# Enhancing Wireless Sensor Network Routing by High Quality Link Set Cooperative Routing Algorithm

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**ABSTRACT**

In general Wireless Sensor Networks (WSN's), improving the network reliability by using cooperative communication to select the relay node with low overhead is a challenging task. Also the design of routing scheme based on link quality is a critical problem. Due to the resource constraints, connections between the nodes are changeable one. It leads to the network to create a various routes which are necessary. By using the established path, it delivers the data to the base station in a reliable manner. This paper concentrates on a cross layer approach by using various cooperative metric such as Packet Delivery Rate (PDR), Packet Reception Rate (PRR), Required Number of Packet transmission (RNP), Average number of packet sent/resent and Expected Transmission Time (ETX). These parameters are taken as a fuzzy parameter that exploits the cooperative diversity at the routing layer. We propose a Fuzzy based High Quality Link Set Routing (FHQLSR) which selects the high quality relay node and evaluates the quality of link in each node by using RNP and ETX parameters. This FHQLSR scheme is used to find the effective relay node that forward packets to the base station via high quality link and also find the optimal path using Improved Dijikstra's Algorithm (IDA) in the multi hop networks. By considering routing and link quality parameters, the FHQLSR scheme improves the overall reliability, scalability and stability of the network.

**Keywords**

Cooperative communication, FHQLSR, Reliability. Scalability, Stability, Wireless Sensor Networks (WSN).

## I. Introduction

In traditional Wireless network, signals emitted by the neighboring nodes were treated as interference and several methods have been developed to alleviate its effect. However such signals usually contain some valuable information which can be properly forwarded to the surrounding node(s), and the reception performance at the base station can be improved. These facts motivate the application of new technology known as cooperative communication [2]. Recently cooperative communication provides distributed coding scheme to achieve gain by using single antenna instead of using multiple antennas. This is used to fill the gap between the cooperative communications technique developed by physical layer, Admission Control layer and Routing layer. This paper mainly focuses on finding the good tradeoff between the issues at the cross layer use and routing layer.It tries to extend cooperative communication, the design of routing layer and its metrics that reflect the potential gain and find the optimum paths using the new cooperative metrics [6]. Cooperative Expected Transmission Time(CETT) is defined as the estimated frame transmission time over one single hop, with the presence of potential relay nodes within it reachable network. But CETT do not provide accurate estimate in software requirements because radio link suffers from executive packet loss. So in this paper, we consider the metric based quality estimation of the routing path that established the effective communication relays in the cooperative communication. The following metrics Packet Delivery Rate (PDR), throughput and energy efficiency are considered for our proposed routing algorithm. The optimal path between the source and base station via relay node is established by using new optimal link metrics such as RNT (Required Number of Transmission) and ETX (Expected Transmission Time) [7]. Existing algorithm which focuses on all cooperative benefits are exploited from the Medium Access Control layer(MAC) to the routing layer.We consider the Fuzzy Based High Quality link Set Routing Algorithms (FHQLSR) that posse the efficient routing by selecting high quality of relay nodes in the network. The fuzzy parameters required are PDR, PRR, RNP, and ETX that produced the high quality of relay nodes that forwarded packets from source to base station.

Our proposed work also focuses on comparison of both Link Quality Estimators (LQE) such as RNP and ETX which is a type of FHQLSR routing. The simulation results show that the performance of ETX is better than the RNP.

## II. Related Works

Fuzzy logic based relay selection achieve the optimal balance between the error performance and total energy consumed in a route selection method for multi hop networks based on SNR and BER [13].Multi relay cooperation is a promising method to achieve spatial diversity in order to control the fading conditions, cooperative relaying in the two hops VCN enables. One or more relaynodes were used to process multicast signal overhead from the source and retransmitted it to the destination. The transmitted signals are then combined in the destination using suitable combining techniques. Thus relay selection is an important issue to attain system throughput. Comparatively, ETX link quality estimator provides a higher stability and lower cost performance under different network conditions [12], stable routes are built by selecting links with high quality and identifying those of bad quality.

The study of link quality estimation in WSN is a fundamental building block for an efficient cross-layer design of higher layer wireless network protocols. The sophisticated routing protocols is to overcome link unreliability in order to efficiently maintain network connectivity .In order to achieve this, they rely on Link Quality Estimator(LQE) as a support mechanism to select the most stable routes for data delivery [8-11].In an existing method, a distributed scheme was used to find a relay node for MAC layer scheme. It had been observed that it is an efficient way without any over head on signal and processing [1].There is no support on stable routes by Link Quality Estimator. Other existing methods are considered a significant improvement of system performance which had been demonstrated in terms of parameters such as probability, energy efficiency and coverage extension. Recently MAC design distributed wireless had considered these parameters [3-5]. Many studies have been carried out on relay selection in two hop cooperative system.

Fuzzy logic based relay selection has achieved the optimal balance between the error performance and total consumed energy in a route selection scheme for multi hop networks based on SNR and BTR [13]. In[13], SNR and delay as fuzzy variables, does not provide accurate estimation.

Fuzzy Logic Control is a technique, which is used to incorporate the human logic into computer programs. It mainly used in a low computational resource constrained networks. It incorporates in a routing decision process to find the optimal path to transfer the data from source to destination (base station).In this paper, our system makes use of fuzzy logic, which is able to help the route decision making process to reduce the number of paths and also bear out the routing efficiency by considering both its own and surrounding node parameters as a input to the fuzzy logic system.

In general, the wireless links are error prone in nature. So we have taken PDR, PRR, RNP and ETX as a fuzzy parameter.Our proposed method is Fuzzy based High Quality Relay Selection method (FHQRS) for a cooperative communication system. This method shows a better stability, scalability and improves the overall reliability of the nature.

## III Methodology

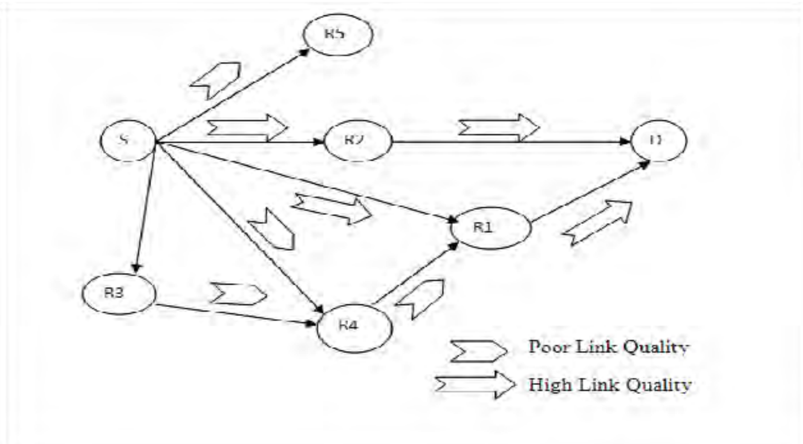


Fig 1: FHQLSR routing topology

Figure 1 illustrates the basic topology structure with a single source and destination. In the selected topology, concepts are incorporated to demonstrate how the proposed FBHQLSR routing scheme works. In this network, both S and D can hear $R1$ and $R3$ but cannot hear each other. $R2$ and $R4$ can hear S and $R1$, but cannot hear the other nodes. When DSR or AODV routing is used, the routing metric is calculated for each link between any node pair which can hear each other. The possible paths for traffic from S to D will have four alternatives: (1) S → $R1$ → D; (2) S → $R3$ → D; (3) S → $R2$ → $R1$ → D; or (4) S → $R4$ → $R1$ → D. Here, we assume that link S → $R3$ → D has better link quality and therefore is selected as the best route by these routing. When cooperative communications are introduced into this network, $R2$ or $R4$ can function as a relay node between S and $R1$. In this way, the link quality between S and $R1$ is upgraded when cooperative transmission is applied.

As a result, path S → $R1$ → D may surpass path S → $R3$ → D. Choosing the best metric among these four alternatives, the optimal relay is selected. Thereafter, the obtained best value is compared with the ETX link metric. If the best cooperative link metric is adopted for data transmission over the link from S to $R1$, and the link metric from S to $R1$ is updated to the best cooperative routing metric. With the new metric in routing algorithms, S → $R1$ → D, using $R4$ as

a relay with *ETX* for the link between S and $R1$, is selected to be the working path instead of S → $R3$ → D. Better network performance can be achieved using the new path with cooperative transmissions. On the other hand, if the best cooperative link metric is inferior to the original ETX link metric, the link metric remains the same, that is, S → $R3$ → D as the working path.

In summary,with cooperative routing not only the best path for data transmission is selected,but also the best cooperative ETX metric as well as the best relay candidate are chosen.

## IV. Fuzzy Based High Quality Link set Routing

### *4.1 Fuzzy Energy Cost:*

Generally, in sensor nodes the cost for transmitting the data is a variable whereas the idle cost and cost for receiving and sensing the data are constant. Hence the total cost of the network is calculated based on the transmission cost. Therefore the new equation for the total energy cost is $1 - (1 - cost[u])\ ETX\ (u, v)$ –(1) The proposed routing algorithm follows the same principle as the original Dijkstra's shortest path algorithm, but updated with small modifications for analogous operations.

The pseudo code of the implementation is listed as Algorithm . In our algorithm, different metrics are used to calculate link cost. With regard to routing based on packet delivery ratio the link cost is the probability of unsuccessful transmission through the link. The data packets are delivered successfully to the destination along the path only when the transmission on each link is successful. Therefore, in the modified Dijkstra's algorithm, use equation(1) instead of "*sum*" operation to calculate the cost accumulated along the path. The average end-to-end throughput is the geometric mean of the throughput on each link, and the link cost is the reciprocal value of the link throughput. The accumulated cost along the path with regard to throughput is calculated by using the equation $cost[u]+1/ETX(u, v)$. The routing algorithm for energy efficiency shares the same principle with the algorithm for throughput, with the reciprocal value of the energy efficiency on each link as its link cost. ETX relies on active monitoring It enables to provide accurate link quality estimate.

### *4.2 Fuzzy High Quality Value*

For the calculation based on the fuzzy quality process, each sensor node compares its present reading with the previous reading and an average of the quality readings of all the sensors is determined. The average value is then compared with the threshold value.If fuzzyETX> fuzzy ETX threshold then consistent state.If fuzzyETX < fuzzy ETX threshold then inconsistent state.Total Fuzzy High QualityValue is calculated as, Fuzzy High Quality Value =fuzzy ETX + fuzzy RNP

The resultant of the system is the one with the high membership grade. Table 1 shows the conditions for decision making in fuzzy logic for inputs and its corresponding results. i.e Figure 2 shows the block representation of the decision making in our fuzzy system.

Table 1 Fuzzification Rules

| **Fuzzy PDR (P)** | **Fuzzy PRR (R)** | **Fuzzy EnergyCost(E)** | **FHQV(F)** | **Result** |
|---|---|---|---|---|
| High | High | Less | High | Best Relay |
| Less | High | Less | High | Normal Relay |
| Less | Less | High | Less | Worst Relay |
| Less | High | High | Less | Worst Relay |

Let fuzzy PDR, Fuzzy PRR, Energy Cost, FHQLV be denoted by P, R, E and F:

If P, R, F are High and if E is Less then node is a best Relay node.

If P, R, F are less and if E is high then node is a Worst Relay node.

If P, R, F are Less and if E is Less then node is a Worst Relay node.

If P, R are Less and F are E is High then node is a Normal Relay node.

### *4.3. Fuzzy Based High Quality Link Routing Algorithm*

The following procedure was adapted in the routing algorithm.

1. Create a network topology using highest fuzzy value result.
2. Select the relay node according to the fuzzification formula.
3. To forward the packets using relay node using fuzzification
4. Find the fuzzy set in each network
5. Calculate the shortest path for each set using link quality measure
6. Find the optimized path using fuzzification value and ETX value
7. Compare these ETX value with different link quality estimator like RNP and PRR. We will get the best stability link for each free optimized path
8. We have included the parameters PDR, energy efficiency, throughput, PER, no of nodes or node density, compared with ETX and RNP

The algorithm is as follows for

Definining fuzzy based Improved Dijkstra algorithm (IDA)

function :IDA(I, S, D, F):

for every vertex v in Graph:

**//Step 1: Initialization**

cost [v]:= infinity;

pricing[v]:=zero;

every previously defined fuzzy value

last analysis [v]:= undefined;

**//Step-2 Optimal Path Analysis for fuzzification**

Opt[F]: Defined values;

end for;

cost [S]:= 0;

G:= the set of all nodes in Graph;

While G is not empty:

u:= vertex in G with minimum cost [ ];

if cost [u] = infinity:

break;

**//Step-3 remaining vertices inaccessible from S**

fi;

remove u from G;

for each neighbor v of u:

// Involving fuzzification value using ETX

removed from G.

**//Step 4 - Quality Measurement**

**temp:= 1− (1−cost [u]) ETX(u,v);**

***//link cost for PDR***

**temp:= cost [u] + 1/ETX(u,v);**

**//Link cost for Energy Efficiency**

if alt < cost [v]:

cost [v]:= temp;

**//Updating new metric value**

previous [v]:= u;

**//Updating new route path analysis**

end for;

end while;

return cost [ ];
path:= empty sequence
***//Path optimization between S and D***
d:= D
while previous [d] is defined:
insert u at the beginning of path
d:= previous [d]
end while
return path;
end IDA.

## V. Simulation analysis

In the laboratory setup, following simulation parameters were taken for consideration under Network Simulator (NS2) environment. Major parameters of performance metric viz. Packet Delivery Rate, Energy drain rate, packet received rate and drop rate were taken for comparison between the three mechanisms namely Ambient Trust Sensor Routing (ATSR), Link State Routing Protocol Using Route Trusts (LSRTP) and Fuzzy based High Quality Link Set Routing (FHQLSR).

Table II Simulation environment

| Simulation parameters | Simulation values |
|---|---|
| WSN standard | IEEE 802.15.4 |
| Number of nodes | 40 |
| Base protocol | AODV |
| Algorithm | FHQLSR |
| System Bandwidth | 2 Mbps |
| Protocol Layer | Cross Layer MAC |
| Antenna | Omni Directional |
| Simulation Environment | 1500 * 1500 |
| Channel Propagation | Wireless / Two ray ground |

### *5.1 Packet Transmission Rate*

The figure 2 depicts the characteristic of node density with respect to number of packets applied to various algorithms. Packet Transmission Rate is defined as the number of packets transmitted in the network over a period of time. Here we have calculated the PTR with respect to the node density. Node density is the number nodes taken under simulation. The simulation analysis shows that the protocol FHQLSR shows better performance in terms of Packet Transmission Rate with respect to node density.

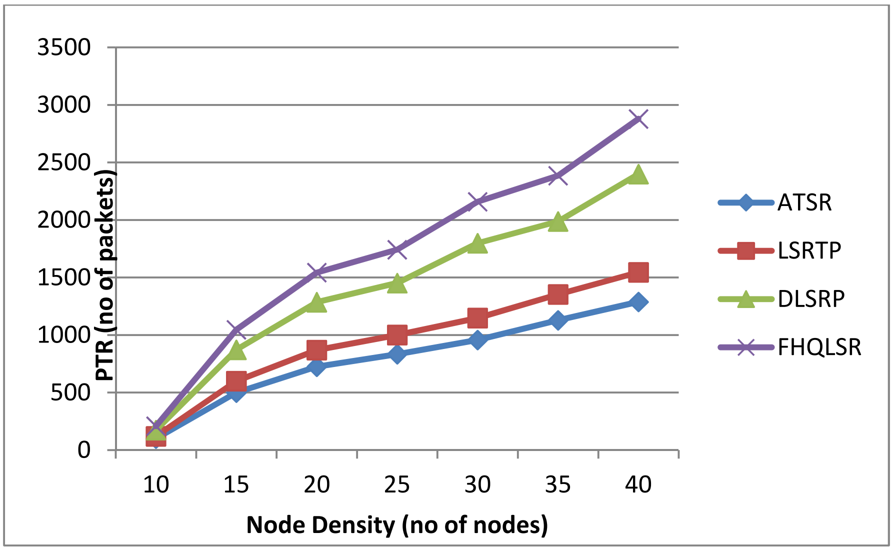


Fig 2 depicts the characteristic of node density with PTR Values

### *5.2 Packet Reception Rate*

The figure 3 depicts the characteristics of node density with respect to number of packets received to various algorithms Packet Reception Rate is defined as the number of packets received in the sink over a period of time. In the WSN simulation analysis environment this study shows that packets reception rate parameter for FHQLSR, LSRTP and ATSR are compared over node density parameter. It is evident from the observations that FHQLSR shows better results.

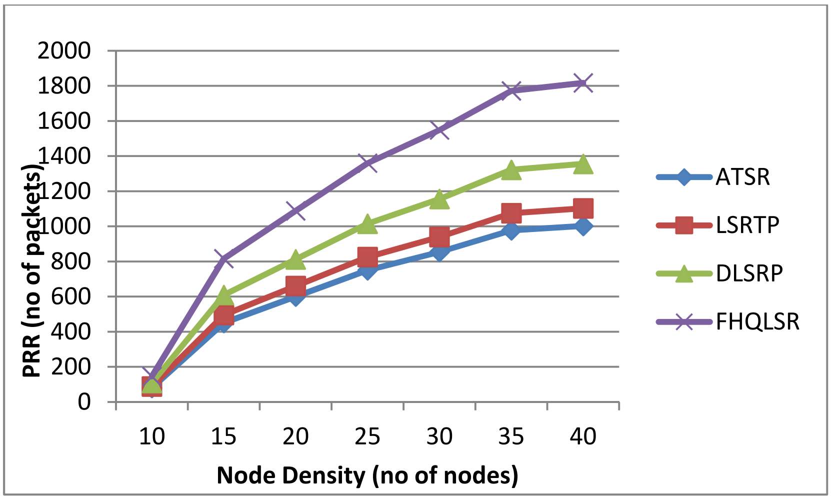


Fig3 describes the PRR values for different node density

### *5.3 Energy Drain Rate*

Energy Drain Rate is the amount of energy used in the network path for data transmission of the nodes. The residual energy at the end of the simulation has to be higher for better performance. From figure 4 the comparative analysis in our experiments shows better value for FHQLSR over other protocols. This is the indication of higher residual energy which means less amount of energy is drained while using FHQLSR protocol over WSN environment.

Table IV Energy values for various node density

| No. of nodes | FHQLSR | DLSRP | LSRTP | ATSR |
|---|---|---|---|---|
| 10 | 5 | 5 | 5 | 5 |
| 15 | 4.9 | 4.7 | 4.4 | 4.2 |
| 20 | 4.7 | 4.5 | 3.9 | 3.2 |
| 25 | 4.4352 | 3.696 | 3.36 | 2.8 |
| 30 | 4.1184 | 3.432 | 3.12 | 2.6 |
| 35 | 2.2176 | 1.848 | 1.68 | 1.4 |
| 40 | 1.4256 | 1.188 | 1.08 | 0.9 |

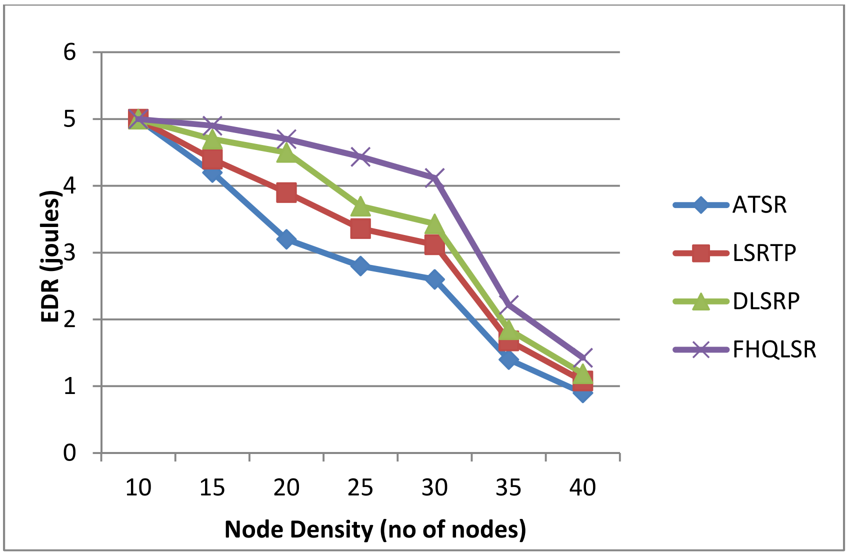


Figure 4 Shows the Energy drain rate for Various node Density

It is evident from the above table IV, that residual energy operating with various numbers of nodes is higher in the proposed algorithm FHQLSR. Even if we increase further the number of nodes this algorithm is suitable for n x n sensor network.

## VI. Conclusion and future works

In normal WSN, multi hop routing has been established using Co-operative Communication. Links unreliability poses a critical issue in such an environment. The scope of the work allowed the network to establish routes necessary to correct and efficiently deliver network data to the destination in a more reliable manner. The proposed Fuzzy based High Quality Link Set Routing has achieved better data aggregation in an efficient and effective manner in terms of the parameters such as Packet Delivery Ratio, Energy Efficiency, Scalability and Throughput. The results obtained were enhanced using the proposed method. In the future implementations, various Malicious Node Attacks can be tested in the fuzzy based high quality link set routing techniques and the research can further be extended towards empirical comparison and analysis of Malicious Node Attacks.

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