Enhanced MAC Layer Based On Fitness Function For WSN Using Fuzzy Inference System

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Abstract -Wireless sensor network (WSN) is one of the supporting technologies of Internet of Things, and has broad application prospects, and much characteristics different from traditional wireless networks. A large number of sensor nodes are randomly deployed in monitoring area inside or near and the monitored data are sent along with other sensor nodes through multi-hop transmission to the sink node. This is one of the main transmission modes in the WSN. Nodes transfer their data through wireless channel in WSN. Wireless channel, as a medium of communication, has limited spectrum. It can cause conflicts within the data due to congestion. Medium Access Control (MAC) protocol will efficiently coordinate the access of multiple sensor nodes to shared channel, enabling the data sent by different nodes to avoid conflicts. In addition, the limited bandwidth resource can be used fairly and efficiently. In this research work an enhanced MAC protocol is proposed and is designed based on the Fuzzy Inference System (FIS). Using this approach, priority packet sets are identified based on the Residual Delay and Residual Buffer to avoid the packet collisions.

Keywords*-Wireless Sensor Networks; data transmission; Mac Protocol; Fuzzy Inference System.*

I INTRODUCTION

Wireless Sensor Network (WSN) consists of a group of sensor nodes that converts one type of energy (or) signal in to another [1][2]. A sensor node consists of five components. They are (I) Controller: Controller is the Central Processing Unit of the sensor node. Functions of the controller are that it collects the information and process it and decides where to send based on actuators behavior. (2) Sensors and Actuators: Sensors are the devices that observe the physical values of the environment and the Actuators are the motors that are responsible for controlling the device.(3) Communication device : For communication purpose both transceiver and receiver are necessary for a sensor node. Communication between individual sensors can be done using ultrasound, radio frequency, magnetic inductance etc. (4) Memory: Memory is essential for storing intermediate sensor data. (5) Power supply: In WSN, nodes are typically function on batteries. Manual recharging or replacing of WSN nodes are quite impossible for many real time applications. So the batteries of sensor nodes can be recharged from the external ambience such as vibration temperature pressure solar power etc., if possible.

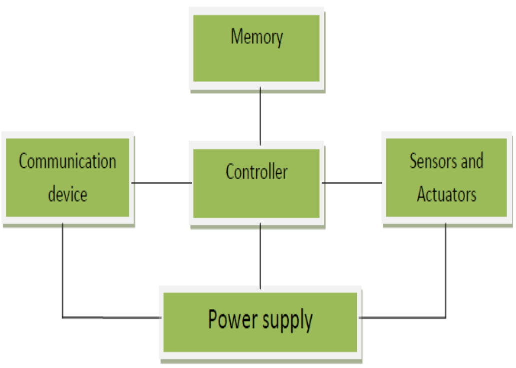

Fig 1.Sensor Node Architecture

This WSN have wide range of applications in almost all real time fields. One such application is monitoring and recording of environmental conditions at various locations. This environmental monitoring is most essential for the benefit of human society. The nodes in the network are used for collecting information and transmit it to base station at regular intervals through communication medium [3]. Nodes communicate only when the neighbor nodes are within their spectrum range. Transmission of data can be done by either single hop or multi hop. In single hop transmission source node transmit their data directly to the destination. This type of transmission elapse more energy when the destination is too long. Whereas in multi hop transmission source node transmit their data to nearest neighbor and this will be continued until it reaches the destination.

While transmitting packets from one node to another a lot of issues were arisen [4]. As it is a wireless medium, packets transmitted in the similar frequency band interfere with each other. In order to avoid and control the contention and collision problem between wireless nodes, Medium Access Control (MAC) layer is used [5].In the seven layer OSI reference model ,MAC layer is one of the sub layer of the Data Link Layer (DLL).While designing MAC protocol one must consider the following two most important attributes. (1) Designing energy efficient protocol to extend the life time of a sensor node.(2) Routing protocols must support scalability and adaptability. The secondary attributes for designing MAC layer are latency, bandwidth utilization, quality of service, synchronization and throughput. The MAC layer is responsible for transmitting packets to and from one Network Interface Card (NIC) to other through shared medium. Addressing Mechanism and Channel utilization are the basic functions of MAC layer. Furthermore MAC attributes are used to improve energy efficiency, scalability, node density, topology change, channel utilization, throughput etc.

In regard to a sensor node, communication unit has the largest share in energy consumption. Minimizing this will enhance the lifetime of the system and Quality of Service (QoS) has to be improved further in WSN. In MAC layer, one of the main issues to increase the energy consumption is collision i.e., Packets become unavailable when two packets collide being transmitted in overlapping time interval, thus the packets need to be resent. Resending means additional energy is used. Collision also increases the delay. So it is necessary to concentrate on end to end delay time of each and every packet of a node in order to reduce the packet drop. In order to achieve this, a suitable routing algorithm is required to transfer data from source to destination within the stipulated delay time. Routing protocols can be broadly divided in to proactive and reactive. Based on ad-hoc routing, it can be categorized in to two types. They are table driven and on-demand driven. In the first type, each and every node in the network should maintain a table and it contains sequence number, next hop and the destination. But the major drawback is that it is not suitable for dynamic networks. In the second type, routes are established only on demand. We can also combine the advantages of both table driven and on demand driven as hybrid routing which acts as both proactive and reactive.

The packet transmission order for a node can be determined by packet scheduling algorithm. By considering the end-to-end delay and the onset time of a packet, the transmission order can be determined using Shortest Remaining Time First . In this paper we propose a new mechanism called Fitness Function in order to identify the priority packets of a node using AODV protocol. The fitness function can be calculated by choosing minimum value of Residual Delay and Residual Buffer.

Additionally this paper describes about the review of literature in section 2 and the proposed mechanism is explained in section 3. Section 4 deals with the simulations results and concluded in section 5.

II RELATED WORK

Ewa Niewiadomska-szyokiewier and Pilip Natrdalik [6-10] proposed LE-AODV & SLE-AODV routing protocol for energy aware and secure communication. LE-AODV is a hybrid technique which combines both AODV and LEACH. AODV is a Ad hoc On Demand Distance Vector. It creates route only when demand. Low Energy Adaptive Clustering Hierarchy (LEACH) is used for energy conservation of sensor nodes. In order to extend the network lifetime , an activity control based energy conservation techniques are used and for secure routing AES cryptography techniques are used. The scope of this paper is to increase the energy of the sensor nodes and also increases the sensing range. The proposed protocol improves communication mode from single hop to multi hop.

In [11-15], In order to improve the QoS, a delay scheduling algorithm was proposed based on urgency metrics. The metrics are chosen based on packet, node and route to improve the throughput of the network. The scheduling algorithm in MAC layer and routing algorithm in network layer are closely tied to maximize the number of arriving packets at the destination.

In [16-20], an energy efficient Multi Layer MAC protocol (ML-MAC) was proposed to attain low duty cycle, elongate network lifetime & minimum collisions. The proposed protocol divides the WSN nodes in to several groups (layers) based on their geographical region in order to reduce the data loss. In this technique only one layer is active during communication and the remaining layers are at sleep mode to save network energy. It also supports reliable transmission of data and decreases collisions. Finally ML-MAC is efficient for reducing collisions and increases the sensor node energy during communication.

Adnan Ahmed and others [21] presented a Trust and Energy aware Secure Routing Protocol (TESRP) for detecting malicious nodes in the network. It also increases the confidence and energy saving capacity of each and every node through shortest path selection. The proposed protocol supports network scalability, when compared to existing schemes.

For reliable multicasting in WSNs, Ashutosh Bhatia*,R.C.Hansdah [22] proposed a TDMA based energy aware (TRM-MAC). The factors affecting reliability and energy resources are due to collisions, overhearing and idle listening can be eliminated using TDMA. To improve the reliability of WSN at MAC layer, the author used ACK and NACK approaches with TDMA. The core contribution of this paper is to identify and select the nodes that needs ACK approach to improve reliability and also decides which nodes uses NACK approach to avoid collisions.

In [23-28], proposed a Real time X-layer protocol (RTXP) which is a MAC & routing real time communication protocol designed to increase the packet delivery ratio. Deterministic requirements are introduced at MAC and routing layers to handle real-time requirements. RTXP is also implemented on harsh radio channel and proved that it is useful in highly unreliable networks like WSN.

III PROPOSED MECHANISM

Energy conservation is an important parameter when using Wireless Sensor Network because, recharging and replacing of sensor nodes are impossible for many real time applications[29]. In the proposed system , we are using AODV protocol for route discovery and communication .Every node in the network forwards its packet only when it receives route reply and also it comfirms that whether the node has sufficient energy to forward otherwise it drops it. Hence the data transmission using AODV can takes place only through energy efficient path. Energy can be calculated by subtracting the consumed energy from initial energy of a particular node.In the existing system, Destination sequenced Distance Vector (DSDV) protocol is used and it is compared with the proposed AODV protocol .From the results we conclude that AODV is efficient while we are increasing the number of nodes as 50,100,150,200 etc. Energy conservation and Network Life Time are dependable parameters in WSN. If we save the energy of each and every node in the WSN, the Life Time of the network will be elongated. It is proved that AODV efficiently elongates the network lifetime when compared to DSDV.

We propose a new mechanism called Fitness Function which identifies the priority packets using fuzzy logic. In order to avoid end to end delay and energy dissipation of nodes, we introduce a new parameter called residual delay and residual buffer to estimate the energy level at every offspring node using AODV protocol. Then the fuzzy Inference system controls the data transmission rate of offspring nodes based on the parameter value in the wireless networks[14][15].

A. Residual Delay :

Each and every packet should have a time limit to reach the destination. The packet will be dropped, If the time is elapsed. Residual Delay sensitive packet means the packet that is having minimum time to reach the destination. So our main intention is to send the Residual Delay sensitive packets and to control and distribute the network traffic load evenly across the whole network within the delay requirements over multi-hop data transmission from source to destination .To attain this goal, Necessity metrics are defined.

1 Packet Necessity:

$N_{Pack}(i)$ is the packet Necessity of the i th packet in the buffer. The Necessity of packet ($N_{Pack}(t)$) at the i th node along the route (R) at time t is defined as.

$$N_{Pack}(t) = For_{necc}\left(\frac{RD(T)}{Dmax}\right)$$

Where Residual delay can be calculated by

$$RD(t) = Dmax - d^{i}_{cum}(t)$$

Dmax is the maximum tolerable end to end delay and $d^{i}_{cum}(t)$ represents cumulative delay from source to i th node.

2 Node Necessity:

The sum of packet Necessity of all the packets in the buffer is defined as Node Necessity.

ie., ($N_{node}(t)$).

$$N_{node}(t) = \sum_{i=1}^{n_{pack}} N_{pack(i)}(t)$$

Where n_{pack} is the number of packets available in the buffer and $N_{pack(i)}(t)$ is the packet necessity of the i th packet in the buffer.The value of Node Necessity is lager, if there are more number of necessity packets available in the buffer.

3 Route Necessity:

The sum of node necessity of all the intermediate nodes of a particular route (R) is defined as Route Necessity ie., ($N_{route}(t)$)

$$N_{route}(t) = \sum_{i \in R} N_{node(i)}(t)$$

Where R denotes the route that includes all the intermediate nodes and $N_{node(i)}(t)$ represents the node necessity of the i th node along the route. The route that has minimum route necessity is chosen as the pathway to transmit the data.

B.Residual Buffer :

If a node I wants to transmit a packet to another node j (j is a neighbor of i).This is possible only when node j has sufficient buffer size to hold the packet from i. While we are using Residual Buffer criterion during routing, we can avoid packet drop at the receiver because of buffer overflow.

Residual Buffer at node i can be calculated as follows:

$$RB(i) = \frac{NQ(i)}{TB\ (i)}$$

Where NQ(i) denotes number of packets in the i^{th} queue buffer and TB(i) represents the total buffer size at node i.

The value of RB(i) is always in the range[0 ,1].

$$RB(i)= \begin{cases} Best\ case\quad if\ 0 \leq RB(i) \leq 1 \\ Worst\ Case\ if\ \ RB(i) \geq 1 \end{cases}$$

C. Fuzzy Inference System (FIS) :

Fuzzy Inference System consists of five mechanisms: (i) Fuzzification of the crisp inputs (ii) Apply Fuzzy operator in the antecedent (iii) Implication from the antecedent to the consequent (iv) Aggregation of the consequents across the rules (v) Defuzzification.

Fuzzification process maps the crisp inputs to corresponding fuzzy sets. Rules play a vital role on every fuzzy regulator. In this paper, the relation between the residual delay and residual buffer are taken as crisp inputs and the rules are frame using the crisp variables as shown in the below table.

S.No	RD	RB	VA
1	small	Small	DVS
2	small	Medium	DS
3	small	Large	DM
4	Medium	Small	DS
5	Medium	Medium	DM
6	Medium	Large	DL
7	large	Small	DM
8	large	Medium	DL
9	large	Large	DVL

Table .1 FVAIS Rules

The nodes whose end to end delay is greater than the Fitness function are called congestion prone nodes. In this situation, the child nodes will be informed using some alarm signal. When child nodes received this signal, it alter their transmission rate using proposed Fuzzy Inference System (FIS). It is significant that packet forward rate for each node can be regulated by adjusting the FIS. Finally this FIS delay data transmission rate in order to reduce congestion.

D Fuzzification Process :

Fuzzification process takes Residual Delay and Residual Buffer as two crisp inputs and determine the degree to which they belong to each of the appropriate fuzzy sets via membership function as follows:

$$\mu_{A}: X \rightarrow [0,1]$$

Where [0,1] represents real numbers between 0 and 1(including 0 and 1)

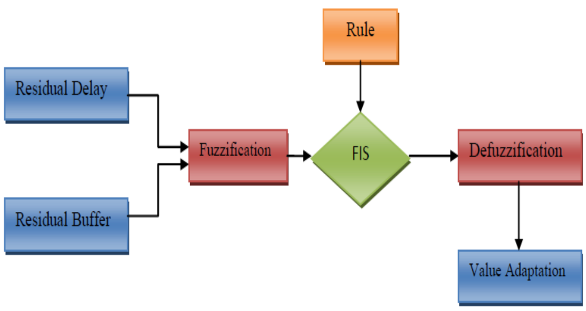

Fig.2 .Block Diagram of FIS.

Consider the inputs as,

RD = Residual Delay ∈ {small, Medium, large}

RB = Residual Buffer ∈ { small, Medium, large}

The next step is to apply the inputs to the fuzzy system (FIS), then it produces the output fuzzy set as follows:

VA = Value Adjustment ∈ {DVS, DS, DM, DL, DVL}

The output value represents five fuzzy states including: DVS (Delay Very Small), Ds (Delay small), DM (Delay Medium), DL (Delay Large) and DVL (Delay Very Large). All the values should be in the range [0,1].

We must determine the rule weight before applying the implication method. Then the rule weight is applied to the number given by the antecedent. Since decisions are based on testing all the rules in FIS and then the each rule outputs are combined in to a single fuzzy set.

We used triangular function to represent these sets. The fuzzy number A = (a, b, c) is called triangular function is defined as

$$\mu_{A}(x) = \begin{cases} 0 & , x \leq a \\ \frac{x-a}{b-a} & , a < x \leq b \\ 1 & x = b \\ \frac{c-x}{c-b} & , b < x \leq c \\ 0 & x \geq c \end{cases}$$

E Defuzzification Process:

Defuzzification is the method of reducing a fuzzy set to a crisp single valued quantity. so we must find out the minimum value between $\mu(RD)$ and $\mu(RB)$ and we are using AND logic in order to write fuzzy rules.

$$\mu(RD \cap RB) = \min(\mu RD, \mu RB)$$

To find the crisp output of our fuzzy system ,we are using Centroid defuzzification method for calculating the center of Area(COA)

$$\text{COA } (Z^*) = \frac{\int \mu_{c(z)} z \, dz}{\int \mu_{c(z)} dz} \quad \text{for all } z \in Z$$

For optimal MAC design, packet collision is to be reduced. So, optimal prioritized packet sets are selected based on the Fuzzy Inference Algorithm. In this algorithm, minimum of Residual Delay and Residual Buffer occupancy is considered as fitness function to select packet which is to be transmitted first.

Fitness = min (Residual Delay + Residual Buffer)

IV RESULTS AND DISCUSSIONS

Network simulator 2 (NS2) is a distinct event simulator used to create real time network traffic and topology for research. The simulation results of various performance metrics such as Energy Efficiency, Network Life Time, Delay Time and Delay Ratio using NS2 were shown below. The proposed method gives better result, when we increase the number of nodes in the network as 50,100,150,200,250.

No. of Nodes	50, 100, 150, 200, 250
Area Size	1000m X 1000m
MAC TYPE	MAC / 802_11
Propagation	Two Ray Ground
Antenna	Omni Antenna
Interference range	550 m
Transmission Range	250m
Simulation Time	100 sec
Traffic Source	CBR
Packet Size	1024 bytes
Rate	80 kbps

Table 2. Simulation parameters

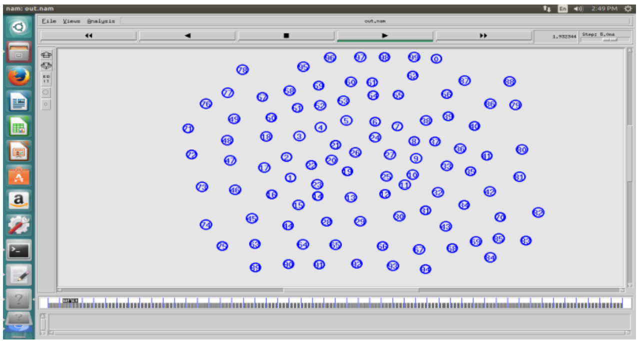

Fig.3 NAM window for 100 nodes

A Simulation Analysis

Here, we compare the existing techniques (RTXP) using DSDV protocol with the Proposed approach (ER-IMAC) based on AODV protocol and it is explained based on performance evaluation metrics.

In Fig.4a shows the energy consumption of the sensor nodes and it is compared with the proposed and the existing system. The size of the network increases slowly from 50,100,150,200 and 250.The proposed system depicts that how the energy will be consumed when we increase network size. From the graph, we infer that at the starting size of 50 nodes the energy level is high in the existing system than proposed one. At last the result of the graph shows that proposed system consume less energy when compared to the existing one.

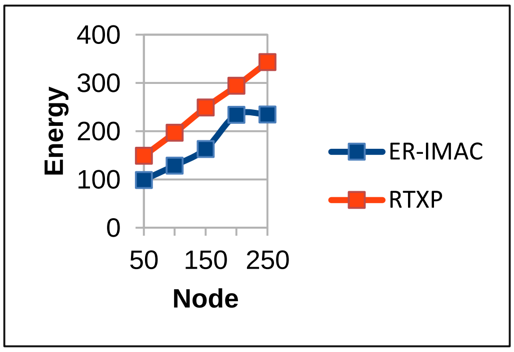

Fig.4 (a) Node vs Energy

Figure 4(b) shows the Network LifeTime comparison for various network size in the existing and the proposed system. In the proposed system ,the network life time is high when the size is minimum .It slowly goes down when the size of the network increases. But in the existing work it is very minimum from the starting when compared to proposed. Finally as shown in the figure,the Network LifeTime for the proposed system is elongated than existing one.

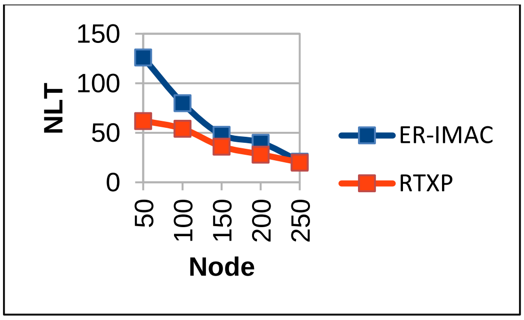

Fig.4 (b) Node vs Network Life Time

Node vs Packet Delivery Ratio for the existing and the proposed system was depicted in the graph 4(c). In the existing system , as the number of nodes increases the delay ratio decreases drastically when compared to the proposed system.

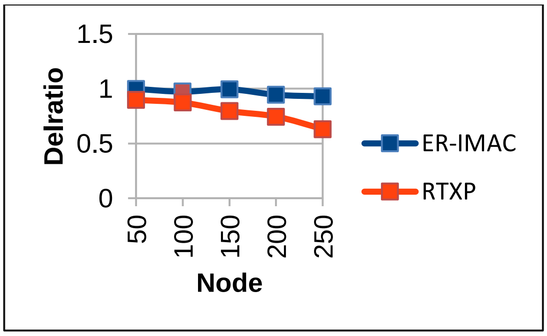

Fig . 4(c) Node vs Packet Delivery Ratio

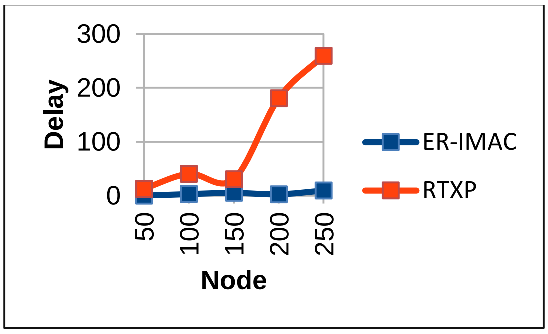

Fig.4(d) Node vs Delay

From the graph 4(d) plotted between the Node vs Delay ,it is clear that the proposed work is showing better performance than existing work.Also the delay time is very much less even for the varying topologies(50 – 250 nodes).

It means that for more number of nodes the data are communicated very fastly without more delay. So it is concluded that our work shows best performance for any number of nodes

V. CONCLUSION

Due to collision of packets the transmission energy is reduced, while transmitting through Mac layer. To overcome this, an enhanced MAC layer is designed based on the Fitness function to avoid collision problem during data transmission. Fuzzy Inference Algorithm is used to identify the priority packet sets based on minimal value of Residual Delay and Residual Buffer. The proposed method supports scaling of networks regarding energy consumption, reduces end to end delay, extends Network Life Time etc.

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