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Energy Efficient Synchronization Scheme Using Heterogeneity with Mobile Sink in WSN

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Abstract: ***The energy of the sensor nodes in the Wireless Sensor Networks (WSNs) is a limited resource and causes the fluctuation in the lifetime of the network. Also, the throughput and delay of the network depend on how long the network sustains i.e. energy consumption of the network. One way to increase the feasibility of network is the introduction of heterogeneous nodes regarding energy, and the other is to synchronize the local clock of the member node with the global clock of the cluster head and the sink in the network. Earlier, a typical WSN was composed of static sensor nodes and a static sink placed inside the observed region. In such a setup, the major energy consumer is the communication module of each node. In practice, multi-hop communication is required for sending data from sources to sink nodes. Consequently, the energy consumption depends on the communication distance. So in this paper Sink mobility is introduced along with the node heterogeneity based synchronization scheme in order to reduce the energy consumption of the network and hence increasing the lifetime of the network as compared to the existing Node Heterogeneity aware Energy Efficient Synchronization Algorithm (NHES).***

Keywords: ***heterogeneity, sustainability, static sink,mobile sink.***

I. INTRODUCTION

Time and clock synchronization are two substantial services for the collective and organized operations in WSNs. Time synchronization in the WSN is mainly contrived by low-cost clocks, frequent topological changes, error sources during communication, node failures, static sink and the resource constraint attribute of the nodes. For instance, network protocols such as time division multiple access (TDMA) surely demands synchronization among sensor nodes. The unsynchronized clocks in the network take more time to send the packet to sink and hence consumes more amount of energy. Due to static sink the distance between nodes and sink is more which results in more energy consumption in data transmission.

The nodes used in the formation of the network are supplied with limited amount of energy, and cannot sustain for a long time. Also, some part of node energy is utilized in the synchronization of activities of the nodes. To increase the lifetime and solve the problem, some percentage of the nodes with varying energy are added to the network and sink is also made movable in order to reduce average energy consumption. The energy consumption of the synchronization algorithm is minimized by matching the global clock of the sink and the local clock of the node[1,2].

The activities of the node are arranged according to the time frame, and all the slots are synchronized with the global clock of the network. The unusable network conditions and constraint resources of WSN make it imperative to develop a time and clock synchronized protocol that can sustain the network long time with reduced energy consumption. The spanning tree mechanism used operates level by level reducing the multi-hop communication restricting the requirement of large network bandwidth. The improper scheduling and synchronization of the packets generated from the lower layer of the network to the upper layer cause more energy consumption. Also, retransmission delay is caused due to the variation in the clock skews and improper slot allocation to transfer the aggregated packets. The efficient way to reduce the retransmission delay is scheduling MAC protocol to manage the time slots of nodes and cluster head (CH) with global time scale. The data propagation from node to sink may be in one–hop or multi-hop, it depends on the depth of the spanning tree formed in intra and inter-cluster communication. The packet scheduling activities of the nodes are dependent on the availability of the channel, at least, equal to the synchronization time [2]. The neighboring node will synchronize their schedules periodically to prevent long term clock drift.

The paper focuses on a hybrid approach to minimize the energy consumption with increased throughput, hence bandwidth utilization and reduced delay with the controlled mobility of the sink. The nodes used are heterogeneous in terms of energy which helps to increase the network lifetime. It considers clustered architecture with the spanning tree in the presence of non-ideal clocks.

The result shows that introduction of mobile sink (NHES-MS) gives better results than the static sink used in NHES algorithm. The remaining part of the paper progresses with different sections as; Section II focuses on the present work related to synchronization and scheduling algorithms. Section III presents the required assumptions and network model. Section IV briefs about the NHES-MS. Section V discusses simulation setup and results, and Section VI conclusion along with the future scope.

II. RELATED WORK

This section explores the idea how one can use TDMA technique for scheduling and synchronization technique to improve the QoS. [2] Considers the spanning tree mechanism to improve the energy consumption as compared with TPSN. It shows the reduced sync errors. [3] Defines a time synchronization protocol based on spanning tree. A spanning tree formed by the nodes and is divided into multiple sub-trees. The sub-tree synchronization process helps to match the clock time within the level. It minimizes the clock adjustment time and hence reduce the dealy in the network.

In [4] Clustered Time Synchronization algorithm and energy model is presented, that reduces the energy consumption beside accuracy while synchronizing the WSNs. Reference Broadcast Synchronization Protocol [5] (RBS) uses the synchronization between the two receivers by the intermediate node within the listening range of the sender and receiver. The intermediate node sends the message for recording the time hence saves the energy in clock updates. The major disadvantage of the protocol is that the energy is wasted to synchronize the reference sender.

[6] Proposes the distributed clustering data aggregation algorithm with consideration of mobile and heterogeneous nodes into the clusters. The mobility of node often changes the structures and accordingly consumes more energy. In [8] Author considers the network with heterogeneous nodes in respect to energy with a mobile sink. It shows enhancement in throughput and network lifetime. Due to the mobility of sink control overheads are increased and drains some part of node energy. [9] Consider hybrid synchronization scheme for WSN used to evaluate the vibrations with minimum sync errors. Authors used the partial offset time synchronization of TPSN and clock adjustment for decreased energy consumption of K nodes. [9] Proposes the hybrid scheme to make sure the sync accuracy with minimum energy. It considers partial scheme to calculate the time offset of few child nodes. In [10] time synchronization of node and network is done at the time of cluster tree formation. It reduces the energy consumption and relative time drifts used in data collection from the tree. [11] Proposes the cycle-based sync scheduling in the delay-sensitive applications to achieve low packet delay and high throughput in the communication of packets from intra to inter-cluster communication. It rearranges the transmission order by upgrading the cycle length. It has a limitation of overhead with increased network size and synchronization error. [12] Proposes TDMA based slot allocation for transferring the accumulated packets from CH to sink with reduced energy consumption even though the mobility of node restructures the cluster and increases the energy consumption. The TDMA scheduling requires the proper synchronization for reduced packet collisions. [13] Proposes the bandwidth efficient hybrid synchronization algorithm [BESDA] which uses the combination of scheduling and synchronization algorithm to enhance the throughput . [14] Mobility–aware Hybrid synchronization (MHS)consider the random mobility of node to improve the throughput and delay, but the mobility of nodes causes the energy consumption in aggregating the packets from nodes to CH and CH to sink.

In order to overcome the drawbacks observed for a static sink, the use of a mobile sink has been proposed . A mobile sink can follow different types of mobility arrangements in the sensor field, such as random mobility, predictable/fixed path mobility, or controlled mobility, which has consequences regarding energy efficiency and data collection strategies. WSN lifetime can be definitely improved if the energy spent in data relaying is reduced. One method to avoid formation of energy holes is to use sink mobility. When the energy of the sensors near a sink is in well amount, the sink can move to a new location where residual energy is low. This approach will balance the energy consumption and will increase network lifetime. Recent advances in the field of robotics make it possible to integrate robots as sinks (or gateways) in WSNs [17]. Adding mobile devices to WSNs infrastructure has attracted increased attention recently. Much of the work has been conducted on data gathering applications, where the mobile sinks move randomly [17], using predetermined paths [16], or autonomously . A random moving sink is not aware of the sensor residual energy, and thus might threaten the energy balance among the sensors. The predetermined path models lack adaptability and scalability with network size. The moving strategies where the sinks take the moving decisions autonomously can better adapt to various network conditions.

III. PROPOSED NETWORK MODEL

The paper proposes the cluster- based Time Synchronization for WSN. It uses the spanning tree mechanism for synchronizing the slots as well as clocks of the heterogeneous nodes with the global clock of the network (Sink).Sink is mobile here, and the route for

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sink is determined after the CH selection according to average residual energy concept.

The clusters in the network are used to form the spanning tree with 'V' set of CH connected with 'E' wireless links T (V, E) as shown in Fig.1.

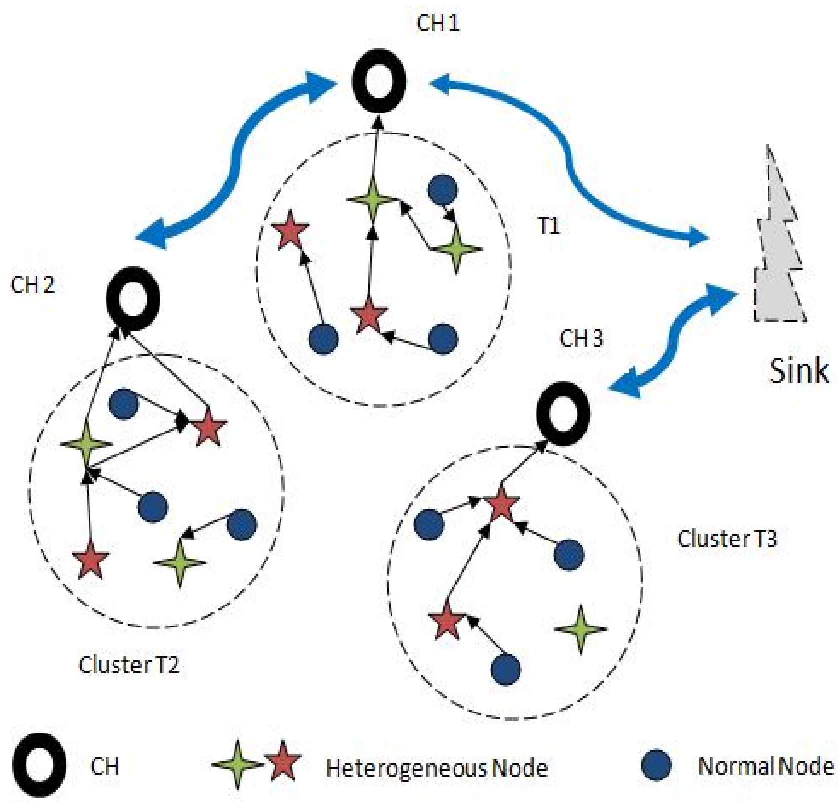

Figure 1: Network Model

The network T (V, E) is divided into many sub-trees of clusters T1, T2, T3,…, Tn. The sink is placed at the root of the tree. The network has sub-tree of clusters (inter-cluster) with one CH and a number of nodes within the cluster. Also, a spanning tree of all nodes in the cluster is made and then divided into sub-levels (intra-cluster). Each sub-tree is a set of nodes including CH and several child nodes. The frequency of each clock is approximately fixed and maintains the time stamp which is synchronized with the global clock of the network during synchronization process. The algorithm used in synchronization process is also given.

We are using controlled mobility of sink in our new algorithm (NHES-MS) in order to minimize the energy consumption as compared in our previous NHES model. Controlled mobility refers to schemes where sink mobility is controlled or guided based on a parameter of interest such as residual energy of the nodes.

IV. PROPOSED MECHANISM

The main objective of NHES-MS node heterogeneity-aware synchronization scheme with mobile sink is to minimize the energy consumption and delay. The formation of algorithm progress as:

A. Form the cluster tree and perform level by level aggregation.

B. Synchronize the activities of the node to reduce energy consumption by reducing errors and delay.

C. Schedule the activities of the nodes according to free slots.

D. Reduce the errors due to clock skew hence the energy consumption and delay.

E. Area of WSN is divided into 8 parts and average residual energy of every part is calculated and Sink route is defined on the basis of average residual energy calculated.

The Flowchart for the proposed mechanism is given below:

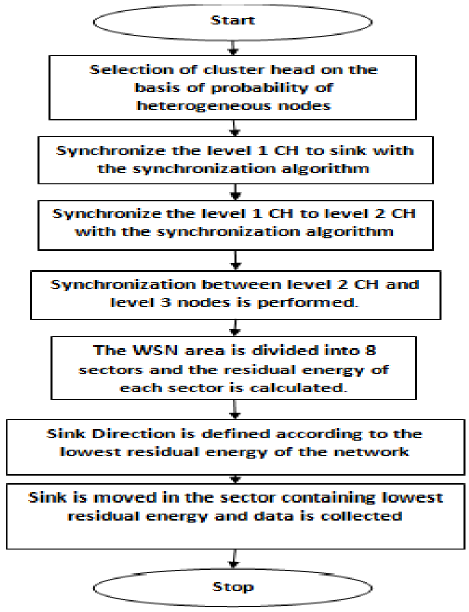

Fig 4: Flowchart for the proposed mechanism

F. Spanning Tree Formation

The main goal of synchronizing the local clock of all nodes within the cluster with CH and then with sink is to reduce the sync errors and delay hereby reducing energy consumption. In the initial stage, all the randomly distributed nodes are grouped into a number of clusters based on the clustering algorithm [7,8] at time interval 't'. The CH is assumed to have level 0 and broadcast the message, nodes receiving broadcast messages at one hop are connected and represents as set of forest. The Kruskal algorithm is used to form the minimum spanning tree of nodes with the edge forming the loop are discarded as shown in Fig.2.

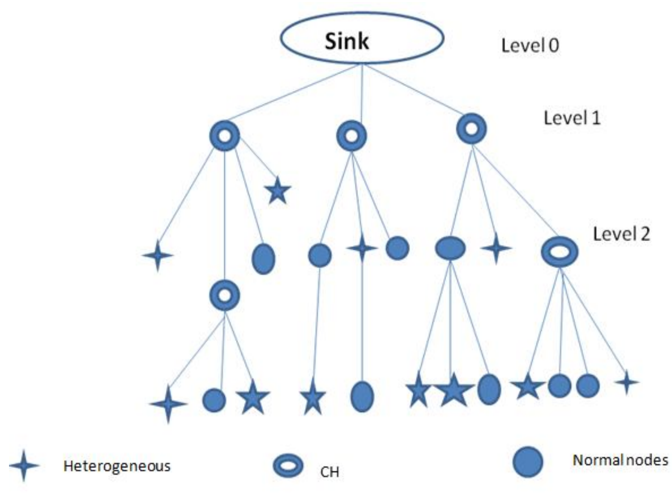

Fig.3. Spanning tree mechanism

In the second level (inter-cluster), the spanning tree of CH is formed with different level and sink at root with 0 level. The CH directly connected to sink are at level 1 and the remaining CH and nodes will maintain the higher order according to the depth of spanning tree. All the CHs at level 1 are synchronized with level 0, level2 with level1 and so on. The process of synchronization continues in the same manner inside the cluster till all nodes in the network have been synchronized. The errors due to clock skew between local and global clock will occur during the synchronization process. The level by level synchronization of child and parent node reduces the clock drifts and overheads required to maintain equal time scale among all nodes at one time.

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G. Algorithm used for synchronizing the nodes

1) Head clock drift and offset is broadcast.
2) Member's clock drift and offset is calculated.
3) Node time is calculated by the given formula:
4) Node_time=current time*drift+offset ;
5) Difference between head and member's clock drift i.e., deldrift is calculated.
6) In the same manner deloffset is calculated
7) Two clocks are synchronized by adding the difference value of drift and offset to the member clock.

H. Energy and delay analysis

1) The main objective of adding the heterogeneous nodes is to sustain the network for a long time with minimum energy consumption and delay.
2) NHES considers the energy model with introduction of controlled node heterogeneity
3) the total initial energy of cluster is:

$$E_i = n(\alpha E_n + \beta E_a + \gamma E_s)$$

Where,
α = % of normal nodes with energy En = 20 J,
β = % of advanced node with energy Ea = 30J,
γ = % of super nodes with energy Es = 40J,

The energy consumption ,, from node to CH, CH to sink, and the number of packets transmitted by the nodes in the lower level to CH, and to 0 levels by CH, is:

$$e(di) = k(e_t di^{\mu} + e_0$$

Where
μ- path loss and depends on the distance of a node to CH and sink,
k- the number of packets,
et- transmitter energy,
e0 - initial energy.

The enrgy consumption according to radio states as transmitter(E_{tx}), receiver (E_{rcv}), listen (E_{lst}) and sleep (E_{slp}) and clock skew 'es' is

$$\text{Energy consumption} = (E_{tx} + E_{rcv} + n * E_{lst}) L * t_{slot} * e_s$$

Where synchronization period 'T' is composed of consecutive time slots L. The total time is logically divided into slots as tslot, and these time slots are synchronized among nodes to avoid collision of packets and clock skews.
The total time is logically divided into slots as tslot, and these time slots are synchronized among nodes to avoid collision of packets and clock skews.
The total time required to send the aggregated packets to sink:

Tsink = k. tslot

Hence, total time required for packets to reach to sink is: *T = [((N/K)-1) +K] tslot*

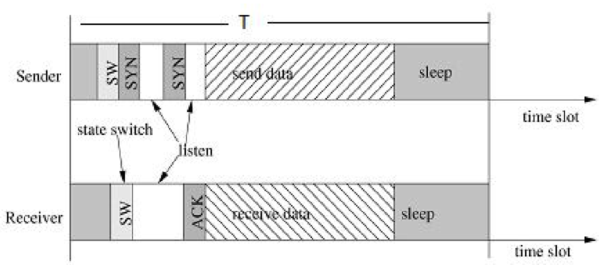

Figure 4: Synchronization Frame

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I. Sink Mobility

We are using controlled mobility of sink in order to minimize the energy consumption as compared in our previous NHES model. controlled mobility refers to schemes where sink mobility is controlled or guided based on a parameter of interest such as residual energy of the nodes, or on a predefined objective function, or on predefined observable events., Here the sink tries to stay away from the nodes with high residual energy and tries to be in the vicinity of those nodes that have less residual energy. This helps balancing the energy dissipation from the nodes, and hence reduces E-avg (average energy of model). To perform this kind of approach we divide the area of the wireless sensor networks in 8 parts (45 degree each).

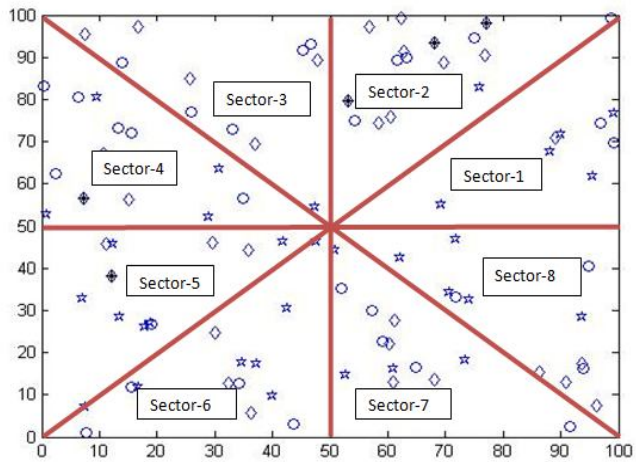

Figure 5: Area of WSN is divided into 8 sectors to define the route for sink

Sink is moved after we calculate the residual energy of every sector , whichever sector has the lowest energy sink move into that sector so that it can receive all the information from the nodes before they die. In this way sink moves continuously into sectors which are having lowest residual energy. In this way our NHES-MS model became more energy efficient and delay is also reduced due to synchronization method employed.

V. RESULT AND DISCUSSION

The simulation is performed in MATLAB R2013a .The parameters considered for simulation of randomly placed heterogeneous nodes are summarized in Table I.

The cluster based spanning tree used operates level by level in the intra and inter-cluster aggregation and communication of packets towards the sink. The sink route is them decided according to the residual energy concept The performance of the newly developed Node heterogeneity aware energy efficient synchronization algorithm with mobile sink (NHES-MS) is compared with NHES(static sink algorithm).

Particulars	Value
Area	100*100(in meters)
Number of nodes	100
Number of sink	1(mobile)
Initial Energy	20 J
Energy of heterogeneous nodes	20 J, 30 J, 40 J
Number of packets(k)	4000

Table I: Simulation Details

A. Average Energy Consumption

This graph is showing the comparison between base NHES algorithm and the newly developed NHES with Mobile sink (NHES-MS) algorithm. The graph is representing average energy consumption is reduced by adding sink mobility in the network.

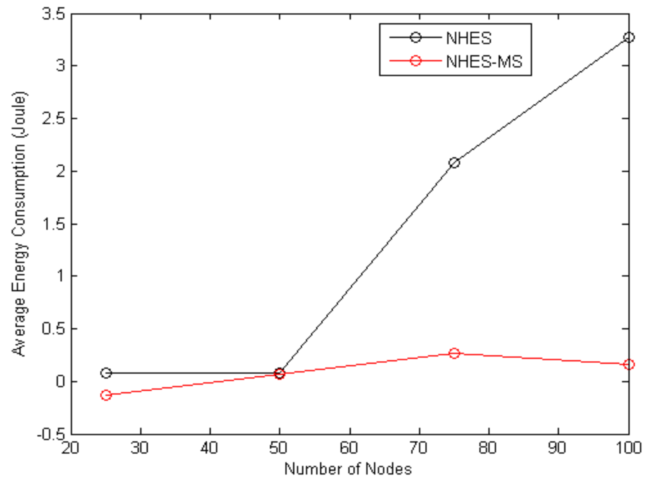

Figure 6: Average Energy Consumption

B. Average Delay

The average delay in the network is also reduced by adding sink mobility, as the mobile sink reduces end to end delay between transmitter and receiver. Hereby reducing the average delay of the Network

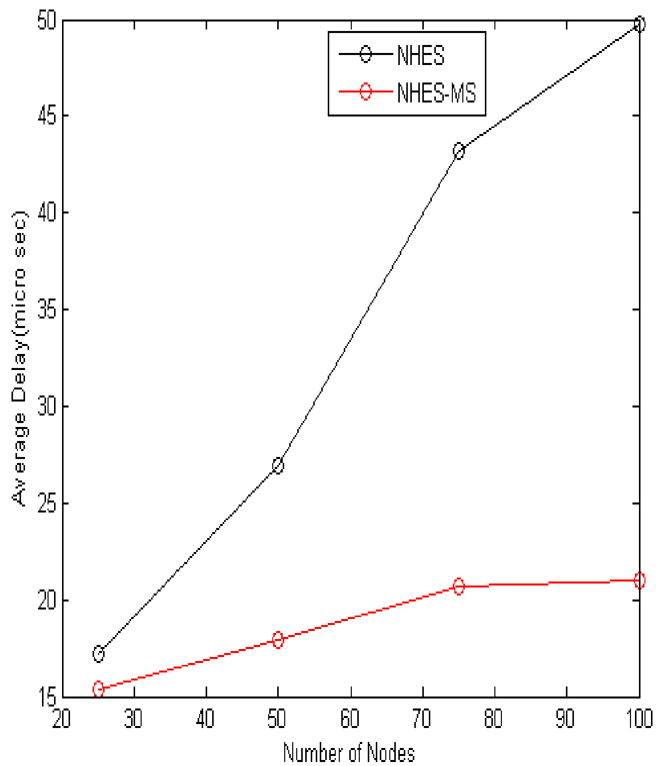

Figure 7: Average Delay

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C. Synchronization Error

This graph is representing the reuced synchronization error in the new mobile sink NHES algorithm.

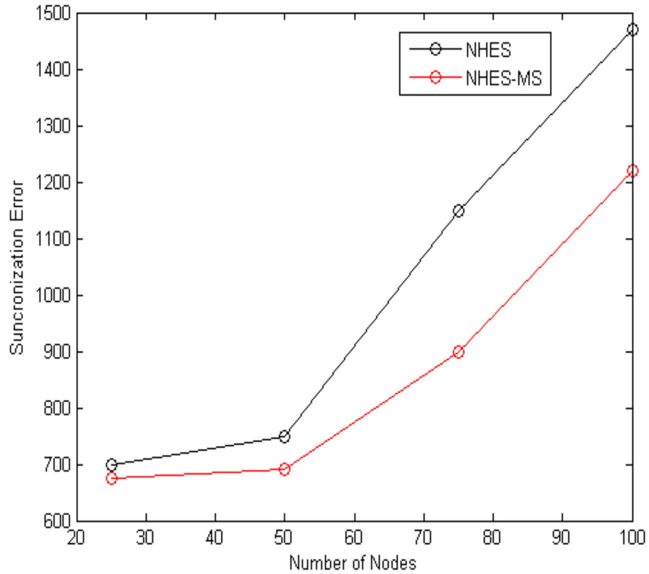

Figure 8: Synchronization Error

VI. CONCLUSION AND FUTURE SCOPE

The proposed synchronization algorithm with spanning tree mechanism and sink mobility shows improvement in energy consumption and delay as compared with existing NHES model. The addition of heterogeneous nodes in the network along with the synchronization of local and global clock helps to sustain the network for a long time. The clock synchronization reduces the clock drifts and hence errors which result in an increase of the throughput, and reduces the delay. With the introduction of controlled node heterogeneity, the performance of the synchronized algorithm is improved. Also, the pair-wise synchronization reduces the possibility of retransmission of packets and reduces the delay. From the results and discussion it is noted that existing NHES model has become energy efficient due to introduction of controlled sink mobility.

This Sink mobility based NHES algorithm(NHES-MS) can be made more efficient if we perform data gathering technique using PSO. To overcome the challenges of Data gathering and enhancement of lifetime of mobile nodes a new data gathering technique with multiple mobile sinks can be proposed which is based on particle swarm optimization (PSO) technique.

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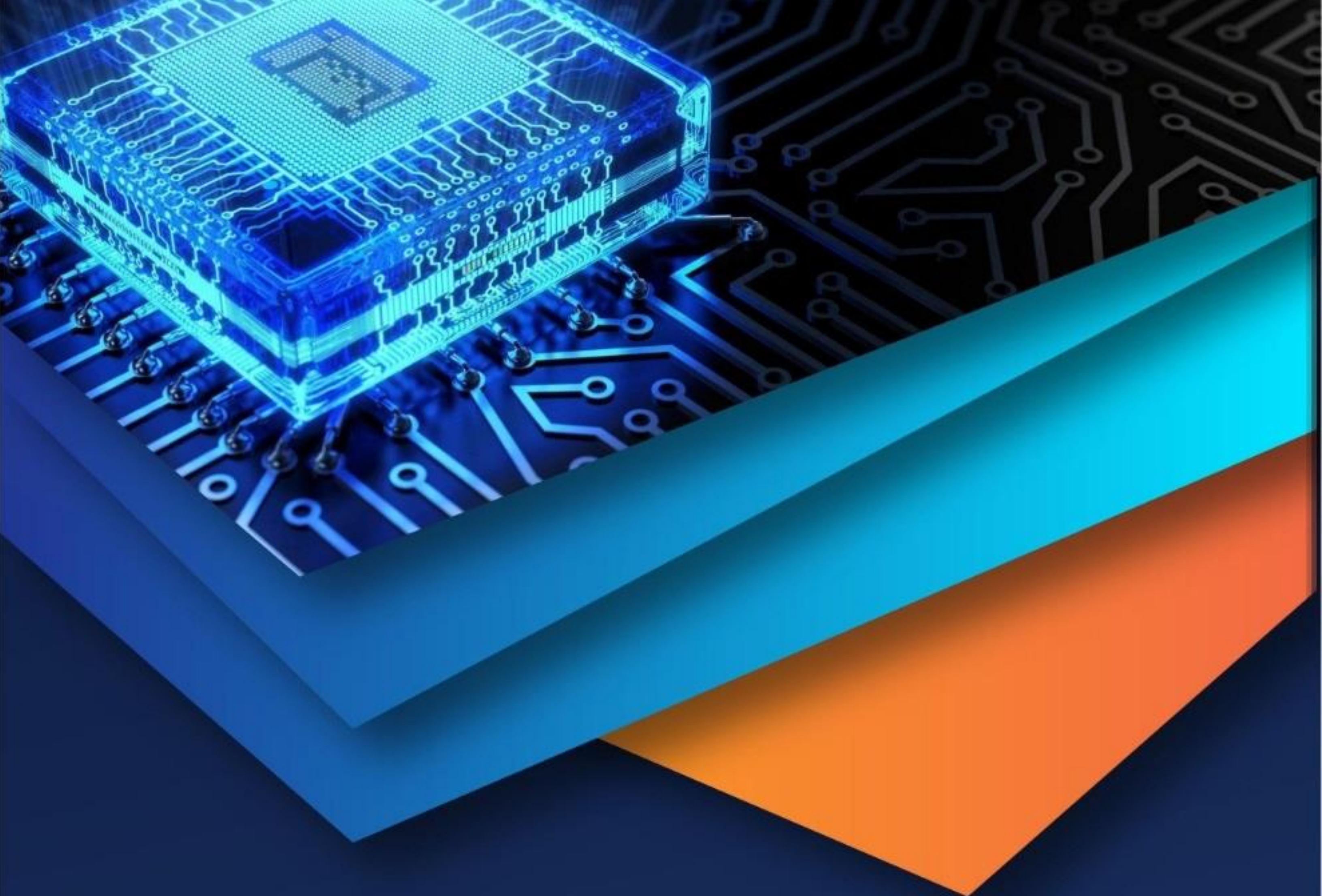

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