Universal Journal of Computer Science and Engineering Technology
1 (2), 105-111, Nov. 2010.

An Energy Aware WSN Geographic Routing Protocol

Adel Gaafar A.Elrahim[1], Hussein A.Elsayed[2], Salwa El Ramly[3], Magdy M. Ibrahim[4]
Electronics & Communication Eng. Dept
Ain Shams University
Cairo, Egypt
[1]adtelecom@yahoo.com, [2]helsayed2003@hotmail.com, [3]salwa_elramly@eng.asu.edu.eg, [4]magdy_ibrahim@yahoo.com

***Abstract*— Wireless Sensor Networks (WSNs) consist of small nodes with sensing, computation, and wireless communications capabilities. Many routing, power management, and data dissemination protocols have been specially designed for WSNs. The focus has been given to the routing protocols which might differ depending on the application and network architecture. In this paper, we propose an energy efficient data forwarding protocol called Energy Aware Geographic Routing Protocol (EAGRP) for wireless sensor networks to extend the life time of the network. In EAGRP, both position information and energy are available at nodes used to route packets from sources to destination. This will prolong the lifetime of the sensor nodes; hence the network life time and thus get higher packet delivery ratio and minimal compromise of energy efficiency. The proposed protocol is an efficient and energy conservative routing technique for multi-hop wireless sensor networks. The routing design of EAGRP is based on two parameters: location and energy levels of nodes. Each node knows the location and energy level of its neighbors. The performance measures have been analyzed with variable number of nodes. Our simulation results indicate that the proposed algorithm gives better performance in terms of higher packet delivery ratio, delay, and energy consumption.**

Keywords- Wireless Sensor Networks; Energy efficient; Position information; Routing protocol.

I. INTRODUCTION

Wireless sensor networks (WSNs) are being used in a wide variety of critical applications such as military and health-care applications. WSNs are deployed densely in a variety of physical environments for accurate monitoring. Therefore, order of receiving sensed events is important for correct interpretation and knowledge of what actually is happening in the area being monitored. Similarly, in intrusion detection applications (alarm application), response time is the critical performance metric. On detection of intrusion, alarm must be signaled within no time. There should be a mechanism at node for robust communication of high priority messages. This can be achieved by keeping nodes all the time powered up which makes nodes out of energy and degrades network life time [1]. Also, there can be a link or node failure that leads to reconfiguration of the network and re-computation of the routing paths, route selection in each communication pattern results in either message delay by choosing long routes or degrades network lifetime by choosing short routes resulting in depleted batteries [2].Therefore the solutions for such environments should have a mechanism to provide low latency, reliable and fault tolerant communication, quick reconfiguration and minimum consumption of energy. Routing protocols have a critical role in most of these activities.

Many routing protocols have been designed to address all of the above problems but each of them is more suitable in some situations (having better performance), while not suitable in other situations; having significant limitations. Therefore, it is critical to assess routing protocols for critical monitoring applications. Hence, to achieve efficient communication, it is required to identify the delivery demand for the communication and to choose a suitable routing protocol. To measure the suitability and performance of any given protocol, some metrics are required. On the basis of these metrics any protocol can be assessed against its performance [3].

Such networks, which are composed of sensor nodes with limited memory capacity, limited processing capabilities, and most importantly limited energy resources, require routing protocols that take into consideration these constraints. Routing protocols have a critical role in most of these activities. Location- based protocols are most commonly used in sensor networks as most of the routing protocols for sensor networks require location information for sensor nodes. In most cases location information is needed in order to calculate the distance between two particular nodes so that energy consumption can be estimated. Since, there is no addressing scheme for sensor networks like IP-addresses and they are spatially deployed on a region, location information can be utilized in routing data in an energy efficient way. Geographic routing that takes advantage of the location information of nodes, are very valuable for sensor networks [4].

Geographic routing algorithms for sensor network have been considered in this research work. For sensor networks, geographic routing is one of the approaches to energy efficiency among the routing algorithms [5, 6]. Geographic routing protocols work on the assumption that every node is aware of its own position in the network; via mechanisms like GPS or distributed localization schemes and that the physical topology of the network is a good approximation of the network connectivity. In other words, these routing protocols assume that if two nodes are physically close to each other, they would have radio connectivity between them, which is true in most cases. Hence the protocols use node location information to route packets from source to

Corresponding Author: Adel Gaafar A.Elrahim, Electronics & Communication Eng. Dept, Ain Shams University, Cairo, Egypt

destination. Every node having its location information is a fair assumption in most sensor networks since application data frequently needs to be annotated by location information [7, 8]. One big advantage of geographic routing schemes is the fact that there is no need to send out route requests or periodic connectivity updates. This can save a lot of protocol overhead and consequently, energy of the nodes. This is an important consideration for sensor networks where the network size could be on the order of thousands of nodes, but each node has extremely limited memory capacity to store routing tables.

The rest of this paper is organized as follows: Section II presents related work. Section III presents motivation and objectives of the proposed research. Section IV describes the proposed algorithm. Section V describes the details of simulation model. Simulation results and discussions are presented in section VI. Section VII concludes this paper.

II. RELATED WORK

Here we discuss four recently proposed routing protocols for reliable and efficient many to one routing in multi-hop WSNs. Geographic Adaptive Fidelity (GAF) [9] divides the network into a grids such that all nodes in one grid can talk to any other node in adjacent grids. Within a grid, only one node remains awake to help in routing packets, and this role is rotated over time. GAF utilizes the concept of routing equivalence within a grid, but the cost of achieving routing equivalence is that the grid sizes are smaller than a node radio range since communication must be possible among all nodes in adjacent grids. Thus this increases the number of hops that a route needs to take, which increases both the power consumption in the network, as well as the interference level.

Dynamic Source Routing (DSR) is a simple and efficient routing protocol designed specifically for use in multi-hop wireless sensor networks of mobile nodes. Using DSR, the network is completely self-organizing and self-configuring, requiring no existing network infrastructure or administration. Network nodes cooperate to forward packets for each other to allow communication over multiple “hops” between nodes not directly within wireless transmission range of one another. The key distinguishing feature of DSR is the use of source routing. That is, the sender knows the complete hop-by-hop route to the destination. These routes are stored in a route cache. The complete routing algorithm is described in [10, 11]. 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.

Ad Hoc on-Demand Distance Vector Routing Protocol (AODV) is an algorithm for the operation of wireless networks. Each node operates as a specialized router and routes are obtained as needed. AODV adopts a very different mechanism to maintain routing information. It uses traditional routing tables, one entry per destination. This is in contrast to DSR, which can maintain multiple route cache entries for each destination. An important feature of AODV is the maintenance of timer-based states in each node, regarding utilization of individual routing table entries. A routing table entry is expired if not used recently. A set of predecessor nodes is maintained for each routing table entry, indicating the set of neighboring nodes which use that entry to route data packets. The complete routing algorithm is described in [12, 13]. In all, DSR allows cache more paths from a source to a destination, while AODV just uses the path first discovered. Thus, DSR has significant greater amount of routing information than AODV. Meanwhile, DSR has access to many alternate routes which saves route discovery floods, the performance then will be better if they are actually in use [14].

Greedy Perimeter Stateless Routing (GPSR) [15] is one of the well-known geographic routing schemes that are proposed using perimeter or face routing to route around voids or obstacles when greedy forwarding fails. When a packet is stuck at a void or obstacle, face routing is used to route around dead-ends until nodes closer to the destination are found. Geographic Hash Tables (GHT) [16] was proposed specifically for sensor networks, and uses a geographic hash table system to store the key-value pair at the sensor node closest to the hash of the key.

III. MOTIVATION FOR CURRENT WORK

Many routing algorithms for WSNs have been developed but most of them do not take into consideration the limited energy resources for sensor nodes. This is a main drawback in most routing algorithms where they should choose the routes based on the energy available at nodes. This will prolong the lifetime of the sensor nodes and thus the network lifetime. The problem can be stated as follows: Develop an efficient power-aware routing algorithm for sensor networks that:

- Decreases the end-to-end delay
- Increases the network reliability
- Minimizes the power consumption during packet transmission and data processing
- Maximizes residual power of nodes and consequently extends the lifetime of the network

The algorithm should guarantee QoS while taking into consideration the limited power and energy supplies of nodes. As the lifetime of a node is strictly bounded to its battery capacity, the algorithm should wisely utilize nodes while preserving their energy.

Energy consumption is the most important factor to determine the life of a sensor network because usually sensor nodes are driven by battery and have very low energy resources. This makes energy optimization more complicated in sensor networks because it involves not only reduction of energy consumption but also prolonging the life of the network as much as possible. This can be done by having energy awareness in every aspect of design and operation. Due to energy constraints in WSNs, geographic routing has been a challenging issue for researchers. The nodes in the network cooperate in forwarding other nodes packets from source to destination. Hence, certain amount of energy of each node is spent in forwarding the messages of other nodes. Lots of work has been done in this respect but still energy depletion of sensor nodes is a big challenge in sensor networks. The performance of the routing protocol also has to scale with network size. The challenge is then to develop a routing protocol that can meet these conflicting requirements while minimizing compromise.

The aim of this paper is to address the problem of providing energy-efficient geographic routing for WSNs that guarantees QOS and at the same time minimizes energy consumption by calculating the remaining energy level of nodes. We propose a geographic routing protocol called EAGRP which takes into consideration both nodes location information and energy consumption for making routing decisions. EAGRP is simple, scalable as well as energy efficient.

IV. Algorithm Description of ENERGY AWARE GEOGRAPHIC ROUTING PROTOCOL(EAGRP)

In sensor networks, building efficient and scalable protocols is a very challenging task due to the limited resources and the high scale and dynamics. Geographic routing protocols require only local information and thus are very efficient in wireless networks. First, nodes need to know only the location information of their direct neighbors in order to forward packets. Second, such protocols conserve energy and bandwidth since discovery floods and state propagation are not required beyond a single hop. It is based on assumption that the node knows the geographical location of the destination node. This approach to routing involves relaying the message to one of its neighbors that is geographically closest to the destination node. A node that requires sending a message acquires the address of the destination. After preparing the message, it calculates the distance from itself to the destination. Next, it calculates distance from each of its neighbors to the destination. The greedy approach always tries to shorten the distance to be traveled to the destination to the maximum possible extent. Therefore, the node considers only those neighbors that are closer to the destination than itself. The sending node then chooses the node closest to the destination and relays the message onto the neighbor. A node receiving a message may either be the final destination, or it may be one of the intermediate nodes on the route to the destination. If the node is an intermediate hop to the message being relayed, the node will calculate the next hop of the message in the manner described above. Usually, in the greedy forwarding the closest neighbor node will be heavily utilized in routing and forwarding messages, while the other nodes are less utilized. Due to this uneven load distribution it results in heavily loaded nodes to discharge faster when compared to others. This causes few over-utilized nodes which fail and result in formation of holes in network, resulting in increase number of failed/dropped messages in the network. Energy efficient routing scheme should be investigated and developed such that its loads balances the network and prevents the formation of holes.

The distance between two points on the earth's surface calculated by using its latitude and longitude coordinates. Latitude is the angle above or below the equator in degrees. Meanwhile .longitude is the angle east or west of the Greenwich meridian. The concept used to find out distance between two points is similar to calculate a perimeter between two points on sphere. These are standard notation used throughout this paper.

DISTANCE = distance in meters between the first and the second points.

$DISTANCE_{LONG}$ = longitude distance in meters between the first and the second points.

$DISTANCE_{LAT}$ = latitude distance in meters between the first and the second points.

$LONG_1$ = longitude of the first point in degrees.

LAT_1 = latitude of the first point in degrees.

$LONG_2$ = longitude of the second point in degrees.

LAT_2 = latitude of the second point in degrees.

$DISTANCE_{LONG} = LONG_2 - LONG_1$

$DISTANCE_{LAT} = LAT_2 - LAT_1$

$$\text{DISTANCE}=\sqrt{\left(DISTANC_{LONG}\right)^2+\left(DISTANCE_{LAT}\right)^2} \quad (1)$$

For the simulations, a simple energy model has been used in which every node starts with the same initial energy and forwards a packet by consuming one unit of energy. Initially, all nodes have energy level equal to 1 joule .We let the size of a data transmission (including all headers) be L bits and the transmission rate of the sensor be B bps. The time t_{tx} (in sec) taken to transmit one data packet is:

$$t_{tx} = L / B \quad (2)$$

The received time, t_{rx} must be more than t_{tx}.In this study, we set t_{rx} to be the duration of two transmission periods. We denote the energy required in the receive state by E_{rx}, the energy required to transmit a data packet by E_{tx}, the energy of a fully charged node by E_t. We let the received and transmit power of the sensor be P_{rx} and P_{tx} respectively. Therefore, we have

$$E_{tx} = P_{tx} \times t_{tx} \quad (3)$$

$$E_{rx} = P_{rx} \times t_{rx} \quad (4)$$

$$E_t = E_{tx} + E_{rx} \quad (5)$$

The concept of neighbor classification based on node energy level and their distances used in Energy Aware Geographic Routing Protocol has been used to cater of the weak node problem. Some neighbors may be more favorable to choose than the others, not only based on distance, but also based on energy characteristics. It suggests that a neighbor selection scheme should avoid the weak nodes.

Therefore, the procedure used in the proposed (EAGRP) first calculates the average distance of all the neighbors of transmitting node and checks their energy levels. Finally, it selects the neighbor which is alive (i.e. having energy level above the set threshold) and having the maximum energy plus whose distance is equal to or less than the calculated average distance among its entire neighbors. Hence, the proposed scheme uses Energy Efficient routing to select the neighbor that has sufficient energy level and is closest to the destination for forwarding the query. Figure1 shows the flow chart of EAGRP algorithm. It starts and initializes the network by giving the input of number of nodes and establishes their links with the time delay between each link. Then it locates the location of each node and save it in table. Then it finds the all next hop neighbors of the sending node and calculated their average distance from the sending node. It selects the node among its next hop neighbors which having energy level above than the set threshold (0.027 joule) and make the decision. If no node among its neighbors it will drop the packet otherwise it will select the neighbor node whose distance is less than or equal to the calculated average distance plus having maximum energy level among those neighbors and transmit the packet to it by decreasing the transmitting energy of the sending node. The selected neighbor will receive the packet and this process will continue until the packet reaches to its destination and all other packets will follow the same procedure.

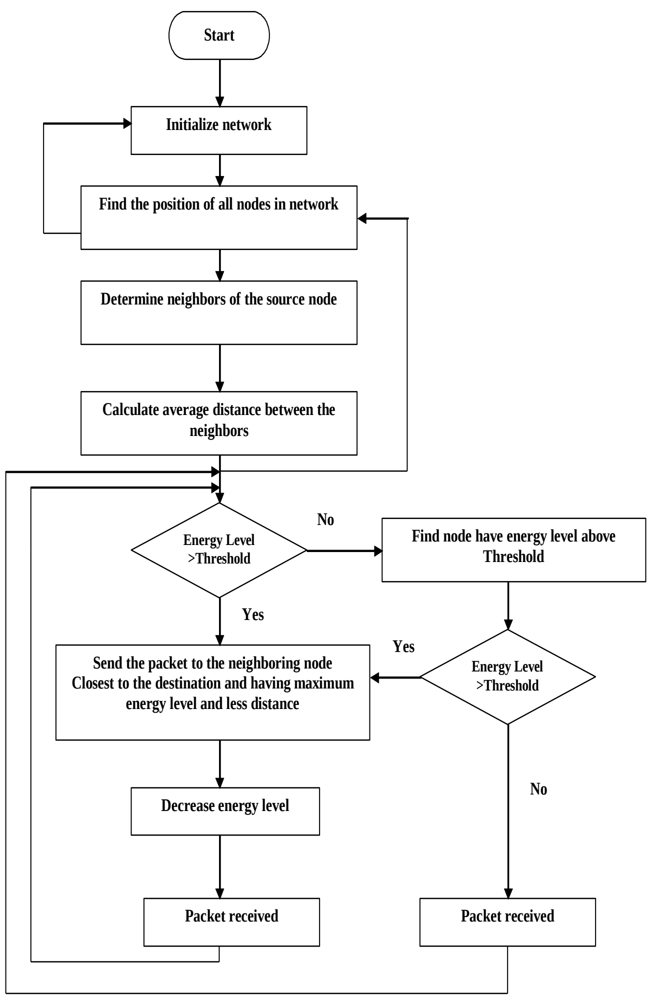

Figure 1. Flow chart for EAGRP

V. SIMULATION MODEL

1. Simulation Tool (OPNET)

In this section a comparative study between the behaviors of the three routing protocols: EAGRP, DSR, and AODV will be given by simulation of WSN chosen to represent application. The well known OPNET simulation tool is used. OPNET provides a comprehensive development environment for modeling and performance evaluation of communication networks and distributed systems. The package consists of a number of tools, each one focusing on particular aspects of the modeling task. These tools fall into three major categories that correspond to the three phases of modeling and simulation projects: Specification, Data Collection and Simulation and Analysis.

Different simulations results are presented with different number of nodes in order to check performance of the proposed algorithm. The goal of the study was to investigate the behavior of EAGRP, DSR and AODV for delay, packet delivery ratio, throughput, and energy consumption.

2. Simulation Setup

We designed WSN according to the application we selected for this study. WSN is made of static nodes representing data gathering applications. In the simulation, all nodes generated data packets that are routed to the destination node located in the centre of the WSN. We simulated network sizes from 25 to 100 nodes with 100% active source nodes. Random topology has been considered in this implementation. WSN was simulated in the presence of different factors having effect on routing protocols performance. We categorized our simulation on the basis of nodes type, scalability, and different number of source nodes.

Simulation time for each scenario was set to 500 seconds and repetitive simulations for each scenario were performed to verify the reliability of our results. The network was modeled on an area having dimension of 300 x 300 meters. The packet size is of 512 bytes, and the packet rate is 2 packets /sec.

All nodes in this network are considered as source nodes communicating with constant bit rate 1 Mbps. The numbers of nodes chosen are 25, 40, 50, 65, 75, 90 and 100 nodes. The input parameters used for all scenarios were the same as shown in table 1 except the number of nodes. The application type simulated was FTP. Initially, each node has same energy level (1Joule). Any node having energy less than or equal to a set threshold will be considered as dead, this was chosen to be in the simulations presented in this paper.

One node is located as the destination i.e. one node is declared as target node for all data receiving as was mentioned in the assumptions that many to one scenario has been considered. Figure 2 shows a sample network with 25 nodes.

3. Selected Performance Metrics for Evaluation

In order to check three protocols performance in terms of its effectiveness there are a number of metrics that can be used to compare between them. We used packet delivery ratio, end-to-end delay, energy consumption, and throughput for the evaluation. The metrics that we selected are defined as follow:

A. Packets Delivery Ratio

Measures the percentage of data packets generated by nodes that are successfully delivered, expressed as:

$$\frac{\text{Total number of data packets successfully delivered}}{\text{Total number of data packet sent}} \times 100\%$$

B. End-to-End Delay of Data Packets

There are possible delays caused by buffering during route discovery latency, queuing at the interface queue, retransmission delays at the MAC, and propagation and transfer times. This metric measure the average time it takes to route a data packet from the source node to the destination node.

The lower the end-to-end delay the better the application performance. If the value of End-to-end delay is high then it means the protocol performance is not good due to the network congestion.

C. Energy Consumption

The energy metric is taken as the average energy consumption per node calculated through simulation time. We calculate energy expended in transmission and reception by the nodes' RF transceivers.

D. Throughput

Total data traffic in bits/sec successfully received and forwarded to the higher layer. Throughput shows protocol's successful deliveries for a time; this means that the higher throughput is the better will be the protocol performance.

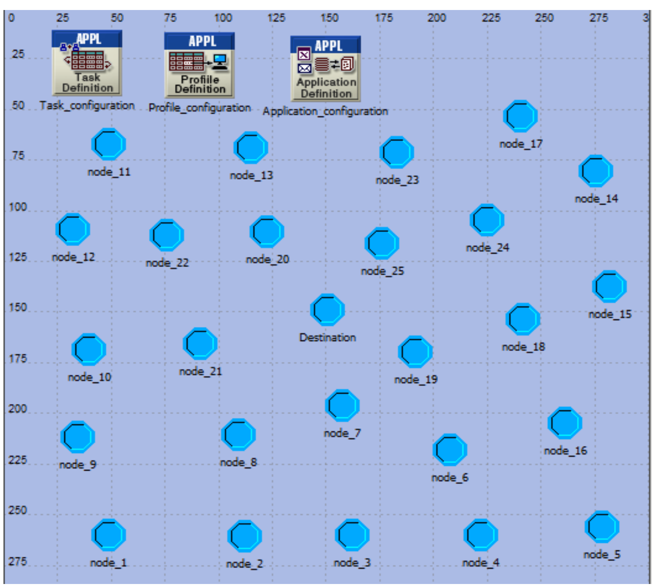

Figure 2. Sample simulation environment with 25 nodes

TABLE 1. SIMULATION PARAMETERS

Simulation time	500 sec
Simulation area	300 m x 300m
Number of nodes	25, 40, 50, 65, 75, 90, 100
Packet size	512 bytes
Packet rate	2 packets/sec
MAC type	IEEE802.11
Data Rate	1 Mbps
Initial node energy	1 Joule
Data rate	1 Mbps

VI. RESULTS & DISCUSSIONS

Packet Delivery Ratio: DSR nodes can obtain the latest routing information and packets are routed on valid paths with high probability. Multiple paths are kept in the routing table giving DSR a good degree of reliability. DSR exhibits moderately high packet delivery ratio. Although the route discovery process in AODV is similar to DSR, each node only maintains a single routing table entry for each destination .A single route discovery in AODV reveals less information data than in DSR. Hence, within the same time, fewer routes are discovered with consequence that the number of packets delivered is less.

It is evident from figure 3 that the proposed EAGRP algorithm provides better data delivery rate ratio than AODV and DSR algorithms. The successful packet delivery ratio of EAGRP achieved about 98% on average compared to 87% for DSR and 80% for AODV. The main focus is on varying size of network by keeping other parameters constant. The objective is to design an algorithm that can scale to thousands of nodes in future sensor networks, therefore the research has been focused on how the algorithm scales and performs better with networks of different sizes. It has been observed that the amount of packets delivered ratio is larger for all the network size. It means that EAGRP improves the performance much more as the number of source nodes increases.

Delay: Figure 4 present the delay encountered by the three routing protocols during the simulation period for all scenarios. It is clear from figures that DSR incurs the highest delay, especially on large size of nodes. DSR exhibits large packet delay because its routes discovery takes more time. Every intermediate node tries to extract and record information before forwarding a reply. The same thing happens when a data packet is routed from node to node. Hence, while route discovery in DSR yields more information for delivery, packet transmission slows down. AODV gives the lowest delay as compared to DSR. AODV, routes are established on demand and destination sequence numbers are used to find the latest route to the destination, the connection setup process is less.

DSR does not have a mechanism for knowing which route in the cache is stale, and data packet may be forwarded to broken links. Also the delay is affected by buffering and queuing delays, route discovery is also considered in the delay and gives advantage to AODV routing protocol. The destination node in AODV routing protocol only replies to the first arriving route request RREQ which favors the least congested route instead of the shortest route as with DSR. This happens because DSR replies to all RREQ which makes it difficult to determine which route is the shortest.

Figure 4 indicates that the delay encountered by EAGRP is always the smallest delay even when the number of nodes is increasing. So EAGRP is successful in terms of time delay.

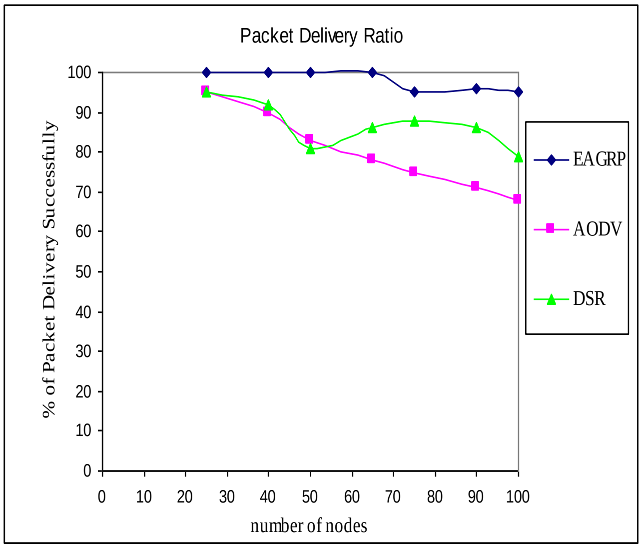

Figure 3. The packet delivery ratio versus number of nodes.

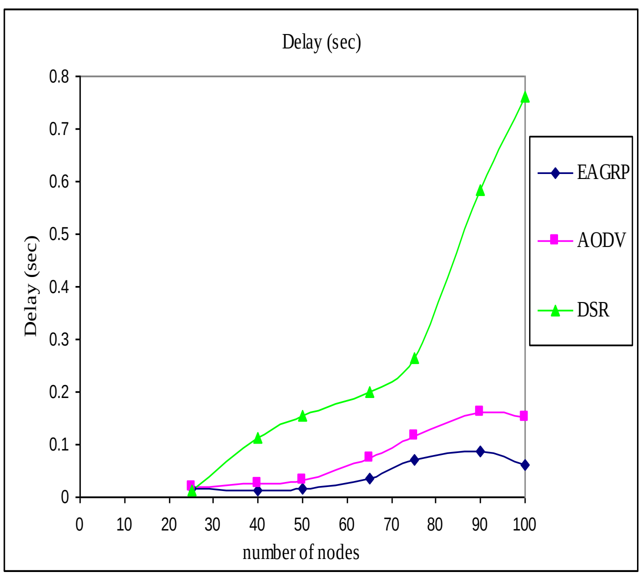

Figure 4. The end to end delay versus number of nodes.

Energy Consumption: Figure 5 presents the energy consumption for the three protocols. Route discovery in AODV is energy intensive. The data packet carries pointers to the full route in itself, which incurs additional energy overheads during routing compared to data packets of routing protocols that carry only neighborhood information. The additional energy consumed is proportional to network size. With an operating environment, it may be very difficult to establish a full route from source to the destination at given point in time. The source will keep sending route discovery but will not receive a definite route response from the destination. Route discovery packet will accordingly flood the network consuming more energy. As in AODV, however, route discovery broadcast in DSR can lead to significant energy consumption especially in larger network. As an improvement over AODV, DSR uses a route cache to reduce route discovery costs.

EAGRP exhibit the lowest energy overheads as shown in figure 5. Energy overheads of EAGRP are competitive with that of DSR. It is also indicated that the packet drop rate is very small in EAGRP approach as compared to the AODV algorithm. Hence, EAGRP approach conserves more energy and is more efficient than DSR and AODV algorithm. The slightly improvement over DSR with larger networks size may be attributed in part to EAGRP dynamically accounting for selecting shortest path to destination.

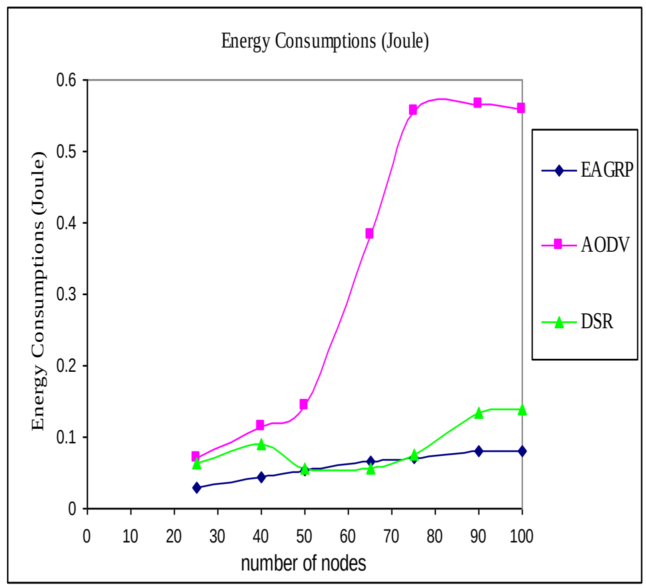

Figure 5. The energy Consumption versus the number of nodes.

Throughput: Figures 6 shows the throughput of EAGRP, DSR, AODV protocols for all scenarios. The throughput depends on the simulation parameters regarding data generation and request for delivery. It can be observed that the three protocols have the same throughput, but when the traffic load is increased we can show that EAGRP leads to more throughput than DSR and AODV.

DSR showed that it was able to deliver packets more than AODV because it already had routes to destination stored in its cache and had no need to route discover again. But under high traffic load, it is shown from figure that DSR outperforms AODV.

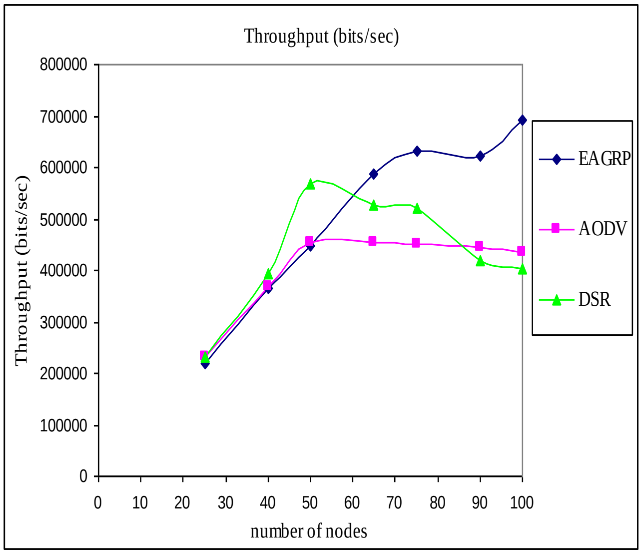

Figure 6. The throughput versus the number of nodes.

VII. CONCLUSION

There have been many routing algorithms proposed for sensor networks. Yet, these algorithms are not applicable to sensor networks due to several factors. Almost all of the routing protocols can be classified as data-centric, hierarchical or location-based although there are few distinct ones based on network flow or QoS awareness. Geographic routing in sensor networks has been a challenging issue for researchers considering the energy constraints in these networks. The nodes in the network cooperate in forwarding other nodes' packets from source to destination. Hence, certain amount of energy of each node is spent in forwarding the messages of other nodes. Lots of work has been done in this respect but still energy depletion of sensor nodes is a big challenge in sensor networks. Sensor nodes use their energy in forwarding messages in network but at some point when node deplete its all energy it fails to transmit the further messages resulting in loss of data.

The performance of three routing protocols had been examined. A simulation model was developed using OPNET. This paper has proposed new routing algorithm EAGRP for sensor networks.

In this research Energy Aware Geographic Routing Protocol (EAGRP) algorithm has been proposed for geographic routing in sensor networks. The algorithm has been implemented and its performance has been compared with those of DSR and AODV protocols. The simulations are carried out for different number of nodes employing these three algorithms considering the different metrics.

Simulation results have shown that the EAGRP performs competitively against the other two routing protocols in terms of packet delivery ratio, delay, energy consumption, and throughput.

REFRENCES

[1] J. L. Hill, "System Architecture for Wireless Sensor Networks," PhD dissertation, Univ. of California, Berkeley, spring, 2003.

[2] G. Acs and L. Buttyabv, "A taxonomy of Routing Protocols for Wireless Sensor Networks," BUTE Telecommunication department, Jan. 2007.

[3] S.Corson and J. Macker, "Routing Protocol Performance Issues and Evaluation Considerations," Naval Research Laboratory, Jan.1999.

[4] B. Karp and H. Kung, "GPSR: Greedy perimeter stateless routing for wireless networks," in the Proceedings of the 6th Annual ACM/IEEE International Conference on Mobile Computing and Networking (MOBICOM), pp.243-254, Boston, August 2000.

[5] K. Kar, M. Kodialam, T. V. Lakshman, and L. Tassiulas, "Routing for network capacity maximization in energy-constrained ad-hoc networks," in IEEE INFOCOM, Sanfrancisco, March 2003.

[6] C. Savarese, J. Rabaey, and K. Langendoen, "Robust positioning algorithms for distributed ad-hoc wireless sensor networks," In USENIX Technical Annual Conference, June 2002.

[7] D. Niculescu and B. Nath, "Ad-hoc positioning system (APS) using AoA, " In IEEE INFOCOM, Apr. 2003.

[8] Y. Xu, J. Heidemann, and D. Estrin, "Geography-informed energy conservation for ad hoc routing, " in the Proceedings of the 7th Annual ACM/IEEE International Conference on Mobile Computing and Networking (MobiCom'01), Rome, Italy, July 2001.

[9] F. Kuhn, R. Wattenhofer, Y. Zhang, and A. Zollinger, "Geometric ad-hoc routing: Of theory and practice," in 22nd ACM Symposium on the Principles of Distributed Computing (PODC), Boston, July 2003.

[10] Tao Yang, et al. "Performance Behavior of AODV, DSR and DSDV Protocols for Different Radio Models in Ad-Hoc Sensor Networks," In Proceeding International Conference on Parallel Processing Workshops, Sept. 2007.

[11] Manjeshwar,A. Agrawal, "TEEN: A Routing Protocol for Enhanced Efficiency in Wireless Sensor Networks,"in Parallel and Distributed Processing Symposium,IEEE Proceedings 15th International,Aug 2008.

[12] Notani, "Performance Simulation of Multihop Routing Algorithms for Ad-Hoc Wireless Sensor Networks Using TOSSIM, " In proceeding in 10th International Conference on Advanced Communication Technology, Vol. 1, pp. 508-513, Feb. 2008.

[13] Perkins,C.E., E. M. Royer, S. R. Das and M.K. Marine, "Performance Comparison of Two On-demand Routing Protocols for Ad hoc Networks," pages 16-28 , IEEE Personal Communications, 2001.

[14] Camp, T., Boleng, J. Davies, "A Survey of Mobility Models for Ad Hoc Network Research," Colorado School of Mines, Colorado, USA, 2002.

[15] B. Karp and H. T. Kung. GPSR, " Greedy perimeter stateless routing for wireless networks," In IEEE/ACM MobiCom, Aug. 2000.

[16] S. Ratnasamy et. al. GHT, " A Geographic Hash Table for data-centric storage," In ACM WSNA, Sep. 2002.