# Secure Energy Efficient Geographical Opportunistic Routing for Wireless Sensor Networks

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**Abstract** – *Design of Efficient routing algorithms is the most essential and prioritized task to improve the QoS in WSNs. There are mission critical applications which inherently demands high level reliability, security and energy efficiency. Existing Geographical opportunistic routing methods have attempted to increase the quality of these parameters by considering Packet Reception Ratio(PRR) and One_hop Packet Progress (OPP) of next hop node towards the sink. But these parameters alone cannot provide reliable, energy efficient and secure communication. In order to achieve better QoS we have designed and implement Secured Energy efficient Geographic Opportunistic Routing (SEGOR) for WSN. It is designed with an efficient mechanism by considering unique parameters such as Trust level, Residual energy, Energy requirement, Packet Reception Ratio (PRR) and Single-hop Packet Progress (SPP) at each hop from source to sink. This protocol provides more reliable, secured and energy efficient routing when compared to earlier works.*

**Keywords –** Candidate Set, Geographic Opportunistic Routing, Trust level, Sensor Networks.

## 1. Introduction

Design of efficient QoS based routing protocol is a major issue due to scarse resources in WSNs. Dead-line-driven applications demands better QoS based routing algorithms to meet their basic requirements [1]. The energy efficiency in routing play an important role in extension of network life time, energy balance and network throughput [2-4].

Synchronized communication and reliability are the two major factors that has significant role in delay reduction process in a network. It is one of the challenging tasks to achieve better results of these parameters due to uncertain channel conditions and partial network failures. These conditions causes frequent changes in network topology and connection that introduces higher energy consumption and delay. These issues are addressed in some of the earlier works and have proposed different solutions to improve the timely communication and reliability [7-10], Reliability and latency play crucial role in attaining better network throughput. Some of the earlier State-of-Art works have discussed these issues and proposed multipath routing schemes to enhance the values of these parameters to provide better QOS for WSNs [12-14].But these schemes involve higher energy consumption, channel contention and interferences**.**

### *A. Motivation*

Reliable data delivery is an important issues in WSNs. Achievement of the better security and the latency is another challenging task. In earlier works, the multipath routing techniques are used for secure and fast data transmission with minimum latency. But these techniques are unable to achieve the reliability to the required extent. The geographical Opportunistic Routing (GOR) technique is designed to provide reliable data transmission. But it results in poor energy efficiency and latency due to less significant parameters. Hence, it is necessary to device an efficient approach to maximize energy efficiency, reliability and minimize latency with most significant and relevant design parameters. SEGOR is one such approach that is designed on the basis of Geographical Opportunistic Routing with crucial and relevant parameters.

***B. Contribution***

We have developed a secure energy efficient Geographical Opportunistic Routing to achieve better QoS in WSNs. It combines network with MAC layer to identify the next hop node towards the sink using QoS parameter. Selection of Candidate set nodes is done at Network layer using Single hop Packet Progress (SPP). And the selection of forwarding node among the candidate set of nodes is done at MAC layer, based on Residual Energy ($R_e$), Energy requirement ($E_r$), Packet Reception Ratio (PRR) and Trust Level ($T_l$),.This approach achieves reliable data delivery, low latency, and utilizes energy effectively.

## 2.Literature survey

Xiaoxia et al., [13] designed multi constrained QoS with multipath routing (MCMP) in WSNs. It provides soft QoS to different types of packets that helps to get link information from source to destination. Soft QoS are mapped to each link based on local link state information. Here each packet chooses multiple paths to reach the destination. MCMP improves link reliability and packet delivery ratio. But duplication of packets increases because of multipath selection which causes high redundancy.

Antoine et al., [15] developed an energy constrained multipath routing (ECMP) for WSNs. ECMP selects the minimum number of hops with minimum energy for both short and long paths. The path based model is converted into link based model using probabilistic approximations. It formulates the problem based on the routing to minimize the energy consumption on each path with QoS constraints. But issues related to the redundant delivery of paths are yet to be resolved.

Razzaque et al., [16] presented multi Constrained Qos (MCQoS) geographic routing for heterogeneous traffic in sensor networks. MCQoS proposed combined routing model and Distributed Aggregate Routing Algorithm (DARA) for multiple source, multiple path and location aware networks. DARA considered halting time of packet at intermediate nodes, differentiated delay speed of packets and scheduling mechanisms to design probabilistic model. This protocol provides better reliability, delay guarantee and energy efficiency. Further it is necessary to resolve the issue related to aggregate routing function due to heterogeneous node deployment and routing hole problems.

Long et al., [18] proposed an idea of Exploiting Geographic Opportunistic Routing (EGOR) for soft QoS provisioning in WSNs. It explains the Geographic Opportunistic Routing (GOR) for multi constrained QoS provisioning in WSNs. The GOR involves huge computation delay that makes it unfit to be considered for QoS provisioning. EGOR provides better balance with respect to time complexity and QoS metrics, but it exhibit lower performance for delay sensitive applications.

Rahul et al., [19] developed a solution to effective use of opportunistic routing. It provides systematic performance evaluation by considering congestion rate, node density and quality of the channel to use opportunistic routing more effectively. The power consumption and packet delay at each node are the two metrics used to evaluate this protocol. It also detects optimal operations for opportunistic routing to saves the energy consumption at each node. This solution is good only for medium node density networks.

Sanjit et al., [20] describes an Opportunistic routing (ExOR) for WSNs. It is an combines routing and MAC protocol that enhances throughput of huge unicast transmissions in multihop wireless networks. It chooses best of multiple receivers to forward each packet so that it uses long radio links with high packet rate. It greatly increases connection throughput without using network capacity when compared to traditional routing. This protocol is more effective when it is used for multiple bit transmit rates.

Xufei et al., [21] designed energy efficient opportunistic (EEOR) routing in WSNs. This protocol minimizes the energy consumption of each node by selecting appropriate prioritized forwarder list.

It considers both fixed and dynamically varying transmission power of each node while designing routing strategy. It provides better energy consumption, packet loss ratio and average delivery delay. There is a need for better forwarder list to minimize the energy consumption for multicast and broadcast environments with accurate estimation of penalty cost for additional over heads to select unique node in the forwarder list.

Shui et al., [22] proposed Link Correlation Aware Opportunistic Routing in wireless sensor networks. It analyzes the opportunistic routing framework with respect to link correlation and proposed link correlation metric to improve the performance of opportunisties. It selects low correlated links along with the nodes as forwarder candidates. But the effective measurement of link correlation depends on node density and topologies.

Prosenjit et al., [23] presents an algorithm for routing to provide failsafe delivery in ad hoc wireless sensor networks. This algorithm describes routing, broadcasting and geocasting in terms of unit graphs. In this algorithm, network is model as unit graph and points are considered as nodes in the plane. Any two nodes can communicate, if the distance is less than some threshold value. It is proved that no packet duplication is required to deliver the packet to the destinations. This is algorithm is suitable for only static networks.

Kai et al., [24] proposed a new local metric called Expected Packet Advancement (EPA) per unit energy consumption based on geographic Collaborative Forwarding (GCF) scheme.EPA balances the energy consumption, reliability and packet advancement process. In addition, the localized candidate selection algorithm has proposed to determine the forwarding candidate set to maximize the EPA.

Karim et al., [25] designed energy competent forwarding policies for geographic routing in lossy wireless sensor networks. The realistic conditions of geographic routing protocols are analyzed and identified the problems such as weak link problem and related distance trade-offs. It is shown that reception based strategies are more efficient than only distance based strategies. But link losses are time-variant in mobile networks.

Jhonson et al., [26] proposed hop count optimal location based routing algorithms for ad hoc wireless networks. It includes idyllic hop count routing, expected progress routing and projection progress routing. It is necessary to consider further realistic Physical layer parameters like, power consumption, cost awareness and guaranteed delivery of packets for better results.

David et al., [27] analyzed the state-of –Art of multi objective evolutionary algorithms. The evaluation includes pareto ranking, fitness functions, niching fitness sharing, mating restrictions and tributary population. Further it is necessary to evaluate MOEA parallelization possibilities in depth.

In our work, we developed Secured energy efficient geographical opportunistic routing that mainly considers cost of the energy, security aspects, Reliability and delay constraints. The parameters viz., One hop Packet Progress (OPP), Residual Energy (Re), Energy requirement (Er), Packet Reception Ratio (PRR) and Trust Level (Tl), maximizes energy efficiency, reliability, Network life time and minimizes end-to-end delay.

## 3.Background

Existing QoS routing protocols exploit multipath routing and Geographical Opportunistic Routing (GOR). But multipath routing introduces much energy cost and channel interferences [18] and where as existing GORs are unable to achieve required level of reliability and delay constraints in WSNs.

To overcome this drawback, efficient QoS aware Geographical Opportunistic Routing EQGOR [28] is designed to improve the QoS routing in WSNs. It integrates both network layer and MAC layer to compute better QoS path. The network layer identifies the candidate set of nodes by considering the positive value of OPP. The MAC layer, selects a forwarding node from nodes in candidate set, based on pairs of information (PRR and OPP) maintained by each sensor node. It minimize end-to-end delay and maximizes energy efficiency. But the PRR based protocols have not considered the security and energy aspects, which are significant in improving reliability and delay constraints.

In order to achieve better QoS routing, we have to consider the parameters viz., Residual energy, Energy requirement and trust level along with OPP and PRR. Our algorithm SEGOR provides the better security, reliability, network life time and end-to-end delay.

## 4. Problem Definition

In a given WSN with *n* number of densely deployed, nodes, each node collects the information about the parameters viz., One hop Packet Progress (*OPP*), Packet Reception Ratio (*PRR)* and Residual energy ($R_e$), Energy requirement to transmit each packet $E_r$ of its neighbor by broadcasting a packet. If an event generated at node *i,* it sends the data packets to the base station through its neighbors using opportunistic routing that integrates both network layer and MAC layer. The network layer identifies the candidate set of nodes based on the OPP, and then the MAC layer selects one forwarding node among candidate set on the basis of minimum PRR, $E_r$, OPP values and maximum $R_e$, and $T_l$ values. This process repeats until the packet reaches the destination. The main objectives of our research work are to

***Objectives:***

1. Achieves better data reliability and latency.
2. Increases the energy efficiency and network life time.

***Assumptions:***

1. Initially all the sensor nodes have equal amount of energy.
2. The sink has higher energy compared to other sensor nodes.

## 5.System And Mathematical Model

Figure 1 depicts model of proposed SEGOR. SEGOR system architecture is divided into five phases. Node deployment is done in phase one. In phase second, all the nodes in a network calculate routing parameter information of its neighbors viz., $R_e$, $E_r$, $T_l$, OPP and PRR and update these values in their routing table between Maximum Updating time Interval (MUI) and Least Updating time Interval (LUI). Third phase involves the monitoring of event generation. The nodes one hop away from event generated node are considered as neighbor nodes. Fourth phase involves the SEGOR path computation by integrating both network layer and MAC layer parameters.

***a. Residual Energy ($R_e$)***

It is the remaining energy node after transmission process. The Residual energy $R_e$ can be computed as:

$$R_e = I_e - (E_t + E_r), \tag{1}$$

where, $I_e$ is Initial Energy, $E_r$ and $E_t$ are the energy required for Receiving and Transmission respectively. Transmission $E_t$ is the energy required to transmit each packet and is computed as follows:

$$E_t = P_t + T_t, \tag{2}$$

Energy required is calculated as follows

$$E_r = P_r + T_r, \tag{3}$$

$P_r$ amount of packets received, $T_r$ required time to receive a packet.

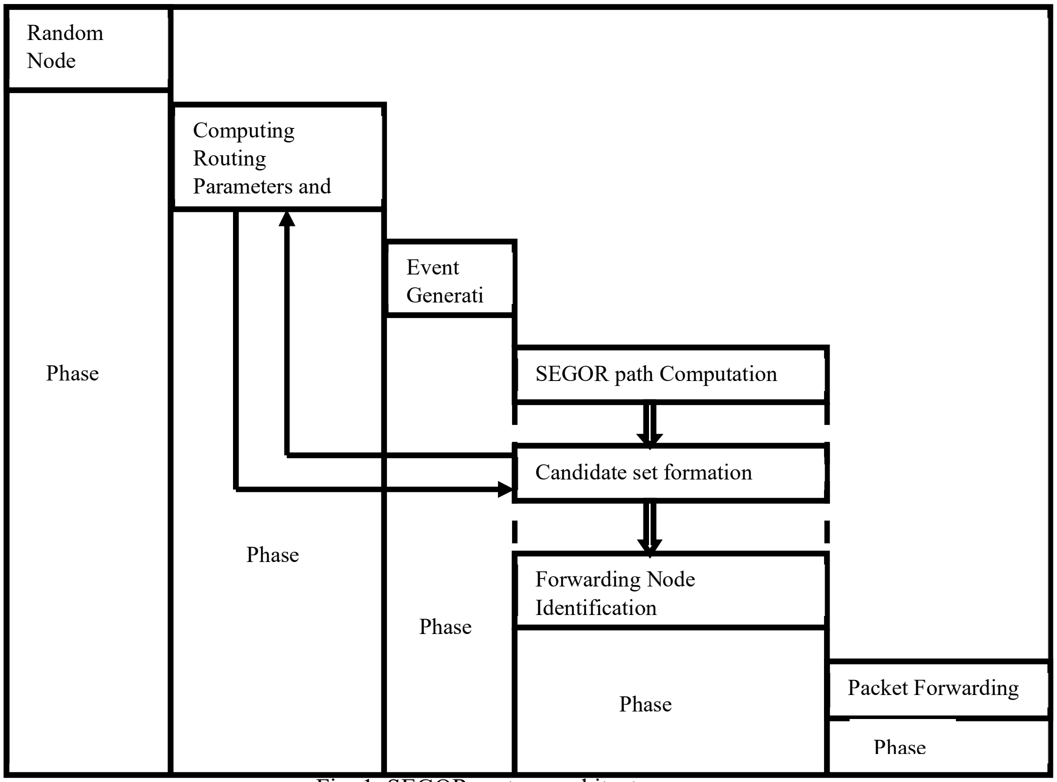

Fig. 1. SEGOR system architecture

***b. Energy Monitor ($E_M$)***

Energy Monitor, $E_M$ computes the energy requirement, $E_r$ level of each node, to transmit a packet towards the sink. Energy required is the average energy that a node utilizes to deliver a unit-sized packet from source to base station. The energy requirement $E_r$ of *node i* is calculated as

$$E_r(i) = \frac{Packet_{Size} * T_e}{distance(i, sink)} \tag{4}$$

where $T_e$ is the transmission energy required for each packet and the $distance(i, sink)$ is distance from *node i* to *sink.*

***c. Trust Monitor ($T_M$)***

Trust Monitor $T_M$ decides the trust level of node. Trust level, $T_l$ of a node is a decimal value between 0 and 1. The trust level is estimated on the basis of the probability rate that a node successfully delivers data to a base station. Initial value of $T_l$ is assumed to be 0.5.

$$T_l = T_l - \frac{number\ of\ packets\ received\ by\ the\ sink}{number\ of\ packet\ sent\ from\ source} \tag{5}$$

***d. Packet Reception Ratio (PRR)***

The Packet Reception is difference between the number of packets sent and received by each node:

$$PRR = Np_s - Np_{sr} \tag{6}$$

where $Np_s$ and $Np_r$ are the number of packet received and sent respectively.

***e. One hop Packet Progress (OPP)***

The One hop Packet Progress is a difference of distance between source to sink and neighbor node to sink. It is given by

$$SPP = Distance(i,sink) - Distance(j,sink) \quad (7)$$

where *i* and *j* are source and neighbor node respectively. *Distance(i,sink)* and *Distance(j,sink)* distance from node *i* to sink and node *j* to sink respectively.
The distance can be calculated using the Euclidian distance formula.

$$Distance(s,d)=\sqrt{(s1-s2)^2+(d1-d2)^2} \quad (8)$$

where *s* is source and *d* destination.

***f. Routing Table Updation***

In a network, each node consists of the routing table, which stores the computed values of Residual energy $R_e$, Trust level $T_l$, Energy requirement $E_r$, OPP and PRR. The routing table updation is carried out in three different instances. In the first instance, the normal routing table updation is done between the Least Updating time Interval (LUI) and Maximum Updating time Interval (MUI). The second instance routing table updation occurs after the expiry of both MUI and LUI. The routing table gets updated at the third instance when change occurs in trust value and after expiry of LUI. The complete Routing Table Updation is presented in Function 1. (Table 1).

Table 1. Routing Table Updation

**Function 1:Routing_Table_Updation( )**
**input** : LUI, MUI, time, $T_l$=0.5
*messagePending = false*
**if** *time >= LUI* **&&** *time < MUI* **then**
*updateTable( )*
**else if** *time > MUI* **&&** *time > LUI* **then**
*updateTable( )*
**else if** $T_l$ *varies* **&&** *time > LUI* **then**
*updateTable( )*
**else**
*messagePending = true*
**end if**

***g. SEGOR Path Computation***

Fourth phase involves the computation of SEGOR Path. The candidate nodes set are computed in network layer by using values of OPP parameter. Then forwarding node is identified using routing parameter viz., $R_e$, $E_r$, $T_l$, and OPP among candidate set. Finally, the forwarding node is considered as a next hop node to forward packet. These steps are presented in Function.2 (Table 2).

***i. Candidate Set Formation(CSF)***

Candidate Set Formation (CSF) is based on the OPP values each node. The positive OPP values indicates that the nodes are nearer to the sink and where as negative OPP values indicates that the nodes are away from the sink when compared to the source node. Hence, the node which are having positive OPP values are included into the Candidate Set.

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Table 2. SEGOR Path Computation

```
Function 2 : SEGOR_Path_ Computation()
        Assumption :  α = 2
for each neighbor node j in a network do
        Calculate R_e
        Calculate E_r
        Calculate T_l
        Calculate OPP
        Calculate PRR
end for
for each neighbor node j to n do
        if OPP > 0 then
                insert j to {candidate set}
        end if
end for
min_PRR = PRR of first node in a {candidate set}
for each neighbor node k in a candidate set do
        if PRR < min_PRR then
            min_PRR = PRR
        end if
end for
for each neighbor node k in a candidate set do
         diff = PRR – min_PRR
         if  diff ≤ α then
                if  max R_e && min E_r && max T_l then
                        select node k as forwarding candidate node
                end if
         end if
end for
```

### *ii. Forwarding Node Identification (FNI)*

FNI involves identifying the node which has the minimum PRR value among all other nodes in candidate set. In the next step, the difference between the PRR values of all nodes with minimum PRR node will be calculated. Then the nodes that possess the difference value that is less than or equal to $\alpha$ (Where α value is set to *2*) are considered for intermediate list for forwarding node identification. Finally, the node that possess maximum value of the parameters viz., $R_e$, $E_r$, $T_l$, and OPP with minimum PRR value in intermediate list is considered as forwarding node.

The last phase involves packet transmission from source to sink. The phases are presented in SEGOR algorithm (Table 3).

Table 3**. SEGOR Algorithm**

```
Algorithm : SEGOR Algorithm
input : number of nodes - N nodes
    Step 1 :  Random Node Deployment
    Step 2:  Routing_Table_ updation()
    Step 3 :  Generation of an event
    Step 4 :  Neighbor node Identification
    Step 5 :  Computation of Quality of Service Path
              SEGOR_Path_Computation( )
    Step 6 :  Repeat above step until all the packets
              move
             from source to sink
```

## V. SIMULATION AND PERFORMANCE ANALYSIS

### a. PERFORMANCE ANALYSIS

Table 4.depicts the simulation parameters and their values.

Table 4. Simulation Parameters

| Parameter | Values |
|---|---|
| Network Size | 1000m * 1000m |
| Node Number | 300 |
| Node Distribution | Random |
| Initial Energy | 1J |
| Data Packet Size | 64 bits |
| Simulation time | 14000s |

Table 5 listed with comparative values of PDR and EE of SEGOR with EQGOR and MPQP. Fig.3. shows the diagram of these values. It is observed that SEGOR exhibits higher packet delivery rate between 4000 to 8200 sec and 12000 to 14000 sec when compared to EQGOR and MPQP. This is a clear indication of enhanced reliability due to the consideration of proper *PRR* value and Trust value $T_l$ while selecting forwarding node from the candidate set node. Thus there is an increase of 48 % in PDR in comparison with EQGOR and MPQP.

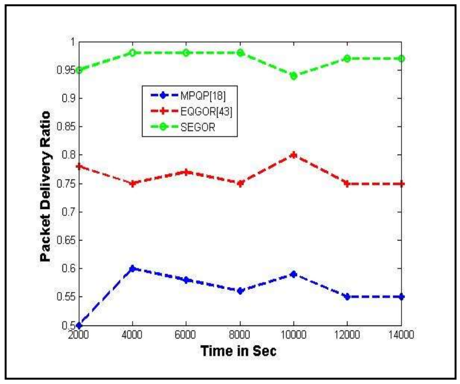


Fig. 3. Packet Delivery Ratio

Table 5. Comparative values of PDR and EE of SEGOR with EQGOR and MPQP.

| Simulation Time | Packet Delivery Ratio (PDR) | | | Energy Efficiency (EE) | | |
|---|---|---|---|---|---|---|
| | MPQP | EQGOR | SEGOR | MPQP | EQGOR | SEGOR |
| 2000 | 0.55 | 0.78 | 0.95 | 0.95 | 0.95 | 0.95 |
| 4000 | 0.56 | 0.75 | 0.98 | 0.95 | 0.92 | 0.95 |
| 6000 | 0.58 | 0.77 | 0.98 | 0.95 | 0.89 | 0.95 |
| 8000 | 0.56 | 0.75 | 0.98 | 0.9 | 0.89 | 0.95 |
| 10000 | 0.59 | 0.7 | 0.94 | 0.8 | 0.89 | 0.9 |
| 12000 | 0.55 | 0.65 | 0.97 | 0.72 | 0.8 | 0.9 |
| 14000 | 0.55 | 0.6 | 0.97 | 0.7 | 0.8 | 0.89 |

Fig. 4. Illustrates the comparison values of Energy efficiency of SEGOR with EQGOR and MPQP. SEGOR reveal higher energy efficiency between 2000 to8000sec. Even though it decreases gradually after 8000 sec, it maintains higher energy level compare to other two protocols. This is specifically due to consideration of the parameters, viz., and Residual energy $R_e$ Energy requirement $E_r$ of each forwarding node from the candidate set nodes. Thus there is progress of 32 % of energy efficiency in comparison with EQGOR and MPQP.

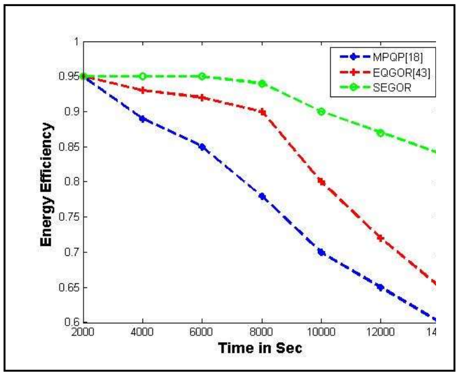


Fig. 4. Energy Efficiency

Table 6 Comparative Values of End-to-End delay of SEGOR with EQGOR and MPQP.

| Reliability of QoS Requirement | End-to End Delay (E2ED) | | |
|---|---|---|---|
| | MPQP | EQGOR | SEGOR |
| 0.6 | 0.02 | 0.04 | 0.125 |
| 0.65 | 0.02 | 0.04 | 0.126 |
| 0.7 | 0.02 | 0.04 | 0.175 |
| 0.75 | 0.02 | 0.04 | 0.176 |
| 0.8 | 0.02 | 0.04 | 0.176 |
| 0.85 | 0.02 | 0.04 | 0.176 |
| 0.9 | 0.02 | 0.04 | 0.22 |
| 0.95 | 0.02 | 0.04 | 0.22 |
| 1.0 | 0.02 | 0.04 | 0.23 |

Table 6. Shows the comparative values of End-to-End delay of SEGOR with EQGOR and MPQP. Fig. 5. represents End-to-End delay of SEGOR, EQGOR and MPQP. It is observed that SEGOR archives very minimum delay when compared to other two protocols. The PRR and OPP values have great impact on the selection of candidate set nodes and forwarding node in the selection of SEGOR path. It consider most eligible forwarding node based on the value of $\alpha$ (Where α value is set to $2$). The $\alpha$ value imposes very stringent procedure in selection of shortest path from source to sink. SEGOR maintains least and constant delay throughout the simulation. There is an improvement of 22% in End-to-End delay in comparison with EQGOR and MPQP.

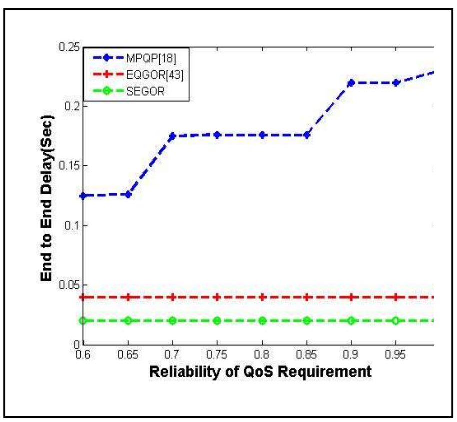


Fig. 5. End-to-End delay.

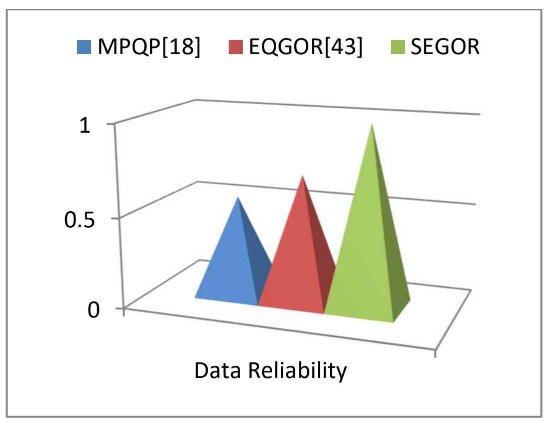


Fig. 6. Data Reliability

Fig. 6. demonstrates the Data reliability achieves by SEGOR, EQGOR and MPQP. This diagram clearly indicates that SEGOR exhibits higher Data reliability in comparison with other two algorithms. It is due to the consideration of Energy parameters such as Residual Energy ($R_e$), Energy requirement ($E_r$), and security parameters viz., Packet Reception Ratio (PRR) and Trust Level ($T_l$).

## VII. CONCLUSIONS

Reliability and secure communication are the most essential requirements to achieve QoS in WSNs. The Geographical opportunistic and Multipath Routing are attempted to achieve these requirements by considering parameters such as PRR and SPP. But these parameters are not able to provide better reliability and secured energy efficient communication. The SEGOR has considered most prominent parameters such as Residual Energy ($R_e$), Energy requirement ($E_r$), Packet Reception Ratio (PRR) and Trust Level ($T_l$), and One hop packet progress (OPP) to find efficient route from source to sink. This protocol achieves secure energy efficient routing with increased reliability, energy efficiency, security and minimized End-to-End Delay. Further it can be extended to extremely delay sensitive applications in WSNs.

REFERENCES


[1] Bo Wang, Xunxun Chen, and Weiling Chang, " An efficient trust-based opportunistic routing for ad hoc networks", *In proceedings of IEEE International Conference on Wireless Communications & Signal Processing (WCSP),* pp.1-7, Oct. 2012.

[2] Caixia Li, Fang Pu, Aiping Gu, and Linlang Liu, " A Sink-Controlled Energy-Efficient and Geographical Routing Protocol in Wireless Sensor Networks", *In proceedings of IEEE International Conference on Computer and Management (CAMAN),* pp. 1-4, May. 2011.

[3] Young-Long Chen, Wei-Hsiang Huang, and Li-Hsien Chang, "A Color-theory-based Geographical Energy Efficient Routing algo-rithm for Wireless Sensor Networks", *In proceedings of IEEE International Conference on Fuzzy Theory and it's Applications (iFUZZY),* pp. 78-81, Nov.2012.

[4] Eun Kyung Lee, Varkey, J.P, Pompili, D., "On the impact of Neighborhood Discovery on Geographical Routing in Wireless Sensor Networks", *In Proceedings of IEEE Sarnoff Symposium*, pp. 1-5, May. 2011.

[5] Kumar, P., Chaturvedi, A., Kulkarni, M., "Geographical Location Based Hierarchical Routing strategy for Wireless Sensor Networks ," *In Proceedings of IEEE International Conference on Devices, Circuits and Systems (ICDCS),* pp. 9-14, March.2012.

[6] Zhongliang Zhao, Rosario, D. Braun, T. Cerqueira, E. , "Topology and Link quality-aware Geographical Opportunistic Routing in wireless ad-hoc networks", *In Proceedings of Wireless Communications and Mobile Computing Conference (IWCMC),* pp. 1522-1527, July.2013.

[7] Bo-Sheng Chiou., Ying-Jen Lin., Yu-Ching Hsu., Shyh-Yih Wang., "K-hop Search Based Geographical Opportunistic Routing for Query Messages in Vehicular Networks", *In Proceedings of IEEE International Symposium on Next-Generation Electronics (ISNE),* pp. 279-282, Feb.2013.

[8] Xinming Zhang .,Fan Yan., Lei Tao., Sung, D.K., "Optimal Candidate Set for Opportunistic Routing in Asynchronous Wireless Sensor Networks", *In Proceedings of IEEE International Conference on Computer Communication and Networks (ICCCN),* pp.1-8, Aug.2014.

[9] J. Kuruvila, A. Nayak, and I. Stojmenovic, ''Greedy Localized Routing for Maximizing Probability of Delivery in Wireless Ad Hoc Networks with a Realistic Physical Layer,'' *In International Journal on Parallel Distributed Computing,* vol. 66, no. 4, pp. 499-506, Apr. 2006.

[10] Jia Liu .,Junzhao Du. , Jie Zhang., Xiaojun Li., "RANC: Opportunistic Multi-path Routing Protocol in WSNs Using Reality-Aware Network Coding ," *In the Proceedings of IEEE International Conference on Ubiquitous Intelligence & Computing and Autonomic & Trusted Computing (UIC/ATC),* pp. 185-190, Oct.2010.

[11] Yanyan Han., Hongyi Wu, Zhipeng Yang, and Deshi Li, "Delay-constrained single-copy multi-path data transmission in mobile opportunistic networks ," *In proceeding of IEEE International Conference on Sensing, Communication, and Networking (SECON),* pp.37-45, July.2014.

[12] E. Felemban, C.-G. Lee, and E. Ekici, ''MMSPEED: Multipath Multi-Speed Protocol for QoS Guarantee of Reliability and Timeliness in Wireless Sensor Networks,'' *In IEEE Transactions on Mobile Computing*, vol. 5, no. 6, pp. 738-754, June 2006.

[13] X. Huang and Y. Fang, ''Multiconstrained QoS Multipath Routing in Wireless Sensor Networks,'' *In International Journal on Wireless Networking*, vol. 14, no. 4, pp. 465-478, Aug. 2008.

[14] B. Yahya and J. Ben-othman, ''An Energy Efficient and QoS Aware Multipath Routing Protocol for Wireless Sensor Networks,'' *In Proceedings of IEEE LCN*, pp. 93-100, 2009.

[15] A.B. Bagula and K.G. Mazandu, ''Energy Constrained Multipath Routing in Wireless Sensor Networks,'' *In Proceedings of UIC*, pp. 453-467, 2008

[16] M.A. Razzaque, M.M. Alam, M. Or-Rashid, and C.S. Hong, ''Multi-Constrained QoS Geographic Routing for Heterogeneous Traffic in Sensor Networks,''*In Proceedings of IEEE CCNC*, pp. 157-162, Jan. 2008.

[17] F. Kuipers and P. Van Mieghem, ''Conditions That Impact the Complexity of QoS Routing,'' *In IEEE/ACM Transactions on Networking,* vol. 13, no. 4, pp. 717-730, Aug. 2005.

[18] [25] L. Cheng, J. Cao, C. Chen, J. Ma, and S. Das, ''Exploiting Geographic Opportunistic Routing for Soft QoS Provisioning in Wireless Sensor Networks,'' *In Proeedings of IEEE MASS*, Nov. 2010, pp. 292-301.

[19] ] R. Shah, S. Wietholter, A. Wolisz, and J. Rabaey, ''When Does Opportunistic Routing Make Sense?'' *In Proceedings of IEEE PerCom Workshops*, 2005, pp. 350-356.

[20] S. Biswas and R. Morris, ''ExOR: Opportunistic Multi-Hop Routing for Wireless Networks,'' *In SIGCOMM Computer Commuication. Review*, vol. 35, no. 4, pp. 133-144, Oct. 2005.

[21] ] X. Mao, S. Tang, X. Xu, X.-Y. Li, and H. Ma, ''Energy-Efficient Opportunistic Routing in Wireless Sensor Networks,'' *In IEEE Transactions on Parallel Distrbiutig. System,* vol. 22, no. 11, pp. 1934-1942, Nov. 2011.

[22] ] A. Basalamah, S.M. Kim, S. Guo, T. He, and Y. Tobe, ''Link Correlation Aware Opportunistic Routing,'' *In Proceedings of IEEE INFOCOM*, pp. 3036-3040, 2012.

[23] P. Bose, P. Morin, I. Stojmenovic´, and J. Urrutia, ''Routing with Guaranteed Delivery in Ad Hoc Wireless Networks,'' *In Proceedings of DIALM*, pp. 48-55, 1999.

[24] ] K. Zeng, W. Lou, J. Yang, and D.R.I. Brown, ''On Geographic Collaborative Forwarding in Wireless Ad Hoc and Sensor Networks,'' *In Proceedings of WASA*, pp. 11-18, 2007.

[25] K. Seada, M. Zuniga, A. Helmy, and B. Krishnamachari, ''Energy-Efficient Forwarding Strategies for Geographic Routing in Lossy Wireless Sensor Networks,*'' In Proceedings of ACM SenSystem*, pp. 108-121, 2004.

[26] J. Kuruvila, A. Nayak, and I. Stojmenovic, ''Hop Count Optimal Position Based Packet Routing Algorithms for Ad Hoc Wireless Networks with a Realistic Physical Layer,*'' In Proceedings of IEEE MASS*, pp. 398-405, 2004.

[27] [41] D.A.V.Veldhuizen and G.B. Lamont, ''Multiobjective Evolutionary Algorithms: Analyzing the State-of-the-Art,'' *In International Journal on Evolutionary Computing*, vol. 8, no. 2, pp. 125-147, June 2000. [Online].

*[28]* Long Cheng, Jianwei Niu, Jianmong Cao, Sajal K Das and Yu Gu, "QoS Aware Geographical Opportunistic Routing in Wireless Sensor Networks", *In IEEE Transactions on Parallel and Distributing Systems,* vol. 25, no. 1, pp. 1864-1875, July 2014.

[29] *Praveen kumar kv, M K Banga, "ZEMDC: Zone based Energy efficient Mobile Data Collector in Wireless Sensor Networks", International Journal of Intelligent Engineering and Systems, Vol.10, No.6, 2017,pp 284-292*