Performance Evaluation of Energy Consumption in MANET

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ABSTRACT
The mobility of nodes in MANET may result in dynamic topology with high rate of link breakage and network partitions leading to interruption in communication and packet loss. Many routing protocols have been proposed in the literature with different characteristics and properties. The routing protocols suffer from various overheads causing energy loss which is further aggravated by link breaks. The present work concentrate on the energy consumption issues of routing protocols. We have evaluated the performance of DSDV, DSR and AODV routing protocols with respect to energy consumption indicating their usage of node's energy.

General Terms
MANET.

Keywords
Energy consumption, ad hoc network, link break, overhead, routing etc.

1. INTRODUCTION
Mobile Ad-hoc Networks (MANET) have several particularities [1] that limit its achievable performance such as nodes mobility, energy consumption, wireless nature and lack of central infrastructure etc. The nodes in MANET are mobile resulting in dynamic topology leading to link failures and partitions of network. This leads to interruption in the transmission of data packets. The nodes depend on the fixed power supply reserve. And the nodes energy may be consumed in transmitting data, receiving the data, in managing the congestion and in overhearing because of the shared medium. The dynamic nature of MANET makes these problems more severe. The routing protocols are the key element of network layer. Ideal routing protocol should be capable of finding and delivering data through optimal paths (latency, bandwidth and device power consumption) even in case of link failures. The fixed power reserve of mobile devices limits its transmission range. Table driven, On Demand and Hybrid routing protocols are the three main categories of routing protocols. Table- driven routing protocols have continuous flow of routing information to keep the nodes updated and consistent [3]. Update messages are sent even when there is no topological change. Hence an overhead is involved all the time. On demand routing protocol discover the route when needed. In contrast with table-driven protocols, source has to wait till route has been discovered but the overhead is significantly less than the table-driven protocols. On-Demand routing protocol provide better performance for networks where mobility is frequent and several simulation studies are also available [3]. An active communication may break and incur delay due to link break that may have happened due to nodes movement. The routing protocols detect the failed link and find an alternative path. But in the detection of failed link and finding another path, a significant cost (energy consumption) and delay is incurred. Because several retries have to time out before finalizing failure of path. In some case if have not been taken care of properly data which was on the way may be lost. Also cost may increase many fold due to mobility and random movement of nodes. The network may likely have increased link failures result in more energy consumption. Several approaches for detection of link failure have been defined such as hello messages, MAC layer feedback and passive acknowledgements [2]. Two limits are associated with the RTS/ CTS mechanism one is short retry limit (SRL) and other is long retry limit (LRL). By default value of SRL is set to 7 and LRL's is 4. SRL indicates the number of times node does retransmission of RTS to check accessibility of neighbor node. And LRL is associated with the retransmission of data packets in absence of acknowledgments. If a packet cannot be transmitted within these two limits then trigger a link failure [7].

2. PROBLEM FORMULATION
Most of the energy related study in MANET has been done to reduce energy consumption in either transmission or suggesting a different routing approach altogether but following the same concepts being used by standard routing protocols. Few have explored the idea to reduce the energy consumption due to routing overheads [4]. This may be because it requires the cross layer design approach. And to the best of my knowledge none has analyzed the energy consumption due to link failure. If during an ongoing transmission link failed either due to over utilization, node movement, or congestion etc. the transmission interrupts for a significant amount of time because before finding or using another route, the source node of the link failure has to wait for timeout interval and also has to inform all the nodes using that link in their path through route error (RERR) packets. In performing these activities as is expected a significant amount of energy is consumed. In this paper we measured the energy consumption behavior of three routing protocols; respectively the Destination Sequenced Distance Vector Routing (DSDV), Ad-hoc On Demand Distance Vector routing (AODV) and the Dynamic source Routing (DSR). These three protocols were selected so that a comparison with the results obtained in [5] could be done. The methodology consisted of selecting the

basic scenario considering representative parameters for performance evaluation and then varying the selected parameters to generate wide enough different scenarios. The selected parameters were 1) sources, 2) pause time, 3) the mobile node number, 4) area, 5) sending rate and 6) the speed. In addition to the energy consumption behavior of routing protocols, we have also measured the throughput, network lifetime, variance of residual battery energy and energy consumed per data delivered [14]. These metrics will help in comparing the performance of selected protocols.

The simulation results were obtained using the ns-2 simulator [13]. ns-2 is a discrete event, object oriented simulator developed at University of California, Berkeley. Communication Management Unit's (CMU's) wireless extension to ns-2 provides the implementation of routing protocols.

3. TYPES OF ROUTING PROTOCOLS

The MANET routing protocols maintain the routes of the MANET and do not require any infrastructure to connect with other nodes in the network. Ad hoc routing protocols can broadly be classified into proactive, reactive and hybrid protocols. The approached involve a trade-off between the amount of energy consumption, overhead and other performance measure required to maintain routes between node pairs. Proactive protocols, also known as table-driven protocols, maintain routes between nodes in the network at all times, including the situation when the routes are not currently being used. Reactive protocols, also known as on-demand protocols, involve discovering routes to other nodes only when they are needed. A route discovery process is invoked when a node wishes to communicate with another for which it has no route table entry. There exist another class of protocols, such as ZRP (zone routing protocols), which employs a combination of proactive and reactive methods.

3.1 Studied Protocols

In Destination-Sequenced Distance- Vector (DSDV) routing protocol every node periodically propagate routing information updates throughout the network. Each node maintains the routing table. The routing table is indexed by sequence4 numbers and list the every reachable destination the next hop. The sequence number differentiates stale routes from new ones.

The Dynamic Source Routing (DSR) routing protocol composed of two mechanisms namely route discovery and route maintenance that work together to allow the discovery and maintenance of source routes in MANET [8]. DSR protocol requires each packet to carry the full address (hop information) from source to destination. The destination piggybacks the route information in RREP packet avoiding infinite recursion of route discoveries. The protocol does not require periodic beaconing so nodes may conserve power. Another advantage of DSR is that nodes cache may contain multiple routes to destination and it is very advantageous for low mobility networks [12].

AODV: Ad hoc on-demand distance vector (AODV) is based on DSR and DSDV algorithms. The basic route discovery and route maintenance is based on DSR and uses the hop-by-hop sequence numbers and beacons of DSDV [10]. During route discovery the source node broadcast a ROUTE REQUEST (RREQ) message with broadcast id and node sequence number. Intermediate node forwards the RREQ if it is not already received or does not have the route to the destination. The forwarding node also creates reverse route for itself from the destination. When the RREQ is received by a node with route to the destination, if sends ROUTE REPLY (RREP) with the number of hops (required to reach destination) information. All the intermediate nodes which forwards this RREP creates forward route to the destination. This protocol is adaptable to highly dynamic network but may experience large delays during route construction and link failure may further introduce extra delay due to rediscovery of route.

4. SIMULATION AND METRICS

The aim of these simulations was to analyze the selected routing protocols (DSDV, DSR and AODV) for their efficiency in terms of energy, overhead, throughput as well as network life time. The basic methodology consists of simulating with a basic scenario and then by varying selected parameters, simulates the generated scenarios. The selected parameters are sources, pause time, nodes, area, sending rate and mobility speed. In the simulation the nodes move according to random way point mobility model [8]. Each node starts moving from its initial position toward random position with the speed varying between 0 and maximum speed and when reaches the target position stay there for pause time and again start its journey towards next chosen random target. The traffic sources used in the simulations generated constant bit rate (CBR) data traffic. The TCP sources are not being chosen because it adapts to the load of the network [10]. For the same data traffic and movement scenario, the time of sending the packet of a node will be different in case of TCP, hence will become difficult to compare the performance of different protocols. The energy model taken is as used by [5]. The values used correspond to 2,400 MHZ Wave LAN implementation of IEEE 802.11. The radio frequency value is set as 0.2818 W for transmission range of 250 m. The following equations are used to compute energy required to transmit/ receive the packets of given size:

$$Energy_{Tx} = (\text{Transmitted Power x Packet Size}) / 2 \times 10^6$$

$$Energy_{Rx} = (\text{Receiving Power x Packet Size}) / 2 \times 10^6$$

4.1 Simulation Parameters

Channel type	Wireless channel
Radio-propagation model	Two Ray Ground
Antena type	Omni Antenna
Interface queue type	Drop Tail/ Pri Queue
Maximum packet in Queue	50
Network interface type	Phy/ WirelessPhy
MAC type	802_11
Topological area	500 x 500 sq. m
txPower	1.65 W
rxPower	1.15 W

idlePower	1.0 W
Sleep Power	0.001 W
Initial energy of a Node	1000.0 Joules
Routing protocols	DSDV/ DSR/ AODV
Number of mobile nodes	25
Maximum speed	15 m/s
Rate	4 Packet/ s
Pause time	5,10,15,20, 25 sec.
Simulation time	500 sec.

Each simulation had the duration of 500 simulated seconds. Because the performance of the simulations is highly related with mobility models, the results analyzed here represents an average of ten different executions of the simulation considering the same traffic models but with different randomly generated mobility scenarios. We have evaluated the following performance indexes. (a) Total energy consumed (in Joules), (b) energy consumed depending on the types of packet type (Data, MAC and Routing).

5. RESULTS AND ANALYSIS

Figure 1 depicts the energy consumption of the network versus number of nodes and speed of nodes. On demand routing protocols (DSR, AODV) consumes more energy as compared to table driven protocol (DSDV). DSR performs better than AODV although uses source routing. It might be due to caching mechanism used in DSR which reduces the discovery routes overhead. The energy consumption due to routing overhead of DSR is negligible as compared to AODV. Figure 1 (a) shows that the energy consumption decrease with the increase of nodes, while in Figure 1 (b) the variation in energy consumption of AODV at different speed is minimum, hence can easily handle the network changes.

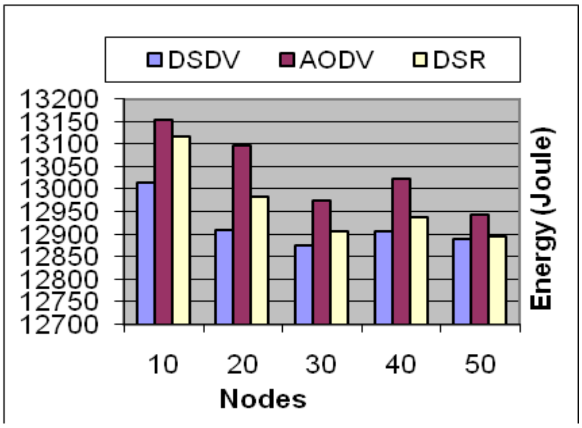

Fig. 1(a): Energy Consumption Vs Nodes

Figure 2, 3 and 4 shows the energy consumed in different types of packets of selected routing protocols. The routing energy consumption increases with the increase of either nodes or speed and it is minimum for DSR and maximum for DSDV. The MAC energy consumption decreases and it is minimum for DSDV. The DSR consumes less energy as compared to AODV because DSR uses cache for route maintenance whereas AODV starts a new route discovery for link breakage.

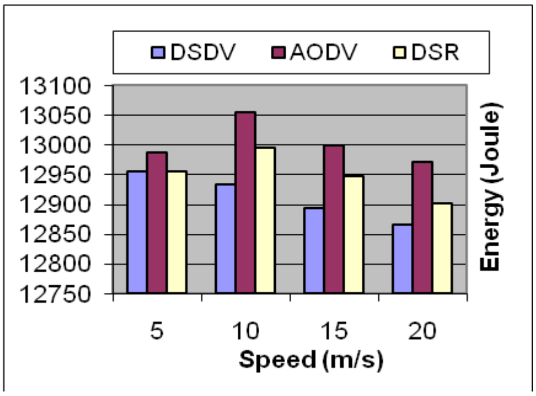

Fig. 1(b): Energy Consumption Vs Speed

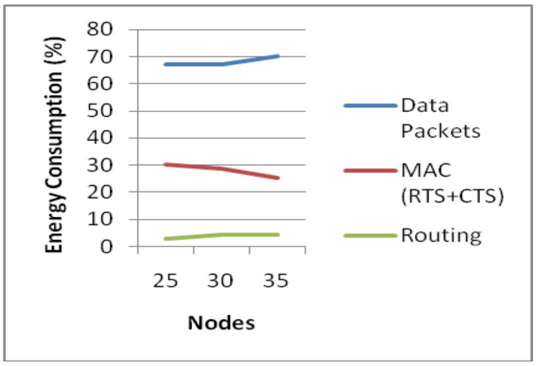

Fig. 2(a): Energy Consumption of AODV

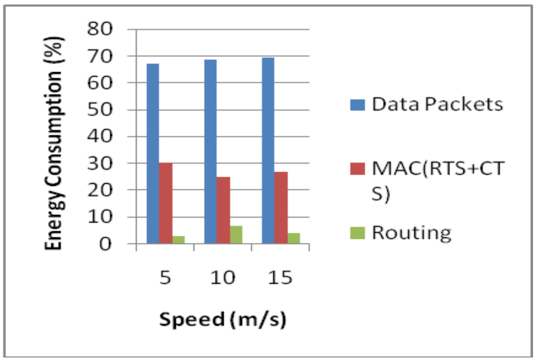

Fig. 2(b): Energy Consumption of AODV

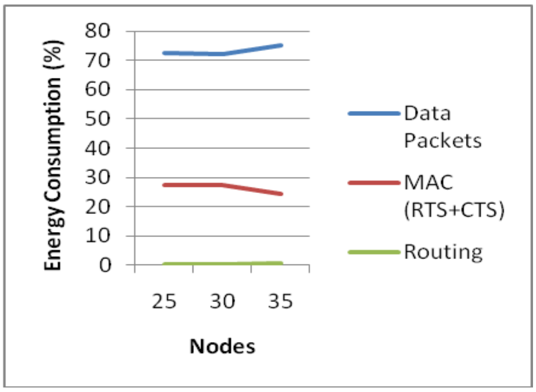

Fig. 3(a): Energy Consumption of DSR

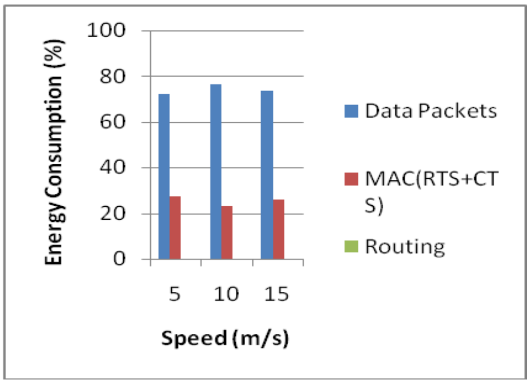

Fig. 3(b): Energy Consumption of DSR

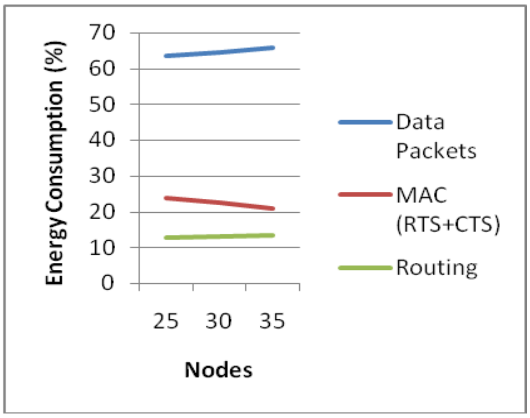

Fig. 4(a): Energy Consumption of DSDV

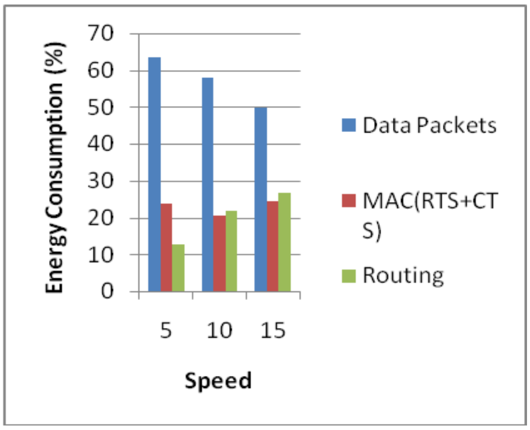

Fig. 4(b): Energy Consumption of DSDV

Figure 5 shows the throughput (PDF) of DSDV, DSR and AODV at different speed and nodes. The DSR and AODV outperform DSDV. And throughput is constant irrespective of the speed or nodes. DSDV performance decreases as the mobility increases because of the presence of stale routing table entries and packets are sent or forwarded over broken links and it degrades at high speed. The throughput of DSR is better than AODV, because DSR has access to a significantly greater amount of routing information than AODV in single cycle of route discovery. Being the source routing protocol, DSR can learn routes to each intermediate nodes on the route to the destination in a single request- reply cycle. And AODV uses too many routing packets to build necessary routing information. The throughput of DSDV varies with the number of nodes. It decreases initially when the number of nodes is 30 but after that it increases for 40 nodes. Also DSDV behavior has been tested thoroughly and found variable behavior.

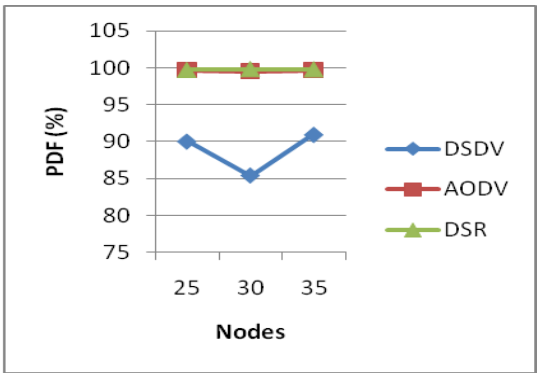

Fig. 5(a): Packet Delivery Fraction (PDF)

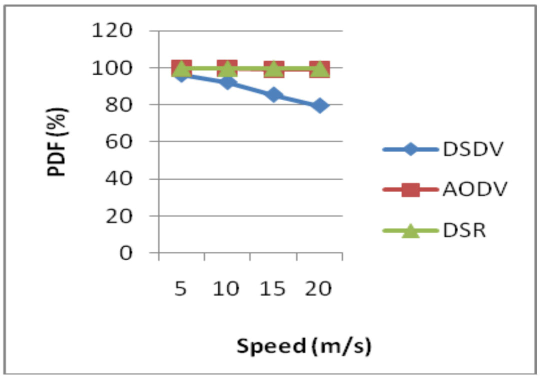

Fig. 5(b): Packet Delivery Fraction (PDF)

Figure 6 depicts that the energy consumption of reactive protocols is considerably constant when the movement speed is varying while it increases against the number of nodes. But both the reactive protocols (AODV, DSR) outperform DSDV. The Energy Consumption per Successful Data Delivery (ECPSDD) of DSDV increases against speed because the probability of link breakage also increases. So an additional energy is consumed in constructing new routes. The ECSDD of DSR is less than AODV because DSR uses less number of routing overhead than AODV.

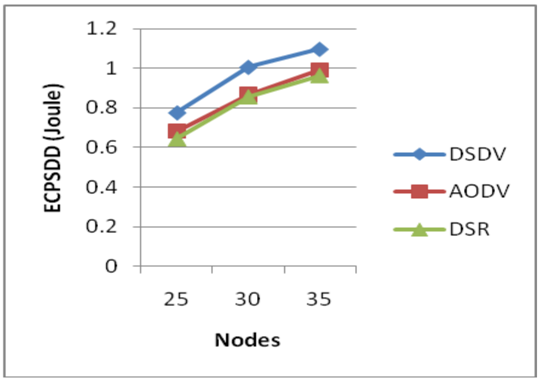

Fig. 6(a): Energy Consumption per Successful data delivery

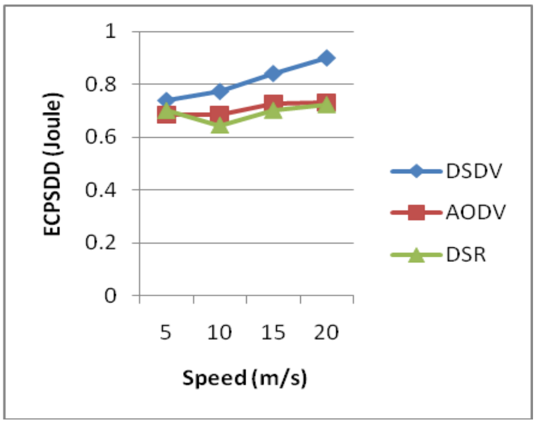

Fig. 6(b): Energy Consumption per Successful data delivery

Figure 7 show the network life time of the three MANETs routing protocols. The DSDV protocol keeps the network energetic longer than the AODV and DSR. Figure 8 shows that the energy variance of residual battery energy (EVRB) of nodes of DSR is not distributed properly as compared to AODV and DSDV. DSDV prolongs the network lifetime although consume more energy per packet than DSR and AODV, the energy consumption for routing overhead is distributed among all the nodes of the network result in minimizing the exploitation of specific nodes energy repeatedly and also fairly utilizes the nodes energy. In spite of being unfair utilization of nodes (exploitation) by DSR (Figure 8) DSR network life time is more (Figure 7) because energy consumption per packet of DSR is less than AODV. But AODV shows (Figure 8) better load balancing than DSR. The network lifetime of AODV is shorter than DSR (Figure 7), because high mobility causes link breakage and AODV is aggressive to maintain broken links incur energy cost.

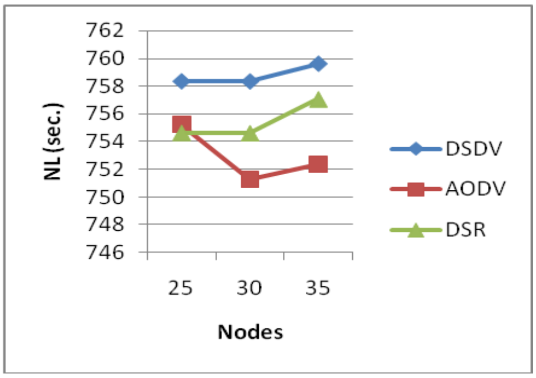

Fig. 7(a): Network Life Time

Figure 9 shows the number of link breaks detected by routing protocols. AODV shows the minimum number of link breaks. DSDV detects maximum link breaks because cannot adapt to the dynamic environment and condition deteriorates further with the increase of mobility. DSR link breaks are also increasing with the speed but AODV is able to adapt itself with the mobility and keeping the link failures to minimum. We know Short Retry Limit of RTS (07) and Long Retry Limit of Data packet (04) is checked [7] before triggering a link failure in IEEE 802.11 MAC. And as per the considered

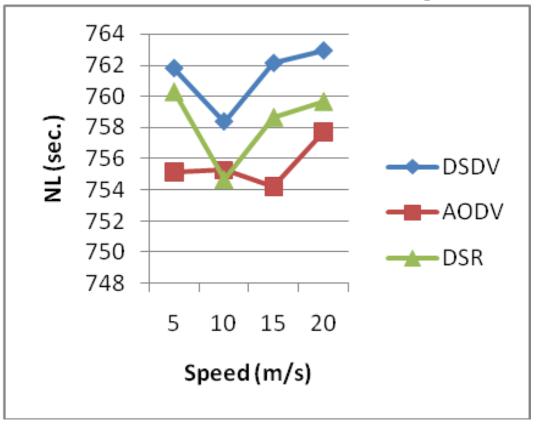

Fig. 7(b): Network Life Time

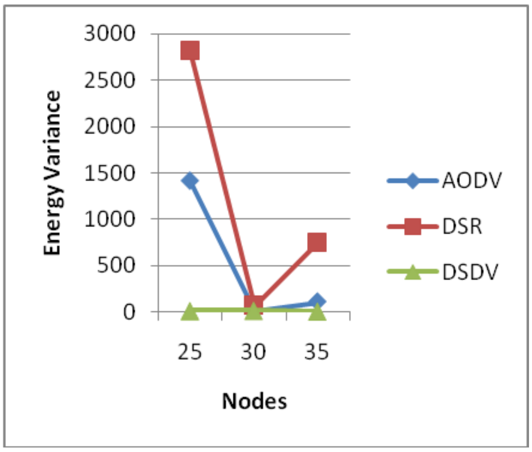

Fig. 8(a): Energy Variance Vs Nodes

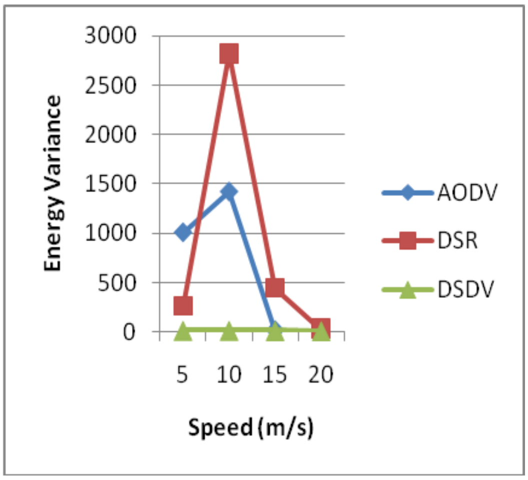

Fig. 8(b): Energy Variance Vs Speed

Energy model, energy consumed in transmitting and receiving depends on the size of the packet sent/ receive. So a link failure may cause at least 15.5 Joule (3.37 x 4 Joule for data packets and 2.02 Joule for RTS packets). Hence the protocols reporting more link failures will consume larger amount of energy of the network.

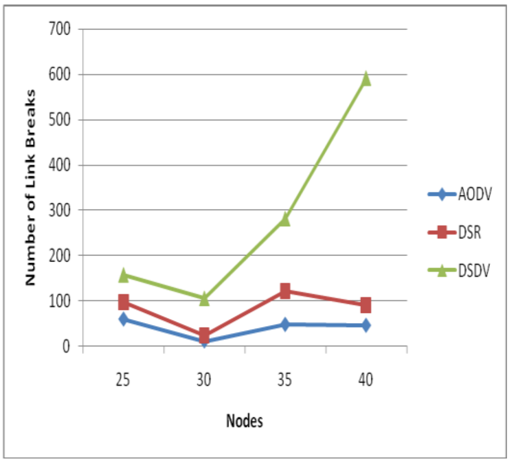

Fig. 9(a): Link Breaks Vs Nodes

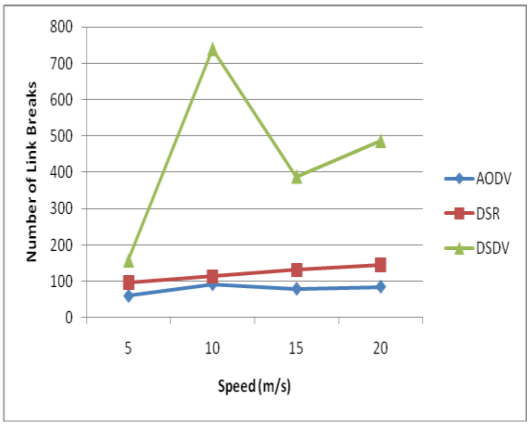

Fig. 4(b): Link Breaks Vs Speed

6. CONCLUSION AND FUTURE WORK

This study has evaluated three ad-hoc routing protocols in different scenarios considering nodes density and mobility. Overall the findings suggest that the existing routing protocols have not been designed to provide energy efficient route instead to offer best efforts of less delay. That is why have shown significant differences in energy consumption. There is no single protocol qualifying all the performance metrics. DSDV consumes the minimum energy and maximum amount is consumed in routing overhead. DSDV makes the network lifetime longer than others but consumes larger amount of energy per packet and less throughput for high mobility. DSR outperforms others and consumes minimum amount of energy per packet also the throughput is nearly same as that of AODV.

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