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An exploration of integration of IoT and 5G networks and a fuzzy approach for clustering to enhance the lifetime of such networks

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Abstract

Medium access control protocols play an important role for allocating the medium to the smart devices connected on the networks. These networks include IoT and sensor networks, IoT and 5G networks, IoT and optical networks using 5G communication etc. MAC protocols ensure the efficient and fair communication through these networks from devices to base station. Wireless sensor networks are considered as the back bone for the internet controlled applications. These networks set up link between virtual and real world. The selection of the suitable MAC protocol can help in improving the network life time so the data collected by the nodes is delivered to its destination. So this paper explores the various MAC protocols available for IoT and 5G applications and .The parameters of study for these MAC protocols used for the real time applications includes residual energy, throughput, packet delivery ratio, latency and network lifetime. The paper also explores the usages of machine learning and AI used in MAC protocols for these high speed IoT networks. The work addresses the improvement of network lifetime and residual energy by applying Fuzzy approach for the selection of cluster head . The energy consumption increases if the clusters are not balanced in terms of the nodes so we have used the grid formation of the clusters. We used the Fuzzy Logic Inference system (FIS) in the cluster formation technique. The probabilistic method for election of cluster head does not consider the parameters such as residual energy, node position and base station distance. This result in the improper selection of the cluster head .The use of multiple parameters in the FIS improves the network lifetime and residual energy as compared to the classical LEACH protocol. Fuzzy logic approach solves the uncertainties occurring in the system especially when it is handling the larger amount of data. The fuzzy approach shows the prolonged network lifetime in terms of first node die and the Last node

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Die. We have also used the statistical regression approach to calculate the residual energy and network life time in terms of alive nodes. Finally this chapter ends with the discussion of challenges and future scope of the MAC protocols used for the real time applications. The work is important as it gives opportunity for the research areas in high speed IoT and 5G networks for using AI and ML intelligent to develop QoS MAC protocols.

Subject Classification: *68M18.*

Keywords: *Medium Access Control Protocols, IoT, 5G, Residual Energy, Fuzzy Logic, Network Lifetime.*

1. Introduction

5G technologies give better opportunities for action control, monitoring and surveillance applications and data analysis. The increased communication bandwidth and data rate of 5G will provide the communication among high bandwidth clients and hence the information will be reaching fast. The hybrid networks will be consisting of low power Bluetooth/LTE networks in unattended area and high speed 5G networks in cities. The MAC protocol design is application specific for ad-hoc networks. Some applications demand high speed networks and for them the throughput is of utmost importance whereas some are used for monitoring environment, border surveillance, health monitoring etc which requires sometimes low throughput and require high throughput on happening of an event like fire conditions, suspicious activities at border or an heart attack to a patients. In these cases network require low latency and high throughput. Network life time is always important in networks which are deployed in unattended areas. In Lora technology Lora nodes are low power and having range of 10 km but the data rate is very low and we can only transmit test not the files and videos. For sending images and videos we would require technology like Bluetooth LTE technology as ad-hoc network in multihop scenario in unattended areas and then Wi-Fi or optical networks 5G/6G connection for sending the data at high speed. Now in such situation the power of Bluetooth devices should be used efficiently so that they may send the information to the Wi-Fi or internet connectivity and hence to cloud or base stations. [24-25] discuss the architecture of integration of low power wireless ad-hoc networks and high speed 5G networks.

WSN plays significant role for real time application such as crop monitoring in agricultural fields, machinery health monitoring in Industries, Patient health monitoring, surveillance, Flora and fauna applications, environmental emergency, military operations etc. few

applications are depicted in Figure 1 All these application are event triggered and mainly involve tiny sensors such as Gas sensors, humidity sensors, temperature sensors, RF sensors, seismic sensors etc, but these sensors when deployed for any application in the field's face the challenge of draining battery due to which they die out completely and unable to sense any physical change. As sensors are distributed in an area where human intervention is not possible, so neither we can replace sensor nor can we replace battery. Owing to limited energy of sensors in WSNs, it is required to have desirable network lifetime so that sensors will be able to aggregate data and communicate to base station. Real time application involve continuous sensing of physical parameter by the sensors in order to save the network lifetime there are number of schemes one such scheme is the use of hierarchal routing protocol for WSN . The LEACH protocol shows improved network lifetime by applying twofold cluster head selection using Fuzzy logic. This dual cluster head is selected in the set up phase their energy is compared with the defined threshold equation (1) to be declared as CH so that the other member nodes can join on the basis of shortest distance.

$$T(n) = p/1\text{-}[(r \bmod(1/p)] \; n \in G \tag{1}$$

Here, T(n) is the threshold, p is the expected number of cluster head, r is the round, G is the number of node that has not get a chance to become CH.

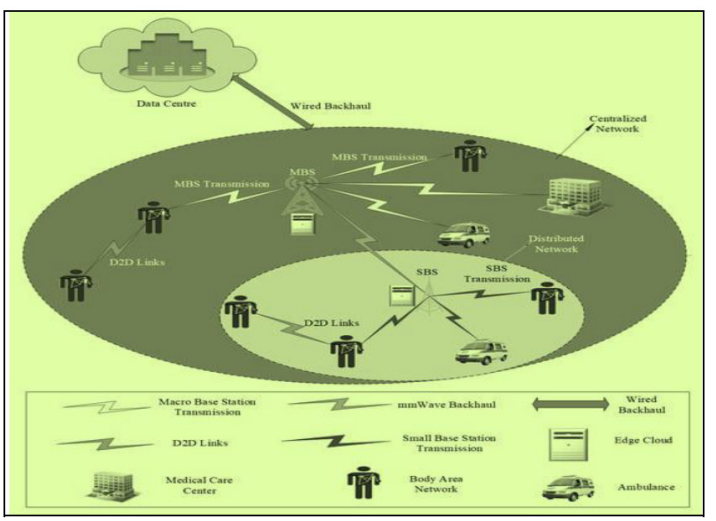


Figure 1

Architecture of integration of WSN and 5G networks [26]

Section 1.5 discusses the detailed implementation of two-fold cluster heads using fuzzy logic. Each sensor nodes generates a random number between 0 and 1 (temp_rand). This is the defined threshold value for comparison with the two-fold CH or the dual CH collected from FIS model. The CH which has less measure is then compared with the threshold value as given by (1) if this is less than T(n) then it will be selected as cluster head.

2. Literature Review

2.1 *Methodology used for cluster head selection in previous protocols*

Heinzelman et. al. (2000), [1] Low Energy Adaptive Clustering Hierarchy (LEACH) is one of the most admired clustering routing protocols. LEACH selects clusters on the basis of probability method and assumes that each node has the chance to become CH. This protocol has two stages. The first stage is the set up stage it governs the CH selection and formation of clusters. Each node selects a random number between 0 and 1. Threshold energy is defined which is then compared with the random number assigned to each node .If this number is less than the threshold energy then the node will be the CH in the present round. As per the threshold energy equation (1) the Non-CH nodes will have more chance to become CH in the next round. In this way all the nodes have chance to become CH. The second stage is steady state in which the CH collects data from its non CH member nodes within the cluster. Later the gathered data is transferred to the base station. The authors in AliReza Naderloo et. al. (2023) developed the method to select cluster head using Fuzzy Logic. The complete network [2] was divided into zone and on the basis angle of node to base station, distance of node from the centre of the zone, residual energy and network zoning was used to elect Cluster head logic. Base station find the area of each node and subsequently using fuzzy approach it determines CH from each zone. Sensor nodes battery gets drained off while working in the field Type 2 fuzzy system [3] is used for selection of CH as presented by Sujatha .J et. al. (2022). [4]There are various parameters of study for WSN, but for real time applications such as IOT based application network lifetime plays very crucial role. N. T. Singh et. al. (2023) highlighted the significance of network life span in WSN. The LEACH protocol randomly selects cluster head on the basis of comparing with the predefined threshold energy. Hong-YI-Tan et. al. (2019) [5] defined the new equation of for the sensor node on the basis of centroid

obtained from Fuzzy Logic. This new threshold value is compared with the LEACH defined threshold .This two step comparison does not lead to the improvement in the network lifetime, instead the Fuzzy output directly applied to the sensor node will result in improved network lifetime.[6] represented five descriptors for the FIS model. The node density and higher compactness node leads to saving energy of the network and thus the enhanced network life time. [7] Highlights the scope of WSN for real time applications showing the communication of sensors with underwater unmanned vehicle. The SWOT analysis is represented in [7].The efficiency of LEACH protocol decreases after the first node dies. S.Y Park et. al. [8], (2020) discussed the dual fuzzy implementation for the cluster head selection and cluster configuration. Once the nodes are selected as CH, the second Fuzzy logic is applied to non-CHs nodes this improves the short-back of energy for the sensor nodes. The distribution of sensor nodes hold important concept in any network scenario. [9] Considers the Sugeno and Kang fuzzy evaluation for CH election. Each node goes through four states namely preliminary state, engaging state for node to be CH, Final CH state, member state. WSN is one of the essential components for IOT applications; authors in [10] represented a selection of cache node along with the CH. The data is transferred from this unique cache node to the main server.

2.2 *Fuzzy based cluster head selection approach for IoT/5G MAC Protocols*

WSN is lifeline for real time IOT applications since it comprises of tiny sensor nodes to make a complete loop for IOT based real time applications but sensor nodes suffers limited battery life. Real time data communication is the challenging issues for wireless Sensor networks. Various architectures, topologies, routing protocols had been looked upon for making WSN more energy efficient. A. R. Raut et. al. (2021) overcomes the limitations of WSN to handle real time transmission by application of machine learning technique to MAC protocol thus giving intelligence to the protocol to adapt itself according to the scenario [11]. Several optimization algorithms results in performance improvement of WSN [12]. Out of various approach hierarchal clustering routing is one of the technique to reduce the energy consumption of sensor nodes thus resulting in the enhancement of network life. [13] Behera, T.M et. al. (2022) gives the significant role of bio-inspired protocols along with Low Energy Adaptive Clustering Hierarchal Protocol(LEACH).The scheduled based TDMA MAC LEACH clustering protocol has found many use cases for the real time applications specially in IOT field. Sensor nodes scattered

In the field randomly or in some pattern in both the arrangements some nodes are near and some are distant to the main server. [14] Considered region distance descriptor as the main parameter to improve the performance of LEACH protocol. There are numerous descriptors applied to the AI method Fuzzy logic to further improve the performance of WSN. LEACH can work at the abstract level for several IOT applications as explained in [15]. [16-17] talks about the cloud computing mechanisms like hadoop and artificial intelligence to be used for providing the better utility of the work .Also in the next generation networks, when we are in the era of developing the protocols for specific applications [18-21] discuss how the machine leaning and IoT are used for making the product more efficient. So in future the protocol designing may use the AI and cloud computing for efficient performance. It defines the optimum value of cluster head along with the residual energy of the sensor nodes. In the proposed design fuzzy logic is applied to distance and residual energy to select two cluster heads in the first step then the CH with minimum energy is compared with the defined threshold energy this approach has increased network lifetime. Table 1 shows application of Fuzzy logic for selection of CH and different descriptors selected for FIS input.

Table 1

FIS inputs for selection of CH.

Fuzzy Descriptors	Parameters considered	Reference
Node distance to centre of region, Residual energy, node angle to BS	Network Life time, Network Stability	[2]
Type2 fleecy reasoning	Network Life time	[3]
Energy, BS distance, Avg-. Energy, density, Compactness	First node dies, half nodes died, Network Lifetime	[6]
Energy, Distance to CH, Distance to BS	First Node dies(FND), Half nodes died(HND) and last node died(LND)	[8]
Node energy, Node membership function, neighbor nod energy	FND, LND, Network lifetime	[9]
Residual energy, degree, centrality, distance to BS	Network Lifetime, Dead nodes on the BS position	[18]
Energy level, Distance to BS, Distance to CH		[19]

3. Performance parameters of MAC protocol for IoT and 5G applications

WSN has several performance indicators. LEACH protocol when implemented to handle real time applications in WSN its efficiency is measured in terms of network lifetime, residual energy, total residual energy throughput and PDR the proposed model measure the network lifetime using two fold CH selections.

3.1 *Network Lifetime*

Network lifetime is defined by the operation of sensor nodes for longer duration of time while they are deployed for any of the application. It basically represented the presence of sensor nodes for detection of any event or physical change. In WSN network lifetime is defines the time when first node dies in the network.

3.2 *Residual Energy*

When the sensor node transmits or receives any packet in a network its energy gets reduced .The residual energy of the sensor node is defined by the energy of the sensor node remains after it performs this action.

3.3 *Throughput and PDR*

Sensor nodes when in active state means they are sensing the event or transmitting or receiving data either from one sensor node to other sensor in the same network or to base station the amount of packets successfully received to sensor node or to base station is defined as throughput.

4. Simulations of Fuzzy two-fold cluster head selection Protocols

The proposed design for WSN shows the implementation of fuzzy interference system with residual energy and distance to base station as the inputs and two cluster heads as CH1 and CH2 as the outputs. The energy of both the cluster head is compared first and then it is compared with the threshold energy. The membership function for the two-fold cluster head election is defined in Table 2; linguistics given to variables defines the fuzziness of the fuzzy set. Fuzzy approach to select CH is applied in the set up phase and steady state phase is similar to the LEACH protocol. The rule view for selection of CH is given in Figure 3; FIS representation of inputs shown defining the degree of truth is given in

Figure 2 .The proposed model use the mamdani method as described in [17] it is implemented with MATLAB following the three processes as fuzzification, rules evaluation and defuzzification to get the crisp value again.

Table 2

Membership functions for two-fold CH selection.

Variables	Input and output to FIS	Linguistics
Inputs	Residual Energy	Low, Medium, High
	Distance to CH	Very close, moderate, far
Outputs	CH1 or CH2	Very low, low, medium, medium high, High, Very High

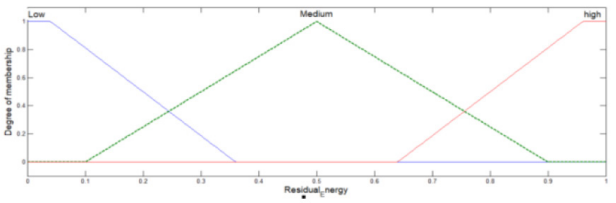


Fig 2 (a)

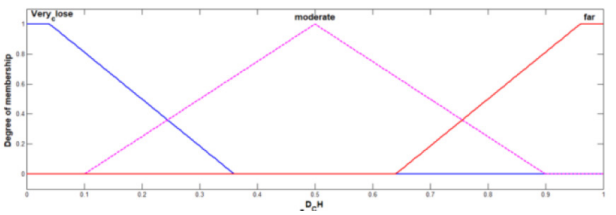


Fig 2 (b)

Figure 2

Membership Function for (a) Residual Energy; (b) Distance to Cluster head

4.2 *Result and analysis*

The output for the present model is represented by rule view. The two extreme conditions are given below:

Rule 1: Residual energy is low and distance to base station is low then CH2 is selected.

Rule 2: Residual energy is high and distance to base station is high then CH1 is selected.

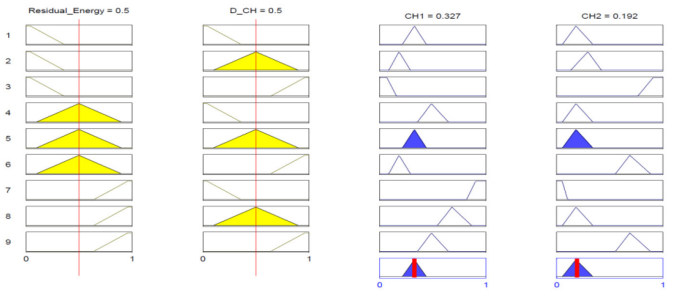


Figure 3

The rule base for fuzzification

The approach of dual cluster head selection has improved the network lifetime as shown in Figure 3 at the 400th round the two-fold CH save the energy to 40.7%.

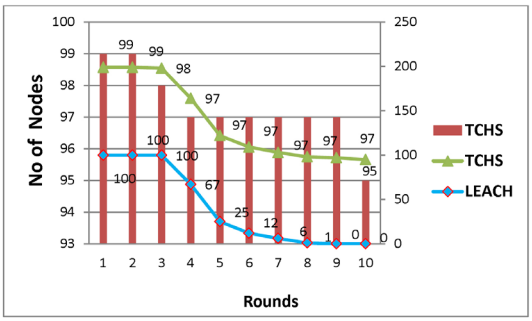


Figure 4

Residual Energy Vs No. of rounds for Two-fold CH selection design

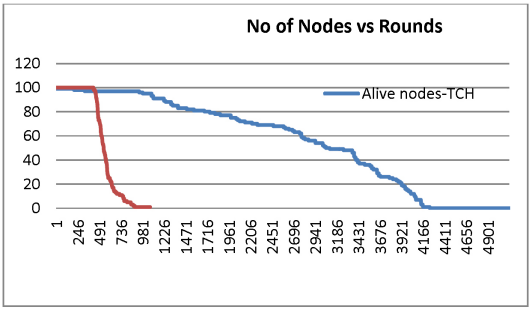


Figure 5

Network Lifetime improvement for two-fold model for LEACH [1] protocol.

The sample of rounds is chosen for the number of alive nodes with respect to the rounds shown in Table 3

Table 3
Alive nodes two-fold CH

Round	LEACH	TCHS
100	100	99
200	100	99
300	100	98
400	67	97
500	25	97
600	12	97
700	6	97
800	1	97
900	0	97
1000	0	95

The final crisp value at the output is found by the centre of gravity method as given by (2).

$$G1 = \Sigma_{j=1}^{n} \mu_{A(x)_j x_i} \; / \; \Sigma_{j=1}^{n} \mu_{A(x)_j} \tag{2}$$

Here, μ_A defines the area of the jth rule, n is total rules used in FIS model.

The other performance parameters for LEACH are found in [16] M. Malik et. al. by using the optimization algorithm. As shown in Figure 4 numbers of alive nodes remain for longer time in the two-fold fuzzy approach the time to die the last node is longer as compared to LEACH protocol this dual CH has improved the network span. The number of live nodes with respect to number of round performance of the network is shown in Figure 5 which gives an idea about the improved network life time.

5. Future aspects and conclusion

Although sensor nodes has gained its importance in numerous WSN and IOT applications due to its smaller size, low power, less cost, scalability, availability, ease in arranging but still it faces challenge of limited energy.

As the first node dies it loses its functionality and subsequently the network life reduced. There are many techniques from optimization algorithm, AI to machine learning applied to WSN to enhance the network span. The proposed method of two-fold cluster head selection has improved the performance of LEACH protocol. The future scope can be making the sensor intelligent so that it will work on its own to save its energy or turn off its radio when not in use in this way save energy. Future development involves developing intelligent algorithms to adapt themselves according to dynamics of the environment and take necessary action while taking minimum time of execution so that real time applications can be looked upon timely. The unattended areas will use dual clustering approach in low power Adhoc networks and will be integrated with high speed 5G networks. So the overall lifetime of hybrid network is improved.

6. Conflicts of Interest

The authors declare that they have no competing interests.

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