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Article

Improved Load Balancing Algorithm for Network Lifetime Enhancement in WSN

Savitri Kanshette[1], Prashant Sangulagi[1], Ashok Sutagundar[2]

[1]Bheemanna Khandre institute of technology, Bhalki, Karnataka, India.
[2]Basaveshwar Engineering College, Bagalkot, Karnataka, India.

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Corresponding Author:
Savitri Kanshette, Bheemanna Khandre Institute of Technology, Bhalki, Karnataka, India.
E-mail Id:
savitrikanshette1996@gmail.com
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ABSTRACT

Wireless sensor networks have been utilized and utilized for their enormous ability in the modern years, because they are perfect solutions for wireless networking applications in real time. Nodes, along with an effective routing scheme shape the back bone of the wireless sensor networks (WSN) determine the overall performance of the WSN. Recently work on load balancing algorithms has been studied as the existence of incoming traffic consisting of information packets is often stochastic and in essence unpredictable. Since the nodes are restricted by their power supply in the form of batteries that cannot be replaced regularly, they are vulnerable to overuse in transmitting all knowledge to a single or chosen node nearest to the base station resulting in rapid power supply drainage. Therefore it is important to provide an intelligent and effective load balancing system for sensor cloud to insure that the job load is spread in a more or less consistent manner resulting in perfect power savings at WSN and proper data deposition in cloud servers.

Keywords: Wireless Sensor Networks, Load Balancing Algorithms, Soft Computing, Fuzzy Inference Engine, Cluster Head Selection, Sensor Cloud, Cloud Computing

Introduction

Communication technologies have been experiencing a great revolution in the past decade especially with the advent of state of the art communication protocols and gadgets. Hand held and portable gadgets are being effectively used for a wide range of applications in recent past. Portable and hand held equipment derive their evolution from wireless sensor networks which for an open or closed loop network with the nodes deciding to be part of the network or leave the network at their own free will. These nodes are provided with certain processing capabilities depending upon the application to which they being put use to. They are autonomous in nature especially in case of MANETs and VANETs where they can make certain decisions on their own. Nodes which form the backbone of wireless sensor networks (WSNs) are provided with a limited supply of battery power to initiate and perform the aforementioned processing functions. In recent times, WSNs are being more prominently deployed for remote monitoring and surveillance in locations where human presence is not desirable. They find effective utility in monitoring of volcanic activity, disaster prone areas to aid in search and rescue, evacuation operations etc. They are also being actively used in surveillance of hostile territory along border lines or even mounted on unmanned aerial vehicles to go deep into enemy territory unnoticed. WSNs have become more critical in such applications as surveillance regularly includes detecting and transmission of interactive media substance like video, sound and superior quality pictures identified with development of adversary vehicles, troops and so on In all the previously mentioned cases, power utility is a significant worry for these hubs as they require more force particularly if there should arise an occurrence of transmission of media content. The idea of organization of these hubs in far off areas additionally doesn't work with recurrence substitution of batteries and subsequently requires keen and streamlined utilization of accessible battery ability to release its capacities in a continuous and compelling manner. A typical wireless sensor network is depicted in figure 1.

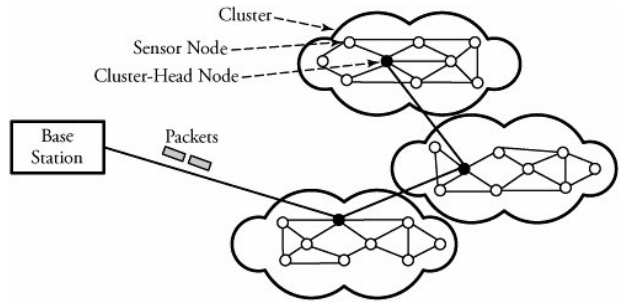

Figure 1.Typical wireless sensor network

Figure 1 outlines a regular organization of a remote sensor network alongside the terminal client and passage for information access. Contingent on the kind of utilization, the hub arrangement in the location of movement may shift from a couple of hubs to a few many hubs detecting information either in a homogenous or heterogeneous climate.

In each of the case, sensing of data from the environment at the terminal side and transmitting them to the next forwarding node is the primary duty of the nodes in the framework. Another issue related to battery and power utility by nodes is reflected in the lifetime of the entire network as the subsequent failure of nodes due to improper utilization of power or overloading may result in consequent network lifetime reduction. Another issue which may lead to power drain from the nodes is due to improper load balancing system in the network. In general nodes with good connectivity links to base station take up more loads become overloaded causing quick drain of power from the nodes while the rest of the nodes which are alternately termed as underutilized nodes take up less power resulting in partial loss of nodes near the base station resulting in overall reduction in network lifetime. Typical sensor architecture is depicted in figure 2 shown below.

Figure 2 illustrates the internal architecture of a general wireless sensor node which consists of a power source along with the processing unit and associated circuitry. Conventional batteries used in these nodes are available as Nickel Cadmium, Carbon Zinc capable of providing 300mAh and 320 mAh powers.

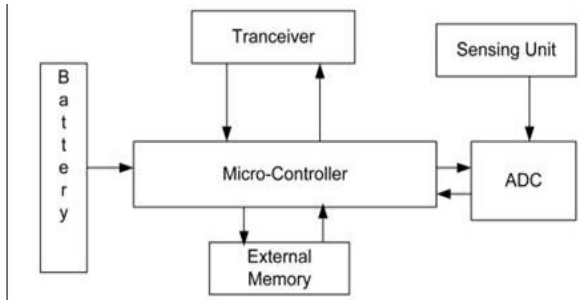

Figure 2.Internal architecture of a wireless sensor node

Henceforth, appropriate and canny strategies for power the board comparable to the heap necessities and request from the base station ought to be considered to give a heap adjusted and energy effective hub sending framework. Steering assumes a significant part in preparing the heap adjusted and energy effective hub arrangement conspire as it is the directing calculation which decides the ideal way including dynamic hubs dependent on the heap necessity from source to sink. A directing calculation is by and large multi objective in nature and ward on a few credits like throughput, data transfer capacity, bounce tally, energy utilization, bundle size and so forth This examination article proposes a delicate figuring way to deal with give a dynamic and efficient burden adjusting calculation for an energy productive directing in the given WSN. A fuzzy clustered approach is proposed in this paper for the single objective of load balancing. The rest of the paper is organized into an extensive survey of literature related to the objective of this research paper, implementation of the proposed algorithm, the experimental results and inferences drawn based on the observations.

Advantages

1. Network setups can be completed without settled framework.
2. Suitable for the non-reachable places, for example, over the ocean, mountains, country regions or profound woods.
3. Flexible if there is irregular circumstance when extra workstation is required.
4. Implementation valuing is shoddy.
5. It stays away from a lot of wiring.
6. It may suit new gadgets whenever.
7. it's adaptable to experience physical parcels.
8. It can be gotten to by utilizing a unified screen.

Disadvantages

1. Less secure because software engineers can enter the will point and get all the information.
2.

3. Lower speed when stood out from a wired framework.
4. More jumbled to organize diverged from a wired framework.
5. Easily plagued by climate (dividers, microwave, broad divisions in light of banner debilitating, etc).
6. It is basic for software engineers to hack it we were unable to control multiplication of waves.
7. Comparatively low speed of correspondence.
8. Gets occupied by different components like Blue-tooth.
9. Still Costly (generally imperatively). Utilizations of Wireless Sensor Networks.

The applications for WSNs include following, observing and controlling. WSNs are chiefly used for natural surroundings observing, question following, atomic reactor control, fire location, and movement checking. Range checking is an extremely regular utilization of WSNs, in which the WSN is conveyed over a locale where some occurrence may be observed.

Related Work

The efficiency of a WSN implementation is largely influenced by an efficient routing scheme which have investigated and researched in literature in a vast manner. Certain findings of the literature related to the proposed objective have been elaborated in this section. Most of the wireless sensor networks are implemented in a cluster based approach[3,13] and graph cut based methods[6,9] which greatly help in reducing the complexity of the entire network. Cluster based methods reduce the entire network by partitioning them into several sub clusters based on similarity features. Each cluster is coordinated and controlled by a cluster head which is selected based on several optimization attributes. Several algorithms and routing schemes which take into account the load into consideration have also been observed in the literature. A weighted method of routing for load balancing is proposed in the literature.[2] The weights are assigned based on distance factors between the Cluster Head (CH) and the members of its cluster taking part in the communication and the residual energy of the nodes. A threshold based method has been used to detect node overloading at a future point of time from the current processing. A three layered secured and load balancing protocol has the first layer corresponds to the sensor nodes, the intermediate correspond to the CHs and the third layer corresponds to the pseudo sink nodes. It operates on threshold based method where the aggregated data is sent to the pseudo layer thus reducing the overhead on the CH. This method is found to be quite effective as it improves the packet delivery time as these packets need not wait for the aggregation factor to rise above the threshold. A directed diffusion method of clustering and load balanced routing algorithm is observed where reduction of as load on the nodes is done by establishing multiple paths between the communicating terminals (source and destination). In spite of improving the load balancing condition, it results in some deficiency in energy optimization as the algorithm does not consider node energy or battery levels while establishing the multi path between source and sink. Moreover, complexity is increased by a certain extent compared to conventional algorithms. Load balancing algorithms have also been tested one existing LEACH algorithms in the form of R-LEACH algorithms where energy conservation is achieved by rotating the CH on a frequent basis thus providing a uniform circulation of nodes to be CHs which eliminates the condition of power drain of a single node being the CH. However, this method is not quite optimal with respect to energy and congestion time, it produces an efficient load balancing method and prevents any node from being overloaded. Another variant of the rotation mechanism is found in HEED algorithm which the CH is replaced based on proximity of node to the next forwarding node and residual energy.

A load balancing clustering a specific group of nodes known as gateway nodes are primarily vested with the functions of sensing the traffic on the channel and load requirements and establishing communication paths between the source and sink. Geographic aware routing algorithms which basically work on the principle of location awareness of nodes have been adapted to handle dynamically varying loads and traffic on the channel using geographic load balancing routing algorithms by using greedy search algorithms which take the node overhead as well as the hop distance as the parameters in the search process. With the help of this search process and subsequent optimization, the GLBR algorithm routes the incoming traffic to another node if the current load is overloaded. Scalable cluster based load balancing algorithms have been researched in the literature where the given network is partitioned into several overlapping sub clusters with multi hop capability. Other works also indicate a multi hop load balancing algorithm modified on existing PEGASIS [21,23] algorithms where a small percentage of nodes from the overall node availability is selected to be cluster heads for the time being. Their primary objective is to coordinated and complete the intra cluster communication thus reducing the overhead on other nodes in the cluster. Another method of load compensation is achieved by continuously monitoring the access points. In case of overloading, points from another cluster are migrated to the overloaded clusters to share the work load. Dynamic load balancing in case of distributed WSNs have been achieved using a tree splitting approach of the nodes into domains and balancing of load based on residual energy of the nodes in the domain is achieved through the routing algorithm. Experimental results indicate an improved network lifetime in this approach. The proposed technique is also scalable and flexible with nodes given the freedom to change domains as and when required. A similar kind of tree splitting approach has been observed in the literature where sensing the traffic burden on the node under study and forwarding the probability of next node allocation to the parent node based on its residual energy. A dynamic load balancing algorithm based on a stochastic and mathematic formulation has been observed in the literature where three steps of rotation are carried out based on broadcast method done by the sink. The sink broadcasts the packet information to all nodes and the node with the least time and cost is selected as the CH and the rotation done thrice to reduce the overall energy consumption and load overhead.

Other algorithms found in the literature are multi objective optimization-based algorithms of which traffic congestion and load balancing form one of the parameters in the optimization target set. Several soft computing algorithms have been proposed in the which are multi objective in approach and considering load balancing as one of the research issues in the NP-hard completeness problem. Genetic algorithms[18] and neural network models have been effectively used to obtain an energy efficient routing algorithm with load balancing been given as one of the inputs to the neural network input layer models. Other models include fuzzy decision-based models being used in wireless multimedia networks in hybrid combinations with evolutionary algorithms on a multi objective optimization approach. Although multi objective optimization provides improvement in overall Quality of Service (QoS), improvements on load balancing have also been observed to a certain extent. In any case, calculations with load adjusting as a solitary goal of advancement are very few as seen in the writing. Numerous calculations exist in multi target advancement yet load adjusting is accomplished at the expense expanding jump check, expanding blockage and so forth which isn't reasonable for an independent framework with load adjusting as the sole goal. Subsequently, in view of the overview of writing did, the issue of burden adjusting to improve network lifetime is considered as NP-complete hardness issue and regulated fluffy based bunch directing calculation is proposed and formed in this paper.

Proposed Work

In this section we describe the proposed work and methodologies used to achieve our objectives. The in-detailed explanation of cloud computing and sensor cloud is as follows

What is Cloud Computing?

Cloud computing is a term referred to storing and accessing data over the internet. It doesn't store any data on the hard disk of your personal computer. In cloud computing, you can access data from a remote server. Cloud computing is the delivery of on-demand computing resources – everything from applications to data centers – over the internet on a pay-for-use basis.

Sensor Cloud

A sensor cloud gathers and cycles data from a few sensor networks empowers data sharing for large scope and work together the applications on cloud among clients. It coordinates a few organizations with number of detecting applications and distributed computing stage by permitting applications to be get disciplinary that may traversed over authoritative reaches [34]. Sensor cloud empowers clients to effectively assemble, access, handling, imagining and breaking down, putting away, sharing and looking through enormous number of sensor information from a few sorts of utilizations.

Advantages

Here, are important benefits for using Cloud computing in your organization:

Cost Savings: Cost saving is the biggest benefit of cloud computing. It helps you to save substantial capital cost as it does not need any physical hardware investments. Also, you do not need trained personnel to maintain the hardware. The buying and managing of equipment is done by the cloud service provider.

Strategic edge: Cloud computing offers a competitive edge over your competitors. It helps you to access the latest and applications any time without spending your time and money on installations.

High Speed: Cloud computing allows you to deploy your service quickly in fewer clicks. This faster deployment allows you to get the resources required for your system within fewer minutes.

Back-up and restore data: Once the data is stored in a Cloud, it is easier to get the back-up and recovery of that, which is otherwise very time taking process on-premise.

Automatic Software Integration: In the cloud, software integration is something that occurs automatically. Therefore, you don't need to take additional efforts to customize and integrate your applications as per your preferences.

Reliability: Reliability is one of the biggest pluses of cloud computing.

Mobility: Employees who are working on the premises or at the remote locations can easily access all the cloud services. All they need is internet connectivity.

Unlimited storage capacity: The cloud offers almost limitless storage capacity. At any time you can quickly expand your storage capacity with very nominal monthly fees.

Collaboration: The cloud computing platform helps employees who are located in different geographies to collaborate in a highly convenient and secure manner.

Quick Deployment: Last but not least, cloud computing gives you the advantage of rapid deployment. So, when you decide to use the cloud, your entire system can be fully functional in very few minutes. Although, the amount of time taken depends on what kind of technologies are used in your business.

Any given wireless sensor network could be viewed off as an un-partitioned and uni-directed graph G=(NUE,C)

Where N defines the numbers of nodes present in the given network and C indicating the transmission links between the nodes. E reflects the terminal environment which is sensing by nature. Two different nodes N1 and N2 in the environment C is said to be connected if N1 << N2. Under normal conditions, the state of nodes is in one of four possible states as shown in figure 3.

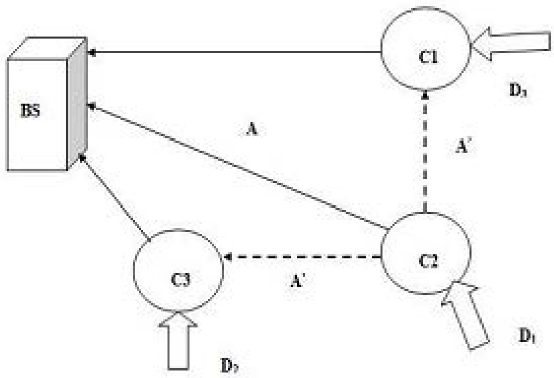

Figure 3.Illustration of incoming traffic scenario for a 2D topology

Given a wireless sensor network as shown in figure 3, with N nodes, the objective of this research is to determine a load balancing routing strategy to transfer information packets from source to destination. This could be achieved by considering a first order radio propagation model where the total energy consumed in transmitting an information bit could be arrived as,

$$ETX\ t = Ec\ t + Ei(t) \quad (1)$$

In (1), Ec t denotes the power consumed by the associated circuitry in transmitting the one bit of information while Eint(t) denotes the power consumed by sensor circuitry in improving the intensity of the sensed data or transmitted data. In the above equation, the energy associated with terminal nodes related to sensing of state of environment is considered to be uniform and the energy changes due to variation of incoming load or traffic alone is considered.

Considering aNxM distribution of nodes in a wireless sensor network, the load balancing problem can be formulated by considering the subsequent scenario depicted in figure 3.

It could be seen that three traffic patterns in the form of data packets D1, D2 and D3 are incident on the three nodes C1, C2 and C3 which are closest to the base station BS. It is evident that the nodes closest to the BS bear the entire burden of incoming traffic from all other nodes and are considered to be overloaded in the general sense. The matrix of the traffic pattern on the nodes closest to the BS could be formulated as D,

$$d11d12d1k = d21d22d2k\ dk1dk2dkk \quad (2)$$

And the associated cost matrix with respect to (2) is listed as C,

$$c11c12c1k = c21c22c2k\ ck1ck2ckk \quad (3)$$

From figure 3, it could be seen that node C2 issues a broadcast related to the volume of traffic incident on it as A while those related to C1 and C3 are labeled A‟. It could be seen from figure 3 that broadcast from C2 to C1 is more costly relatively issuing a direct broadcast to the BS which could be formulated as,

$$ERX\ [C1, C2] = D3\ \beta Ed + A'D1\beta\ Ed(1 + D1) \quad (4)$$

And the transmitted power is given as,

$$ETX\ t[C1,C2] = ERX\ t[C1,C2] + \beta Ed \quad (5)$$

On a similar note, the energy required for transmitting from node C2 to BS could be derived as,

$$ERX\ t[C2,C2] = D1\ \beta Ed + A(1 + D1) \quad (6)$$

In the equations (4), (5) and (6), β denotes the propagation constant along the channel and Ed denotes the power consumed by node for a distance „d‟ units. Hence the objective of the load balancing algorithm would be to minimize the energy consumed by nodes C1, C2 and C3 which could be formulated as O

$$\emptyset = \min\{\max ERX\ t\ C1,C2\ , ERX\ t\ C2,C2\} \quad (7)$$

Equation 7 could also be alternately stated as an optimization problem as O,

$$\emptyset = \min[E\ t\ ] \quad (8)$$

Where,

$$E(t) = \max ERX\ t\ C1,C2, ERX\ t\ C2,C2 \quad (9)$$

A soft computing based supervised model is proposed in this work based on a clustered topology to reduce the complexity where the cluster heads alone take part in the communication process thus reducing the overall energy consumption thus improving the life time of the nodes.

Results and Discussion

Network Simulator 2 has been used to implement and simulate the proposed load balancing fuzzy clustering algorithm. The objective of the proposed algorithm is to dynamically adjust and adapt the network settings and configuration parameters to changing patterns of input traffic of packets. Minimization of energy consumption while maintaining the load balancing at optimal levels to prevent underutilization or overloading of any node is the sole objective of this research work. The proposed algorithm progresses in two phases in a sequential manner with a nested structure of implementation. During the first phase, a normal traffic condition is assumed t initiate the dynamic well organized load balancing algorithm and a clustering algorithm partitions the input network into cluster subsets based on feature vectors like residual energy, bandwidth, distance to the base station etc. The proposed algorithm has been tested with three corner nodes near the base station which are normally overloaded as almost all of the information from the terminal sensor nodes are routed through them to the base station. Whenever the current traffic condition Currentis overcome by the incoming traffic by a threshold, the fuzzy module is invoked with residual energy, distance of node under consideration to base station, node density in the environment and traffic volume for the input to the fuzzy inference engine. Unlike the other algorithms, the CHs act as the main nodes with rotation of nodes done whenever the incoming packet traffic or load exceeds the current traffic volume. This ensures that all CHs are given an uniformly distributed loading condition thereby preventing a quick drain of any one of the CH due to over utilization. Moreover, drastic energy reduction is observed in this method as the CMs do not take part in active communication. On the other hand, the idle nodes in the cluster group take turns to become the next CH dictated by the fuzzy inference engine. The simulation settings taken for the experimentation is specified in Table 1.

Table 1.Simulation specification

Parameter	Value
Network size	1000×1000 m
Number of sensor nodes	100-200
Radio propagation range	250 m
Channel capacity	2 M bits/sec
Initial Node energy	2J
Physical layer	IEEE 802.11b DCF
Data packet size	1000 bytes
Buffer size	65 data packets
Simulation time	360 Seconds

Following the setting of configuration parameters as listed in table 2, the node distribution pattern in a random manner in proposed work is depicted in figure 6. The proposed algorithm has been successfully implemented and tested against conventional LEACH algorithms (cluster based approach without load balancing), dynamic load balancing algorithm nd Greedy Load balanced routing algorithm which is essentially a graph cut based algorithm. The algorithm proceeds with initialization of 200 nodes deployed in a random manner. The intra node distance is used as the metric for clustering process and it is repetitive until the residual node count equals to zero. The output of the proposed routing scheme has been quantified in terms of delay analysis, packet drop ratio, network lifetime and average energy consumption of nodes. Two load balancing algorithms have been used for comparison by way of DLBA and GLBA while a non-load balancing algorithm in the form of LEACH has been taken for comparative analysis of the response of proposed algorithm. The membership function used in the proposed work is illustrated in figure 4.

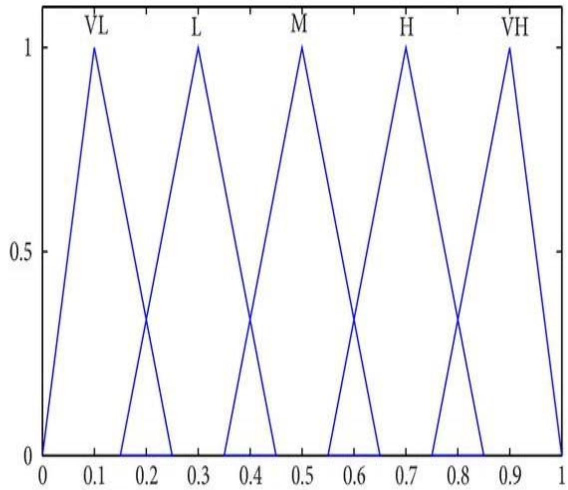

Figure 4.Membership function of proposed clustered fuzzy algorithm

Table 2.Threshold ranges of membership values used in proposed work

Index	Value/Range
Very Low – VL	[0.00-0.12-0.28]
Low – L	[0.15-0.32-0.45]
Medium – M	[0.35-0.47-0.65]
High – H	[0.55-0.68-0.85]
Very High - VH	[0.75-0.91-1.00]

When the input traffic exceeds the current load condition on the servicing node, the fuzzy logic is invoked and the rules are designed based on the threshold distribution as listed in table 2. Based on the ranges, the incoming traffic are categorized accordingly and passed through the inference engine to obtain the desired crisp output regarding selection of CH among the set of candidate CMs. The efficiency of theproposed work over other techniques have been quantified in terms of four factors namely the end to end delay, average energy consumption, throughput and network lifetime.

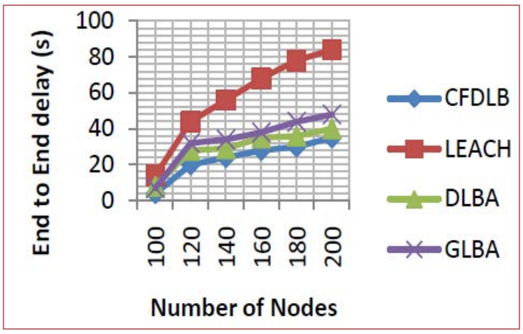

Figure 5.Delay analyses for the proposed work

Figure 5 illustrates the performance of the proposed energy efficient algorithm as compared against Low energy adaptive clustering hierarchy algorithm (LEACH), Dynamic load balancing algorithm (DLBA) and Greedy load balancing algorithm (GLBA). It could be seen that the end to end delay in the proposed work is drastically reduced by over 50% for a maximum node count of 200 nodes and of up to 42% when the number of nodes is at 100. The response time of the proposed algorithm for the given network is obtained by varying the node count to observe the complexity of the proposed algorithm.

The next metric in justifying the performance of the proposed CFDLB is the packet drop ratio which is observed in the plot depicted in figure 6.

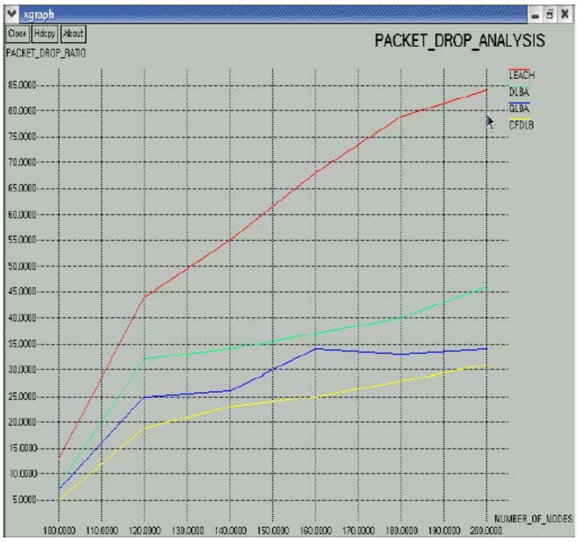

Figure 6.Performance of packet drop ratio

It could be clearly observed that the proposed energy efficient algorithm outperforms the conventional cluster based techniques like LEACH, DLBA and GLBA ensuring a maximum transfer of information from source to destination which is reflective from the reduced packet drop ratio analysis. A packet drop ratio of up to 74% improvement is observed in the proposed algorithm as compared to LEACH algorithm, 56% improvement when compared to DLBA and 42% improvement when compared to Greedy based load balancing algorithm.

Figure 7 depicts the routing overhead incurred during route discovery. The performance has been computed by varying the number of paths and observing the incurred overhead. Proposed CFDLB exhibits a reduced overhead indicating reduced burden on the nodes nearest to the base station.

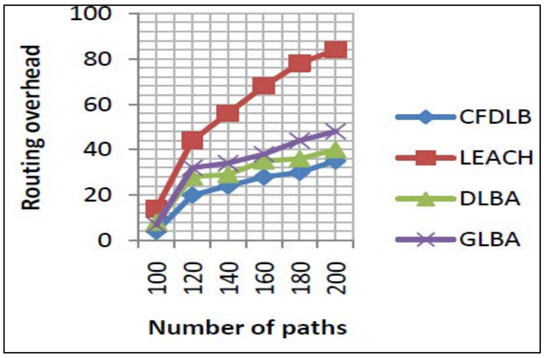

Figure 7.Routing overhead comparison of proposed CFDLB

Figure 8 depicts the energy consumption analysis measured in Joules with increasing number of node counts.

Figure 9 depicts the residual energy measured over a period of time period and it could be seen that the residual energy is maximum for the proposed fuzzy based approach indicating a good load balancing at the sink node.

A final analysis is in terms of standard deviation of power consumption for increasing number of nodes which depicts and reflects a fair distribution of load balancing among the nodes. Figure 10 depicts the plot of standard deviation.

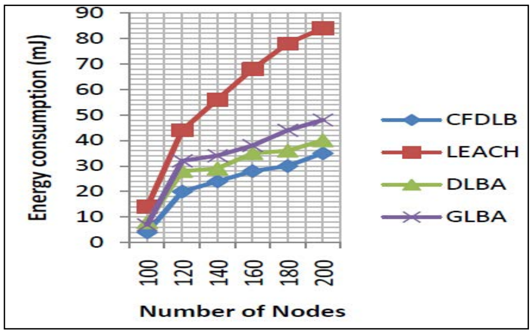

Figure 8.Energy consumption analysis of proposed work

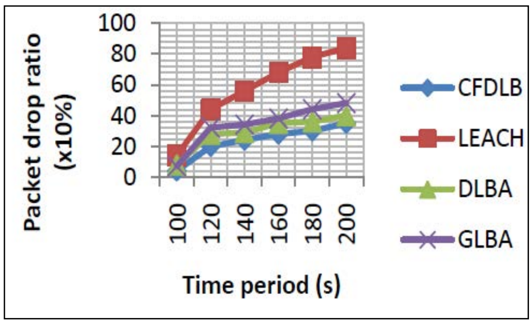

Figure 9.Analysis of residual energy for proposed work

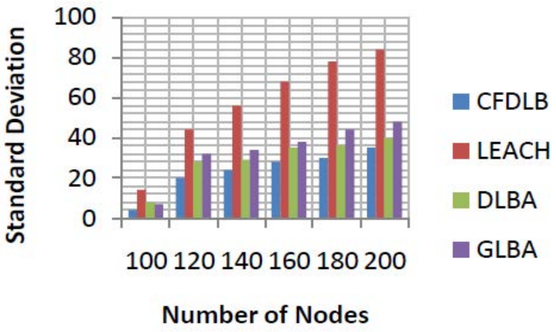

Figure 10.Comparative analysis of standard deviation

From the above plot it could be observed and concluded that the proposed clustered fuzzy algorithm records a low standard deviation relative to the other three techniques which indicates a uniform distribution of load reflected as minimal power consumption of nodes in the plot.

Conclusion

Throughout this research article a wireless sensor network was used for investigation and a dynamically well-organized load balancing algorithm focused on a clustered fuzzy engine running on four attributes at its input layer throughout order to generate a controlled and defined goal performance of optimal CH preference. Thanks to the clustering method, the algorithm shows reduced computational complexity dependent on a fuzzy assumption, and the algorithm is recursive in design. The fuzzy engine and clustering algorithm, focused on the incoming traffic volume and load, is named in recursive manner from the current instant time to agree on a new cluster head among the applicant nodes. The suggested solution implements a cluster head rotational optimization strategy to spread the load across the collection of nodes in the cluster while preventing the incoming traffic overloading of a single CH. The proposed algorithm is evaluated for its efficiency to three other strategies, namely LEACH, DLBA and GLBA, and is quantified in terms of the packet drop ratio reflecting its latency, end-to - end delay analysis reflecting congestion minimization in the transmission route, routing overhead reflecting the difficulty of the number of appropriate paths chosen based on incoming traffic, average the degree of load sharing among the CHs. As a future scope of work, minimization of load balancing together with improvement of complexity and residual energy could be explored using nature inspired multi objective optimization algorithms.

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