# Performance Study on Multicast Routing Protocols for Scalable Wireless Sensor Networks

Manikandan, H[1], Narasimhan, D[2]
[1]Department of CSE, Srinivasa Ramanujan Centre, SASTRA University, India,
[2]Department of Mathematics, Srinivasa Ramanujan Centre, SASTRA University, India,
[1]manikandan.h@src.sastra.edu, [2]narasimhan@src.sastra.edu

**Abstract—Multicast protocols are used to transfer the messages with a selected group of devices. Multicast is an effective method to maintenance group communication and decrease communicating energy. Multicasting can efficiently support a wide variety of applications. It is challenging to design a separate multicast routing protocol for sensor networks. The multicast routing protocols are fall under these three categories. Mesh based routing protocols, Tree based routing protocols and Hierarchical routing protocols. The ODMRP and MAODV protocols are effective multicast routing Protocols in MANETs. Here we analyse the performance based on some important matrices of the two multicast routing protocols ODMRP (On-Demand Multicast Routing Protocol) and MAODV (Multi-cast Ad-hoc On-demand Distance Vector) protocols for Wireless sensor networks. This paper presents the performance analysis of these two protocols with various performance measures with respect to Energy efficiency, scalability and reliability.**

**Keywords-** MAODV, Multicast Routing, ODMRP, WSN

## I. INTRODUCTION

In recent years, lots of work has been proposed into the research of routing protocols in WSN, due to the various constraints of sensor nodes and the limited life time of the devices. Sensor Nodes have appeared as a capable to sense and monitor the activities of real world parameters such as heat, humidity, weather and so on. The Basic thinking behind WSNs is that, the capability of the node is limited, the cumulative energy of the entire network is enough for the required the application. In various applications the positioning of sensor devices is achieved in an ad hoc fashion. Once positioned, the small devices must be able to organize themselves into radio communication network. A distributed WSN often consists of numbers of such nodes. In WSN, there will be dynamic changes, including nodes injection, nodes leaving from one network to other, nodes movements and changes of wireless channel conditions are the challenges. The sensor networks can be used in different application areas like Disaster relief, Military surveillance, Habitat Monitoring, personal health care systems, Home Networks, Agriculture, Space exploration, Radiological, Weather Monitoring etc. In some specific applications the most energy-efficient way is to use multicast transmission to suppress the duplicate transmission of same data packets.

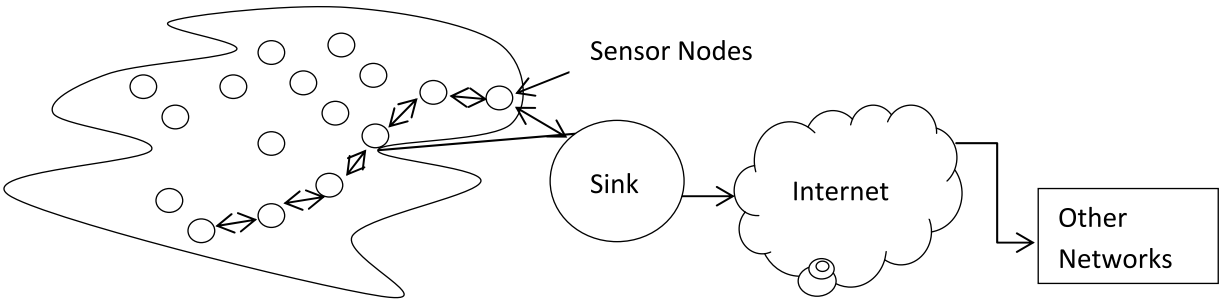


Fig 1. Architecture of WSN

The main purpose of a sensor device is to sense and collect data from a certain domain, process the data and transmit it to the sink. Due to the limited capabilities of sensors, the communication with the sink could be initially perceived without a routing protocol. Multicasting is the transmission of packets to a group of nodes identified by a single destination address. It is intended for group oriented communication. Multicasting reduces the transmitting costs that send the same data packets to multiple sinks. It minimizes the bandwidth consumption, router processing and delivery delay. The Tree-based multicast routing ensures fast and efficient communications over the nodes. Whereas the Mesh based protocols established multiple paths between source and sinks and provide effective mobility support and robustness.

## II. RELATED WORK

The multicast routing performs energy-efficient and scalable routing in sensor networks. In a structured architecture the nodes organize themselves into groups and each group has a leader. The less energy constrained nodes acts as the leader and process, and forward the packets towards the sink. Abid Ali Minhas, Fazl-e-Hadi, Danish Sattar, KashifMustaq and S. Ali Rizvi projected the comparison of various routing protocols in perspective of energy efficiency. They compare tree based protocols and cluster based protocols [1].Weiliang Li and Jianjun Hao proposed to improve the throughput of the network and reduce the control overhead by using Tree-based multicast routing protocols in Ad-hoc Networks [2]. In WSN the multicast communication only between the sensor devices and several sinks (distributed management). Here some of the existing multicast routing protocols of Ad hoc network have been considered. When network load increased, MAODV ensures network performance and improves protocol robustness. Its PDR was found to be active with condensed latency and network control overhead. E.M Belding-Royer and C E Perkins, anticipated about the on-demand distance vector routing protocol in Multicast operation of the ad-hoc [4]. On Demand Multicast Routing Protocol (ODMRP) is a multicast routing protocol designed for ad hoc networks with dynamic moving hosts [5] was projected by J.G Jetcheva, D.B. Johnson. All these dissimilarities may cause changes of the links between any two stations, and then result in topological structure dynamic moving. Each distinct node must have the capacity to perform dynamically examining and rerouting in order to forward message [6].For WSN, Juan A. Sanchez et al. projected GMR [8], a geographic multicast routing protocol. GMR proposes cost-based neighbor selection; it allows finding the efficiency of packet delivery and optimization of the tree. It is a localized algorithm. Chen Y [10] fabricated multicast tree based on the concept of spiral tree, and then considered multicast routing with redundant route. This algorithm is quite dense which needs choosing the direct path with the most branch nodes. Qingfeng Huang et al. [11] held the idea that messages are constrained by space and time, so place forward MobiCast protocol, which allows messages perform only drowning in effective region and implement Just-in-time delivery. Although the way of limited flooding is easy, there are some problems in resource and bandwidth consumption.

### *A. Characteristics of Wireless Sensor Networks*

Wireless Sensor Networks (WSN) is considered by connectivity through a collection of too small sized and minimum battery life sensor nodes with changing topology. The sensor nodes have capability of sensing various types of physical and environmental circumstances, data transferring, and wireless communication. The sensor network is composed of a significant number of nodes deployed in a wide area in which not all nodes are straight connected. Then, the data exchange is supported by multi hop communications. Routing protocols are in charge of discovering and maintaining the routes in the network. Variety of sensing proficiencies results in profusion of application extents. WSN require more effective methods for data forwarding and processing. The sensor node has the following distinctive characteristics.

- Communication Capabilities: Sensor nodes data transmission bandwidth is narrow and changeful and the distances between the nodes are only few hundred meters. These nodes are easily affected by the natural environment hazards. So, the hardware and software of these nodes must be robust and provide fault-tolerant capability.
- Dynamic topology: The devices will exit from the WSN because of low battery power and other failures. Some nodes be removed or new nodes are added into the network frequently. These will bring about changes in the topology. So the network must have the functionalities of reconfiguration, self-healing and dynamic.
- Node Deployment: Sensor nodes are densely deployed and support for scalability. Sensor nodes are deployed based on the application and it affects the performance of routing protocol. The nodes are placed either deterministic or self-organizing.
- Power Considerations: The nodes are battery powered and tiny sized. The process of routing the packets is severely influenced by energy concerns. The multi-hop routing introduces significant overhead in routing.

### *B. Classification of Routing Protocols Based on Topology*

Classification of Multicast routing protocols for MANETs is based on how the paths can be constructed among group members. Based on this the routing protocols are divided into tree based and mesh-based routing protocols and Hybrid routing protocols. These protocols can also be applicable for the sensor networks, because some of the WSN applications need multicast communication with changing topology.

*1) ODMRP (On demand Multicast Routing Protocol):* ODMRP protocol is based on Mesh topology, and also the first cluster-based routing protocol proposed in WSN. This protocol is also support unicast capability. The ODMRP uses the concept of forwarding packets to a group [6]. In this protocol, group membership and multicast routes are recognized and restructured by the source on demand. There are four phases in ODMRP Protocol. a) Multicast Route Establishment b) Route Construction (c) Route Maintenance and (d) Data Forwarding. In Route establishment, the JOIN_REQUEST packets are broad casted by the source to the entire network periodically. When a node receives the JOIN_REQUEST packets it stores the node ID and re broadcast the packets. If the packet received by the receiver, it updates its source entry in its table. The JOIN_TABLEs are advertised periodically to its neighbors. The JOIN_TABLE request is then propagated by each forwarding group member until it influences the source through the shortest path. This process creates forwarding group. In Route Construction and Maintenance, the source can directed packets to destination through selected routes and forwarding groups. Periodic control packets are broadcasted only when withdrawing data packets are still present. The receiving node verifies the received data packets. If it is not a duplicate and set the flag for the multicast group has not terminated and then only the packets are forwarded. It minimizes traffic overhead. After the construction of route, the source can sent packets to receivers through the selected route. Control packets are transmitted only when outgoing data packets are still present.

The ODMRP have the following advantages.

- Low Channel Overhead
- Robustness
- Exploitation of the broadcast nature of wireless environments
- Scalability to huge number of devices

When multicast sources have data to send, but do not have routing or membership information, they flood a JOIN DATA packet. When a node wants to send information to some other node in multicast network, it must initiate some steps to find the most right path between itself and the target node. It does so by flooding the network with RREQ packets. Initially the source node sends these RREQ packets to its direct neighbours. The neighbouring node receives the RREQ packet and checks and replies back with RREQ packet if it has a path available to the destination node. If, however, it does not have the path, it simply forwards the received RREQ packets to its neighbours. In this way the whole of the network is flooded with these RREQ packets. Due to this flooding of RREQ packets, a lot of network resources are used up in path finding only. This result causes congestion in the networks. Another problem arises due to multiple transmissions of various RREQ and RREP packets over the network. It becomes difficult to handle such a large number of packets and hence some packets are dropped. This creates problem in route discovery which increases the route discovery time and consequently, reduces the efficiency of the networks.

*2) MAODV (Multicast Ad hoc On Demand Vector) Protocol:* MAODV protocol is the multicast revision of AODV protocol. This protocol is based on tree structure, which is shared by sources and receivers for a given multicast group. In this protocol the group sequence number is retained by the root node of the tree. This is also used to elect the leader node [1]. A broadcast route discovery mechanism is engaged by MAODV to discover several paths. Every time if a node requests to join a group ROUTE_REQUEST message is broadcasted. Later, a member node or leader will respond to this request with a ROUTE_REPLY message. The multicast route is established with the latest sequence number. If source node receives duplicate reply messages, whereas route is decided based on the minimum hop count, if the sequence numbers are same. It broadcast the Hello messages to maintain link connectivity. This routing protocol creates a shared multicast tree, which links all the group members. It also helps the group members to get joined to the multicast tree through the forwarding nodes. Member nodes can join or leave the group at several times. One of the member node acts as a leader. It initiates a route request at first and initializes the group sequence to one. This node is responsible for maintaining the multicast sequence number. At regular intervals it broadcasts Hello messages across the network to maintain the multicast sequence number. The freshness of the network can be check by the latest sequence number. Older sequence numbers are removed from the table entry. All the packets pass the sequence numbers. The advantage of the protocol is to maintain routing information, one entry per destination can be made in the routing tables. MAODV depend on routing table entries to propagate a ROUTE_REPLY back to the source and to the destination. In this routing protocol, each node maintains at least one route per destination and, the destination replies only once to the first arriving request during a route discovery. If the single route fails, it initiates new route discovery mechanism. When frequent changes in topology the route discovery needs to be initiated over and over again. It induces more flooding of the packets and causes significant latency and overhead.

## III.SCALABLE ENERGY EFFICIENT MULTICAST ROUTING IN WSN

The performance of the sensor devices are related with communications (sending and receiving data), employ considerable energy than data processing and memory management. One of the main concerns in WSN is to maximize the life time of the sensor nodes, that the routing algorithm could save more energy as possible in the network. If you are increases the number of nodes in the deployment the appropriate routing protocol must reduce considerable energy consumption. The important issue in designing energy-efficient multicast routing protocols is the energy constraints, due to the limited battery powered tiny sensor nodes. Most multicast routing protocols, the members and non-members must maintain the multicast states to broadcast the packets. These protocols must have the fault tolerance capability, if there is any link failure. The protocols issue control messages to correct the link failures.

*A. Calculation of Persisted Energy*

The sending station has the following four states. Sleep, idle, receive and transmit. Once the group generated, the broadcasting nodes will handover to active state, but the non-broadcasting nodes handover to sleep state. Active state performs communication with other nodes. The persisted energy can be calculated as,

$$
\begin{aligned}
E_{pm} &= E_{in} - (E_s+E_r+E_t) \\
&= E_{in} - (W_sT_s+W_rT_r+W_tT_t) \\
&= E_{in} - (W_s\,(L_s/R) + W_r\,(L_r/R) + W_tT_t)
\end{aligned}
$$

Where $E_{in}$ is the initial energy of a sensor node, $E_s$, $E_r$ and $E_t$ represents transmission power depletion in idle state. $W_sT_s$, $W_rT_r$ and $W_tT_t$ represents power in watts of transmission. $T_s$ exemplify sending time, which equivalents to the length of the packet. $L_s$ divided by the data transfer rate R. Likewise $T_r$ is the packet receiving time which equals to the length of the received packet $L_r$ divided by the data transfer rate R and $T_t$ is the idel time.

## IV.SIMULATION SETUP

To analyse the performance, we ran simulations using NS2 with the extension of sensor nodes. The simulation of ODMRP and AODV Multicast routing protocols consists of 50 sensor nodes moving in a 1000m X 1000 m simulation area for 600 seconds of simulated time. NS2 now has become one of the first selected software to implement network simulation in the academic field [10].

*A. Modeling for Wireless Sensor Network and Multicast Protocol*

ODMRP protocol is based on Mesh topology, and also the first cluster-based routing protocol proposed in WSN. In this simulation model 50 nodes are distributed randomly in a simulation area and the source and the destination are randomly selected in these nodes. The transmission distance of each transceiver is 100m, simulation time is 600s. Multicast Source traffic is CBR (constant bit rate), the packet arriving interval is 1s, and packet size is 512 bytes. Set all nodes belong to one multicast group, consider static scenario and mobile scenario.

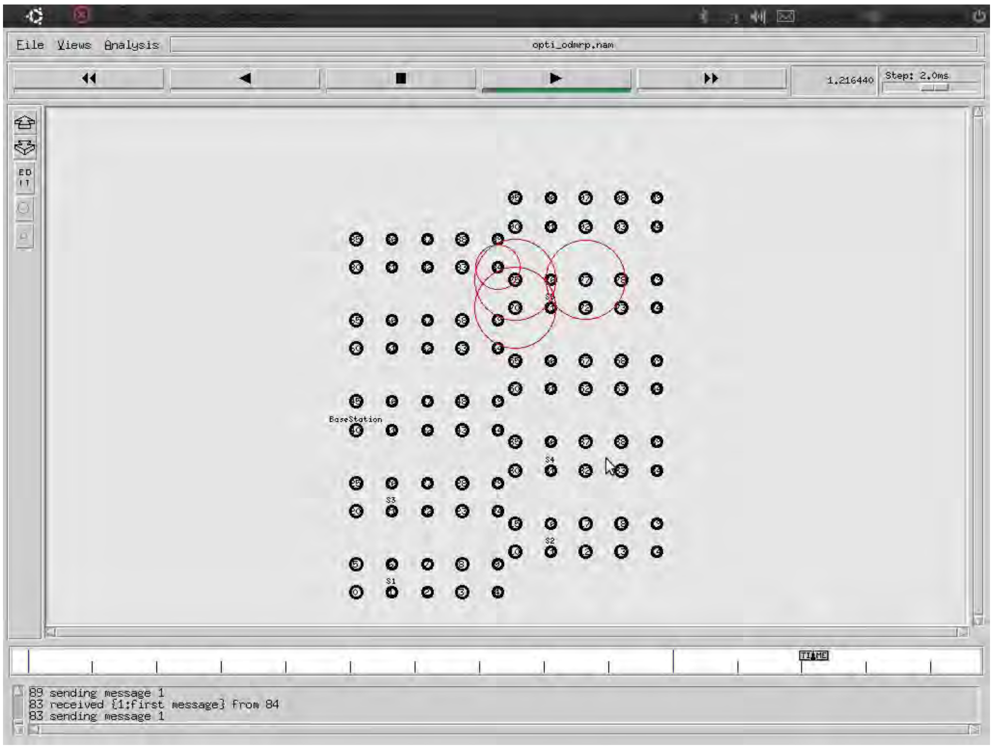


Fig.2 Simulation Model Environment for ODMRP with 100 nodes

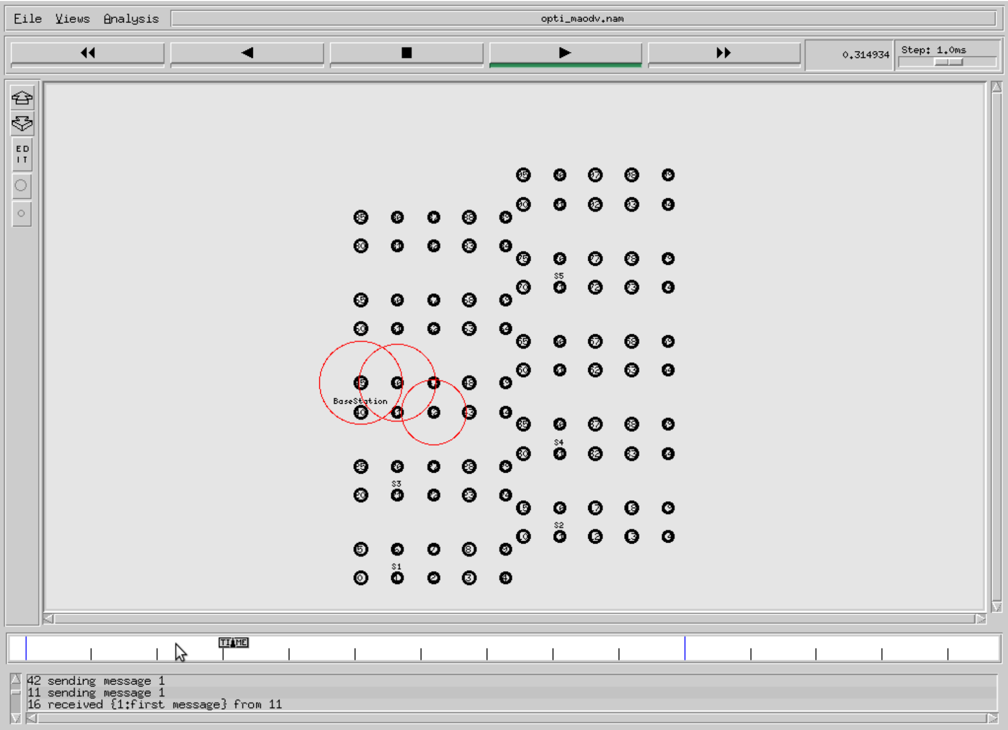


Fig.3. Simulation Model Environment for MAODV with 100 Nodes

*B. Establishment of Simulation Model*

a) Establishment of Simulation Environment 100 nodes are randomly scattered on 100m×100m area. The range of area is horizontal coordinate x (0~100), longitudinal coordinate y (0~100), coordinates of base station are BS (50， 175) as showed in the above figures.

b) Simulation Parameters Setting Table I. shows the initial values of related parameters setting according to the simulation requirements.

TABLE I
Network Parameters in Experiment

| **Parameters** | **Value** |
|---|---|
| number of sensor nodes (including base station nodes） | 100 |
| optimal number of cluster heads | 5 |
| initial energy of node | 2J |
| Mobility Model | Random Way Point |
| wireless communication line bandwidth | 1Mbps |
| time of each round | 20s |
| distribution area of nodes | 1000m×1000m |
| network monitor area | 000m×1000m |
| size of packet header | 32Bytes |
| data size of packet | 500Bytes |
| simulation time | 2000s |
| Routing Protocol | ODMRP & MAODV |

*C. Performance Metrics*

In order to evaluate the performance of Multicast routing protocols both ODMRP and MAODV were run and compared under identical mobility patterns and traffic scenarios. We used to compare the Adversarial Environment with varying number of nodes. We used the field of 50 nodes distributed a 1000m X 1000m area in random way point model and ran simulations with multiple sinks. The Sinks were selected randomly. We evaluate four metrics to compare the routing protocols with multicasting under trusted environment where all the nodes in the network are assumed to be gentle. The mobility model of nodes is random-waypoint. Changing the number of multicast receivers and mobility speed, we analyze the performance of the protocols with the following metrics.

1) *Typical packet transfer ratio:* This is the ratio of the packets generated by the sources that are reached to the destination.
2) *Typical routing load:* This is the ratio of overhead packets delivered. ODMRP has larger control overhead due to advertisement of the packets.
3) *Typical route procurement latency:* This is the average packet delay between the sources for discovering a route to a destination and the acknowledgement of the corresponding reply.
4) *Typical energy consumption:* The total energy consumption among the group members.
5) *Typical End-to-End Delay:* It is average time a packet takes for delivery to its destination after it was transmitted.
6) *Scalability:* The total number of sensor nodes in the network. Here radio transmission is the most energy-consuming operation.

The following graphs shows the output of the simulation results with the above performance metrics.

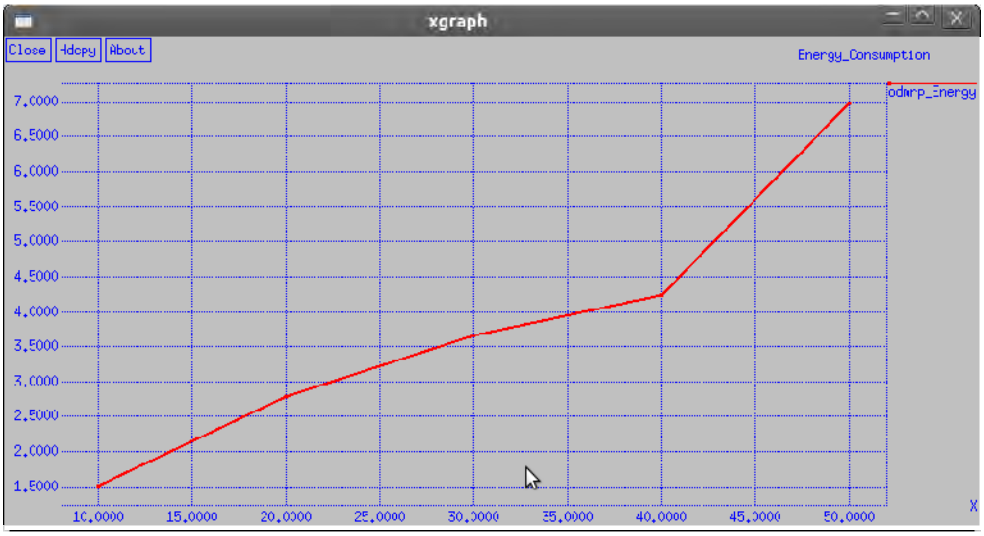


Fig 4. Average Energy Consumption

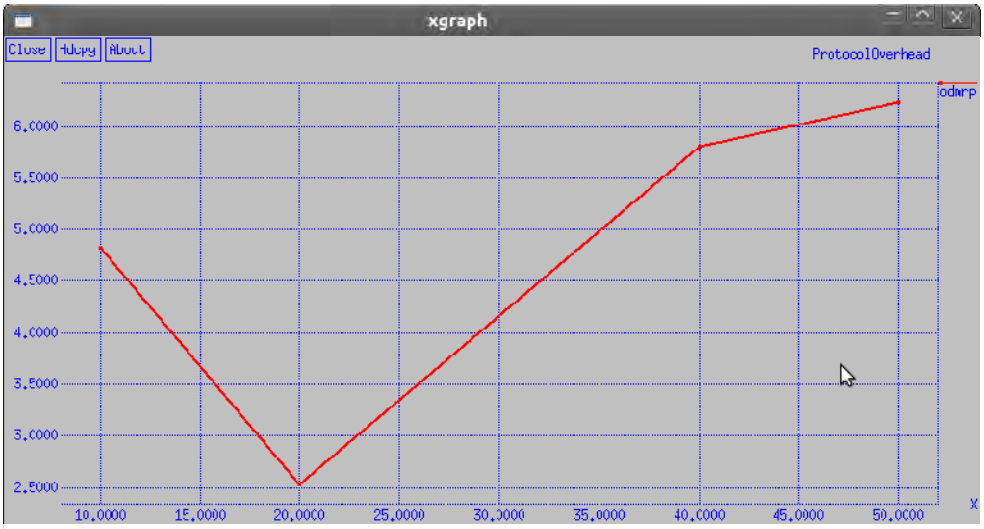


Fig 5. Routing Protocol Overhead

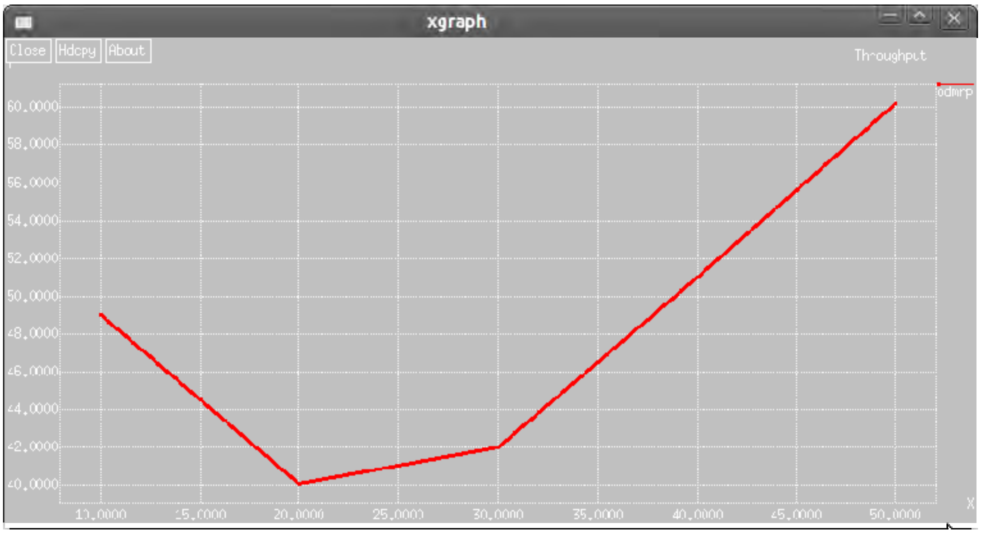


Fig 6. Average Throughput

## V.COMPARISON

We compare the multicast routing protocols for sensor networks discussed above with respect to some metrics we identified. The table shows the comparison of the multicast routing protocols ODMRP and MAODV.

Based on the analysis of the protocols we ensure that the features of ODMPRP and MAODV well suited for some of the applications of WSN. The desirable features of the protocols are,

- Dynamic Architecture
- Scalability
- Randomizing Path
- Better throughput for transfer and receive data

## VI.CONCLUSIONS

Sensor networks that are proficient of sensing numerous physical sensations will become ubiquitous in the proximate upcoming. Multicasting can well suitable for variety of WSN applications. On the other hand, sensor nodes will keep on resource poor when related to their MANET equivalents. Moreover, unlike MANETs, sensor networks are aimed, in general, for explicit applications. Hence, designing efficient routing protocols for sensor networks that garb sensor networks distribution in various applications are important. Performance of the multicast routing protocol ODMRP and MAODV in Wireless Sensor Networks was assessed in this paper. The following conclusions are perceived. Our results show the mesh-based protocols beat with tree based protocols, due to the presence of more alternative paths and less overhead.

## REFERENCES

[1] Abid Ali Minhas, Fazl-e-Hadi, Danish Sattar, KashifMustaq and S. Ali Rizvi “Energy Efficient Multicast Routing Protocols for Wireless Sensor Networks” IEEE 2011.
[2] Weiliang Li and Jianjun Hao “Research on the Improvement of Multicast Ad Hoc On-demand Distance Vector in MANETS” IEEE Vol.1 2010.
[3] C W Wu and Y C Tay, “AMRIS: A Multicast Protocol for Ad Hoc Wireless Networks”, In Proc. of the IEEE Military Communications Conference (MILCOM-99), Atlantic City, NJ, November 1999. 25–29.
[4] E M Belding-Royer and C E Perkins, “Multicast operation of the ad-hoc on-demand distance vector routing protocol”, In Proc. Of ACM/IEEE MOBICOM’99, Seattle, WA, August 1999. 207–218.
[5] J G Jetcheva, D B Johnson, “Adaptive Demand-Driven Multicast Routing in Multi-Hop Wireless Ad Hoc Networks”, In Proc. of ACM MobiHoc’01, Long Beach, CA, October, 2001. 33–44.
[6] Heng Liu, Yan-tao Liu, Ting Yan, “Making On-demand Multicast Routing Protocol Aware of Energy in Wireless Sensor Networks” In Proc of IEEE, 2008.
[7] M.Gerla et al., “On-demand multicast routing protocol (ODMRP) for ad hoc networks”. Internet draft, <draft-ietfmanet-odmrp-04.txt>, (2000)
[8] Juan A. Sanchez,Pedro M. Ruiz, and Ivan Stojmenovic, “GMR: Geographic Multicast Routing for Wireless Sensor Networks”, IEEE Sensor, Mesh, and Ad Hoc Communications and Networks SECON, Sept. 25-28, 2006, Reston, Virginia, USA.
[9] Chen Y. “Research on multicast routing protocols in sensor networks” [MS. Thesis]. Changsha: Hunan University, 2005.
[10] YU Bin, SUN Bin, WEN Nuan, etc.NS2 And Network Simulation [M].Beijing:Posts & Telecom Press,2007.4.