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# Improving Quality of Service in Wireless Sensor Networks using Multi-Criteria Decision Algorithm and Tabu Table

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***Abstract*— In this paper, we have proposed a new routing protocol based on Quality of Services (QOS). This protocol is based on data type and quality of services requirements for each data set. With each packet, the protocol tries to perform routing according to QoS-based metrics within data and by considering the energy efficiency of path. This protocol first determines data types in terms of sensitivity to QoS metrics such as reliability, remaining energy and delay in sensor nodes. The proposed protocol applies a combination of multi criteria selection and forbidden table algorithms, in a way that it measures the fitness of each path with different quality of services and energy efficiency and also if a node reaches to a level of energy that it could not transmit data, a flag is considered for it so that the data of neighbors are not transmitted by that node. The proposed protocol has been simulated in MATLAB software and evaluated and compared with god-routing, MCMP and QoS-net. The obtained results show that the mean delay optimality, network life time and reliability have been improved in the proposed protocol.**

***Keywords*—wireless sensor networks, routing protocol, multi criteria algorithm, Forbidden table, pair wise comparisons, Quality of Services.**

## I. INTRODUCTION

With progress of electronic science and increasing development of technology, some pieces have emerged in industry which able to collect their surrounding information and transmit them to informative databases through wireless communications called sensor node. A set of such wireless sensor nodes following a special goal all together is called wireless sensor networks. These networks consist of hundreds to thousands sensor nodes which are distributed either randomly by a machine or airplane or manually and predefined.

Wireless sensor network is applied extensively in different fields like monitoring environment and natural places, target tracking, nuclear reactor control, fire detection, traffic control, military surveillance and etc. [1, 2]. In spite of various applications of these networks, sensor nodes encounters with lack of computational power, memory and battery and energy is so important and worthy for these networks. Sensor nodes have limitations in terms of sensing area and processing capability. Definitely the location of sensor nodes has been predefined and it is not known that whether such property provides this possibility that we could leave them in dangerous or unavailable places. Although each sensor has negligible capability, the combination of hundreds of small sensors offers new facilities. In fact, the power of wireless sensor networks is their ability to apply a lot of small nodes which are self configuring [3, 4, 5, 6]. In wireless sensor networks, usually failure of a node does not influence on the estimated value. In these networks, many sensor nodes are laid in the studied environment or in a closer range to measure the underlying parameter. The places of these nodes have not been predefined where this fact helps the simplicity of placing sensors in the network. But instead, the protocols applied to these networks must be self organized. According to this fact that these sensors have built-in processors, to reduce the amount of information transmission, these sensors send only the required data after processing the sensed data from the environment [7], [8]. Routing is done in network layer and all the applied techniques and algorithms must provide the best path of transmitting information packets from source to destination according to existing constraints and conditions in the network and also given criteria and parameters. Inherent features of wireless sensor network have resulted in its differentiation from cellular, ad hoc and mobile networks.

The rest of paper is organized as follows. In section II, the previous related works on wireless sensor networks have been presented. In section III, the proposed algorithm is described in detail. Section IV is about comparison and evaluation of proposed algorithm with other algorithms and general conclusion is presented in section V.

## II. RELATED WORKS

Due to differences of wireless sensor network with other wireless networks, so many new routing protocols have been proposed to resolve routing problem [9,10,11]. The routing protocols of wireless sensor networks are classified in terms of environment response into multi path based, query based, negotiation based, similarity based and QoS based routing protocols [12]. The routing protocols are classified into three classes namely reactive, non-reactive and their combination based on the way the source finds destination path. Among the best classifications of wireless sensor networks routing protocols, we can point out to the classifications presented in [10] and [13]. This classification classifies routing protocols upon nodes' performance, available information of each node and network goals into four general classes of data centric, hierarchical, QoS aware and location based. So far, many geographical routing protocols have been presented in wireless sensor networks. Most of these protocols use global information of networks and when nodes are fixed or have slight motion [14]. A common feature among all routing protocols is to locate by using local information of nodes. They select the next path among neighbor nodes which are closer to the destination [15]. SPEED protocol [16] is a heuristic routing protocol designed for immediate wireless sensor networks. In SPEED protocol, the speed of rebroadcasting is determined by distance division and estimation of transmission delay. The success rate of packet transmission is mapped to the required speed where the probability of selecting a node with high broadcasting speed is higher than that of a node which has the required speed. If a neighbor node could not satisfy the required broadcasting speed the probability of packet is reduced in order to balance the network workload. Paper [17], MM-SPEED is the extension of SPEED which is used by multiple delivery speeds for packets with a different successful transmission rate to support different QoSs. Designing a network is influenced by various factors. These factors include fault tolerance, scalability, production cost, workplace, sensor network topology, hardware constrains, transmission area and power consumption. This algorithm only deals with energy consumption. This factor is the most important parameter considered in designing wireless sensor protocols. In designing protocols it is tried to reduce the amount of given information to transmit at first by using information processing as much as possible. DARA protocol [18] uses parameters lick remained energy, delay and reliability in routing and it deals with two data packet type in its own method: critical packets and non-critical packets. It uses similar weighted parameter for both data types, but with this difference that only one set of paths with higher transmission power is selected for critical packets. To estimate delay it usually uses queue theory. In LOCALMOR protocol a locating based routing has been presented for wireless sensor networks. The proposed protocol performs routing based on type of network traffic and for various applications it performs routing in order to improve the QoS requirements. Data traffic is classified into a number of groups in terms of QoS requirements, where various routing techniques are applied for each group. The protocol is designed over modules based on traffic classification. For each packet it tries to satisfy QoS based requirements with energy efficiency. The proposed routing algorithm in paper [19] is a routing for real time systems. Real time routing protocols have time constraint. In designing real time routing in wireless sensor networks, time has great importance.

1) In this algorithm, a new type of communication was presented which is called quadrant based geodirectioncast-forwarding, where it is the combination of geocast and directional forwarding in order to send the packet through multiple paths to the destination, so that multi path forwarding increases the delivery ratio.

2) It gives a real time routing protocol with load distribution where it evaluates the optimal forwarding node based on packet reception rate (PRR), remaining energy of sensor nodes and single hop packet speed. Since the forwarding nodes are selected with the best quality of link, and then data throughput is optimal. By selecting the forwarding nodes with maximum packet rate, transmission of real time packet is ensured. The successive selection of such nodes distributes traffic load in neighbors towards the sink and on the other hand it increases the network lifetime. RTLD protocol has presented high efficiency based on delivery ratio, packet overhead control and energy consumption. In addition to development of real time routing in wireless sensor networks, the rate (speed) of packet is also used in forwarding computations.

In this protocol, the quality of link is studied in physical layer to predict the communication among sensor nodes. In general, the remained energy is estimated so that the distribution of traffic load is broadcasted along forwarding path to the destination. In [20], an analytical framework has been presented to cover and lifetime of wireless sensor network which follows two dimensional Gaussian distribution. Also, it has studied coverage and lifetime along acceptance of different Gaussian parameters (standard deviation,$\sigma_x \neq \sigma_y$) by Gaussian dispersion dimension$(x, y)$. It identifies the main features of coverage/lifetime in terms of Gaussian distribution parameters which is a major issue in designing a wireless sensor network. The strategies of sensor establishment for wireless sensor network which would be able to estimate the predefined coverage and lifetime have been determined by analyzing the obtained results. two establishment algorithms have been developed based on using analytical models and it has shown that the lifetime of wireless sensor network has been increased significantly. In [21], a new routing strategy has been presented to satisfy quality of services in large-scale wireless sensor networks. The existing routing algorithms whose goal is to satisfy QOS only concentrate on networks' reliability. QoS-NET algorithm is divided into two sub network consisting of extended nodes in isolated level. The first subsidiary network includes cellular controllers and the second sub network consists of remained sensor nodes. By considering QOS parameters such as delays and reliability, the routing strategy of QoS-NET has been designed for large-scale WSNs whose goal is to develop network lifetime.

## III. THE PROPOSED PROTOCOL

The proposed protocol is based on providing the best QoS and is a heuristic algorithm. In the proposed routing protocol, we assign a rank to each QoS of path from source to destination in terms of applications' requirement and select the path according to the best QoS. The proposed routing algorithm is intended to simultaneous optimization of multiple QoS parameters (consuming energy, delay or reliability) where to do so multi criteria algorithm [22, 23] and Tabu algorithm have been used. At first we evaluate the priority of each quality where this priority is the significance amount of each quality of services. for example, if in the given packet its energy is three times important than reliability, we consider the priority of energy over reliability as 3 and priority of reliability over energy as 1/3. Then by using the following formulas(1-5) we obtain the rank of each QoSs, this is done to obtain a number for each path by using these formulas. This number represents the efficiency of paths. The more the efficiency of a path, that path is selected and the packet is transmitted from that path.

$$w = \begin{bmatrix} W_{\frac{D}{R}}/W_{\frac{D}{R}} & W_{\frac{D}{R}}/W_{\frac{R}{E}} & W_{\frac{D}{R}}/W_{\frac{E}{D}} \\ W_{\frac{R}{E}}/W_{\frac{D}{R}} & W_{\frac{R}{E}}/W_{\frac{R}{E}} & W_{\frac{R}{E}}/W_{\frac{E}{D}} \\ W_{\frac{E}{D}}/W_{\frac{D}{R}} & W_{\frac{E}{D}}/W_{\frac{R}{E}} & W_{\frac{E}{D}}/W_{\frac{E}{D}} \end{bmatrix}. \quad (1)$$

$$Sum_{weight} = \left[ W_{\frac{D}{R}}/W_{\frac{D}{R}} + W_{\frac{R}{E}}/W_{\frac{D}{R}} + W_{\frac{E}{D}}/W_{\frac{D}{R}} \quad W_{\frac{D}{R}}/W_{\frac{R}{E}} + W_{\frac{R}{E}}/W_{\frac{R}{E}} + W_{\frac{E}{D}}/W_{\frac{R}{E}} \quad W_{\frac{D}{R}}/W_{\frac{E}{D}} + W_{\frac{R}{E}}/W_{\frac{E}{D}} + W_{\frac{E}{D}}/W_{\frac{E}{D}} \right]. \quad (2)$$

$$WS = \begin{bmatrix} w_{1,1}/Sum_{weight(1)} & w_{1,2}/Sum_{weight(1)} & w_{1,3}/Sum_{weight(1)} \\ w_{2,1}/Sum_{weight(1)} & w_{2,2}/Sum_{weight(1)} & w_{2,3}/Sum_{weight(1)} \\ w_{3,1}/Sum_{weight(1)} & w_{3,2}/Sum_{weight(1)} & w_{3,3}/Sum_{weight(1)} \end{bmatrix}. \quad (3)$$

$$S = \begin{bmatrix} \frac{w_{1,1}/Sum_{weight(1)} + w_{1,2}/Sum_{weight(1)} + w_{1,3}/Sum_{weight(1)}}{3} \\ \frac{w_{2,1}/Sum_{weight(1)} + w_{2,2}/Sum_{weight(1)} + w_{2,3}/Sum_{weight(1)}}{3} \\ \frac{w_{3,1}/Sum_{weight(1)} + w_{3,2}/Sum_{weight(1)} + w_{3,3}/Sum_{weight(1)}}{3} \end{bmatrix}. (4)$$

$$\begin{bmatrix} weight\ Delay \\ weight\ Relibility \\ weight\ Energy \end{bmatrix} = \begin{bmatrix} S_{1,1} \\ S_{2,1} \\ S_{3,1} \end{bmatrix}. (5)$$

Formulas listed in table I are for normalizing QoSs and paths.

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Table I: normalization concepts

| | |
|---|---|
| It specifies the priority of QoS | W matrix |
| It sums columns to obtain the significance of whole QoSs. | sum_weight matrix |
| It divides each item in terms of significance of whole QoSs. | WS matrix |
| It sums rows to obtain the efficiency of each QoSs. | S Matrix |
| Delay rank | weight Delay |
| Reliability rank | weight Relibility |
| Energy rank | weight Energy |

In this algorithm it has assumed that all the nodes are fixed and has individual identifier and we consider three types of packets including:

1- Critical packets
2- Packets sensitive to delay and energy
3- Packets sensitive to reliability

We consider a queue for each packet so that as soon as a packet created it places in that queue. Of course, queues also have priority, in a way that at first packets within critical queue are sent, then packets within a queue sensitive to delay and energy and at last packets sensitive to reliability.

We consider a set of nodes within that range as that node's neighbor set in order to find the neighbor of node i. we apply formula 6 to do so.

(7)

$$neigbore\ of\ node_i = if\ x_i - range \le x_j \le x_i + range \quad or\ y_i - range \le y_j \le y_i + range$$

After obtaining paths we compute the fitness of each one and consider the required path for packet as a proper path and send the packet from that path and update these paths in particular time intervals.

Where the fitness function will be as 8-10:

$$\mathrm{D}(\mathrm{route}_j) = Delay\ weight \times \sum_{i=1}^{n} D_i. \quad (8)$$

$$R(\mathrm{route}_j) = Relibility\ weight \times (1 - \prod_{i=1}^{n}(1-R_i)) . \quad (9)$$

$$E(\mathrm{route}_j) = Energy\ weight \times \sum_{i=1}^{n} E_i. \quad (10)$$

Along path whenever a node sends a packet or receives a packet, the node transmitter and also receiver would lose energy, where the 11-13 equations are used.

$$E(resive) = \mathrm{Distance}(k+1,k) * \mathrm{Eelect}. \quad (11)$$

$$E(send) = Eamp * Paket\_size * Distance(k+1,k)\text{^}2. \quad (12)$$

$$Distance(k+1,k) = \sqrt{(x_{k+1} - x_k)^2 + (y_{k+1} - y_k)^2}. \quad (13)$$

TableII: sending and receiving energy formula description

| | |
|---|---|
| $E_{amp}$ | 0.0013 * 10^(-12) |
| $E_{elect}$ | 50 * 10^(-9) |
| K+1 | Node k+1 |

After obtaining the QoS of each path, we obtain the pair wise comparisons [24, 25] over each path over other paths. After calculating each path, the fitness of the best path is specified. Tabu bits of proposed protocol:

1- Tabu bit for node: we assign a state bit for each node. In the proposed protocol the energy threshold is 5J. Whenever the node energy reaches threshold, the node goes into sensing mod and it can not send a packet to its neighbors and only senses its own surrounding.
2- Tabu bit for path: one tabu bit is considered for each path. When a packet is transmitted from path, this bit is set to one and a packet is sent from that path no longer. With this bit we could balance the traffic in whole network, since we can not send simultaneously multiple packets from a single path and all paths are applied and no traffic is created. When the bit of all paths becomes one, again new paths are produced and bits reset.

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When we have paths whose nodes could not send packets, all the tabu bits become zero. The pseudo code of proposed protocol has been represented in Table III.

TABLE III. PSEUDOCODEOFPROPOSEDPROTOCOL

| **Pseudo code of proposed protocol** |
| --- |
| Initialization<br><br>Broadcasting nodes<br><br>Calculate distance of each node<br><br>Calculate reliability<br><br>Calculate neighbor of each nodes<br><br>Number for Energy priority<br><br>Number for reliability<br><br>Number for delay priority<br><br>Quality of service Rating determined using paired comparisons<br><br>Specify the types of packets<br><br>Create directories based on the packet directions<br><br>Priority routes<br><br>Send packets |

## IV. PERFORMANCE EVALUATION PROTOCOL

In this section we compare our proposed algorithm with algorithms MCMP [22], Qos_net[21], GOD_routing[21]. The proposed protocol considers energy efficiency, reliability and delay in routing. Our main goal is to increase the performance of network by energy balancing. Therefore, it is used as a metric of energy efficiency, reliability and delay. We will use 900 nodes in an 1800m$^2$ area at 1000s to simulate. High number of nodes lets the given protocol be scalable. The nodes have been distributed randomly. The radius of transmission power is about 100m and average density is 8.

In simulation, critical packets sensitive to delay, energy and reliability have been used. Figures 1-4 show the output of proposed algorithm according to the efficient parameters. We have run the proposed algorithm 15times, then calculated the average of whole obtained results to reach the final result. The proposed protocol balances traffic, since the tabu bit of a path from where a packet is sent becomes one so that no packet is sent from that path and it has the least battery discharge and its energy depletion is done slightly which is better than protocols MCMP, GOD_routing and Qos_net. Balancing traffic has direct effect on network lifetime, namely when the first node's battery is finished. Figure 1 shows reliability based on packet delivery rate where the reliability of proposed algorithm is only one percent less than algorithm Qos_net, but in turn the network lifetime of the proposed protocol is more and in the proposed protocol it discards less number of packets over protocols God-routing and MCMP, but in algorithm Qos_net less number of packet is discarded compared with our proposed protocol.

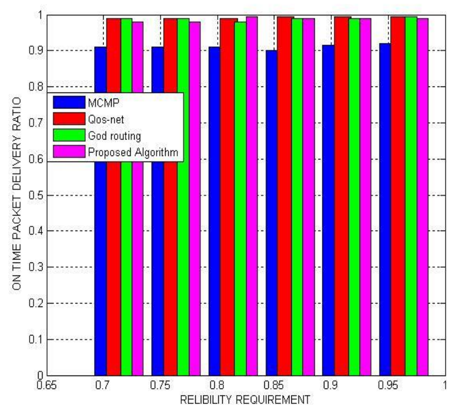


Figure 1: reliability evaluation of proposed protocol

Figure 2 represents the required delay to send a packet. As figure shows, our proposed method has the highest packet delivery rate with the least delay, because in the proposed method we have considered multiple QoS parameters simultaneously. Of course, the packet delivery rate is higher in algorithm God-routing and the packet delivery rate in our protocol is higher due to this fact that we have used those paths that have more remaining energy.

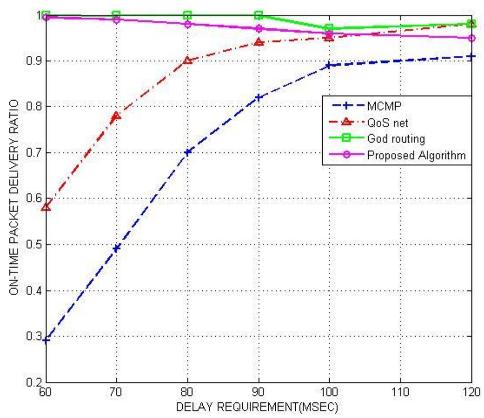


Figure 2: the comparison of required delay to send a packet in the proposed protocol

Figure 3 shows the network lifetime with different number of nodes which is the descending order to proposed algorithm with low slope in comparison with other algorithms which is due to traffic balance in the network where this balance is due to tabu bits considered for each node and path and according to the uniformity of load balance in whole network, the lifetime of network is higher in the proposed protocol.

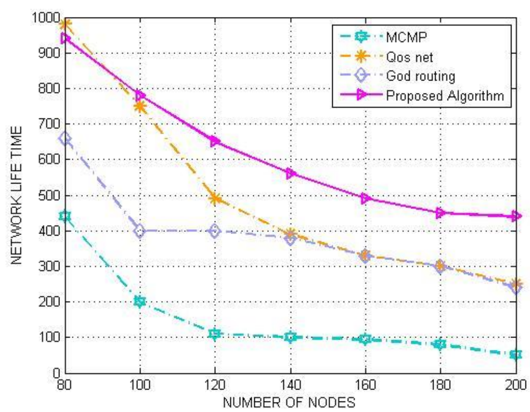


Figure 3: The comparison of network lifetime with different number of nodes in the proposed protocol

Figure 4 portraits the average delay.With respect to number of nodes,it shows that when the number of nodes increases, the average delay is reduced. According to the routing delay that is considered in proposed routing algorithm and a path that with minimum delayshould be chosen, using paired comparisonsleads to less delay.

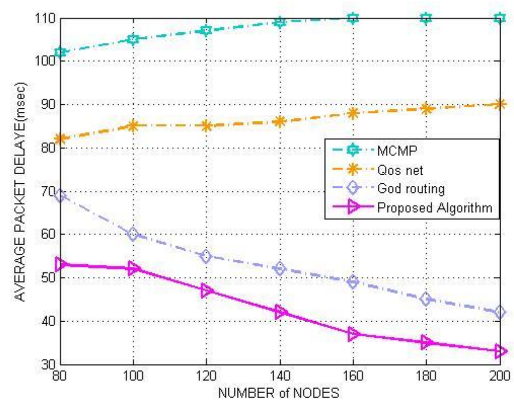


Figure 4: The comparison of average paket delay with different number of nodes in the proposed protocol

## V. CONCLUSION

In this paper, a routing protocol has been introduced for wireless sensor network which has improved path delay, network lifetime and reliability . The proposed algorithm is based on a combination of multi criteria algorithm and tabu table. In order to have longer network lifetime, the energy must be consumed in all the sensor nodes in a balanced manner and a subset of nodes must not consume more energy. Therefore, the network lifetime increases by making balance in energy consumption. The proposed algorithm has been implemented in MATLAB software and the obtained results were compared with the results of MCMP, God_routing and Qos_net methods.The obtained results show that the mean delay optimality, network life time and reliability have been improved in the proposed protocol.

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