QUALITY OF SERVICE BASED ROUTING ALGORITHM FOR WIRELESS SENSOR NETWORK

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Abstract: *Wireless Sensor Network (WSN) is a network comprised of nodes having sensing, processing and communication abilities. Due to its inherent capabilities, WSN can be deployed at remote locations to monitor physical parameters changes. Sensor nodes are generally battery-operated, and due to limited energy resource, WSNs suffer from less network lifetime. Routing algorithms used in WSN should be energy efficient and should provide application-specific quality-of-service. This paper describes the Energy-efficient Quality of Service (QoS) Aware Routing algorithm, which calculates the best possible path to the sink node satisfying the required QoS. The proposed routing algorithm uses ant colony optimization and considers delay, hop count, and energy as routing metrics. The proposed algorithm outperforms Energy-Efficient QoS-Aware Intelligent Hybrid Clustered Routing Protocol (EQIHCR) in terms of energy consumption, delay and packet delivery ratio.*

Keywords: **WSN, QoS, Routing Algorithm, Ant Colony Optimization**

1. Introduction

In the current Industry 4.0 era, technological developments in the sensors lead to use of sensor networks to monitor variety of physical parameters. Wireless Sensor Network (WSN) is defined as an infrastructure composed of sensing, computing and communicating elements that give users the ability to observe and reach events and phenomena in a specific environment [1]. Due to recent developments in microelectronics and embedded systems, WSNs play a significant role in wildlife monitoring, undersea monitoring, military surveillance, automation etc.

Deployment of WSN to monitor the required parameter depends upon the requirement. Generally the nodes in WSN are battery operated, hence has limited lifetime. Sensor node is having components like sensing unit, processor, memory and transceiver. The performance of a WSN is measured by average power consumption as network lifetime depend on it. Usually, energy consumption is only the parameter of concern in WSN [2]. But certain applications like battlefield surveilliance, forest fire monitoring requires desired value of parameters like delay, bandwidth in addition to energy consumption. This leads to use of Quality of service (QoS) concept in WSN. QoS is defined as a collective effect of chosen performance parameters, which satisfies user application's requirement. For example, in military surveilliance application, captured image or video should be sent to base station within time limit with desired quality of image or video. So this application, requires good value of delay, throughput and jitter to be maintained to achieve desired QoS [3].

Conventional QoS mechanisms being used in wired networks like overprovisioning, buffering, traffic shaping, aren't suitable for WSNs. The reason behind the same is limitations on resources like memory, processing abilities, transmission and reception

capabilities available with sensor node. There are several techniques to achieve desired QoS in WSN and use of appropriate QoS based routing algorithm is one of them. Routing is nothing but finding out the best possible path from source to destination. Satisfying QoS requirements in real-time applications pose multiple challenges on WSN. Hence in real time applications, routing algorithms should use innovative methodologies to maintain QoS over an prescribed time period. These algorithms should be adaptive to the real time changes in application's state[4].

In wireless sensor networks, maybe event-driven or query-driven, data is to be forwarded from one node to another over a suitable path. This path should be energy efficient, providing the required QoS. Finding out the best possible path satisfying both the requirements is a tedious task and requires an optimized solution. Ant colony optimization, which is inspired from ant's behavior during foraging of food. Finding the best possible path involves traversing all the possible paths from source to destination, gathering information about required parameters, and selecting the path offering the best value of the chosen parameter. Nodes on the selected path will be updated accordingly in terms of pheromone, a chemical substance secreted by ants over the traversed path. The next node will be selected based on probability calculation involving pheromone and required parameter during data packet forwarding process. Each node maintains pheromone table and this table gets updated after forwarding the data packet[5].

2. Related Work

Energy consumption is an important issue related to routing in wireless sensor networks (WSNs). As stated before, sensor nodes are constrained in terms of energy supply, storage, and bandwidth. Such constraints combined with a typical deployment of a large number of sensor nodes pose many challenges to the design and management of sensor networks.

N. Z. Cedeno et.al [6] , studied AODV routing protocol which is very popular protocol in wireless networks. AODV is used in wireless sensor networks as a routing protocol. Authors discussed about QoS parameters like packet delivery ratio, throughput. It is observed that with the increasing number of nodes, QoS parameter values got improved.

In [7], detailed survey about energy consumption techniques is presented. The main contribution of this survey is that it has considered energy consumption for communication and sensing is considered separately. It also highlighted, work done by different authors in these fileds.

Parvinder Singh and Rajeshwar Singh highlighted problems raised due to improper cluster head selection in clustering algorithms like LEACH [8]. Authors concentrated on the selection of an appropriate cluster head using fitness function to reduce energy consumption and load balancing. For the selection of node as a cluster head, node's distance from base station, number of nodes in the cluster, the node's frequency of becoming a cluster head is considered. Repeated data transfer is also avoided. Simulation results show considerable improvements in energy consumption and QoS parameters. However, the authors didn't think security and privacy issues during data transfer on channel.

Ghassan Samara, Mohammad Aljaidi [9] described efficient energy, cost reduction and QoS based routing protocol (ECQSR). Energy consumption is controlled by dividing the data traffic among nodes in the field, achieving the load balancing. In addition to this, the proposed algorithm uses forward error correction for reliable data delivery. Cost reduction is achieved by selecting the best path offering the least cost. Such a path is determined using nearest neighbor algorithm. The proposed algorithm is compared with simulated annealing algorithm on the basis of path-length average in which ECQSR offer the energy-efficient, least cost path satisfying required QoS. However, the authors do not describe the methodology clearly, and QoS parameter calculation process in not mentioned.

Alba Rozas et.al. [10] discussed constraints and difficulties for QoS management, which can be network or application specific. According to authors Low-Energy Adaptive Clustering Hierarchy (LEACH) is widely used routing protocol due to clustering mechanism leading to less energy consumption. However LEACH is not QoS-aware. To add QoS awareness, authors propose LEACH-APP, a new clustering protocol based on LEACH that takes the network's application into account and aims to provide a better overall QoS management. LEACH-APP is designed for network with different types of traffic originated from multiple sources. Further, packets from each traffic class is grouped to make traffic category. Each category is assigned with different priority which is determined as per importance of network's application. Based on user's environment or input, priority of each category can be modified during run time. The authors' experiments show that use of LEACH-APP results in increase the throughput of system by roughly 250% and decreases the latency by almost 80%. LEACH-APP provides a more supple and prevailing QoS management. But it should be noted that LEACH-APP focuses on optimization of QoS for selected traffic streams. It does not guarantee QoS parameter fulfilment. Also, it has been observed that non-prioritized traffic suffers from the inadequacy of resources. But overall, it is a good protocol as far as clustering-based protocols are concerned.

L. Aziz and H. Aznaoui [11], proposed another approach for achieving energy efficiency. This approach use multicriteria model for selection of forwarder node. This method improves intercluster communication by selecting efficient hops. The proposed protocol performs better than LEACH in terms of network lifetime and residual energy. The cluster heads can also be selected as per weight calculated on the basis on residual energy and distance between cluster head and source node. This kind of methodology is used in [12]

The work described in [5] , is about calculating short length and energy-efficient path in WSN. Artificial ants called forward agents are created by source node and travel on all possible destinations. During the journey, the forward agent collects information about concerned parameters. One ant called backword agent will be created at the destination node which travels on reverse path modifying pheromone values. During the data transfer phase, every node selects the next node based on energy and pheromone value. However, the authors mentioned that they did not consider energy-saving techniques based on node movement.

3. Network Model and Assumptions

Energy Efficient QoS Aware Routing Algorithm (EEQRA) aims to improve the quality of service in wireless sensor network. This can be achieved by an efficient routing algorithm. So, the main aim of EEQRA is to develop QoS based algorithm. Also, EEQRA should be energy efficient. So another aim of the proposed work includes the reduction of energy consumption and thus increase the lifetime of the network.

Objectives kept in mind while developing EEQRA are related to QoS and energy efficiency. The first objective of EEQRA is to develop QoS based routing algorithm for WSN to determine the optimal routing path meeting the demand of QoS from the available path. Along with desired QoS, optimal path given by the proposed algorithm should increase the lifetime of the network. This can be achieved by reducing energy consumption per packet per node. The proposed path should be energy efficient also.

Energy Efficient QoS based Routing Algorithm (EEQRA) is proposed to satisfy the objectives mentioned above. EEQRA is based on ant colony optimization (ACO) algorithm. Ants initially explore all possible path and finalize the path. Later, ants secrets chemical substance called pheromone, which gets deposited on the selected path. Ants choose the path having more pheromone value. As pheromone gets evaporate over the time,

pheromone deposited on the other paths gets evaporate. These pheromone values are calculated based on desired performance parameters.

3.1 WSN Model

A network model is prepared on the basis of graph theory. Wireless sensor network consists of sensor nodes, and they are supposed to communicate with the sink node. A typical scenario can be modeled using graph theory. Let us consider the number of nodes present in the scenario as V where $V \in (v_1, v_2, \ldots\ldots v_n)$ which are connected using edges belonging to set of edges $E \in (e_1, e_2, \ldots\ldots e_n)$.

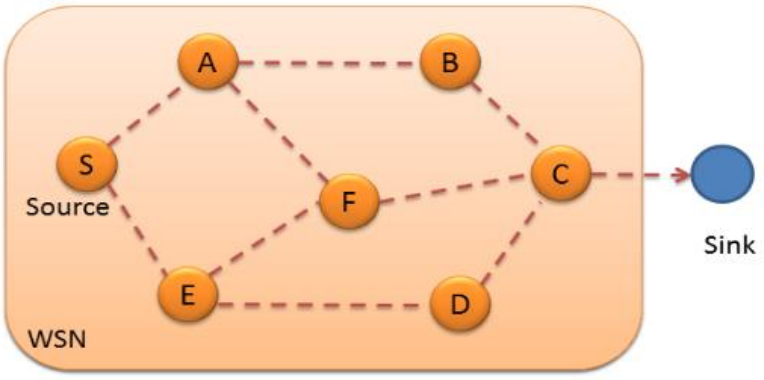

Fig. 4.1: Modeling of the Research Problem

In the fig. 4.1, node S is considered source, and it is supposed to send packets to the the sink node. Here it is considered as all nodes properties are the same, so energy consumption is the same. Dotted lines indicate wireless links. If the event occurs, the source node should have the best path according to the chosen routing metric and the required quality of service.

There are several sensor nodes and a sink node (also called a base station). The source sensor must reach the sink node.

- Assumption 1: Location of sink node does not change during the entire duration of collecting data from sensor nodes.
- Assumption 2: Deployment of nodes is random in nature.
- Assumption 3: Initially,, all nodes have the the same battery level, and energy consumption at all nodes is uniform.
- Assumption 4: Energy required to transmit the packet is uniform at all nodes, and it is directly proportional to the distance between two nodes.

3.2 Mathematical Model

Calculation of Path Selection Probability (PSP)

During the data transmission phase, the next node is to be selected till the packet reach at the destination. Next node j is selected on the basis of path selection probability, calculated as in Eq. (1)

$$PSP_j = \frac{PSP_j}{\sum_{i=0}^{n} PSP_i} \qquad \text{Eq. (1)}$$

Where n is the number of adjacent nodes of any particular node.

Performance Metrics

To evaluate the performance of the proposed algorithm, performance metric chosen are delay, energy, packet delivery ratio and network lifetime.

1.Delay

In the proposed algorithm, total delay for the path is considered. To do so, delay at the node as well as delay incurred during transmission, both are considered.

$$Delay\ D_{ij} = \sum_{e_{ij} \in E} Propagation\ \&\ trans.delay + \sum_{V_i \in N} Queing\ \&\ Proce.delay \quad \text{Eq. (2)}$$

2.Energy

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

$$E_i = e_{i0} - (cw.\sum_{j \in N, i \neq j} X_{ij} + ct.\sum_{j \in N, i \neq j} d_{ij}.X_{ij}),\ all\ i \in N, i \neq n \quad \text{Eq. (3)}$$

Where e_{i0} is Initial energy of node i, for all i ∈ N, (ei0 > 0), cw is the energy consumed during sensor wake-up (constant), and ct is Rate of energy consumption during transmission (constant).

3.Packet Delivery Ratio (PDR)

It is necessary to check how many packets reach destination out of transmitted by the source node.

$$PDR = \frac{Total\ no.of\ packets\ received\ by\ sink\ node}{Total\ no.of\ packets\ transmitted\ by\ source\ node} \quad \text{Eq. (4)}$$

4. Energy Efficient QoS Aware Routing Algorithm

The proposed algorithm is divided in 2 phases named route exploration and data transmission.

4.1 Route Exploration

All nodes are supposed to send information to the sink node whenever a significant event occurs. As sensor nodes have constraints in energy, available memory; proactive routing algorithms are not efficient. Also, sometimes nodes may move from one place to another. In that case, also, the use of proactive routing algorithms is not a feasible solution.

So the proposed algorithm is reactive routing algorithm which does not maintain a list of routes to each node, instead it explores routes as and when needed. The proposed algorithm is based on ant colony optimization.

This phase of the routing algorithm is again divided in 2 parts; route request and route reply.

A) Route Request

In this process, source node S will create a forward agent with forward agent packet as payload. Initially, S is not aware of neighbours so it will broadcast forward agents. S also mentions the sequence number for each agent. At the intermediate node, forward agent packet will be checked and packet will be added in its route list and forwarded in following conditions.

These forward agent packets will reach the destination node where these packets will be processed to make the path table in which Quality factor values (Q) will be stored for each path.

B) Route Reply

At the destination node, backward agents will be created as per the packet format and sent on the reverse path. These backward agents will reach intermediate node as per the network conditions and update the routing table of the intermediate node.

At the end intermediate node, it will have routing table consisting of information about the neighbor node, pheromone value associated with it and path selection probability. Source node will wait for backward ants before the start of data transmission phase.

4.2 Data Transmission

Whenever the desired event occurs at any sensor node in WSN except sink node and if sensor node decides to transmit data packet to sink node, there is a need to find out the next node to transmit it. Negative reinforcement will be applied to all the nodes at periodic intervals.

5. Simulation Results and Discussion

MATLAB® is chosen as simulation platform to simulate the EEQRA algorithm. MATLAB® is proven as good desktop environment to implement routing algorithms related to WSN. Simulation parameters considered are mentioned in Table I.

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

As discussed in the algorithm, EEQRA can provide application-specific QoS. Delay, energy and hop count are selected as QoS parameters. EEQRA is capable of finding out the best possible path from source to destination based on given parameter. Figure 1 shows different paths for different QoS parameter.

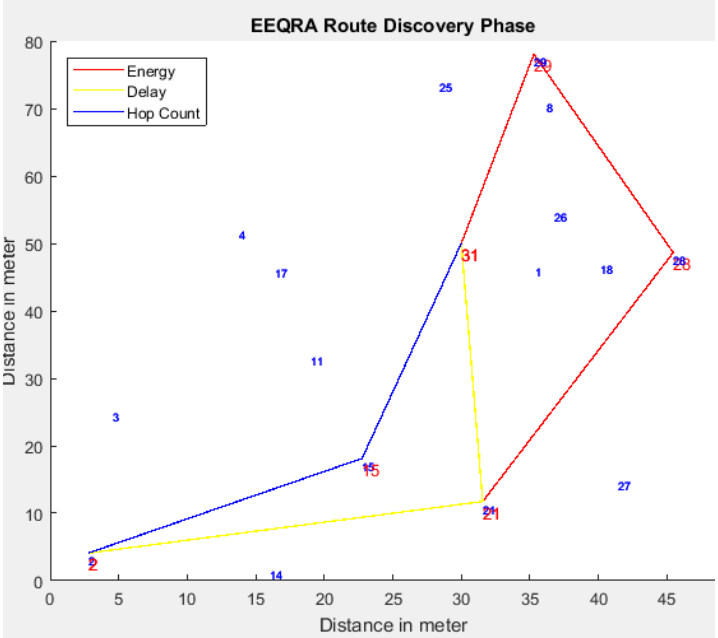

Figure 1 QoS specific path generation

To compare the performance parameters, EEQRA is implemented in MATLAB®, and its outcomes are compared with Energy-Efficient QoS-Aware Intelligent Hybrid Clustered Routing Protocol (EQIHCR). Two protocols are compared on the basis of energy consumption. The reason behind selection of this protocol for comparison lie in the output of protocol. Both of the protocols are QoS based routing protocol.

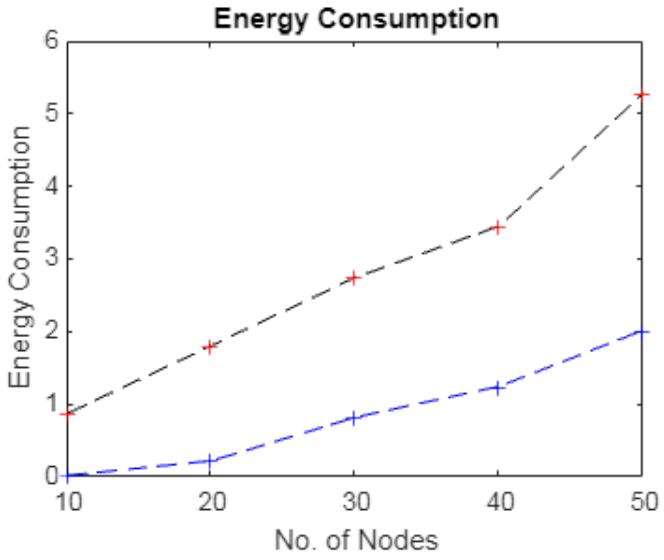

Figure 2 Energy Consumption Comparison of EEQRA and EQIHCR

From Figure 2, it is concluded that proposed algorithm EEQRA is consuming less energy as compared to EQIHCR. Justification for this result is in that EQIHCR selects cluster head throughwhich packets are forwarded. However, in EEQRA every node can forward the packet to destination over the path selected by same node. Also, less energy is consumed during route discovery process used by EEQRA compared to cluster head selection process in EQIHCR.

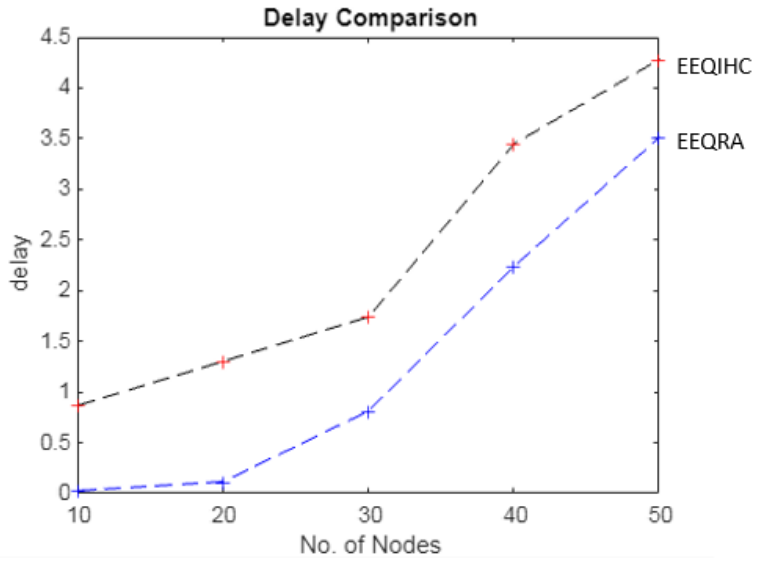

Figure 3 Delay Comparison of EEQRA and EQIHCR

From Figure 3 & Figure 4, it is concluded that EEQRA outperforms EQIHCR as far as delay is concerned but packet delivery ratio of EEQRA is less as compared to EQIHCR. In EEQRA, packet is forwarded by each node over prescribed path which is finalized in route discovery phase. So, every node is aware about neighbor node to whom data packet is to be forwarded. It saves the time to process each data packet. However, EEQRA try to find out the path for every received packet increasing the delay. As far as PDR is concerned, EEQRA does not use acknowledgement mechanism between each pair of intermediate nodes. This is the reason for decreased PDR.

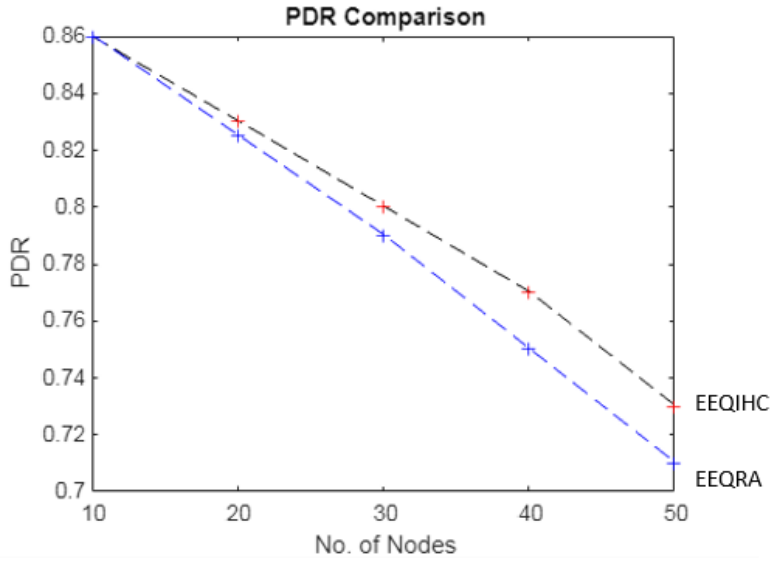

Figure 4 Packet Delivery Ratio Comparison of EEQRA and EQIHCR

6. Conclusion

EEQRA is implemented entirely on MATLAB®. Route discovery phase and data transmission phase is implemented. EEQRA outcomes are compared with Energy-Efficient QoS-Aware Intelligent Hybrid Clustered Routing Protocol (EQIHCR) for performance comparison. EEQRA is proved energy efficient as compared to EEQRA. Delay and packet delivery ratio is also compared. It is found that EEQRA outperforms EQIHCR as far as delay is concerned but packet delivery ratio of EEQRA is less compared to EQIHCR.

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