

Energy- Aware QoS Based Routing Protocols for Heterogeneous WSNs: A Survey

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ABSTRACT

WSNs (Wireless Sensor Networks) are a huge collection of sensor nodes which have limited battery power and limited computational capacity. The power limitation causes the nodes to premature dead so the node power should be used efficiently to prolong the network lifetime. In time critical applications, the data should reach the destination within a deadline and without any packet loss which means the QoS metrics such as reliability and delay are very essential for delivering the data to destination. One of the vital challenges for research in wireless sensor networks is the implementation of routing protocols which achieve both Quality of Service (QoS) and energy efficiency. The main task of the routing protocol is to discover and maintain the routes to transmit the data over the network. At present, to increase the performance of the networks, to achieve load balancing and to provide fault tolerance multipath routing techniques are widely used rather than single path routing technique. We present a review on the existing routing protocols for WSN by considering energy efficiency and QoS. We focus on the main motivation behind the development of each protocol and explain the function of various protocols in detail. We compare the protocols based on energy efficiency and QoS metrics. Finally we conclude the study by giving future research directions.

Keywords

WSNs, Routing Protocol, Multipath Routing, Fault Tolerance, Cross Layer Module.

1. INTRODUCTION

Wireless sensor network consists of number of sensor nodes deployed in the target area to gather information, collaborate with each other and send the gathered data to the sink node in a multi hop fashion [1]. In traditional methods sensor nodes send their data directly to the sink node in a single-

hop approach. This has many drawbacks such as expensive and faster energy depletion since the target sensing nodes are far away from the sink node [2]. To overcome this drawback, multi-hop based approach is carried out over short communication radius which saves energy and reduces communication interference. Due to the dense deployment of the nodes we can have multiple paths for data transmission from the source nodes to the sink [3].

Many of the applications require QoS like military applications, fire detection and biomedical applications. On the battlefield, sensors can be used to detect unfriendly objects, vehicles, aircraft, and personnel. On the health care applications [4], [5] and [6], smart wearable and companionable wireless devices can be attached to or the sensors can be implanted inside the human body to observe the essential signs of the patient body. The routing protocols are required to choose the best path that satisfies the QoS requirements as well as improves the lifetime of the network. The characteristics of WSNs are rapid deployment, self-organization, and fault-tolerance which make them adaptable for real time and non-real time applications [7].

2. MOTIVATION

The sensor nodes are having limited energy, storage capacity and bandwidth. The energy of the sensor nodes are consumed while sensing, processing and transmission. So energy of the node should be used efficiently to avoid early dead. In recent years, WSNs are used in mission critical applications. For example, in fire detection application when the event has detected, immediately the sensor node must gather and transmit the information about the event to the sink within the deadline and without any packet loss. But in many cases, the packets failed to reach the sink within deadline and without any packet loss. The main reason for this is the limited functionalities and inaccurate observation or low reporting rate of the sensor nodes.

Many of the applications require QoS delivery for the data transmission. The known fact is that the QoS always conflicts with energy efficiency since the designs require more energy to minimize packet errors or failures and to reduce latency. There are many existing routing protocols which try to minimize the packet errors by considering retransmission which requires more energy and to find best routing path for real time data, it needs to perform some operations that also consumes more energy. Hence, a thorough study has to be made to learn about the trade-off between energy efficiency and QoS. The purpose of this survey is to focus on how the WSNs provide the QoS and energy efficiency for real time applications.

3. DIFFERENT KINDS OF ROUTING SCHEMES

The routing protocols are classified into three types according to their characteristics: Proactive, reactive and hybrid routing [8]. The routing protocols can be classified according to their operations as follows: Route construction, Network Structure, Communication Model, Number of paths and QoS [9]. The routing protocols dependent to the network structure are further classified into flat routing or hierarchical routing. The communication model based routing protocols can be further classified into three ways: Query-based, Coherent and non-coherent based and Negotiation-based [9].

3.1 Classification of routing protocols according to route construction

The three different routing strategies are identified in wireless networks: proactive, reactive, and hybrid. In case of proactive routing, all the paths are constructed by periodically broadcasting control messages before they are actually needed then these constructed paths information are stored on the routing table of each node. In case of reactive routing, the paths are constructed between source and destination only when needed and it is dependent on dynamic route search. The hybrid routing strategy relies on both proactive and reactive routing protocols to achieve stability and scalability in large networks.

3.2 Classification of Routing Protocols based on Network Structure

The nodes in a sensor network can be organized in one of the following three ways: flat, hierarchical based and location based. In flat routing protocols all the nodes are treated in the same way and they have minimal overhead to maintain the infrastructure between the interacting nodes. In hierarchical routing strategy, the nodes are grouped into clusters. Each member in the cluster sends data to the corresponding cluster head which aggregates the data and forwards to the sink through multiple hops. The election algorithm selects the cluster heads based on parameters like residual energy and distance. The cluster head has the additional responsibility of coordinating the activities of its members and forwarding data from one cluster to another.

3.3 Classification of Routing Protocols based on communication model

The routing protocol based on communication model can be classified into two types according to their operations: negotiation based routing and query based routing. The negotiation based protocols try to eliminate the redundant data by including high level data descriptors in the data transmission. In query based protocols, the sink node starts the communication by distributing a query for data over the network [10].

3.4 Classification of Routing Protocols based on number of paths

Based on the number of paths used to route data from sensor nodes to the sink node, routing protocols are divided into single path routing protocols and multi path routing protocols. In single path routing one path is constructed from source to sink to route the data. Due to this the nodes in the selected path may die soon and the network lifetime is reduced. To improve the network lifetime and reliability multi-path routing protocols are proposed which construct multiple paths to achieve load balancing, fault tolerance. The wireless sensor network routing can be made very efficient and robust by incorporating different type of local state information such as Link quality, distance between the nodes, Residual energy, Position information etc. Disjoint Path routing protocols [11] construct multiple disjoint paths between source and destination in one of two ways: Link-disjoint path: The paths between source and destination have no common link. Node-disjoint path: The paths between source and destination have no common node. The both link disjoint path and node disjoint path have one active path, and number of backup paths. A service flow will be redirected to the backup path if the active path fails. Load balancing is another important aspect to avoid network congestion and optimize network throughput and to prolong the network lifetime.

3.5 Classification of Routing Protocols based on QoS

The Quality-of-Service (QoS) provisioning in WSNs is a challenging task, because of two reasons. First, resource constraints, the dynamic network topology, unbalanced traffic, data redundancy, scarcity of node energy, energy consumption for computation and bandwidth pose challenges on the design of QoS support routing protocol in WSNs [12]. Second, there exist wide differences in traffic generation rate, latency and reliability amongst the data packets. The QoS based protocols aims to achieve QoS metrics such as reliability, delay, energy efficiency and throughput [13].

The rest of the paper is structured as follows. Section 2 describes the taxonomy of recently proposed routing protocols for wireless sensor networks. Section 3 compares the studied protocols based on QoS metrics, energy efficiency and path selection criteria. Section 4 concludes and gives future research directions.

4. TAXONOMY OF EXISTING ROUTING PROTOCOLS FOR WSNs

4.1 Energy efficient and QoS based routing protocol (EQSR)

The Energy efficient and QoS based routing protocol (EQSR) [7] is designed to satisfy the QoS requirements of real-time applications. . To increase reliability EQSR uses multipath routing and XOR-based Forward

Error Correction (FEC) technique which provides data redundancy during the data transmission. To meet delay requirements EQSR employs queuing model which classify the traffic into real-time traffic and non-real-time traffic through service differentiation technique. To find out the path EQSR executes three phases: Initialization phase, Primary Path discovery phase, Alternative Paths discovery phase. During the initialization phase each sensor node broadcasts a HELLO message to its neighbor nodes. The HELLO message includes fields for source ID, hop count, residual energy, free buffer and link quality which are used to calculate the link cost as given by equation (1).

$$\alpha E_{\text{resd},y} + \beta B_{\text{buffer},y} + \gamma I_{\text{interference},xy} \quad (1)$$

In Primary Path discovery phase, the sink node starts to find the routes through sending RREQ message to its preferred neighbor chosen by the equation (2). This process is continues until the source node receives the RREQ message.

$$\text{Next_hop} = \text{Max}_{y \in N_x} \{ \alpha E_{\text{resd},y} + \beta B_{\text{buffer},y} + \gamma I_{\text{interference},xy} \} \quad (2)$$

Where, N_x is the neighbor set of node x . $E_{\text{resd},y}$ and $B_{\text{buffer},y}$ depicts the residual energy and free buffer size at neighbor y , respectively. $I_{\text{interference},xy}$ is the signal to noise ratio between node x and node y .

EQSR constructs node disjoint multiple paths during Alternative Paths discovery phase. In this phase, the sink sends RREQ message to its next most preferred one hop neighbor to construct alternative paths after the construction of primary path. To construct node disjoint paths EQSR restricts that each node should accept only one RREQ message. For that reason each node accepts the first RREQ message and discards remaining messages. The number of required paths k can be estimated according to the need of successfully delivering a message to sink by using the equation (3).

$$k = x_{\alpha} \sqrt{\sum_{i=1}^N p_i (1 - p_i)} + \sum_{i=1}^N p_i \quad (3)$$

Where, x_{α} is the corresponding bound from the standard normal distribution for various levels of α and p_i is the probability of successfully delivering a message to sink.

EQSR calculates the transmission delay of paths by measuring the propagation delay of RREQ message and gives the best paths for real-time traffic and remaining paths for non-real-time traffic. The algorithm find out

k node disjoint paths, out of which l paths are used for sending real time data and m paths are used for sending non real time data. Finally, Error Correction Codes (ECC) for data packets is calculated by lightweight XOR-based FEC algorithm. The EQSR improves the QoS metrics such as reliability and delay, but it introduces high control overhead because of FEC mechanism which performs the encoding and decoding operations.

Simulations are done in Ns2 and the results depict that the EQSR protocol performs very well than MCMP protocol for real time traffic. But the MCMP outperforms the EQSR protocol for non-real time traffic since additional delay is introduced in EQSR due to the queuing model. EQSR offers lower energy efficiency than MCMP since some energy is wasted for calculating the FEC. The packet delivery ratio is increased in EQSR than MCMP because the EQSR uses forward error correction (FEC) technique.

4.2 Localized Multi Objectives Routing protocol (LOCALMOR)

The new localized multi objectives routing protocol [14] differentiates the data traffic according to their requirements of QoS metrics. It classifies the traffic into critical packet, delay sensitive packet, reliable sensitive packet and regular packet. For each data packet, this protocol tries to satisfy the required QoS in an energy efficient way. To improve the reliability it considers multi-sink single-path approach. The neighbor manager is accountable for executing HELLO packet, implementing estimation methods and running other modules. The neighbor table is updated by HELLO packet which has the information related to node's current position, residual energy, and estimated packet reception ratio and transmission delay for each packet transmission. The sending node v_i considers the time window which is specified in terms of the number of packet transmitted and the receiving node v_j updates its current window in terms of the number of packet successfully received denoted as r and number of known packet missed denoted as f. The number of transmitted and received packets can be calculated with the help of sequence number of each packet. When the current window size is equal to main window size then the link reliability (or packet reception ratio) between node V_i and node V_j ($prr_{vi,vj}$) is calculated by using the estimator called Window Mean Exponential Weighted Moving Average (WMEWMA) in regular time interval shown in equation (4). The initial value of $prr_{vi,vj}$ is zero.

$$prr_{vi,vj} = \alpha \cdot prr_{vi,vj} + (1 - \alpha) \frac{r}{(r+f)} \quad (4)$$

Here, α is a tunable parameter of the moving average. The delay can be calculated by using equation (5) and (6) with the help of EWMA estimator. To estimate the delay it considers both queuing delay and transmission

delay. This protocol uses several queues in which each type of packet is inserted into a separate queue. The queuing delay is different for each packet type and it is calculated through local time stamp in terms of exact waiting time of each packet.

$$w_{vi}[\text{packet.type}] = \alpha \cdot w_{vi}[\text{packet.type}] + (1 - \alpha) \cdot \omega \quad (5)$$

$$dtr_{vi} = \alpha \cdot dtr_{vi} + (1 - \alpha)(t_{ACK} - \text{size(ACK)}/bw - t_0) \quad (6)$$

Where w_{vi} is queuing delay, $w_{vi}[\text{packet.type}]$ is queuing delay for each type of packet, dtr_{vi} is transmission delay, t_0 the time the packet is ready for transmission, t_{ACK} the time of the reception of acknowledgment (ACK) packet, bw the bandwidth, and size(ACK) the size of the ACK packet. The initial value of $w_{vi}[\text{packet.type}]$ and dtr_{vi} is zero.

This protocol has different modules namely energy module, reliability module and latency module. The energy module considers both transmission cost and residual energy of routers to attain power efficiency. For that, the min-max approach is used to find the energy efficient node. Reliability module achieves the required reliability by sending a copy the data packet to both primary and secondary sinks. When more than one node has the same value for maximum reliability, the most power efficient node is selected by energy module. Latency module calculates the required speed by dividing distance by the time remaining to the deadline, rt . The remaining time to deadline rt is calculated by equation (7).

$$rt = rt_{rec} - (t_{tr} - t_{rec} + \text{size}/bw) \quad (7)$$

Where t_{rec} represents the reception time, t_{tr} the transmission time, rt_{rec} is the previous value of rt . If the incoming packet is delay sensitive packet then it selects the node which meets the required deadline. If more than one node satisfies the required deadline then the most energy efficient node is selected. If the incoming packet is critical packet then it first calls the reliability module then latency module and energy module. Finally the queuing manager uses the multi-queue priority policy in which four separated queues are used for each type of packet. Critical packet has the highest priority than Delay sensitive packet and reliability sensitive packet has lowest priority. To avoid starvation a time out policy is proposed for each lower priority queue. When a packet arrives at a queue, a timeout value is assigned and when the timer expires the packet is moved to the highest priority queue.

Simulation results depict that Packet reception ratio increases linearly from 86 to 87 percent for critical packets and 86 to 98 percent for reliable sensitive packets whereas it is constant for delay-sensitive packets at the interval of 80 to 83 percent. Moreover, above 96 percent of packets were successfully transmitted with reasonable delay. The energy deviation is small for low and moderate number of critical packets but the energy deviation is gradually increases as the number of critical packet increase. However, the LOCALMOR protocol achieves better lifetime than any other existing protocols.

4.3 QoS-aware Peering Routing Protocol for Reliability Sensitive Data (QPRR)

Zahoor et al. proposed a novel routing protocol in consideration of the QoS requirements of body area networks (BAN) data. This QoS-aware Peering Routing Protocol for Reliability Sensitive Data (QPRR) [4] protocol improves the reliability of critical BAN data while transferring the data from source to destination. For sending reliable sensitive packets (RSP), the protocol calculates the reliability of all possible paths. These path reliabilities can be obtained by using neighbor table information. The routing table can hold up to three most reliable paths among all possible paths.

To transmit any RSP data between source and destination it should consider the following criteria. If the first path itself can accomplish the reliability requirement then the source node transmits RSP through it. If the first path reliability is lower than required reliability then QPRR aggregates the reliability of two paths and then QPRR compares the required reliability with two paths aggregated reliability. If the two paths aggregated reliability is greater than required reliability then the copy of RSP packets transmitted through two paths. If not QPRR aggregates three paths reliability then compares it with required reliability. If the three paths reliability is greater than required reliability then the copy of RSP packet transmitted through three paths. Otherwise the packet is dropped. The path reliability between source 'i' to destination 'Dst' is calculated by using the following equation (8).

$$R_{\text{path}(i, \text{Dst})} = R_{\text{link}(i, j)} \times R_{\text{path}(j, \text{Dst})} \quad (8)$$

The link reliability between nodes 'i' to node 'j' can be calculated by using EWMA (Exponentially weighted moving average) formula as follows:

$$R_{\text{link}(i, j)} = (1 - \alpha)R_{\text{link}(i, j)} + \alpha.X_i \quad (9)$$



The average probability of successful transmission is calculated by using equation (10).

$$X_i = \frac{N_{Acks}}{N_{Trans}} \quad (10)$$

Where, $R_{path(i,Dst)}$ is the path reliability between node 'i' to destination. $R_{link(i,j)}$ is the link reliability between node 'i' to node 'j'. $R_{path(j,Dst)}$ is the path reliability between node 'j' to destination. α is the average weighting factor that satisfies $0 < \alpha \leq 1$. This protocol takes α as 0.4. N_{Acks} is the number of acknowledgement received and N_{Trans} is the number of packets transmitted.

Simulation results show that the QPRR reliability is above 75% for low dense nodes and above 74% for high dense nodes and it uses low transmission power which provides better transmission rate. The QPRR provides better reliability but the drawback is the network traffic load is increased.

4.4 Energy Efficient Node Disjoint Multipath Routing Protocol (EENDMRP)

The Energy Efficient Node Disjoint Multipath Routing Protocol (EENDMRP) [15] provided for the reliability analysis of route redundancy in WSN. EENDMRP concentrates on route redundancy in a single node level redundancy over a single path, single node level redundancy through multi node over single path, and single node level redundancy through multiple level multiple nodes in a single path. EENDMRP is a proactive protocol and it considers number of stages between source and destination. The sink node is at stage zero. The one hop neighbors of sink node are stage 1 likewise for each node a stage is assigned towards source node. This is done for avoid the construction of path with loops. It considers the node which has residual energy greater than threshold energy during path construction in the WSNs.

To construct the route each node exchanges the route construction (RCON) packet. If the RCON packet is received by node which is not in the route that reaches the sink then the node processes the RCON packet. If the RCON packet is received by node which is already in the route that reaches the sink then it compares the node's hop count value with packet's hop count value. If the node's hop-count value is greater than packet's hop-count value and the node's residual energy greater than threshold energy value then RCON is processed. If not, it drops the packet. Each node's routing table is updated while receiving RCON packet which has the fields such as node id and hop-count value. Finally, all possible node disjoint paths are constructed between source and destination. If any node in the

path failed to transmit the packets due to node death or node dislocation, then EENDMRP reports the source node by sending route error packet (RERR). The source node removes the failed path from the routing table and calls the route maintenance phase then the alternate path is provided between the node which created the RERR packet and sink node.

4.5 Lifetime Maximizing Dynamic Energy Efficient Routing Protocol

In [16], the authors proposed Energy efficient routing protocol to balance the energy consumption among nodes and to avoid the premature death of nodes. The proposed energy efficient routing protocol has three phases namely initialization phase, selection of next hop and generation of DEERT phase and tree maintenance phase. During the initialization phase a level is assigned to each node based on the hop distance from the sink node which at level 0. A node can select its next hop from lower level or in the same level. The data packets are transmitted from higher level node to lower level node. Every node selects the next hop neighbor based on the cost of the link between itself and its neighbor and the load of the neighbor. The link cost between the nodes u and v is calculated by equation (11).

$$C_{uv} = \min\{RE_u - E_{tx}, RE_v - E_{rx}\} \quad (11)$$

Where, E_{tx} is transmission cost of node. E_{rx} is reception cost of node and RE_u and RE_v is the residual energy of nodes u and v respectively.

The load of node is calculated based on the sum of energy consumed for transmission of a packet to a neighbor node and energy consumed for receiving a packet from the children nodes and energy used for overhearing. In the tree construction phase, a distinct energy efficient routing tree rooted at the sink node is constructed based on the link cost for efficiently routing the data. After a fixed amount of time, the tree is reconstructed again.

The tree maintenance algorithm reconstructs the tree in the following cases:

- If there is no response from neighboring nodes then that node is considered as dead node.
- If the residual energy of the neighbor node is lower than threshold value.
- If there is no appropriate next hop node then the source node transmits its data directly to the sink node and updates its level and other parameters consequently.

Simulation results depict that the DEERT has a better performance than SBT, DEBR and aggregation tree based routing in terms of number of nodes alive after certain number of rounds thus improving the lifetime of the



network. In the beginning, the DEBR end to end delay in terms of hop count is lesser than proposed protocol whereas the end to end delay of DEBR is increased when the number of rounds increases. This protocol concentrates only on energy efficiency but does not support for QoS.

4.6 Braided multipath routing protocol

The braided multipath routing protocol [17] is provided for transmitting the data packets from source to destination and giving the network ability to adapt to fluctuations or failures. The source node constructs the path after detecting the target. Once the target is detected then the node sends its ID in a packet declaring that it has attained a target. The node which receives this packet will response with its own ID to the source node declaring that the preceding node as part of its path. Then the new node broadcasts its ID to the next hop which response and forward the message likewise the process is continued until it reach the sink. Then several paths will be created from source to destination. For that, the destination node will give priority numbers to the paths and they select the path which has the minimum number of hops to the source and the nodes in that path are informed to selected backup nodes.

To save the energy of all other nodes in the network, the nodes are entering into an energy saving mode and activating from time to time to check the ups and downs in the network. If any packet is transmitted from target to sink then the sink will check its own route to this target and update its path when the received one has minimum number of hops than the stored one.

Simulation results show that the braided algorithm uses backup nodes which improve fault tolerance in the network. It is possible that only one or two backup nodes can be established by path, leaving the other nodes without backup thus making the path susceptible. In networks of higher density the backup nodes improve fault tolerance at low costs.

4.7 Link Quality estimation based Routing protocol (LQER)

The LQER (Link Quality estimation based Routing) protocol [18] is designed to improve reliability and energy efficiency in WSNs. It incorporated minimum hop count field and dynamic window concept ($m; k$). A path is constructed between the source and the sink nodes based on the hop-count value. The sink node broadcast an advertisement (ADV) message to its neighbors by setting the hop-count value as zero. For other nodes in the networks, the hop count value is calculated based on the number of hops of that node to the sink.



If the current hop-count value is same or greater than next hop-count value then that node is added as a forwarding node in the path. Or else the message is rejected. Here, m is the number of data packets successfully transmitted and k is the total number of packets transmitted. The dynamic window concept is used to record the historical link status of data packets based on m and k . The sufficient reliability can be achieved by using historical link status information which keeps the word of k bit. If the data transmission is not successful then that bit is represented as 0. Otherwise it is represented as 1. The leftmost bit is oldest bit while the right most bit is newest bit. When the new packet is transmitted, all the packets in the word of k bits are shifted one position to the left and one bit is added in right most position to indicate the current status. The quality of link p is calculated by equation (12).

$$p = m/k \quad (12)$$

The historical link table can be updated dynamically with a low computing cost and complexity. When the routing data is ready to transmit, LQER lists all the neighbor nodes of current node and chooses the path with largest value of p to transmit routing data.

Simulation results show that Successful transmission rate in LQER is greater than that in MHFR and MCR. When the number of nodes increases, the deviation is small in LQER, which specifies a good scalability of data delivery effectiveness whereas the successful transmission rate decreases rapidly in MHFR and MCR.

4.8 QoS-aware Peering Routing Protocol for Delay Sensitive Data(QPRD)

The QoS-aware Peering Routing Protocol for Delay Sensitive Data (QPRD) [5] is provided for handling delay-sensitive packets. It calculates the node delay and path delay of all constructed path between source and destination and finds the best path among all possible paths according to the delay requirement. Each node has a routing table which contains information of next hop with the lowest end to end delay. A delay sensitive packet (DSP) is transmitted in a path if the latency of the path is less than or equal to the delay requirement of the packet.

QPRD has other modules to choose the best path for transmitting the packet. They are MAC receiver module, Delay module, Packet classifier module, Hello protocol module, Routing service module, QoS-aware queuing module and MAC transmitter. The MAC receiver forwards the packets only

if the packets MAC address matches with its own MAC address. The delay module calculates node delay by using the equation (13).

$$DL_{\text{node (i)}} = DL_{\text{trans (i)}} + DL_{\text{queues +channel}} + DL_{\text{proc}} \quad (13)$$

Where, $DL_{\text{queue+channel}}$ are queuing and channel delay, $DL_{\text{trans(i)}}$ is transmission time of a packet, DL_{proc} is processing delay of a node. The transmission time is calculated by dividing the total number of bits in each packet by data rate. Exponentially Weighted Moving Average (EWMA) formula is used to estimate queuing and channel delay. The path delay of node i to destination $DL_{\text{path(i,Dst)}}$ is calculated by using equation (14).

$$DL_{\text{path (i,Dst)}} = DL_{\text{node (i)}} + DL_{\text{path (j,Dst)}} \quad (14)$$

The packet classifier differentiates data packet and Hello packets and the packets are processed according to the type. The hello packet is broadcasted to each neighbor node. In hello protocol module, the neighbor table constructor constructs the neighbor table based on the node delay and path delay. The routing services module is accountable for creating the routing table and classifying the data packets into Delay-Sensitive Packets (DSPs) and Ordinary Packets (OPs). For DSP, it chooses the path with minimum end to end delay. For ordinary packet (OP), it chooses the energy efficient next hop. The QoS-aware Queuing Module (QQM) separates the data packets into DSP and OP. It maintains separate queue for each type of data packet. The DSP has the highest priority than OP. The OP queue can transmit its data only if the DSP queue is empty. For fair treatment of lowest priority data, a timeout policy is used. Finally the MAC transmitter receives all packets and stores it in queue. It transmits the packet in first in first out policy.

Simulation results show that in static environment 94% of the DSPs are transmitted within the deadline limits and in mobile environment it provides an improvement of 35% than DMQoS.

4.9 Energy aware peering routing protocol (EPR)

The energy aware peering routing protocol (EPR) [6] is designed to provide a reduced network traffic load, improved energy efficiency and improved reliability. It selects the next hop which has higher battery power and shorter distance to the sink. It has three main parts namely hello message module, neighbor table construction module and routing table creation module. The hello message module is used to update the neighbor node information such as destination location, destination ID, sender node's ID, distance from next hop to destination and residual energy of neighbor node.



The neighbor node information will be added in the sender node's neighbor table by using hello protocol. If a node does not receive any hello message from its neighbors for a particular time then it assumes that the neighbor has moved away or the link to the neighbor has broken down. The distance between the nodes i and DST can be calculated by the following equation (15).

$$D_{(i,DST)} = \sqrt{(X_i - X_{DST})^2 + (Y_i - Y_{DST})^2} \quad (15)$$

Where, X_i , Y_i denote the X , Y coordinates of node i . X_{DST} , Y_{DST} denote the X , Y coordinates of the destination. The communication cost can be calculated by using the parameters such as distance between two nodes and node's residual energy. The routing table will select the neighbor node with lower communication cost from the neighbor table.

Simulation results show that about 34% of average traffic load is decreased and about 23% of data transmission rate is increased than other similar protocols.

4.10 Integrated link quality estimation-based routing Protocol(I-LQER)

I-LQER (integrated link quality estimation-based routing protocol) [19] is designed to provide quality of service and to reduce power consumption. I-LQER assigns different weights for the link quality records and link stability is calculated based on this value. The link quality is estimated by considering weighted factor along with m/k . Here, m is the number of data packets successfully transmitted and k is the total number of packets transmitted. It selects the node which has the greatest link quality.

It believes that the nearest period of transmission has relevance with current transmission. If the node has a high probability to maintain the current link quality then that node is taken as a good stability node. If the node has a low probability to maintain the current link quality then that node is taken as a low stability node. It compares the nodes record status in the nearest period. Based on that, it selects the best node to forward the data. For example, if we consider two nodes P and Q with link quality record status as 00 0011 1111 1111 and 11 1111 0100 0000 respectively where 1 denotes the good link quality and 0 denotes the bad link quality, then the node P has a better link quality stability than node Q .

Simulation results depict that the performance of I-LQER is superior to LQER protocol in terms of end to end delay. For a network with 10 sensor nodes, I-LQER gives an average delay of 9.00 ms and LQER gives an average delay of 10.63 ms. when the number of nodes is increased to 100, then I-LQER offers an average delay of 19.80 ms and LQER gives an

average delay of 28.03ms. This shows that I-LQER has a better scalability than LQER.

5. COMPARISON OF DIFFERENT ROUTING PROTOCOLS

We compare the studied protocols based on reliability, delay, energy efficiency and load balancing issues. Maximum number of protocols studied in this paper construct single path to deliver data from the source to the sink. Some protocols construct multiple paths for data delivery. All the protocols use different criteria for the path selection. Almost all the protocols studied focus on energy efficient routing. Table 1 and 2 gives the results of our comparison. Only few protocols like LOCALMOR and EQSR provides QoS support for heterogeneous traffic based on the type of traffic.

Table 1. Comparison of the routing protocols based on energy efficiency and QoS.

Scheme	Reliability	Delay (timely delivery)	Energy efficiency	Traffic differentiation	Mobility support
QPRR	Yes	No	Yes	OP, RSD	Good
QPRD	No	Yes	Yes	OP, DSP	Good
LOCALMOR	Yes	Yes	Yes	CSP, DSP, RSP	Low
EQSR	Yes	Yes	Yes	Real time, Non Real time	No
DEERT	No	No	Yes	-	-
EPR	No	No	Yes	OP	Good
I-LQER	Yes	No	Yes	-	Yes
Braided multipath algorithm	Yes	No	No	-	-
EENDMRP	Yes	No	Yes	-	-
LQER	Yes	No	Yes	-	-

Table 2. Comparison of the routing protocols based on multipath support.

Scheme	Number of Paths	Path reconstruction	Path metric	Load balancing	Path chooser
QPRR	Up to three paths	No	End to end reliable path	-	Source node
QPRD	Single path	No	Least end to end delay path	-	Source node
LOCALMOR	Single path	No	Minimum delay, maximum	Yes	Source node

			reliability and maximum residual energy according to the packet requirement		
EQSR	Multi path	No	minimum end to end delay path for real time traffic	Yes	Source node
DEERT	Single path	Yes	Maximum battery power	Yes	Source node
EPR	Single path	No	End to End Energy efficient path	Yes	Source node
I-LQER	Single path	No	Reliable path by considering link quality and link stability	No	Source node
Braided multipath algorithm	Multi path	No	The path with minimum number hops	Yes	Sink node
EENDMRP	Multi path	Yes	The path with minimum number of hops, maximum residual energy and maximum path cost	Yes	Source node
LQER	Single path	No	Reliable path by considering link quality	-	Source node

6. ERROR RECOVERY SCHEMES

6.1 Automatic Repeat Request (ARQ)

ARQ is the error recovery mechanism which uses the cyclic redundancy check(CRC) technique to find error packet and it can retransmit the error packet until the packet becomes error free at receiver side. If the packet is successfully received by the receiver then it will send the positive acknowledgement (ACK) to sender, otherwise it will send the negative acknowledgement (NACK). If the ACK is not received by the sender within the timeout frame then it will retransmit the packet. The drawback of ARQ is retransmission which induces the additional cost.

6.2 Forward Error Correction (FEC)

FEC mechanism is mostly preferable in multi-hop WSNs to control the packet transmission errors by adding the error correcting codes (ECCs) with the sending data. The receiver can detect and correct the amount of bit

errors with the help of error correcting codes. However, the cost of retransmission is very high since the FEC performs the encoding and decoding operations which consume more energy.

7. CROSS LAYER MODULE

The concept of cross layer module is incorporating different classical layer functionalities into a single functional protocol whereas the classical layer structure is preserved i.e., the functionalities of each layer still remains unbroken. Many cross layer module have been implemented to improve the communication reliability, to improve energy efficiency and to avoid load congestion. Most of the existing research integrates the MAC and physical layers to reduce energy consumption and improve reliability, the MAC and routing layers are integrated to extend the network lifetime, the routing and physical layers are integrated to optimize the network throughput, the transport and physical layer are integrated to control congestion [20] and the application and MAC layer are integrated to provide QoS [21]. The cross layer module improves the network performance and reduces the implementation complexity and also outperforms the classical layer model [22]. The network performance can be further improved while combining multipath routing, FEC mechanism and cross layer module.

8. CONCLUSION AND FUTURE DIRECTIONS

The invention of smart, light-weight sensors makes the wireless sensor network popular. Regarding the routing protocols, the reduced energy consumption, the QoS, the scalability and the fault tolerance are the main limitations in wireless sensor networks. This paper presents a study in what way the recently proposed routing protocols are adapted to these characteristics in WSNs. Although in the past years the energy efficient and QoS based routing has been examined through various studies, yet there are numerous significant research issues that should be further explored. The Promising areas can be shortened as follows: 1) much research work has to be done on multipath routing protocol to support both energy efficiency and QoS 2) The cross layer module and the multipath routing with forward error correction (FEC) technique can be used to increase the network performance.

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