Lifetime Enhancement using OLE algorithm in Wireless Sensor Network

[1]Sargam Gupta, [2]Prof. Pawan Kumar Patnaik

[1]Persuing M. Tech, [2]Assistant Professor
Department of Computer Science and Engineering,
Bhilai Institute of Technology, Durg, Chhattisgarh, India

***Abstract*—Wireless Sensor Network (WSN) are powered by Battery but in most cases it is difficult to change the battery hence the Design of WSN should be modified so that we can optimize the lifetime of batteries by dealing the trade-off between Lifetime and Quality of service (QOS).This Protocol might increase the performance of WSN by decreasing the Packet Loss Percentage and other QOS parameters.**

***IndexTerms*—WSN; QOS; Protocols; Lifetime**

I. INTRODUCTION

WSN has now become very advance due to the focus of various Researchers in this area, over the last few decades. In order to monitors the condition of an environment. A large of Sensors can be deployed which sensed data from the area such as Temperature, Pressure, Air flow, Speed etc. WSN contains a large number of minor sensor nodes. The communication among these sensor networks is low powered. These nodes communicate with one another or directly by Base-Station node referred to as as Base Station. Sensor network has very high density of sensor nodes in a large geographical area. The accuracy of information provided by these sensor networks is very high. The Base station could also be a stationary or mobile and that they are capable of connecting the sensor network to outside world using an existing communication web, wherever users will have access to the reported information [1].WSN is an small or big device having capabilities of detection and measuring physical parameters. The key challenge a Wireless sensor Networks (WSN) routing must cope with is that the energy efficiency and prolonging network lifespan. A WSN have following characteristics:

Application-oriented, Less Infrastructure, No public address,Supportedcommunicationmodels: hierarchical/distributedWSNs;or homogenous/heterogeneous WSNs; Limited resources of sensors (radio range, bandwidth, energy, memory and processing capabilities);[2] Some of most significant characteristics of those networks are: Wireless communications and connections, Low dependability and failure capability in detector nodes; Dynamic topology and self-organization; Hop-by-hop communications (multi-hop routing); Cooperation of detector nodes and alternative WSNs' devices to every other's; Inter-nodes broadcast-nature communications; easy extendibility and configuration Scalability; Direct communication, contact and interaction with physical environment;Usually single-purpose and application directed networks;Putting down and consistency capabilities of detector nodes on completely different operational environments;Automatically and non-interrupted operation; Communication management capability between mobile nodes; Hardware limitations of sensing element nodes; These data are collected and transmitted to the sink through Network. These Sensors can be deployed in such a place where Human presence is Risky. In such places Recharging batteries or replaces them is very difficult or in some cases impossible. Hence there's a demand for enhancing the battery power therefore on increase the lifespan of the sensing element network. Studies conducted by Researchers show that Energy consumption for WSN is attributable to the communication among sensors in brief called as Routing. The important method of saving energy is the clustering. Hence clustering sensors into small groups saves energy and increases network lifetime. In clustering each cluster has a cluster Head and others are cluster members. Sensor members send data using low power to CH (Cluster Head) while CH sends these data to sink using high power communication.

The clustering of the sensors must be proper so that a trade-off should be made between two conditions:

(1)If number of cluster is present than large number of cluster Head have to communicate with the Sink results High power Consumption.

(2)If numbers of clusters are low than diameter of cluster increased hence more energy is needed for CM (Cluster member) to communicate with the CH.

In this paper, the discussion is about OLE (Optimized Lifetime Enhancement) in WSN, a protocol that achieves sensible performance in terms of lifespan. Hence a simulation is done on OLE in terms of QOS parameter such as Lifetime, end to end Delay, Packet loss Ratio, Throughput. Simulation shows that OLE performance is better in terms of Delay and throughput.

II. RELETED WORK

Various Protocols within WSN are proposed to increase the performance of WSN but these protocols differ in many ways such as Selection of CH and Cluster formation method. Those can be given as below:

LOW ENRGY ADAPTATION CLUSTERING HIERARCHY (LEACH):

In this the selection of CH in cluster is Random which are predefined which is having probability of 0% to become CH up to certain number of Rounds. Each node has to select a CH close to it and send data to it using TDMA. Hence this results an inaccurate selection of CH, Size and number of cluster. Finally the load on each increases and long TDMA increases the latency in data Gathering. The objective of LEACH is to decrease the energy consumption required to make and maintain the clusters to improve the Lifetime of WSN. This is a HIERARCHICAL protocol in which nodes transmit data to the cluster Head and Cluster Head in turn sends data to the Sink. In each Round a cluster member is selected as the cluster Head according to its energy level. In this protocol each node has a radio power to transmit to other nodes or cluster head but by using that radio in full power waste the energy.

LEACH-centralized (LEACH-C):

This is the improved and centralized version of LEACH. In which each node sends information about location and energy level to the BS (Base Station). BS utilizes the overall network information that improves performance of network. Primary hole in this method is that a GPS or other LTM is used to track the location and in condition of node failure this has no method to overcome that failure.

Hybrid, Energy-Efficient, Distributed clustering approach (HEED):

This Protocol is mainly based on residual energy of the nodes. To increase the lifetime and efficiency a parameter is used which is known as communication cost. This shows the Density in the Cluster. HEED needs multiple broadcasts for cluster formation hence consumes more Energy.

Proxy-Enable Adaptive Clustering Hierarchy (PEACH):

This protocol is improves version of LEACH in terms of Lifetime. In this a proxy node is selected which can take roll of a current CH of low power during a single round. The advantage of this protocol is to detect and manipulate the cluster head failure, Hence Lower the overhead of clustering again. This protocol can increase Lifetime and reliability of WSN. In this protocol a proxy node is selected as the Cluster head and during one round of communication. This protocol can increase the lifetime by 15% as compared to the LEACH protocol.

Power-Efficient and Adaptive Clustering Hierarchy (PEACH):

The main objective of this method is to maximize the lifetime. This protocol uses multilevel clustering.

III. Methodology

OLE works in rounds as LEACH and each round consists of two main phases, set-up phase and data phase. The set-up phase is subdivided into two phases, cluster formation phase and CHs tree construction phase. In the cluster formation phase, each node takes one of three states (roles), candidate, plain, or head, while in the tree construction phase, each CH takes additional role(s) to form the CHs tree, these roles are child, parent, and root, so that the CH may be a Child Cluster Head only (CCH), Parent Cluster Head (PCH) which indoors is a child, Root Cluster Head which may be a parent but not a child (RCH/RPCH).The flow charts represent the phases of OLE operations are depicted in Figure1, Figure2 and Figure 3

In the flow charts, Ea. is the average residual energy of all neighbors in the cluster range, and it is computed from the neighborhood table information by using Eq. (1) as in [6] and [7].

$$\mathbf{Ea} = \frac{\sum_{j=1}^{m} \mathbf{Vj.E_{residual}}}{\mathbf{m}} \;\ldots\ldots\; (1)$$

Where m is the number of nodes within cluster range and v_j represents any node in this cluster range. The time delay (t) is calculated according to Eq. (2) as in [6] and [7].

$$\mathbf{t = k} \times \left(\mathbf{T_{clustering}}\right) \times \left(\frac{\mathbf{E_a}}{\mathbf{E_{residual}}}\right) \;\ldots\ldots\; (2)$$

Where k is a real value uniformly distributed between 0 and 1, and $T_{clustering}$ is the time duration for CHs election. The weight of a node i is computed by Eq. (3) as in [6] and [7].

$$\mathbf{Weight_i} = \left(\frac{\mathbf{D(RSS_I)\times E_a}}{\mathbf{D(RSS_{MAX})\times E_{residual}}}\right) \;\ldots\ldots\; (3)$$

Where RSS_i denotes node i's received signal strength of the signal broadcasted by the BS, RSS_{max} is a constant which is determined by the location of the BS, and D is a function used for estimating the distance between nodes i and the BS.

3.1 The new proposed algorithm

OLE achieves a good performance in terms of lifetime, but it lacks a mechanism that informs member nodes about their CH death and informs CHs about their parents' death during the round. So, OLE leads to energy loss that is consumed in sending packets to a dead node and loss in the sent packets, and these losses continue until the end of the round.OLE authors concerned only in their evaluation of the protocol on the network lifetime and they did not consider other important QoS parameters such as delay, packet loss, and throughput. It was found that the common cause of OLE losses is the death of the root during the round when it is overloaded. Fig. 4.1 demonstrates the two common cases of root overload. In Fig. 4a, a CH is located in the range of all the remaining CHs and it has the largest weight among them, so all of them select it as a parent and it becomes a root constituting a star topology not a tree topology which increases the aggregation load on it. In Fig. 4b, a CH is far from the other CHs so it is obliged to be a root although.It is very far from the sink which increases the transmission load on it. Fig. 4.2 shows the constructed tree in a round of OLE.It should be mentioned that the most common overload case is the first one, this means that the constructed tree is not ideal, it does not aid in balancing the load of relaying data among the CHs. To eliminate or decrease OLE losses, we can directly use a recovery method from CH (child, parent, or root) death or failure, but this method will exhaust a lot of energy and reduce lifetime and may also affect the other good performance metrics of OLE. So, the protection from loss cause is better than the cure from it. The protection manner used in the modified protocol Low Loss Energy-Aware routing Protocol (LLOLE) consists of two techniques, the first technique is used to increase the lifetime, so that if a loss occurred, the recovery method does not significantly affect the characteristic of LLOLE with respect to the lifetime, and after the recovery, LLOLE lifetime remains on average as OLE lifetime.The lifetime is increased by developing a schedule for nodes to sleep and wake up to save their energy. The second technique is used to reduce the number of occurrence times of the previously mentioned common cause for loss in OLE to reduce losses and the energy consumed in the recovery from it.

3.2. Losses reduction method

The shape of the constructed tree should be controlled to reduce the occurrence of loss cause; to be more precise, the formation of star topology among CHs should be avoided, the maximum limit or the average value of the "branching factor" which can be defined as the variable number represents the number of children of each parent node should be decreased as much as possible especially the branching factor value of the root node, the branching factor values of all CHs should be convergent to distribute the tree aggregation load among them, and this done by modifying the weight used in the tree construction phase. OLE uses the same weight for head selection and tree construction. To study this weight well, first it should be studied as a head selection weight, the equation of head selection weight should satisfy that relation among its parameters: the less ratio of the average residual energy of node neighbors to its residual energy $\left(\frac{E_a}{E_{residual}}\right)$, the greater the node weight, the greater the likelihood of that node to become a CH (so that the selected CH will collect in its cluster the maximum number of small residual energy nodes decreasing the load on them and giving the other nodes which have relatively higher energy the chance to become CHs), this requires reversing the ratio $\frac{E_a}{E_{residual}}$ which used in the equation of head selection weight in OLE. The weight used in LLOLE for head selection uses the reversed ratio as in Eq. (4). For tree construction phase, the weight in Eq. (4) is not applicable because the tree construction is performed in level 1 of the hierarchy where the network is summarized to the graph composed of CHs only, so, in tree construction phase, E_a has no meaning and no effect, rather, it may have a negative impact on the selection of inappropriate CH as a root; and above E_a at the time of sending Root_Compting_Msg is no longer a correct estimation of the average residual energy at this time, because it is calculated at the start of the round before nodes send and/or receive different numbers of other messages. So, the tree construction weight in LLOLE is calculated as in Eq. (5).

By applying this weight in the example of Fig. 5, two trees will constructed as shown in Fig. 6. As shown in Fig. 6, this weight decreased the branching factors of all CHs and made them convergent, reduced the load on the root node with respect to the number of children (i.e., with respect to the energy consumed in aggregation), select the appropriate CH for the root role which has the largest residual energy and smallest distance to the sink, and reduced the load of the root with respect to the energy consumed in the transmission to the sink. But it should be noted that the number of roots increased which resulted in a reduction in lifetime while the losses were decreased slightly.

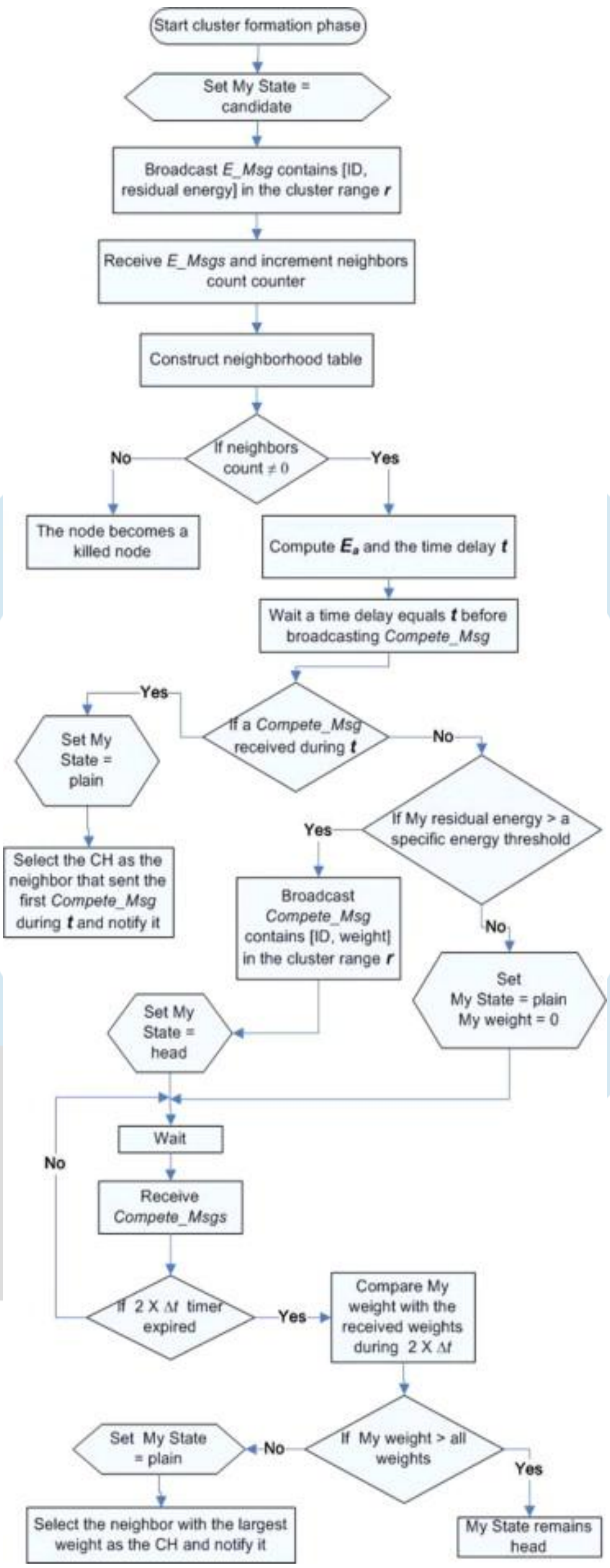


Figure 1: Cluster formation phase flow chart

This problem was solved by making a second iteration for tree construction in which the root nodes formed in first iteration broadcast Root_Compting_Msg message in larger transmission range RR. This message contains the weight of the root calculated as in the first iteration and also contains a list of the children of the sending root. After a specified period, each root

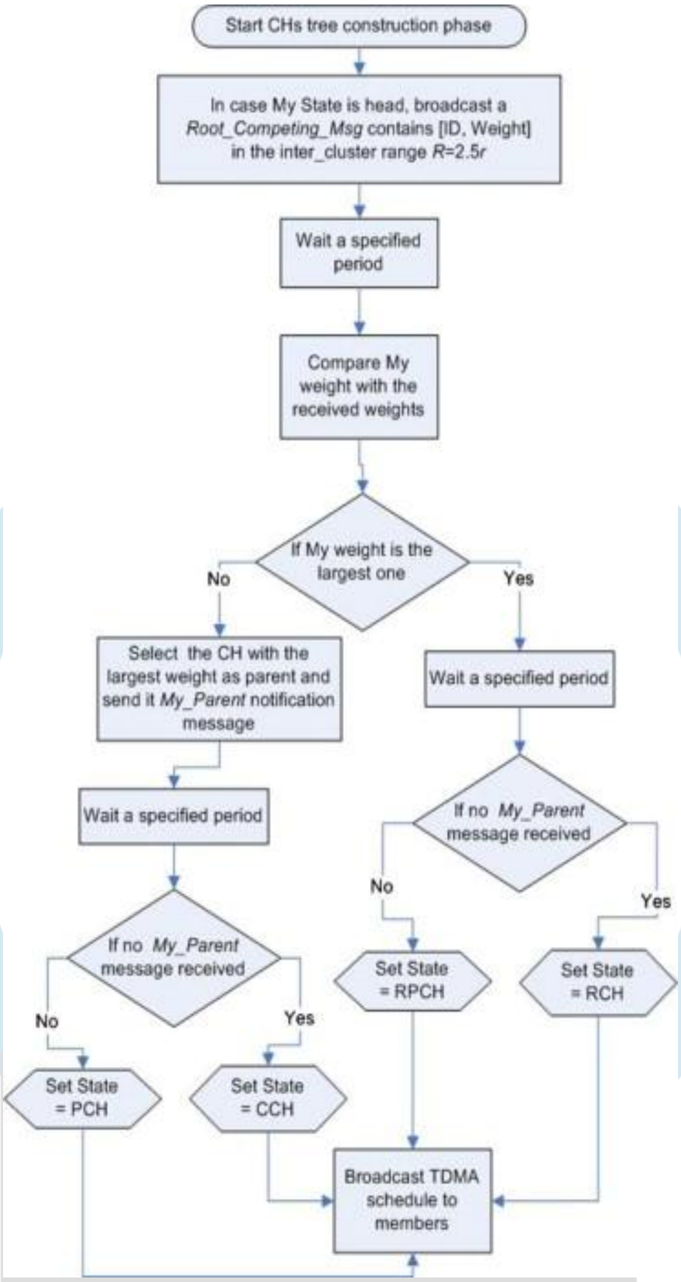


Figure 2: Tree construction phase flow chart

compares the weights it received during this period with its own, if it has the largest weight, it remains a root; if not, before it chooses the root with the largest weight as parent it considers the children of this root, if one of them or more are located in its transmission range R used in the first iteration, it chooses the child with the largest weight as parent, otherwise it chooses the root itself. This decreases the aggregation load on the selected root in iteration2, and decreases the transmission load on the root that joins with its tree the tree of the selected root in iteration2. By this method the two constructed trees in the previous example will be integrated into one tree as shown in Fig. 7. It should be noted that the algorithm still has the advantages of using the modified weight; in addition, the number of roots was reduced and the probability of the existence of an isolated root was also reduced (the second common case of packets loss cause in OLE). But, if the number of roots generated in the first iteration equals one, the second iteration becomes useless, but it wastes time and energy, so to deal with this shortcoming without sending or receiving any additional control messages, all nodes take the decision to use the second iteration for a specified constant number of rounds and invert this decision for another specified constant number of rounds, taking into consideration that the error resulting from the first decision is better than the resulting error from the second decision-making. The used method for aggregation in the protocol cannot be ignored, because it may be a cause of losses. Up to now in OLE and LLOLE implementations, each parent waits after the frame time a period for its children to aggregate their aggregated data with its cluster members' data and send the total

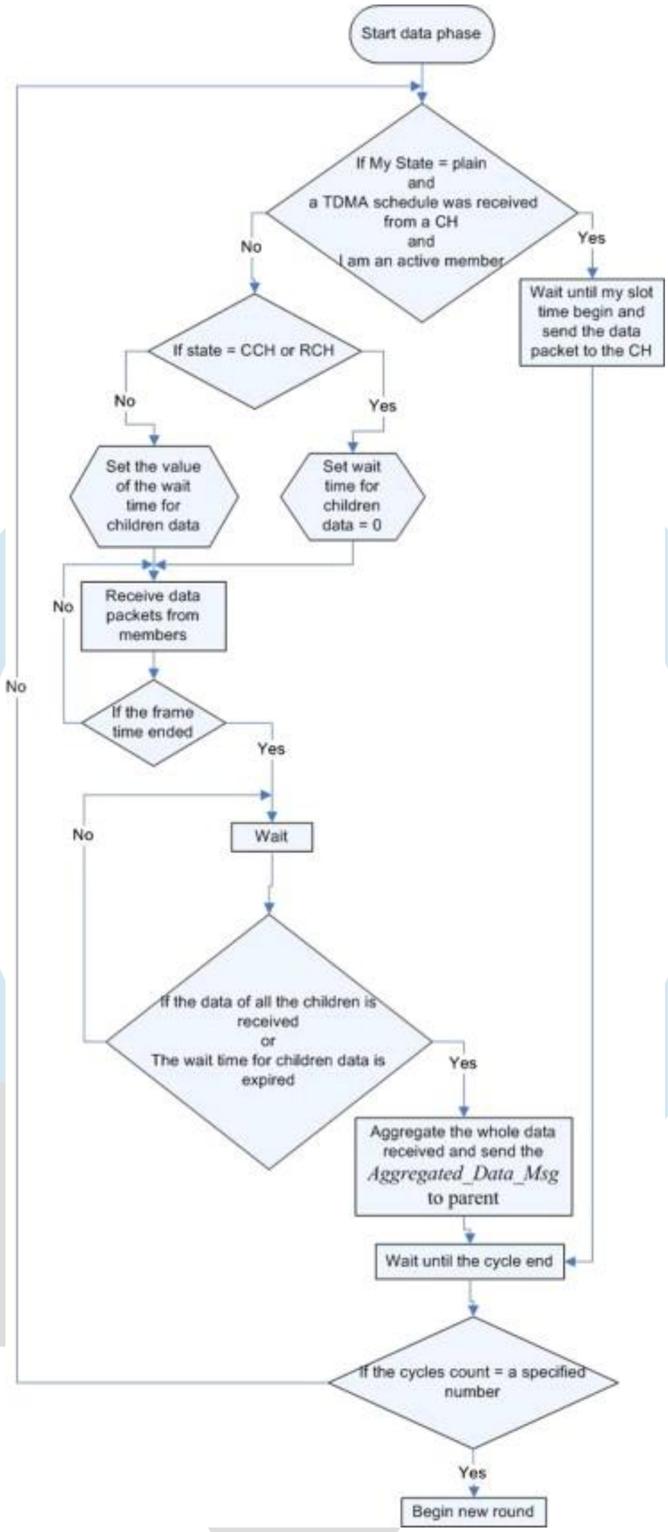
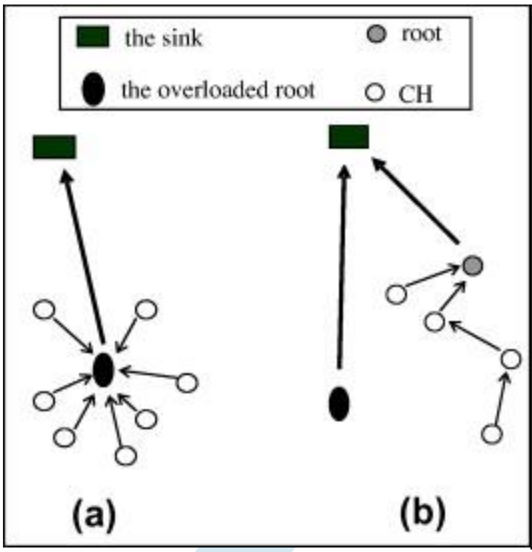


Figure 3: Data phase flow chart.

aggregated data to its parent once. This wait period has been set equal to (2 × expected number of CHs − 2) × T_{child_aggre}, but, the root waits a period equals (2 × expected number of CHs − 1) × T_{child_aggre}, where T_{child_aggre} is the maximum time needed for the packet to propagate from children to parent.

After frame time during this wait period, if a parent received thedata messages from all its children, it will cut this period, aggregate data, and send it to its parent. This aggregation method cannot deal with some situations, such as the situation when a parent waits for one of its children, while this child dead. The parent of this waiting parent will wait it and so on. Because parents stay the same time waiting their children, each child will send its aggregated message to its parent after its parent sends its aggregated message to its parent, so its data will be lost. The solution of this problem is to differentiate the wait time for each



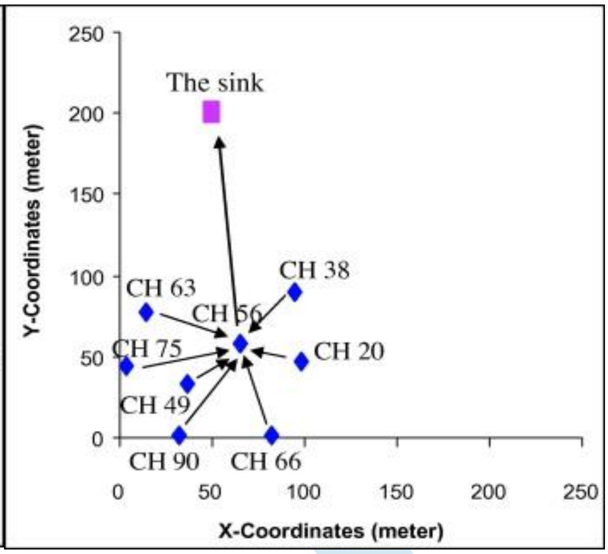


Figure 4: The two common root overload cases in OLE: there is one root and all of the CHs are its children directly and (b) the CH is isolated from the other CHs.

Figure 5: An example of the first case of root overload.

parent according to its level in the tree. This done by maintaining a variable for each CH represents its level in the tree, and initializing it to value "one" at the beginning of each cycle

$$\text{LLEAP CH Selection weight} = \frac{(D(RSS_i) \times E_{residual})}{(D(RSS_{max}) \times E_a)} \ldots\ldots. (4)$$

$$\text{LLEAP tree construction weight} = \left(D(RSS_i) \times \frac{E_{residual}}{D(RSS_{max})}\right) \ldots. (5)$$

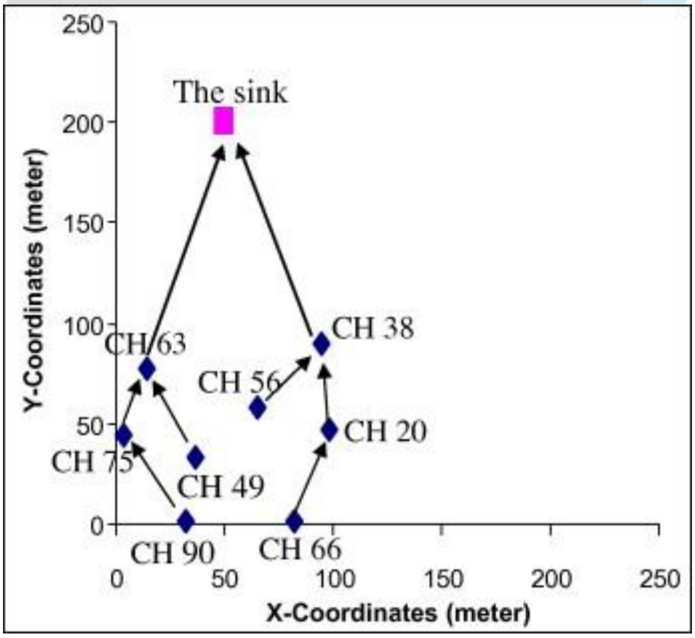


Figure 6: The network of Figure 5 after applying the new weight.

Each head sends its value of this variable with the aggregated data message to its parent, and each parent updates its level variable value at the time for aggregation, and also updates its wait time (see Fig. 8) according to Eqs. (6) and (7) respectively:

The new value (or new level) = previous level + the largest level value among levels in all the aggregated data messages received from its children.

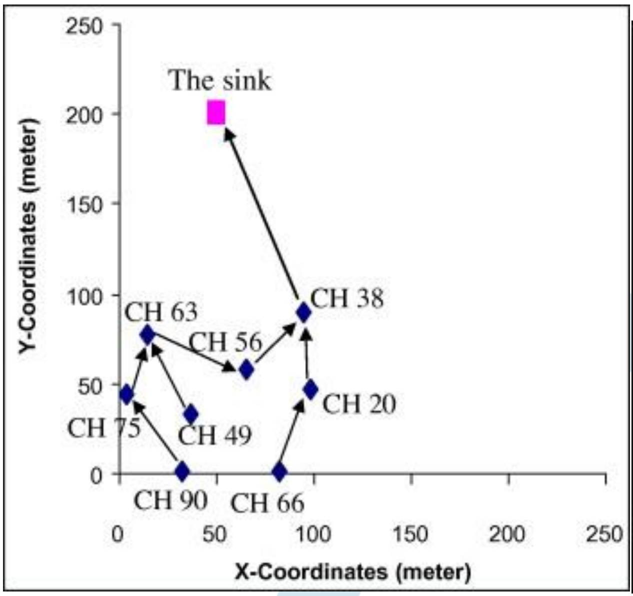


Figure 7: The constructed tree after adding the second Tree construction

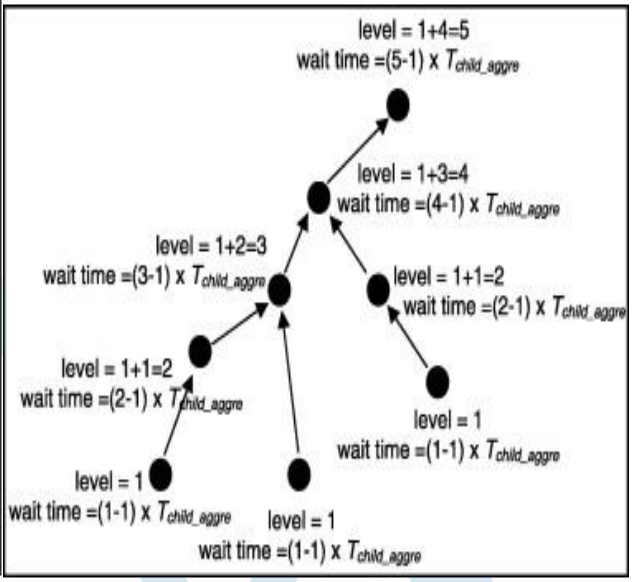


Figure 8: Level and wait time for CHs

IV. THE NETWORK MODEL AND SCENARIO ASSUMPTIONS

The simulation assumed that there are N static sensors nodes are randomly and densely scattered in a two-dimensional square field A, and the sensor network has the following properties:

1. There is only one sink in the field, which is deployed at a fixed place outside A.
2. Sensor nodes are location-unaware, non-rechargeable, and always have data to send.
3. The node can vary its transmission power depending on the distance to the receiver.
4. For simplicity, it is assumed that the probability of signal collision and interference in the wireless channel is ignorable and the radio transmitter, radio amplifier and data fusion unit are the main energy consumers of a sensor node.
5. Packets loss due to factors other than node death does not exist or is ignorable.
6. The Radio H.W. energy dissipation model used is as in [9].
7. The consumed energy in aggregating L k-bit signals into a single k-bit signal = $L \times E_{DA} \times k$, where E_{DA} denotes the energy consumed by data fusion. As assumed in OLE paper, there are five cycles in each round.
8. A node considered to be dead or killed when it becomes not capable of transmitting data to the sink, and this occurs in three cases:

(1)The node residual energy becomes below a threshold (E_{death}) equals to the energy required for a member node to participate in a round, so that it transmits at least one data packet.
(2) There is no head in its cluster range.
(3)There is no any node in its cluster range for any reason and it cannot be a head.

V. CONCLUSION

This paper provides about the optimization lifetime enhancement in wireless sensor network and this technique is successful at various stages during the simulation in terms of QOS. Simulation results show that OLE offers improvement over LEAP, LEAP-C, and HEED in terms of loss percentage, throughput, delay by on average 90.3 %, 8.9%, 1% respectively and lifetime is reduced by 6%.

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