International Journal of Technology and Emerging Sciences (IJTES)

www.mapscipub.com

Volume 02 || Issue 03 || July 2022 || pp. 43-47 E-ISSN: 2583-1925

A fuzzy logic-based method to optimize energy consumption for WSN

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Abstract - *As is quite evident from all the contemporary literature being published in the field of electronics and computer science, IOT is going to be one of the most important pieces of technology as demand for energy keeps increasing. We will keep increasing our reliance on IOT based systems. And in this case study I have rather focused my attention on one of the most important problems that is plaguing IOT, and that is the optimization problem in IOT networks As IOT is typically deployed in resource constrained environment optimal usage of energy resources is paramount therefore we will be mainly focusing on solution based on fuzzy logic to cope with the energy consumption issue in battery-powered devices composing a WSN for smart homes since they are significantly better at the task in hand than other computationally heavy methods such as PSO(Particle Swarm Optimization).*

***Key Words*: CLEANER, LEACH, FLC, CH, Takagi-sugeno**

1. INTRODUCTION *(Size 11, Times New Roman font)*

In WSN each node requires energy to send and receive messages therefore in a resource constrained environment we must be very careful about how we are allocating the resources and choose the best possible optimization method to achieve this task. And this is where I firmly believe FLCs can play a consequential role by creating a structure that can minimize the number of dead nodes and maximize the remaining energy that a particular node processes thereby extending the life of the network. The end goal here is to extend the life of a network without needing any outside intervention thereby decreasing the cost of maintaining the network and ensuring that is becomes cheaper as time passes on.

Along with this I believe this technology that is being developed has a hugely consequential role to play in the coming future where not only the generation of power is important but the efficient and effective implementation of energy allotment is as or even more important than it's own generation. In our generation where the technological and academic landscape is completely defined by climate change and energy efficiency it is vital for us to develop these kinds of technologies to their greatest extends and make sure we all have a life that is not only better but also healthier to ensure this we must develop technologies that accommodate IOT based products to increase efficiency and effectiveness of a system that are deeply involved in our day to day activities. To this end it is my firm believe that even the infinitesimal increment in the efficiency of WSN will lead to monumental changes in our society specifically how it behave and how it works and how it interacts with us and the environment around us. As even if this particular technology only has a minimal effect on our society even then it does have the potential to create a ripple effect that can cascade throughout our society and create incremental changes that will lead to a better and more technologically advanced world that will in turn lead to a more prosperous ,peaceful and healthier world. This is quite the optimistic view as such but it is my firm believe that without such ideals the world cannot evolve further and would eventually lead to the slow and agonizing demise of our wonderful civilization that our ancestors have created for us because just as an example the idea that there would be a man on the moon just 70 years after the first powered flight of man is an absurd one but yet that did happen and changed the way our world today works so novel ideas such as these have great power to move people's hearts and minds and bring about great and enormous change and opportunities that will according to me change the world for a better tomorrow.

The extent to which why have chosen to conduct research in energy consumption of WSN specifically is a direct conclusion that we came to after conducting extensive investigation into IOT problems and identified this to be one of the more important one of all the other problem about which there is sufficient information to be found but this indeed stood out from the rest.

2. RELATED WORK

In contemporary literature extensive work has been conducted in the area of WSN node energy consumption wherein experts have present great number of method to optimize the energy consumption of each node, methods based on FLCs and not based on FLCs and the first paper [1] that I read in my quest to find a reasonable answer to this question, is not based on FLC rather it is based on a novel idea where the cluster head (CH) in each cluster of static node is chosen by calculating the distance of each sensor from the mobile sink thereby decreasing the amount of energy required to transmit the message as sensors closer to a static sink tend to lose more energy because of the more traffic burden to transfer data to the sink node. Now in all the other FLC based papers I read the authors propose different solutions to the same problem just by using fuzzy logic. In [2] the authors have used the particle swarm optimization(PSO) in which particles are randomly generated within a space with a certain velocity and they keep moving around in that space until a satisfactory result is obtained by continuously updating their velocity. The PSO is then integrated with the FLC, where the FLC is responsible for selecting the CH with the help of fuzzy variables such as D,E.

In CH selection each node generates a random variable r which is then compared to the probability P and if r<=P then that node is then selected as CH but by defining fuzzy variables D, E, y where D is the number of dead nodes and E is the remaining energy in node and y is the selection probability adjustment, and then applying the IF-THEN fuzzy inference rule we can obtain the value of the adjusted probability y after which we just add the value of y to the initial value of probability thereby getting the new probability of selection. We then minimize the fitness function(D/E) by using the FLC above then keep repeating the process by feeding in the parameters to be optimized back into the PSO and keep repeating until the stopping condition is achieved. In [3] the authors, unlike in [1] and [2] tried to increase not only the lifetime of the network but also its quality of service by increasing the remaining energy and the packet error rate(PER). They have achieved this by using the bellman ford algorithm with the cost function based on some critical matrices, where the bellman ford algorithm computes the shortest distance in a bottom-top manner. It first calculates the shortest distances which have at-most one edge in the path. Then, it calculates the shortest paths with at-most 2 edges, and so on. For this approach, as it is an FLC we need normalized value where we define Psuccess which is the probability of a packet, to be received successfully by the successor node which his already normalized Psuccess lies between 0 and 1 and the residual energy is normalized by dividing it by the initial energy of the node, the cost function Lc(ij) represents the amount of weight of a link between two nodes and is defined as the inverse of S prob(ij) to the power of 10 where S prob(ij) is the probability of the i^{th} node sending a message to the j^{th} node and by employing this method we can achieve optimal results by decreasing the PDR and increasing the residual energy. In the [4] just like the [1] and [2] we are going to tackle the hot spot problem wherein due to the high traffic of data a particular node might shut down due to the lack of energy and this leads to the complete failure of the network itself this happens because of the partitioning of the network which happens because of the load imbalance. Now to avoid this authors have used the IEEE 802.15.4 protocol which has 2 modes of operation they are active mode and sleep mode where the In CH selection each node generates a random variable r which is then compared to the probability P and if r<=P then that node is then selected as CH but by defining fuzzy variables D, E, y where D is the number of dead nodes and E is the remaining energy in node and y is the selection probability adjustment, and then applying the IF-THEN fuzzy inference rule we can obtain the value of the adjusted probability y after which we just add the value of y to the initial value of probability thereby getting the new probability of selection. We then minimize the fitness function(D/E) by using the FLC above then keep repeating the process by feeding in the parameters to be optimized back into the PSO and keep repeating until the stopping condition is achieved. 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The FLC_1 controls the STR in accordance to the energy left in the battery and also takes into account the ratio of throughput to the workload, three membership functions are described for both input and output variables. The chosen membership functions have values low, medium and high. Triangular-shaped membership functions are chosen for both input and output of fuzzy logic contorller_1. The FLC_2 controls the TX based on two inputs, one is the remaining energy in the battery and the remaining one is the network connection strength of every node during its actives mode. Three membership functions are described for both input and output variables, that is similar to the fuzzy logic contorller_1. Triangular shaped membership functions are chosen for both input and output of FLC_2. The crisp input for the battery level is the same as FLC_1. By doing so the 2 FLC working in parallel can increase the lifetime of the WSN. In [5] the authors propose another solution for extending the life time of the WSN by providing better ways to transmit messages between the nodes as it is quite common for nodes in WSN to use multi hop there by providing a fuzzy inference system to help the directed diffusion routing protocol which itself is based on the ant colony optimization (ACO) algorithm. The ACO algorithm is a stochastic technique for solving computational problems which can be broken down to deducing efficient paths through graphs, it simulates the primal behavior of ants, in the wild ants look for the pheromones released by other ants, prefer to choose the path with higher pheromone concentration and a shorter distance, and release a certain threshold of pheromone to form a positive feedback. In this way the tour of the artificial ant is considered to be the combination of input and the route taken by the ant as the output. In this paper the inference system has proposed 2 input variables: energy level of each node and the number of hopes needed to send the message to the sink node. This way the rule base contains 15 rules and 5 primary terms for each output variable thereby providing the ant with 5^15 combinations out of which the ant has to choose the optimal path

and by employing such methods we can also decrease the rate of packet loss throughout the network as well.

3. Our work

One of the biggest problems in WSN, as I have mentioned before is the lifespan of the network which is severely restricted due to the energy constraints put upon the sensors and as the previous papers have mentioned, one of the ways to solve this problem is by introducing the concept of cluster heads (CH) and by having an optimal way to choose these CHs we can significantly decrease the amount of energy that each node requires to operate.

The method proposed by the authors in this paper is the concept of CLEANER(a CLusterbased approach for ENERgy-efficiency) which is itself an extension of LEACH wherein the nodes create a cluster and elect a CH by generating a random number between 0 and 1 by each node, this number is then compared to the threshold value T(n) .

$$T(n) = \eta \frac{P}{1-P\left(r \bmod \frac{1}{P}\right)} + \alpha\left(1 - e^{\frac{-RE^2}{2\sigma^2 RE}}\right) \quad (1)$$

And if the number is less than T(n) then that node is elected as the CH but as the paper point out there are many drawbacks to this method one which exists is in the choosing of the random number as while choosing this number no consideration is shown to the amount of residual energy within each node thereby potentially threatening the network itself by creating a point of failure, another consequence of this is that a node with almost no energy can become a CH and therefore leading to complete failure of the network itself. This is where we introduce CLEANER where during the initialization of the network the base station(BS) sends start-up message which prompts the node to compute the distance between it and the BS using RSSI this allows the node to adjust the amount of energy required to transmit data to the BS since higher transmission rate consumes more energy then each nodes generates a random number between 0 and 1 then as i previously mentioned for LEACH the number is then compared to threshold number T(n)(different for LEACH) and the node with the lower number becomes the CH. Now another important part in this process is the formation of cluster, during this phase each node chooses the best CH using the above explained method then each node compute the probability value of each CH candidate using the Takagi-Sugeno(TS) approach rather than the Mamdani approach since it is provide higher computational efficiency but is a bit more resource intensive. The TS receives information from the node as input then converts it into fuzzy variables then the defuzzifing process produces a crisp set output, from the fuzzy set and rules that it is the output of the inference engine. The rules are expressed in the form of logical IF-THEN statements for converting then fuzzy inputs to crisp outputs. Hence the classical to fuzzy logic conversion is based on the final output y inferred from n which is the average of all yi with their respective weights.

$$IF\ f(x_1 isA_1, ..., x_k isA_k)\ THEN\ y = g(x_1, ..., x_k), \quad (2)$$

$$y_i = p_0 + p_1 x_1, ..., + p_k x_k, \quad (3)$$

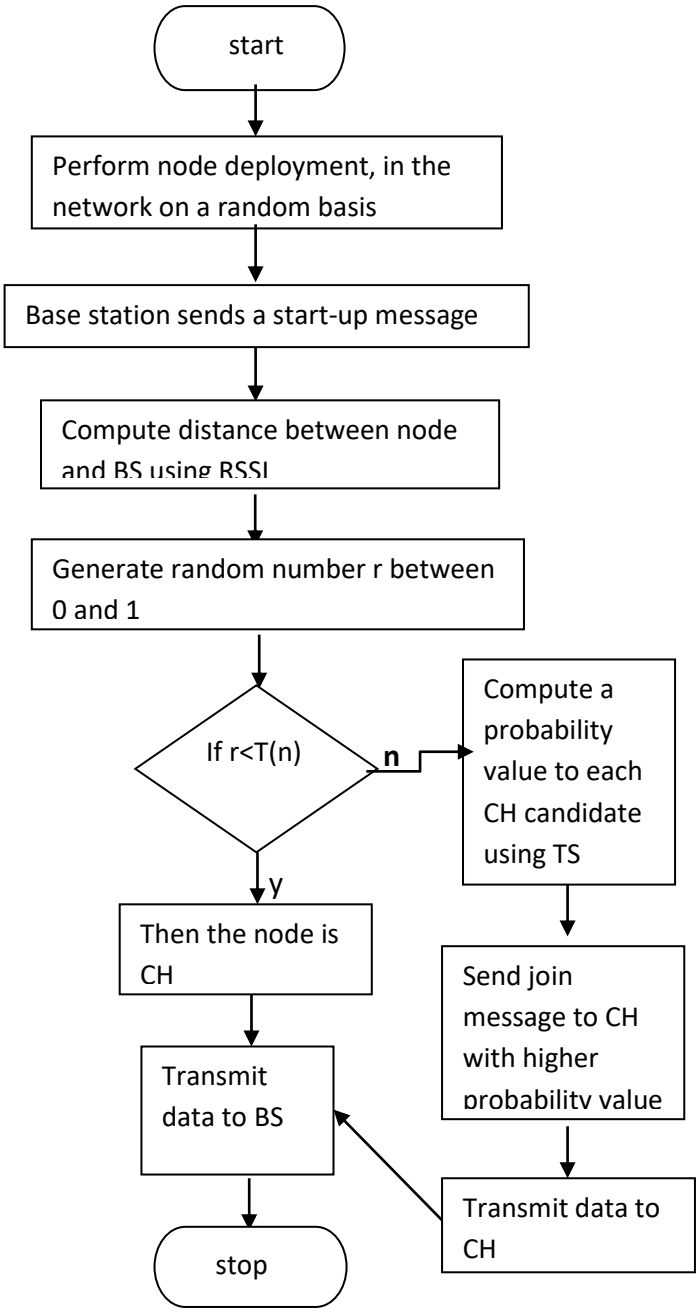
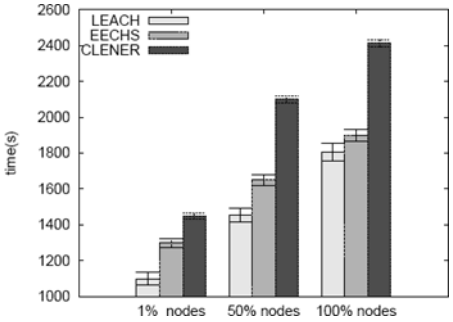


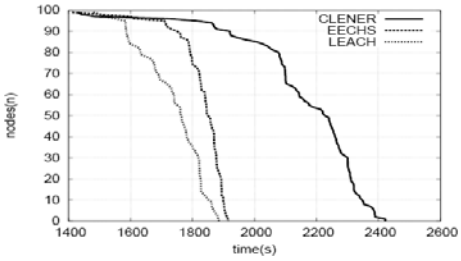
Figure flowchart

3. PERFROMANCE

Experimental setup of the above theoretical model does indeed projects the fact that the proposed model does in fact increases the number of clusters per round this is due to the fact that the proposed model is based on the concept of residual energy and

takes it in as the prime variable as well as the fact that the network lifetime also increases significantly due to this very fact.





4. CONCLUSION

This paper presents the concept of CLENER in which the main task was tub divided into two, first the cluster formation and the CH selection. Specifically by adding in the parameters of remaining energy and distance from the BS a better and CH can be selected rather than basing this completely on a stochastic process along with letting each node choose the most optimal CH for itself we increase the network life span significantly. The specific reason as to why we have chosen this particular method has been clearly explained above and why this particular piece of technology is important is also something that I would like to elaborate on here, as in our modern world where we are quite short on time and options when it comes to the fact of trying to fight climate change I think these kinds of technologies which can increase our energy efficiency dramatically will become an integral part of our society and day to day life to ensure we have a better future and a livable planet

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Vishal Nair is a student of mechanical engineering in the department of mechanical engineering YCCE Nagpur and has actively taken part in research fields pertaining to fuzzy logic based solutions to WSN power consumption problems in very day IOT based technology

Dr. Shubhangi Rathkanthiwar has a career in teaching that has spanned over 33 years and her field of expertise includes Signal Processing in Wireless Communications, ANN, Embedded systems, IoT modules in Telemedicine, etc. She has been an author in more than 107 papers that have been published in prestigious International journals and Conferences, and has 6 books, 3 patent applications granted by Government of India, 8 patent applications filed and two copyrights to her credit. She has developed and guided several projects and megaprojects, which are of great social relevance. Moto behind 'Make in India', 'Digital India' and 'Smart City.

Development' is clearly reflected through patentable intelligent embedded systems developed and guided by her Dr. Shubhangi Rathkanthiwar clearly indicate her success as exceptional leader on various fronts, including academics, research, literature and social activities at national as well as international level. Her research was nominated for award in UC Berkley, USA. She has been to numerous nations including USA, China, Singapore, England, Scotland, etc. for presenting research and academic collaborations.

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