra energy.

In our previous work [3], the implemented protocol has the provision that the nodes can be in active mode with the reference probability 1-p and they can be in sleep mode with probability p. The probability is fixed at the initial stage. Every node (which wants to communicate) maintains a control buffer called B which represents the current number of active neighbors. The rest of the nodes in the network will be in either sleep (p) or awaken (1-p) state. The higher value of B represents more number of active neighbors. This leads to consumption of more power. So, to reduce the amount of energy consumption, we start with all initializing nodes in the network B to one. At the same time, zero value of B states that there is no existence of any active neighbors. So, the communication cannot be established. To avoid this situation, we start with B value as one. It means that a node initially broadcasts Route Request packets only to its closest neighbor, thus requiring the least power. That neighbor node rebroadcasts the same control packet to other nodes in the network by means of sleep-awake schedule and once the path is established, data packets are transmitted in similar manner.

Contributions of this paper are twofold. First, it introduces a novel design of an Adaptive sleep mode by placing a RAS (Radio Activated Switch) that can be implemented on top of 802.11 MAC layer without requiring any change in the standard protocol. The second contribution is to apply this schedule of synchronization mechanism of Adaptive sleep-awake technique in an interface for significant reduction of the energy consumption due to idle listening.

The rest of the paper is organized as follows. In Section 2, we review the literature on related topics of efficient protocol design in wireless ad hoc networks. In Section 3, we describe the proposed adaptive sleep-awake synchronization protocol in detail. We describe the simulation experimental setup in Section 4. In Section 5, we evaluate and compare the performance of existing sleep Protocol which uses the AODV as routing protocol with our proposed algorithm with adaptive and without adaptive technique and with non adaptive technique.

2 Related Work

The energy computation based on Gossip Sleep Protocol has been discussed as below. Zygmunt J. Haas et al [4] proposed a gossip based approach, where each node forwards a message with some probability, to reduce the overhead of the routing protocols. They stated that gossiping can reduce control traffic up to 35% when compared to flooding. This reduces the energy consumption. But, retries increase latency in large networks. So, the timeout period will have to be large so as to allow the message to propagate throughout the network. Xiaobing Hou et al [5] proposed a novel energy saving scheme, termed 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. GSP does not require a wireless node to maintain the states of other nodes. It requires few operations and scales to large networks. Two versions of GSP, one for synchronous networks and one for asynchronous networks are proposed. But, the sleep mode may increase the length and the failure rate of a path. The advantages of the GSP approach through both simulations and analysis is discussed in this paper. Mubashir Husain Rehmani [6] et al gives a full report about working of AODV routing protocol in ns-2. Sunho Lim et al [7] proposed a new communication mechanism, called Random Cast, through which a sender can specify the desired level of overhearing. They have made a prudent balance between energy and routing performance. So, it reduces redundant rebroadcasts for a broadcast packet and thus saves more energy. AL-Gabri Malek et al [8] addressed a new solution to reduce the energy consumption of an individual node. They have proposed two approaches: transmission power control and load distribution to reduce the power consumption. In this work, they stated that if weaker transmission power is selected, it makes the topology sparse. So, partitions are introduced in the network and produces high end-to-end delay due to a larger hop count. Shibo Wu et al [9] proposed a set of probabilistic multipath routing algorithms, which generate braided multi paths based only on local information to overcome drained nodes on these paths which results in short network life when the communication in the network is unevenly distributed. This probabilistic multipath routing contributes up to an additional 30% to network lifetime. Amulya Ratna Swain et al [10] have addressed reduced rate of average energy consumption for each node as they are able to put more number of nodes to sleep condition.

One critical issue for almost all kinds of portable devices supported by battery powers is power saving. Without power, a mobile device will become useless. Battery power is a limited resource, and it is believed that battery technology is not likely to progress as fast as computing and communication technologies do. Hence, increasing the lifetime of batteries is an important issue, especially for a MANET node, power is utilized from batteries only.

Power saving is an important issue. It has been taken for critical analysis for almost all kinds of portable devices. All such devices are operated by battery powers. A mobile device will become no use when its power gets drained. But, battery technology has not been advanced as like computing and communication technologies. Battery power is a limited resource. For functioning of a MANET node, batteries are only the reliable source..

Analysis for the power conserving issue in MANET nodes can generally be categorized as follows:

- Importance on Transmission power: In wireless communication, based on transmitted power, some of the parameters like bit error rate, transmission rate, and inter-radio interference are computed. But, these parameters attributes are different from each other. In [2], power control is implemented to reduce interference and improve throughput on the MAC layer. Determination of transmission power on each mobile host, decides to select the best network topology is discussed in [11-13]. Based on power adjustment, network throughput can be increased. The concerned issue for packet radio networks is analyzed in [14].
- Routing based on remaining Power: Routing protocol depends on the remaining power in each node. The solution has been addressed based on Power-aware and other various power cost functions [15-19]. In [15], a mobile host's battery level is computed. It has been compared with the preset threshold value. If it falls below a certain threshold, it will not forward packets for other hosts. A mixed network scenario which consists of battery powered and power plugged hosts is considered in [16]. Heuristic clustering approaches for two multi-casting are addressed in [17] for two different distributed methods. This is used to minimize the transmission power. In [18], five different metrics for battery power consumption are discussed. Ref. [19] includes the hosts' lifetime and computed power metric for a distant one for solution.
- Routing based on Low Power mode: All solutions are resulted to formulate wireless devices which can be operate on low-power sleep modes. A radio of IEEE 802.11, which has a power-saving mode [20], only needs to be awake periodically. A mobile host in HIPERLAN allows defining power-saving mode to its own active period. An active node may conserve powers by turning off its equalizer according to the transmission bit rate. Comparisons addressing the power-saving mechanisms of IEEE 802.11 and HIPERLAN in ad hoc networks are presented in [21]. A hybrid characteristic of multi-hop communication, unpredictable mobility, battery- power, and no clock synchronization mechanism is considering for MANETs.

We consider MANETs as being characterized by multi-hop communication, unpredictable mobility, no plug-in power, and no clock synchronization mechanism. In particular, the last characteristic-synchronization would complicate the problem since a host has to predict when another host will wake up to receive packets. Thus, the protocol must be asynchronous.

3. Gossip Routing in Ad hoc Networks

In Gossip routing, the packet retransmission is based on the probability value. The main objective of gossip is to minimize the number of retransmissions, while maintaining the main benefits of flooding. A message is normally transmitted as a broadcast rather than a unicast communication in adhoc networks. So, that message is received by all the nodes which are at one hop distance away from the sender. Since wireless resources are expensive, they use this physical-layer broadcasting feature of the radio transmission. In the gossiping protocol [4], they control the probability of this physical-layer broadcast. So, the receiving number of nodes can be reduced so as to reduce the energy consumption and at the same time the concept of broadcasting is maintained.

The basic gossiping protocol is simple. A source sends a route request with probability p. 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 [5] at most once. Thus, in almost all executions of the algorithm, either scarcely any nodes receive the message, or most of them do. Ideally, they made less number of executions where the gossip dies out relatively low while also keeping the gossip probability low, to reduce the message overhead [4].

As mentioned earlier, the current ad hoc network routing protocols require all the nodes to be awake and keep listening. This wastes a lot of energy. Even if there is no traffic or heavy traffic, the traditional ad hoc routing protocols necessitate all the nodes to continue listening, thereby wasting the energy. This reduces the lifetime of the nodes as well as the network's lifetime [5].The major objective as proposed in Gossip Sleep Protocol (GSP) is used to achieve energy efficiency by putting some nodes in a sleep mode. The potential disadvantage of this approach is that packets may go through longer paths if the nodes sleeping are on the shortest paths [4] between source and destination nodes, resulting in more energy consumption in the network-wide communication. Also, paths will be broken more often due to mode change of the nodes. Therefore, more overhead is generated to overcome the path failures and this will consume some extra energy. In addition, sleeping of nodes results in decrease of the network throughput and increase of end to end delay.

4. Proposed Modified Energy Conserve routing protocol

In this work, based on the Adaptive Energy Efficient Routing for Gossip based (AEERG) ad hoc routing [3], we propose a modified Protocol to achieve energy efficiency and reliability in wireless ad hoc networks in an efficient manner. In this protocol, at the initial stage, the nodes can be in active mode with probability 1-p or sleep mode with probability p. Every node in the network, which wants to communicate, maintains a control buffer called B. It represents the current number of active neighbors. The higher value of B represents many numbers of active neighbors, leading to consumption of more power by the node uses to send packets, and thus the communication is more reliable. So, to reduce the amount of energy consumption, the algorithm starts with every node in the network initializes B to one. It means that a node initially sends Route Request packets only to its closest neighbor, thus requiring least power. The neighbor node rebroadcasts the same control packet to other nodes in the network by means of sleep-awake schedule and once the path is established, data packets are transmitted in similar manner. The same process is initiated at each transmitting node. The rest of the nodes in the network will be in either sleep or awaken state.

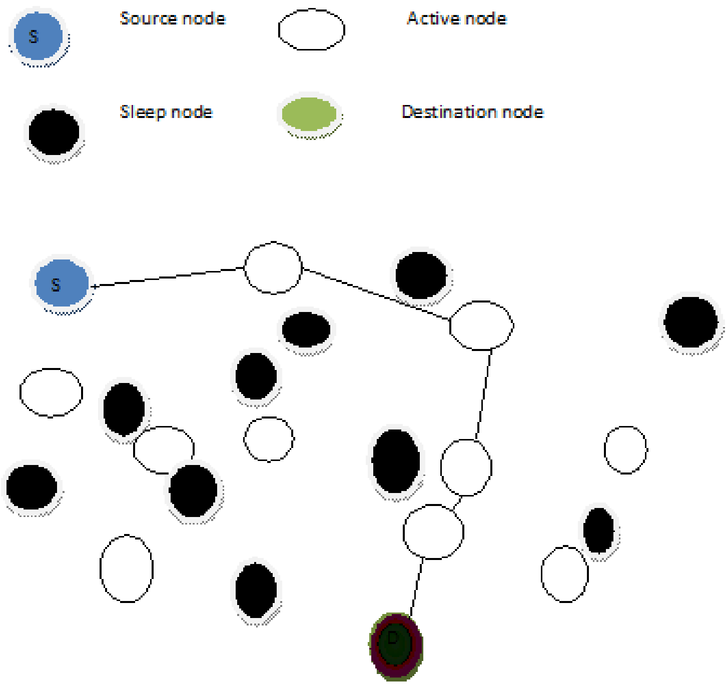


Fig.1. Illustration of a simple Sleep-Active node network

In this work, to improve the reliability, adaptive technique is incorporated. In each node, a Remote Activated Switch (RAS) is placed. The schematic representation of the switch RAS is shown in Figure.1.Whenever a node becomes idle, it enters into a sleep state, i.e., the standard receiver/transmitter is turned off as well as part of the device electronics. Waking-up signals are received and demodulated by the RAS, and then the signal information is passed to the logic circuit that detects the sequence.

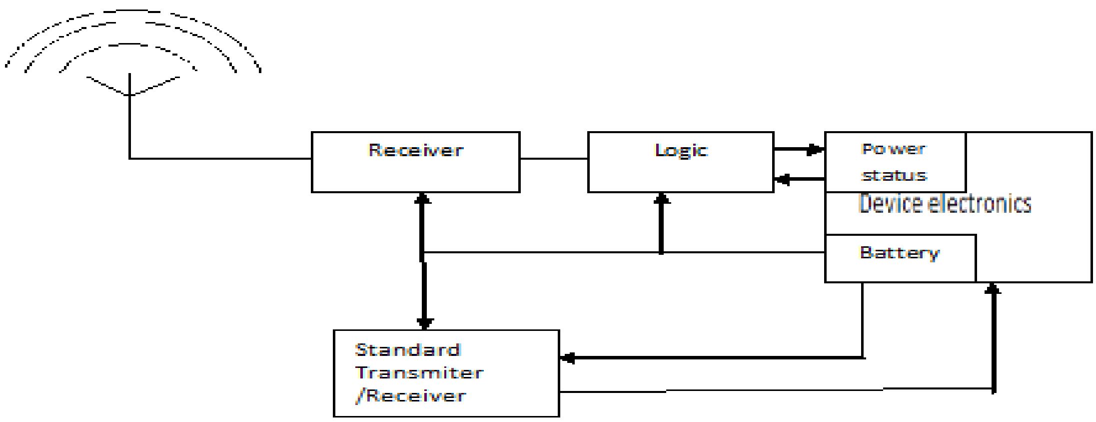


Fig..2 Basic Communication model circuit diagram

If the received sequence matches the device's sequence, it turns on the standard receiver. Notice that the RAS receiver may be either totally passive (e.g., an amplitude demodulator) or supplied by the battery source through connection 1.

The intermediate nodes which are in the path are triggered to the active mode. Now, packet delivery ratio is computed for data packets in the destination node and sent as a feedback to the source node. In the source node, it is compared with the preset threshold value. Now, based on the time of feedback value arrival, we can estimate the shortest path. The time at which the feedback received is noted as T value. Timing information of other paths through which we received the feedback is noted down. Now, the comparison of T with other computed time is done. This will help to determine the long delay response path. The nodes in that path are triggered into the sleep node. If the packet delivery ratio is greater than threshold value, the intermediate nodes are (which have been brought to active mode) triggered to sleep mode. The process repeats for every periodic interval.

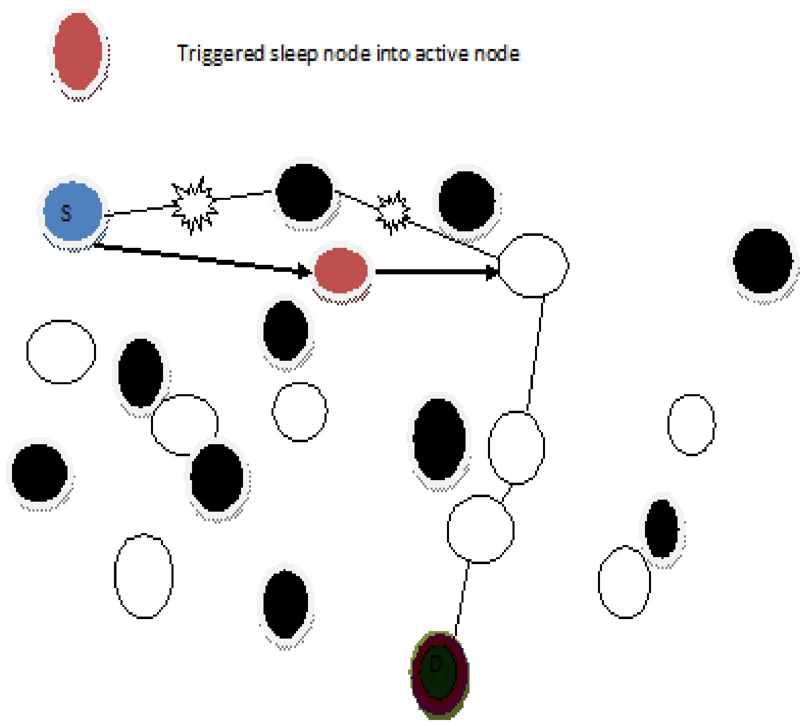


Fig. 3 Illustratration of triggering node from sleep mode

If the packet delivery ratio is less than the required threshold value, due to the present primary path, other alternate path is also included. It results with greater delay compared to the shortest path time T. This path is taken into account. By means of secondary path also, the packets are transmitted. Now, the feedback of packet delivery ratio is computed. If it is above the threshold value, the nodes in the second chosen path which yield greater delay are triggered to sleep mode. In this work, the threshold value is set as 0.5. For this threshold value, very few nodes are driven to awaken state. But for 0.6, 0.7, 0.8 and 0.9 threshold values, more number of nodes are needed to be driven for awaken state.

Based on RF tags technology, we can develop a switch that can be used to remotely activate a radio device while being in sleep state. In this way, nodes are woken up when necessary rather than getting active periodically to verify whether there is pending traffic. This has been observed as proposed with adaptive protocol. It is termed as m-AODV1 protocol. Without RAS, if the nodes are communicating by simple beacon signal, it has been observed as Proposed with non-adaptive protocol. It is termed as m-AODV2 protocol.

Ad Hoc on Demand Distance Vector (AODV) protocol is used as the routing protocol. So, the RREQ packets are sent initially to establish the path between source and destination. The above proposed algorithm is used for these control packets also. Once the path is established by means of RREP packets, the data packets are transmitted with constant size of 512 kilobytes. At the end of the packet transmission, the packet delivery ratio is computed at the destination and the same is fedback to source. This enables us to compute the feasibility of data communication. If the received value is less than the threshold value, the sleep nodes in the path are triggered to awaken mode. This leads to increased reliability.

The major objective of this protocol is to achieve energy efficiency by putting more number of nodes in a sleep mode. With this protocol, we can achieve reliability, energy conservation and less delay compared to existing protocols. In this protocol, once the threshold value is achieved the nodes are again driven to sleep mode. This will conserve some extra amount of power compared to the existing power saving schemes.

5. Simulation Results

NS2 is used to simulate the proposed algorithm. The channel capacity of mobile hosts is set to 2 Mbps. For the MAC layer protocol the Distributed Coordination Function (DCF) of IEEE 802.11 (for wireless LANs) is used. It has the functionality to notify the network layer about link breakage. In the simulation experiment, mobile nodes have been moved within a 600 meter x 400 meter region for 50 seconds simulation time. The number of mobile nodes is kept as 50.We assumed that each node moves independently with the constant average speed of 20m/s. All nodes had the same transmission range of 250 meters. The simulated traffic is Constant Bit Rate (CBR). The pause time of the mobile node is kept as 10 sec. Pause time is the time duration for which all nodes hold the same positions at waypoints. The mobility model used is the random way point model which generates waypoints at random. It means that a node moves in a given speed to a random waypoint and when it reaches that point, it will remain there for an amount of pause time. Then, it chooses another waypoint at random and begins moving toward it. For analyzing the performance, number of forwarding nodes is varied and the simulation results are observed.

Table.1 observed values of proposed algorithm for the metric of Energy consumption

	Energy Consumption in Joules		
Number of Nodes	AODV	AODV with Proposed Algorithm (m-AODV1)	AODV proposed Algorithm with non adaptive (m-AODV2)
10	12.58	5.78	8.62
20	13.35	6.44	9.56
25	14.08	6.98	10.28
30	14.88	7.34	11.28
40	15.01	7.598	12.89
50	15.01	7.778	13.98

5.1 Performance Metrics

Mobile ad hoc networks have several inherent characteristics such as dynamic topology, time-varying and bandwidth constrained wireless channels, multi-hop routing, and distributed control and management.

To find the suitability of a routing protocol, metrics are needed to study the performance. Specifically, this work evaluates the performance of the proposed protocol with AODV routing protocol based on the following performance metrics: Energy consumption, Average Drop and Packet delivery ratio.

The above metrics are analyzed with the increasing number of forwarding nodes. The performance analysis of proposed protocol with adaptive technique is termed as m-AODV1.The performance analysis of proposed protocol with non- adaptive technique is termed as m-AODV2.

5.1.1 Energy consumption

Energy consumption metric is calculated as the ratio of the total energy consumed to the total number of nodes present in the deployed network. This metric unit is measured in joules. For lucent IEEE 802.11i wavelan pc card with 2Mbps bandwidth, Radio mode Power Consumption is listed as below.

Transmit 0.660 W

Receive 0.395 W

Idle 0.035 W

and for Sleep 0.008 W.

Figure.4 gives the Energy consumption of network when the number of nodes is varied.

From the figure.4 we can see, Energy consumption is less in the proposed scheme (m-AODV1) than other schemes. Even though, the number of nodes is increased due to adaptiveness, the energy consumption is only marginally increasing (just above the constant value) for the proposed scheme. But in the proposed non adaptive technique, the energy consumption is gradually increased due to packets taking the alternate path (presence of sleep nodes in the shortest path) to reach the destination. The routing protocol AODV consumes the maximum energy due to always awaken mode nodes in the path of the routing.

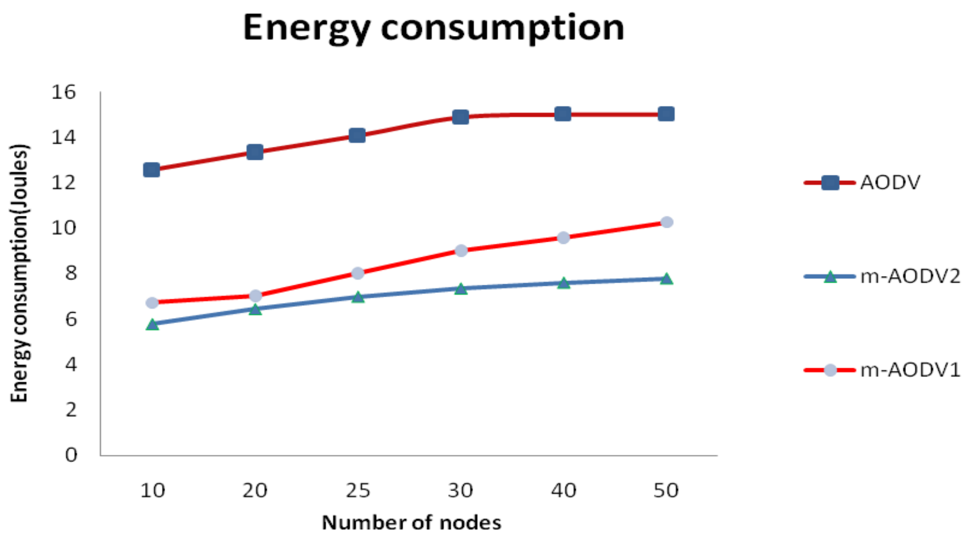


Fig.4 Performance analysis: Energy Consumption for increasing Number of nodes

5.1.2 Packet Delivery Ratio

Packet delivery ratio is calculated by ratio of the number of data packets received at the destination to the number of data packets originated at the source. The maximum value of packet delivery ratio indicates the improvement on reliability. It indicates the maximum number of packets, which can be received by the destination node. It determines the maximum throughput of the network. The better the delivery ratio, the better is the routing protocol. The figure.3 gives the Delivery Ratio of protocols when the number of forwarding nodes is increased for all the schemes.

Table.2 observed values of Proposed Algorithm for the parameter Packet Delivery Ratio

Number of Forwarding Nodes	Packets Delivery Ratio in Percentage		
	AODV	AODV with Proposed Algorithm (m-AODV1)	AODV with Proposed Algorithm with non adaptive (m-AODV2)
10	89.12	94.34	92.12
20	89.97	95.12	92.98
25	90.45	95.89	93.4
30	91.1	96.78	93.10
40	91.8	97.34	93.01
50	91.8	98.23	92.87

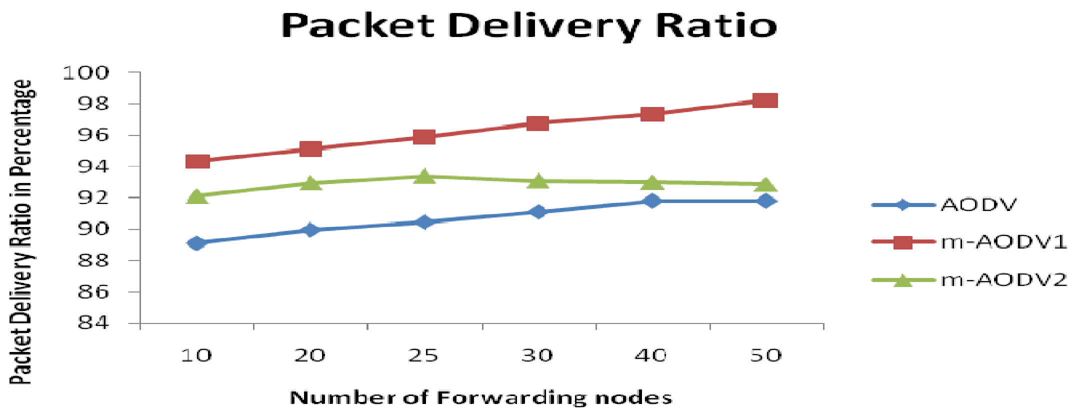


Fig.5 Performance analysis: Packet Delivery Ratio with varied number of forwarding nodes

As we can see from the figure.5, the delivery ratio is more in the case of proposed schemes than the AODV. Due to the change of mode by trigger signal, the proposed scheme has got good delivery ratio compared to other schemes. But, in the (m-AODV2) proposed protocol non adaptive technique the packet delivery ratio is almost a constant. When the number of nodes is varied from 30 onwards, the constant behavior is due to the absence of adaptive technique. The packet delivery ratio has very low value as the routing protocol of AODV because of the sleep mode behavior.

5.1.3 Packets Throughput

Number of packets dropped is calculated, based on the trace file generated by simulation. It calculates the number of packets dropped (in percentage) during the data packets communication. This metric is calculated by 'D. It is measured by the number of packets (bytes per second) dropped when they are transmitted by source so as to reach the destination. This includes all possible drops caused by control as well as data packets. But dropped data packets are alone taken for calculation.

Table.3 observed values of proposed algorithm for the metric Throughput

Number of Nodes	Packets Throughput (Bytes/sec)		
	AODV	AODV with Proposed Algorithm (m-AODV1)	AODV with proposed Algorithm with non adaptive (m-AODV2)
10	94756	134500	96345
20	92675	134100	95345
25	98231	135098	98231
30	90234	136032	98156
40	89432	136186	98012

In the initial position, since the number of neighbor node is one, the drop will be the same for both the schemes of Adaptive and Non adaptive (m-AODV1 and m-AODV2). But when the number of forwarding node is increased due to the trigger signal used for the adaptiveness, the drop will be decreases in the proposed scheme (m-AODV1 and m-AODV2), as shown in figure.4.

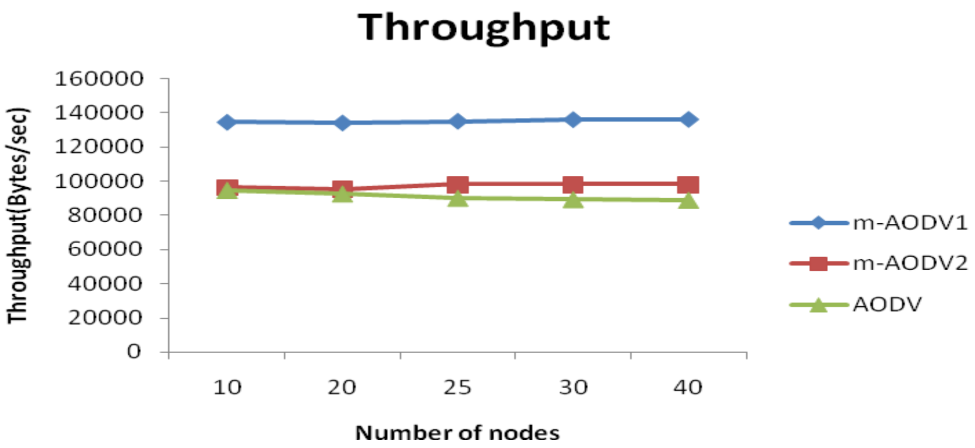


Fig.6 Performance Analysis: Throughput with varied number of nodes

From figure.6, we observe that proposed non adaptive protocol (m-AODV2) shows significant amount of packets dropping. The drop is due to sleep mode of nodes and the dynamic nature of nodes. The throughput in the proposed algorithm with AODV (m-AODV1) is 17-18% higher compared to the AODV protocol. In Proposed non adaptive protocol (m-AODV2), the throughput is 15-16% higher compared to the proposed adaptive protocol (m-AODV1).

5.2 comparison of TCP and CBR Traffic flow

The network topology configuration can provide valuable information to network management in detecting preferred routes and bottlenecks, discovering network partitioning, and in detecting faults. The scheme used to compare the robustness with respect to average end-to end delay. It is used to find the rapid changes in the network topology. Throughput analysis is used for the evaluation of network efficiency.

Nodes are deployed in a high-traffic environment with multiple connections for the Proposed Algorithm with Adaptive Protocol which is termed as m-AODV-2. A Comparison between Transport Control Protocol (TCP) and User Datagram Protocol (UDP) flows throughout the network is simulated using ns-2 simulator and the results are as given below. Constant Bit Rate (CBR) is the traffic flow used in UDP.

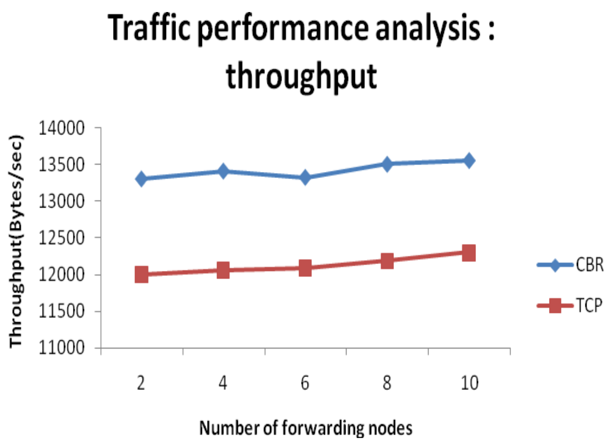
5.2.1 Throughput analysis

Figure.7 shows the traffic performance analysis of CBR and TCP for the successful arrival of packets at the destination. From the figure,we can say that CBR traffic achieves higher throughput as compared to TCP. CBR can transfer packets without acknowledgement so that we cannot have reliability. But for small distances, CBR gives better performance. In wireless communications, it is preferrable to use CBR. Transport Control Protocol can communicate only with acknowledgement, so that reliability can be achieved. In TCP, retransmission is activated due to absence of acknowledgement This retranmission of the same packet will leads to congestion. In wireless networks it is better to have CBR for small distance communication.

Table.4 Comparisons of multiple link traffic loads for Throughput analysis

Number of nodes	CBR	TCP
2	13306	12001
4	13410	12061
6	13327	12093
8	13500	12189
10	13550	12302

Fig.7 Performance analysis of Throughput for CBR and TCP



5.2.3 Packet Delivery Ratio Analysis

From figure.8, we find that Packet Delivery Ratio (PDR) in CBR is 5% greater than with TCP traffic. Since in TCP, the packet should be retransmitted till it gets acknowledgement. But in CBR without acknowledgement, the packets can be continuously transmitted. So in CBR, PDR is greater than with TCP.

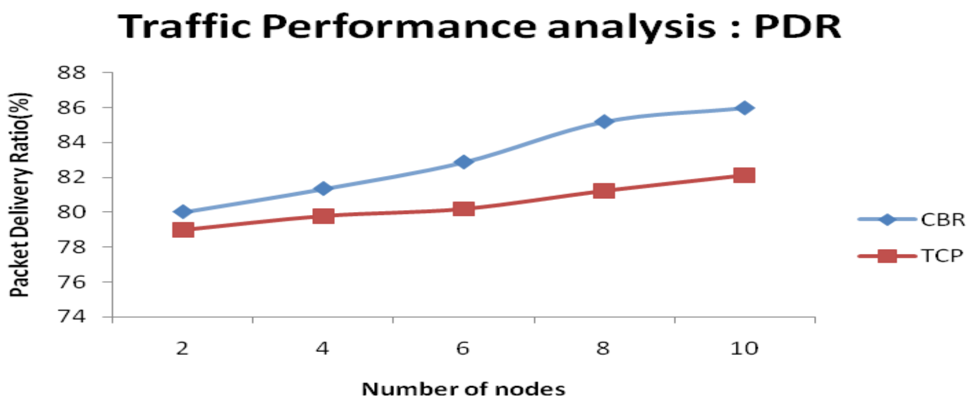


Fig. 8 Packet Delivery Ratio analysis

6. Conclusion

In this paper proposes a modification Energy Efficient and Reliable Gossip Routing Protocol in reference [3]. This protocol assures the increased delivery ratio and less amount of packet drop that leads to better reliability. This protocol results with low energy consumption for power managed routing. By simulation results, we have shown that the proposed protocol achieves good delivery ratio, less amount of packet drops and less energy consumption. For further enhancement of this work, we plan to optimize the Queue and TCP traffic scheduler for better performance.

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S.Rajeswari obtained her B.E. in Electronics and Communication Engg., At Government College of Technology, Coimbatore (Bharathiyar university, 1991), M.Tech in Communication Systems (National Institute of Technology, Thiruchirapalli, 2004). She is currently doing her research work in ad hoc networks which includes Routing Protocols, Power management and Reliability.

Dr.Y.Venkataramani obtained his B.Tech & M.Tech from I.I.T Chennai. He received his Ph.D. from I.I.T. Kanpur. He has served as a faculty for 34 years at NIT, Calicut and retired as Head of the Department. At present he is working as Dean (Research & Development) in the institution of Saranathan College of Engineering,Trichy. His areas of interest include Computer Networks, Speech Processing and Image Processing.