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A Research Article on Efficient Next –Node Selection Algorithm for WBAN by Using Fuzzy Logic

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Abstract

In this study, we have proposed an energy efficient next node selection scheme based upon fuzzy logic to improve its QoS parameters. Fuzzy logic provides very good solutions if there is any uncertainty or partial truth in input variables. Here residual energy, latency, link utilization and link reliability is used to estimate the link cost function corresponding to different links available to the source node. In this algorithm, Link with the highest link cost is preferred and in this way next node is selected and it will continue till the sink node. This approach provides improvements in power efficiency and packet delivery ratio as compare to DMQoS technique. The proposed scheme has been simulated using Mamdani-Fuzzy logic toolbox in MATLAB.

Keywords: Next-node selection, Fuzzy Logic, Residual Energy, Link Reliability, latency, Link Cost, Link Utilization Factor, Energy Efficient, WBAN, algorithms, FIS.

(I) INTRODUCTION

In this modern world, everyone needs a sound healthcare to improve quality of their lives. Wireless body area network get tremendous attention in e-healthcare to monitor and diagnose the patient [7]. Wireless body area network consists of different types of bio-sensors like ECG, EEG, Pulse oximetry, Motion sensors

,Glucose sensors etc. communicating with each other and to the central node called coordinator, which are implanted or worn by the target. These sensors are continuously monitoring and sending the real time parameters of a patient's body. Depending on these parameters a medical expert will provide the command to activate suitable action if situation is not normal. In WBAN, various wireless communication technologies like Zigbee, Bluetooth, 2.4 GHz ISM band and Intrabody communication are deployed to transfer the data between all the sensors and coordinator node [2]. But in WBAN unlike WSN there are number of limitations like battery power, coverage range, antenna height of transceiver, heterogeneous transfer rates, high signal attenuation etc. [2] But transmission with high QoS parameters like minimum interference, high packet delivery ratio (PDR), high throughput, minimum consumed energy, low latency, high link reliability etc. is the ultimate requirement due to their application fields.

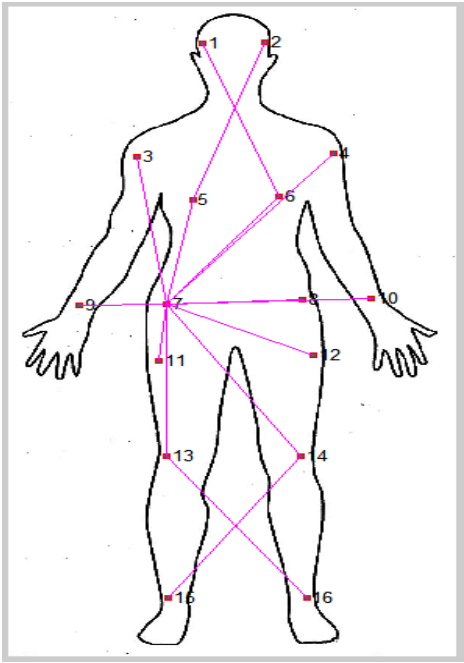

Fig.1 Different sensors placed on body in WBAN

Consequently, adequate resource management and service provisioning mechanisms become necessary to meet the increasing demand of quality of service parameters. Resource management framework starts with an effective packets routing protocol especially an adaptive routing metric protocol [10]. Recently number of such protocols are flourished for WBAN to improve the QoS parameters like adaptive power efficient MAC protocol named as Med MAC in which a novel based synchronization is utilized to give 10-15% of power efficiency than 802.15.4, low

power idle listening, S-MAC, T-MAC protocol which provides power efficiency over CSMA/CA [3] [4]. Fuzzy logic system had evolved very fast to solve various industrial problems and it is proving very effective in WBAN also [2]. Because it is a robust system and it could perform well even with imprecise input values also [7].
Further this paper is arranged in the following way: Section (II) will be network parameters and model, Section (III) Fuzzy Inference System, Section (IV) Proposed algorithm, Section (V) System Implementation, Section (VI) Results & Discussion and in the end section (VII) will conclude this research work.

(II) NETWORK PARAMETERS AND MODEL

(A) Link Reliability

This parameter tells about that how many retransmissions had to perform to get a successful transfer of the message over a link between two nodes. It is an essential QoS parameter in any network. Because energy consumption will increase, as the number of retransmissions will increase. Link reliability could be calculated by the equation of exponentially weighted moving average (EWAM) as given below [11]:

$$R_{ij} = (1-\gamma)R_{ij} + \gamma\left(\frac{Tr_{successful,ij}}{Tr_{Total,ij}}\right)$$

Where,
γ = Average weighting factor
R_{ij} = Link reliability
$Tr_{successful,ij}$ = No. Of packets successfully transmitted through the link between nodes N_i and N_j
$Tr_{Total,ij}$ = Total no. of packets transmitted and retransmitted through the link between nodes N_i and N_j.

(B) Latency

Latency is measure of delay caused in data transmission over a link. It consists of propagation delay and serialization delay. Minimization of latency is desired because power consumption and degradation in performance will increases with increment in latency of the link [14]. It should be less than 125 milliseconds in medical applications.

Latency= propagation delay + serialization delay

where,
Propagation delay= distance of link (m)/ transmission medium speed (m/s)
Serialization delay= packet size (bits)/data rate (bps) [14]

(C) Residual energy

Energy requirements are the basic needs for any device to work properly. In WBAN, sensors which are used have limited amount of power with them and replacing the batteries or recharging them would be a difficult job especially with the implanted sensors as compare to the wearable or attached sensors over the body. So the energy resources must be used efficiently and residual energy tells about the remaining energy with the device after completion of its previous tasks. A proper energy model is presented to calculate the residual energy, consumed energy etc. [11]

For node Ni, Residual Energy is:

$$E_{res,i}=E_{init,i}-E_{con,i}$$

where,

$E_{con,i}$= Total consumed energy in nodes N_i

$E_{init,i}$= Initial Energy of nodes N_i

Total consumed energy in nodes N_i can be calculated as:

$$E_{con,i}=A_i*E_{Tx}+B_i*E_{Rx}$$

where,

A_i = No. of bits transmitted by node N_i

B_i = No. of bits Received by node N_i

E_{Tx}= Total energy consumed in transmission

E_{Rx}= Total energy consumed in reception

$$E_{Tx}= E_{TxElec}+ E_{amp}*D^2$$

$$E_{Rx}= E_{RxElec}$$

where,

E_{TxElec} = Energy consumed in transmitter antenna

E_{RxElec} = Energy consumed in receiver antenna

E_{amp} = Energy consumed in Amplifier section

D = Distance between nodes N_i and N_j

(D) Link Utilization Function

Link Utilization function could consists of various parameters as per the requirement metric of the network. Here we are taking the Residual energy, queue size and link reliability functions to evaluate the link Utilization function and based on these maximum link Utilization in desired because if it is higher the network will offer high quality of services in terms of parameters like stability, throughput, latency, delay etc. [11]

Link Utilization function will be calculated as:

$$C_{ij} = C_E \times \frac{E_{res,j}}{E_{init,j}} + C_Q \times \frac{Q_{empty,j}}{Q_{total,j}} + C_L \times R_{ij}$$

where,

C_{ij} = link Utilization value of link between node N_i and N_j

$Q_{empty,j}$ = Available Queue size of node N_j

$Q_{total,j}$ = total Queue size of node N_j

C_Q &C_E & C_L = constants and the remaining notations have their meaning as before.

(E) Network model parameters

Here in this proposed work we have implemented a network with 16 nodes which are shown as in the fig.1. We have considered some of the parameters to get the results which are summarized in Table 1[11]

Table 1

Parameters	**Values**
Traffic	CBR
Mobility	No
No. of packet	20
Size of packets	32bytes
Initial Transmission power(mW)	2 mW
No. of nodes	16
Power consumed in antenna (TX & Rx)	0.3 mW
Data rate	50 Kbps
Mac Protocol	802.15.4
C_E, C_L, C_Q	3,3,2
Distance Range Value	40 cm

(III) FUZZY INFERENCE SYSTEM

Fuzzy Inference system is designed to formulate and simulate the fuzzy logic based problems. Fuzzy logic is a type of logic which took partial truth into the account and based on this good solution for the problem is suggested when imprecision, imperfect and incomplete data is presented. Fuzzy logic is in extensively in use in different fields like signal processing, bio-medical and aerospace and in various automation industries also [12]. Fuzzy Inference system consists of four main parts which are as:

1) Fuzzifier: It will convert all the input variables (crisp) into the fuzzy variables based upon membership functions values in database.

2) Knowledge Base: All the data regarding degree and values of membership functions and rules data get stored into this section. Rule base consists on IF-THEN based statements and AND-OR logics which proves to be handy in calculating the results [13].

3) Fuzzy Inference Engine: It performs all the decision making work based upon the rule base data and the inputs variables and maps them to corresponding fuzzy output variables [13].

4) Defuzzifier: After the aggregation of all the outputs variables, the mapped fuzzy output variable would get converted into the real value i.e. crisp value which is used as decision value [12]. In this work, we use the Centroid technique for defuzzification which consists of determining the point at which a vertical line divides the combined set into two equal parts [15].

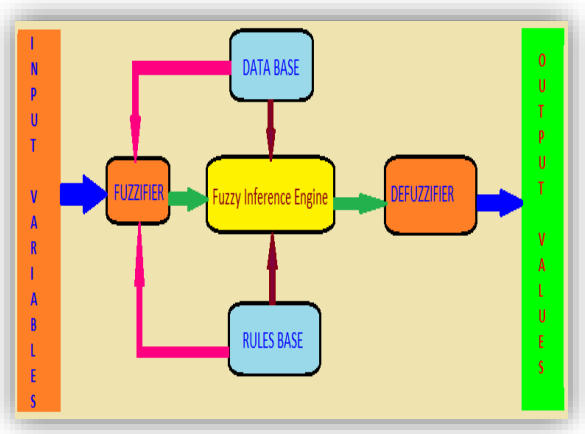

Fig.2 Fuzzy Inference System [2]

(IV) PROPOSED ALGORITHM

First of all before sending the actual data in first loop all the neighboring nodes within acceptable distance are calculated. Then in second loop parameters of the nodes like residual energy, reliability, latency, utilization factor will be calculated and fed to fuzzy inference system so that corresponding link cost would be found. The node with highest link cost will be accepted for the path formation. This mechanism provides the packet delivery ratio and power efficiency during transmission [11]. The proposed algorithms for initial phase, evaluation phase and node selection phase are given as:

Algorithm

(A) Initial phase

1. **Input:** Nodes= Number of nodes, Sink node, Source node, Distance range value.
2. For i=1:nodes
3. For j=1:nodes
4. Calculate the distance ($Distt_{i,j}$) between source node N_i and all other nodes N_j.
5. End
6. End
7. Find all the nodes having distance less than specified Distance range value from source node N_i and update them to the neighboring nodes list of source node N_i.

(B) **Evaluation phase**

1. For i=1:nodes
2. For j=1:nodes
3. Calculate the link reliability ($R_{i,j}$) with all the neighbors of node i
4. Calculate the link utilization factor (Uti) with all the neighbors of node i
5. Calculate the Residual Energy(E_{Res}) with all the neighbors of node i
6. Calculate the $latency_{i,j}$ with all the neighbors of node i
7. End
8. End
9. For i=1:nodes
10. For j=1:nodes
11. Evaluate the link cost by using Mamdani-Fuzzy logic toolbox in MATLAB.
12. End
13. End

(C) Node selection phase

1. If nodes is not equal to sink node
2. For i=1:nodes
3. For j=1:nodes
4. If distance of node N_j from source node N_i ($Distt_{i,j}$) is less than the specified Distance range value and have the highest link cost value
5. Then select that node and update it to the nodes list to form the final path
6. Then go to that node and repeat same steps of section (A), (B) and (C) again
7. Else
8. Reject it
9. Go to step 2
10. End
11. End

(V) SYSTEM IMPLEMENTATION

(A) Fuzzy Inference System Wireless Body Area Network System (FIS-WBAN)

In this proposed work, we have implemented the 16 nodes into the network where central coordinator could be a Smartphone or a RF-node placed on the waist and ankle of the patient. Coordinator node will collect data from the remote nodes and this will behave as hub or gateway for other remote sites which provides the instructions to sensors and actuators. In real life applications, multi hop WBAN network is formed [11], [6]. The proposed FIS-WBAN with 4 inputs, 1 output and 81 fuzzy rules is implemented as shown in fig.3:

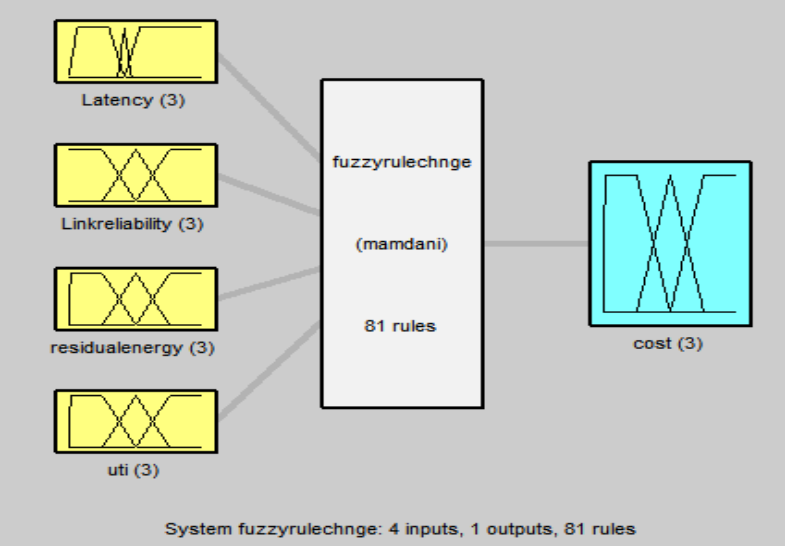

Fig.3 FIS-WBAN

(B) Input membership Functions

Link reliability, link utilization function, residual energy and latency are used as membership functions which are mapped into fuzzy values from their crisp values. Some initial values for them are considered to show the idea but more generic values must be used for designing of such type of system [11].

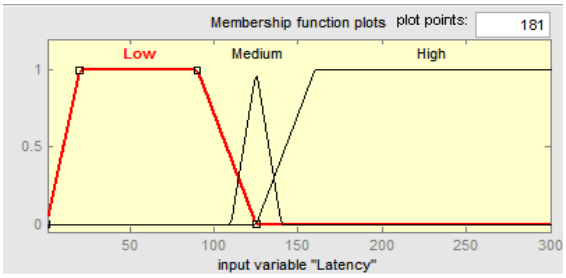

Fig.4 Latency

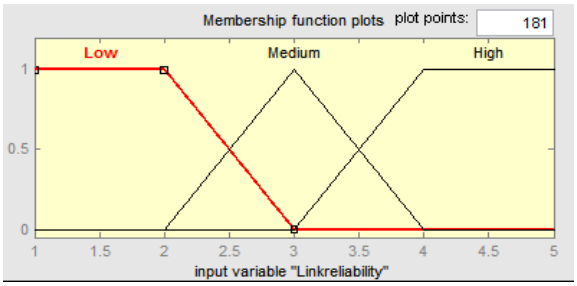

Fig.5 Link reliability

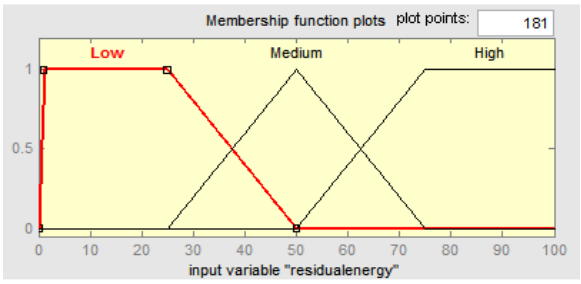

Fig.6 Residual energy

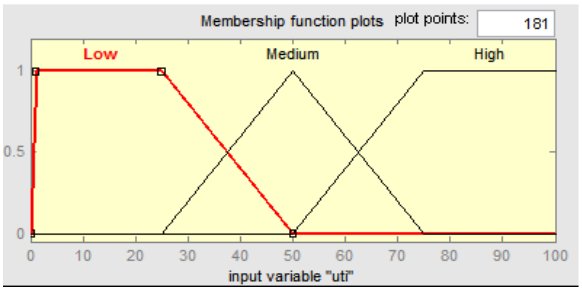

Fig.7 Link utilization factor

(C) Fuzzy knowledge base

Fuzzy knowledge base consists of rule base and membership function values as shown in fig. 4-7[13]. Fuzzy logic doesn't require the precise input values. All the rules are defined by using If and Then statements in which all the variables are connected by AND (Minimum) operation. Each rule illustrates the relation between input and output fuzzy sets [7]. All the Rules utilized in this approach are given in Fig.8.

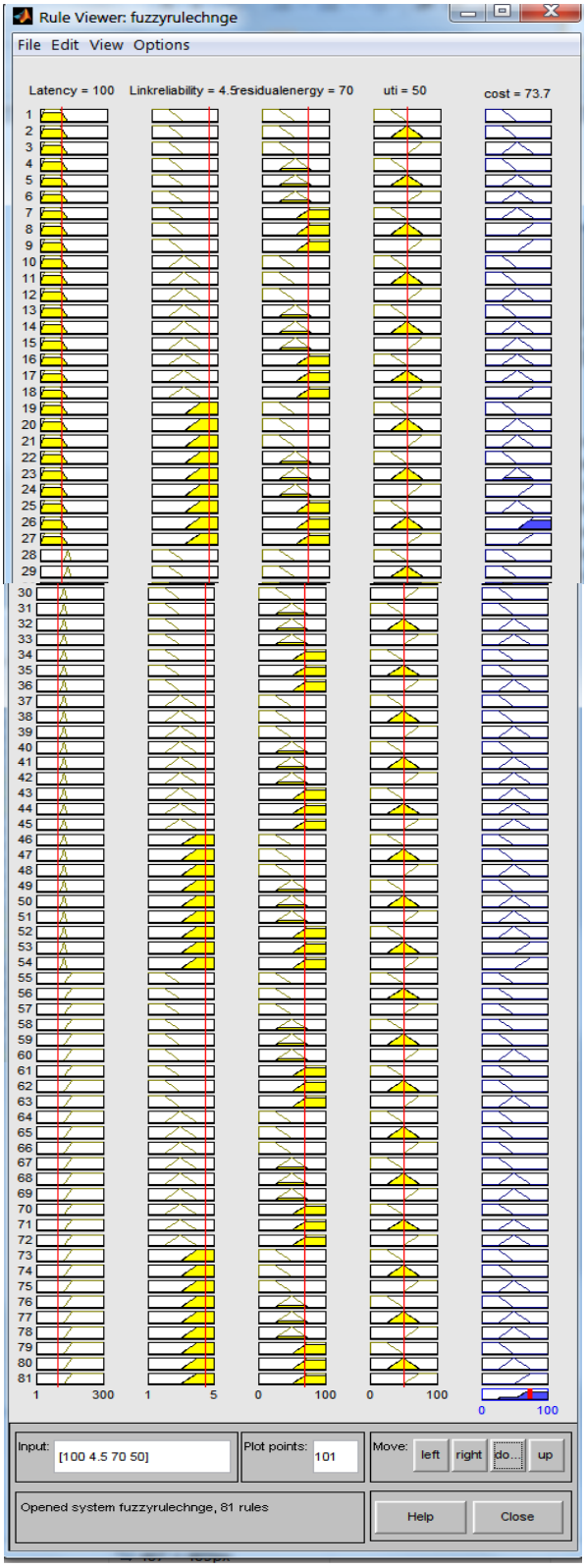

Fig.8 Rules viewer

(D) Output Membership Function

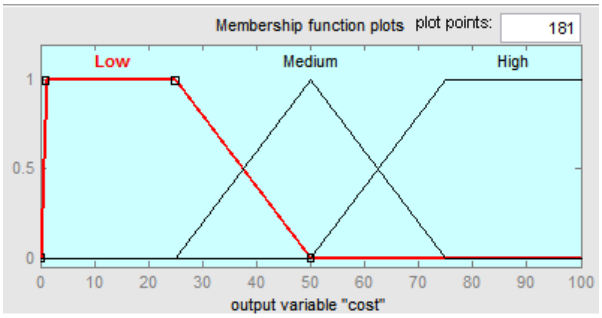

Fig.9 Link cost function

(VI) RESULTS & DISCUSSION

Mamdani-Fuzzy toolbox in MATLAB is used to simulate all these values [6]. Corresponding to all the rules and input variables as shown in fig 4-9, their simulated surface values with respect to output link cost function are shown in the fig.10.

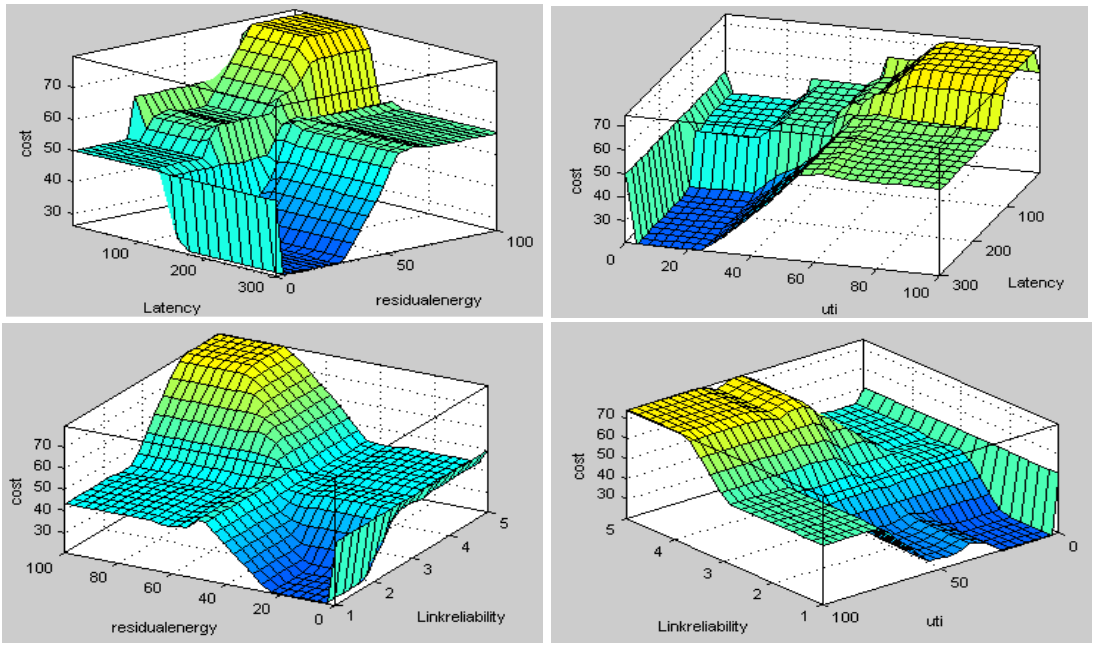

Fig.10a Surface Views

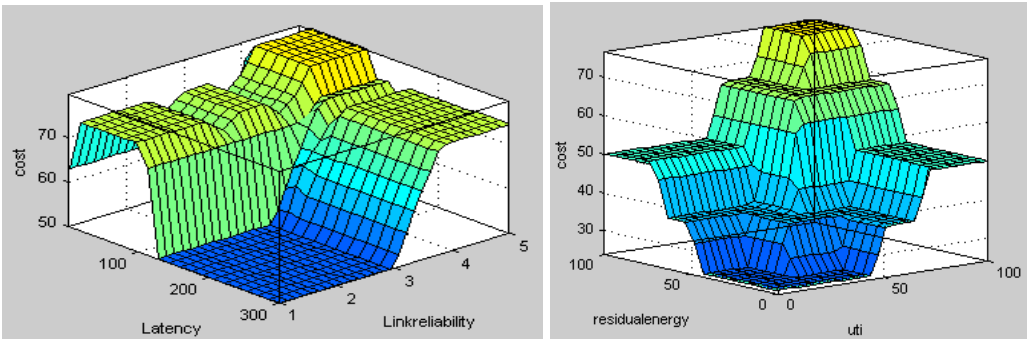

Fig.10b Surface Views

While analyzing the outputs of the proposed scheme, good improvement in power consumption over the DMQoS technique with same parameters is obtained. With 16 nodes in a network, average power consumption through the paths is 0.1781 mW when coordinator is present at ankle while it is 0.197 mW when coordinator is present on waist.

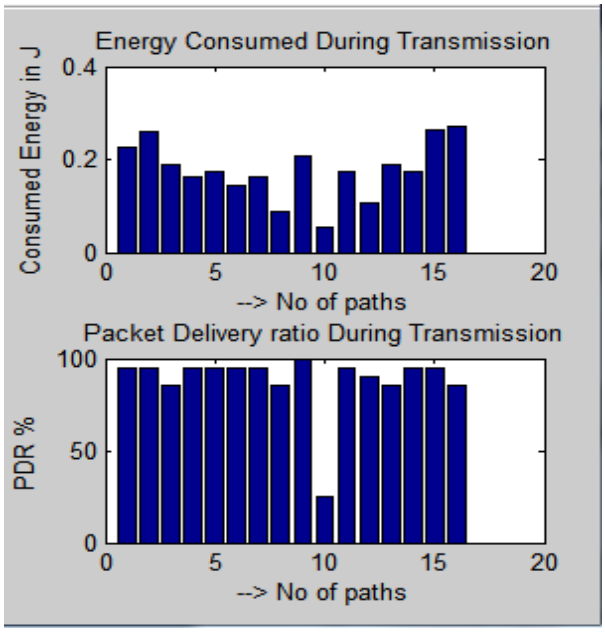

Fig.11 Consumed Energy and Packets Dropped (coordinator is on ankle)

Packet delivery ratio of 89 % is obtained when coordinator is on ankle while it would be 90% when coordinator is on waist.

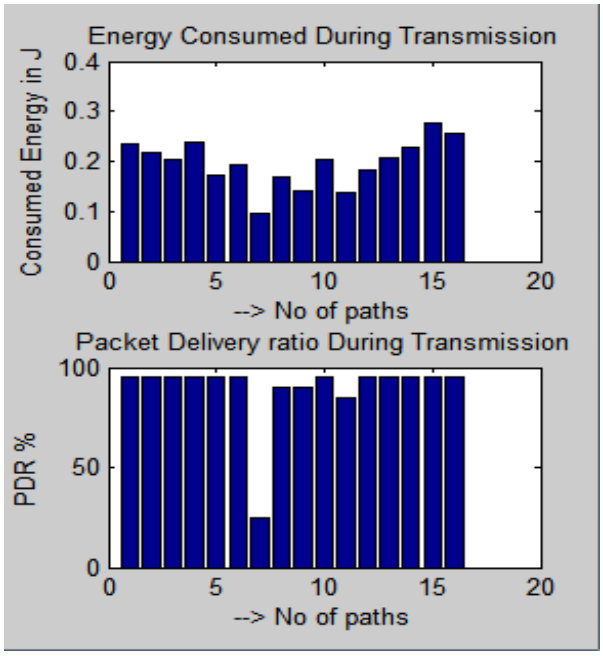

Fig.12 Consumed Energy and Packets Dropped (coordinator is on Waist)

(VII) CONCLUSION

In this paper, energy efficient next node selection scheme based upon fuzzy logic has been presented to improve its QoS parameters by controlling residual energy, reliability, latency, utilization factor. The proposed algorithm has been successfully simulated and it has been verified that this approach gives better results as compare to DMQoS in terms of power saving scenario and packet delivery ratio.

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