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Implementation of energy-efficent routing protocol within real time clustering wireless sensor networks

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ABSTRACT

Wireless sensor networks (WSNs) are characterized by huge sensors that are having a limited amount of energy and specifying their behavior. Sensor networks combine distributed sensing, processing, and communication capabilities to create a powerful system. There are issues with the length of sensors connected to the network since features inside the sensors frequently require energy, which is likely to limit WSN performance. In creating WSN application architectures, extending network longevity, scalability, and load balancing are important factors. Using clustering techniques, the challenge of prolonging overall network lifetime and increasing the first dead node duration in the network may be tackled. Clustering is a valuable approach for breaking a network into parts known as clusters and giving solutions for energy consumption concerns including data collection, aggregating, and routing to sink nodes by cluster heads (CHs). In this paper, we suggest optimum clustering in multi-path and multi-hop protocols as a feasible option for reducing energy consumption and extending the lifetime of wireless sensor networks. In compared to the low energy adaptive clustering hierarchy (LEACH) clustering method, simulation results show that the new technique, optimal real time clustering (ORTC), is promising in terms of extending network lifetime.

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1. INTRODUCTION

In recent years, researchers have focused research efforts on optimizing energy consumption of wireless sensor networks (WSNs). Works had been carried out to prolong network lifetime, reduce consumped energy and improve network's performances in terms of stability and reliability [1]. WSN sensor nodes are resource restricted in terms of energy, communication range, memory capacity, and computing capabilities. Target tracking, environmental monitoring, and warfare applications are examples of WSN requirements and applications. In a multi-hop architecture, the fundamental purpose of WSNs is to distribute information from the source to the sink [2]. Towards achieving these, various protocols have been proposed. These protocols are commonly referred to as energy-efficient algorithms [3]. The algorithms have been implemented in various wireless protocols such as low energy adaptive clustering hierarchy (LEACH), ad hoc on-demand distance vector (AODV), and threshold-sensitive energy efficient sensor network (TEEN) protocols. However, further studies are required to investigate the potential of these protocols in increasing network lifetime and decreasing energy consumption [4].

LEACH protocol [5] organizes entire network nodes to small clusters and selects one node as a cluster head (CH). In every cluster, a node first senses its destination prior to transmitting data to the CH in the cluster [6]. Then, the CH receives all data from all nodes and compresses, aggregates and directs information to base station (BS). These nodes that are elected as cluster heads exhaust greater power associated to further nodes by way of, they are essential to transmit information to a selected base station. LEACH protocol rotates all nodes that are required to act as cluster heads arbitrarily so as to distribute energy consumption in the wireless network. Time division multiple access (TDMA) [7], code division multiple access (CDMA) medium access control (MAC) is utilized to reduce inter-clusters and intra-clusters conflicts. LEACH protocol is utilized for monitoring application and centralizing information in the base station that is periodically updated [8].

LEACH protocol procedures may be categorized into two phases: i) setting up leach protocol phase and ii) steadying leach protocol phase. In the first phase, clusters are shaped, and cluster heads are elected in every cluster. However, related to second phase, the information could be aggregated and transmitted to the BSs [9]. The steadying phase requires a longer time as compared to setting up phase, so as to minimize cost.

a. Setting up phase: during this phase, preformulating part of nodes elect themselves as cluster heads. T(n), threshold value, is obtained through computing chosen ratio of cluster head, P, present round, r_d, then number of nodes which could yet for being selected by means of cluster head, G at previous rounds, 1/P [10]. Setting up phase is formally expressed as (1):

$$T_n = \frac{P}{1\text{-P}} \times \left[\text{r mod}(\frac{1}{P})\right] \quad (1)$$

$$T(n) = 0 \; else$$

Each node that assumes a role of a cluster-head selects an arbitrary value that is less than 1. As this arbitrary value is lesser than T(n), the node would be elected as CH during the present round. Subsequently, the chosen CH sends a message (advertisement message) to all nodes within the entire wireless network and requests to connect to their cluster heads [11].

Depending on the advertisement signal strength, member nodes that receive the message will agree to connect to clusters [12] and notify their own CHs within their cluster via transmitting message of an acknowledgement (Ack message). Subsequently receive an Ack message, based on participant nodes number within the clustering-head in addition to the kind of demanded data_for the wireless network within the system, heads in the clusters will subsequently take actions. The heads in the clusters will generate a TDMA schedule and give every node its own time slot, in which it can send sensing information. All members in the cluster will receive the TDMA schedule [13]. When the dimensions of any cluster become very large, the CH will select a new cluster-head as its cluster. The node that has been elected as a CH in the present round will not be able to become a CH again if all member nodes in the network have not become a head in the cluster [14].

b. Steadying phase: during this phase, member nodes in the cluster begin detecting and transmitting information to their CHs depending on TDMA schedules [15]. All cluster heads will receive information from their member nodes, aggregate, and transmit the information afterward to BS. After a certain period of time, the network will initiate the setting up phase again to elect new CHs. Every cluster that is connected utilizes varied CDMA codes for reducing interference from nodes which belong to other clusters [16].

In this paper, the proposing of different improving energy-effective optimal real time clustering (ORTC) protocol to address the shortcomings of current techniques and prolong the WSNs lifetime even further. This suggested protocol adds four parameters: beginning nodes energy, remaining nodes energy, the network's total energy, and in addition to the network's average energy in the threshold setting. For assessing the implementation method of the proposed ORTC, an extensive ran simulation in MATLAB. From the perspective of network prolonged existence, the simulation findings show that the ORTC algorithm outperforms and considered an energy-efficient protocol designed to increase network lifetime.

2. METHOD

Transmission and receipt of data packets are the primary sources of energy consumption in WSNs [17]. As a result, we must properly regulate and manage energy usage in order to create energy-aware routing protocols for WSNs. The absence of energy consumption control caused by the many-to-one traffic scheme would result in the rapid loss and destruction of energy resources of nodes near the sink, which is referred to as the energy hole problem [18]. The energy hole problem and the periodic choosing of the ideal path have an influence on the life time of WSNs in the majority of routing algorithms. The network will be partitioned as a result of these two issues, and the WSN will be unable to perform its vital job.

Explaining LEACH operations may be distributed into many rounds. For each one, begins with a setting up phase (first phase) then ends with a steadying phase (second phase) as explained in Figure 1. In the first phase, clusters are formed while in the second phase, information is sent to a BS [19]. In the setting up phase, whereby in off state, the protocol determines if a sensor node requests for being a CH or otherwise, based on the situation of residual energy and the frequency it has been elected as a head in the cluster. The protocol checks the value of an arbitrary number between 0 and 1 [20]. After a certain time, if the value selected is lower than threshold value, then an elected node can become a cluster-head within a next round. This threshold value is resulted from (1), the p represents the probability of CH selection (chosen by cluster), r denotes present round, 1/p represents a nodes group which had been elected in place of cluster-heads in the last round [21]. Within the first step, all sensor nodes possess an opportunity for being chosen as cluster-heads depending on their respective probability value [22]. After the election of a node as a cluster head, then such node would not be allowed for becoming cluster-head for the next 1/p round. If a probability of becoming a head in the cluster is very low for some nodes, according to the protocol, most nodes would stand a chance to be chosen as a head in the cluster. When the cluster-head is elected, it declares its location by sending an advertisement message (ADV) [23], [24]. An ADV contains a small message comprising a node ID in addition to the header that represents an announcement message. ADVs are saved by all nodes, which may be received for following rounds. The cluster-heads appointment is implemented according to received signal strength. In case of a probability resulting from the algorithm does not elect a cluster-head, the selection of one cluster-head will be executed at random. Every member node sends a request message as a membership to the cluster head [25].

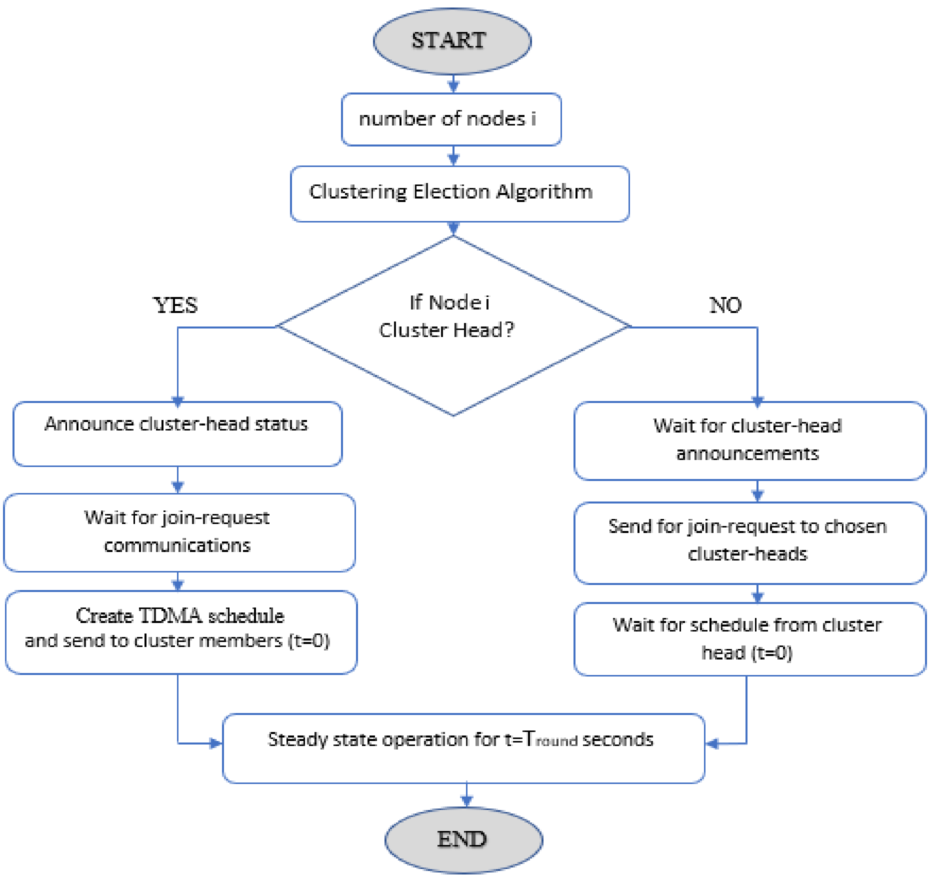

Figure 1. LEACH protocol

3. OPTIMAL REAL TIME CLUSTERING APROACH

The ORTC routing protocol is improved by including energy-efficient routing structures as well as multi-hop intra-cluster [26]. Operations of an ORTC protocol can be divided within two phases, whereby, the phase activates by a setting up phase to prepare clustering, followed by a steadying state phase, in which information is sent to a BS [27]. Flow chart in Figure 2 represents the operation of this protocol. At first, the operator must give an input corresponding to the number of nodes. Positions of nodes are generated randomly and displayed. When the nodes are positioned, every node utilizes neighboring detection algorithm for determine such neighboring nodes [28]. Through utilizing the algorithm of cluster head assortment, cluster-heads may be chosen amid the nodes. Such CHs guide ADV messages to all neighbor nodes. Clusters stand designed within the static bound size. Every cluster node establishes a routing flowchart that nodes data routing may be updated. Depending on randomly distribution time slot assignment (DRAND) process that was applied, various time slots are created for nodes that share similar frequency channel. CH collects information from all member nodes in the cluster and aggregate and forward this information to BS [29].

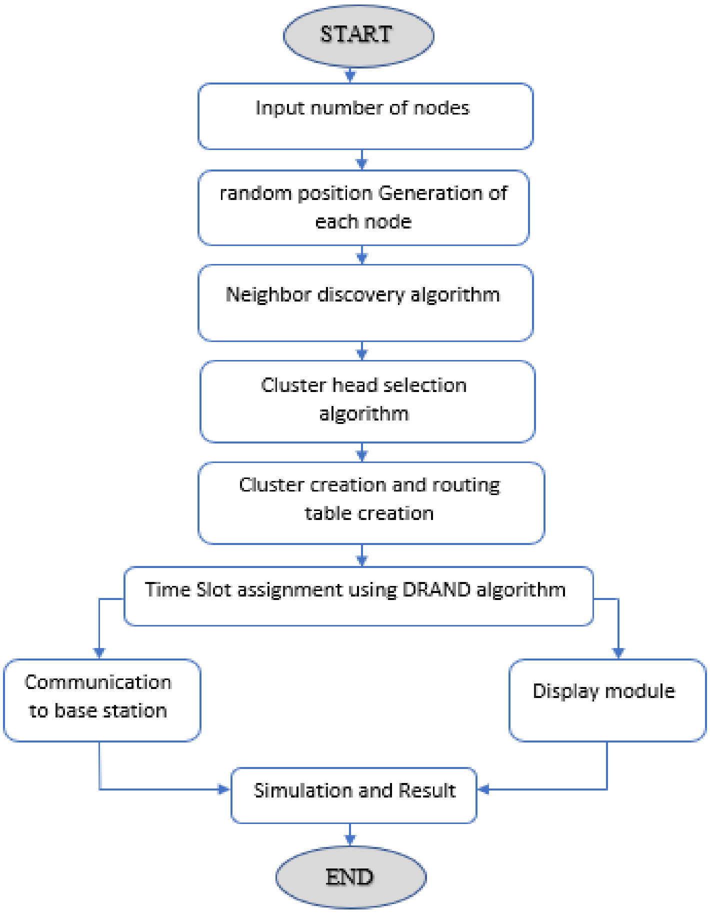

Figure 2. ORTC flowchart

4. NETWORK PARAMETERS AND ASSUMPTION

The LEACH and ORTC were simulated using MATLAB. Several parameters were put into consideration while validating these protocols, as shown in [30]: i) the rounds number versus dead nodes number with changing p value (probability value), ii) rounds number versus all node's typical energy with the changing of p value, iii) rounds number versus dead node number, and iv) rounds number versus typical energy of any nodes with a changing no. of nodes. By implementing these two selected protocols simulation, some initialization hypothesis had been prepared, as shown: i) all nodes begin at the same initial energy, ii) nodes positions be fixed or static, iii) they posses very limit domain of transmission until another energy dissipation equation is utilized, iv) nodes are distributed in homogeneous category, and v) all nodes are in send state.

Even though SNs are often powered by batteries, their lifetime is limited and dependent on their limited energy source. As a result, one of the most difficult concerns in WSN is energy consumption. Several strategies, protocols, and algorithms have been presented to address this difficulty, concentrating on how optimizing energy usage, eliminate interferences due to transmission, also extend the lifetime of nodes. Table 1 gives the WSN's parameter arrangements that are employing within the simulation.

Table 1. Simulation parameters

Parameter	Value
Simulation Area	150×100 m^2
Channel type	Wireless channel
BS Location	(150,50)
Energy Model	Battery
Transmitted amplifier	12 pJ/bit/m^2
Transmitted amplifier Emp	0.0015 pJ/bit/m^2
Data aggregation Energy	6 mJ
Transmitted Energy E Tx	60 nJ
Received Energy E Rx	60 nJ

5. RESULTS AND DISCUSSION

Clustering can be considered as the greatest effective techniques for connection, covering, and lifetime enhancement in network management, in which a collection of sensor nodes forms a cluster whereby a nodes communicate with one another and transmit such sensed data for the significant node labeled CH. CH nodes and cluster sensor nodes (CS) are the two types of nodes in the cluster. Each cluster contains one CH at least, which is responsible for collecting data from totally SNs in the cluster then sending it to the BS in the form of sink node. Figure 3 presents the results of simulated protocols for LEACH and ORTC protocols under 0.2 probability value. The probability value describes a 2% chance of whole nodes becoming cluster heads.

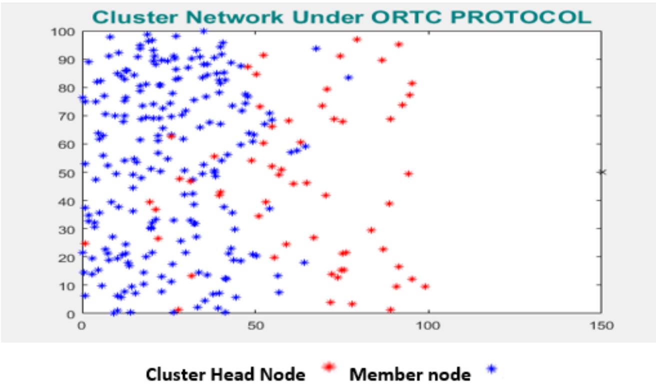

Figure 3. Wireless sensor network of ORTC for 500 nodes

Based on Figures 4 and 5, the energy average of a node under ORTC protocol is higher than energy average under LEACH. This suggests that the proposed protocol may work effectively depending upon a dead nodes numbers, while Figure 6 shows alive nodes comparison. After fifty rounds, alive nodes under LEACH protocol approaches zero as all nodes exhausted their energies. In contrast, the number of the alive nodes in the proposed protocol after 100 rounds is about 300, which may indicate the prolonging of network lifetime and perhaps showing a good performance for the sensor network.

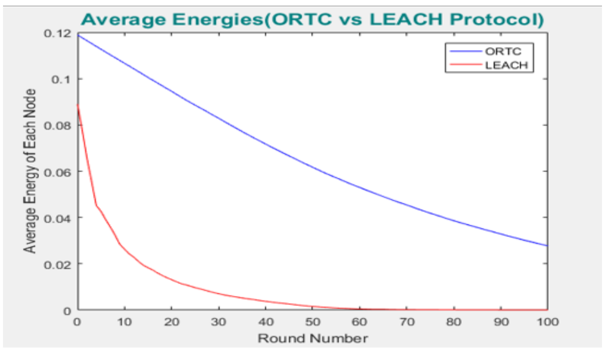

Figure 4. Average energy of each node

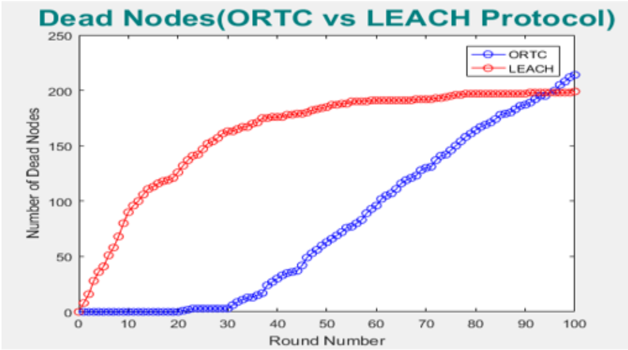

Figure 5. Comparison the dead nodes between ORTC and LEACH protocol under 100 rounds

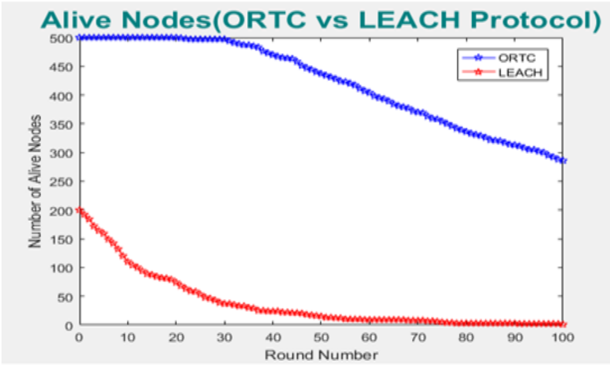

Figure 6. Comparison of alive nodes between ORTC and LEACH protocols under 100 rounds

Figures 7-9 show that the proposed approach ORTC protocol contain CH that can still transmit packets after round fifty effectively, thus increasing the packet transmission rate. On the other hand, the LEACH protocol has stopped transmitting after 50^{th} round with the number of CHs lesser than the CHs of the proposed protocol. This suggests that LEACH is only suitable to be used in small network while the ORTC protocol may be applied in a larger network with high transmission reliability.

From the simulated results, the proposed protocol ORTC provides a greater number of alive nodes as compared to LEACH. This insinuates that data transmission rate in ORTC is higher, which consequently increases network lifetime. This protocol would allow average energy of nodes to be preserved which would likely reduce battery replacement issue. ORTC is promising as compared to LEACH protocol that suffers from various drawbacks such as resulting in greater overhead while implementing dynamic clustering, arbitrary CH election that ignores consumed and residual energy, covers a small area and CHs positions that are not organized and distributed uniformly.

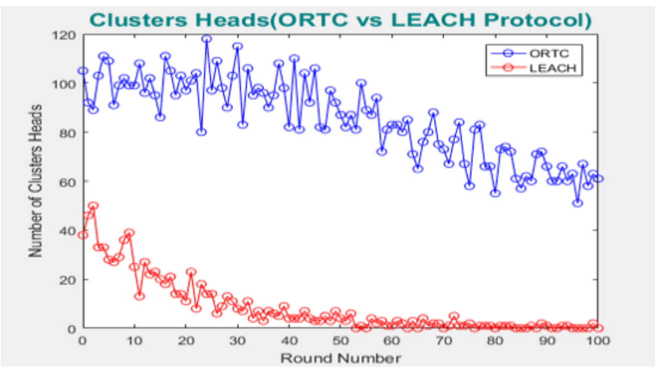

Figure 7. Comparison CH nodes between ORTC and LEACH protocol under 100 rounds

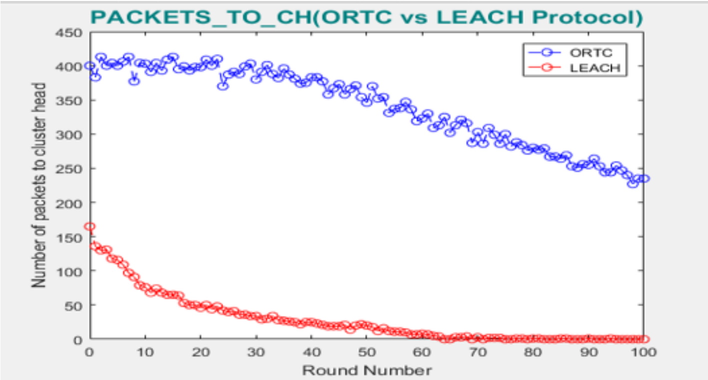

Figure 8. No. of packets sent to CH for both ORTC and LEACH protocol under 100 rounds

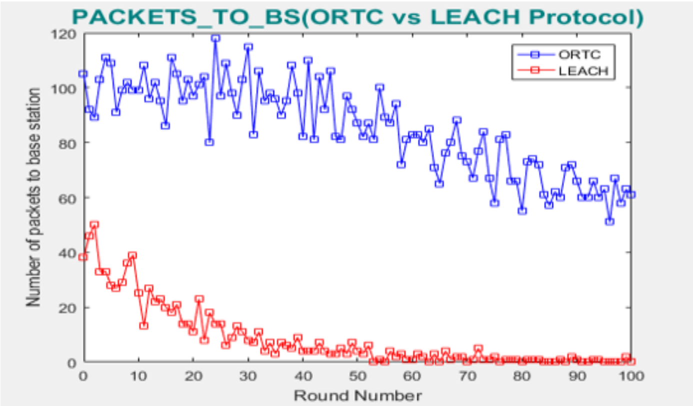

Figure 9. Packets sent to BS for both ORTC and LEACH protocol under 100 rounds

6. CONCLUSION

In order to develop WSNs applications, energy efficiency, sensor nodes deployment, and the communication interfering reduction are all essential considerations. Sensor node types, ideal number of nodes and clusters, and sensor node placements must all be carefully considered. This is to make it easier to improve performance needs such sensing, coverage, connection, network longevity, and data dependability. So, based on the findings of the network simulation, energy consumption has been lowered by adopting the newly suggested protocol on wireless sensor network design. The protocol also addresses the issue of energy balancing by spreading load and energy consumption throughout the network's nodes. The proposed protocol modifies the TDMA schedule each time it elects a new CH in order to coordinate communication across sensor nodes. The protocol also ensures that all nodes are informed, which directly solve energy problem. Moreover, the protocol managed to show promising results in terms of energy average, when simulated in a long transmission sensor network. From the analyses of the simulated result, LEACH should only be favored in cases of small network where the whole number of nodes is lower than fifty nodes, whereas the ORTC should be chosen for application in a large network. The ORTC also affords greater probability percentage for a CH to be elected among nodes, which reduces energy consumption, extends network lifetime while at the same time improving packets transmission rate.

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