ISSN (Print) : 2319-5940
ISSN (Online) : 2278-1021

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 2, Issue 3, March 2013

Performance Metrics Evaluation of Routing Protocols in MANET

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Abstract: A major issue with ad hoc networks is energy consumption since nodes are usually mobile and battery operated. A recent trend in ad hoc network routing is the reactive on-demand philosophy where routes are established only when required. This paper proposes a new scheme called Efficient Power Routing DSR (EPRDSR) to improve existing on-demand routing protocols by introducing the power efficient algorithm in whole Mobile Ad hoc Network (MANET). The scheme establishes quick adaptation to distributed processing, dynamic linking and low processing at all times. This scheme uses the concept of power awareness among route selection nodes by checking power status of each node in the topology which insures fast selection of routes with minimal efforts and faster recovery. The results indicate that EPRDSR is able to discover the required path with lesser overheads, the network lifetime increased by around 65-70%, the packet delivery ratio improved and the packet experienced a low average delay. This methodology is incorporated with the existing DSR protocol and the performance has been studied through simulation and scheme performs very well. The main goal of EPRDSR protocol is not only to extend the lifetime of each node, but also to prolong the network lifetime of each connection. This paper presents a performance comparison of power aware routing protocols such as proposed EPRDSR and Minimum Total Transmission Power Routing (MTPR) and reactive protocol is DSR based on metrics such as throughput, packet delivery ratio and average end-to-end delay by using the NS-2 simulator.

Keywords: DSR, MTPR, network lifetime, power aware.

I. INTRODUCTION

The nodes in an ad hoc network are constrained by battery power for their operation. To route a packet from a source to a destination involves a sufficient number of intermediate nodes. Hence, battery power of a node is a precious resource that must be used efficiently in order to avoid early termination of a node or a network. Thus, energy management is an important issue in such networks. Efficient battery management, transmission power management [7] and system power management are the major means of increasing the life of a node. These management schemes deals in the management of energy resources. by controlling the early depletion of the battery, adjust the transmission power to decide the proper power level of a node and incorporate the low power strategies into the protocols used in various layers of protocol stack. There are so many issues and solutions which witnesses the need of energy management [1] in ad hoc wireless networks. The prime concern of this paper is to develop an efficient routing protocol for the ad hoc networks which may take care of energy needs and as well as proper handling of real and non real time data as per their need.

The power at the network layer can be conserved by reducing the power consumed for two main operations, namely, communication and computation. The communication related power consumption is mainly due to transmit- receive module present in the nodes. Whenever a node remains active, that is, during transmission or reception of a packet, power gets consumed. Even when the node is not actively participating in communication, but is in the listening mode waiting for the packets, the battery keeps discharging [2]. The computation power refers to the power spent in calculations that take place in the nodes during routing and power adjustments.

ISSN (Print) : 2319-5940
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Applications of MANET

- **Military Scenarios:** MANET supports tactical network for military communications and automated battle fields.
- **Rescue Operations:** It provides Disaster recovery, means replacement of fixed infrastructure network in case of environmental disaster.
- **Data Networks:** MANET provides support to the network for the exchange of data between mobile devices.
- **Device Networks:** Device Networks supports the wireless connections between various mobile devices so that they can communicate.
- **Free Internet Connection Sharing:** It also allows us to share the internet with other mobile devices.
- **Sensor Network:** It consists of devices that have capability of sensing, computation and wireless networking. Wireless sensor network combines the power of all three of them, like smoke detectors, electricity, gas and water meters.

II. A BRIEF SURVEY OF THE LITERATURE

The design of efficient routing protocols is a fundamental problem in a MANET. Many different protocols have been proposed in the literature, each one based on different characteristics and properties [3]. Ad hoc networks are multi-hop wireless networks where all nodes cooperatively maintain network connectivity. These types of networks are useful in any situation where temporary network connectivity is needed [4], such as in emergency or rescue operations, disaster relief efforts, and military networks. In multi-hop wireless ad-hoc networks, designing energy-efficient routing protocols is important because nodes have limited power [5]. However, it is also an inherently hard problem due to two important factors: First, the nodes may be mobile, which requires the energy-efficient routing protocol [13], [6] to be fully distributed and adaptive to the current states of nodes; second, the wireless links may be unidirectional due to asymmetric power configurations of adjacent nodes.

Recent studies have stressed the need for designing protocols to ensure longer battery life [7], [8]. In the current routing protocols, nodes are powered on most of the time even when they are doing no useful work. Much useful energy of the nodes is wasted in overhearing other transmissions. The routing protocols are designed in such a way that the paths are computed based on minimizing hop count or delay. Thus, some nodes become involved in routing packets for many source-destination pairs. The energy resources of these nodes get depleted faster than other nodes, which in some cases, may lead to partitioning of the network, thus decreasing the lifetime of the network. The lifetime of the network [9], [10] in the scientific papers reviewed is usually defined according to the following criteria: 1) the time period until the first node burns out its entire battery budget, 2) the time until certain percentage of the nodes fail, 3) the time until network partitioning. The problem of node failure [11], which results in network partitioning, is serious in ad hoc networks. In contrast, a single node failure in sensor networks is usually unimportant if it does not lead to a loss of sensing and communication coverage [12]. MANETs are oriented towards personal communications and the loss of connectivity to any node is significant.

Thus, energy efficient routing is one of the paramount significance for MANET's design. For this reason, many research efforts have been devoted to prolong the mobile node battery capacity at different aspects[11]. This article fist discusses the metrics used for energy efficient routing protocols and then some of the popular energy efficient routing protocols designed for MANETs.

III. DESIGN AND IMPLEMENTATION OF PROPOSED EPRDSR

In this section we briefly review the main concepts regarding the three protocols we analysed, respectively the EPRDSR, MTPR and DSR. This area is anyway a very dynamic one, and many other proposals are being developed.

A. *Existing Dynamic Source Routing (DSR) Protocol mechanism [5]*

DSR is a routing protocol designed for MANETs. It is a source-routing protocol and composed of two main mechanisms: route discovery and route maintenance. In the process of route discovery, a route request is send from a node *S* to a node *D* by broadcast, only when *S* attempts to send a packet to *D* and has no available route to *D* in its route cache. So the node *S* does not always know a route to *D* and the route request proceeds completely on-demand to reduce the routing overhead. Intermediate nodes piggyback their ID into the source route included in the route request message and relay that route request by broadcast, if they do not know an available path to *D*. When the route request reaches *D* or some intermediate node which knows the route to *D* (by checking its route cache), a route reply is uni-casted to *S* with the complete path from *S* to *D*. Nodes could receive the same route request more than one time, but only the first one will be handled. Node *S* could also receive multiple routing replies. The first arrival route is used immediately. If in the following routing replies, a shorter path from *S* to *D* is included, the new route will be used instead of the old one. If *S* cannot receive a route reply after a period time, the route request will be resent until a path to *D* is finally discovered. Route maintenance is the

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International Journal of Advanced Research in Computer and Communication Engineering
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mechanism by which node *S* is able to detect, while using a source route to *D*, if the network topology has changed such that it can no longer use its route to *D* because a link along the route no longer works. When route maintenance indicates a source route is broken, *S* can attempt to use any other route it happens to know to *D*, or can invoke route discovery again to find a new route for subsequent packets to *D*. Route maintenance is used only when *S* is actually sending packets to *D*.

B. *Minimum Total Transmission Power Routing (MTPR) mechanism [6]*

In a non-partitioned ad-hoc network, there exists at least one path for a node to communicate with any other node. So theoretically, any node can reach any other node through a random forwarding path. However, the power consumption along different paths varies, due to its dependence on variations of distance between directly communicating nodes and noise interference levels. The greater the values these parameters hold, the larger amount of power is demanded to transmit. Minimum total transmission energy, such as *MTPR*, focuses on end-to-end energy efficiency. Generally, the route selected by conserving energy is the shortest distance path or minimum hop path. Even though some nodes may be dissipating more energy due to dynamics of link characteristics such as distance or error rate, the end-to-end shortest path naturally leads to conservation of energy in transmission.

The majority of energy efficient routing protocols for MANET try to reduce energy consumption by means of an energy efficient routing metric, used in routing table computation instead of the minimum-hop metric. This way, a routing protocol can easily introduce energy efficiency in its packet forwarding. These protocols try either to route data through the path with maximum energy bottleneck, or to minimize the end-to-end transmission energy for packets, or a weighted combination of both. A first approach for energy-efficient routing is known as MTPR. That mechanism uses a simple energy metric, represented by the total energy consumed to forward the information along the route. This way, MTPR reduces the overall transmission power consumed per packet, but it does not directly affect the lifetime of each node (because it does not take into account the available energy of network nodes). However, minimizing transmission energy only differs from shortest-hop routing if nodes can adjust transmission power levels, so that multiple short hops are more advantageous, from an energy point of view, than a single long hop. In 802.11 we do not have access to this capability, so that, in a fixed transmission power context, this metric corresponds to a Shortest Path routing.

C. *IMPLEMENTATION OF PROPOSED EPRDSR MECHANISM*

In order to compare DSR to EPRDSR, each node tracks its current energy level using energy units. When a node receives a route reply or an ACK, it updates its energy field in the packet path, as seen in table 1. Once the source node receives either a route reply or an ACK, it updates its energy table with the energy values in the path. When choosing a path, the DSR implementation chooses the path with the minimum number of hops. For EPRDSR, however, the path is chosen based on energy. First, we calculate the bottleneck energy for each path, that is, the lowest hop energy of the path. The path is then selected by choosing the path with the maximum lowest hop energy. For example, consider the following scenario. There are two paths to choose from the network. The first path contains three hops with energy values 150, 100 and 200, and the second path contains four hops with energy values 150, 75, 225 and 300. The score for the first path is 100, while the score for the second path is 75. Because 100 is greater than 75, the first path would be chosen.

1) Power Aware Model in EPRDSR

This model is discussed below:
The Energy is calculated by using this formula.

$$Energy = Power * Time \qquad (1)$$

The energy consumption is measured by the transmitting power or receiving power multiply the transmitted time.

$$P_t = \frac{(8*Packet\ Size)}{Bandwidth} \qquad (2)$$

The Transmitting Energy E_{tx} is defined as

$$E_{tx} = P_{tx} * P_t \qquad (3)$$

The Receiving Energy E_{rx} is defined as

$$E_{rx} = P_{rx} * P_t \qquad (4)$$

Energy consumption of a node after time t is calculated using the following equation

$$E_{con}(t) = N_t * C_1 + N_r * C_2 \qquad (5)$$

Where, $E_{con}(t)$, energy consumed by a node after time *t*.
N_t, no. of packets transmitted by the node after time *t*.
N_r , no. of packets received by the node after time *t*.

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C_1 and C_2 are constant factors having a value between 0 and 1.
Let E be the initial energy of a node and the residual energy E_{Res} of a node at time t, can be calculated by using the formula

$$E_{Res} = E - E_{con}(t) \quad (6)$$

Where E_{Res} : residual energy, E_{con} : consumed energy Total energy consumption of all Nodes is measured as the summation of all node's residual energy plus the product of initial energy and number of nodes.

$$T_{Econ} = N * Initial\ Energy - E_{Res} \quad (7)$$

Where T_{Econ} : total consumed energy, N: total number of mobile nodes in MANET

The following algorithm illustrates the Route Discovery process.

Route Discovery Algorithm

Step 1: Source node S.

- Creates the RREQ packet with field values set as SA=S, DA= D, Seq.No= I, TTL= T, Hops=H, BW=0, Min_energy = Initial energy;
- Broad cast the RREQ packet to next neighbor node whose BWth >= BW.
- Step 2: If the intermediate node will receive the RREQ packet.
- The Min_energy field in RREQ is updated by initial energy.
- Forward the RREQ packet to node 2.
- Calculate Node's Residual energy.
- This Residual Energy value is compared with Min_energy value in Routing table. The route is selected on the basis of Min_energy >= R_{energy} and BWth > = BW. Otherwise the link between Node1 and Node2 are unavailable.
- Step 3: If the node receiving the RREQ packet in D, then the node D.
- Generates the RREP packet for uni-casting to source. The bandwidth field of the RREP packet is updated with the cumulative bandwidth of the path and Energy field should be updated by cumulative Energy.
- D uni-casts all the node disjoint paths back to the source node S.

2) *Route Selection*

When the RREQ receives at the neighbour node, it forwards a RREP packet back to the source. Otherwise, it rebroadcasts the RREQ. If they may receive a processed RREQ, they discard the RREQ and do not forward it. If RREQ of multiple paths are received at source node, it stored by the hop count value. In MTPR the route is selected on the basis of minimum number of hops. But the EPRDSR protocol select the best path by sorting multi-route in descending order of nodal residual energy and bandwidth and the data packets are forwarded by using the maximal nodal residual energy.

3) *Route Maintenance*

In case the energy value is less than the threshold value minimum energy then link is broken, an Route Error message (RERR) is sent back to the previous node to indicate the route breakage. If node receives this RERR message, it informs to the source node then it starts route discovery procedure again.

4) *Route Discovery*

In route discovery procedure, the EPRDSR builds a route between source to destination using a route request and route reply query cycle. When a source node wants to send a packet to destination for which it does not already have a route, it forward a RREQ packet to all the neighbours across the network. The performance of EPRDSR is improved by adding energy model parameters in RREQ packet, two additional fields are added in the RREQ header information such as bandwidth and energy constraints.

The extended Route Request packet of EPRDSR is shown in table 1.

SA	DA	Seq. No	Hop _Count	Time _out	Band_ width	Min_ Energy

Table 1: Extended Route Request packet structure.

In EPRDSR routing discovery process, the source node in the network sends the extended RREQ message to the destination node through number of intermediate nodes. The data transmission in wireless network can be directly within one hop or through number of intermediate nodes. The extended RREQ message contains the source and destination node IP address, Advertised hop count value, Timeout value, Bandwidth of the link and minimum energy value. The computed bandwidth and minimal nodal energy is greater than the threshold value of bandwidth and energy then only the RREQ message forward to the next neighbor node otherwise it discarded. When the RREQ message

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International Journal of Advanced Research in Computer and Communication Engineering
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arrive at next node, the bandwidth and minimal nodal energy is updated into the route list entries.

At the initial stage the source node's initial energy is entered into minimum energy field, the residual energy is computed at every node in the network. This residual energy is compared with minimum energy field of RREQ packet. If this value is less than the minimum energy field, then it replaced by residual energy. While selecting the best path, the minimum energy should be kept as the lowest among all the nodes in this route. Once the RREQ packet is received by the destination node, the node will produce RREP packet and send back to the source node. RREP packet is also included two additional fields Bandwidth and minimum energy, the RREP packet records the routing information from the source to destination. The duplicate packet ID is received by the destination node, and then it responds with a maximum of RREP packets to the source node.

IV. ANALYSIS OF EXPERIMENTAL RESULTS AND METRICS STUDY

For evaluating EPRDSR protocol, simulation results are obtained by experiments with different energy levels, different traffic loads and different movement patterns of nodes.

A. *Routing Performance with Enough Power*

In the first set of experiments, every node is given a battery with full capacity initially. In this scenario, no nodes turn off due to running out of energy. This is to test the routing performance of EPRDSR in a regular network scenario. A total of 100 CBR streams are generated within the 1000-second simulation time.

B. *Varying number of mobile nodes*

Fig.1, 2 and 3 show the simulation results when varying the number of nodes while maintaining the throughput, packet delivery ratio and end to end delay. We have selected MANET communities of 50, 75 and 100 nodes. The DSR behaviour highly depends on this factor. When passing from 25 to 50 nodes, the protocol suffers an increment of 45%. This characteristic makes this protocol not scalable. With respect to EPRDSR and MTPR, the energy increment for a MANET of 50 nodes with respect to a MANET of 25 nodes is quite similar and is about 17%. This increment is mainly due to route maintenance process with DSR, the increment is mainly due to the propagation of route table between nodes.

C. *Varying pause time*

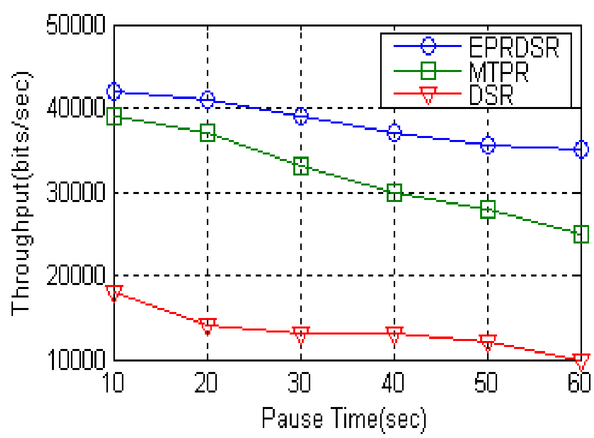
In this section, we explore the effect of varying pause time over the basic scenario. We run simulations varying the pause times from 10, 20, 30, 40 and 50 simulated seconds obtaining a range of scenarios that span from continuous motion nodes.

Fig.1, 2 and 3 are highlights the power consumed by routing protocols. EPRDSR and MTPR offer the best performance while DSR shows the poor results. Typically on-demand protocol (DSR) presents an energy descendent trend as the motion rate drops, the power aware routing protocols (EPRDSR, MTPR) present the power consumption that remains practically constant or small decreases as pause time varies.

D. *Throughput*

It is the ratio of the total amount of data that reaches a receiver from a sender to the time it takes for the receiver to get the last packet. When comparing the routing throughput by each of the protocols, EPRDSR has the high throughput. It measures of effectiveness of a routing protocol. The throughput values of DSR, MTPR and EPRDSR protocols for 50, 75 and 100 nodes at pause time 10,20,30,40 and 50s and they are plotted on the different scales to best show the effects of varying throughput of the above routing protocols as shown fig. 1, 2 & 3. Based on the simulation results, the throughput value of DSR decreases initially and reduces when the time increases.

The throughput value of MTPR slowly increases initially and maintains its value when the time increases. EPRDSR performs well than MTPR and DSR. The throughput value of DSR decreases at lower pause time and grows as the time increases. Hence, EPRDSR shows better performance with respect to throughput among these three protocols.



ISSN (Print) : 2319-5940
ISSN (Online) : 2278-1021

International Journal of Advanced Research in Computer and Communication Engineering
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Fig. 1: Throughput for 50 nodes

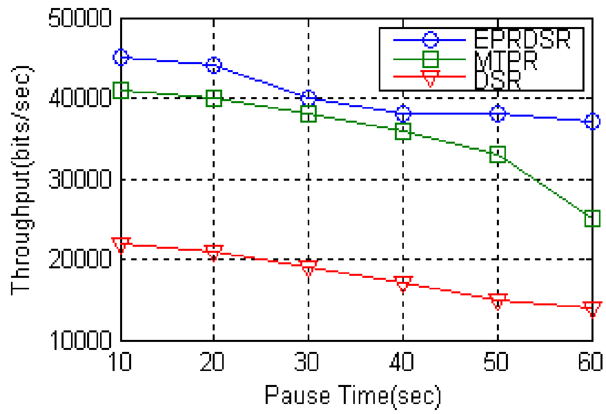

Fig.2 Throughput for 75 nodes

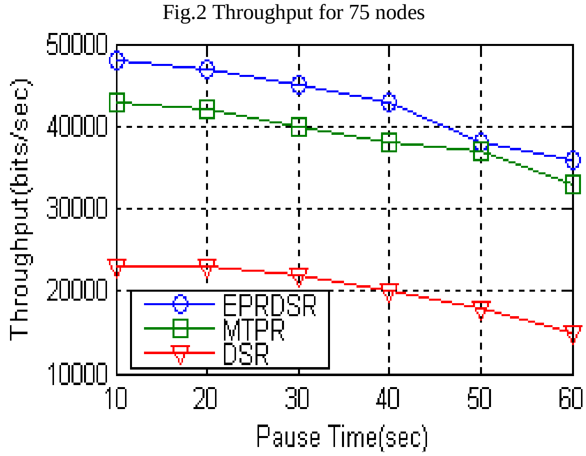

Fig.3 Throughput for 100 nodes

E. *Packet Delivery Ratio (PDR)*

The ratio of the data packets delivered to the destination to those generated by CBR sources. This metric illustrates the effectiveness of best effort routing protocols. This performance measure also determines the completeness and correctness of the routing protocol. If P is fraction of successfully delivered packets, N is total number of flows, f is id, R is packets received from f and T is transmitted from f, then F can be determined by

$$F = \frac{1}{N}\sum_{f=1}^{c}\frac{R_f}{T_f} \qquad (8)$$

It has been found that in all cases EPRDSR perform better than MTPR and DSR in packet delivery ratio. Fig. 4 shows the throughput in packet delivery ratio for 100 nodes. As is clear this scheme improves the throughput performance of EPRDSR as well.

The ratio of the originated application's data packets of each protocol which was able to deliver at varying time are shown in fig. 5, 6 and 7. As packet delivery ratio shows both the completeness and correctness of the routing protocol and also measure of efficiency the PDR value of EPRDSR is higher than all other protocols. The PDR values of EPRDSR and MTPR are higher than that of DSR. The PDR value of DSR is less in lower pause time and gradually grows in higher pause time. From the above study, in view of packet delivery ratio, reliability of EPRDSR and MTPR protocols are greater than DSR protocol.

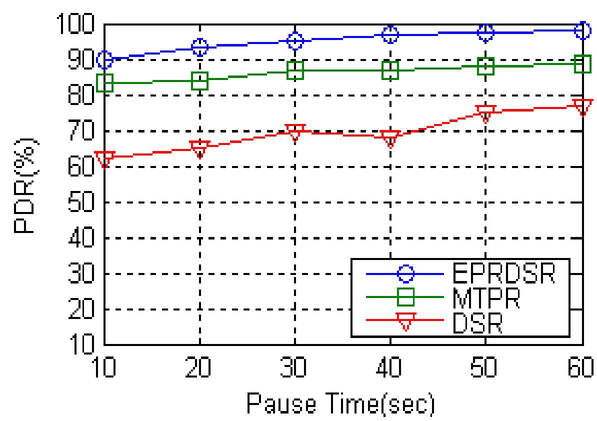

Fig.4 Result of PDR for 50 nodes

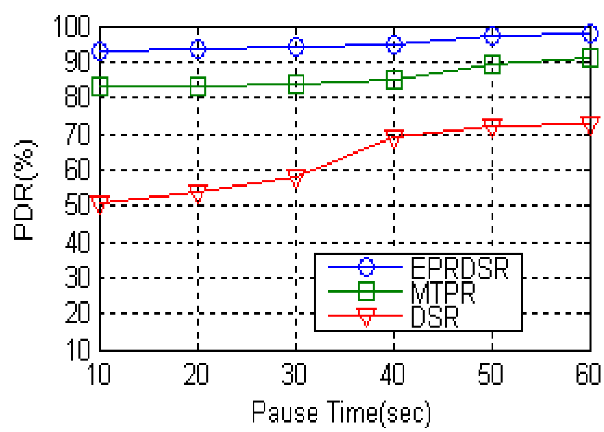

Fig.5 Result of PDR for 75 nodes

ISSN (Print) : 2319-5940
ISSN (Online) : 2278-1021

International Journal of Advanced Research in Computer and Communication Engineering
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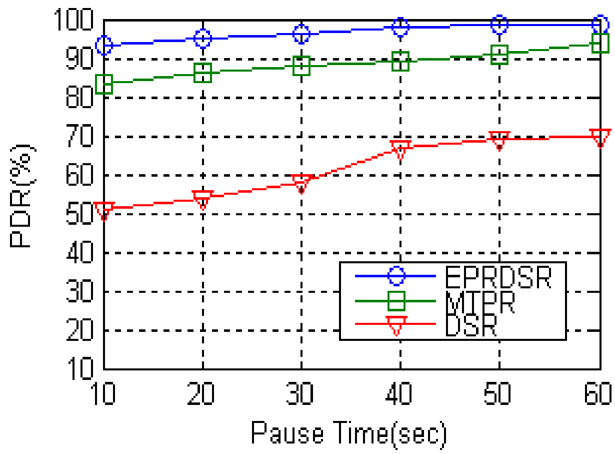

Fig.5 Result of PDR for 100 nodes

F. *Average End-to-End delay*

Average end-to-end delay is the delay experienced by the successfully delivered packets in reaching their destinations. This is a good metric for comparing protocols. This denotes how efficient the underlying routing algorithm is, because delay primarily depends on optimality of path chosen.

$$Average\ End\ to\ End\ delay = \frac{1}{S}\sum_{i=1}^{s}(r_i - s_i) \quad (9)$$

where S is number of packets received successfully, r_i is time at which packet is received and s_i is time at which it is sent, i is unique packet identifier. Simulations have been conducted for 100 nodes.

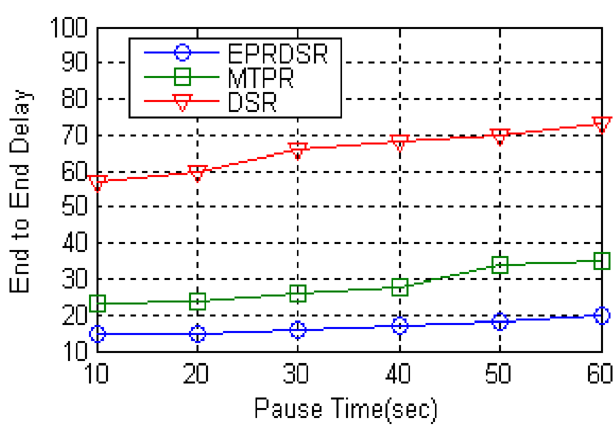

Fig.7 Comparison of End to End Delay for 50 nodes

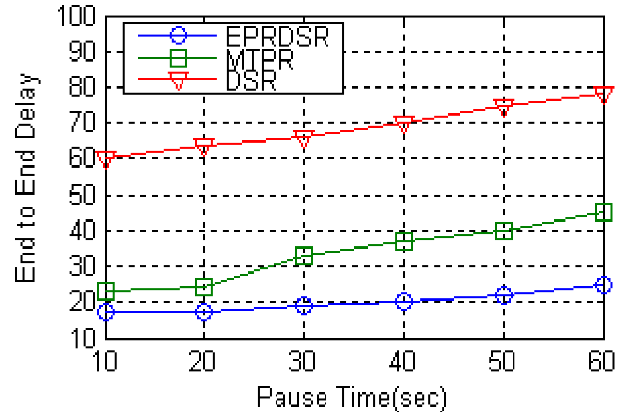

Fig.8 Comparison of End to End Delay for 75 nodes

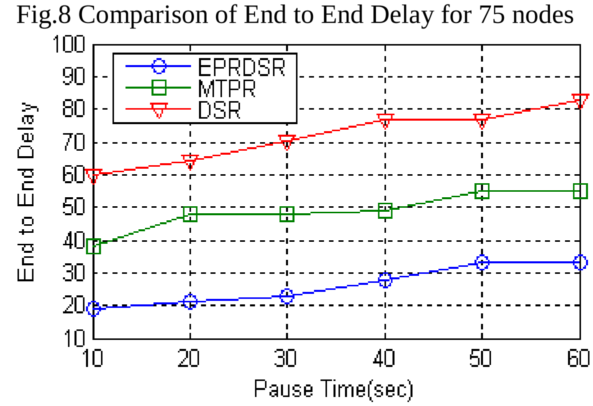

Fig.9 Comparison of End to End Delay for 100 nodes

The fig.8, 9 and10 depict the average end-to-end delay for the EPRSDSR, MTPR and DSR protocols for the number of nodes 50, 75 and 100 respectively. It is clear that EPRSDSR has the shortest end-to-end delay than MTPR and DSR. Hence, it consumes lesser time than others. As DSR needs more time in route discovery, it produces more end-to-end delay. From the above study on end-to-end delay, EPRSDSR has high reliability than MTPR and DSR.

G. *Power consumption*

We believe that delay should be given the highest priority when dealing with data packets over the wireless network. On the other hand, many researchers have focused and emphasized on saving power of the node battery to last for longer time (without recharging) and a lot of researchers. In this work, we also minimize power to an extent that it does not degrade improved delay performance.

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International Journal of Advanced Research in Computer and Communication Engineering
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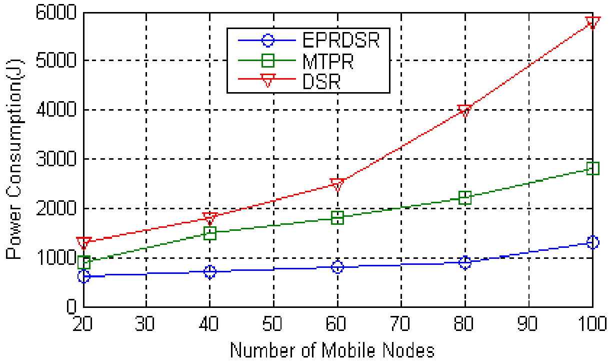

Fig.10 Routing power consumption comparison

Fig.10 shows the simulation results when varying the number of mobile nodes while maintaining the power consumption. We have selected MANET communities of 100 nodes. The EPRDSR behaviour highly depends on this factor. When passing from 20 to 60 nodes, EPRDSR protocol power consumption increment of 7%, MTPR is 25% and DSR is increment of 58%. This characteristic makes DSR protocol is not scalable.

V. CONCLUSION

In this paper, the performance of the three MANET routing protocols such as EPRDSR, MTPR and DSR were analyzed using NS-2 Simulator. We have done comprehensive simulation results of packet delivery ratio, throughput, and average end-to-end delay over the routing protocols EPRDSR, MTPR and DSR by varying mobile nodes and pause time. As DSR routing protocol needs to find route by on demand, end-to-end delay will be higher than MTPR and EPRDSR. For the higher mobility and pause time, EPRDSR performs better in case of packet delivery ratio. Its performance has been found much better than other existing protocols (DSR and MTPR) in finding the active routes increases. Overall, EPRDSR outperforms MTPR and DSR because it has less routing overhead when nodes have high mobility considering the above said three metrics. We expect that these scenarios will be common in ad hoc networking applications.

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BIOGRAPHY

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ISSN (Print) : 2319-5940
ISSN (Online) : 2278-1021

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 2, Issue 3, March 2013

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