Power Control and Performance Improvement of Reactive Routing Protocols using QualNet Simulator

Dharam Vir[1], Dr. S.K. Agarwal[2] and Dr. S.A. Imam[3]

[1]Research Scholar, Electronics Engg. Department, YMCA University of Science & Technology, Faridabad, India

[2]Professor & Dean Electronics Engg. Department, YMCA University of Science & Technology, Faridabad, India

[3]Assistant Professor, Electronics & Comm. Engg. Department, Jamia Millia Islamia, New Delh, India

Abstract

Mobile ad hoc networks (MANETs) consist of a collection of two or more nodes, which are connected in decentralized manner for enabling wireless communication. All nodes are mobile and can be connected dynamically in an arbitrary manner. A wireless sensor network consists from a collection of transceivers positioned in the plane. Each transceiver is equipped with a limited battery charge capacity. The battery charge capacity is reduced after each transmission, depending on the transmission distance. One of the major problems in wireless ad hoc network is designing a route network traffic algorithm that will maximize the lifetime of the network i.e., the number of successful transmissions. Routing algorithms for WSNs are responsible for selecting and maintaining the routes in the network and ensure reliable and effective communication in limited periods. The power constraint of WSNs make power saving become the most important objective of various routing protocol algorithms. In this paper we effort to improve power control, performance and efficiency of reactive routing protocol. Performance of on-demand routing protocols is evaluated considering the parameters average end-to end delay, packet delivery ratio and throughput using network simulator Qualnet 5.0. The simulation shows that DSR protocol exhibits good performance in comparison to other routing protocols.

Keywords: AODV, DSR, Wireless Sensor Networks, Power efficiency, Proactive, Reactive, Hybrid

1. INTRODUCTION

Wireless Sensor Networks (WSN) is found in many applications including military, smart homes, environmental monitoring, health applications, habitat monitoring. A Wireless Sensor Network consists of many sensor nodes deployed in environment and connected to a base station that processes the sensed data from the sensors. One of the key characteristics of sensor nodes is that they are energy constrained. Typically sensor nodes rely on finite energy sources like battery for power in unmanned positions. Routing protocol plays an important role if two hosts wish to exchange packets which may not be able to communicate directly [1] [11]. All nodes are mobile and can be connected dynamically in an arbitrary manner. All nodes of these networks behave as routers and take part in discovery and maintenance of routes to other nodes in the network. This situation becomes more complicated if more nodes are added within the network. An Ad-Hoc routing protocol must be able to decide the best path between the nodes, minimize the bandwidth overhead to enable proper routing, minimize the time required to converge after the topology changes. Power consumption is an important issue in wireless sensor networks (WSNs). In a sensor node, energy is consumed by the power supply, the sensor, the computation unit and the radio unit. In some application scenarios, replenishment of power resources might be impossible. Sensor node life time, therefore, shows strong dependence on battery life [2] [15]. In a multihop ad-hoc sensor network, each node plays the dual role of data originator and data router. The malfunctioning of a small number of nodes can cause significant topological changes and might require rerouting of packets and reorganization of the network. Hence, power conservation and power management take on additional importance. The main task of sensor node in a sensor field is to distinguish the events, perform quick local data processing, and transmit the data. Power consumption can hence be dividing into three domains: sensing, communication and data processing. The total energy consumption includes both transmission energy and circuit energy consumption. Due to massive number of deployment and remote, unattended positions, replacements of batteries are quite impossible. Harvesting energy from the environment is currently a promising but under developed research area and therefore, energy and efficiency has to be used judiciously [2] [9]. The expectancy of longer lifetime of sensor nodes has put researchers to work on every possible aspect of sensor nodes in gaining power consumption and energy efficiency. In this paper AODV, DSR and DYMO on demand protocols based on IEEE 802.11 are analyzed for their performance on different performance measuring metrics versus varying traffic CBR load using QualNet 5.0 network simulator.

2. CLASSIFICATION OF SENSOR NETWORKS AND SIMULATION OBJECTIVES

Sensor Networks can be classified on the basis of their mode of functioning and the type of objective application into three major types. They are three types as follows;

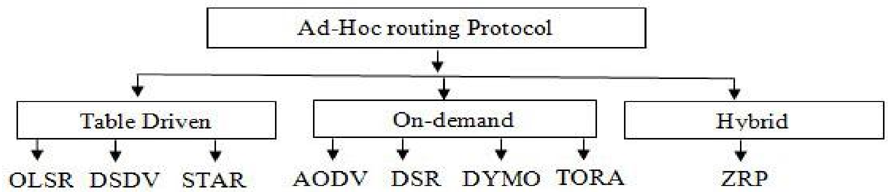

Figure 1: Classification of Ad-Hoc routing protocols

Proactive or Table-driven routing protocol: Proactive protocols, also called table driven, continuously evaluate the routes within the network, so that when a packet needs to be forwarded the route is already known and can be immediately used. Table driven protocols maintain consistent and up to date routing information about each node in the network. These protocols require each node to store their routing information and whenever there is a change in network topology, the updates has to be made throughout the network [3] [7]. The table driven protocols for example are:
1. Destination sequenced Distance vector routing (DSDV)
2. Source Tree Adaptive Routing (STAR).

Reactive or On-demand routing protocol: Reactive routing protocols, also called on demand, invoke a route determination procedure only on demand. A node wishing to communicate with another node first seeks for a route in its routing table. If it finds one the communication starts immediately, otherwise the node initiates a route discovery phase. Once a Route has been established, it is maintained until either the destination becomes inaccessible (along every path from the source), or until the route is no longer used, or expired [3]. For example
1. Ad-Hoc On-demand Distance Vector (AODV)
2. Dynamic Source Routing (DSR)

Hybrid routing protocols: This type of protocols combines the advantages of proactive and of reactive routing. The routing is initially established with some proactively prospected routes and then serves the demand from additionally activated nodes through reactive flooding. The choice for one or the other method requires predetermination for typical cases. The features of such algorithms are [3]:
1. Depends on amount of nodes activated.
2. Reaction to traffic demand depends on gradient of traffic volume.
For example
2. Zone Routing Protocol (ZRP)
These classes of routing protocols are reported but choosing best among them is very difficult as one may be performing well in one type of scenario but may not work in another type of scenario. It is examined in the paper with the simulation of DSR, AODV and DYMO routing protocols and the comparative characteristic summary of proactive, reactive and hybrid routing protocols is presented in Table 1 [14].

Table 1: Characteristic Summary of Reactive, Proactive and Hybrid routing Protocols

Metrics	Proactive	Reactive	Hybrid
Network association	Flat/ Hierarchical	Flat	Hierarchical
Topology broadcasting	Periodical	On-demand	Both
Route latency	Always available	Available when needed	Both
Mobility management	Periodical updates	Route maintenance	Both
Communication transparency	High	Low	Medium

Most of sensor networks are application based and they have specific application for different requirements. The following are the main design objectives of design a scenarios for our work on sensor networks.

Small node size: The sensor nodes are usually deployed in an insensitive or aggressive environment in large numbers, reducing node size can make possible node deployment. It will also reduce the power consumption and cost of sensor nodes [4] [5].

Low node cost: The sensor nodes are usually deployed in an insensitive or aggressive environment in large numbers and cannot be reused; reducing cost of sensor nodes is important and will result into the cost reduction of complete network [4].

Low power consumption: When sensor nodes are powered by battery and it is often very difficult or even impossible to charge or recharge their batteries, it is crucial to reduce the power consumption of sensor nodes so that the lifetime of the sensor nodes, as well as the whole network is deferred [4].

Reliability: Network protocols designed for sensor networks must offer error control and improvement in mechanisms to ensure reliable data delivery over noisy and time-varying wireless channels.

Scalability: Since the number sensor nodes in sensor networks are in the order of tens, hundreds, or thousands, network protocols designed for sensor networks should be scalable to different network sizes.

Self-configurability: In the sensor networks, once deployed, sensor nodes should be able to separately arrange themselves into a communication network and reconfigure there in the event of topology changes and node failures.

Channel utilization: The sensor networks have limited bandwidth resources; communication protocols designed for sensor networks should efficiently make use of the bandwidth to improve channel utilization [8] [13].

Fault tolerance: Sensor nodes are prone to failures due to harsh deployment environments and unattended operations. Thus, sensor nodes should be fault tolerant and have the abilities of self testing, self-calibrating, self-repairing, and self recovering [7].

Adaptability: In sensor networks, a node may fail, join, or move, which would result in changes in node density and network topology. Thus, network protocols designed for sensor networks should be adaptive to such density and topology changes [4] [16].

Security: A sensor network should introduce effective security mechanisms to prevent the data information in the network or a sensor node from unauthorized access or malevolent attacks [4].

3. ENERGY EFFICIENT WIRELESS SENSOR NETWORK PROTOCOLS

Protocols for sensor networks must be designed in such a way that the limited power available at the sensor nodes is efficiently used. Routing in WSN is quite challenging due to its intrinsic constraints and basic characteristics that distinguish WSN from other wireless networks. There is no global addressing scheme in WSN. Therefore, routing protocols of IP based networks cannot be used in WSN. Data from multiple sources can create significant redundancy in the data traffic. There are many number of routing protocols have been proposed for WSN and can be broadly categorized as follows. Energy efficient classified into six different types, namely, data centric, hierarchical, location-aware, mobility based, heterogeneity based and Quality of Service (QoS) based [6].

3.1 Ad-Hoc Wireless Sensor Network

Here we have described the reactive protocols DSR, AODV and Proactive protocol DYMO in brief.

1) Ad-Hoc On-demand Distance Vector (AODV)

It is a distance vector routing for mobile ad-hoc networks. AODV is an on-demand routing approach, i.e. there are no periodical exchanges of routing information. It offers quick variation to dynamic link environment, low processing and memory overhead, low network utilization, and determines unicast routes to destinations within the ad hoc network.

Each AODV router is in effect a state machine that processes incoming requests from the network entity. When the network entity needs to send a message to another node, it calls upon AODV to determine the next-hop. Whenever an AODV router receives a request to send a message, it checks its routing table to see if a route exists. Each routing table entry consists of the following fields:

- Destination address
- Next hop address
- Destination sequence number
- Hop count

If a route exists, the router simply forwards the message to the next hop. Otherwise, it saves the message in a message queue, and then it initiates a route request to determine a route. Upon acceptance of the routing information, it updates its routing table and sends the queued message(s). AODV nodes use four types of messages to communicate among each other. Route Request (RREQ) and Route Reply (RREP) messages are used for route discovery. Route Error (RERR) messages and HELLO messages are used for route maintenance. The destination sequence number is used to make this routing protocol loop free [7].

The protocol consists of two phases: Route Discovery and Route Maintenance.

a) Route Discovery

Nodes are wishing to communicate with another node first seeks for a route in its routing table. If it finds one the communication starts without delay, otherwise the node initiates a route discovery phase. The route discovery process consists of a route-request message (RREQ) which is broadcasted. If a node has a valid route to the destination, it replies to the route-request with a route-reply (RREP) message. Additionally, the replying node creates a so called reverse route entry in its routing table which contains the address of the source node, the number of hops to the source, and the next hop's address, the address of the node from which the message was received. A lifetime is associated with each reverse route entry, if the route entry is not used within the lifetime it will be removed [7].

b) Route Maintenance

The second phase of the protocol is called route maintenance. It is performed by the source node and can be subdivided into: a (RERR) route error message is sent to the source node. Intermediate nodes receiving a RERR update their routing table by setting the distance of the destination to infinity. If the source node receives a RERR it will initiate a new route discovery. To prevent global broadcast messages AODV introduces a local connectivity management. This is done by periodical interactions so called HELLO messages which are small RREP packets containing a node's address and additional information [7].

3.2 Dynamic Source Routing Protocol

DSR protocol, as its name implies, is a source routing protocol: a complete sequence of intermediate nodes from a source to a destination will be determined at the source node and all packets transmitted by the source node to a destination node follow the same path. Every packet header contains the complete progression of nodes to reach a destination. DSR protocol is a reactive protocol and its primary objectives are:

- To avoid long convergence time of routing information.
- To eliminate a large routing table for forwarding packets at intermediate nodes.
- To avoid periodic announcements of link states required in proactive protocols, by separating route discovery from route maintenance.

The routing table of a data structure designed to hold routing information to reach every possible destination in a network, is not used in the DSR protocol. In DSR, routes are discovered on demand and a route cache is used to hold routes that are currently in use. As with most of the reactive protocols, DSR consists of two procedures: route discovery and route maintenance [10].

a. Route Discovery

When a node in the ad hoc network attempts to send a data packet to a destination for which route is not known, it uses a route discovery process to find a route. Route discovery uses simple flooding technique in the network with route request (RREQ) packets. Each node receiving an RREQ rebroadcasts its auxiliary, unless it is the destination or it has a route to the destination in its route cache. Such a node replies to the RREQ with a route reply (RREP) packet that is routed back to the original source. RREQ and RREP packets are also source routed. The RREQ builds up the path traversed so far.

b) Route Maintenance

The periodic routing updates and sent to all the nodes. If any link on a source route is broken, the source node is notified using a route error (RERR) packet. The source removes any route using this link from its cache. A new route discovery process must be initiated by the source if this route is still needed. The forwarding node caches the source route in a packet it forwards for possible future use [7].

3.3 Dynamic Manet On-Demand (DYMO)

The Dynamic MANET On-demand (DYMO) routing protocol is a multihop, unicast reactive routing protocol which is intended for used by mobile nodes in wireless multihop networks. In this Routing Message (Control Packet) is generated only when the node receives a data packet and it does not have any routing information. The basic operation of DYMO protocol is route discovery and route management. The DYMO is a memory concerned routing protocol and stores minimal routing information and so the Control Packets is generated when a node receives the data packet and it doesn't have any valid route information. The protocol consists of two phases: Route Discovery and Route Maintenance [7].

a) Route Discovery

The source router generates Route Request (RREQ) messages and floods them for destination routers for whom it doesn't have route information. Intermediate nodes store a route to the originating router by adding it into its routing table during this dissemination process. The objective node after receiving the RREQ responds by sending Route Reply (RREP) message. RREP is sent by unicast technique towards the source. An intermediate node that receives the RREP creates a route to the target and so finally it reaches to originator. Then routes are established between source node and destination node in both directions [12].

b) Route Maintenance

Route maintenance consists of two operations. It avoids expiring good routes and so it updates reverse route lifetime on data reception and forward route lifetime on data transmission. The DYMO nodes monitors link over which traffic is flowing in order to handle up with dynamic network topology. A Route Error (RERR) message is generated when a node receives a data packet for the destination for which route is not known or the route is broken. This RERR notifies other nodes about the link failure. The source node reinitiate route discovery quickly as it receives this RERR. Hello messages are used by all nodes to maintain routes to its neighbor nodes. The sequence numbers are used in DYMO to make it loop free. The DYMO routing protocol is designed for memory constrained devices in mobile ad hoc networks (MANETs) as it quickly determines route information dynamically [9] [14].

4. SIMULATION SETUP

The Qualnet 5.0 simulator is used for the analysis. Qualnet is a network modeling tool, which is used to model wired and wireless network. It uses simulation and emulation to predict the behavior and performance of the networks to improve the design, operation and management. The animated simulation is shown in fig. 2.

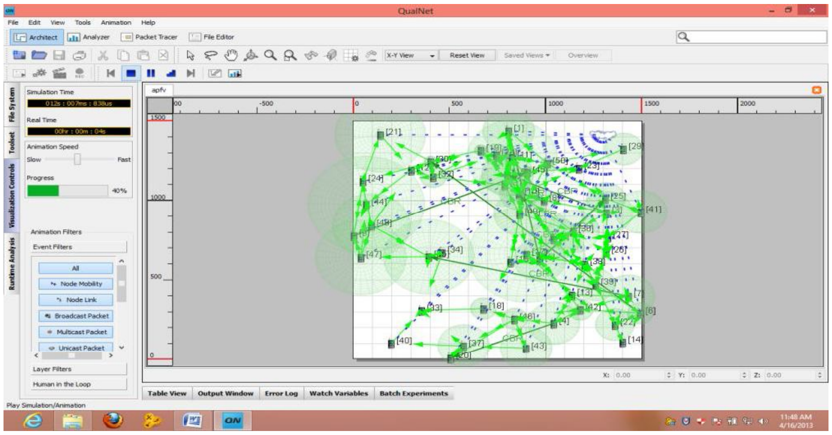

Figure 2. The animation simulation of AODV with 50 nodes with CBR

The IEEE 802.11 for wireless LANs is used as the MAC layer protocol. In the scenario UDP (User Datagram Protocol) connection is used and over it data traffic of Constant bit rate (CBR) is applied between source and destination. The 50 nodes are placed randomly over the region of 1500mx1500m.

Table 2. Scenario parameter.

Routing protocols	AODV, DSR, DYMO
Radio type	802.11b
No. of channels	1
Channel frequency	2.4 GHz
Mobility	Stationary
Path loss model	Two way
Energy model	Mica Motes
Shadowing model	Constant
Pause time	30 s
Simulation time	300 s
Battery model	Linear Model

Simulation area	1500 × 1500
Number of nodes	50
Packet size	512 bytes
Mobility model	Random waypoint model with no pause time
Simulation Environment model	a) Network model b) Channel model c) Mobility model d) Traffic model

The mobility model uses the random waypoint model in a rectangular field. The multiple CBR application are applied over 8 different source nodes (1-5, 2-10, 3-15, 4-20, 5-25, 6-30, 7-35, 9-45) source and destinations nodes respectively. The data traffic load is varied as 1, 5, 10 packets per sec to analyze the performance of AODV, DSR and DYMO routing protocols. The simulations parameters are shown in table 3.

Table 3. Performance matrices.

Packet delivery ratio	The (PDR) is defined as the ratio between the numbers of data packets received by the destination to the number of data packets sent by the source [8].
End-to-end delay	The average end-to-end specifies the packet is transmitting from source to destination and calculates the difference between send times and received times. Delays due to route discovery, queuing, propagation and transfer time are included in the delay metric.
Throughput	Throughput is the Average rate of successful data packets received at destination over a communication channel. It is usually measured in bits per second (bit/s or bps), and sometimes in data packets per second.
Control packet overhead	The number of controlled transmissions performed by the protocols per successfully delivered data packet. Then power consumed in control packet overhearing mode is: Pover = PR Where Pover is power consumed in Overhearing Mode and PR is power consumed in Reception Mode [8].
Energy Consumed in Transmit mode	A node is said to be in transmission mode when it sends data packet to other nodes in network. These nodes require energy to transmit data packet, such energy is called Transmission Energy (Tx), of that nodes. Transmission energy is depended on size of data packet (in Bits), means when the size of a data packet is increased the required transmission energy is also increased. The transmission energy can be formulated as: Tx = (330*Plength)/2*106 or PT= Tx / Tt Where Tx is transmission Energy, PT is Transmission Power, T t is time taken to transmit data packet and Plength is length of data packet in Bits [8].
Energy Consumed in Receive Mode	When a node receives a data packet from other nodes then it said to be in Reception Mode and the energy taken to receive packet is called Reception Energy (Rx), . Then Reception Energy can be given as: Rx = (230* Plength)/2*10 6 Or PR = R x / Tr Where Rx is a Reception Energy, PR is a Reception Power, Tr is a time taken to receive data packet, and Plength is length of data packet in Bits.

Energy Consumed in Idle Mode and	The node is neither transmitting nor receiving any data packets. But this mode consumes power because the nodes have to listen to the wireless medium continuously in order to detect a packet that it should receive, so that the node can then switch into receive mode from idle mode. PI= PR Where PI is power consumed in Idle Mode and PR is power consumed in Reception Mode [9].
Routing Power	This is the power at which a node has transmitted the packet to neighbor. Routing Power (RP) = (Throughput / Avg. End-to-End Delay) [8].

5. RESULT & DISCUSSION

The Qualnet 5.0.1 network simulator is used to analyze the parametric performance of Dynamic Source Routing (DSR), Ad Hoc On-Demand Distance-Vector Protocol (AODV) and DYMO. The animation of broadcasting, nodes mobility and transmission of data is shown in figure 1. The performance is analyzed with varying traffic load. In this analysis thirteen different CBR traffic as described in simulation setup is applied on separate source to destination nodes. The results are shown in figures from 3 to 6 [17].

We evaluated:

1) Average Jitter:

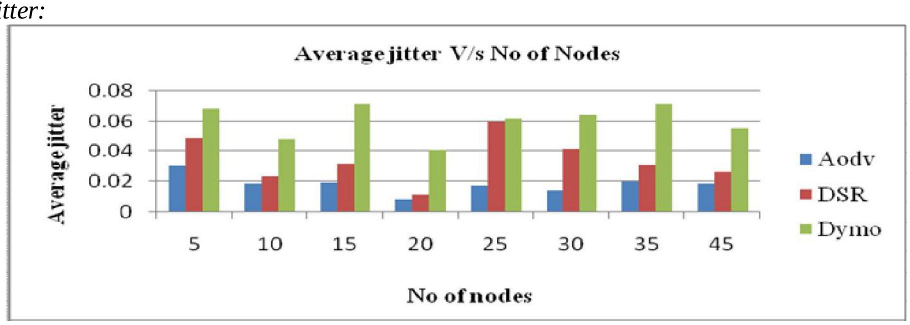

Figure 3. Improved performance comparison of AODV, DSR and DYMO protocols with respect to average jitter with varying no. of nodes in Application Layer.

2) Average End-to-end delay:

In case of AODV, the increasing total average End-to-End delay is 0.06961308, in the case of DSR the Average End-to-End delay is 0.09695472 and in the case of DYMO the Average End-to-End delay is 0.19853857.

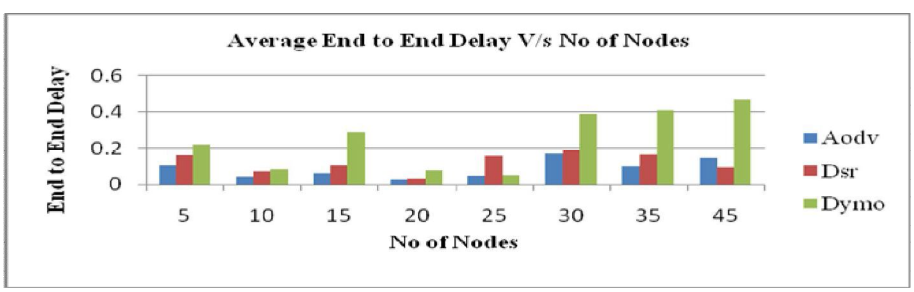

Figure 4. Improved performance comparison of AODV, DSR and DYMO protocols with respect to average end to end delay with varying no. of nodes in Application Layer.

3) Throughput:
As a network size varies from 10, 15 and nodes slightly change in throughput of AODV and DSR, DYMO protocol having lowest throughput.

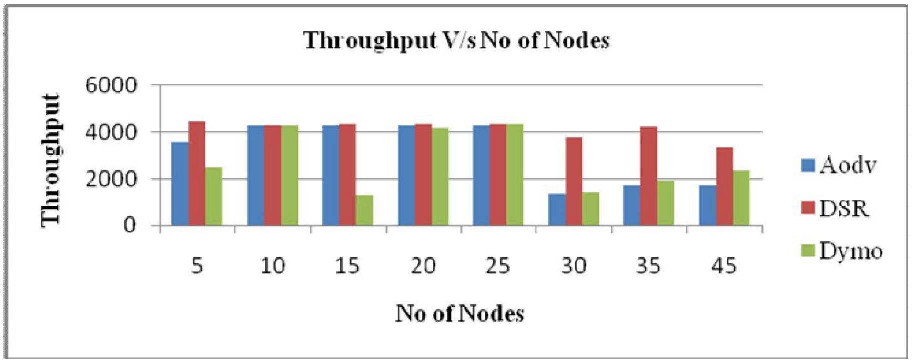

Figure 5. Improved performance comparison of AODV, DSR and DYMO protocols with respect to throughput with varying no. of nodes in Application Layer.

4) Energy consumed in transmit mode:

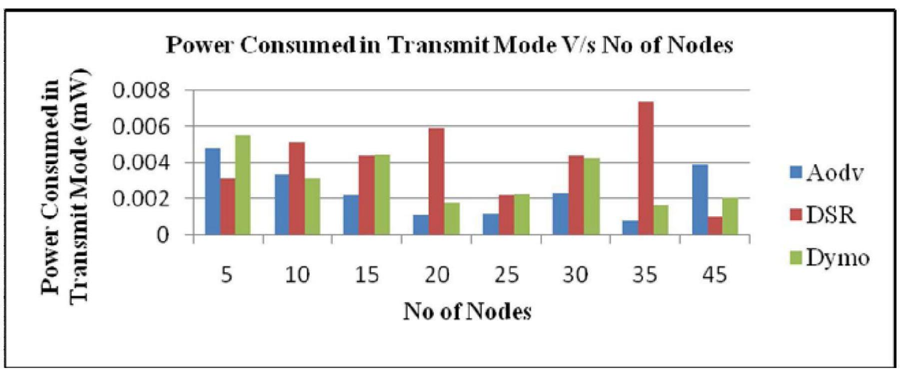

Figure 6: Power control comparison of AODV, DSR and DYMO protocols with respect to Energy Consumed in Transmit mode in Physical Layer

It is observed that energy average consumed by DYMO protocol is maximum, DSR is minimum and AODV protocol consumes medium energy when compared to DYMO and DSR. From the figure it is observed that the variance in energy consumed by DYMO protocol in Transmit mode is 0.007685, as the network size changes from 5 nodes to 45 nodes. In the case of DSR it is 0.0040124 and in the case of AODV it is 0.0043009. When considering the energy consumed in Transmit mode DYMO is consumed more and DSR consumes very less in Transmit mode but in the case of AODV, it is consumes in between AODV and DSR.

5) Energy consumed in receive mode:

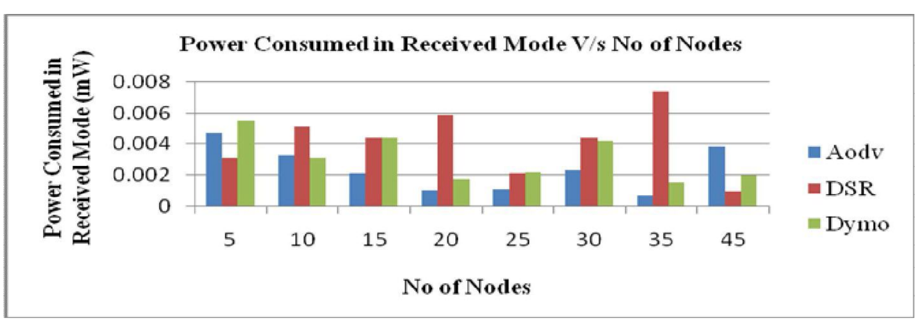

Figure 7: Power control comparison of AODV, DSR and DYMO protocols with respect to Energy Consumed in Transmit mode in Physical Layer

It is observed that energy consumed by DYMO protocol is maximum AODV is minimum and DSR protocol consumes medium energy then compare to AODV and DYMO. From the figure it is observed that the variance in energy consumed by AODV protocol in Receive mode is 0.0086194, as the network size changes from 5 nodes to 45 nodes. In the case of DSR it is 0.0120079 and in the case of DYMO it is 0.023969. When we are considering the energy consumed in Receive mode DYMO is consumed more and AODV consumes very less in receive mode but in the case of DSR, it is consumed in between AODV and DYMO.

6) Energy consumed in idle mode:

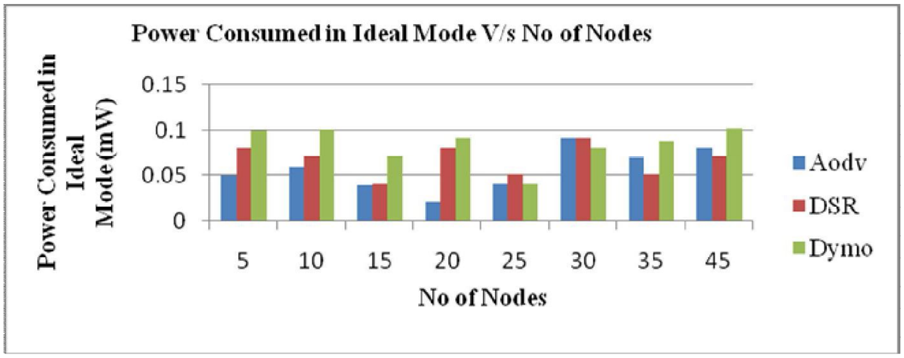

Figure 8: Power control comparison of AODV, DSR and DYMO protocols with respect to Energy Consumed in ideal mode in Physical Layer

It is observed that average energy consumed by DYMO protocol is maximum AODV is minimum and DSR protocol consumes medium energy in idle mode when compared to AODV and DSR. From the figure it is observed that the difference in energy consumed by AODV protocol in idle mode is 0.04554277, as the network size changes from 5 nodes to 45 nodes. In the case of DSR it is 0.0539819 and in the case of DYMO it is 0.0675151. When we are considering the energy consumed in idle mode DYMO consumed more and AODVR consumes very less in idle mode but in the case of DSR, it is consumes in between AODV and DYMO.

6. Conclusion and Future Scope

The decisive aim of a routing protocol to design is to extend the lifetime of the network by keeping the sensors alive for a maximum time. Since power depleted on transmission is very high compared to that of sensing, the routing algorithm should be implemented to reduce energy consumption while transmitting data. We observed that increasing numbers of nodes also increase power consumption due to routing control packets as well as increasing number of nodes. We can reduce the power consumption by reducing the number of routing control packets to increase the life time of network.

It is observed that AODV outperforms both of the DSR and DYMO routing protocols in terms of the packet delivery ratio as it uses fresh routes and DYMO performs poorer because of aggressive use of cache. The throughput is best in case of the AODV as it avoids good routes and outperforms both DSR and DYMO. It is also performs better with heavy load. The poor performance of DYMO is also attributed to absence of proper mechanism to expire the stale routes and therefore the jitter and the average end-to-end delay is also very high in comparison to AODV and DSR. The dropped packets due to no routes and error replies are more in case of DYMO as routes breakages are more than both AODV and DSR due to route maintenance and mobility. It is found that the Packet deliver is better in case of AODV with increased traffic load and mobility. In future we will try to minimize the energy consumed by MANETS in different modes of operations by developing an algorithm for reducing the number of routing control packets.

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AUTHOR’S

DharamVir received the M.Tech Degree form MDU Rothak (Haryana) and B.E Degree in Electronics and Communication Engg.from Jamia Millia Islamia, Central University, New Delhi 2008, 2004 respectively. He started his carrier as R&D Engineer in the field of computers and networking, since 1992, he is the part of YMCA University of Science & Technology as Head of Section (Electronics & Inst. Control) in the Department of Electronics Engineering. He is pursuing Ph.D in the field of Power aware routing in Mobile Ad hoc Networks. He has more than 20 publications in journals and conference of repute presently he is working in the field of performance improvement in MANET routing (Power aware routing protocol).

Dr. S.K. Agarwal received the M.Tech Degree from Delhi Technical University.New Delhi and PhD degree in Electronics Engg. From Jamia Millia Islamia, Central University, New Delhi in 1998 and 2008, respectively,since 1990. He has been part of YMCA University of Science & Technology Faridabad (Haryana), as Dean and Chairman in Department of Electronics Engineering. He has more than 40 publications in journals and national/international conferences of repute. His current research interests are in the field of Control System, electronics and biosensors, Analog Electronics, wireless communication and digital circuits.

Dr. Sayed Akthar Imam received the B.E Engg. degree (Electrical Engg) from Jamia Millia Islamia, M. Tech (Instrumentation & Control System) from AMU, Aligarh and PhD degree in Electronics & Comm. Engg from Jamia Millia Islamia (a Central University), New Delhi, in 1990, 1998, and 2008, respectively. Since 1990, he has been part of Jamia Millia Islamia University, where he is Assistant Professor in the Department of Electronics and Communication Engineering. He has more than 110 publications in journals and national/international conferences of repute. His current research interests are in the field of sensing technologies, wireless sensor networks, ad hoc networks, Electronic and Bio-instrumentation, Digital Signal Processing.