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CIRCLES ROUTING PROTOCOL FOR WIRELESS SENSOR NETWORK

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***Abstract**: Wireless Sensor Network (WSN) is an emerging technology for monitoring physical world. WSN consists of large number of sensor nodes operated by battery mostly in harsh environment. These wireless nodes are very limited in battery power and communication processes. Gathering sensed information in an efficient manner is critical to operate the sensor network for a long period time. In this paper, a new Routing Protocol CRP (Circles Routing Protocol) is proposed. The CRP is developed for achieving QoS (Quality of Service) in terms of network life time, power consumption, packet delivery, and network throughput by distributing the energy load among all sensor nodes. The dynamic behavior of the proposed CRP depends on executing the following steps.Firstly, CRP cutting down the playground into many clusters by using the advantage of the grid construction to physically partition the playground into many small individual clusters. Secondly, CRP electing one node in each cluster, as a Cluster Head (CH), form a circular chain within each cluster to collect and fuse data from the other nodes. Thirdly, CRP collecting every four adjacent clusters in one group called inter four clusters. Then, CRP constructing a circular chain within these four clusters containing the four CH nodes. Fourthly, CRP electing one of these CH nodes as an inter CH node to collect and fuse data from the other CH nodes. Finally, CRP constructing a circular chain containing the four inter CH nodes. Then CRP electing one of inter CH nodes to be the outer CH node which collects and fuses the data from the other nodes and subsequently transmit this data to the Base Station (BS). In the performance analysis, we use the NS-2 Simulator as a simulation technique to study and analysis the performance of CRP protocol. To verify from the correctness of the obtained performance results, we compare the CRP results with those obtained from LEACH (Low-Energy Adaptive Clustering Hierarchy) and PEGASIS (Power-Efficient Gathering in Sensor Information System) protocols.*

***Keywords:** Wireless sensor network, Routing Protocols, Chain based routing, LEACH Routing Protocol, PEGASIS Routing Protocol.*

1. Introduction

Rapid technological advances in micro-electro-mechanical systems (MEMS) and low-power wireless communication have enabled the deployment of large scale wireless sensor networks [4]. The potential applications of sensor networks are highly varied, such as environmental monitoring, target tracking, and battlefield surveillance. Wireless sensor network is composed of hundreds or thousands of sensor nodes which are usually battery-powered and deployed in an unprotected environment to collect the surrounding information and then transmit report messages to a remote BS [21]. The BS aggregates and analyzes the report messages received then decides whether is there an unusual or exceptional event occurrence in the deployed region [3]. These WSNs can be used in a various applications such as disaster management, military field reconnaissance, border protection and security surveillance [24,15,18]. WSNs have unique characteristics such as denser level of node deployment, higher unreliability of sensor nodes, severe energy computation, and storage constraints [22,23], which present many new challenges in the development and application of WSNs.

In recent years variety of protocols were proposed for prolonging the life of WSN and for routing the correct data to the base station, such as LEACH Routing Protocol [1,2,5,8,9,12] that uses single-hop routing and consider dynamic clustering every round, Therefore, it is not applicable to networks deployed in large regions and consumed much computation power. CHs consume a larger amount of energy when they are located farther away from the sink. PEGASIS Routing Protocol [2,5,7,10,11] which doesn't have dynamic topology adjustment, since a sensor node needs to know about energy status of its neighbors in order to know where to route its data. Such topology adjustment increases the delay time and computational power of the nodes. PEGASIS assumes that each sensor node able to communicate with the BS directly, and random selection of the leader nodes leads to poor consideration of communication range and connectivity of nodes. In practical cases, sensor nodes use multi-hop communication to reach the BS. TEEN Routing Protocol [5,13] that constructs the clusters in complex way, which consumes computational power and increases the network overheads.

In this paper, we propose a new routing protocol called CRP (Circles Routing Protocol). The proposed CRP protocol exploits a new cost function for routing, which considers the energy state of each sensor node as well as fixed cluster formation. The core of CRP is to guarantee the connectivity of the network, save energy cost, extend the network life time, improve network throughput, minimize the transmission delay, and enhances the average delivery ratio. The proposed CRP uses the advantage of dividing the playground by using the Grid theory [16] to divide playground (sensing area) into many clusters, CRP arranges the wireless sensor nodes into numbers of chains according to the number of formed clusters, and it runs in two phases.

- In phase one: CRP works in each single cluster individually by constructing a circular chain and elects the CH node from the nodes on the circular chain. Which collects data from the circle nodes and fuses them in one data structure.
- In phase two: CRP cuts the Playground into four main equal clusters (outer four clusters), each one of these clusters will be cut into four equal clusters (inter four clusters) as shown in figure 1. Then CRP elects the Inter Cluster Head node (ICH) for inter four clusters between the four CH nodes. The elected ICH collects the data from the other CH nodes and fuses them to become one data structure. Then CRP elects Master Cluster Head node (MCH) for the outer four clusters between the four ICH nodes. The elected MCH collects the data from the other ICH nodes and fuses them to becme one data structure then subsequently transmits these data directly to the BS.

The rest of this paper is organized as follows: Section 2 presents related work. Section 3 presents the contributions of the research work. Section 4 describes the modeling assumptions. The Proposed CRP Protocol is described in detail in Section 5. Section 6 describes the simulation method. Section 7 presents simulation results and discussions. Conclusion and future work are presented in Section 8.

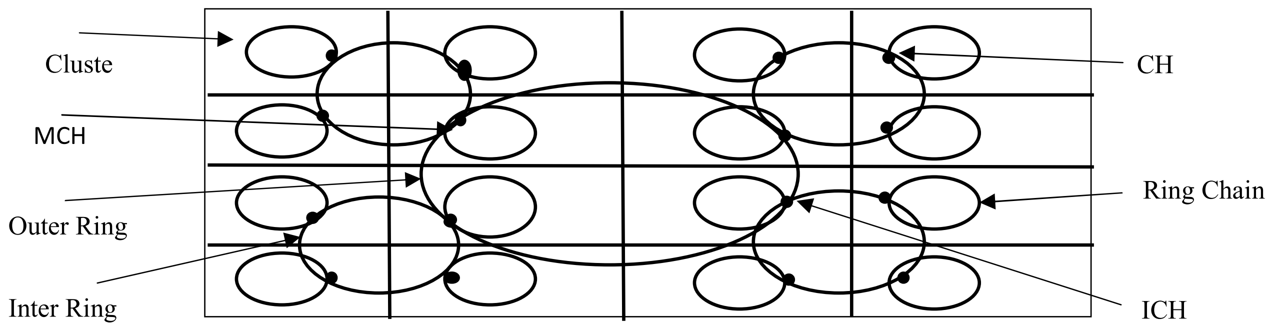

Figure. 1 : CRP Circles Scenario

2. Related Work

During the last few years, many energy efficient clustering protocols have been proposed for wireless sensor networks to prolong the network lifetime. We review some of the most recent and dominate work. LEACH [1,8,9,12] is the first and most popular energy efficient hierarchical clustering algorithm for wireless sensor networks that was proposed for reducing energy consumption. The operation of LEACH is divided into rounds which each round consists of two phases, the set up phase and the steady state phase. In the set up phase, cluster heads are selected and clusters are organized. In the steady state phase, the actual data transmissions to the BS take place. After the steady state phase, the next round begins. During the set up phase, every sensor node elects itself as cluster head with some probability and broadcasts its decision. The remaining sensor nodes receive the broadcast from one or more cluster heads and make their association decision based on minimum communication cost. Energy of the cluster head node is dissipated at higher rate than ordinary sensor nodes. To balance the overall energy consumption across the network, the role of the cluster head is rotated among all sensors. Another disadvantage of LEACH is that it does not guarantee good cluster head distribution and assumes uniform energy consumption for cluster heads, also it has short network life time due to the direct communication between each sensor node and the cluster head node to deliver the data, and it consumed a large amount of power due to the dynamically construction of clusters every round.

PEGASIS [2,5,7,10,11] is a chain based power efficient protocol constructed on the basis of LEACH. Rather than forming multiple clusters, PEGASIS forms a chain from sensor nodes so that each node receives from and transmits to a neighbor and only one node is selected from that chain as leader node to transmit to the base station [6]. PEGASIS eliminates the overhead caused by dynamic cluster formation in LEACH, and decreases the number of transmissions and receptions by using data aggregation although the clustering overhead is avoided, but considering this topology increases the delay time and computational power of the nodes. However, the communication achievement faded by the excessive delay introduced by the single chain for the distant node. Also random selection of the leader nodes and communicating each node with the neighbor node only leads to poor consideration of communication range and connectivity of nodes.

TEEN [5,13] Threshold sensitive Energy Efficient sensor Network protocol, is a hierarchical protocol whose main goal is to cope with sudden changes in the sensed attributes such as temperature. The nodes sense their environment continuously, but the energy consumption in this algorithm can potentially be much less than that in the proactive network, because data transmission is done less frequently. In TEEN, a 2-tier clustering topology and two thresholds, hard threshold and soft threshold, are defined.

The former threshold is a threshold value for the sensed attribute. It is the absolute value of the attribute beyond which, the node sensing this value must switch on its transmitter and report to its CH. However, there exist a few drawbacks in TEEN as follows: (1) It is not suitable for periodic reports applications since the user may not get any data at all if the values of the attributes may not reach the threshold, (2) There exist wasted time-slots and a possibility that the BS may not be able to distinguish dead nodes from alive ones, because only when the data arrive at the hard threshold and has a variant higher than the soft threshold did the sensors report the data to the BS; (3) If CHs are not in the communication range of each other the data may be lost, because information propagation is accomplished only by CHs. Also TEEN constructs the clusters in complex way, which consumes computational power and increases the network overheads.

Tang et al [5,14] proposed a Chain-Cluster based Mixed routing (CCM) algorithm for wireless sensor networks. CCM, organizes the sensor nodes as a set of horizontal chains and a vertical cluster with only chain heads. Data transmissions in CCM proceed in two stages: chain routing and then cluster routing. In the first stage, sensor nodes in each chain transmit data to their own chain head node in parallel, using an improved chain routing protocol. In the second stage, all chain head nodes are grouped as a cluster in a self-organized manner, where they transmit fused data to a voted cluster head using the cluster based routing. But this routing protocol suffers from short network life time, it has high communications overhead, and it is used in a special kind of networks and can't be generalized.

3. Contributions of the proposed research work:

- Design static clustering routing protocol (CRP) using grid theory, taking fixed shape advantages of clusters to achieve: (i) eliminating adaptive re-clustering every round to save power consumption, (ii) enhancing network connectivity between nodes, (iii) increasing wireless sensors network throughput, (iv) avoid deploying the sensor nodes in one cluster to decrease the transmission overheads and delay time.
- Extend the wireless sensor nodes life time by cutting down the playground to many small pre-defined clusters. CRP will operate in each single cluster individually, then joins every four adjacent clusters together to form new bigger clusters.
- Split the playground to three consecutive levels of clusters (basic level, inter four clusters and outer four clusters) that lets CRP benefits dealing with small amount of sensor nodes which reduces the power consumption.
- Eliminate the direct communications between CH nodes and the BS, by developing three levels of CH nodes, where every CH node sends the collected data to the next level of CH nodes. This consumes less power and remains for a longer time.
- Develop a model for the communication between the three levels of CH nodes.
- Develop a model for NS-2 simulator, describing the performance of the proposed CRP protocol.

4. Modeling Assumption

a- Nodes are dispersed randomly among a 2-dimentional space e.g. (X , Y).
b- All sensor nodes are homogeneous and have the same initial energy supply (battery power).
c- Radio channel is symmetric, i.e., the energy consumption for transmitting a message from one node to another is the same as on the reverse direction.

4.1 Radio Energy Model

The energy model presented in [17,19] is adopted for the communication energy dissipation. The energy expended to send a k-bit message over a distance d for each sensor node is as in equation (1).

$$E_{TX}(K,D) = \begin{cases} KEelec + K\varepsilon_{fs}\, d^2 & ,d < d0 \\ KEelec + K\varepsilon_{amp}\, d^4 & ,d \geq d0 \end{cases} \quad (1)$$

Where $Eelec$ is the amount of energy consumed in electronics, ε_{amp} and ε_{fs} are the energy consumed in amplifiers. The energy expended in receiving a k-bit message is as shown Eq. (2).

$$E_{RX}(K) = K * E_{elec} \quad (2)$$

The energy expended for aggregating m data packets to a single packet is as follows (in equation (3))

$$E_{fuse}(m,k) = m * k * E_{DA} \quad (3)$$

The electronics energy E_{elec}, is the energy dissipated per bit to run the transmitter or the receiver circuit, and depends on factors such as the digital coding, and modulation. Whereas the amplifier energy, $\varepsilon_{fs}\, d^2$ or $\varepsilon_{amp}\, d^4$, depends on the acceptable bit-error rate. From Equation (2), we can see that receiving data is also a high overhead procedure. Thus, the number of transmission and receiving operations must be cut to reduce the energy dissipation.

5. The Proposed CRP Protocol

In all clustering protocols, CHs manage all the nodes, collects data from the nodes, aggregates data, and then sends the aggregated data to the next cluster head in order until it reaches the BS. Some of the clustering protocols periodically re-cluster the network in order to distribute the energy consumption among all sensor nodes in a wireless sensor network. These protocols suffer from energy consumption of dynamic clustering formation overhead. In static clustering protocols, clusters are formed once and the role of the CH is rotated among the nodes in the cluster. Static clustering eliminates the overhead caused by dynamic clustering formation, but the fixed clusters do not allow new nodes to be added to the network, and the nodes performance is not affected by nodes death. In this section we present a new efficient routing protocol that achieves minimum energy consumption, minimum delay, and long network life time. CRP divides the playground (sensing area) into many predefined static clusters (According to the area to be served) by using the Grid Algorithm, each of these clusters will have one circular chains to collect the data from the sensor nodes, Greedy algorithm is used to construct these circular chains in every predefined cluster, the proposed CRP algorithm will deal with a limited number of nodes in each cluster so there will not be so much data transmission delay because of large number of hops in a long chain as in some other clustering protocols. The operation of CRP protocol is organized as rounds, each round of this protocols consists of two phases.

- Clustering and chain formation phase.
- Resizing the clusters and aggregating data Phase.

5. 1 Clustering phase

This phase is responsible of (i) forming clusters and choosing the Cluster Lead node (CL) for each cluster depending on the internal residual energy of each node and its distance away from the middle of that cluster. (ii) Forming a circular chain which all the nodes in the cluster will follow to transmit their data to the next node in order. (iii) Electing the CH nodes according to the residual energy of the nodes and the minimum distance between the nodes and the edge of the cluster in the direction of the BS. Because of much overhead of clustering process, this phase is not performed in each round, it takes place for first time and remains until all sensor to die. If the CH node gets to the residual energy threshold, the CH sends a message to BS and informs it that the sensor nodes will elect a new CH in the next round. This phase is made up of three stages.

5.1.1 Formation of Clusters

By using the Grid formation algorithm [16], we can divide the playground into equally sized clusters, as shown in figure 2. The algorithm of constructing the Grid:

```
For x=0 to x=n
    For y=0 to y= m
        Do
            {   (f(x,y) = ( X0+xZa, Y0+ yZb )    }
```

X0: The point which has X =0. Y0: the point which has Y=0. (X0, Y0) = (0, 0)
Za: The length of the cluster. Zb: The width of the Cluster.
n-: number of horizontal lines. m: the number of vertical lines.

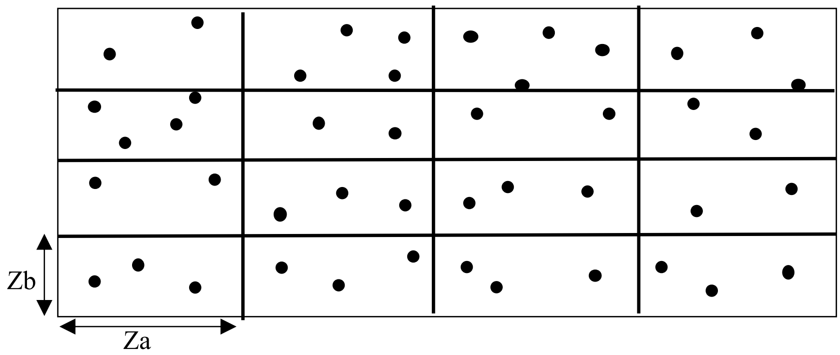

Figure. 2 : Formation of Gird

5. 1. 2 Chain Formation within each Cluster

In each cluster the CRP will select one node as Cluster Lead node (CL), according to the maximum residual energy between the nodes in that cluster and the shortest distance to the center of the cluster. The CL node applies the greedy algorithm to form a circular chain centered at the center of that cluster, with diameter = d within each individual cluster. Where d = minimum of ((Za) or (Zb))*p, where p takes value between (0-1). As shown in figure 3, so each node on that circular chain will collect the data and transmits it to the neighbor node (next in order) until reaching the CH node, which collects the data from all nodes in the circular chain and fuses them in one data structure. As shown in the figure 4.

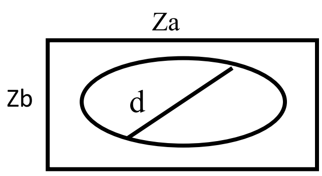

Figure. 3 : Properties of the Cluster

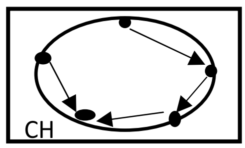

Figure. 4 : Circle Chain

5. 1. 3 Cluster Head Election

The CL node in each cluster maintains a neighborhood table to store the information about its neighbors. In clustering phase each node in one cluster broadcasts a message containing information about its current location and residual energy using Carrier-Sense Multiple Access (CSMA) protocol within its radio range until reaching the boarders of the cluster [6]. All nodes within the radio range of one node can be seen as the neighbors of that node. Each node receives the message from all neighbors and updates the neighborhood table then sends it to that CL node which collects all the messages from the nodes, and refine them. As shown in fig 5, the CL node elects the CH node according to the highest weight using equation (4) [17,19].

$$\text{Weight} = \frac{REi}{\text{Dist}^2\ x} \qquad (4)$$

Where REi : Residual Energy of node i.

Dist^2 x : Distance between node i and the cluster edge.

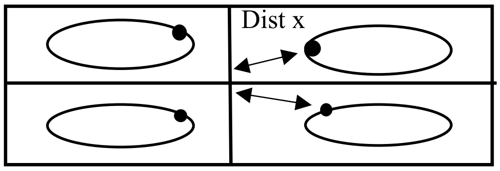

Figure. 5 : Distance between a node and a cluster edge

5.2 Resizing the clusters and aggregating data Phase

The routing protocol CRP will perform groups of circular loops by gathering every four adjacent circular loops in one bigger circular loop. This stage is made up of three stages.

5.2.1 The Inter Four Clusters

The routing protocol CRP cuts the Playground into four main equal clusters (Outer four clusters), each one of these clusters will be cut into equally four clusters (Inter four clusters). Each cluster of the Inter four clusters will elect its CH node as illustrated in previous phase. Then CRP forms a circular chain containing these four CH nodes. Then elects one of these CH nodes as an ICH (Inter Cluster Head) node by using equation (4) according to two factors (i) the residual energy, (ii) the minimum distance to the center of the Inter four clusters. The elected ICH node will collect the data from the other CH nodes and fuses them to become one data structure, then transmits it to the next level of CH. This election remains until the ICH node gets the energy threshold, then CRP select the next node in order as a new ICH node.

5.2.2 The Outer Four Clusters

After finishing the clustering phase and electing the CH nodes, CRP will refine these clusters into equally four main clusters (outer four clusters), each main cluster will be divided into equally four clusters (Inter four clusters). After electing the four ICH nodes, the CRP creates a circular chain containing these four ICH nodes. Then, elects the Master Cluster Head node (MCH) between these ICH nodes by using equation 4 according to two factors:- (i) the residual energy, (ii) the minimum distance to the BS. The elected MCH will collect the data from the other ICH nodes and fuses them to become

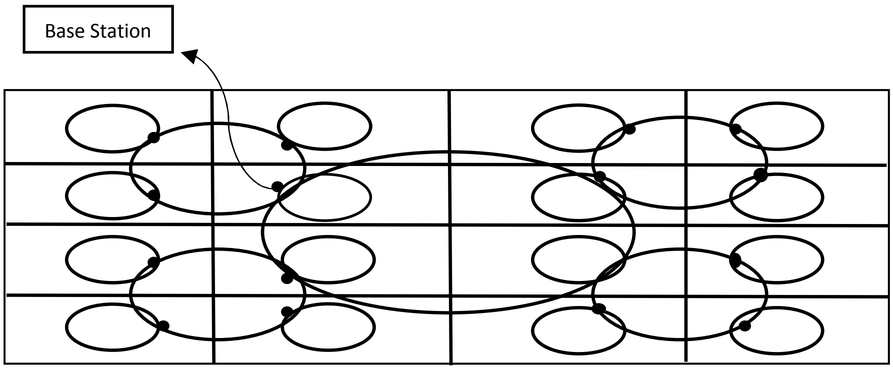

Figure. 6 : Grid clusters, Circles formation and Transmitting data to BS

one data structure then consequently sends them to the BS. This selection remains until the MCH gets the energy threshold, then the CRP will select the next node in order as a new MCH node, as shown in Figure 6.

5.2.3 Data Transmission

Data transmission phase is divided into several frames and sensor nodes transmit and receive the data at each frame [20]. For gathering data in each frame, each sensor nodes in each cluster transmits its data to the next node in the circular chain until reaching the CH node which collects and fuses these data in one data frame. Each CH node sends its data to the next CH node in the circular chain until it reaches the ICH node which collects and fuses these data into one data frame. Each ICH node sends its data to the next ICH node in the circular chain until it reaches the MCH node which collects and fuses and consequently transmits them to the BS.

6. Performance Analysis of the CRP Protocol

We evaluated the performance of the CRP protocol with NS-2 Simulation program against LEACH and PEGASIS routing protocols. The simulation is carried out with a randomly distributed network topology of variant sensor nodes, the rest of simulation parameters are listed in the following table. To establish this implementation we have added some features to the NS-2 simulator program, some of them, (i) Design a scenario files (TCL) which contains the needed parameters to run the proposed CRP (Circles Routing Protocol), (ii) Download the source code of LEACH and PEGASIS routing protocols, modify and embed them within NS-2 libraries, (iii) Develop and embed the proposed CRP with detailed functions (in C++) within the NS-2 libraries, these functions describe every detailed step of the CRP procedures,

Send_Data_to-BS: This function is responsible for transiting the collecting data from the MCH to the BS.

Collect_info_in CH: This function is responsible for collecting the necessary data of all the nodes within each cluster.

Find_Best_Cluster: This function is responsible for forming each cluster and their corresponding nodes within the playground.

Informed_Cluster_Head:	This function is responsible for sending updates message to all nodes within each cluster informing them about the new CH node.
Recv_ADV_SCH,:	This function is responsible for sending an invitation for all nodes within each cluster to join the circular chain under control of the new CH.
Rec_Join_REQ:	Responsible for sending the approval message from all nodes within each cluster to join the circular chain under control of the new CH.
Create_Chain_CH:	This function is responsible for electing the CH.
Chain_Formation_All:	This function is responsible for forming and creating the circular bath within each cluster.
Form_Grid:	This function is responsible for drawing the Grid and dividing the playground into equally clusters.
Decide_Initial_Clusterhead:	This function is responsible for electing the CH node within each cluster

Following is the Algorithm of the proposed CRP Protocol.

Phase one: Clustering and chain formation

Form Grid on the WSN Playground
For X = 0 to X = n
{ For Y = 0 to Y = m
{
f(x,y) = (X0+ xZa , Y0+yZb)
}
}
Partition the N nodes of the given WSN into S clusters (S=0 to S=n-1) and let Y be the number of nodes in each cluster Si
For i = 0 to i = S-1 do
{
Each node broadcasts a message in the range r
Each node resize the message from all nodes in the range r
Each node computes distance from boundaries of their clusters and update neighbor table
Select a cluster leader (CLi) randomly, based on the position from the center of the cluster
CLi creates a circular chain according to diameter d = min (Za,Zb)*p
Each (CLi) broadcasts an ADV_MSG in the cluster range
Each non (CLi) sends a Join_REQ to CLi to join the circle and CLi
CLi begins to Elect Cluster Head node by comparing weight of each node

Weight = $\frac{REi}{dist^2\ x}$

If weight of Chi > weight of CHn of all nodes, Node i acts as CH (CHi)

Each (CHi) broadcasts an ADV_MSG in the cluster range
Each non (CHi) sends a Join_REQ to CLi to join the circle and CHi
Send location of (CHi) to BS
While Y > 1 do
{ node N1 in the circle sends its
N(n-1) fuses its own data with the received data from previous node
Send the fused data to next node }
End
}

Phase Two : Resizing the clusters and aggregating data

Divide the WSN area to 4 partitions, L = 4
Divide each partition to equally 4 partitions, W = 4
For L = 1 to L = 4
{ For W = 1 to W = 4
{ Identify the four cluster heads (CHw)
Establish a circular chain contains these CHw
Elect one of CHw as inter Cluster Head Node (ICHi) according to weight
Weight = $\frac{REi}{dist\ 2\ o}$, where o is the distance from nodes to center of inter four cluster
If weight of ICHi > weight of ICH of all its neighbors, then node I acts as ICHi
Each ICHn broadcasts an ADV_MSG in the cluster range
Each non ICH sends a Join_REQ to CLi to join the circular chain and ICHn
While Y > 1 do {
Node N1 in the circular chain sends its
N(n-1) fuses its own data with the received data from previous node
Send the fused data to next node }
Identify the four Inter cluster heads (ICHw)
Establish a circular chain contains these ICHw
Elect one of ICHw as MCHi according to weight
Weight = $\frac{REi}{dist\ 2\ o}$, where o is the distance from nodes to BS
If weight of MCHi > weight of ICHw of all its neighbors, then node i acts as MCH
Each ICHn broadcasts an ADV_MSG in the cluster range
Each non MCH sends a Join_REQ to CLi to join the circular chain and MCH
While Y > 1 do {
Node N1 in the circular chain sends its
N(n-1) fuses its own data with the received data from previous node
Send the fused data to next node }}
MCH sends the collected data to BS

Following is the flow chart of the Circles Routing Protocol (CRP)

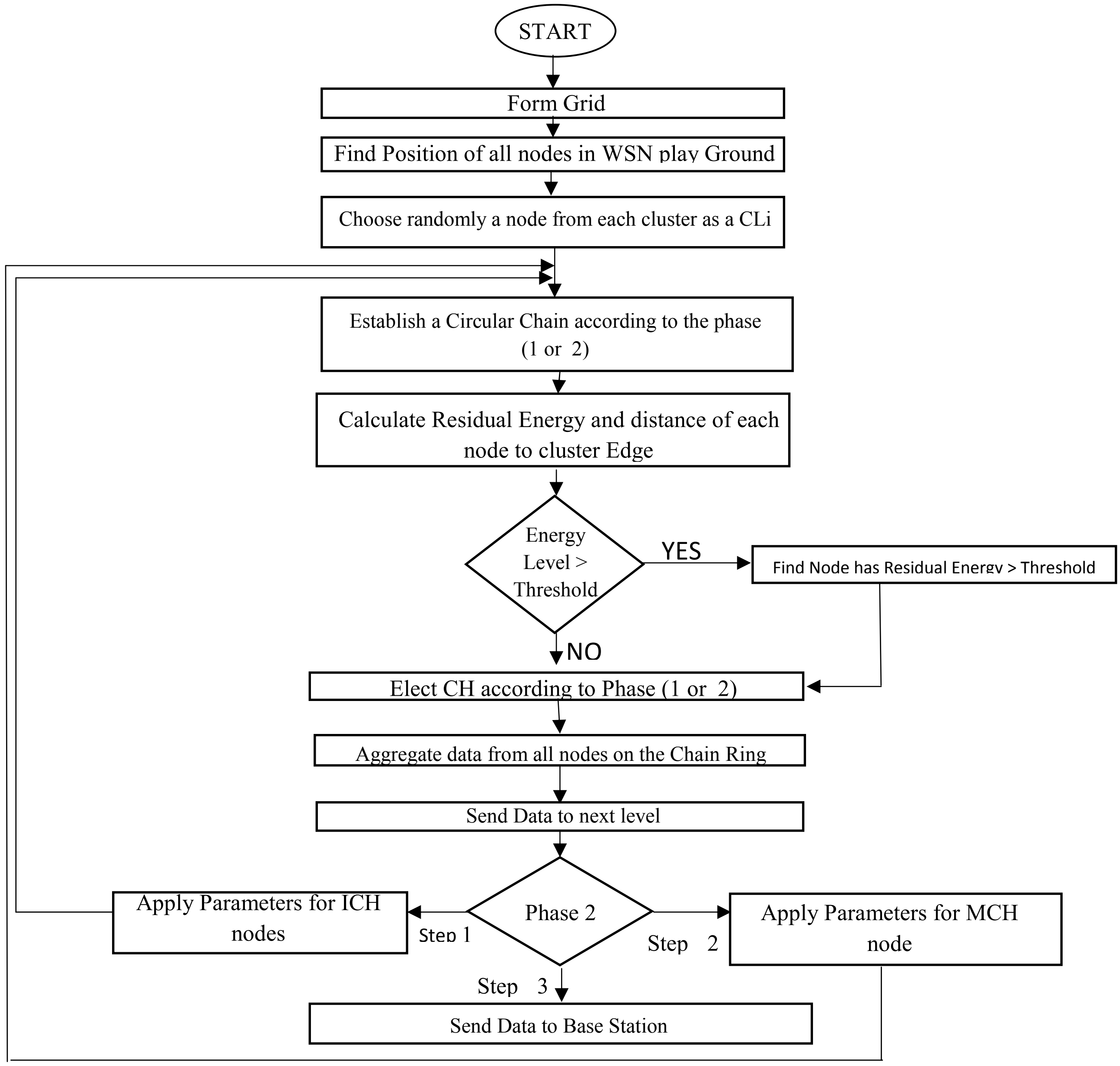

Figure. 7 : Flow Chart of CRP

Table 1 NS-2 Simulation Parameters

Parameters	**Values**
Network Size	100m x 100m
Number of Nodes	10, 25 , 50, 100 , 200
Base station location	(50m,175m)
Data packet size	40 Bytes
Initial energy of nodes	10 J
Cluster Radius	15 m
E_{elec}	50 nJ/bit
ε_{fs}	100 pJ/bt/ m2
ε_{amp}	0.0013 pJ/bit/ m4
EDA	5 nJ/bit/signal

7.1 Network Life Time

An important performance parameter for the wireless sensor network is the Network Life Time. Network Life Time is the ability of the Wireless Sensor Nodes to work until the death of all nodes. In order to perform accurate analysis, we incorporate the following parameters throughout designing the CRP (i) initial residual energy of each node, (ii) choosing smallest distance of the cluster edge to elect the CH node, (iii) aggregating and forwarding data from a node to the next neighbor node, (iv) for saving computation power, we apply the concept of static clustering instead of dynamic clustering every round. By this way, less power would be spent by the network nodes and hence the lifetime of the WSN will increases.

It is clear from Figure 8 that the proposed CRP has better performance than other protocols in terms of network lifetime. CRP extends the wireless sensor nodes lifetime approximately 38% over PEGASUS and 45% over LEACH. The CRP has sensor nodes that are alive more than the other protocols at any time. CRP ideally balances energy consumption for all network nodes.

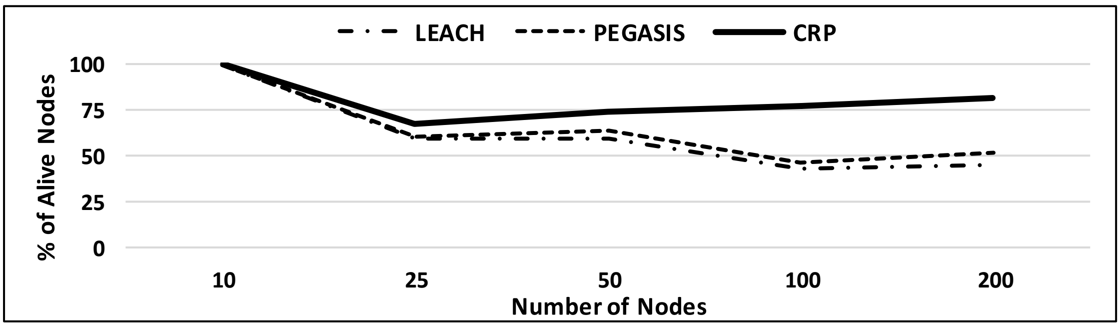

Figure. 8 : Network Life Time

7.2 Energy Consumption

Energy consumption can be defined is the total amount of energy (communications and computations power) consumed by all network nodes during the simulation time until the data is delivered to the BS. From Figure 9, it has been observed that the amount of power utilized by the network under applying CRP is less than the other protocols. Figure 9 shows that CRP saves energy consumption for all network nodes approximately 12.5% compared with those of PEGASUS and 17.5% compared with those of LEACH.

It is interesting to note that the improvement of our CRP protocol compared to PEGASUS or LEACH protocol has been verified due to the following reasons. Firstly, the CRP protocol incorporates the concept of static clustering technique. The static clustering technique consumes much less power than dynamic clustering technique. Finally, the small transmission distance between most of the network nodes as they need to transmit only to their nearest neighbors in the circular chain instead of transmitting directly to the far away BS or CH. This concept leads to consume less power and enhance the life time of the CH node.

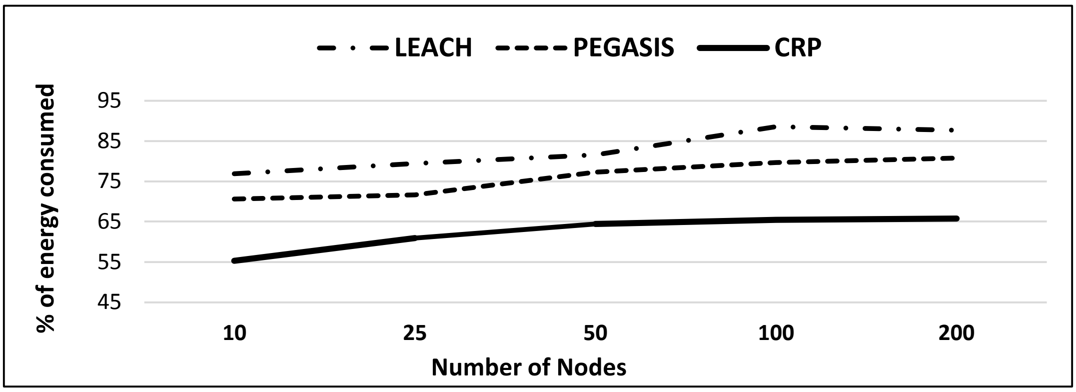

Figure. 9 : Energy Consumption

7.3 Network Throughput

Network Throughput is defined as the total data traffic in Bits/Sec successfully received at the BS from all the network nodes. Figure 10 illustrates that the throughput of network nodes under the proposed CRP is better than that of LEACH or PEGASIS protocols. From our analysis to the the results shown in figure 10, we remark that the proposed protocol CRP has better Network Throughput approximately 24% over PEGASIS protocol and 29% over LEACH protocol. This enhancement is mainly due to the increase of network life time.

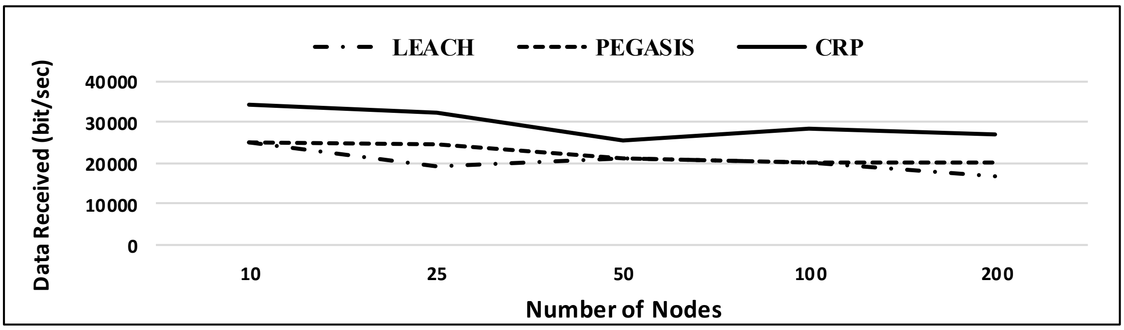

Figure. 10 : Network Throughput

7.4 Transmission Delay

Transmission Delay is defined as the total amount of time needed to push the collected data gathered by all nodes to the BS node. The performance results of Figure 11 illustrate that the transmission delay of CRP protocol is less than that of LEACH protocol by 55% and less than that of PEGASIS routing protocol by 45 %. This enhancement is mainly due to the small transmission distance between most of nodes as they need to transmit their data to the nearest neighbor in the circular chain.

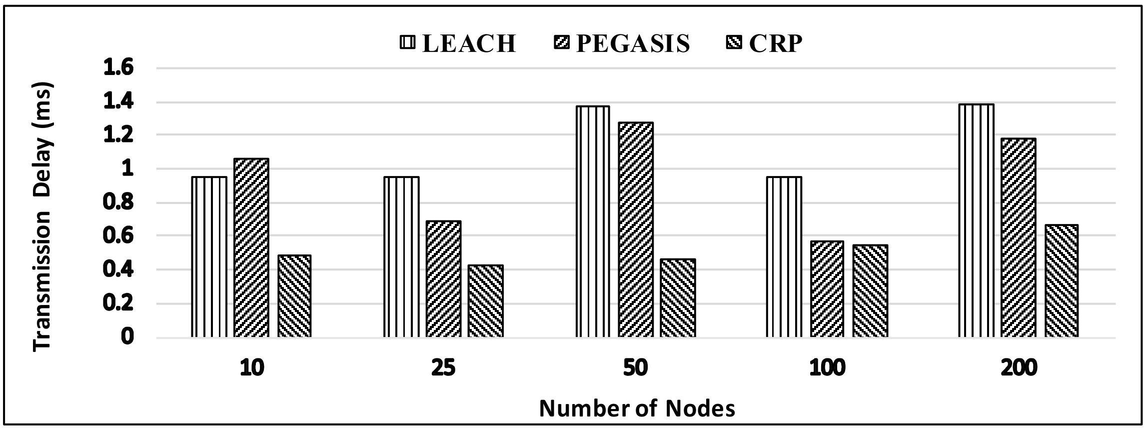

Figure. 12 : Average Delivery Ratio

7.5 Average Delivery Ratio

Average Delivery Ratio is defined as the percentage of data packets generated by all nodes that are successfully delivered to BS. The average delivery ratio can be calculated as follows: [Total number of data packets successfully delivered / total number of data packet sent] × 100%. The performance results of Figure 12 illustrate that the CRP protocol has a greater average delivery ratio approximately 23% over that of LEACH protocol and 15% over that of PEGASIS protocol. This enhancement is mainly due to the increase of network life time.

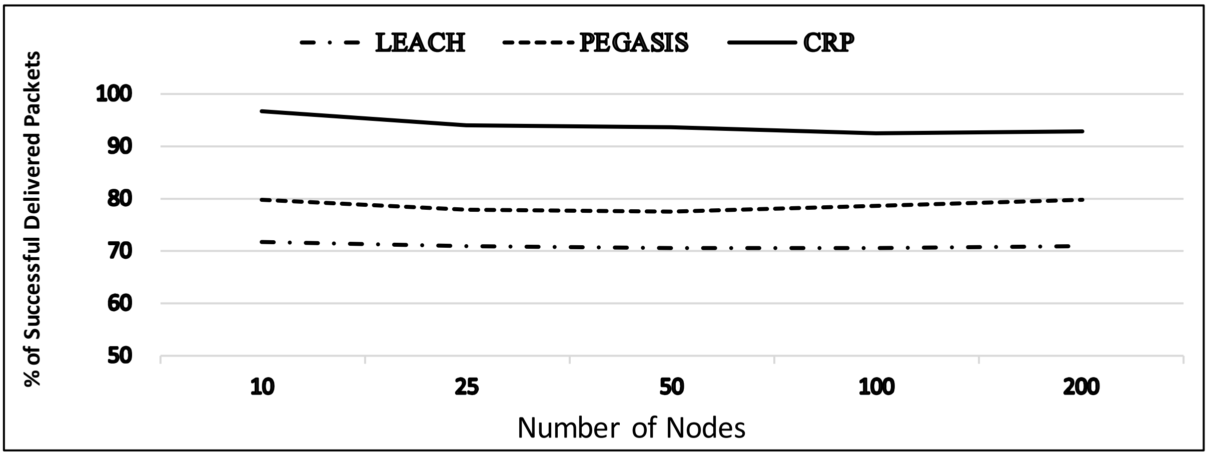

Figure. 12 : Average Delivery Ratio

8 Conclusions

In this paper, CRP (Circles Routing Protocol) has been presented to enhance the performance of WSNs, where the network nodes operate on limited battery energy. One of the main challenges of these networks is the reduction of their consumed communication time and computation power. The CRP offers the advantage of small transmission distances for most of the network nodes. Furtherer more, the CRP distributes the energy load among the network nodes. This concept leads to increase the node lifetime and improve the quality of the network. The basic concept of the CRP depends on dividing the WSN into a number of clusters statically and collects data from each cluster individually by creating a circular chain within each cluster. The dynamic behavior of the CRP protocols can be illustrated as follows. Every node in the circular chain transmits its requested data to the nearest neighbor node instead of transmitting requested data to BS or CH. Then, CRP aggregates every four clusters heads together to form a bigger cluster. Then CRP repeats the aggregation for every new four cluster nodes to form a new cluster. Subsequently, CRP gathers the data in one node (MCH) which consequently transmits these data to the BS.

In order to evaluate the performance of the proposed CRP routing protocol, we compare its performance results with those obtained from LEACH and PEGASIS routing protocols. Based on these comparisons, we found that the results of the developed protocol are more efficient in terms of Network Life Time, Energy Consumption, Throughput, Transmission Delay and Average Delivery Ration. The improvement in the CRP compared to LEACH and PEGASIS routing protocols returns to the CRP incorporates the static clustering technique which depends on the nested circular chains. This clustering technique leads to minimize the communication process between neighboring nodes, and the computation process on the network nodes.

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