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Presenting an improved method to reduce power consumption by scheduling sleep and wakeup periods of nodes in wireless sensor networks

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Abstract:
Wireless Sensor Networks (WSN) is an emerging technology in today's world. Wireless sensor networks have been prominent technologies in many fields, so reducing network energy consumption and increasing network lifetime is very important. To achieve this goal, cluster-based sleep/wake scheduling method is proposed. In this method, some nodes are considered as initial nodes through which decisions are made about the heads of clusters. In each cluster, the cluster head selects a node with the highest energy and keeps it in active mode and sends the remaining nodes to sleep mode. Then again, the initiating nodes collect the remaining energy details of these clusters and compare it with the standard threshold value. If the cluster energy is less than the threshold value, then that particular cluster will be sent to sleep mode. Finally, transmission is done by the active cluster to the sink node. Through this way, it is possible to reduce the energy consumption in the network and increase the lifespan of the network. By simulating the results, it is proven that the proposed method reduces the energy consumption and increases the packet delivery ratio.

Keywords: wireless sensor networks (WSN), sleep/wake up scheduling, cluster head (CH), initiator nodes (I)).
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1. Introduction

WSNs are a well-known emerging technology with a wide range of applications having varying characteristics and network requirements. Generally, each sensor in a WSN collects and processes data, which are routed to a sink node or base station via other sensors. In general, a wireless sensor network (WSN) is a collection of sensor nodes connected to each other by wireless communication channels. Every sensor node is a small device that can collect data from the surrounding area, perform simple calculations, and communicate with other sensors or with the base station (BS). Due to this feature, wireless sensor networks have become a very important issue with rapid development, which are vulnerable to a wide range of attacks due to deployment in hostile environments. A WSN is a large network of resource-limited sensor nodes with multiple predefined functions, such as sensing and processing with a number of low-cost resource-limited sensor nodes, to measure important environmental information and transmit it to a sink node that The agent provides the gateway to another network or the access point for the human interface. These sensor networks are composed of limited energy nodes embedding limited transmission, processing and measurement capabilities. Therefore, the life cycle of the network is shortened and hence the implementation of energy efficient technique becomes an important requirement for WSN. [1] [2] [3] [12].

The need for an energy-efficient schedule

In order to provide high-quality data services, several levels of sensing coverage and network connectivity are required in the practical implementation of a WSN. In wireless networks with battery-consuming devices, the energy saving mechanism is extremely important in increasing the lifetime of the network. Energy conservation is important during periods of no activity as well as during incidents. Reducing traffic eavesdropping is critical because the transceiver consumes the same power as the transmission for standby listening. In wireless sensor networks, a sleep-wake duty cycle path is adopted for energy efficiency and energy conservation, because each sensor node is usually equipped with a battery that is power limited. In wireless networks, a cluster is a group of nodes that is generally considered as a scalable method for managing large sensor networks, and each cluster contains a single cluster head (CH). Network sensor nodes can be managed locally by the cluster head in a cluster - a node is chosen to coordinate the nodes within the cluster and take responsibility for communication between the cluster and the base station or other cluster heads. Clusters provide a convenient framework for resource management, information synthesis, and local decision making. Because in a cluster all the nodes will be awake to communicate with the cluster head. This communication occurs regardless of the energy of the nodes in the cluster. During this process, all nodes in the cluster consume energy, regardless of which node has the ability to transmit information. Therefore, in order to reduce this energy consumption by nodes that are not able to transmit information or communicate in the cluster with the cluster head, the sleep/wake scheduling technique is implemented in the network. Through this sleep/wake scheduling process, energy conservation is possible in the network. This is possible by dividing the nodes of the cluster into active nodes and inactive nodes. Active nodes are nodes with high energy and able to communicate with the cluster head, and inactive nodes are nodes with low energy and these nodes are not able to communicate with the cluster head. These inactive nodes are sent to sleep mode with low energy. And the remaining nodes remain in the awake state, which is able to communicate with the cluster head. Through this method, it is possible to save the energy of the network and increase the life of the network. [4] [5] [6] [7] [8] [9] [14].

Benefits of scheduling

- With the sleep/wake schedule, the sensors are densely deployed inside the same cluster, the connection of the area covered by the active sensors can be guaranteed .[4]
- •If another source has no traffic to send, slot assignment will be interrupted along the flow path from the source to the sink. Therefore, nodes can adjust their sleep schedule according to changing traffic patterns, which is important for energy conservation. [6] [15
- •For continuous monitoring systems, synchronization-based sleep/wake scheduling schemes are often used because the traffic pattern is periodic. [9].
- Energy consumption can be controlled when sleep/wake scheduling is applied to the network node, that is, when a task needs to be done, only some nodes are allocated through the task message. [4] [10].

Scheduling issue

- If two neighboring clusters are not densely connected, they cannot merge into a larger cluster. [4]
- A cluster that broadcasts a merge request does not accept a merge request from other clusters, so the cluster must send a message to other clusters, otherwise it may lead to spending more time
- •Ideally, in a sensor network, a scheduling protocol must determine a transmission schedule for each packet, otherwise collisions may occur. [6]
- Spending time can be more because the transmitted data packet visits all the nodes on the way and waits until the acceptance process is completed [7].
- When the sensor nodes are divided into several clusters, only a few sensors from different clusters are selected for active status, if this is repeated and the same nodes are kept inactive as much as possible, then it is possible lead to problems for the network in the future.

In [16], a method combining energy efficiency and multiple path selection for data fusion in WSN was proposed. The network is divided into different clusters and the clusters with the highest remaining energy are selected as the cluster heads. The sink calculates multiple paths for each cluster head to transmit data. Distribution source programming and lift scheme wavelet transform are used for data compression in CH. During each transfer round, the path is changed in a turn-by-turn fashion to conserve energy. This process is repeated for each cluster. But this method consumes more energy because all the nodes in the network remain active without transmitting anything. This leads to a decrease in the lifetime of the network. To overcome this problem, this paper proposes a guaranteed distributed sleep/wake schedule scheme, where only the transmission node remains in the active state and the other nodes go to the sleep state.

2. Research background

Guofang Nan et al. [4] have proposed a distributed sleep/wake schedule scheme with guaranteed coverage. The main goal of this method is to extend the network lifetime while ensuring network coverage. Here, in this method, sensor nodes are divided into clusters based on sensing coverage criteria and allow more than one node in each cluster to be kept active at the same time through a dynamic node selection mechanism. The main advantage of this method is that it guarantees an effective way of saving energy in the network.

Sha Liu et al. [6] contributed to an energy-efficient sleep scheduling protocol called BSMac for sensor networks while maintaining high efficiency and low latency, which is based on a new architecture called BoostNet, which In that base station broadcasts critical planning coordination information using wide transmission range to reach all sensor nodes in one hop. The main contribution of this paper to the energy saving planning approach is that it conserves energy during the occurrence of the event and does not require any transmission by the sensors during the period of inactivity, and uses the high in-band transmission power from the base station for optimization. The network parameters are used without the need for a second transmitter and receiver in the sensor nodes.

Yan Wu et al., [7] have proposed an optimal sleep/wake schedule algorithm that satisfies a certain message recording probability threshold with minimal energy consumption. In this method, there is an inherent substitution relationship between energy consumption and message delivery performance. The advantage of this article is that the authors have developed an optimization problem whose purpose is to determine the threshold of the probability of recording in each hop so that the lifetime of the network is maximized.

Bo Jiang et al. [10] proposed an energy-aware sleep scheduling algorithm, called SSMTT, to support multi-target tracking sensor networks. SSMTT exploits the wake-up effect of interfering targets to save energy in hyperactive communication. Researchers have provided a solution that includes planning the sleep pattern of sensor nodes. The advantage of this method is that compared to handling multiple targets separately through single target tracking algorithms, it is possible to achieve better energy efficiency.

Chih-Min Chao et al., [11] proposed a quorum-based MAC protocol that enables sensor nodes to sleep longer under light loads. As the traffic flows towards the sink node in wireless sensor networks, a new concept, next hop group, is also proposed to reduce the transmission delay. The advantage of this presented method is that it reduces the energy loss because the nodes are kept awake only at a specific time. Also, when a method fails to adjust the sleep duration of a sensor node based on its traffic load, as a result, it causes lower energy efficiency or higher delay time, this method prevails. Also, sensors may be deployed in inconsistent environments and thus may fail unexpectedly.

3. Problem identification and proposed solution

In this paper, distributed sleep/wake scheduling with guaranteed coverage is the proposed method. Here, the cluster formation is formed from the previous work, that is, when an initiator node selects the energy information of the node and selects the cluster head that has the highest remaining energy. Through the guaranteed distributed sleep/wake schedule scheme, the energy of the entire cluster is compared, which provides a connection value for each cluster in order to communicate with the active nodes of other clusters. When the selected cluster head node receives the JREQ Joint Request message from the member nodes, it sends a JREP Joint Reply message back to the node. After that, if the remaining energy of the specific cluster head is greater than the given threshold value, only one node with a higher energy will be in the active state and the other nodes will be in the sleep state, and also the clusters with lower remaining energy will be in the inactive state. falls asleep Then the CH transmits the data to the well node. The advantage of the proposed format is based on the remaining energy of the cluster nodes, which is decided to be placed in the active mode or in the sleep mode, which will increase the lifetime of the network[19]

Cluster head selection

In selecting the cluster head, the node with the highest remaining energy is first selected as the cluster head to extend the lifetime of the network. In order to collect network information from the closest sensor nodes, initiator nodes are considered.

Assume that the sink node here has information about all the sensor nodes and their position in the network. The cluster head (CH) is determined based on the remaining energy of the nodes specified by the initiator nodes (I). In a network, CH uses more energy than other nodes. But the network performance degrades when the cluster head energy drops. To overcome this situation, the network energy consumption must be balanced by ensuring that the CH continues to change in a cluster depending on its remaining energy.

The process of choosing the cluster head in the network is done through the following steps

- Initiating node I broadcasts a request for energy (EREQ) message with its remaining energy level information (RLini) to its surrounding nodes.
- The sensor node Si compares its energy level (RLi) with the initiator
- •If RLi > RLini, then Si is an energy response message (EREP). he sends. Otherwise, Si waits for the cluster head advertisement message (CHADV).
- The initiator node (I) selects the cluster head with the maximum residual energy, and the initiator node is the node with the second maximum residual energy.
- The initiator node changes whenever the energy level of the node decreases
- •After the CH is selected by the initiator node (I), clusters are formed in the network.
- Nodes in the cluster send a CHADV to the CH, and the CH sends it along with the cluster ID to the well node
- •Joint JREQ request is transmitted by member node along with CHADV.

The transmission range is minimized because the initiator gathers energy information about the nearest sensors. A node with more energy than the initiator's energy level ensures the minimization of EREP message transmission.

When the selected cluster head node receives the JREQ message from the member node, it sends a joint response JREP message to the open node. Then the CH transmits the data to the node.

In Figure 1, initiators I1, I2, and I3 send EREQ energy requests to all surrounding nodes. For example, in this figure, when node I1 sends EREQ to nodes, the energy consumption of nodes is compared with I1. Since node 2 has a higher energy level than I1, and therefore node 2 is chosen as the cluster head, and node 4, which has the next highest energy level, is chosen as the next initiator for choosing the cluster head.

Likewise, when node I2 sends EREQ to nodes, the energy consumption of nodes is compared with I2. Here, node 9 has the highest energy level and is selected as the cluster head, and node 11, which has the next highest energy level, is selected as the next initiator for the cluster head. Then, when the I3 node sends EREQ to the surrounding nodes, the energy consumption of the nodes is compared with I3. Since node 22 has the highest energy level, it is selected as the cluster head and no other surrounding nodes have the next highest energy level than the initiator I3. Therefore, node I3 is selected as the next initiating node.

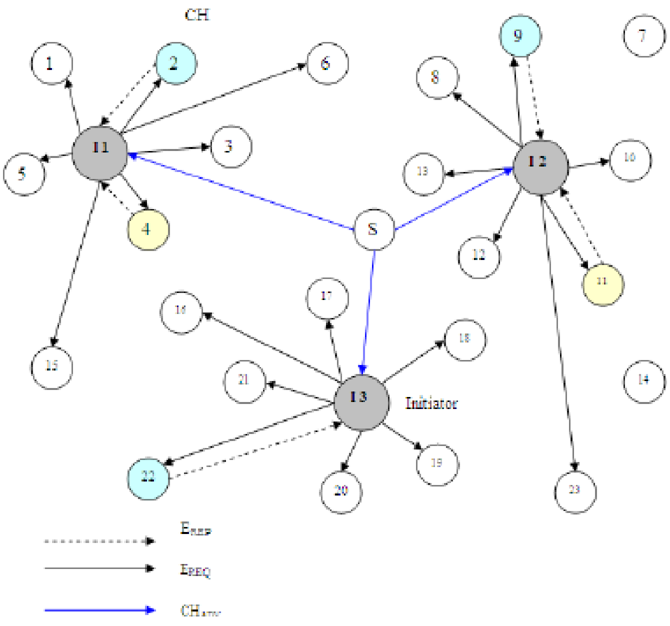


Figure 1- Selecting the cluster head

sleep/wake schedule

The sleep/wake schedule is an effective process in which the network energy is saved to the maximum extent. In the network, as soon as the cluster is formed, each cluster starts using the sleep/wake scheduling process. In order to save energy, only one or two nodes with the highest remaining energy in each cluster are required to be kept active, while the rest are kept in sleep mode[18]

At the beginning of this planning, all the nodes in the cluster will be active in order to analyze the remaining energies. This analysis is done to select an active node with the highest remaining energy in a cluster. And this active node will do the measurement work in a cluster. The node that will perform the measurement task is selected by the cluster head. The cluster head sends a task message to instruct the selected node to perform its task as an active node. And also the cluster head sends a sleep message to all the remaining nodes. When a certain task is completed, all nodes in sleep mode send a WORK_REQ to the cluster head to participate in node selection when the next round starts. While WORK_REQs are received from all sleeping nodes in the cluster, the head will execute the active node selection process[20,21]

Here, an initiator node sends an energy request (EREQ) to all clusters, and the clusters send an energy response (EREP) to the initiator node. Through this process, the initiator node collects the details of the remaining energy of all the clusters in the network. The energy of each cluster is compared with a standard threshold value which is fixed. If the initiator node finds any other cluster with residual energy less than a fixed standard threshold value, that particular cluster is sent to sleep mode until the particular transfer in the network is completed. Through this method, network energy is consumed in a limited manner.

In Figure 2, the initiator node in the network sends an energy request message to all the clusters in the network in order to know about the remaining energy. Then the entire cluster sends an energy response to the initiating node. With this method, the initiator node collects the remaining energy levels of the clusters. The initiator node compares the remaining energy of the cluster with a fixed standard threshold, if the energy of each cluster is less than the threshold value, that particular cluster is sent to sleep mode. For example, in the figure above, if the threshold value is 10 and the energy level of cluster 1 is considered equal to 12, cluster 2 is equal to 13, cluster 3 is equal to 11, and clusters 4 and 5 are respectively 5 and 6. Now, in this case after these values are collected by the initiating node, they are compared to the threshold. For this reason, it can be seen that only three clusters are transmitting data to the sink node, and the fourth and fifth clusters are sent to sleep mode.

At first, an initiator node randomly sends an energy request (EREQ) to all surrounding nodes to collect the remaining energy information of the node. The initiating node compares its energy with the energy of the node. If the energy of the node is more than the initiator node, then the sensor node (Si) sends an energy response (EREP) to the initiator node. In this way, a decision is made about the CH and this CH broadcasts CHADV to the sensor nodes. Each node sends a joint request (JREQ) to the CH, upon accepting this request, the CH sends a joint response (JREP) to the sensor nodes and thus the cluster is formed. In a cluster, CH selects a node with high residual energy and keeps that node in active mode and sends the remaining nodes to sleep mode. Then again the initiator node sends an EREQ to the cluster for its remaining energy and this energy will be compared with the threshold value. If the energy value is less than the threshold value, this particular cluster is sent to sleep mode. And finally, the transmission to the well node is done by the clusters in the network.

In a sensor network, consider some nodes such as the initiator node to collect the details of the remaining energy of the sensor nodes.

```
Initiator I1 selects cluster head based on energy level information.
For each neighboring Ni of I1, i=1,2....r
If RLi > RLini, then
Si sends an Energy Response (EREP) message.
otherwise
Si waits for Cluster Head Advertisement message (CHADV).
I1 selects node St as CH1 so that RLt = max {RLi} and i=1,2....r
CH1 sends a CHADV to Ni.
Each Ni node sends JREQ request to CH1
As soon as JREP is received from CH, Ni nodes join the cluster.
The cluster selects a node with high residual energy and keeps that node in active mode and sends the remaining nodes to sleep mode.
The initiator node I1 sends an energy request to the cluster if (cluster RL) > threshold value
The cluster will be in active state
otherwise
The cluster is put to sleep
Transfer data to the well node
 .The end
```

The components of the problem algorithm include the following.

Every genetic algorithm needs an initial solution or in other words n-code in order to start the algorithm. For this purpose, a chromosome string of the initial answer is randomly generated. Each chromosome has a number of genes or houses in which a number is placed. This step is perhaps the most difficult step of solving the problem by the algorithm method. Instead of working on the parameters or variables of the problem, the genetic algorithm deals with their coded form. Each initial answer contains a row that contains n+k-1 columns (n is the number of active nodes and k is the number of the cluster center). Numbers 1 to n indicate active nodes and numbers greater than n indicate clusters. In this research, the initial answer includes a chromosome with n+k-1 houses, which includes ordinal numbers between 1 and n+k-1.

House n+1 represents the first cluster and house n+I represents the i-th cluster. In this case, the numbers placed before the n+i-th house are the active nodes that are served by the i-th cluster. The active nodes that are located after the last house greater than the number n are assigned to the last cluster.

For the problem, there are propositions that can be considered as answers, either true or false. We call these propositions possible answers. In this problem, according to the number of the initial population, the answer is generated and placed in each line, for example, if the population is 50, then 50 answers of the algorithm presented in the previous step are generated and placed in line one to line 50 of the initial population.

An evaluation function is needed to evaluate the answer. The purpose of writing the evaluation function is to obtain the total costs and check the limitations. The fitness function is obtained by applying the appropriate transformation on the objective function, that is, the function that is supposed to be optimized. This function evaluates each string with a numerical value that determines its quality. The higher the quality of the answer string, the higher the value of the answer, and the probability of participation in the production of the next generation will also increase. If the desired answer does not comply with the desired restrictions. The purpose of raising the evaluation function is to find the cost amount and check the problem's limitations.

After the fitness value was calculated for each chromosome of the population. We randomly select two chromosomes and select the one with a better fitting value as the parent. We select the second parent in the same way and then we continue this work until the population size minus one.

Elitism is the name of the method in which the best chromosomes are preserved and directly transmitted to the next generation. which increases the speed of the genetic algorithm. Therefore, in each stage, the best answer of the previous stage will go directly to the next stage. In order to perform the intersection operation, two parents are first created by the tournament function. Through the crossing of two parents, it will become a child and enter a new population. In order to create new children, we have used the two-point crossover operator in such a way that the two parents in the previous section are selected first. Then two intersection points are randomly selected, the genes between these two points in the first parent are transferred to the first offspring, and the remaining genes in the second parent are copied in the first offspring.

After implementing the intersection operator, each child may change randomly. Shift mutation operator is used in line one. In this method, there are two types of mutation genetic operators in this research. In the first and third lines, the Swap move operator is used, choose two cutting points randomly. Reverse the numbers inside the genes between these two points. In this way, a random number is generated, if this number is lower than the mutation rate, the mutation will occur. In this method, in the first step, a random number between zero and one is selected. If the random number is lower than the mutation rate, two points are randomly selected on the parent and the numbers in these points are exchanged.

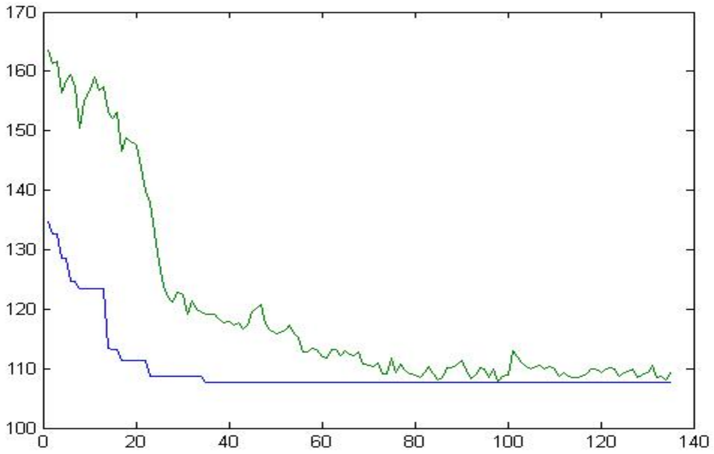
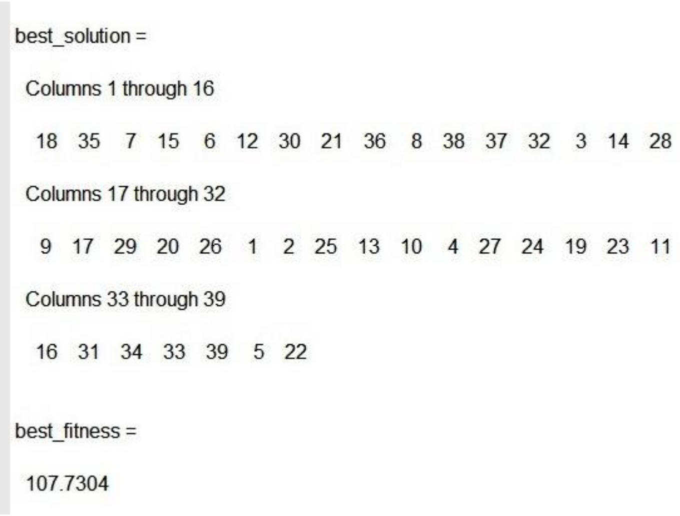


Figure 2. Answer process diagram



```
best_solution =

 Columns 1 through 16

  18   35    7   15    6   12   30   21   36    8   38   37   32    3   14   28

 Columns 17 through 32

   9   17   29   20   26    1    2   25   13   10    4   27   24   19   23   11

 Columns 33 through 39

  16   31   34   33   39    5   22


best_fitness =

 107.7304
```

Figure 3. is an example of the answer

Simulation results

Cluster based sleep/wake scheduling technique (CBSST) is evaluated through NS2 simulation. A random network located in an area of 500 x 500 meters is considered. At first, 100 sensor nodes in the square grid area are replaced by placing each sensor in a 50x50 grid cell. 10 cluster heads are deployed in the network area based on our protocol. It is assumed that the well is located 100 meters away from the area marked above. In the simulation, the channel capacity of mobile hosts is set at the same value of 2 Mbps. CBR simulation traffic is with UDP source and sink. The number of resources in each cluster varies from 1 to 4.

Table 1- Simulation parameters

Number of nodes	100
Mac	802.11
Routing protocol	EEMD
Simulation time	50 sec
Traffic source	CBR
package size	512 bytes
rate	100 to 300kb
Transmission range	150m
Number of clusters	1 to 4
power transfer	0.395 w
get power	0.660 w
Standby power	0.035 w

Primary energy	7.1 Joules
Number of clusters	10

Performance Criteria

CBSST performance method is compared with EEMD technique. They are mainly examined according to the following criteria.

- Average end-to-end delay: The end-to-end delay is averaged from all the remaining data packets from the destination sources.
- Average packet delivery ratio: This ratio is the number of successfully received packets and the total number of transmitted packets.
- Energy: average energy used for data transmission
- Drop: The number of dropped packets is reduced during data transmission

Results

A- Based on the rate

Transfer rates are varied as 250, 100, 150, 200, and 300 Kb for CBR traffic, and performance metrics are evaluated.

Figures 3-6 show the results for delay, packet delivery ratio, packet drop and energy consumption, respectively, for both EEMD and CBSST techniques, when the rate increases. According to the results, it can be seen that CBSST has a better performance than EEMD.

B- cluster-based

The number of clusters are different as 1, 2, 3 and 4 and the performance criteria are evaluated.

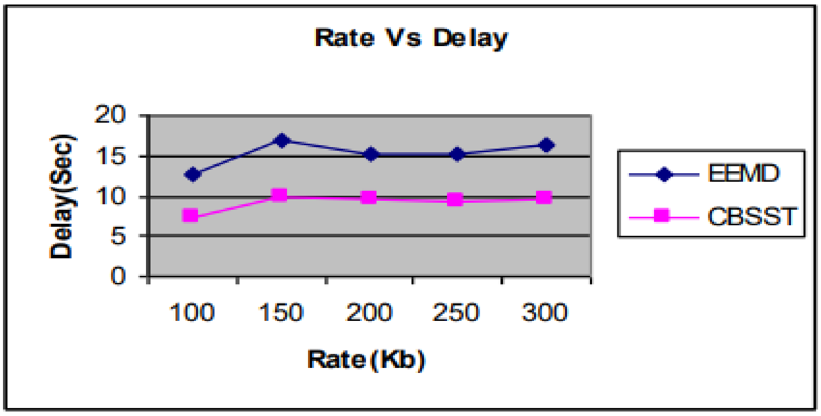


Figure 4- Speed versus delay

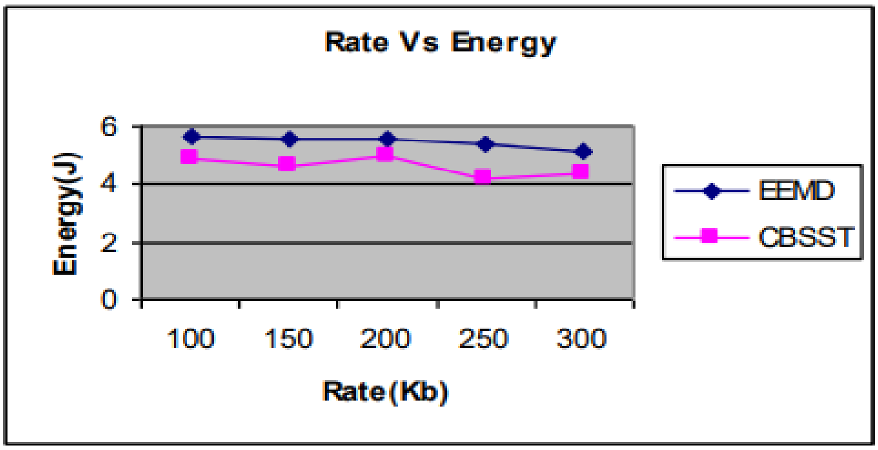


Figure 5- Speed versus energy

The results show the delay, packet delivery ratio, packet drop and energy consumption, respectively, for both EEMD and CBSST techniques when the number of clusters increases. From the results, it can be seen that CBSST has a better performance than EEMD.

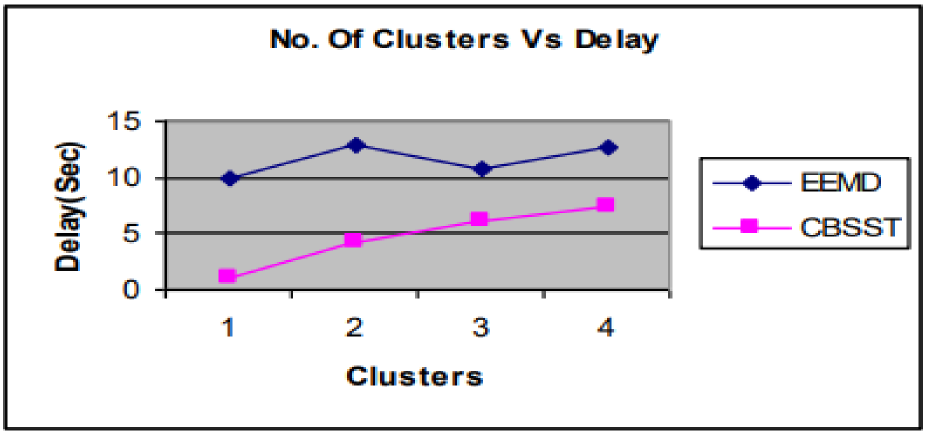


Figure 6- Clusters versus delay

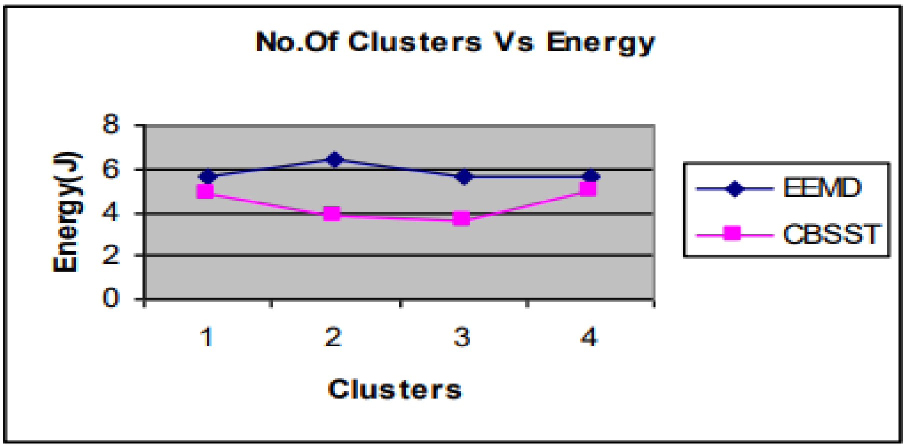


Figure 7- Clusters versus energy

4. Conclusion

Network lifetime remains as a significant requirement in Wireless Sensor Network (WSN) exploited to prolong network processing. Deployment of low power sensor nodes in WSN is essential to utilize the energy efficiently. Clustering and sleep scheduling are the two major processes involved in improving network lifetime. However, abrupt and energy unaware selection of cluster head (CH) is non-optimal in WSN which reflects in the drop of energy among sensor nodes. Initially, all sensor nodes have the same amount of energy and they stop working when their batteries are exhausted. The network lifetime depends on the coverage rate of the sensing area. Thus, the simulations are running until the coverage rate falls below a certain threshold. In this case, the network fails to accomplish its missions. A large number of practical sensing and actuating appli- cations require immediate notication of rare but urgent events and also fast delivery of time sensitive actuation com- mands. In this paper, we consider the design of ecien t wakeup scheduling schemes for energy constrained sensor nodes that adhere to the bidirectional end-to-end delay con- straints posed by such applications. We evaluate several existing scheduling schemes and propose novel scheduling methods that outperform existing ones. We also present a new family of wakeup methods, called multi-parent schemes, which take a cross-layer approach where multiple routes for transfer of messages and wakeup schedules for various nodes are crafted in synergy to increase longevity while reduc- ing message delivery latencies. We analyze the power-delay and lifetime-latency tradeos for several wakeup methods and show that our proposed techniques signican tly improve the performance and allow for much longer network lifetime while satisfying the latency constraints.

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