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Energy Efficient Sleep-Scheduling for Cluster Based Aggregation in Wireless Sensor Network

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Abstract: Due to vast application of wireless sensor network, it has gained popularity among its researcher. The sensors in WSN generate data while it monitors its surrounding area, they perform the data gathering and transmission to the sink node. However, the key challenge is to schedule the node activities for transmission of the data by maintaining the energy consumption. In order to overcome this issue, a cluster based scheduling in WSN is proposed. An energy efficient wake up scheduling algorithm is proposed that support the high data rate transmission and reduces the energy consumption. In this technique, each node wake up only twice that is, once to receive the data from neighbor node and next time to transmit data to sink node. Also, to a Probability-based Prediction and Sleep Scheduling (PPSS) protocol is used to lessen the amount of energy consumption. This is achieved by reducing the number of awakened node in the target vicinity.

Key words: WSN, node, awakened, transmission, protocol

INTRODUCTION

WSN: Wireless Sensor Network (WSN) is a collection of sensor nodes interconnected by wireless communication channels. Each sensor node is a small device that can collect data from its surrounding area, carry out simple computations andcommunicate with other sensors or with the Base Station (BS). Wireless Sensor Networks (WSN) has several sensors enable nodes which are distributed in an environment and use batteries as energy resource. These tiny sensor nodes have sensing, data processing andcommunicating components (Anisi *et al*., 2011). Wireless Sensor Networks (WSN) is used for crucial applications such as environmental monitoring, Habitat monitoring, battlefield surveillance, nuclear, chemical and biological attack detection (Gandhi *et al*., 2008).

Cluster based scheduling in WSN: Wireless Networks cluster is a group of nodes which is generally considered to be a scalable method to manage large sensor networks and each cluster consists of a single Cluster Head (CH). The network sensors nodes can be managed locally by a cluster head in a cluster. Here a node elected to coordinate the nodes within the cluster and to be responsible for communication between the cluster and the base station or other cluster heads. Clusters provide a convenient framework for resource management, data fusion andlocal decision making (Sasikala and Chandrasekar, 2013).

A fixed or adaptive approach may be used for cluster maintenance. In a fixed maintenance scheme, cluster membership does not change over time. In an adaptive clustering scheme, nodes may change their associations with different clusters over time (Deng *et al*., 2005). In WSNs, a scheduling has been adopted for energy efficiency and conservation, since each sensor node is typically equipped with a battery (Wu *et al*., 2010).

In sleep scheduling method, sender nodes should wait until receiver nodes are active and ready to receive the message. Sleep scheduling should increase the network life time. But sometimes it may increase broadcasting delay. Most of sleep scheduling methods focuses to minimize the energy consumption. To minimize the broadcasting delay in WSN, the time wasted for waiting during the broadcasting needs to be minimized. So there is a need for balance both energy consumption and broadcasting delay in wireless sensor network. The destination node wakes up immediately when the source nodes obtain the broadcasting packets (Baby and Jacob, 2013).

Rotating active and inactive sensors in the cluster, some of which provide redundant data is one way that sensors can be intelligently managed to extend network lifetime. Some researchers even suggest putting

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redundant sensor nodes into the network and allowing the extra sensors to sleep to extend network lifetime (Wu *et al*., 2010). If two neighboring clusters are not densely connected, they cannot be merged into a larger one. A cluster which broadcasts a merging request would not accept a merging request from other clusters so the cluster should send a message to the other cluster otherwise it may lead to the time consumption. In a sensor network, a scheduling protocol must determine a transmission schedule for each packet otherwise collisions may take place. Time consumption can be more since the transmitted data packets visits all nodes which comes in the way and it will wait till the reception process is completed. When the sensor nodes are divided into multiple clusters only a few sensors are selected from different clusters to be in active status, if this repeats and the same nodes are kept inactive maximum times, then it may cause problem to the network in the future (Sasikala and Chandrasekar, 2013). However, the node scheduling leads to the following problem: which nodes are to be selected to put into sleep in a round, so that functional lifetime of the network extends, without affecting network coverage and connectivity (Paul and Sao, 2011).

Literature review: Wu *et al*. (2010) have proposed efficient centralized and distributed scheduling algorithms to reduce the energy cost and removing the unnecessary listening cost for state switching and clock synchronization. Every node needs wake up time at twice in one scheduling period, one for receiving data from its children and one for sending data to its parent. Also it proposed an efficient method to construct energy-efficient data gathering tree, whose energy cost and time span of the scheduling are both within constants times of the optimum. Zhao *et al*. (2012) have presented a novel sleep-scheduling technique called Virtual Backbone Scheduling (VBS). VBS formed multiple overlapped backbones which work alternatively to prolong the network lifetime. In VBS, traffic was forwarded by backbone sensor nodes andthe rest of the sensor nodes turn off their radios to save energy. The rotation of multiple backbones constructs sure that the energy consumption of all sensor nodes is balanced, which fully utilized the energy and achieves a longer network lifetime. The scheduling problem of VBS is formulated as the Maximum Lifetime Backbone Scheduling (MLBS) problem. To avoid NP-hard problem in MLBS, this proposed an algorithms based on the Schedule Transition Graph (STG) and Virtual Scheduling Graph (VSG). Also this presented an Iterative Local Replacement (ILR) scheme as a distributed implementation.

BoJiang have proposed a Probability-based Prediction and Sleep Scheduling protocol (PPSS) to improve energy efficiency of proactive wake up. It designed a target prediction method based on both kinematics and probability. Based on this prediction results, PPSS selected the nodes to awaken and reduced their active time, so as to enhance energy efficiency with limited tracking performance loss. It evaluated the efficiency of PPSS with both simulation-based and implementation-based experiments. However, the optimization is difficult for PPSS, because it cannot cover special cases such as the target movement with abrupt direction changes.

Avril *et al*. (2014) have presented a paper for scheduling sleeping/running mode of each sensor in a 1-hop clustered WSN, in order to minimize the time spent in running mode andto efficiently avoid collisions. In a 1-hop cluster, communications can be easily managed. It proposed a correct schedule of the discussion over the different clusters that avoid collisions on sensors belonging to several clusters. It constructs a communication ring over the sensors network. Also it proposed to use ring communication architecture so there is only one sensor that sends data at a time andonly one other sensor that is receiving them. Xu *et al*. (2013) have projected a delay-efficient data aggregation scheduling in wireless sensor networks subject to Signal to Interference-plus Noise Ratio (SINR) constraints. The scheme constructed a routing tree and proposed two scheduling algorithms that can generate collision-free link schedules for data aggregation. In wireless nodes plane, each node contained some data to report the objective of design routing and a node transmission schedule for data aggregation with SINR constraints. The proposed algorithms are asymptotically optimum on delay in random wireless sensor networks. But it does not guarantee the optimum performance to design efficient data aggregation method.

Lee and Lee (2012) have proposed an Ant-Colony-Based Scheduling Algorithm (ACB-SA) to solve the Efficient-Energy Coverage (EEC) problem. Also, use the probability sensor detection model and apply this proposed algorithm to a heterogeneous sensor set, which represents a more realistic approach to solving the EEC problem. It proposed a solution to the EEC problem under real-number space, which used real numbers as position values for the sensors and the Point of Interests (PoI). This intensity of this energy is exponentially attenuated with the distance between the PoI and the measuring sensor.

Nasser *et al*. (2013) have proposed a Dynamic Multilevel Priority (DMP) packet scheduling scheme in which each node, except those at the last level of the virtual hierarchy in the zone based topology of WSN has three levels of priority queues. Real-time packets are placed into the highest-priority queue and can prevent data packets in other queues. Non-real-time packets are placed into two other queues based on a certain threshold of their expected processing time. Leaf nodes had two queues for real-time and non-real-time data packets since they do not receive data from other nodes and thus, reduce end-to-end delay. However, if a real-time task holds the resources for a longer period of time, other tasks need to wait for an undefined period time, causing the occurrence of a deadlock. This deadlock situation degrades the performance of task scheduling schemes in terms of end-to-end delay.

MATERIALS AND METHODS

Proposed solution: In our previous research Jothi and Chandrasekaran (2014) fuzzy based optimal clustering protocol is proposed for maximizing lifetime in WSN. Here, at first a number of provisional cluster heads are elected in a random manner. The information collected from the neighbor nodes is fuzzified using fuzzy logic technique and appropriate cluster head and size are estimated. The cluster heads are updated based on uninterrupted operational mechanism of each cluster head.

As an extension to this work, we propose to develop a power aware scheduling algorithm for cluster based data aggregation.

Overview: To support the highest data rate and reduce the energy consumption the wake-up scheduling of TDMA as the MAC layer (Wu *et al*., 2010) is used. For energy efficient scheduling at each timeslot each node wakes up at most twice only: once for receiving data from neighbor node and once for sending data to BS. When BS wakes up it will listen for the message SYN and reply a message ACK if it gets correct ACK, the sender starts sending data. Furthermore to reduce the energy, the awakened node reduction Probability-based Prediction and Sleep Scheduling (PPSS) protocol is used. To achieve target of nodes at low probability and out of transmission range it will limit the number of awakened nodes within an awake region. Here choosing of awakened node based on the probability that moving directions of target. The awake regions scope is determined based on the distance of an awakened node from the alarm node. Figure 1 represents the proposed block diagram. In our proposed technique, energy efficient wake up scheduling algorithm is used. To achieve this, an efficient allocation of time slot in different state is done to avoid wastage of energy consumption.

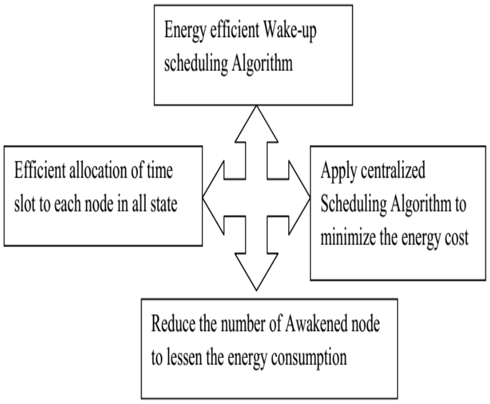

Fig. 1: Represents the proposed block diagram. In our proposed technique, energy

Moreover, centralized scheduling algorithm helps to reduce the total energy cost. Also, the number of awakened node is reduced to decrease the energy consumption.

Energy efficient wake-up scheduling algorithm: This section describes about the energy efficient wake up scheduling algorithm that reduces energy consumption and enhances data rate. A scheduling of activities for all nodes is to allocate each time slot $1 \leq t \leq T$ to one of the following four states:

- Transmitting
- Receiving
- Listening
- Sleeping

As, we are using TDMA, hence no nodes need to stay in listening states, in case all nodes are absolutely synchronized. In case, the synchronization is required, nodes can also have added state listening to allow adjacent node to synchronize their activities as shown in Fig.2 for illustration. In this technique, it is assumed that the sender node use a short preamble to synchronize the receiving node (as similar to X-MAC). In other word, it can be explained that when a sender wakes up, it transmits a message SYN(it contains its address and receiver's address and time slot required for sending data) and then it listen for ACK message from the receiver node. Once, receiver wakes up (after a state switch time denoted as SW), then it listen for the message SYN and reply a message ACK in case it gets one completed SYN message. After receiving the correct ACK message, the sender starts transmitting data.

For example, for a node n_i, in case it is scheduled to transmit at time slot t which is denoted as $U_{i,S,t} = 1$ be

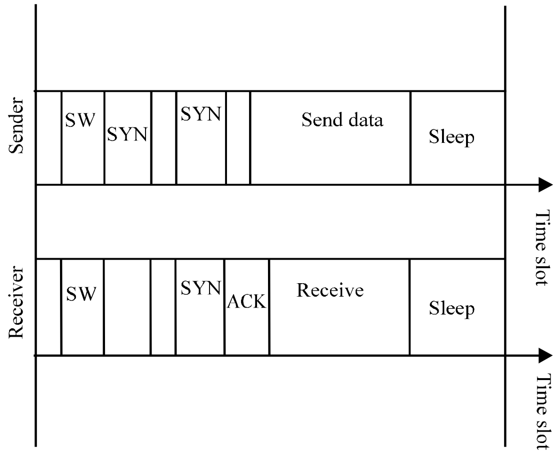

Fig. 2: Represents synchronization activity between two nodes

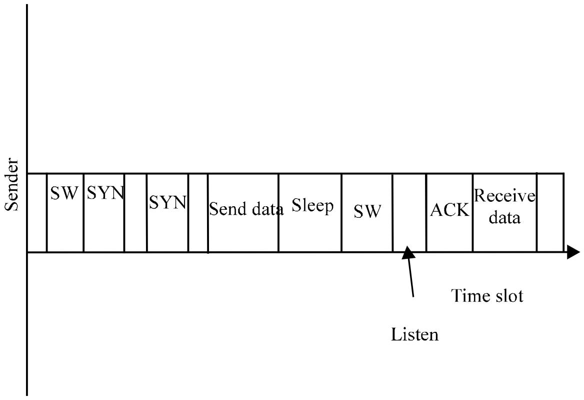

Fig. 3: Represents time slot allocated for sensor in one period

denoted as $U_{i,S,t} = 1$. Also, variables $U_{i,Rt}\in\{0, 1\}$, $U_{i,Pt}\in\{0, 1\}$ and $U_{i,Lt}\in\{0, 1\}$ to represent whether the node n_i is scheduled to receive, sleep or listen at time slot t or not respectively. Moreover, $V_{P,S}$, $V_{P,R}$, or $V_{P,L}$ represents energy consumed by transition state as shown in Table 1 for notation used. Generally, the energy consumed from an active state (like transmitting, receiving and listening) to an idle state (deep sleeping or sleeping) is frequently ignored. The time allocation for each sensor node for one period is shown in Fig. 3. It is important to note that energy cost by a node n_i in all state is denoted as:

$$\sum_{t=1}^{T}(U_{i,S,t}\times P_{tu}+U_{i,R,t}\times P_{rcv}+U_{i,L,t}\times P_{Lst}+U_{i,P,t}\times P_{slp})\times t_s$$

The energy cost for state transition is given as:

Table 1: Energy consumed by transition state

Symbol	Meaning
$U_{i,S,t}$	Indicator whether node n_i transmitting at time t
$U_{i,R,t}$	Indicator whether node n_i receiving at time t
$U_{i,P,t}$	Indicator whether node n_i sleeping at time t
$U_{i,L,t}$	Indicator whether node n_i listening at time t
$V_{P,S}$	Energy consumption from sleeping to transmitting
$V_{P,R}$	Energy consumption from sleeping to receiving
$V_{P,L}$	Energy consumption from sleeping to listening

$$\sum_{t=1}^{T}(X_{i,P,t}\times X_{i,S,t+1}\times V_{P,S}+X_{i,P,t}\cdot X_{i,R,t+1}\times V_{P,R}+X_{i,P,t}\times X_{i,L,t+1}\times V_{P,L})$$

where, T+1 is treated as 1. The main goal of a schedule is to minimize the summation of these two energy costs.

Centralized scheduling algorithm: This section describes about the centralized scheduling algorithm. The traditional scheduling algorithm is unable to minimize the energy cost of each sensor node as some sensor node wake up for multiple times in a scheduling period T. The proposed centralized scheduling algorithm reduces the energy cost. To achieve this, the activities of a subset of sensors are scheduled in one bundle. Let $I_T(n_i)$ represents the set of children nodes of node n_i in data gathering tree. Then, it can be said that $I_T(n_i)$ comprises of virtual cluster V_i. For each cluster V_i we define its weight as:

$$X_i = \sum_{n_j\in I_T(n_i)} x_j$$

Hence, $X_i = \sum_{nj\in IT}(n_i)$ represents the total number of timeslots that node n_i should wake up to receive the data from its children in data gathering tree G.

In spite of scheduling the transmitting time slot for each and every child node of node n_i, a chunk of consecutive X_i time slot is scheduled to the cluster V_i of these children node. After that each child n_j is allocated a consecutive x_j time slot from this chunk. Then all children will transmit their data in this period and the parent will receive the data at same time. Hence, energy consumption due to state transition is certainly saved as each node needs only to wake up twice: once for receiving all data from its children node and once while transmitting its data to its own parent.

The cluster is scheduled in the decreasing order of their weight. In order to schedule a cluster v_i, first-fit approach is used. The chunk of time slots scheduled to sensors in V_i is the earliest consecutive X_i time slot such that it will not have any interference with scheduled conflicting clusters. Hence, the proposed schedule assures that it will cause any interference for the transmission of any sensors in V_i.

The algorithm is defined as:

```
For each sensor $n_i$ do
Compute its receiving weight $X_i = \sum_{nj\in IT}(n_i)$
Sort sensor in decreasing order of weight $X_i$
For I =1-n do
Allocate cluster $V_i$ (equally sensor node $n_i$ for receiving) earliest available time slots for transmitting that will not overlap with time slots allocated to conflicting clusters.
Each sensor node $n_j$ in $V_i$ will be consequently allocated $x_j$ consecutive time slots for transmitting
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It is important to notice that two conflicting cluster can be scheduled together. For example, consider that $V_1 = \{m_1, m_2\}$ and $V_1 = \{m_3, m_4\}$ and each sensor node requires $x_i = 2$ time slots for transmission. Also, consider that only one pair of nodes m_1 and m_3 cannot be scheduled simultaneously. Then following schedule is considered as valid:

- Node m_1 uses time slot 1, 2
- Node m_2 uses time slots 3, 4
- Node m_3 uses time slot 3, 4
- Node m_4 uses time slots 1, 2

Awakened node reduction: The number of awakened node is reduced by applying two efforts:

- Controlling the scope of awake region
- Selecting a subset of nodes in an awake region

In general, a sensor node's transmission range Y is far longer than its sensing range y. Hence, when the nodes are densely deployed to assure about the sensing coverage, a broadcasts alarm message accomplish all the neighbors within the transmission range. Still, some of the neighbor can only detect the target with a relatively low probability andsome they never detect the target. Hence, the energy consumed to be in active state by these nodes will be wasted. To prevent this waste, an effective technique is used to determine a subset among all the neighbor nodes in order to reduce the number of awakened nodes. During sleep delay phase, the target may move far away from the alarm node for a particular distance. Hence, it is clear that it is needless for nodes within distance to wake up, as the target has already passed by. In the meantime, all the nodes in an awake region must be in the one-hop transmission range of the alarm node. Hence, an awake region must be in a ring shaped, i.e., the part between two concentric circles.

Moreover, the number of awakened node can be further reduced by selecting only some nodes in the awake region as awakened nodes. By selecting an awakened node based on a probability related to moving direction, awakened node can be lessened considerably.

Constrain awake region scope

Consideration: Let q be the distance of wakened node from the alarm node. Consider that the target node's position is exactly same as alarm node's position in order to simplify the calculation. The step involved in the proposed technique to control the awake region can be explained as:

Compute an awake region's scope by determining the value scope of q
The target then move by D_{n+1}, during sleep delay LD
If $q \geq \eta D_{n+1}$ is set, then probability that awakened node is unable to cover the target after a sleep delay is>(1-68%)/2 = 16%
Also, $q \leq Y$ as nodes outside of the alarm node's transmission range cannot be awakened
Determine the scope of an awake region as below:
$\{\eta D_{n+1}-\tau D_{n+1}, 0\} \leq q \leq D$
The number of nodes in an awake region can be obtained as:$\sigma\pi[Y^2-\max\{\eta D_{n+1}-\tau D_{n+1}, 0\}^2]$ where σ is the node density

Selection of awakened nodes: For the estimation of an awake region's scope, target's scalar speed is considered. It is observed that the decrement percentage of the number of awakened node can be obtained as:

$$\frac{\max\{\eta D_{n+1}-\tau D_{n+1},0\}^2}{Y^2}$$

For example, 6.25% if $Y = 60$, $\eta D_{n+1} = 20$ and $\tau D_{n+1} = 5$ which is not considerable for enhancing energy efficiency. The main goal of proposed scheme is to reduce the number of awakened node by considering the prediction result based on moving direction of awakened node in order to save the energy consumption. It is observed that the probability of a target moving along the direction of $\vec{D}$ (i.e.,$Z[\theta_{n+1}]$) represented asα is the highest andthis makes all the node in this direction to be awakened. Since, $[\theta_{n+1}]$ decreases on other direction, therefore the number of awakened node on those direction can be reduced. Hence, the probability that a candidate node on the direction $\alpha+\delta$ reschedules its sleep pattern or becomes an awakened node can be given as:

$$B_{cc}(\delta) = \frac{f_{\Delta_{n+1}}(d)}{f_{\Delta_{n+1}}(0)} = \begin{cases} -\frac{1}{b}\delta+1 & (\delta^3 0) \\ \frac{1}{b}\delta+1 & (\delta<0) \end{cases}$$

where, 'cc' represents the sleeping scheduling. Therefore, total number of awakened node in an awake region will be:

$$N = \int_{-\pi}^{\pi} B_{cc}(\delta) \times \frac{\sigma\pi(Y^2\text{-}\max\{\eta D_{n+1}\text{-}\tau D_{n+1},0\}^2)}{2p} d\delta$$

$$= \sigma(Y^2\text{-}\max\{\eta D_{n+1}\text{-}\tau D_{n+1},0\}^2) \times \int_{0}^{\pi} (-\frac{1}{b}\delta+1) d\delta$$

$$= \frac{\sqrt{6}}{2} \sigma\tau_{n+1}(Y^2\text{-}\max\{\eta D_{n+1}\text{-}\tau D_{n+1},0\}^2))$$

For example, the number of nodes according to the proposed technique is only 19% based on of that of circle scheme, when $Y = 60$, $\eta D_{n+1} = 20$, $\tau D_{n+1} = 5$ and $\tau D_{n+1} = \pi/6$. In other word, the energy consumption of proposed scheme is only 19 percent of that of circle technique.

The Overall Algorithm

```
// Energy Efficient Scheduling Algorithm//
Allocation of time slot to each node
When node wakes up, it transmits a SYN message and listen for ACK message from receiver
When receiver wakes up it listen SYN message and reply a message ACK
If one SYN message is completed, the sender starts transmitting data.
// centralized scheduling algorithm//
For each sensor do
Compute its receiving weight
Sort sensor in decreasing order of weight
For I = 1-n do
Allocate cluster (equally sensor node for receiving) earliest available time slots for transmitting that will not overlap with time slots allocated to conflicting clusters.
Each sensor node in will be consequently allocated consecutive time slots for transmitting
// Awakened Node Reduction//
//Controlling Scope awake region//
If $q \geq \eta D_{n+1}\text{-}\tau D_{n+1}$
Then probability that awakened node is unable to cover the target after a sleep delay is>(1-68%)/2 = 16%
Number of nodes in awake region is $\sigma\pi[Y^2\text{-}\max\{\eta D_{n+1}\text{-}\tau D_{n+1}, 0\}^2$
// Selection of awakened node//
Find the probability that a candidate nodes become an wakened node
Then reduce the number of awakened node based on the direction of movement in an awake region
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RESULTS AND DISCUSSION

Simulation model and parameters: The Network Simulator (NS-2) (Jiang *et al*., 2013) is used to simulate the proposed technique. In the simulation, 50 mobile nodes move in a 500 meter×500 mr region for 50 sec of simulation time. All nodes have the same transmission range of 40 meters. The simulated traffic is Constant Bit Rate (CBR). The proposed Energy Efficient Sleep-scheduling for Cluster Based Aggregation (EESCBA) technique is compared with the Energy Efficient Centralized Scheduler (EECS) (Jothi and Chandrasekaran, 2014). The performance metrics delay, packet delivery ratio, packet drop and average residual energy are evaluated. The simulation settings and parameters are summarized in Table 2. The number of nodes is varied from 25-75 and the results depicted in Fig. 4-7. From Fig. 4-7, it can be seen that EESSCBA outperforms

Table 2: Simulation sJanuary 6, 2017ettings

Variables	Values
No. Of nodes	25,50,75 and 100
Area size	500×500
Mac	IEEE 802.11
Transmission range	250 m
Simulation time	50 sec
Traffic source	CBR
Packet size	512
Initial energy	10.3 j
Receiving power	0.395
Transmission power	0.660
Rate	250 kb

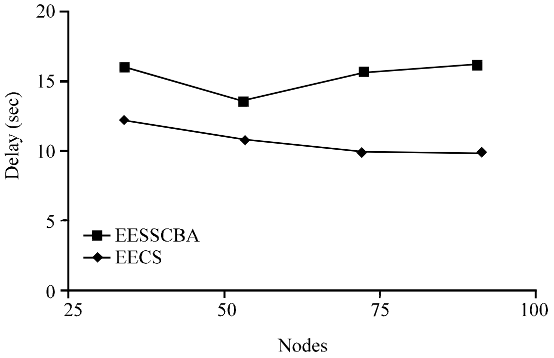

Fig. 4: Nodes vs delay

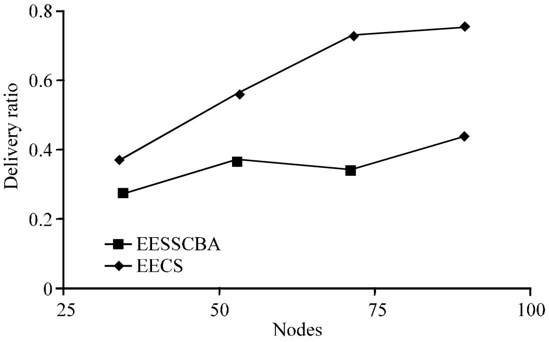

Fig. 5: Nodws vs delivery ratio

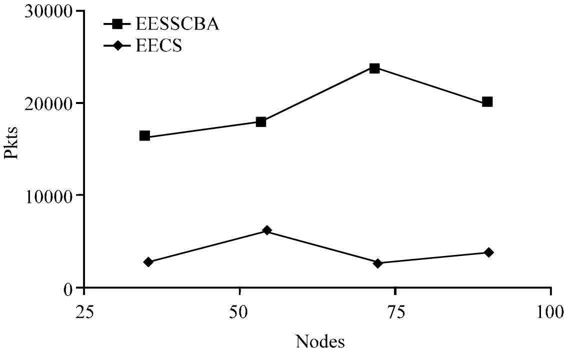

Fig. 6: Nodes vs drop

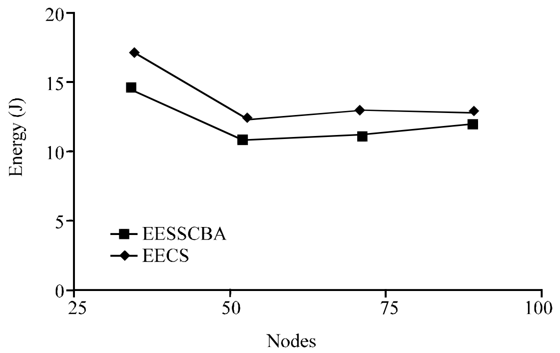

Fig. 7: Nodes vs residual energy

EECS in terms of delay by 30%, delivery ratio by 38%, packet drop by 80% and residual energy by 11%.

CONCLUSION

In this researcher, we have proposed a cluster based Scheduling in WSN. An energy efficient wake up scheduling algorithm is considered that supports the high data rate transmission and reduces the energy consumption. In this technique, an efficient time allocation is done for all the states of scheduling activity, to maintain the synchronization between the nodes. Here, each node wake up only twice, that is, once to receive the data from neighbor node and next time to transmit data to sink node. Also, to reduce the total energy consumption, Probability-based Prediction and Sleep Scheduling (PPSS) protocol is used. The protocol reduces a considerable amount of energy consumption.

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