A Level-Wise Periodic Tree Construction Mechanism for Sleep Scheduling in WSN

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***Abstract*—The wireless sensor network (WSN) has been extensively used to monitor and control the natural ecosystem on a large scale like air quality, natural life, etc. Low battery power, small storage, and limited processing ability are the most critical areas of concern in WSN. To reduce energy utilization, the sensor nodes in WSN work in a cyclic process between active and sleep mode. A certain number of nodes are chosen active, and they are responsible for sensing as well as data transmission, and the rest of the nodes are gone to sleep. With the objective to lengthen the durability of the network, we have presented a level wise periodic tree construction algorithm. The algorithm uses a specific set of nodes to participate in tree construction. To minimize the overall energy consumption, all nodes do not need to participate in transmission and reception. As per the suggested procedure, the main goal is to put the nodes, which are currently active and have already spent a significant amount of energy, to sleep mode. The proposed approach will provide a chance to the leaf nodes to become active and uphold the connectivity. The performance of the proposed protocol is evaluated using the Castalia simulator. The simulation results show that the proposed level wise periodic tree construction approach increases the durability of the network in conjunction with the non level approach.**

***Index Terms*—WSN, Sleep scheduling, Energy Efficiency, Hierarchical Structure.**

I. INTRODUCTION

In recent decades, continuous upbringing in terms of sensing, storage, and communication have enabled wireless sensor networks (WSNs) to be used in a diversified manner. Minute observance of atmospheric conditions, monitoring the natural life, biomedical surveillance, calamity detection, etc., are some of the major applications of WSNs. Deployment of a larger number of sensor nodes within a network leads to the execution of bottleneck. The primary concerns behind the bottleneck execution are minimum battery power, minimal memory and lower computational capacity of sensor nodes [1], [2]. Therefore, reduction in continuous data transmission can enhance the overall network lifetime [3], [4]. In such type of scenarios, clustering algorithms can play a major role [5], [6].

To have the maximum coverage and network dependability, most of the WSN applications need an enormous number of nodes to be deployed densely. The dense deployment of the sensor nodes expands the quality of transmission. At the same time, the network would not get exhausted in terms of energy. The minimal power in densely deployed sensor nodes affects the overall network lifetime. To minimize the overall energy consumption of a network, WSNs operate in a mandatory cycle mode. In mandatory cycle mode, the sensor nodes can effectively toggle in between active and sleep states [7], [29]. The nodes, when going to the sleep state, switch off their own radios to conserve power. Similarly, the nodes in the active state switch on their radio. This mechanism enables a lesser number of nodes to stay active throughout the entire network. For each estimation cycle, more than a few active sensor nodes are chosen. Hence, the overall procedure is quite energy efficient and productive.

The selection of active nodes in WSN must satisfy two basic requirements, i.e., coverage and connectivity. While covering an area of interest, the deactivation of a few sensor nodes may save energy. Nevertheless, it should ensure that no regions should leave uncovered. Appropriate management in covering an area of interest is, however, vital as far as overall power consumption is concerned. This can enhance the lifetime of the network. On the other side, the data sensed by the active nodes must be reached at the sink node for further use, which requires connectivity among the active nodes. The mode of communication among the active nodes can either be single hop or multi hop. The overall transmission cost is directly proportional to the number of active sensor nodes. The transmission cost goes higher if the number of active nodes within a network increases. Therefore, it is required to make a few nodes active for data transmission and ensuring connectivity.

In this manuscript, we have proposed a sleep scheduling mechanism that reduces the overall energy consumption in a WSN with ensuring network connectivity. The proposed approach makes use of the hierarchical structure, which is constructed periodically in parts rather than for the whole network with a target to minimize energy consumption. The rest of the paper is organized as follows. Section II presents the state of art. Section III presents the proposed approach to enhance network longevity. The detailed simulation and generated results are presented in Section IV. The manuscript concludes in Section V.

II. STATE OF ART

Nowadays, an infinite number of applications are dependent upon WSNs. Basically, in a densely deployed WSN, the energy consumption of the sensor nodes is high. This has a direct

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impact on the overall network lifetime. Looking at this issue, researchers have invested a great deal of time in finding the solution. Hence, there is an abundance of research papers available in the background. In this section, we present an in depth literature study related to a reduction in energy consumption in WSNs.

The construction of hierarchical structure plays a vital role in designing different media access control (MAC) and routing protocols for WSN [36], [28]. Considering this fact, Dash et al.[29] proposed a distributed algorithm[] to construct the hierarchical structure where each node maintains two parents expect the sink node. The selection of parent nodes is mostly based on their remaining energy. Here, the authors claim that the energy consumption over the whole network has considerably reduced as the approach makes more nodes to be in and sleep and also due to its distributed nature.

A combination of connectivity and complete in WSN is proposed in [8], [28]. The proposed approach seemed to be quite useful in enhancing the overall network lifetime. It supported k level coverage and connectivity in the desired area. Based on the problem requirement, the level of monitoring through sensor nodes was modified. To check whether the convergence point of the parameter of the detecting region is being covered by the excess number of sensor nodes or not, a strategy for minimizing the total number of active nodes is being proposed. The sensor node is said to be an additional sensor node if and only if all the convergence points of the parameter are covered by neighboring nodes. Initially, all the sensor nodes must be in OFF state. Each sensor node inside a network carries a qualification calculation. The qualification calculation signifies the event based on which the node should go to ON state or remain in OFF state. As per the proposed approach, the transmission range of the sensor nodes becomes multiple times higher than that of the detection range. At the same point of time, the overall coverage verification of the network is also adequate. The network lifetime is based on the energy of each and every sensor node. Even if a single node fails, the network can be split. To enhance the stainability of the node and increase the lifetime of the network, the proper transmission path must be chosen. Potentiality timeserving reliable routing (PTTR) method utilizes the acknowledged idea and guarantees the conveyance of packets as well [13]. The packet traverses from one hop to another hop until it reaches the destination. The next hop node is decided by factors like remaining energy, link duration, and the distance it needs to travel. The source node transmits the aggregate data to the best next hop node. Promptly, the best next hop node sends the acknowledgment back to the sender. Likewise, an equation for Steadfast Routing Factor (SRF) is additionally proposed in SRIR [14], which utilizes energy, distance, and PRR to help in choosing a node as the next hop node. The path is set up by each sensor nodes dynamically towards the sink node similarly in a hop to hop way. In EARQ [15], a node calculates the remaining energy costs, postponement, and performance of the sink node route, construct just with respect to data from neighboring nodes. The likelihood of choosing a path by the node is measured. Whenever there is a requirement of sending a packet is required, the next hop node is randomly selected. A path with lower remaining energy costs is likely to be chosen because the probability is contrary to the remaining energy costs of the sink node. To ensure the optimized density of the sleep nodes and to maintain the overall coverage at the same time, a decentralized algorithm is proposed in [9]. The proposed approach focused on covering the desired area, setting up the connectivity, and enhancing the network lifetime. The region in which the sensor nodes are placed is carved into a grid structure. If the grid center is covered up by the neighboring sensor nodes, the sensor node in the center can go to sleep. To check if the grid center is covered, the sensor node receives an ON message. If the center of the grid is covered, the sensor node can go to the sleep state. In specific applications, for e.g., temperature monitoring continuous screening of the coverage area is not necessary. Such applications need partial coverage for an area of interest. A demand driven connectivity and coverage mechanism for WSNs is suggested in [10]. The sensing range for the sensor nodes is adjusted, looking after the required coverage. The authors proposed a *local route optimization* algorithm to minimize the overall power consumption in the network. Better topology control algorithms integrated with enhanced sleep scheduling mechanisms can enhance the overall lifetime in WSNs [26]. Considering the essential factors like coverage, connectivity, and communication ($C3$), a holistic approach has been proposed in [11]. The proposed algorithm worked in 4 stages as enlisted. $1)$ Isolated the network into virtual rings by using received signal strength indicator (RSSI) $2)$ characterized the rings with group heads at substituting rings $3)$ made rings inside the bunches utilizing the triangular decoration and $4)$ to send the information through group heads. The obtained results ensured *partial coverage, one connectivity, and energy efficient communication* and 90% coverage as per the availability of the sensor nodes.

The framework suggested in [12] clarified the sleep and wake up procedures of the fuzzy clustering algorithm. Initially, all the sensor nodes in the network remained in the sleep state. Once the data transmission begins, the source node communicates the packet to the forwarder array. The packet acts as an alert message and triggers other nodes present inside the network. This generates a list of nodes with maximum battery power. The nodes with maximum energy stay active while other nodes go to sleep state. Hence, the overall energy consumption of the network is minimized. Energy efficient algorithms for the selection of nodes have been introduced for WSNs [16]. A new Correlated Node Set (CNS) and a High Residual Energy First (HREF) node determination calculation decrease the active node number. The Cover Sets Balance calculation (CSB) is fit for picking active nodes; those with high coverage range and high outstanding remaining energy. In every active node determination step, the coverage range and remaining energy are utilized to locate an underlying active node set and then adjust the span of the cover sets, keeping in mind that the end goal is to remove low remaining energy nodes.

WSN's path selection strategy is regularly guided by two basic prerequisites: limiting energy costs or increasing network output. Conventional wired system path selection protocols select the best hubs location between source and destination and forward each packet through that cluster. This approach has generally been followed by most path selection protocols designed for multihop WSNs, and such multi path routing protocols are included. In any event, this did not take into account points of interest for the broadcast nature of wireless communications, i.e., the transmission of a node could be heard by any node within its transmission area. In WSNs, different elements, such as blurring, impedance, and multi path impacts, can prompt transitory overwhelming packet losses in a preselected path [17]. Many energy efficient path selection protocols [18], [19] have been proposed as of late joining with an assortment technique. Most of the latest power conscious methodology did not consider the wireless connections packet failure, i.e., packet loss. An attempt has been made to reduce energy usage by distributing energy absorption among cluster participants. Topology control studies [20], [21], [22] focus on network connectivity and blockiness while improving different design goals. Paper [23] presented a path selection protocol called energy efficient opportunistic routing algorithm (EEOR). The proposed protocol chooses the forwarder set from the neighboring set of nodes and prioritizes them in the light of the energy saving arrangement. In order to address this issue, a large number of protocols have been revised. From the above discussion, it is clear that in a WSN, almost any single node is involved, whether the packet is transmitted or in an idle state. Despite there is no involvement of active nodes in any transmission, they still get exhausted in terms of battery power [30]. The sleep mode, in particular, is actualized to conserve energy. The sleep mode additionally decreases energy utilization. As per the mechanism proposed in [24], it can be seen that sleep mode idea can be actualized in various courses with the assistance of queue network, RTS, and CTS signals or wakeup caution radio idea.

A scheduling based energy aware routing protocol has been presented in [25]. In the proposed approach, the sensor nodes are deployed in a tree structure. As per the mechanism, the sensor nodes are divided into two groups, i.e., internal nodes and leaf nodes. For successful transmission of data, the internal nodes remain active, whereas the leaf nodes stay deactivated. However, the internal nodes are the sensor nodes with maximum battery capacity, and leaf nodes have lower battery capacity. The leaf nodes become active only when they sense some activity in their surrounding. After collecting the data from a certain activity and transmitting the same, the leaf node again returns to sleep mode. In the tree structure, every node has a dedicated parent node, and whenever it senses or receives any data, it always forwards the same to its parent node, except the sink node. This is an iterative process, and it continues till sensed data is transmitted to the sink node. However, after this phase of tree construction and data transmission, there is a significant energy gap between the active internal nodes and the leaf nodes. As a result, the internal nodes may die out quickly as compared to the leaf nodes that result in maintaining connectivity of the tree is short lived. Therefore, it is important to equally maintain energy dissipation in all the nodes of the WSN so that the connectivity can last longer.

The duty cycle is one of the most widely used energy saving mechanisms for WSNs. To maximize the overall network lifetime, the duty cycle mechanism ensembles sleep and wake up time of sensor nodes. An adaptive duty cycle mechanism for MAC protocol in WSNs is proposed in [32]. These adaptive scheme judges the listen time of each node involved in packet transmission and reception scenarios. The proposed approach reduced the waiting time for each transmitted packets and undelivered packets as well. Hence, the overall energy consumption is reduced.

As per the existing literature, the primary focus is on the non sleeping scenarios. The underlying assumption made in most of the pieces of literature says that the nodes in a WSN communicate using a single channel. This mechanism, when embedded in a multi channel asynchronous duty cycle scenario, reduces the performance of the WSNs. To address this issue, a delay efficient data aggregation scheduling problem for multi channel asynchronous duty cycled WSNs is proposed in [33]. The proposed approach is based on two concepts, namely, candidate active conflict graphs (CACGs) and feasible active conflict graphs (FACGs). Using these concepts, the authors proposed an efficient data aggregation scheduling (EDAS)algorithm for WSNs. The proposed algorithm uses the fewest child first rule to choose the forwarding nodes. The overall efficiency of the algorithm is proved through extensive simulation and analysis.

The nodes involved in the transmission of data packets sometimes transmit the redundant data. This is a complete wastage of time and energy. To resolve this issue, an energy efficient sleep scheduling mechanism is presented in [34]. For a reduction in energy consumption, the nodes in WSN is scheduled as active or sleep mode. To organize all the sensor nodes into a cluster, the optimal competition radius is computed. Based on the collected data by the member nodes, A fuzzy matrix is generated. The obtained fuzzy matrix measures the similarity degree of the member nodes. Using the correlation function and the similarity degree, the sensor nodes are divided into different categories. To maintain data integrity, the redundant nodes are selected and put into a sleep state.

In a large scale, WSNs, where the nodes are clustered in the form of a tree structure, may suffer from higher end to end delay. At the same time, the congestion within the network remains high as well. To resolve this issue, and to maximize the converge cast traffic in large scale WSNs, an efficient mechanism is proposed in [35]. The proposed mechanism is the combination of the data generation mechanism of the individual nodes and efficient allocation schemes of the active periods of the sensor nodes.

III. Proposed Approach

As discussed earlier, the internal sensor nodes deployed in a tree structure remains active. After spending a significant amount of energy, the internal nodes go to sleep mode. This allows the leaf nodes to maintain network connectivity. To perform this mechanism, periodic tree reconstruction is needed. In every reconstruction phase, the intermediate nodes

TABLE I
NOTATIONS

Short Name	Description
n_i	i^{th} node
$SS(i)$	Sleep signal for i^{th} node
$RR(i)$	Remaining energy of i^{th} node
$LEVEL(i)$	Level of i^{th} node
$PT(i)$	No. of packets transfer by i^{th} node in the current round
$ALIVE(i)$	True if i^{th} node is alive
$CONS(i)$	No. of consecutive rounds node i is active
$CRL(n)$	Current level reconstruct for the n^{th} round. $CRL(n) = (CRL(n-1)+1)\%max\_level$. A CRL value of 3 means level 1,2,3 will be reconstructed.
$PF_{j,1}$	1st parent field of node j
$PF_{j,2}$	2nd parent field of node j

and the leaf nodes are interchanged. It signifies that, in every two consecutive reconstruction phases, the leaf nodes with higher energy becomes the internal node. Once the internal nodes get exhausted in terms of power, it becomes the leaf node in the next phase. In this mechanism, the overall energy consumption of the nodes is reduced. However, it can not be ruled out that the nodes which are closer to the sink node will expend more energy and thus exhaust sooner than the nodes far away from the sink node.

To overcome this problem and enhance the network lifetime, we hereby propose a level wise tree construction mechanism. As per our algorithm, each and every node does not need to get involved in the tree reconstruction phase. Hence, the nodes which are at a larger distance from the sink nodes get less exhausted in comparison to the nodes nearer to the sink. Therefore, in each reconstruction phase, it is not necessary for all the nodes to participate. The upper level nodes will participate more during the reconstruction phase as compared to the lower level nodes. So, in any reconstruction phase, if *level-1* nodes will participate in reconstruction, then in the next round *level-1* and *level-2* will participate in reconstructing and in the next round *level-1, level-2, level-3* and so on. Once the nodes belong to all the levels participate in the reconstruction phase, then the nodes can again begin where only *level-1* nodes will participate. In the tree reconstruction phase, the nodes which are active in the n^{th} round has a high probability of going to sleep state in $(n+1)^{th}$ round. Nevertheless, the time duration between two consecutive reconstruction phase for nodes which are away from the sink is more than that for nodes which are nearer to the sink. This proposed approach uses a systematic structure of message passing among the nodes to mend the tree locally and thus using a minimum amount of energy to reconstruct without involving all the nodes of the WSN. Any active parent node which wants to go to sleep in the next round needs to find an alternate parent for its children, and else it will not be allowed to go to sleep mode. There exist 4 cases as given below. The symbols used for different paths are shown in figure 1. The notations used in the proposed protocol are given in table I.

1) Both $P(n+1)$ and $P(n)$ received new parent, i.e. node in $(n+1)^{th}$ layer and node in n^{th} layer received new parent. In figure 2, initially, the parent of $P(n+1)$ is $P(n)$ and that of $P(n)$ is $P(n-1)$. $P(n+1)$ found another node as new parent and $P(n)$ found another node as its new parent. So, $P(n-1)$ and $P(n)$ can go to sleep.
2) $P(n)$ is able to find new parent but $P(n+1)$ is unable to find. In figure 3, $P(n+1)$ is unable to find new parent where as $P(n)$ is able to find a node as its new parent. So, $P(n+1)$ can go to sleep.
3) Both $P(n+1)$ and $P(n)$ are unable to find new parent. In figure 4, both $P(n+1)$ and $P(n)$ cannot go to sleep. They have to stay active.
4) $P(n+1)$ is able to find new parent but $P(n)$ is unable to find new parent. In figure 5, $P(n+1)$ is able to find an new parent. But $P(n)$ is unable to find new parent. So, $P(n)$ can go to sleep, but $P(n-1)$ cannot.

Initially, all the nodes are in active mode. The re-construction of the tree happens after the completion of each round. So, after the n^{th} round is finished, the reconstruction phase of $(n+1)^{th}$ round begins.

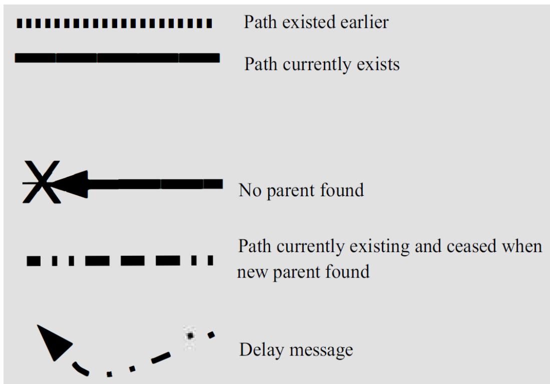

Fig. 1. Symbols used for different path

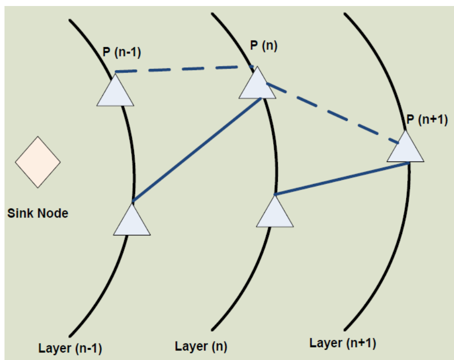

Fig. 2. Case 1:- Both P(n+1) and P(n) received new parent. So, P2 and P1 can both go to sleep.

At the very beginning, $CONS(i)$ and $PT(i)$ of each node is set to zero. An active node n_i can make a request to go to sleep for the $(n+1)^{th}$ round, if in the n^{th} round $PT(i)$ is greater than the threshold value or $CONS(i)$ is equal to a fixed value. Here, we set the fixed value to be 3. Also, the active node n_i must be within the CRL(n) to initiate its

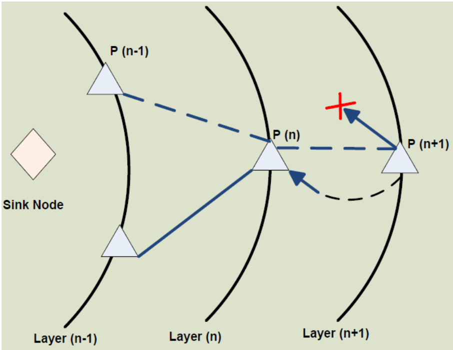

Fig. 3. Case 2:- P(n) is able to find new parent but P(n+1) can not.

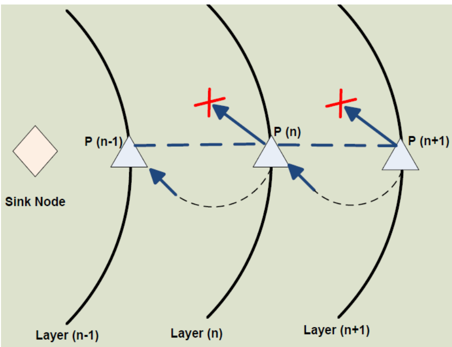

Fig. 4. Case 3:- Both P(n+1) and P(n) unable to find new parent.

sleeping request process. The sink node always remains active during the entire lifetime of WSN.

After an active node, n_i triggers a process to go to sleep, $SS(i)$ is turned on. The tree reconstruction starts with broadcasting the FIND_PARENT message packet to its children. The FIND_PARENT message packet instructs the child nodes of n_i to find a new parent. The active node n_i waits for a random amount of time until all its children get a new parent before it goes to sleep. Once a node n_j, which is a child of n_i receives the FIND_PARENT packet, it initiates its process to find a new parent by broadcasting a WANT_PARENT packet and waits for a random time while it chooses the best parent node from the reply of the other nodes.

A node n_k, which receives a WANT_PARENT packet, is eligible to be a parent only when $SS(k)$ is false and $ALIVE(k)$ is true. Once it meets its eligibility criteria it sends out a PARENT_REPLY packet with information such as $LEVEL(k)$ and $RR(k)$. The node n_k is ready to become a parent of any node if it is chosen by a node n_j, which is looking for a parent. A node n_j, which is looking to find a new parent might receive multiple PARENT_REPLY packets. Out of all the PARENT_REPLY packets from its neighboring nodes, it chooses the most suitable node, n_k, to be its parent based on the following conditions. A node n_j will give a higher priority to a node n_k to be its parent when $LEVEL(k)$ is equal to $LEVEL(j) - 1$ rather than $LEVEL(k)$ is equal to $LEVEL(j)$. Nevertheless, node n_j will out rightly reject all nodes n_k when $LEVEL(k)$ is less than $LEVEL(j)$.

After propagating through this initial choosing criteria, n_j employs another criterion where it selects its parent based

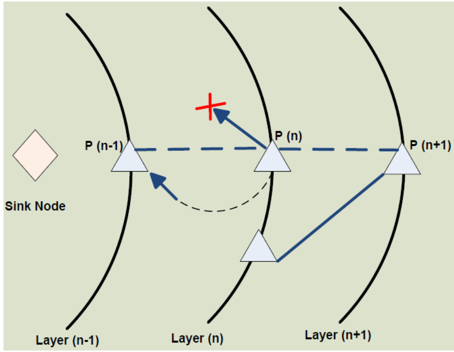

Fig. 5. Case 4:- p(n+1) found new parent but P(n) can not.

on the remaining energy of the nodes. It chooses $n(k1)$ over $n(k2)$ if $RR(k1)$ is greater than $RR(k2)$ provided $LEVEL(k1)$ is equal to $LEVEL(k2)$. After node n_j selects its parent from the multiple PARENT_REPLY packets, it needs to notify its new parent n_k of its new selection. So, it broadcasts an ACKNOWLEDGEMENT packet to n_k. When n_k receives the ACKNOWLEDGEMENT packet, it becomes an internal node and turns active for the $(n+1)^{th}$ round as it is some other nodes parent now.

Once this process gets over, node n_i waits for a random time to check whether all of its children have received their new parent. So, it broadcasts a FIND_CHILD packet into the network. When a node n_j which remains the child of n_i receives the FIND_CHILD packet from n_i, it broadcasts a CHILD_REPLY message to n_i to notify that n_i cannot go to sleep for the $(n+1)^{th}$ round as it did not get rid of all its child nodes. When n_i receives the CHILD_REPLY message, it sends a special MINUS_ONE message to its child n_j instructing the child n_j to use the alternative $(PF)_{j,2}$ as its primary parent and set the $(PF)_{j,1}$ to -1. In this way, n_i tries to get rid of its child n_j.

If this process fails to eliminate n_j as child of n_i, it has to remain active for the $(n+1)^{th}$ round. n_i again tries to go to sleep for the $(n+2)^{th}$ round after the completion of the $(n+1)^{th}$ round. Nevertheless, if every child n_j of n_i is able to receive a new parent, i.e. n_i does not receive any CHILD_REPLY packet, then in that scenario n_i can go to sleep for the $(n+1)^{th}$ round and CONS(i) is reset to 0. When the $(n+1)^{th}$ round starts, CONS(i) for all the active nodes is increased by 1 to keep track of the no of consecutive rounds node n_i is active. After this update, the tree reconstruction phase will be over, and the nodes can resume their task to sense and send data packets to the sink. For each packet being sent to the sink by the node n_i, PT(i) is increased by 1. This whole process is shown in algorithm 1.

IV. Simulation Results

In this paper, the performance of the proposed protocol is measured using the Castalia simulator. In this simulation, we have taken the number of nodes varies from 100 to 500. The nodes are deployed randomly using a uniform distribution approach. For each sensor node, the sensing radius energy

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Function: TIMER_2:
if n(i) sleep constraint satisfied then
    starts the process to sleep;(set timer of start_process)
else
    do nothing until next round
end if
End_of_Function: TIMER_2
Function: start_process:
ss(i)= True
Send FIND_PARENT packet to notify N(j) (their child) that they need to
find new parent.
After a random time interval it triggers "determine_isActive".
End_of_Function:In start_process
if N(j) receives FIND_PARENT packet then
    if ALIVE(N(j)) AND [PFj,1==n(i) OR PFj,2==n(i)]  then
        Broadcasts a WANT_PARENT packet.
        Waits a random time while it chooses the best parent reply.
    end if
end if
if N(k) receives WANT_PARENT packet then
    if (ALIVE(N(k)) == true and SS(N(k)) == false) and (LEVEL(N(k))
    == LEVEL(N(j)) or LEVEL(N(k)) +1 == LEVEL(N(j)) then
        broadcast PARENT_REPLY packet
    end if
end if
if N(j) receives PARENT_REPLY packet then
    if if N(j) wants new parent or PFj,1/PFj,2 is -1) then
        if [LEVEL(N(k+1))==LEVEL(N(l))] OR [if(RR(N(k)) >RR(N(l)))
        AND (LEVEL(N(k))==LEVEL(N(l)))] then
            Select node N(k) as parent over N(l)
        end if
    end if
end if
if N(k) receives ACKNOWLEDGEMENT packet then
    becomes active
end if
Function: Determine_isActive:
finds no of child
if no of child == 0 then
    turns to sleep)
else
    broadcasts MINUS ONE packet which instructs N(j) (its child) to use
    alternate parent field as primary parent field
    waits a random time
    finds no of child
    if no of child == 0 then
        turns to sleep
    else
        remains active
    end if
end if
if N(j) receives MINUS ONE packet then
    if PFj,1 != PFj,2 then
        make the parent which is not n(i) as primary parent field PFj,1.
        set PFj,2 as -1.
    end if
end if
End_of_Function: Determine_isActive
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Algorithm 1: The tree reconstruction phase between two consecutive rounds

consumption, transmission power, etc., are considered as per the detail given in TelosB data sheet [31].

Figure 6 shows the percentage of nodes active in each level of different size networks. The networks reach a maximum level of 3. Level-1, being the closest one to the sink, have the highest percentage of active nodes, while the number of active nodes falls considerably in lower levels. In level-3, there are almost negligible active nodes as most of the nodes present in this level are leaf nodes.

Figure 7 shows the number of active nodes in each level of a network size of 500 deployed in an area of 150x150m^2. This shows an average of 55 number of active nodes in level-1, around 15 number of active nodes in level-2. Initially, there are few numbers of active nodes in level-3, but as the tree construction progresses, the number of active nodes in level_3 falls to zero as most of them become leaf nodes. As the level wise tree construction procedure has been followed, there are crests and troughs in the graph pattern.

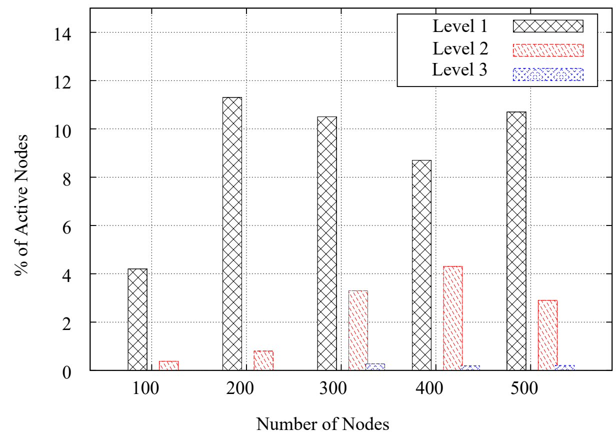

Fig. 6. Active Node in different level at different size network

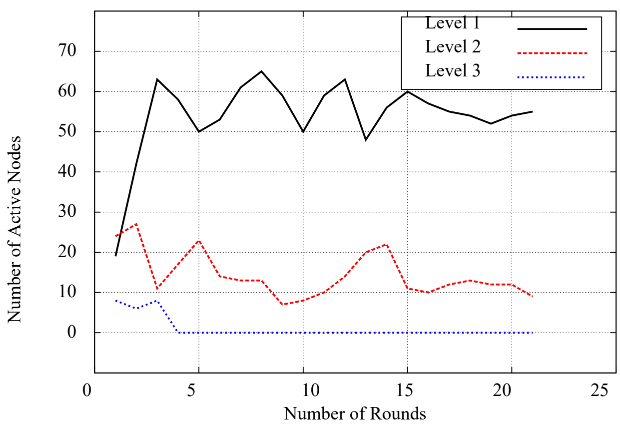

Fig. 7. Level wise active nodes in a WSN having 500 nodes

Figure 8 shows that in a 500 size network, the number of active nodes and the number of nodes out of the active nodes which have consumed significant energy during that round and meets the eligibility criteria to go to sleep in the next round. On an average of 70 active nodes, 30 to 40 nodes are opting to go to sleep in the next round.

Figure 9 shows the lifetime of the nodes in a WSN having 400 nodes deployed in a squared and rectangular area. As per this graph, in both the cases, the nodes start dying from the 26th round onward. The maximum level reached in the rectangular area is 5 as compared to 3 in the squared area. Similarly, Figure 10 shows that the proposed level wise approach increases the longevity of the network as compared

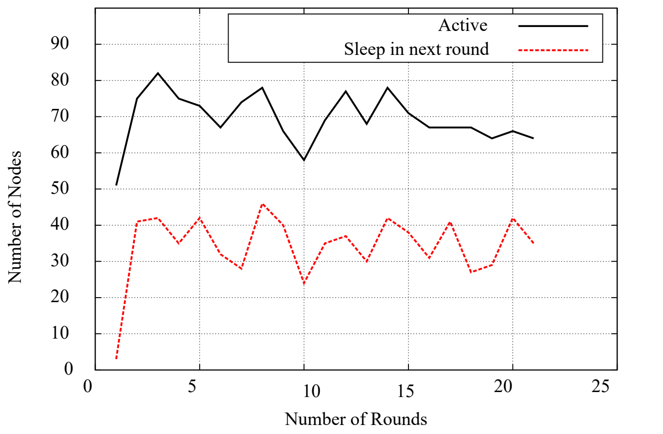

Fig. 8. Active node vs sleep node in next round in a WSN having 500 nodes

to earlier non level wise approach.

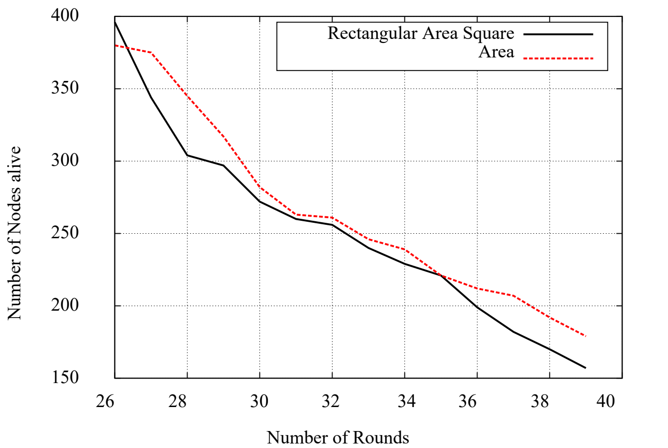

Fig. 9. Number of nodes Alive in a network size of 400 nodes deployed in square area and rectangular area

Figure 11 shows a comparison between a non level wise approach[29] and the proposed approach with respect to the number of nodes alive in different size networks at different rounds. It is seen that in every scenario, the number of nodes alive in level wise approach is more than that in the earlier non level wise approach.

Figure 12 shows the number of nodes alive in different size networks when the data packets are transmitted from the whole network vs. the data packets is transmitted from a particular region of WSN. From this figure, it is clear and obvious that the network lifetime will be more when the data packets are transmitted from a specific region of the network.

V. Conclusion

In this paper, we addressed the requirement of minimum energy consumption in WSNs and proposed a level wise sleep scheduling mechanism along with connectivity that achieves the above requirement. In this proposed approach, a routing tree is built to maintain connectivity, and further, it is mended

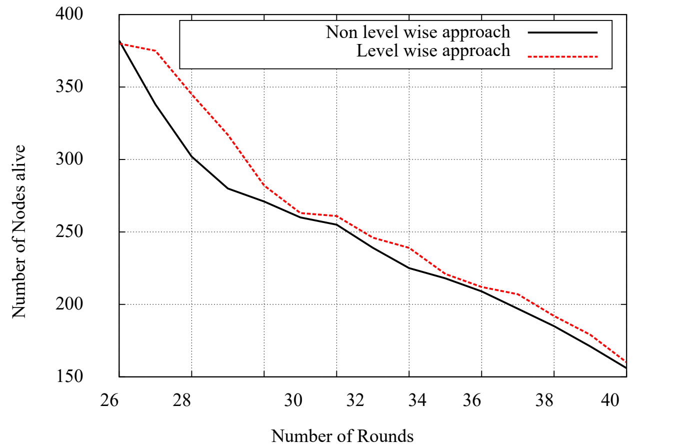

Fig. 10. Number of nodes Alive in a network size of 400 nodes deployed in non level wise approach vs. proposed approach.

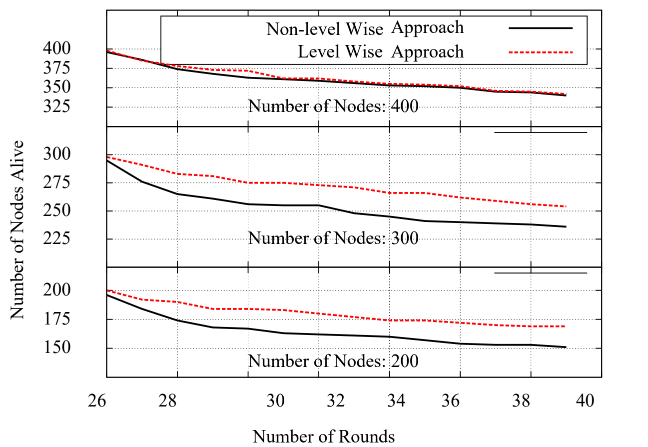

Fig. 11. Number of alive nodes in different size WSN in non level wise approach vs. the proposed approach

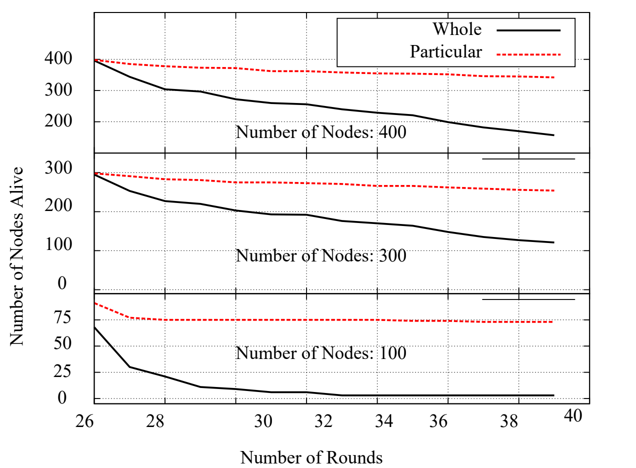

Fig. 12. Number of alive nodes in different size WSN where packets are transmitted from the whole network vs. specific region of the network

periodically in parts to enhance the overall network lifetime along with ensuring equal power consumption among all the nodes in the network. Since the nodes are periodically changing their state in between active and sleep, in order to avoid the network hole, the internal node or the currently active node must communicate with its children before getting deactivated. The correct care has been taken to hand over the responsibility of its children to another active node so that a network hole will not be formed. The generated results proved that the overall energy consumption in the network is minimized and simultaneously maintain connectivity. Still, more comprehensive analysis of detecting network holes and its avoidance may be included as a future scope.

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