An Energy Conserving Low Latency Clustering Approach for Wireless Sensor Networks

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Abstract— An emerging category of wireless sensor networks is the Wireless Body Sensor Networks (WBSNs). With increased sophistication and advancements in wireless sensor networks, several categories of wireless sensor networks have evolved one among which is the wireless body sensor network (WBSN) or the body area network (BAN) which are used interchangeably in this dissertation. Wireless body sensor networks can be defined as the connectivity of sensors in the periphery of the human body which can communicate with each other as well as communicate with a central base station or control station. There are however several factors governing the reliability of the network. One of the key challenges faced with WBSNs is securing data transmission since complex encryption algorithms cannot be employed due to the limited resources of processing power and memory. The proposed technique incorporates the deep Markov model for random bit sequence (RBS) generation from the ECG based data which has been used as the counterpart for the actual heart beats. The features which have been extracted for the inter pulse interval (IPI) are RR interval, SS Interval and QRS complex. The database used for the study is the MIT-BIH library wherein the Electro Cardiogram data is available in the form of .mat files and can be processed for analysis. The security is based on the authentication provided by a random binary stream (RBS) which is 128 bits in length. The RBS is generated from the inter-pulse interval (IPI) extracted from the ECG waveform. The computation parameters considered are the entropy and the hamming distance. The performance evaluation parameters for the proposed technique are the entropy and the hamming distance. It has been shown that the proposed technique achieves better results in terms of hamming distance and entropy compared to previous work.

Keywords: Wireless Sensor Networks, Network Lifetime, Clustering, Latency, Duty Cycle, Energy Consumption.

I. INTRODUCTION

Wireless Sensor Networks: - The field of Wireless Sensor Networks has taken a huge important place in the field of wireless communication. The use of sensors has greatly impacted the smooth working of many industries and technologies. The sensors that sense the accompanying environment for the signals convert to signals indicating the wireless indicators. So these kinds of sensors play a big role in sensing the correct and apt ones and helping in the communication. The power consumption parameter hugely impacts the overall network functioning effectiveness and power of the sensor node. So here several researches are being made on the power saving aspect of the sensor nodes in the WSN's so as to improve the overall network lifetime [5].

1.2 Types of Wireless Sensor Networks: - Wireless Sensor Networks are of many types. They include Terrestrial WSN's, Underground WSN's, Multimedia WSN's and Mobile WSN's et al. Different types of WSN have their own way of working and providing service. Wireless Sensor networks have tremendous application in every sphere and hence if the lifetime of the network is improved, it can yield high performance. The WSN's consist of many sensors inside them that are then arranged in certain ways to form clusters for better performance [4].

1.3 Motivation for Proposed Work

The wireless sensor networks have been an area of extensive research and study in the recent few years. As the energy consumption and delay minimization have been major attributes of performance of a wireless sensor network. Many previous methods and approaches have been put forth in this context for minimization of the time energy consumed. One such method was the improvement in the media access layer. Also the concept of clusters seemed to provide an optimal solution to a great extent. Two more real difficulties are the manner by which to place the cluster heads over the network and what number of clusters would be there in a framework. Also the power consumption parameter hugely impacts the overall network functioning effectiveness and power of the sensor node. So here several researches are being made on the power saving aspect of the sensor nodes in the WSN's so as to improve the overall network lifetime. So the motivation has been to enhance the overall network lifetime in the wireless sensor network for better performance.

II. LITERATURE REVIEW

In IEEE 2019, [1] Huang et al. proposed a communication scheme named first relay node selection based on fast response and multihop relay transmission with variable duty cycle (FRAVD) is proposed. The scheme can effectively reduce the network delay by combining first relay node selection with node duty cycles setting. In FRAVD scheme, first, for the first relay node selection, we propose a strategy based on fast response, that is, select the first relay node from adjacent nodes in the communication range within the shortest response time, and guarantee that the remaining energy and the distance from sink of the node are better than the average.

In Elsevier 2018, [2] Nan Cen et al. presented the idea of LANET: which stands for visible light mobile ad-hoc networks. The data transfer in this case was in the form of visible frequencies. It was shown by dint of the experimental set-up that the proposed system was capable of increasing the network lifetime as the power consumption compared to conventional techniques was lesser in the proposed case.

In IEEE 2018, [3] Yuxin Liu et al. proposed the QTSAT model. This was primarily used for the delay minimization in wireless sensor networks. The system was basically developed using the MAC protocol for the WSNs. Power consumption was not the primary focus of the paper and throughput enhancement was targeted.

In Elsevier 2017, [4] Quing Liu et al. proposed a technique for the implementation of unicast-broadcast mechanism for WSNs. It was shown that often, unicast mechanisms in a broadcast network can provide more energy saving compared to conventional techniques. The evaluation of the system was based on the energy required per transmission.

In Elsevier 2017, [5], Kgotlaetsile Mathews et al. proposed a technique for software defined radio (SDR) concept for wireless sensor networks. It was a new approach for the design of Software Defined (SD) based WSNs. The information leveraged in this case was the channel information of the WSN for increasing the network lifetime.

In IEEE 2017, [6] Cheng Zhan et al. presented the concept of UAV enabled data collection in wireless sensor networks. The idea was to increase the lifetime and decrease the delay latency of the network by switching to the UAV technology of the network. The evaluation parameters were the network lifetime and average delay.

In IEEE 2016, [7] Yuxin Liu et al. proposed a technique for secure and trustworthy techniques for data routing in WSNs. The approach evaluated the chances of data theft in Wireless Sensor Networks in the absence of strong encryption algorithms which may not be practically possible in real life situations due to the limitations of the sensor module.

In IEEE 2016, [8], Ju Ren et al. evaluated the lifetime and energy holes in Wireless Sensor Networks. The technique tried to evaluate the free spectrum and term it as a hole to avoid data congestion in the WSN. Lesser congestion would lead to lesser delays.

In IEEE 2016, [9], Mianxiong Dong et al. presented a concept to increase the lifetime and also decrease the delay in wireless sensor networks. The approach was tested under the constraints of reliability constraints of the WSN architecture. This approach was practical in the sense that WSNs are seldom highly reliable.

In IEEE 2015, [10] Abdul Waheed Khan et al. presented a VDGRA based approach in which a virtual grid based approach was used. The evaluation of the system was done based on network lifetime. It was shown that the proposed approach could attain a network lifetime of around 800 rounds of data transfer for a node count of 400.

In 2015 IEEE, [11] Juan Luo et al. put forth opportunistic algorithm approach for wireless sensor networks. It was shown that ss the network lifetime is of a key importance for the performance of the wireless sensor network, improvement and its enhancement can be very beneficial. This could be done using optimization-based approaches.

In IEEE 2015, [12], Yanjun Yao et al. presented a WSN architecture for delay minimization and lifetime enhancement in heterogeneous networks. It was shown that with Link heterogeneity one can get huge information transmission range easily. As it is more bound towards the link and connectivity framework it yields better and reliable links and connection paths for routing. It gives a good transreceiver which is greater in size and length.

In IEEE 2014, [13] Shuo Guo et al. presented an opportunistic flooding in WSNs. It was proposed that the routing and information exchange must be designed diligently such that the entire functions consume minimum power. Also the power consumption parameter hugely impacts the overall network functioning effectiveness and power of the sensor node.

In IEEE 2014, [14], Changlin Yang et al. proposed a Complete Targets coverage in Energy Harvesting based approach for WSNs. It was shown that the connectivity metric is of enormous use as it decides the protocol of the information transmission. Strong data exchange connectivity amidst the cluster heads and sensor nodes shall impact the time period of the sending and receiving of the data.

In IEEE 2014, [15], Ismail Butun et al. presented an intrusion detection mechanism for wireless sensor networks. The approach was targeted at detecting the chances of possible attacks in WSNs. The need for the study arose due to the fact that node modules are not sophisticated enough to implement complex encryption algorithms to thwart off security threats in WSNs.

In IEEE 2013, [16], Rashmi Ranjan Rout et al. presented a method for the increasing network lifetime using the duty cycle approach and network coding. It was shown that the technique of network coding could indeed increase the network lifetime. It was also shown that strong data exchange connectivity amidst the cluster heads and sensor nodes shall impact the time period of the sending and receiving of the data.

In IEEE 2013, [17], Yanjun Yao et al. presented an approach in which it was shown that with Link heterogeneity one can get huge information transmission range easily. As it is more bound towards the link and connectivity framework it yields better and reliable links and connection paths for routing. It gives a good transreceiver which is greater in size and length.

In Elsevier 2013, [18], Sudhanshu Tyagi et al. proposed a survey on the LEACH algorithm used for clustering techniques. It was shown that clustering is of high importance in this context. The objective here has to be minimum energy consumption by the nodes. The sensor node is operated by battery hence the network lifetime then becomes dependent on the lifetime of the battery. So the routing and information exchange must be designed diligently such that the entire functions consume minimum power.

In IEEE 2012 [19], Samina Ehsan et al. proposed a survey on routing protocols with the Quality of Service or QoS as the primary metric. The proposed system explained the need for the connectivity must all matter when the base station and control station interact with the sensor nodes and the user for the target data. So, proper connection between all the network nodes and units must exist for a robust WSN design. The Qos was responsible for rendering reliability to the WSN data transfer.

In IEEE 2012, [20], Azrina Abd Aziz et al. presented a survey on different techniques on distributed control topologies for the increase in network lifetime of WSNs. The target was the increase in network lifetime for battery powered wireless sensor networks. It was shown that the adaptive routing algorithms could enhance network lifetime.

III. WIRELESS SENSOR NETWORKS

3.1 Overview of Wireless Sensor Networks

Wireless communication is taking a prominent place in the daily communication scenario. Today a big chunk of communication of data and information that is happening is wireless. The sensors that sense the accompanying environment for the signals convert to signals indicating the wireless indicators.[9] So these kinds of sensors play a big role in sensing the correct and apt ones and helping in the communication. In the recent times, the field of wireless sensor network has been a very proactive area of research and study due its indispensable use.

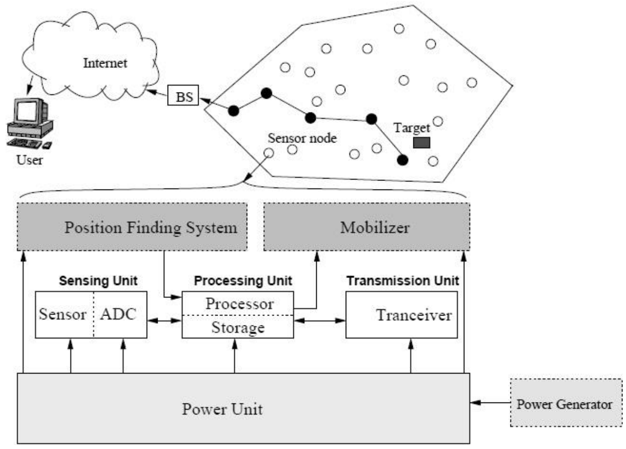

Fig. 3.1 Basic Architecture of Wireless Sensor Network

Figure 3.1 illustrates the basic functioning of a wireless sensor network along with its sensor components. As it can be seen from the picture, the system consists of two main units namely a Position Finding System and a Mobilizer. [14]. The sensing block has the sensor and the analog to digital converter. The sensor mainly tries to detect and sense the wireless input from the environment and then the ADC converts that analog input into a digital format and then that is sent to the controller or the processing unit. Usually, the mobilizer is required for the movement of the sensor node from its current position. The transreceiver in the transmission unit receives or transmits the processed signal. The user is connected to the base station by the internet which is further linked to the sensor node that senses the target. Wireless Sensor networks have tremendous application in every sphere and hence if the lifetime of the network is improved, it can yield high performance.[18].

3.2 Wireless Sensor Networks Histor :- The existence of Wireless Sensor Networks can be tracked back to the 1950's in form of Sound Surveillance System project. It was made by the US military for tracking and finding the submarines of Russia. There were many electronic types of equipment that were utilized such as acoustic sensors etc that were used under the pacific and Atlantic waters [10]. So the wireless sensor networks gained good usefulness at such an early time when the concept of wireless networks started to come to the forefront. The use of cordless phones, and cell phones changed the landscape of the communication medium and the wireless senor networks got momentum. Another program was initiated by the DARPA to study and research more about the wireless senor networks.[6].

3.3 WSN Design protocols and Topologies

There are various topologies of the wireless networks like the star, mesh and tree topologies respectively. In the star topology, each nodes of the network is linked to a specific gateway. In tree, each node is connected to a node that is placed on the top of the tree that is gain linked to the gateway.[11] There is transmission of data from one node to the other within the radio network periphery in the mesh topology. There are certain basic design protocols for the ideal design of wireless sensor networks. They are listed as follows

Reliability Metric

In Wireless Sensor Networks, the design of the networks must ensure reliability. The main job of the sensor nodes is to sense the signals properly and send to the control station. The exchange of data and information between different nodes in the network must ensure and fulfil reliability conditions. When the data communicated from one end to the other, it must make sure that it touches the base station that is there. In the context of the wireless networks the reliability metric is categorized as underneath

Reliability metric with respect to Packet.

Reliability metric by Hop-by-Hop.

The WSNS contain a number of base stations and wireless sensors that are the nodes of the network. These networks are mainly used to sense or detect a particular physical condition such as amount of heat or temperature etc. [12] The packet to packet reliability metric signifies that there is proper packet or event delivery to the nodes. The hop to hop metric ensures that the data transmission is completed within a given number of hop movements.

Size and Density of Network

The size and density of the wireless network is of top importance for proper and good design of the network. The size of the sensor nodes play a useful role for improved performance of the network thereby impacting the overall design. Parameters such as the thickness of the nodes have to be properly planned and thought upon. The density of the sensor nodes in a particular area in the cluster also affects the performance. The size of the WSN network impacts the overall efficacy, reliability and the control station processing ability:

3.4 Wireless Sensor Network Applications and Uses.

Wireless Sensor Networks constitute small devices that sense wireless signals as a part of the wireless communication. There are broad areas of the applications of the wireless sensor networks and are used in a variety of domains that are explained and discussed as follows

WSN's are deployed for Disaster Relief Operations, where they can sense the area of probability of a disaster.

WSN's are used for designing good construction applications, where it can be used to build robust bridges etc.

It can used in detection flora and fauna and tracking of animals.

It is widely applied in the health sector where tracking of patients is necessary.

WSN's is used in traffic monitoring systems and also transport control units.

It finds its extensive use in defence and surveillance systems and military units.

IV. CLUSTERING IN HETEROGENOUS WSNs

4.1 WSN Heterogeneous Model :-The WSN Heterogeneous model contains many different nodes which have different initial energies and capacities. They consist of different capabilities in terms of computation ability, power strength and power of sensing.

Kinds of WSN heterogeneous resources

There exist three general kinds of WSN heterogeneity in the WSN sensor nodes. They are as below:-

- Heterogeneity of Computational power
- Heterogeneity of Linking
- Heterogeneity of Energy

Computational heterogeneity refers to the computational metric of the heterogeneous nodes of the sensor network. It contains of more powerful hardware elements like the robust chip for fast computation and also contains increased memory than the conventional ones. This helps these kinds of sensor nodes to deal with complex data better and also can work with huge piles of information and process it.

With Link heterogeneity one can get huge information transmission range easily. As it is more bound towards the link and connectivity framework it yields better and reliable links and connection paths for routing. It gives a good transreceiver which is greater in size and length. In heterogeneity for Energy, it mainly indicates the sensor nodes are more energy efficient and is designed mainly for the network lifetime improvement and dissipate minimum amount of energy for functioning. [7]

4.2 Heterogeneity in WSNs

Heterogeneity occurs in WSNs when the different nodes in the WSN do not possess the equal amounts of initial energy. Mathematically, Let there be n nodes in the system, then the energy matrix can be represented by:

$$E_i = \begin{matrix} E1 \\ E2 \\ E3 \\ : \\ . \\ En \end{matrix}$$

4.3 Heterogeneous Model for WSNs

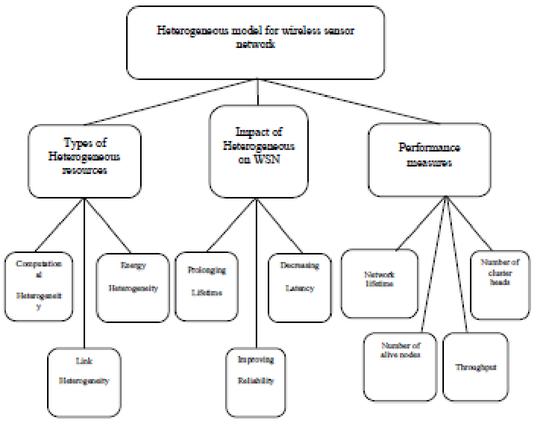

Fig. 4.1 Heterogeneous WSN models

4.3 Clustering:- As the WSN's contains sensor nodes and the information has to be sent from the nodes to the control stations. The concept of clustering is of high importance in this context. The objective here has to be minimum energy consumption by the nodes. The sensor node is operated by battery hence the network lifetime then becomes dependent on the lifetime of the battery. So the routing and information exchange must be designed diligently such that the entire functions consume minimum power.

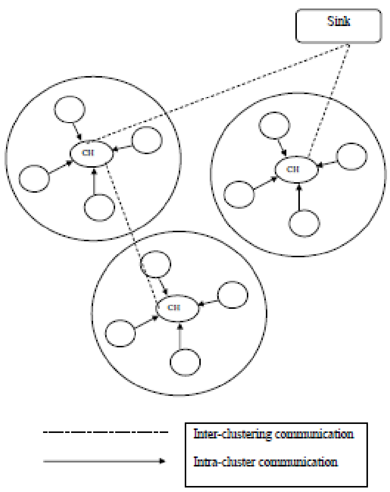

Fig. 4.2 Data communication mechanisms in WSNs

Clustering can help in this regard. It is similar to creating objects of the same type. Several researches have been carried out on the clustering in WSN. The set of the sensor nodes are grouped together in small set of clusters. The cluster of the sensor nodes can be assigned a cluster head that can directly communicate with the control station. This increases the scalability of the network and lifetime of the network as well. It saves energy consumption by imparting more intelligent choices and decisions. The cluster size is to be decided in such a way that the energy expended in the process of data transmission to the Cluster Head and the sink is minimalistic and the network lifetime is maximized.

Topology of the Sensor Network

The wireless sensor network topology has a great influence on the overall architecture of the WSN. It impacts the metrics of robustness, capacity and quality of the entire network design. Similarly, the quality and working of routing between the clusters of nodes also depend upon the type of sensor network topology. There are many topologies that can be used and the network can be designed but the best ones have to be chosen depending upon the type of network and output required. The maintenance of topology and modifications in them also need to take into account as a part of network designing protocol.

V. PROBLEM DOMAIN AND PROPOSED METHODOLOGY

5.1 Problem Identification: - The wireless sensor networks are used in areas where the chances of human intervention are significantly infeasible in nature even with leveraging all possible facilities available in the plant. The network lifetime needs to be high since low network lifetime would mean lesser continuous operation of the plant and frequent shut downs. This would result in plummeting efficiency of the system. The smaller number of iterations of the system can be resolved by using the following methods:

1) Having an optimum cluster size based on the location of the CH and the surrounding nodes. Moreover, a dynamic cluster formation is a must.

2) The average decay rate of the energy of the system has to be reduced so as to increase the overall lifetime.

3) The reduction of dead nodes also needs to be addressed as the dead nodes signify that the whole WSN is not working in the same contiguous manner.

4) Selecting the cluster head (CH) based on residual energy so as NOT to overburden any specific node to be dead while others in the cluster are alive.

5.2 Proposed Solution

The proposed solution revolves around the following approach:

Wireless sensor networks (WSNs) are mainly characterized by their limited and non-replenish able energy supply. Hence, the need for energy efficient infrastructure is becoming increasingly more important since it impacts upon the network operational lifetime. Sensor node clustering is one of the techniques that can expand the lifespan of the whole network through data aggregation at the cluster head. Swarm Intelligence is a branch of optimization where we observe nature and try to learn how different biological phenomena can be imitated in an automated system to optimize the scheduling algorithms. In swarm intelligence, we focus on the collective behavior of simple organisms and their interaction with the environment.

5.3 Principle of PSO: - The PSO algorithm is an evolutionary computing technique, modeled after the social behavior of a flock of birds. In the context of PSO, a swarm refers to a number of potential solutions to the optimization problem, where each potential solution is referred to as a particle. The aim of the PSO is to find the particle position that results in the best evaluation of a given fitness function. In the initialization process of PSO, each particle is given initial parameters randomly and is 'flown' through the multi-dimensional search space. During each generation, each particle uses the information about its previous best individual position and global best position to maximize the probability of moving towards a better solution space that will result in a better fitness.

5.4 Selection of CH

The most critical aspect for the increase in the number of rounds of transmission in the WSN depend on two parameters:

There is no fixed way in which the CH can be selected and it has several possible permutations. The concept of optimum probability is hence used to initially decide the CH. Later the residual energy is taken as the metric.

5.5 Optimal Re-Transmission

Often the situation in the physical vicinity of the WSN could be such that the data sent too frequently can lead to accumulation of redundant data and the information becomes trivial. The concept to be applied in such a case is to apply a threshold exceeding which would lead to the re-transmission. The information obtained in low probability situations is often higher compared to the high probability situations. This is mathematically given by:

The proposed system uses an adaptive clustering mechanism that is used for the increase network lifetime. The approach does not keep the cluster size nor the cluster head fixed but keeps changing them iteratively. The clustering in this case is based on the minimum distance of noses form a base station or control station. This helps in minimizing the power for transmission to the base station or control station form different nodes. The residual energy approach for deciding the cluster head of each iteration is responsible for increased network lifetime as only fixed nodes do not need to take the burden of the data of all the nodes in a cluster. The residual energy of all the nodes in a cluster needs to be evaluated prior to deciding the cluster head (CH). The network lifetime has to be evaluated based on the number of rounds versus number of nodes of the system.

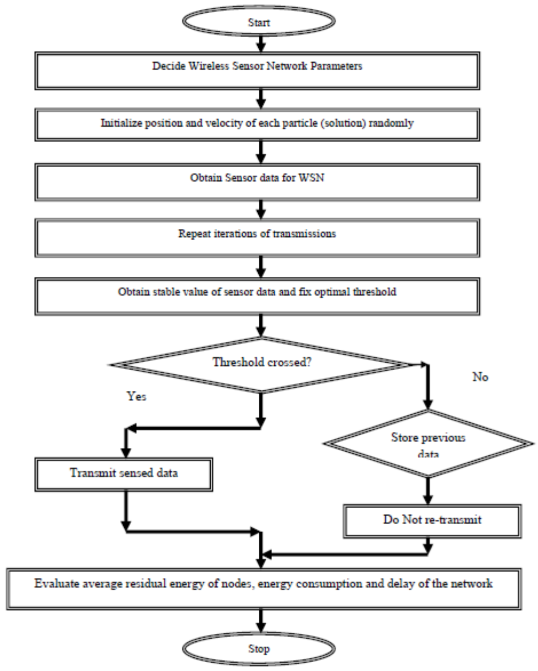

Fig. 5.1 Flowchart of Proposed System

VI. RESULTS AND DISCUSSIONS

6.1 Simulation Results: - Simulation is carried out using MATLAB which is the acronym for Matrix Laboratory.

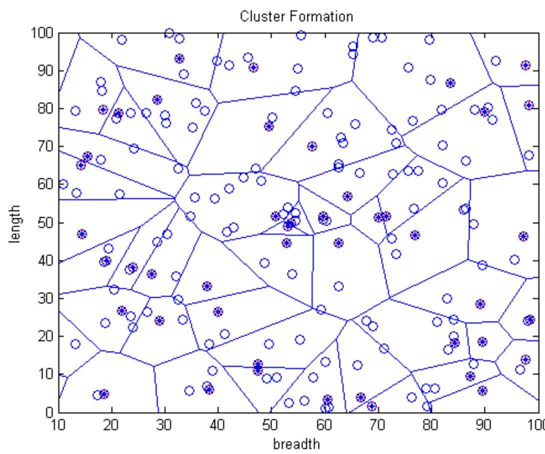

Fig. 6.1 Clustering in the WSN

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The figure above clearly depicts the clustering process in the WSN design. Simple or normal nodes are marked in bubbled blue circles while the cluster heads (CHs) have a solid fill of blue. The cluster boundaries are also marked.

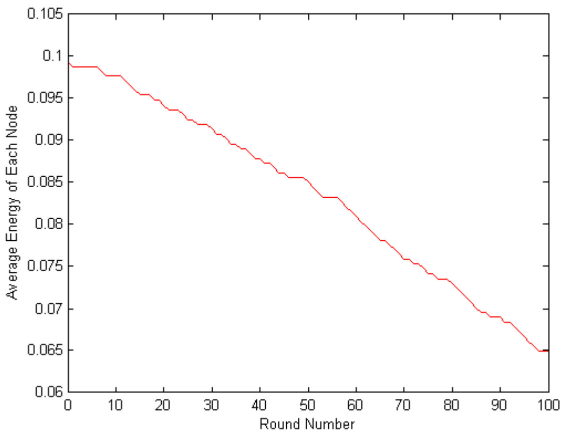

Fig. 6.2 Average Energy of Nodes

The above graph depicts the variation in the average energy of the nodes with the increase in the number of iterations. It can be seen that there is a continuous reduction or decrease in the average energy of the nodes with the number of rounds for which the data is transmitted. The monotonic nature of the fall in the energy can be seen and sudden bursts in the fall can also be seen as the node undergoes some transitions in the form of either:

1) Simple Node

2) Cluster Head

Being a cluster head obviously consumes more energy from the node and makes the energy fall faster than the normal node mode.

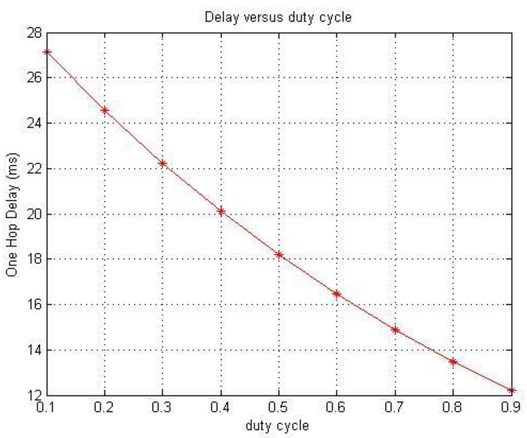

Fig. 6.3 One hop Delay versus duty cycle

The figure above depicts the one hop delay of the data transmission in the wireless sensor network with respect to the duty cycle of the WSN. It can be seen that as the duty cycle increases, the one hop delay decreases.

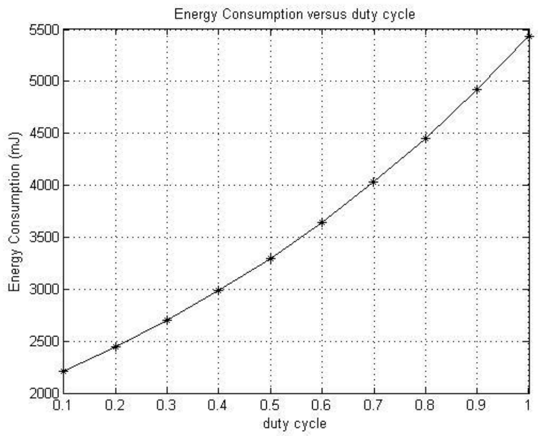

Fig. 6.4 Energy Consumption versus duty cycle for r=80

The figure above depicts the variation of energy consumption of the wireless sensor network as a function of duty cycle. The above figure represents the energy consumption case for the value of r=80.

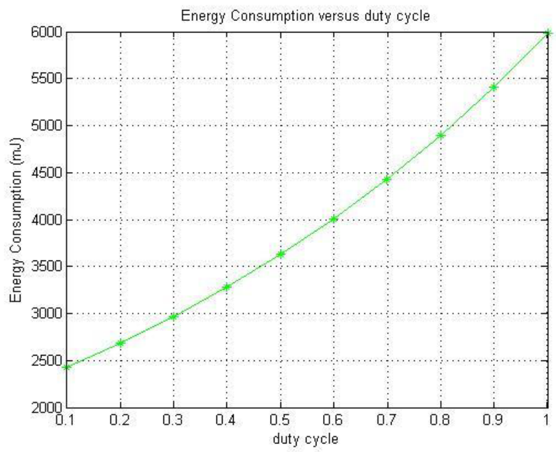

Fig. 6.5 Energy Consumption versus duty cycle for r=100

The figure above depicts the variation of energy consumption of the wireless sensor network as a function of duty cycle. The above figure represents the energy consumption case for the value of r=100.

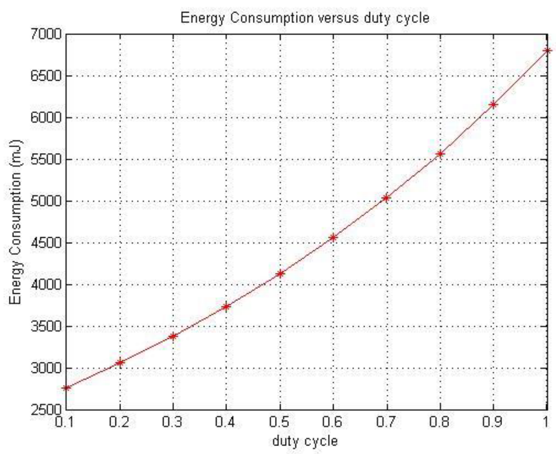

Fig. 6.6 Energy Consumption versus duty cycle for r=120

The figure above depicts the variation of energy consumption of the wireless sensor network as a function of duty cycle. The above figure represents the energy consumption case for the value of r=120.

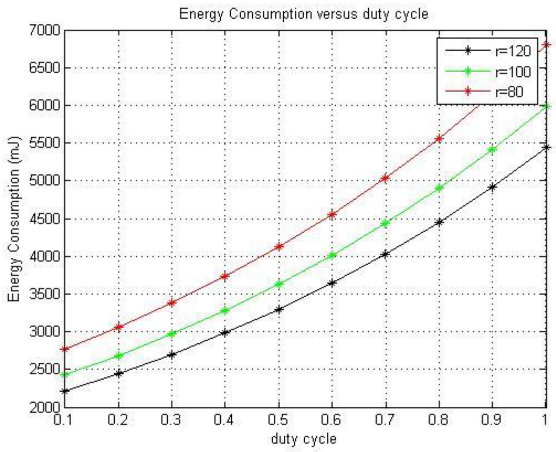

Fig. 6.7 Energy Consumption versus duty cycle for variations in values of r

The figure above depicts the variation of energy consumption of the wireless sensor network as a function of duty cycle. The above figure represents the energy consumption case for variations in the value of r.

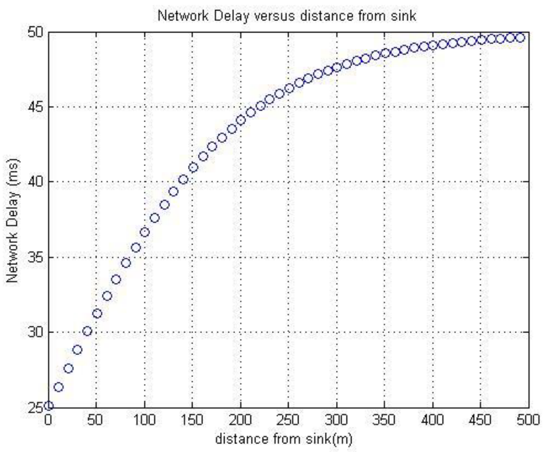

Fig. 6.8 Network Delay versus distance from sink

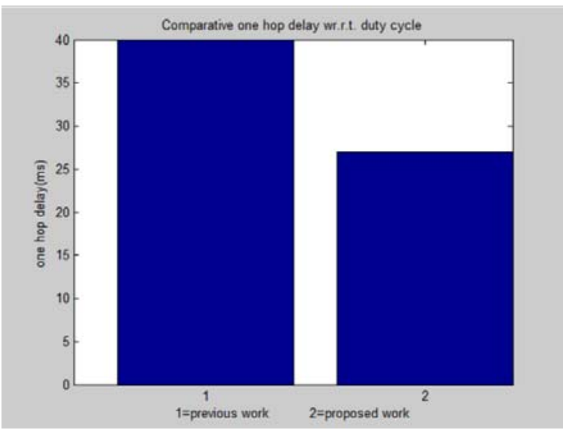

Figure 6.9 Comparative One hop Delay with Previous Work [1]

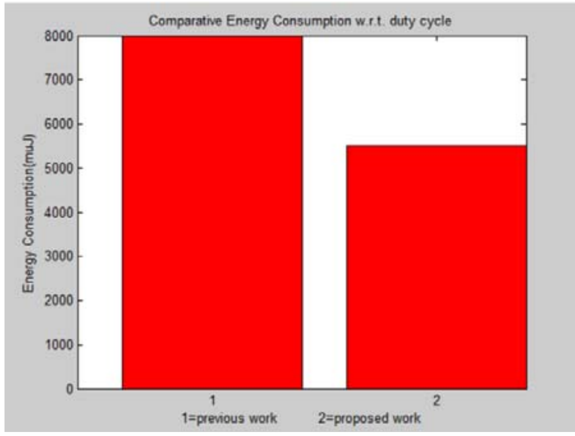

Figure 6.10 Comparative Energy Consumption with Previous Work [1]

The above figure depicts the variation of network delay with respect to the distance from the sink node. It can be seen that the network delay increases as the distance from the sink increases. This happens due to the fact that the data needs to be transmitted over multiple hops.

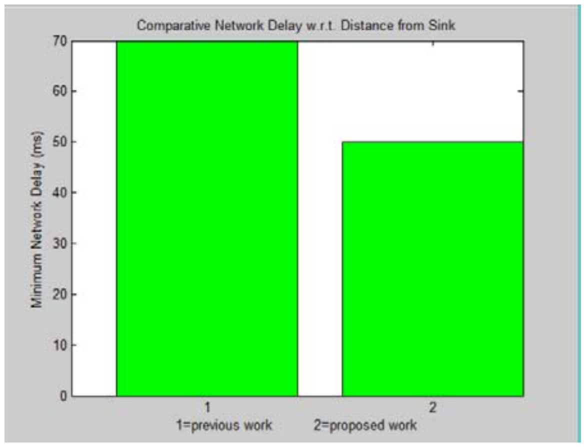

Figure 6.11 Comparative Network Delay with Previous Work [1]

VI. CONCLUSION & FUTURE WORK

It can be concluded from the previous discussions that wireless sensor networks (WSNs) are mainly characterized by their limited and non-replenish able energy supply. Hence, the need for energy efficient infrastructure is becoming increasingly more important since it impacts upon the network operational lifetime. Sensor node clustering is one of the techniques that can expand the lifespan of the whole network through data aggregation at the cluster head. In this proposed work, an energy-aware clustering for wireless sensor networks using Particle Swarm Optimization (PSO) algorithm which is implemented at the base station is presented. We define a new cost function, with the objective of simultaneously minimizing the intra-cluster distance and optimizing the energy consumption of the network. Mobile wireless sensor networks (MWSNs) control systems are emerging as a promising platform which allows a wide range of applications in both military and civilian domains. How to communicate with sink quickly and efficiently is an important issue for MWSNs applied to emergency monitoring. The communication between sensor nodes and sink consists of two concrete phases: 1) first relay node finding and 2) multihop relay transmission.

7.2 Future Scope

Some of the areas where future enhancement can be done are as follows:

1) Since there can be several solutions to the possible problem statement, hence meta heuristic techniques along with genetic algorithm can be used to improve upon the system performance.

2) Mobility of the sink can be analysed to make the approach more holistic.

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