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Data Replication in Clustered WSNs: A Non-Optimal Energy Retention Criterion

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ABSTRACT

Digital electronics and wireless communication technology have gained momentum in recent years and as a result various applications of wireless networks are feasible. Wireless sensor network comprises tiny sensor nodes capable of communicating with each other through some routing mechanisms and transmitting the sensed data to the base station for analysis. The most vital characteristics feature of such high energy constrained networks is that the sensor nodes are battery operated hence once the lifetime of battery is complete the nodes are of no use. So there is a high need for choice of suitable energy retention criterions that can reduce the energy consumption to a high extent in such networks, thereby optimizing the overall lifetime of the sensor networks. Higher energy retention means higher probability of the delivery of data sensed by the individual nodes of the sensor network to the sink node or base station. In this paper we have analyzed data replication factor as a power retention criterion in energy sensitive wireless sensor networks. Data replication may be a positive factor in case of wired networks but in clustered wireless scenario it is a non-optimal criterion. By having a secondary cluster head as a backup node the network may be fault tolerant to some extent but the network lifetime is reduced. We performed the simulation in MATLAB and the results verified that data replication issue by taking a backup cluster head in a clustered sensor network is a negative factor and it degrades the performance of the network thus minimizing its network lifetime.

Keywords: Wireless sensor networks, Data replication, Reliability, Energy retention, Backup cluster head, Data aggregation

I. INTRODUCTION

Wireless sensor network (WSN)[1][2] encompasses several light weight small devices known as sensor nodes dispersed in a self governing manner to supervise the physical and environmental status like pressure, temperature, vibration and sound in several regions. Each node in a sensor network is customarily appareled with number of sensors, a radio transceiver or other wireless transmission device, a tiny microcontroller, and an energy inception in the form of a battery. Maximum energy is consumed during data transmission while data sensing cost for the network is very less [3][4][5].

Hence the power of battery is very much restricted and once it is exhausted these nodes are worthless [6]. These are energy constrained networks which are highly power dependant. Thus to enhance lifetime of a network a power aware algorithm is required to be developed [7][8]. Maximum node-energy utilization is the foremost attainment in wireless sensor networks. Apart from the trustworthiness, network lifetime is also critical measures which affect the overall performance of a sensor network. One of the important issues in wireless sensor networks is data aggregation from all sensor nodes. Main aim of a sensor network is to efficiently accumulate data, combine them and aggregate them so that the overall energy consumption is minimum thus enhancing the longitivity of a sensor network. Though energy consumption remains the main issue but ensuring reliable and more accurate data transfer also to be considered. High reliability

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represents high rate data transmission anticipated by different nodes of sensor network to the sink node or base station. A simple wireless sensor network is illustrated in figure 1.

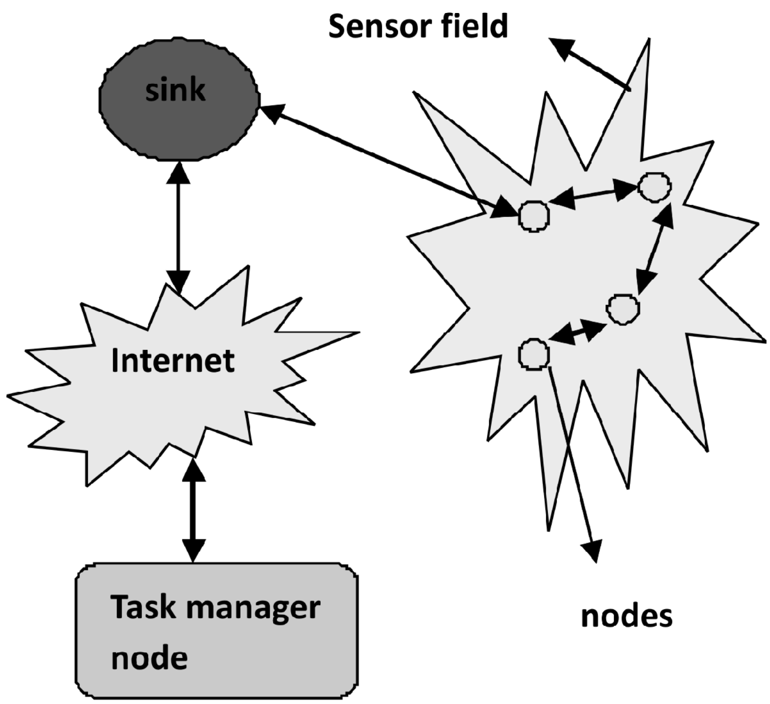


Figure 1: A Wireless sensor network

II. LITERATURE SURVEY

There are several works been carried out in this aspect of sensor networks. Heinzelman [9] introduced a hierarchical clustering algorithm for sensor networks, called Low Energy Adaptive Clustering Hierarchy(LEACH). LEACH is a cluster based protocol, which includes distributed cluster formation. Lindsey and Raghavendra [10].[11] proposed an enhancement over LEACH protocol. The protocol, called Power-Efficient Gathering in Sensor Information Systems (PEGASIS), is a near optimal chain based protocol. Jau-Yang Chang and Pei-Hao Ju in 2012 [12] In this article, efficient power saving scheme and corresponding algorithm must be developed and designed in order to provide reasonable energy consumption and to improve the network lifetime for wireless sensor network systems. K Abbas Nayebi, Hamid Sarbazi-Azad in 2011 [13] elaborated that In many wireless sensor network applications, nodes are mobile, while many protocols proposed for these networks assume a static network. In [14] an energy efficient distributed technique based on clustering was proposed defining size of clusters depending on the hop distance to base station. A heterogeneous sensor network based stable election protocol was developed in [15] to increase the network lifetime before the first node is dead. Another power efficient clustering model based on prediction technique was introduced to improve the network performance in [16]. It is based on heterogeneous nature of monitored objects and energy heterogeneity of sensor nodes. A clustered based routing protocol for sensor network with unequal distribution of sensor nodes was proposed in [17]. The aim of this protocol was efficient load balancing among unequal nodes. Authors presented a distributed energy retention model with energy and computational heterogeneity in [18].

III. PROBLEM STATEMENT

One of the factors that ensure maximum reliability in data transfer is Data Duplication. Data Duplication is achieved by creating multiple copies of the original data and storing them accordingly. Having redundant copies of the same information can ensure reliability since if due to any reason the original data gets corrupted then the same information can be recovered from the duplicate records thus preventing any loss of data. This is a general conception regarding Data Duplication. This issue can be taken one step further and implemented in sensor networks. The data replication possibilities for energy-constrained sensor networks can be analyzed and studied to see that how long can such a energy-constrained sensor network sustain reliably and avoid data loss, even under sheer energy constraints, by doing full replication of data aggregated by a primary cluster head to its least distant nearby sensor node in its cluster.

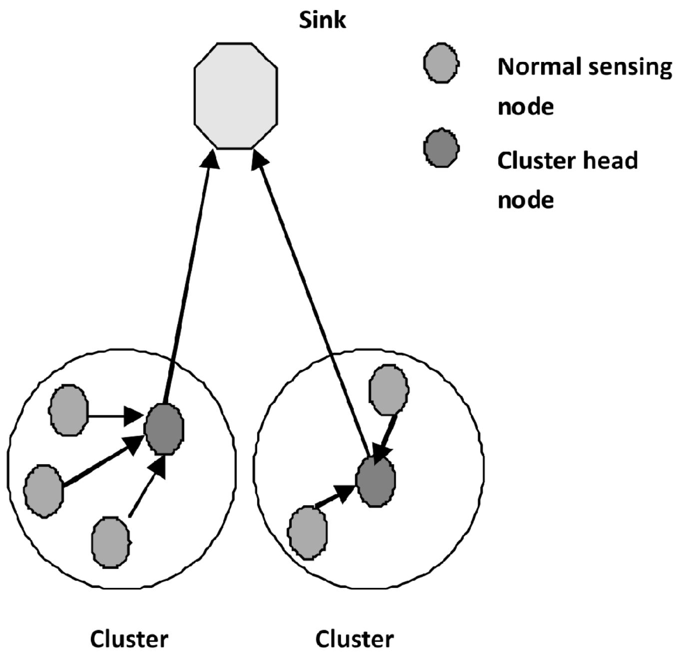


Figure 2: A simple Cluster based architecture

IV. CLUSTERED ARCHITECTURE

Cluster based architecture in wireless sensor network

Aggregating nodes as clusters has become into an interesting issue for the research community for achieving the objective of network scalability .In the recent past, a number of clustering algorithms have been indicatively developed for WSNs [19][20][21-24]. The main motive of a routing protocol is to fabricate the network usefully and efficiently. [25][26]A cluster based routing protocol aggregates sensor nodes where each cluster of nodes has a CH or a gateway. Perceived data is transferred to the CH rather than sending it to the sink node, CH executes an aggregating function on data it draws then sends it to the BS where these data is required. Cluster based routing protocols devised to trim energy consumption by localizing intercommunication between the clusters and aggregating data to lessen transmission to the BS. A clustered WSN is represented in figure 2.

Clustering objectives

Distinct objective of the clustering algorithms are usually fixed to render application requisite such as low data latency or data location awareness. Some of the popular motive is discussed as follows:

Load balancing

One of the critical issues to be addressed here is evenly distribution of sensor nodes among various clusters formed so that data processing at cluster heads can take place effectively. [27] this phenomena of load balancing is very important in clustered wireless networks in order to prevent the cluster heads from getting conjested.

Fault tolerance

Cluster heads breakdown can create great difficulties in realistic scenarios resulting in loss of data. It is even more problematic in operations where WSN are operating in very critical environments. Thus it is preferable to revolve the cluster heads between the nodes in every round so that equidistribution of energy can be attained resulting in achieving fault tolerance and high reliability.

Maximized connectivity and reduced delay

In WSN since the cluster heads are chosen from the sensor nodes, inhibiting the domain of connectivity and upgrading connectivity of inter cluster heads may be more convenient than long-haul connections. Furthermore when data latency is a concern, intracluster connectivity turns into a design objective or limitation.

Minimized cluster count

It is a general practice when cluster heads are specially designed resource-rich nodes. In these cases their stationing is more difficult or tends to be extra costly and susceptible than sensors.

Enhanced network longevity

Due to the presence of various constraints in sensor nodes, the network lifespan is the primary concern specially for appositeness of WSN located in harshed environment. Adaptive clustering is a feasible selection in order to attain more network lifetime.

V. PROPOSED WORK

In Wireless sensor networks which are heavily energy constrained networks energy retention is a very critical criterion here. The primary goal in efficient data aggregation in wireless sensor network is to lessen the overall energy consuming process and to escalate the lifetime of the network. Network lifetime can be enhanced by improving the reliability of the network. In a sensor network high reliability represents the ability of the sink node to collect more accurate data from maximum number of nodes for a long period of time.

Generally it is believed that back up of information provides more reliability in every network because somehow if the original data gets corrupted or is lost due to some reasons the backup data can be accessed so there is no delay in data delivery and data is readily available to the user. This scenario can be applicable to various kinds of networks and thereby making it more reliable and fault tolerant. But the notion of backup data is only feasible in wired networks and in those scenarios where power is not at all a constraint. But in wireless sensor networks and other energy constrained networks where power is a limited criterion backup of information is moreover an overload for the network because when backup of any information is done then additional energy and time is consumed in creating copies of the same data and updating them accordingly which reduces the lifetime of the network thus degrading its performance significantly.

A simple wireless sensor network with cluster based architecture is shown in figure 3. In simple cluster based architecture the sensor nodes are arranged into many variable sized clusters. Every cluster contains different sensor nodes and among those sensor nodes a cluster head is selected for every cluster. During data aggregation process the cluster member nodes record their individual readings and transmit this to their respective cluster heads. Then data aggregation is undertaken by these cluster heads. Data received

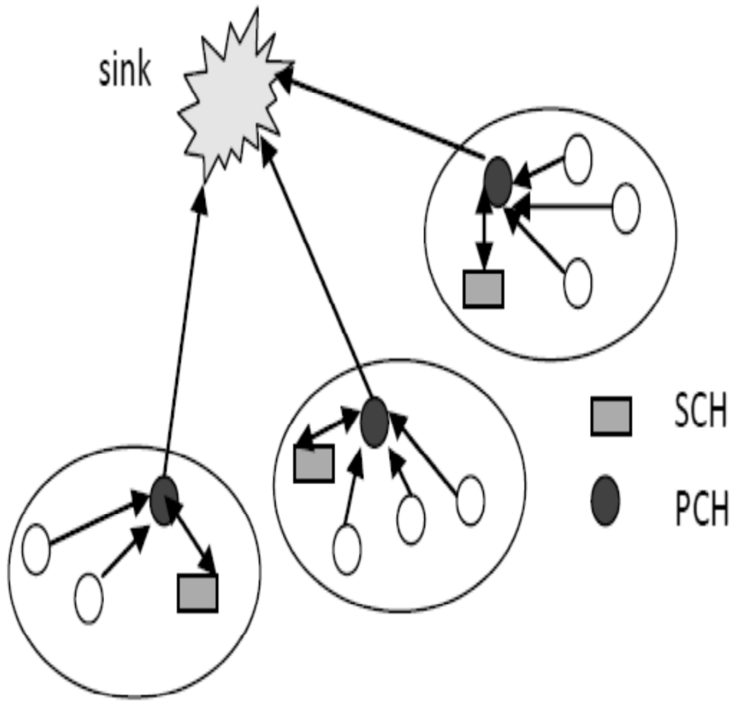


Figure 3: A Cluster based architecture with a back up cluster head

from the member nodes is aggregated by using some aggregator function and then transmit the compressed and aggregated data directly to the base station where the user can access that data through internet. This is the general scenario behind Cluster based data aggregation in wireless sensor networks. Now if we introduce the backup mechanism in such a network the performance of the network significantly degrades. A secondary cluster head (BCH) acts as a backup cluster head in a cluster. The criterion for the selection of the BCH is based on one single criteria i.e., node with the least distance from the main cluster head. Once the clusters are formed in the network using K -Mean's algorithm all the sensor nodes are assigned their respective clusters. Then among the member nodes the node with the least distance from the Primary cluster head is selected as the secondary cluster head node. So once the BCH is chosen for every cluster the data aggregation process is initiated. Data collected from individual sensor nodes from every cluster are sent to their respective Primary cluster heads where data aggregation occurs. PCH is the main data aggregator here and it performs the aggregation task based on the application for which the network has been deployed. After the PCH has aggregated the data it sends that compressed data to the base station directly so that the users can access the data through internet. Data aggregation process is a continuous process and in every round the nodes that have data send their respective data to the PCH. A round of data aggregation is said to be completed when the cluster head sends the aggregated data to the base station. Now within a round any node can send data to the cluster head without any restrictions or limitations. Along with the aggregated data the cluster head also sends the cluster member list and the residual energy level list to the base station so that for the successive rounds the base station can choose the prime cluster head according to the node with maximum residual energy from that list only. Now during the process of data aggregation the main cluster head simultaneously transmits the aggregated data to the BCH also. So the main cluster head performs multi tasking of receiving data from sensor nodes, transmitting data to the sink node and at the same time transmitting data to the BCH. Thus it is obvious that energy consumption by the main cluster head will be much more than other nodes in the network. Similarly the energy spent by the BCH will also be more since it performs the dual functions of receiving aggregated data from the main cluster head as well as transmitting its own local data to the main cluster head. During this entire process the energy consumption is very high and the sensor nodes especially the cluster heads dies out of energy very soon. Suppose during the entire operation if the prime cluster head break down due to certain reasons or the energy of the main cluster head dies out then the whole subjection of data aggregation shifts onto the BCH. By this time the secondary cluster head notifies its other member nodes about its new role of being the main cluster head. Thus from that instant onwards the member nodes transfer their analogous data to the backup cluster head which acts as the main data aggregator and the process of data aggregation continues as before in usual manner. This process continues as long as the respective cluster heads send the aggregated data to the base station node and the cluster heads transmit data as long as the member nodes of individual clusters are alive and send their corresponding data. The moment the cluster heads fails to capture data accurately from respective sensing member nodes data aggregation process stops. Normally it is assumed that this system with backup cluster head is very reliable and fault tolerant since if the main cluster head fails to collect data due to any reason then the backup cluster head can come to the rescue and the data aggregation can continue without much delay and accurate data can reach the sink node. But in reality the situation is very different. A wireless sensor network with backup cluster head mechanism dies out of energy very soon than expected. The reason behind this is that during every round of data aggregation the cluster heads consume much more energy consumption than normal sensing nodes as the cluster heads performs the multi role of collecting and aggregating data from all sensors, sending aggregated data to the sink node while it also performs the normal sensing operation like other non cluster head nodes. Apart from this it also transmits the aggregated data to the backup cluster head simultaneously. Thus energy consumption in these cluster heads is much more than in normal sensing nodes. Therefore the rate at which these cluster heads die out of energy is relatively very high compared to other normal non cluster head nodes.

VI. PERFORMANCE ANALYSIS

In this study the main focus is that a wireless sensor arrangement with a secondary or backup cluster head can degrade the attainment of the network convincingly. To authenticate the factfulness, simulation has been done in the MATLAB environment. Data aggregation has been carried out and is compared with the network without backup cluster head while the entire configuration remains constant for both. 33 rounds of data aggregation operation is simulated and all nodes are supplied with 2kjoules of initial energy.

Simulation results are analyzed graphically. X-axis is labeled with nodes number and Y-axis is labeled with energy retained in joules. The result obtained is shown in figure 4 to figure 10.

For round 1

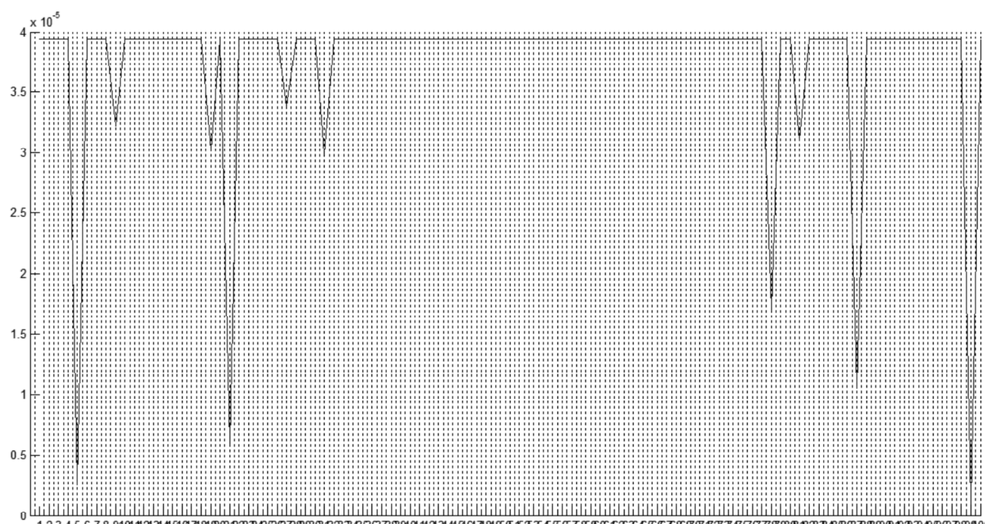


Figure 4: Nodes vs Energy retention

For round 6

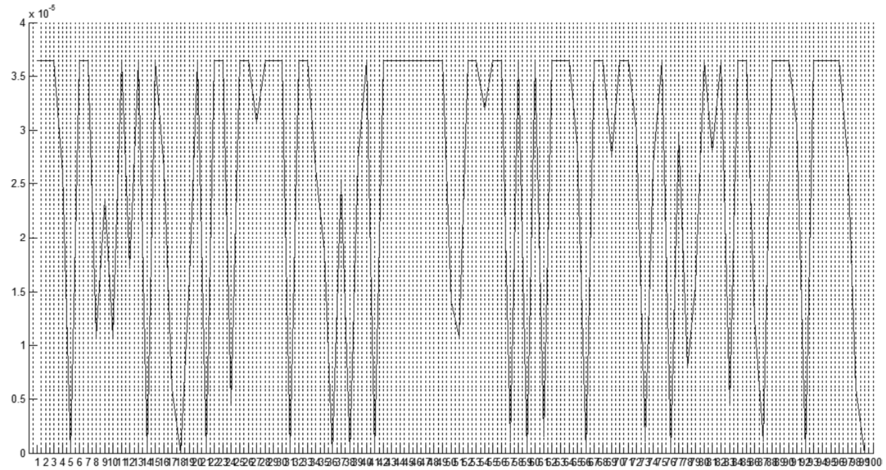


Figure 5: Nodes vs Energy retention

For round 11

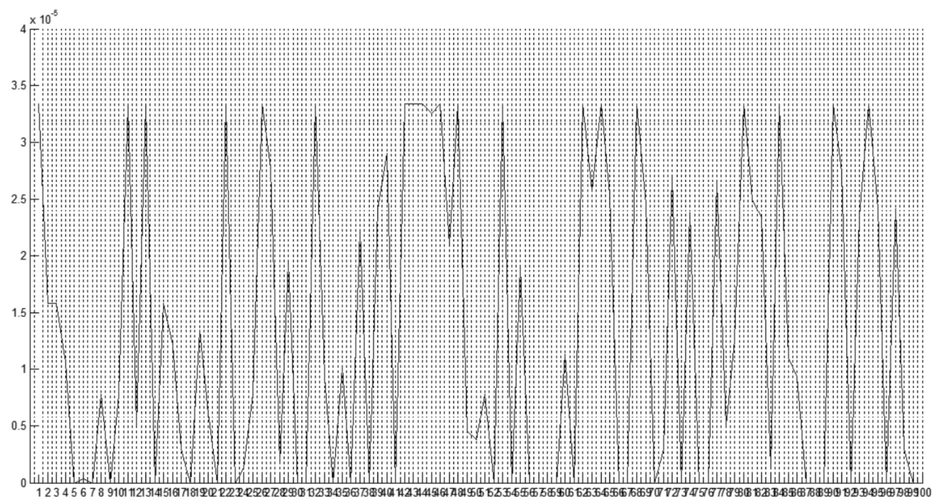


Figure 6: Nodes vs Energy retention

For round 16

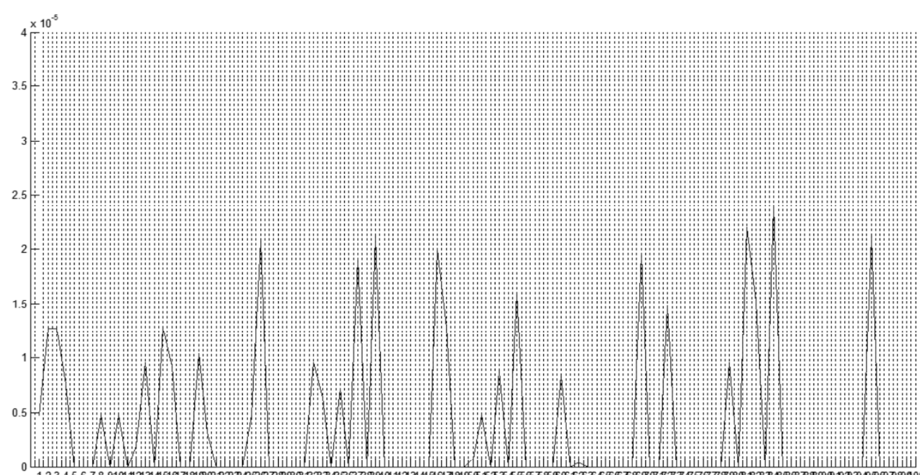


Figure 7: Nodes vs Energy retention

For round 21

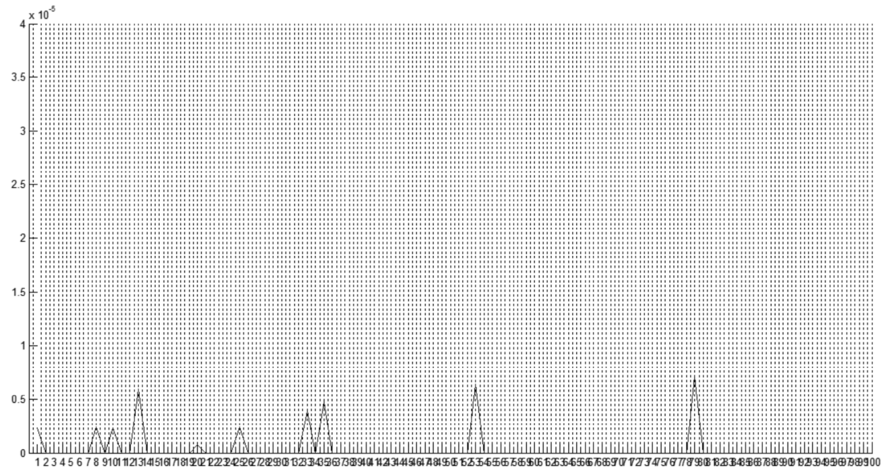


Figure 8: Nodes vs Energy retention

For round 26

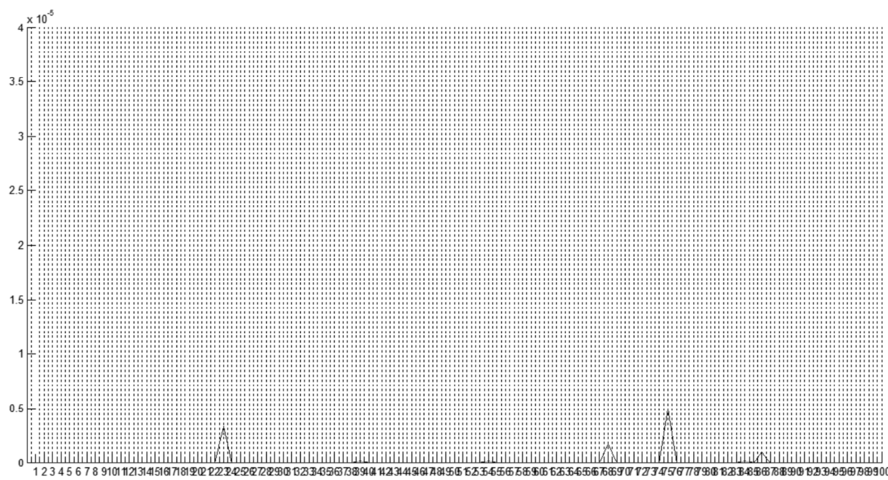


Figure 9: Nodes vs Energy retention

For round 32

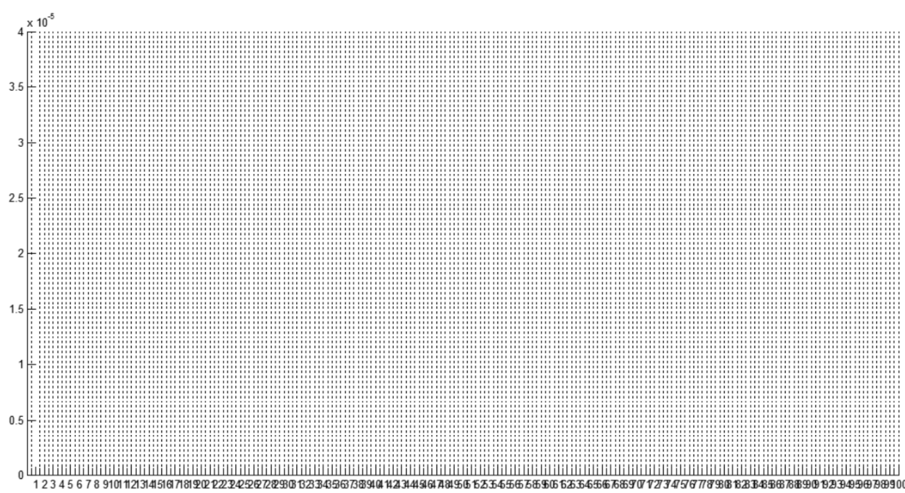


Figure 10: Nodes vs Energy retention

It is observed that in first few rounds of data aggregation the energy consumption is high in less number of sensor nodes and these are the cluster heads but as the number of rounds increases the residual energy retained by the sensor nodes becomes very low while a large number of nodes starts becoming dead. As it is seen towards the end very few nodes are alive with very less energy left in them. Now let us compare this simulation result with the network without any backup cluster head where there is a single cluster head in every cluster with no data replication mechanism which is seen in figure 11 to figure 18.

For round 1

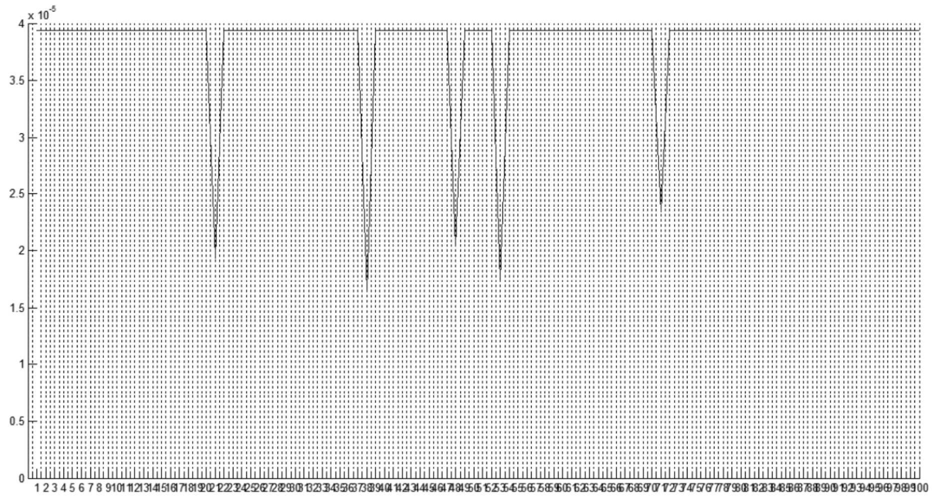


Figure 11: Nodes vs Energy retention

For round 6

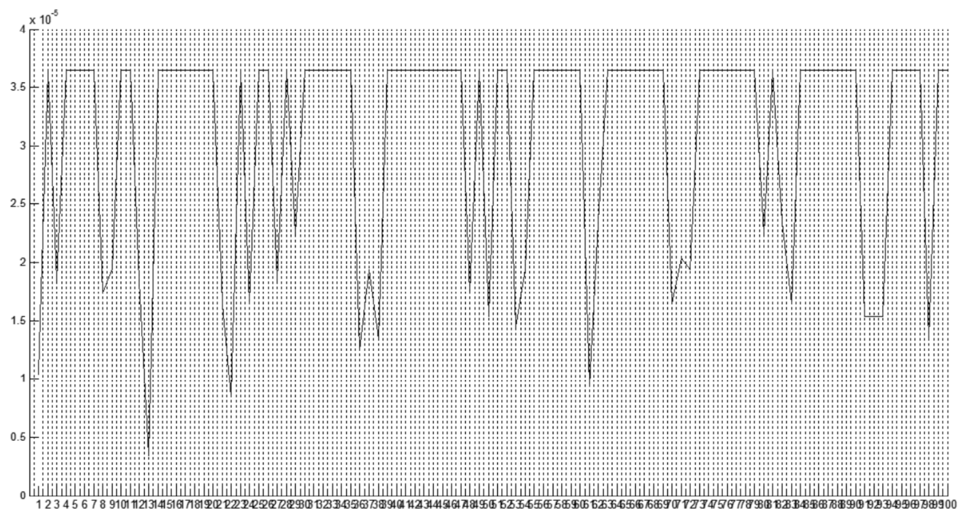


Figure 12: Nodes vs Energy retention

For round 11

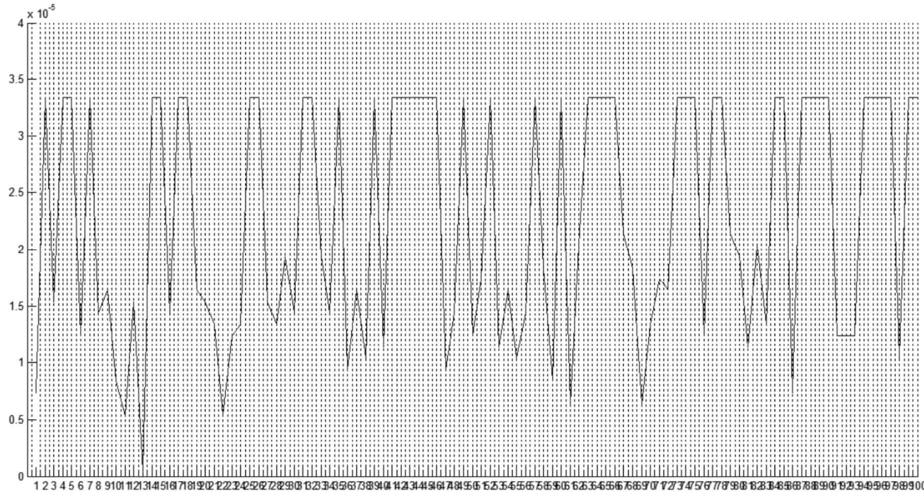


Figure 13: Nodes vs Energy retention

For round 16

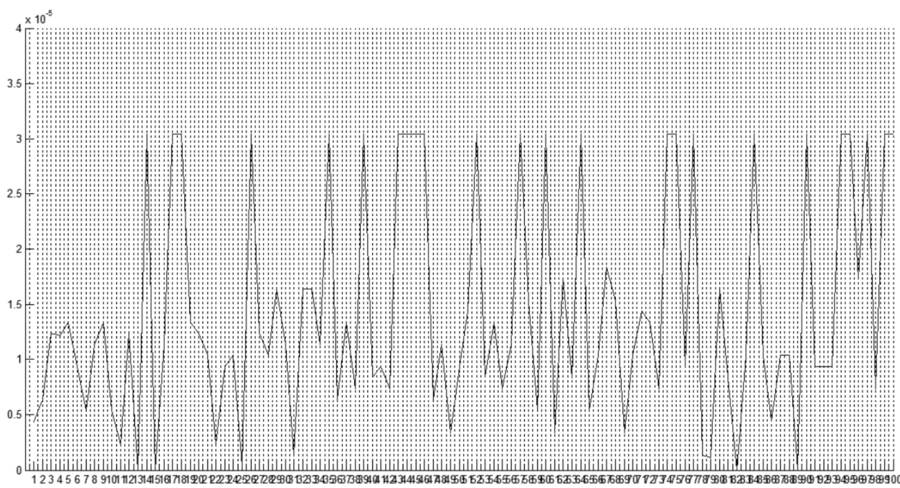


Figure 14: Nodes vs Energy retention

For round 21

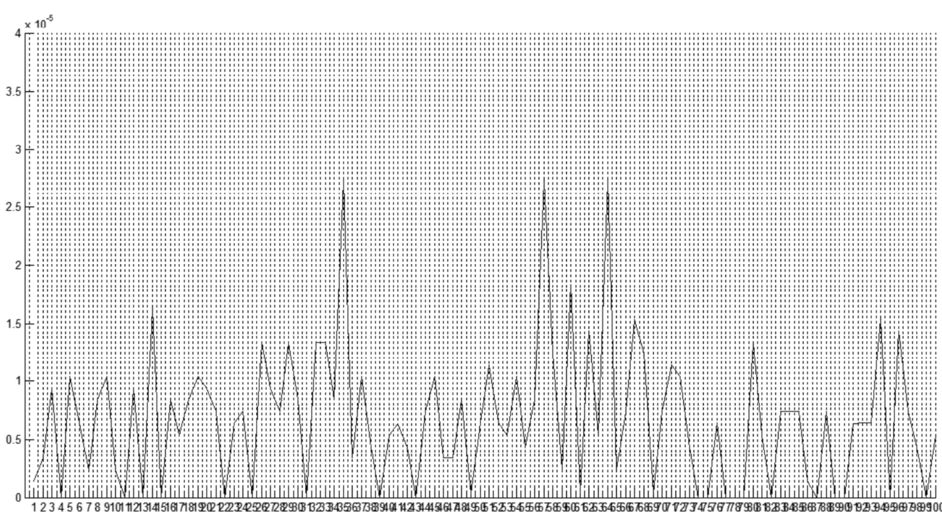


Figure 15: Nodes vs Energy retention

For round 26

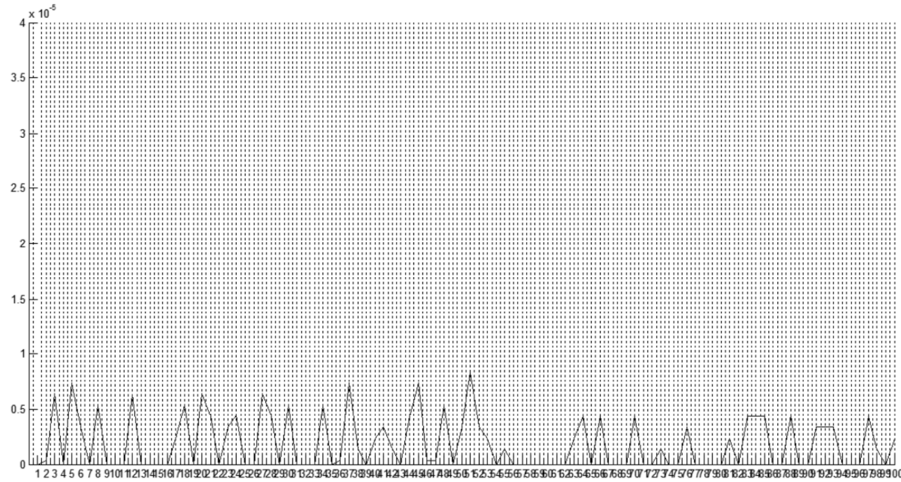


Figure 16: Nodes vs Energy retention

For round 31

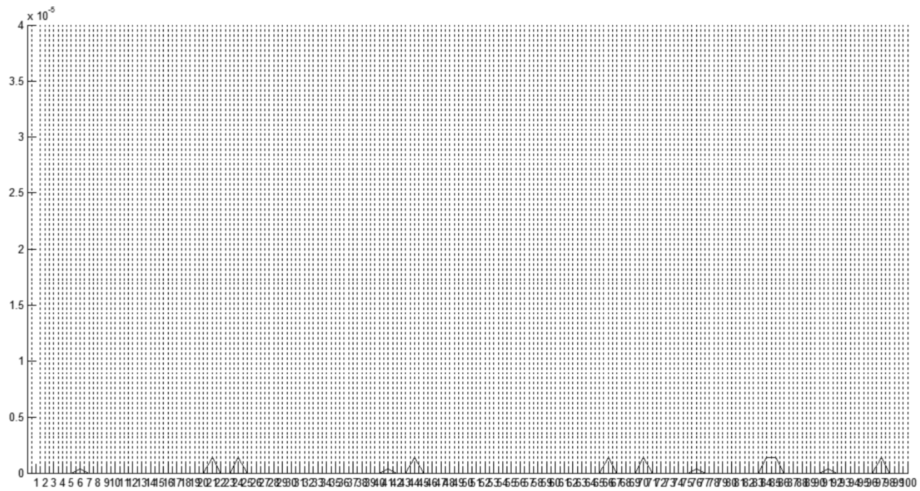


Figure 17: Nodes vs Energy retention

For round 33

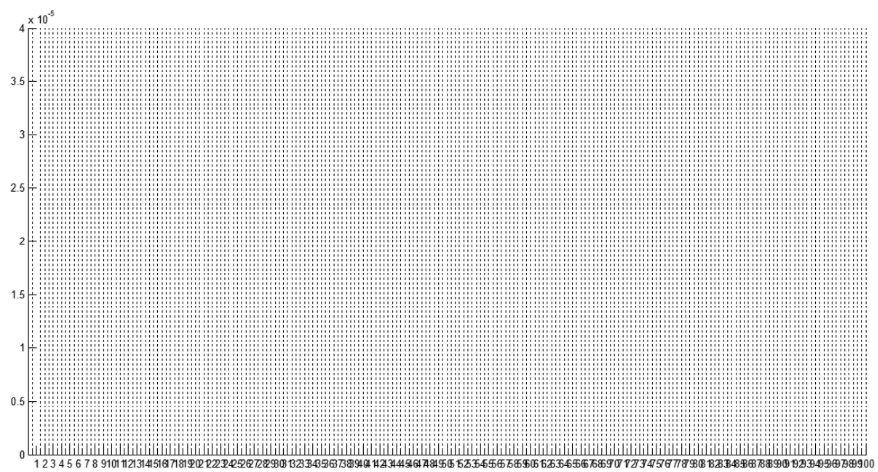
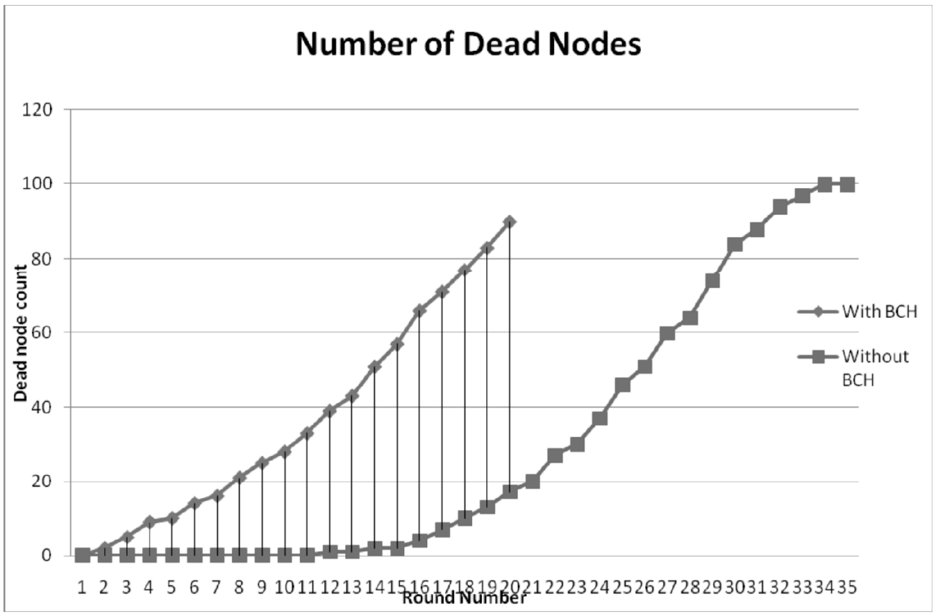


Figure 18: Nodes vs Energy retention

It can be clearly identified that in such a network without any backup cluster head concept the energy retention in sensor nodes are much higher. As the number of rounds of data aggregation is increased performance starts degrading and the nodes start becoming dead more rapidly but still in comparison to the network with backup cluster head the performance of this network with a single cluster head is much better. As it is observed that even after the completion of all rounds some energy is still retained but in case of the network with data replica facility all nodes are dead in round 31 only. The comparison between the two networks can be illustrated graphically by plotting two separate graphs as shown below.



Figurd 19: Dead nodes vs Rounds

Comparison of number of dead nodes with total rounds is shown in figure 19. Here the number of rounds are represented by X-axis and the number of nodes becoming dead are represented by Y-axis As it is observed as the numbers of rounds increases nodes start becoming dead as they consume more and more energy and the rate at which nodes become dead is much rapid in case of network without any backup mechanism. In round 21 only all nodes are dead in the network with backup cluster head thereby reducing the network lifetime.

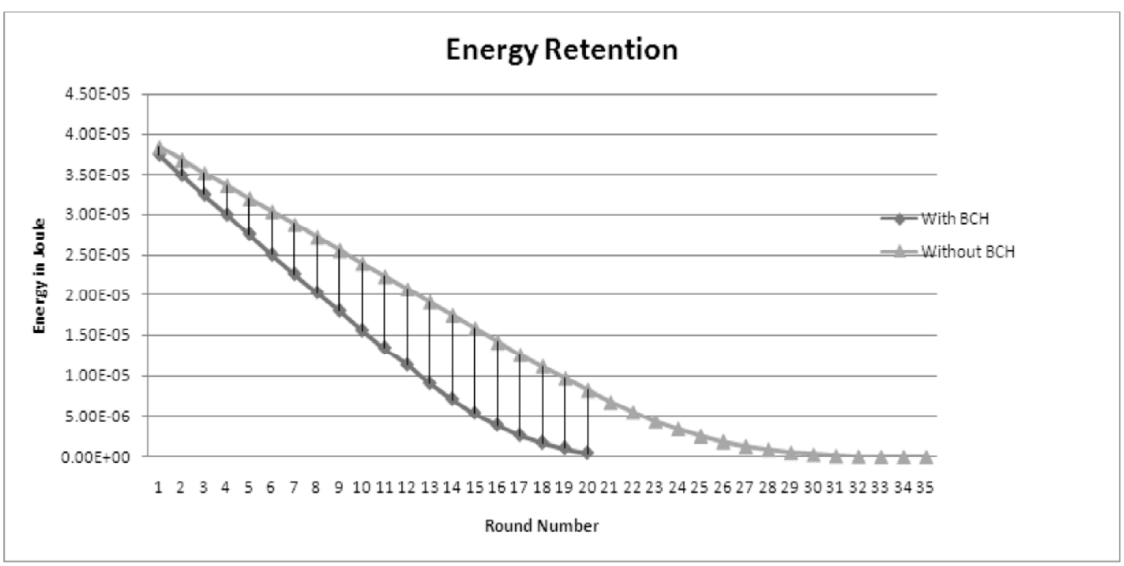


Figure 20: Energy Retention vs rounds

Figure 20 depicts the energy retention graph where the residual energy in the two networks are compared. As it is seen in round 20 the energy retained becomes zero in case of network with backup cluster head while in network with a single cluster head energy is retained till the completion of data aggregation rounds. Thus the data replication based network fails to ensure high reliability in wireless networks where energy is a limiting factor.

VII. CONCLUSION

Technically reliability in a wireless sensor network represents that not a single node in a round achieves zero energy so that the sink node gets the data from all nodes of the network as long as possible. Now as we discussed and observed that in wireless sensor networks the backup data concept is not suitable in real life scenario so this concept does not ensure reliable data transfer. Thus we demonstrated and presented a precise study on data replication as a negative criterion for energy confinement in energy susceptible wireless sensor networks by taking an alternate chunk head in cluster network arrangement and proved that the backup cluster head mechanism for data duplication should not be used in energy constrained networks. Thus for energy-constrained WSNs it is a negative factor that adversely affects Energy retention in such networks thereby degrading its overall performance.

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