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Ensuring Uniform Energy Consumption in Non-Deterministic Wireless Sensor Network to Protract Networks Lifetime

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Abstract**—**Wireless sensor networks have enticed much of the spotlight from researchers all around the world, owing to its extensive applicability in agricultural, industrial and military fields. Energy conservation node deployment stratagems play a notable role for active implementation of Wireless Sensor Networks. Clustering is the approach in wireless sensor networks which improves energy efficiency in the network. The clustering algorithm needs to have an optimum size and number of clusters, as clustering, if not implemented properly, cannot effectively increase the life of the network. In this paper, an algorithm has been proposed to address connectivity issues with the aim of ensuring the uniform energy consumption of nodes in every part of the network. The results obtained after simulation showed that the proposed algorithm has an edge over existing algorithms in terms of throughput and networks lifetime.

Keywords**—**WSN, random deployment, clustering, isolated nodes, network lifetime.

I. Introduction

WIRELESS Sensor networks are concomitant with much vagueness and various discrepancies are innate to it. The last few years have seen intensified research in the field of WSN; though, WSN defies all set protocols and stochastic processes, such as number of access points, perpetually mutating environment, abrupt disparities in network etc. are indigenous to it, yet WSN finds wide applicability in agricultural, industrial, military applications [1], [2], and so on. WSN integrate mammoth quantity of petite sensor nodes for sensing and accumulating information. This information is transmitted to sink using radio communication [3]. Lucrative execution of WSN is extensively predisposed on concerted communication of nodes. This need of transmittal of information distinctly by individual node to the sink node via secure routing [4] in a way to adeptly exploit energy, presents several hitches for researchers in WSN. To settle the debate of secure routing and energy conservation, node deployment strategies play a dominant role [5]. This datum has led massive research on node deployment issues of WSN.

Sensors have limited energy, these restraints of sensor nodes are due to their negligible physical size, and normally they are battery driven. WSN, when arrayed in inaccessible or antagonistic environments, it is impractical to change batteries. All the operations i.e. repositioning, calculation on gathered data, communication with additional nodes etc. devour power. Energy again plays a vigorous part in defining the performance of WSN, energy disbursed by sensors is a primary concern [6], which, if not used in optimum manner, would diminish the networks lifetime. This has enabled numerous researchers around the world to mature several energy-efficient arrangements for WSNs. Clustering of the nodes in the wireless sensor networks is done to attain energy efficiency in the network. Clustering is principally appropriate for relay-based sensor networks that are responsible for hundreds of nodes. In Clustering scheme, one-node is elected as cluster head (CH) with the remaining nodes as cluster members (Fig. 1). Statistics recorded by sensors are heaped up at CH and driven to remote sink after fixed duration of time.

While re-clustering, nodes energy levels are weighed and nodes with higher energy are selected as subsequent the cluster head; though cluster formation and CH selection is added overhead, these arrangements upsurge network lifetime using performance data aggregation [7].

In this paper, we propose an algorithm that ensures the uniform usage of energy and prolongs networks life time with increased throughput.

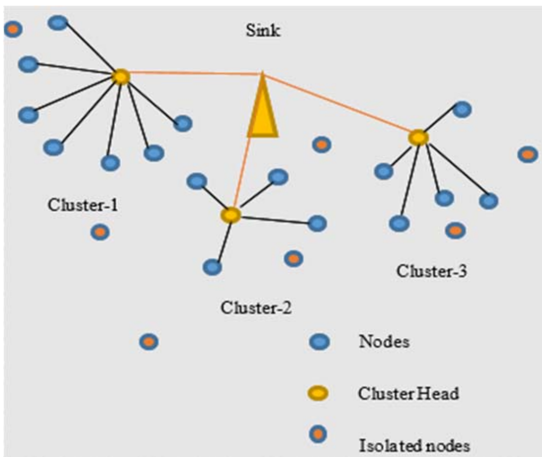

Fig. 1 Clustering in WSN

II. Existing Algorithms

In [8], the authors have proposed a radially optimized zone-divided energy-aware WSN protocol using bat algorithm. The proposed scheme evaluates the distance from the BS and angle at which the WSN develops. By sighting the angle at which the WSN develops, this protocol enables similar chances for

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each node in WSN to have sufficient fields for collaborating and its routing processes.

Low Energy Adaptive Clustering Hierarchy (LEACH) [9] is an innovative scheme which was proposed in 2005. LEACH is also a cluster grounded self-organizing adaptive protocol. Here, Cluster heads are chosen on probability which is predetermined, and remaining nodes link to the cluster of which CH is nearest to them. In LEACH, a node can be selected a CH more than once, thus draining extra energy as compared to other nodes. Moreover, CH choice in LEACH is random, therefore unvarying distribution of CHs is not guaranteed, which sometimes leads to unstable energy draining in WSNs.

Qing et al. [10] developed a clustering pattern entitled Distributed Energy Efficient Clustering (DEEC) to rally energy efficiency for WSNs. In DEEC, the residual energy of a node was taken into deliberation. The ratio amid the remaining energy of a node and the average energy of the system was calculated. Nodes having higher residual energy ratio had greater odds of being labeled as CH.

In [11], the authors have proposed a Medium-contention based Energy-efficient distributed clustering (MEDIC) algorithm, it is self-organized energy efficient clustering scheme. A sensor makes the choice to contest or not to be nominated as a CH.

In [12], the authors proposed a Regional Energy Aware Clustering scheme with Isolated Nodes (REAC-IN) for WSNs. Here, CHs are chosen on the basis of weights of sensor nodes. Weights are assessed in the context of the residual energy of sensor nodes and regional average energy of the cluster to which the node hails. Here, the same node has chances to get selected as a CH, draining more energy which lessens the networks life time.

The proposed algorithm ensures uniform energy consumption throughout the network. The CH would be selected on the basis of Residual energy and distance of node from the center. This would surpass the performance achieved in [12], as the isolated nodes would exhaust their energy in minimal fashion there by increasing the networks life time.

III. Problem Statement

Tasks that sap the energy of a sensor node are relocation, sensing and communicating with neighbors and sink nodes. If a clustering algorithm is not realized properly, some nodes tend to isolate, as cluster heads are designated arbitrarily, as shown in Fig. 1. If an isolated node is situated at a higher distance from a sink node, the isolated node is bound to deplete its energy instigating incomplete coverage, thereby dipping the networks lifetime. To upsurge the networks life time, the proposed algorithm shares the information of isolated nodes of every zone, and if found in communicating range, are clustered together, saving energy consumption.

IV. Proposed Scheme

This protocol intends to provide connectivity to the nodes in every part of the network, as random deployment leads to irregular density of the nodes in the network. If the cluster formation tactic is to go by the rules of the customary protocols such as LEACH or REAC-IN, it would predetermine the number of cluster heads required in the network and then the nodes can opt for the cluster head selection procedure irrespective of their location.

Initially base station visualizes entire area '*B*' square units as 'd' virtual zone, such that each zone is having approximate area '*B/d'* square units. If cluster heads are randomly selected from '*q*' number of partitions, (*d-q)* partitions, remain disregarded or untouched. Nodes in the left alone partitions would be referred to as isolated nodes. Isolated nodes incline to drain energy sooner, as compared to clustered nodes. With the passage of time, chances are high that isolated nodes may transform unattended zones into coronas, thus creating the network partitions inaccessible. To avoid this, it is proposed that the cluster formation will begin from each partition of the network leading to the number of cluster heads equal to number of zones i.e. "*d*".

A. Cluster Head Selection

In the proposed scheme, the residual energy and ratio of distance from the center of the zone are taken into account to elect cluster heads.

i) Distance of node from center of zone.

$$D = \sqrt{\left(x_i - x_z\right)^2 - \left(y_i - y_z\right)^2} \quad (1)$$

$$\textit{Residual Energy} = \textit{Initial Energy} - \textit{Drained Energy}, \quad (2)$$

Node having, highest distance to residual energy ratio, will be selected as the CH.

ii) Ratio= Residual Energy / D.

B. Regrouping Isolated Nodes

Now the network will be left with sections entailing the isolated nodes. Let the communication range of the node in the system be '*r*', and as we know, '*B/d'* units is the area of the partitioned zone of the network. If $\pi r^2 < (B/d)$, then the uncovered region, where isolated nodes can be located, will be the difference of these two former values.

Now, the proposed algorithm concentrates to re-cluster those isolated nodes, which adhere to the following condition:

If (Distance (*i, i*+1) < *r*)
Select Cluster Head
Remaining Nodes to join CH
Communicate with base station via CH
Else,
Communicate with base station directly.

So, if more than two isolated nodes are in the communication range, then they form the cluster and save the communication energy with the base station.

Let there be '*m*' isolated nodes and no isolated node is in the range of each other.

Let $EC_{d;m}$ be the Energy cost per node to communicate directly with base station:

$$TC_{d;pn} = p \times \left(EC_{elec} + EC_{amp} \times D^2_{pn;bs} \right) \quad (3)$$

$$Total\ Energy = M \times TC_{D;PN} \quad (4)$$

Assuming '*m*' isolated nodes out of which '*l*' are in the communicating range of each other, and subsequently form the cluster. Energy cost for (*m-l*) nodes to connect with the base station:

$$\left(m - l \right) \times TC_{d;pn} \quad (5)$$

Out of '*l*' nodes, one would become cluster head, the energy cost would be:

$$TC_{t;pn} = P \times \left(2EC_{elec} + E_{amp} \times \left(D^2_{pn;h} + D^2_{h;bs} \right) \right) \quad (6)$$

The gain for '*l*', *every time* they transmit information to the '*bs*' via CH (one of isolated nodes only), when $TC_{d;pn} > TC_{t;pn}$ will be:

$$Energy\ Saved = l \times E_{amp} \times \left(D^2_{pn;bs} - \left(D^2_{pn;h} + D^2_{h;bs} \right) \right) - E_{elec} \quad (7)$$

Hence, reducing the energy consumption of isolated nodes.

TABLE I
LIST OF VARIABLES USED

Symbols	Meaning
h	Cluster head of last round
bs	Base station
pn	Present node
N_{sz}	Number of nodes in subzone
$D_{pn;h}$	Distance between *pn* and h
$D_{h;bs}$	Distance between h and *bs*
$D_{pn;bs}$	Distance between *pn* and *bs*
EN_i	Residual energy of node '*i*'
RE_{av}	Zonal average residual energy
P	Packet Size
$TC_{t;pn}$	Energy cost for transmitting a k-bit message from *pn* to *bs* via *h*
$TC_{d;pn}$	Energy cost for transmitting a k-bit message from *pn* to *bs*
EC_{elec}	Energy cost of transmitter electronics
EC_{amp}	Energy cost of transmit amplifier
(x_i, y_i)	Coordinates of node 'i'
(x_z, y_z)	Coordinates of center of zone

C. Proposed Algorithm

m= Number of nodes
d= Number of zones
n= Number of nodes in individual Zones
l= number of isolated nodes
for *i*= 1: d
for *j*= 1: n
if Ratio node (*j*) == highest
Set node (*j*) = Cluster head
else
node (*j*) ≠ Cluster head
end
end

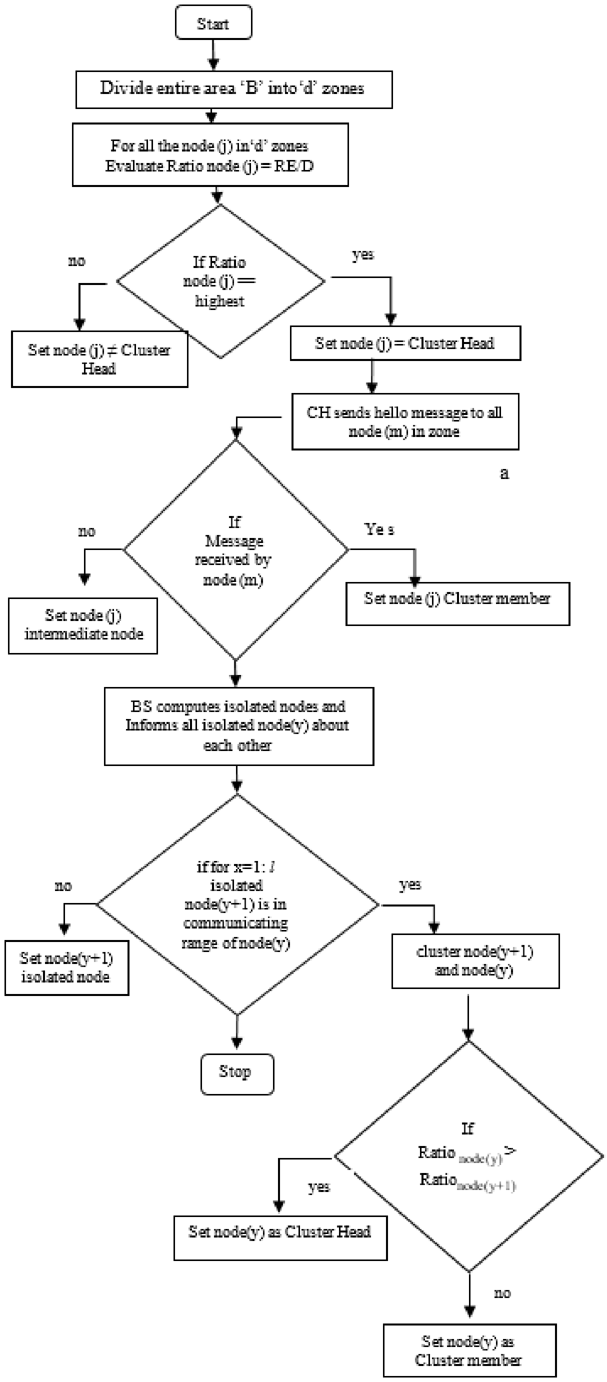

Fig. 2 Flowchart of Proposed Scheme

CH send hello message to node (*j*)
if message received == true
Set node (*j*) = Cluster member
Else
Set node (*j*) = isolated node
End
CH inform bs regarding members
end
for *y*=1: *l*

bs informs isolated nodes (node(y)) about each other
if node(y+1) is in communicating range of node(y)
Choose CH on basis of ratio node(y)
Else
if node(x) is not in communicating range of any other isolated node
send data straight to *bs*
end
end
end

V. Simulation Results

Here, the performance of the proposed algorithm is discussed. MATLAB 2014a is used for simulation. The scenario and network parameters used in our study are kept the same as in [12] and [9] for performance comparison and are listed in Table II. For purpose of uniformity, the base station was presumed to be at the center.

The performances of REAC-IN proposed in [12] were compared with the proposed algorithm. In the previously proposed scheme like LEACH, CH is selected on the basis of predetermined probability. In HEED, depending on the basis residual energy and node degree etc., periodical selection was made. Finally, REAC-IN assessed the regional average energy for the selection procedure of the CH. In the proposed algorithm, the ratio of a nodes residual energy along with the nodes distance from the center of a zone is accounted for in CH selection; this ensures uniform energy consumption. To further save energy consumption, isolated nodes were clustered to enhance energy efficiency.

Next, the performance of the proposed algorithm was compared with REAC-IN, as REAC-IN performance was found better than classic clustering algorithms such as LEACH, HEED and DEEC [12].

Comparisons were made on two parameters, namely number of alive nodes and throughput. In the proposed algorithm, the decay of energy is consumed almost uniformly by all the nodes, which allows the network to be alive even after 3000 iterations.

TABLE II
Parameters for Simulation

Parameter	Value
Network Area	200m × 200m
Sensors	200
Deployment	Random
Base station	Centre of network
Initial energy/sensor	2J
Desired percentage of CH	0.1
EC_{elec}	50 nJ/bit
EC_{amp}	100 pj/ (bit.m^2)

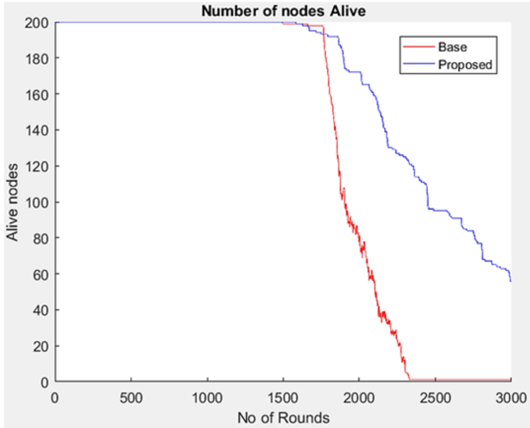

Fig. 3 Alive nodes after 3000 rounds

Fig. 3 shows the number of alive nodes. It is noticeable that the number of nodes alive in REAC-In, fall sharply after 2000 rounds and the network is almost dead after 2350 iterations. The proposed algorithm ensures that the energy of nodes is drained uniformly; this prevents any node exhausting its energy sooner, thus leaving behind coronas. In the proposed scheme, the number of alive nodes starts to fall after 2300 rounds. As more nodes are alive for more rounds, therefore the networks life time is improved.

Fig. 4 shows the throughput in kbps. It is clear that in the proposed scheme better throughput is achieved.

In REAC_IN the nodes start to die after 2000 rounds and the network is almost dead by 2300 iterations leaving behind coronas. Therefore, maximum throughput achieved is less than 3.5×10^6 kbps. Whereas, in the proposed scheme, throughput of more than 4.2×10^6kbps is achieved.

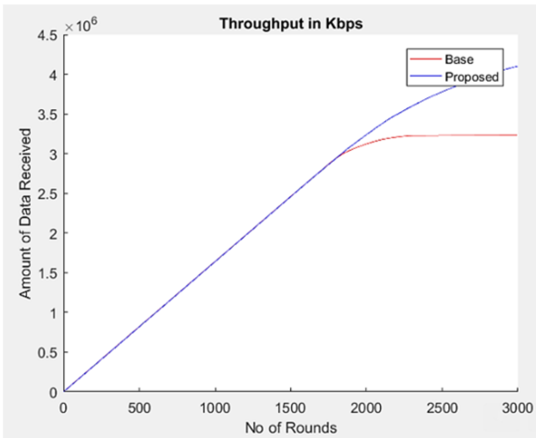

Fig. 4 Throughput in Kbps

VI. Conclusion

Feasible deployment of WSN is disposed on the materiality that how competently energy has been casted off, which is a deciding factor for a networks lifetime. The proposed algorithm ensures that cluster heads are placed in every zone and isolated nodes should also be grouped wherever possible.

The results obtained after simulation matched the mathematical analysis and proved that the proposed algorithm is a more lucrative clustering scheme. The regrouping of the isolated nodes enables to reduce coronas and escalates energy and throughput gains. Reduction of coronas ensures that statistics are discerned from every single part of the network, thus providing a real help to the networks deployed for sensitive applications like military, environmental monitoring and more.

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