MEGOR: Multi-constrained Energy efficient Geographic Opportunistic Routing in Wireless Sensor Network

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***Abstract*—Providing better energy efficient network is the important critical issues in Wireless Sensor Networks. We presented Multi-constrained Energy efficient Geographic Opportunistic Routing algorithm that enhance the network lifetime based on efficient Geographic Opportunistic Routing. Geographic Opportunistic Routing algorithm uses single path multi hop routing technique in which packets are effectively routed from source to the sink node in a given geographical region. Proposed algorithm is devised with unique parameters viz., Single hop Packet Progress, Packet Reception Ratio, Residual Energy and Energy Density to select intermediate next nodes to forward the packet to sink node. The MEGOR exhibits better results in terms of delay, reliability, energy efficiency and network lifetime when compared with earlier state_of_art works.**

***Index Terms*– Candidate Set Region; Energy Density; Packet Reception Ratio; Residual Energy; Single hop Packet Progress.**

I. INTRODUCTION

Sensor Networks [1-2] play vital role in several applications such as structural monitoring system, environmental monitoring system, fire monitoring system and so forth. Wireless Sensor Network (WSN) consists of micro devices called sensors which have ability of sensing, processing, computing and communicating with each other in wireless environment. Each sensor node is designed with limited battery, storage and processing capability.

The energy efficient Quality of Service (QoS) [3]–[5] is a nature of administration intended to gauge the execution of the level of service with enhanced network lifetime. QoS guarantees that ensured service is introduced by a specific application while consuming maximum available resources. In WSNs, every application is required to deliver the best QoS based service to the end users with limited energy consumption. There are several energy efficient QoS routing protocols that have been proposed to improve the network lifetime, energy, delay and reliability. Some of the important energy efficient and QoS Related protocols are as discussed below.

The multipath routing protocols [6-7] are widely used in WSNs to improve the network lifetime while enhancing the performance. But these protocols involve many channel obstructions and conflicts which may introduce more channel interferences and contentions. These routing techniques are also involved in more time penalty towards the connection establishment, and maintenance when compared with single path routing.

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Sequential Assignment Routing (SAR) [8] protocol introduces reliability by minimizing energy consumption and maximizing the fault tolerance. But it involves more computational cost due to multiple parameter validations before forwarding the packets towards the sink. Some of the energy aware routing protocols such as in [9] and [10] projected cluster based routing by opting queuing model for real and non-real time traffic. However, these protocols consider just end-to-end delay.

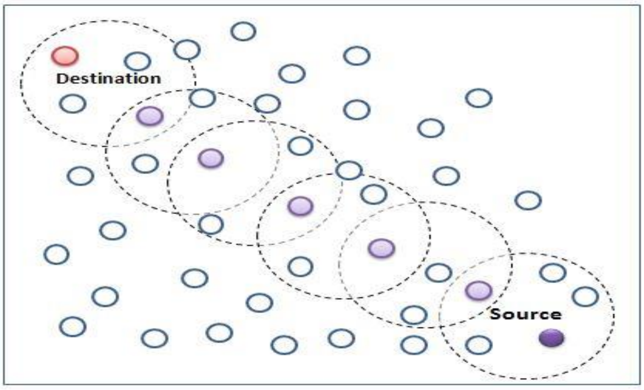

Figure 1: Working of Geographic Opportunistic Routing

Working of Geographic Opportunistic Routing (GOR) in [11] and [12] is depicted in Figure1. The dotted circle represents the candidate set region from source to the sink while establishing the path. Here, every sensor node acquires the location information of other deployed nodes in a network. Then, GOR consolidates the administration of Network and MAC layers in order to choose set of candidate nodes and selection of forwarder node respectively. Generally, the GOR employs common parameters such as link quality, single hop packet progress and distance to choose the candidate nodes and forwarder node.

A. Motivation

WSN applications always demand high network lifetime and Quality of Services such as latency, bandwidth and reliability. The betterment of lifetime in WSNs has been carried out by several protocols. Multipath routing is one such technique that is introduced in wireless sensor applications to increase the reliability. But these protocols introduce more network overhead and energy consumption. There also exists, opportunistic routing techniques which meet certain Energy efficient Quality of Service constraints, optionally they either concentrate on providing reliability or reducing delay. The opportunistic routing concentrates more on the link quality and the distance parameters but it emphasizes less on energy issues like load balancing and network lifetime. Thus, it is necessary to devise an efficient method to consider these issues. The multi constrained Energy efficient geographic opportunistic routing is one such technique that effectively balances energy in all the sensors and thus enhance network lifetime.

B. Contribution

We have designed the multi constrained Energy efficient Geographic Opportunistic Routing protocol to provide energy efficient data transmission within the given geographical region. This protocol constructs dynamic path for every event of information propagation from the source to the sink. It includes the unique factor such as SPP, PRR, residual energy and energy density for selecting the best forwarder node among the candidate set nodes. The forwarder node is chosen mainly depends on the residual energy and energy density along with SPP and PRR. This protocol invariably minimizes the energy consumption and delay besides enhancing the network lifetime and reliability.

C. Organization

The organization of this paper is as follows. Literature survey is presented in section II. Section III gives the concept of background work while section IV defines the problem and objectives. The system and mathematical model along with the proposed algorithm are explained in section V. The detailed performance and evaluation is discussed in section VI. Conclusions are given in section VII.

II. Literature Survey

Xiaoxia*et al.*, [13] proposed Multi Constrained Multi Path routing (MCMP) in wireless sensor networks. A probabilistic model is designed to estimate link state information for sustainable computation. It provides the approximation for local multipath routing algorithms that have been developed to achieve the QoS and network lifetime using multiple factors, such as reliability and delay. MCMP routing algorithm compares its estimated link value with the probabilistic value and sustain a suitable value for the computation. This routing technique introduces more time and space complexity in resolving the precise state information.

Antoine *et al.*, [14] addressed Energy Constraint Multi - Path routing (ECMP) in WSNs. This technique formulates the sensed routing information as an energy conservation problem, based on QoS routing constraints in terms of delay, energy consumption and reliability. It also involves probabilistic approximations to choose the best path for data delivery and avoid energy consumption. This technique involves more space and time complexity due to random traffic rate in a network.

Zijian*et al.*, [15] presented energy efficient collision aware multipath routing (EECA) for WSNs. EECA technique aims to discover two collision-free routes using power adjusted broadcasting and forward data using minimum energy. This algorithm effectively avoids the collision area and conserves the energy. But overhearing of nodes in multipath routing cannot be avoided.

Shuai*et al.*, [16] proposed link association aware opportunistic routing in WSNs. This technique introduces a correlation aware metric to advance the performance of the opportunistic routing. It chooses the sensor nodes with diversely low correlated links as the forwarder candidates and reduces the number of transmissions. This technique concentrates more on link correlation metric and other relevant parameters towards the energy consumption are left unnoticed.

Philip *et al.*, [17] presented Four-Bit Wireless Link Estimation which involves difficulty in estimation of link quality in wireless mesh network. Estimation of link quality involves combining the information from Network, Link and Physical layers. This process gives a narrow and convention-independent link estimation interfaces for the layers, which provides four bits of information. These interfaces reduce the packet delivery cost and increase packet delivery ratio. But the four-bit information considered less precise status information to decide the link quality.

Olaf *et al.*, [18] addresses low power and delay opportunistic routing that involves duty cycle revision. This technique involves a duty cycle setting that awakens the nodes during the packet receiving process from their neighbors and switch to the rest mode on other times. This technique reduces energy consumption and delay by using the neighbors as forwarders but this technique is not suitable for high throughput networks used for bulk transfers.

Johnson *et al.*, [19] proposed Hop Count Optimal Position-Based Packet Routing in WSNs. This protocol introduced a log-normal shadow fading model for realistic physical layer and employed probability function that represents the distance between two nodes used to receive a packet successfully. It was also designed with greedy forwarding technique to carry out the transmission. This technique maximizes the probability of data delivery to sink node. This routing technique considered only fixed length packets that minimize the optimality for each hop on the route.

Michele *et al.*, [20] presented Geographic Random Forwarding (GeRaF) for WSNs. This forwarding method possesses local position information of each node. This technique involves arbitrarily chosen of relaying nodes by considering contention among receivers. This protocol also includes a mechanism to save energy by using sleep and awake modes at the MAC layer. But these modes introduce considerable delay and packet loss.

Junwhan*et al.*, [21] proposed Opportunistic Real Time Routing (ORTR) in WSNs. This protocol is designed to achieve the guaranteed service by using minimum energy and balance overall energy status in a network. It defines an optimal geographical region to select best forwarder node based on energy level to transmit the real time data. The ORTR ensures conveyance of continuous data within the stipulated time. This scheme needs to exchange extra transmissions during message interferences and signal attenuations that result with loss of network performance.

Sanjit*et al.*, [22] introduced exclusive opportunistic routing (ExOR), in which forwarding sensor nodes are chosen, based on their identity and residual transmission cost within the candidate set in a given geographical region. This kind of routing requires storing the information related to the scheduling transmissions and hop configurations onto the commodity hardware for traversing the data. This technique provides a set of opportunities for progressing data packet and is mainly preferred for long distance routing. This protocol integrates the service of MAC and network layer which provides high throughput rate. But it is susceptible to high data loss rate for long radio links.

Niu*et al.*, [23] proposed Reliable Reactive Routing (R3E) which provide consistent and energy efficient data transfer. It chooses the robust guide path for data transmission and greedily forwarded along the guide path within the given region without location information. This kind of routing achieves high data delivery ratio by considering the critical parameters viz., back off delay and packet reception ratio (PRR) with the best guide path. The robust guide path selection involves huge time penalty in dense networks.

Xufei*et al.*, [24] presented Energy-Efficient Opportunistic Routing (EEOR) for WSNs, in which nodes within a designated geographical region have the capability to overhear each other during the data transmission. The forwarder list is formed to overhear by choosing the nodes which are closer and possess minimum energy cost. Further, a forwarder node is opted from forwarder list depending on priority to forward the data to sink. EEOR performs better energy consumption, packet drop ratio and latency. Accurate cost decision for each node in forwarder list is one of the most challenging and time consuming task.

In our work, we have designed Multi constrained Energy efficient Geographic Opportunistic Routing with unique parameters such as SPP, PRR, energy density and residual energy in finding the best forwarder node to construct the optimal dynamic path from source to the sink. It enhances overall network energy efficiency, reliability, throughput and network lifetime.

III. Background

There are several opportunistic routing protocols that assure either minimized delay or better reliability but not the both. Efficient Quality of Service aware GOR (EQGOR) in WSNs [25] is one such routing technique which guarantees both delay and reliability. It also incorporates efficient selection procedure and prioritization algorithm for candidate selection within the geographical region. The nodes within the stipulated radio range around the forwarding node are selected as candidate set. These nodes are prioritized based on the unique parameters such as SPP and PRR. But the nodes with lesser life time, load balancing within the selected region and reliability are ignored.

IV. Problem Definition

WSN consists of N number of sensors where we deem the candidate set from source to the sink by selecting the prioritized forwarder node to transfer the data over the optimal path. The candidate set region around each node is formed based on the specified radio transmission range threshold value T_r. The nodes within the transmission range, T_r around each node are considered as the candidate set, C_s, which includes set of nodes C_i where, i= 1, 2, 3,. . . , n. Then, the forwarding candidate, Fi is chosen from candidate set C_s based on the prioritized value of the parameters SPP, PRR, energy density, P_d and residual energy, P_r. The objectives of our effort are as follows:

(1) Design the energy efficiency optimal path.

(2) Maximize the network lifetime using efficient load balancing mechanism.

Assumptions:

(1) Position information of the entire node within the network is known.

(2) All the sensor nodes contain equal quantity of energy when they are deployed.

V. System Design and Mathematical Model

Our model MEGOR is as depicted in Figure 2. It integrates the network and MAC layer services. The model is partitioned into five stages. Initial phase includes deployment of nodes within the geographic region. The second phase includes selection of candidate set region based on radio transmission range threshold value. Third phase computes the parameters to form the candidate set. Fourth phase finds the forwarder node based on prioritized parameters. The data transfer taken place in fifth phase. All the above phases are described with their respective mathematical model as follows:

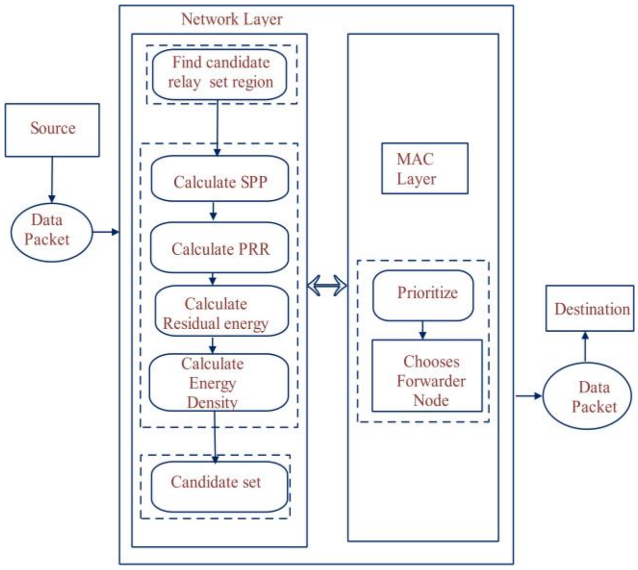

Figure 2: System Architecture of MEGOR

Phase I: Random Node Deployment Phase. The first phase involves random node deployment after assigning the random numbers to each node as node Id. The generation of random numbers and assignment of node Id for all the nodes N is illustrated in Algorithm 1.

Algorithm 1: Random Node Deployment
Input: N- number of sensor nodes

```
Begin
    For i = 1 to N
        Node_id[i] = Random No Generator( );
        // Generates Node id
End
```

Phase II: Candidate Set Region. The second phase describes the selection of candidate set region around each node over the favorable path from source to the sink. The candidate set region Cs is selected based on the radio transmission range threshold value Tr. The selection procedure is described in Algorithm 2.

Algorithm 2: Candidate Set Region
Input: n-Event generated node R_r-Radio range of node

```
Begin
    for i = 1 to N
        If (Rr (i) ⩽Tr)
          include in candidate set region Cs;
          // set within radio range
        End if
    End for
End
```

Phase III: Calculating Parameters. The third phase involves calculating parameters SPP, PRR, energy density and residual energy for the candidates within the C_s. The QoS parameters are discussed as follows:

Single hop Packet Progress (SPP): It is defined as one hop neighbor's distance within the given region of a network. Always the nodes with positive SPP values are chosen to incorporate in candidate set. The SPP of each node is estimated as follows:

$$\mathrm{SPPij} = \mathrm{D(i,d)} - \mathrm{D(j,d)} \quad (1)$$

Where D(i, d) is the distance from the node i to destination, similarly D(j, d) is distance between the neighboring node j to destination.

Packet Reception Ratio (PRR): PRR is the ratio of the packets received to the amount of packets sent. Packet reception ratio represents the data traffic status of each node. The packet reception ratio is considered to include in candidate set. The PRR can be calculated using the following equation (2).

$$\mathrm{PRR} = \frac{\text{Number of packets received form source}}{\textit{Total number of packets sent by source}} \quad (2)$$

Residual Energy: The residual energy, P_r is calculated using the following equation (3).

$$\mathrm{Pr} = \mathrm{Ei} - (\mathrm{Et} + \mathrm{Er}) \quad (3)$$

where, E_i, E_t and E_r are the initial energy, transmitted energy and received energy respectively.

Energy Density: The energy density, P_d is defined as the ratio of summation of residual energy of all candidate nodes to the number of candidate nodes. It can be calculated using the following equation (4).

$$\mathrm{P}_d(\mathrm{i}) = \frac{(P_{r1} + P_{r2} + \cdots . + P_m)}{N_t} \quad (4)$$

where, P_r is the residual energy, N_t is the total number of nodes in a candidate set.

Phase IV: Selection and Prioritization. This phase involves process of selection of forwarder node F_i and prioritization of candidates C_i within the candidate set C_s in a given geographical region. The candidate node C_i that possesses minimum positive SPP value and maximum PRR, residual energy P_r and energy density P_d is selected as forwarder node F_i. The procedure for forwarder node selection and prioritization is illustrated as follows:

Algorithm 3: Selection priority
Input: Candidate set with their positive SPP value, PRR, P_r and P_d , C_i = min positive, max PRR,max P_r and max P_d

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```
Begin
        while(Ci≠ 0)
            For i = 1 to N
            if(Ci > Ci + 1)
                insert(Ci, i, Cs)
        // insert Ci at ith position in candidate set
            else
            swap Ci + 1 with Ci
                insert(Ci + 1, i,Cs)
       // insert Ci + 1 at ith position in candidate
set
            End if
              End for
                return Fi←C1;
        End while
 End
```

Phase V: Data Transfer. This phase involves data transfer from source to the destination through the dynamic path. The MEGOR algorithm is depicted as follows:

Algorithm 4: MEGOR
Input: N- number of nodes

```
Begin
    Step 1: Node Deployment
                Random No Generator ( )
    Step 2: Select Candidate Set Region
                Candidate Set Region ( )
    Step 3: Calculate Quality of Service parameters
            For All N number of nodes
            Calculate SPP, PRR, Pr and Pd
            End for
    Step 4: Selection and Prioritization of
            Forwarding Candidates
            Select priority ( )
    Step 5: Transmit the data to the next node
              Repeat the above steps until the sink
              node is reached
End
```

VI. Simulation And Performance Analysis

A. Performance Metrics

(1) Network Lifetime (NL): It is the maximum amount of time that provides network connectivity without partition.

(2)Energy Efficiency (EE): it is the minimum energy consumption to provide the service.

(3)Packet Drop Ratio (PDR): Ratio of difference between the number of packets sent by source and the number of packets received at sink to the number of packets sent from the source.

(4)Latency: It is defined as time incurred in the propagation of packet from source to sink.

B. Performance Analysis

MEGOR protocol is implemented using NS2 simulator. Table 1 is listed with the parameters considered for the simulation.

Table 1
Parameter Settings

Parameters	Values
Network Size	360000
Number of Nodes	50
Node Distribution	Random
Initial Energy	1J
Data Packet Size	64bit
Sink Node	7
Simulation Time	2(m)

Table 2 shows the comparison values of network lifetime for the proposed protocol MEGOR in comparison with EQGOR and EEOR. Figure 3 depicts the graph for these values. All three protocols retains the same energy level from 2000 ms to 4000 ms and starts differing from 4000 ms to 14000 ms. The MEGOR exhibits slowest decline of energy level after 4000 ms when compared to EQGOR and EEOR. This is clearly due to the adoption of energy efficient mechanism that considers both residual energy and energy density for selecting forwarder node in the candidate set. Thus, our protocol MEGOR enhances the network lifetime by 15% in comparison with EQGOR and EEOR.

Table 2.
Network Lifetime

Network Lifetime Time in(ms)	Total Energy Consumed (inJoules)		
	MEGOR	EQGOR	EEOR
2000	9.8	9.8	9.8
4000	9.8	9.8	9.8
6000	9.5	9.2	8.1
8000	8.5	8.2	7.2
10000	6.8	6.5	5.6
12000	5.5	3.5	3.0
14000	4.3	3.0	2.5

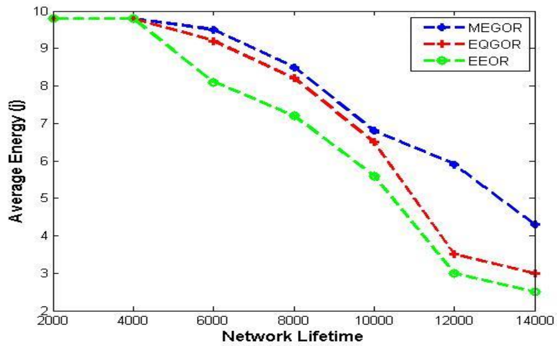

Figure 3 : Network Life Time

Table 3 illustrates the comparison values of Energy Consumption for MEGOR in contrast with EQGOR and EEOR. Figure 4 represents graph for energy efficiency. It is noticed that energy utilizes by each node in MEGOR is much less than EQGOR and EEOR. The lower energy consumption in MEGOR is mainly due to optimal path selection mechanism that effectively reduces the energy consumption among the nodes. Hence, it increases the energy efficiency by 18% in comparison with EQGOR and EEOR.

Table 3
Energy Efficiency

Simulation Time Time in(ms)	Total Energy Consumed(in Joules)		
	MEGOR	EQGOR	EEOR
2000	6.5	6.5	6.5
4000	6.0	6.2	7.0
6000	7.8	8.5	11.0
8000	10.0	12.0	14.6
10000	12.8	14.5	18.0
12000	13.9	15.0	18.5
14000	16.8	18.1	19.5

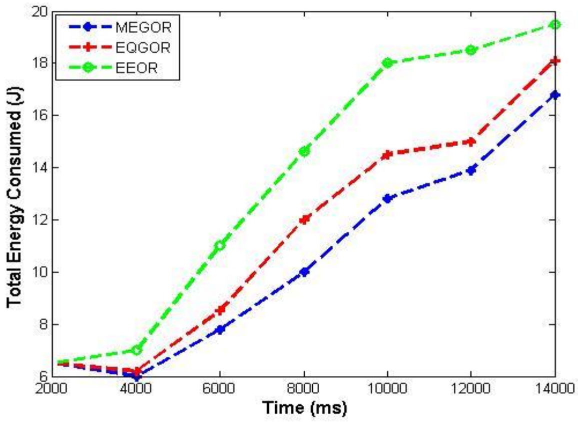

Figure 4 Energy Efficiency

Table 4 depicts the comparison values of PDR for the proposed protocol MEGOR in comparison with EQGOR and EEOR and Figure 5 represents the graph for these values. It is observed that the PDR is much lower in MEGOR when compared with EQGOR and EEOR. This is clearly due to the consideration of unique parameters such as SPP and PRR while selecting the forwarder node from the candidate set. Thus it decreases the PDR by 17% in comparison with EQGOR, EEOR.

Table 4
Packet Drop Ratio

Simulation Time Time in(ms)	Packet Drop Ratio (in Kbps)		
	MEGOR	EQGOR	EEOR
2000	0.2	0.23	0.2
4000	0.23	0.25	0.28
6000	0.28	0.31	0.32
8000	0.30	0.35	0.39
10000	0.33	0.42	0.49
12000	0.42	0.52	0.60
14000	0.47	0.65	0.70

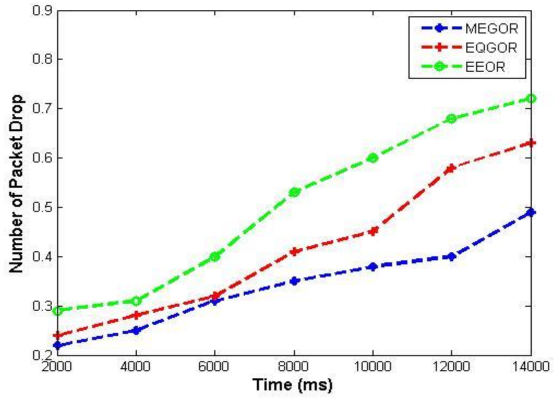

Figure 5 Packet Drop Ratio

Table 5 represents the comparison values of Latency for the proposed protocol MEGOR in comparison with EQGOR and EEOR and Figure 6 illustrates the graph for latency. It is observed that the time taken for data packet transmission is less in MEGOR compared with EQGOR and EEOR. This is because of optimal shortest path that is used to transmit the data. Thus, it reduces the latency by 17% in comparison with EQGOR and EEOR.

Table 5
Latency

Simulation Time	Latency(inKbps)		
Time in(ms)	MEGOR	EQGOR	EEOR
2000	20	20	20
4000	28	30	50
6000	32	43	67
8000	50	60	98
10000	68	80	100
12000	70	90	120
14000	120	150	178

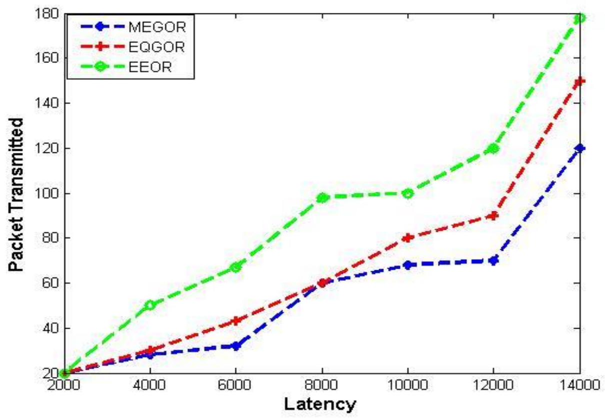

Figure. 6 Latency

VII. CONCLUSIONS

MEGOR protocol provides energy efficient and reliable data delivery. The optimal shortest path supports the robust data delivery due to unique parameters such as SPP and PRR. The mechanism used to select the forwarder node from the candidate set considers the energy density and residual energy as major parameters. This selection procedure greatly increases network lifetime and energy efficiency. And also, it minimizes packet drop ratio and latency. Further, this work can be extended for mobile sink environments.

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