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Energy Efficient and Quality-Of-Service Based Routing Protocol for Wireless Sensor Network

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Abstract
Wireless Sensor Networks (WSN) is an eminent field of research in the era of Internet-of-Thing(IoT) based systems. Development of small size, durable sensors fuelled the growth and due to it's characteristics WSN is applicable in almost all parameter monitoring systems. WSN has applications in structural monitoring of civil structures, precision agriculture, military and healthcare domain. In certain applications, timely and reliable delivery of data sensed by node is the prime task of WSN. Quality of Service (QoS) provision techniques normally depletes much energy which is limited resource in WSN; hence QoS based routing algorithm should be energy efficient. In this paper, Energy Efficient and QoS based Routing Algorithm(EEQRA) is proposed. Proposed algorithm is having two stages, route exploration and data transmission. Out of these two phases route discovery phase is discussed. For efficient route exploration, ant colony optimization technique is used. This work claims new technique using which QoS based path is decided without consuming significant energy. Routes found during the route exploration steps are based on Q factor value. The novelty of the work is that path can be calculated by providing importance to QoS parameter under consideration.

Keywords *– Wireless Sensor Network, Routing, Quality of Service based routing protocols, Ant Colony Optimization*

I. INTRODUCTION

A WSN is a set of tiny sensor nodes which communicate over wireless links having bandwidth constraints. As it is a kind of ad-hoc network, all kind of activities related to the network such as self-movement (if needed), media access, routing etc., must be handled by sensor nodes. Wireless sensor networks (WSN) is a very eminent field of research having a variety of applications, in the field of agriculture, monitoring of civil engineering objects like landscapes, bridges which may be too remote for deployment of wired network infrastructure. Another situation is to deploy the sensor nodes in harsh conditions which are not suitable for conventional surveillance by humans. WSNs can be used to during measurement of several physical phenomena like soil moisture, ambient temperature, vibrations, fluid levels, structural monitoring of civil objects, animal tracking, battlefield surveillance which are crucial tasks in precision agriculture, healthcare, forest monitoring, logistics and transportation, and military applications.

Wireless sensor nodes are battery powered electronic devices. In most of the applications, sensor nodes are deployed in harsh environmental conditions wherein recharging batteries is not possible. For example, in geographical conditions such as battlefields, dense forest etc. sensor nodes are not easily accessible and hence their batteries cannot be recharged. Hence energy consumption

minimization is challenging task in wireless sensor networks. Reduction in energy usage results in increased network lifetime [1].

Besides energy issues, several applications of WSNs require timely and reliable delivery of sensed data to base station or sink. In this case, best possible path should be determined over which sensed data can be forwarded. Quality of Service (QoS) related metrics can be used to determine such a path. Due to differences in characteristics of WSN and conventional ad-hoc network, traditional QoS parameters are not enough while finding out the best possible path.

Due to drastic increase in number of internet users, it is becoming difficult for service providers to maintain QoS over the link. On the similar side, in certain applications like battlefield surveillance, timely and accurate delivery of data is must. It means routing algorithm used in this application must find a route from source node to base station which would offer minimum delay and minimum error. QoS parameters include end-to-end delay, throughput, hop count and link bandwidth. Once a parameter is decided then QoS based routing algorithm should find such a route which would satisfy requirement. In conventional networks, QoS provision techniques use strategy of extensive resource allocation. This technique is not possible in WSN due to limited energy source. So QoS based routing algorithm in WSN should have objectives such as i) To find the best possible path from source node to base station which satisfies pre-decided QoS requirement, ii) To utilize available resources optimally and iii) To sustain any untoward incidence happened in the network during run time [12]. In this work, proposed algorithm is developed which is satisfying first objective.

II. Related Work

Exponential growth of multimedia applications has accelerated the need of QoS based routing algorithms and associated support in WSNs. In multimedia applications minimum delay and enhanced throughput are the prime requirements.

Alba Rozas and Alvaro Araujo proposed improved version of Low-Energy Adaptive Clustering Hierarchy (LEACH protocol) called as LEACH-APP [3]. Each member of cluster will get a time slot in which cluster member will be sending data to cluster head which in turn sends data packets to base station. Priority is assigned to nodes and based on the priority extra slots will be added to nodes having higher priority. Performance of the LEACH-APP protocol is compared with LEACH on the basis of QoS parameters such as throughput at the sink node and latency of packets from source to base station. LEACH-APP commits 250% performance improvement in throughput as compared to LEACH. Also, LEACH-APP requires 80% less delay as compared to LEACH.

Ghassan Samara, Mohammad Aljaidi proposed efficient, energy aware and least cost (ECQSR) protocol [4]. ECQSR aims to balance traffic load by dividing traffic between several nodes. Along with traffic balance, energy consumption is also balanced resulting in enhanced network lifetime. In ECQSR, sensor nodes are distributed in the network in such a way that data transfer between the nodes would be more flexible. For sensor node distribution nearest neighbour (NN) algorithm is used in ECQSR. Performance of ECQSR is compared with simulated annealing (SA) algorithm. It has been proved through computer simulation that ECQSR performs better in terms of enhanced network lifetime and reduced power consumption.

Archana S, Saravanan.N.P discussed about enhanced BiO4SeL QoS aware routing algorithm (EBiO4SeL). This algorithm is having three phases as neighbour node discovery, route exploration and maintenance phase. During route exploration phase, ant colony optimization (ACO)

is used for path sink node discovery from source node to sink node. ACO based algorithms proved their usefulness in many engineering applications and hence it has been used in this algorithm too. To decide best possible path, during route exploration phase, information about the path is gathered and best possible path is decided at. In case of route failure, new path is decided based on pheromone value. Performance of EBiO4SeL is compared with BiO4SeL on the basis of packet delivery ratio, node's network lifetime and it performs better than BiO4SeL. Tunable QoS parameters is the main feature introduced by EBiO4SeL.

B. Chandra Mohan and R. Baskaran surveyed literature available on Ant Colony Optimization, a technique inspired from ant's behaviour. The major contribution of this literature is that authors has presented applications of ACO in major engineering branches like core engineering and circuit branches. As far as application of ACO in routing algorithm is concerned, authors summarized prominent routing protocols which has been developed using ACO. Single and multipath routing algorithm's mathematical model is presented, and algorithms are implemented on network simulator. It has been concluded that small changes or improvements in procedural steps of ACO, leads to excellent improvement in results [6].

Ze Li, Haiying Shen developed QoS-Oriented Distributed (QOD) Routing Protocol for Hybrid Wireless Networks [7]. Hybrid networks are the networks in which different kind of nodes are connected. Every node in such a network can play dual role of transmitter as well as receiver. QOD employs three major algorithms while assuring quality of service. These algorithm includes QOS guaranteed neighbour selection, distributed packet scheduling algorithm and mobility based segment resizing algorithm. These algorithms ensure efficient, timely delivery of packets by taking advantage of neighbour's properties. Performance of QOD is compared with E-AODV which is enhanced version of AODV. Mobility, workload and network size are the three parameters which are used to compare these two protocols. QOD outperforms E-AODV when these protocols compared in a scenario in which nodes are having different mobility, different workload and a different network size.

III. PROPOSED PROTOCOL

Proposed work is related to QoS in wireless sensor network. With the advent of advances in microelectronics and MEMS technologies, sensor network hardware is more capable in terms of processing speed, memory as compared to their early counterpart. Conventional routing algorithms are not enough in WSN when it comes to QoS provision [11]. But only QoS is not important hence along with QoS, stress is to be given on average energy consumption and abrupt changes in network environment. Development of QoS based routing algorithm for WSN to determine the optimal routing path meeting the demand of QoS from available path is the primary objective.

3. 1 System Model and Assumptions

Wireless sensor network model can be represented as graph as shown in Fig.1. Let G(V,E) represents graph of sensor nodes which are treated as set of vertices V which are connected through set of edges E. Vertices are labelled as v_1, v_2,…… v_n and E is set of edges labelled as e_1, e_2,…… e_n . Set of vertices and set of edges are described in equation3.1 and 3.2.

$$V \in (v_1, v_2, \ldots\ldots v_n) \quad (3.1)$$

$$E \in (e_1, e_2, \ldots\ldots e_n). \quad (3.2)$$

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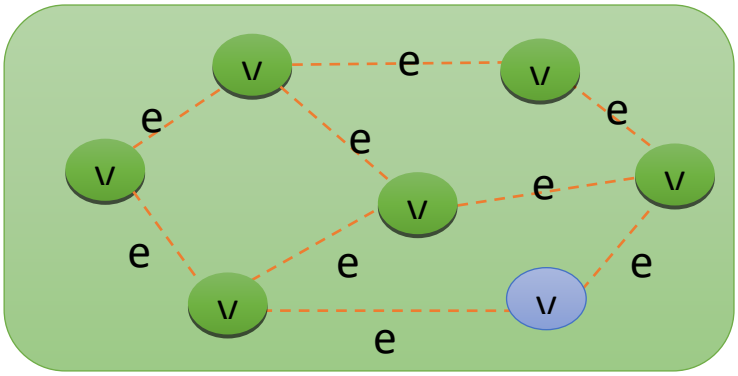

Fig. 1: Proposed model of Wireless Sensor Network

Data sensed by any source node should reach to sink node. User can access the sink node, if required. It is assumed that all sensor nodes are structurally and functionally same. Also it is considered that all sensor nodes are stationary. Data sensed by source nodes needs to be sent to sink node via multi-path link, generally. There are resource constraints on sensor nodes in terms of power, processing capability, storage etc. Sink node which is shown by different colour in Fig.1, not having such restrictions. Hence WSN model should consider these constraints.

To evaluate the performance of proposed algorithm, performance metric chosen are delay, energyand hop count.In proposed algorithm, total delay for the path is to be considered. To do so, delay at node as well as delay incurred during transmission, both is to be considered.

$$DelayD_{ij} = \sum_{e_{ij}\in E} Propagation\&trans.delay + \sum_{V_i\in N} Queing\&Proce.delay \quad (3.3)$$

For sensor node, energy is required during transmission as well as to remain in sleep mode otherwise.

$$E_i = e_{i0} - (cw.\sum_{j\in N, i\neq j} X_{ij} + ct.\sum_{j\in N, i\neq j} d_{ij}.X_{ij}),\ all\ i \in N, i \neq n \quad (3.4)$$

Where e_{i0} is initial energy of i^{th}node, for all $i\in N$, $(e_{i0} > 0)$,cw is energy depleted during sensor wake-up and ct is the rate of energy depletion during transmission. Both $cw$and$ct$are assumed as constant.

3.2 Energy Efficient, QoS based Routing Algorithm (EEQRA)

The proposed algorithm is divided in 2 phases as route exploration and data transmission, out of which first phase is discussed in this paper.

3.2.1 Route Exploration

All nodes are supposed to send information to sink node whenever significant event occurs. As sensor nodes are having constraints in terms of energy, available memory; proactive routing algorithms are not efficient. Also sometimes nodes may move from one place to another. In that case also, use of proactive routing algorithms is not a feasible solution. So the algorithm is reactive routing algorithm which does not maintain list of routes to each node, rather it explores routes as and when needed. The proposed algorithm is based on ant colony optimization.This phase of routing algorithm is again divided in to 2 parts; route request and route reply.

In Route Request phase, source node S will create forward agent which will have forward agent packet as payload. Initially S is not aware of neighbours so it will broadcast forward agents. S also mentions sequence number for each agent. At intermediate node, forward agent packet will be checked and packet will be added in it's route list and forwarded in two conditions. First condition is if source node and sequence number is not present in it's route list and second condition is if path travelled by particular agent is subset of path of already forwarded agent. Forward agent processing at intermediate node n is carried out as per Algorithm 1.

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```
Find source id and sequence number combination
  IF (agent with such combination is already forwarded)
      Find out the route travelled by agent and compare with existing routes
      IF (current agent path is a subset of already existing route)
            Accept the FA packet;
      ELSE
                                          ENDIF
  FA.MRE=min(FA.MRE,n.RE);
  FA.TE+=n.RE;
FA.VN[ ]= id of node n at appropriate place;
  IF (node n has routing information about destination node D)
      Unicast the forward agent;
  ELSE
      Broadcast the forward agent;
  ENDIF
```

Algorithm 1: Forward agent processing at intermediate node n

These forward agent packets will reach destination node where these packets will be processed to make path table in which Quality factor values (Q) will be calculated for each path as per equation 1 shown below.

$$Q_i = \frac{FA.MBR * FA.TE}{D_i * HC_i} \quad (3.5)$$

where Q_i is the quality factor of i[th] path and it is directly proportional to minimum battery remaining (MBR) and total energy (TE) of that path. Q_i is inversely proportional to delay (D) incurred while travelling from source to destination and hop count (HC). Forward agent processing will be carried out at destination node as per Algorithm 2.

```
i=0; t=0;
WHILE Forward agent is received AND t<β*DiDO
     Calculate delay Di;
     Calculate the Q value for path PATHi;
     Qi = FA.MBR*FA.TE / Di*HCi
     Store Qiin path table;
     i++; t++;
REPEAT
Sort path table according to Qi;
Select Δp paths where Δp = Δ * total paths in path table (Δ≈ 0.5)
For every Δp paths create backward agent BA as per the packet format.
```

Algorithm 2: Forward agent processing at destination node

3.2.2 QoS Based Path Selection

In applications of wireless sensor networks, QoS requirement is variable. QoS parameter specific, best possible path is required. EEQRA algorithm is having provision for this requirement. As per equation 3.5, QoS value is calculated at destination node based on energy, delay and hop count. EEQRA can specify the route to be used for specific QoS parameter.

IV. RESULTS

MATLAB® is chosen as simulation tool for implementation of an algorithm. Simulation parameters are summarized in Table 1.The program written in MATLAB®, is accepting total number of nodes and source node number from the user. Then it finds it's immediate neighbours using distance of 20 m as criteria. Every intermediate node is then processing the forward

agent created by source node as per algorithm 1. Finally, destination node receives forward agents and prepare the QOS table as described in the algorithm 2.

TABLE I: SIMULATION PARAMETERS

Parameter	Description
Area	100 m X 100 m
No. of nodes	20 – 200
Position of nodes	Random
Position of sink node	(30 m, 50 m)
Initial energy	0.5 Joule
Energy required to transmit 1 bit	50 nJ
Energy required to receive 1 bit	50 nJ

Network topology is shown in Fig. 2. Blue coloured circles indicate sensor nodes while green coloured plus sign represents sink node.

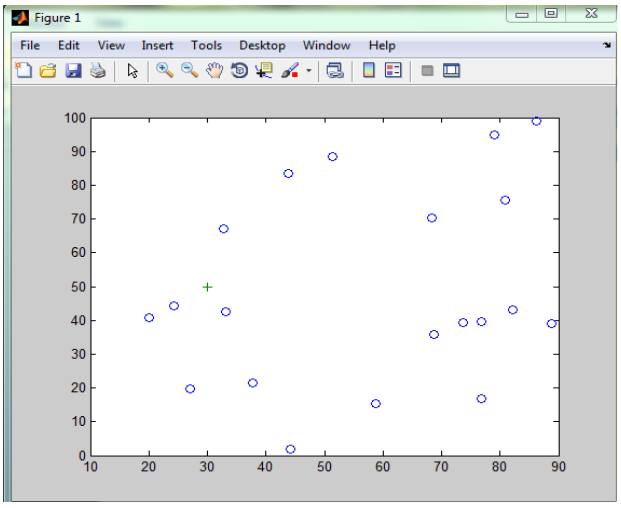

Fig. 2. Sensor Network Topology

As a result of route exploration phase, QoS table is generated. Sample QoS table is shown in Table II. It is observed from Table II that different paths can be generated based on data gathered from forward ants generated by source node.

TABLE II: QOS TABLE GENERATED AT SINK NODE

Path	QoS Value
2 – 21 – 31	0.0604
2 – 15 – 31	0.0486
2 – 11 – 31	0.0405
2 – 3 – 31	0.0348
2 – 14 – 27 – 31	0.0223
2 – 14 – 22 – 31	0.2004
2 – 21 – 28 – 31	0.0189
2 – 21 – 1 – 31	0.0175
2 – 21 – 17 – 31	0.0164
2 – 21 – 18 – 31	0.0154

As per Table II, first path is having highest QoS value which is shown in Fig 3. Also, as discussed in 3.2.2, EEQRA can find out QoS parameter-based path. User must specify the parameter and EEQRA can find the best possible path in the network. One such scenario is shown in Fig. 4.

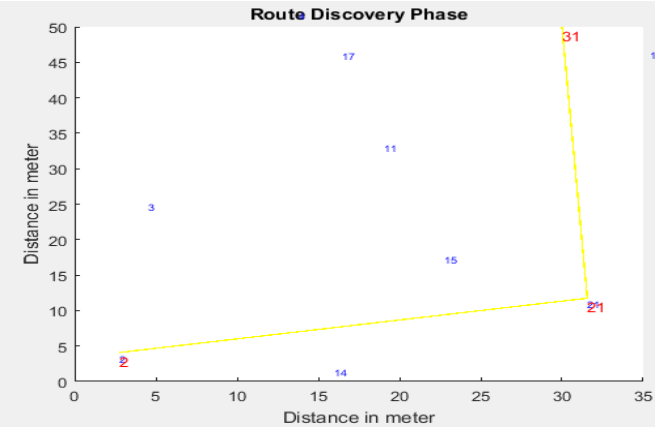

Fig. 3. Overall QoS based path given by EEQRA

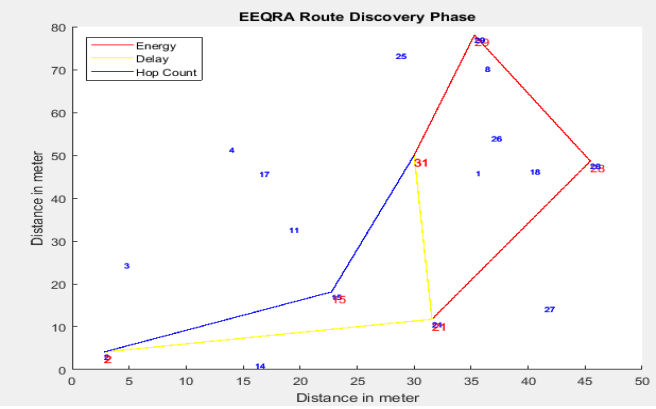

Fig. 4. QoS parameter based path given by EEQRA

V. Conclusions

EEQRAis ant colony optimization-based routing algorithm used to find out the QoS based best possible path in WSN. Ant Colony Optimization (ACO) has been useful for many engineering applications and it has proven worth in finding out the best possible path and EEQRA is not an exception. Basic ant colony optimization algorithm is modified with inclusions of parameters controlling the QoS factor. The advantage of this technique is that based on requirement, best suitable path can be determined with EEQRA protocol. QoS parameter specific path determination by one algorithm is unique feature of EEQRA. If algorithms of machine learning are combined with EEQRA then resultant algorithm will be more efficient.

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