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Ad Hoc Distributed Wireless Sensor Networks with Geological Multi-Layered Energy-Efficient Clustering Scheme

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ABSTRACT

Underwater wireless sensor networks (UWSNs) have been showed as a promising technology to monitor and explore the oceans in lieu of traditional undersea wire line instruments. Nevertheless, the data gathering of UWSNs is still severely limited because of the acoustic channel communication characteristics. This study introduces a geographical multi-layered clump protocol for circumstantial wireless sensing element networks (WSNs), wherever the scale of clusters is variable so the nearer clusters to the bottom station (BS) have a smaller size than farther ones. Moreover, in every cluster, victimization some intelligent fuzzy rules and during a decentralized means, a unique subtree strategy is decided. During this means, some parent nodes area unit chose that area unit accountable for assembling and aggregating knowledge from their adjacent normal nodes and causing them to its cluster head, directly or via different parent nodes, that well decreases intra-cluster communication energy prices. what is more, these 2 compatible techniques will fairly mitigate the recent spot downside ensuing from multi-hop communication with the SB planned protocol performs higher in terms of purposeful network longevity for each small-scale and large-scale sensing element networks.

Keywords: Underwater wireless sensor networks, intra-cluster communication, fuzzy rules.

I. INTRODUCTION

The wireless sensor networks (WSNs) are application specific networks composed of small nodes, which can sense the environment, collect the data, do aggregation and every single node can communicate with each other wirelessly via radio link. Today's fast technology improvements in low-power and wireless communication have provided a good condition for WSNs in real-world applications and distributed sensor applications have increased significantly such as wild life and ocean life monitoring, supervising the vibration of structures, automatic warning, supervising the agricultural applications and target tracking.

Nodes have limitations in memory, process and energy; therefore, it is difficult to design WSNs. Among the abovementioned limitations, energy is the most important one because when the sensors are installed their batteries cannot be replaced or charged. Thus, energy considerations are the most prominent factors in WSNs routing. One of the most famous routing algorithms for WSNs is clustering-based hierarchical routing. In this method, all nodes are divided into groups called clusters based on specific methods. In each cluster, one node is selected as a cluster head (CH) and other nodes are considered as normal nodes. Different parameters are taken into account while selecting a CH in various methods.

In the major part of clustering algorithms, the main goal is to achieve uniform energy distribution to increase network lifetime. In this type of routing, sensor nodes play different roles and they may have different energy consumption according to their role. This group of methods is the best class of routing algorithms for WSNs. A CH is able to manage and schedule intra-cluster activities, and as a result node may change their state to low-power sleep mode and reduce energy consumption.

For direct communication, the CHs furthest away from the BS are the most critical nodes, whereas in multi-hop communication; the CHs closest to the BS are burdened with a heavy relay traffic load and die first. Therefore clustering and multi-hop communication are the most efficient routing schemes in WSNs to balance the relay traffic over the network and effectively overcome the path loss effects. A simple approach to balance energy consumption is to reselect the CHs periodically. In this case, the role of CH is changed. The structure between normal nodes, CHs and BS might be repeated as much as it is required .In this paper, a location aware and reputation based clustering algorithm is proposed where cluster sizes are variable. The size of clusters is directly proportional to availability of sensors within cluster. This paper devise a Distributed Energy and location aware reputation based clustering scheme with adaptive cluster formation process for efficient routing in wireless sensor network. Node heterogeneity is also considered to enhance the stability of proposed work. Cluster head selection in LSRDEC protocol is dependent upon the neighbor location of sensors, position of a particular sensor from the base station, some kind of resources like current and total energy, average energy etc. The cluster formation process is autonomic in LSRDEC as the size of cluster is an independent function of number of sensors.

II. PROPOSED PROTOCOL

The proposed protocol is a distributed and decentralized clustering protocol. It acquires an appropriate structure in order to achieve energy efficiency in both intra- and inter-cluster communications. Moreover, it overcomes the energy-hole problem significantly which, in turn, increases network lifetime. In this protocol, cluster size increases while getting farther from the BS. Actually, a layered structure is formed where clusters close to the BS are smaller than those which are farther from it. In this protocol, to select high-energy level nodes and proper distribution as CHs three criteria are considered including residual energy, number of neighboring nodes in neighborhood radius of the CH, which is demonstrated by Ndeg and distance to the neighboring nodes. In this protocol, in each cluster a sub-tree topology is used. As a matter of fact, each CH selects its parent nodes among volunteer parent nodes in its cluster according to residual energy and the number of volunteer parent nodes in the parent radius. The selection is performed using fuzzy logic. Furthermore, the number of selected nodes depends on Rsize such that the larger the size of cluster, it is highly probable that more parent nodes are selected. Parent nodes are tasked with collecting and aggregating data from their CNs. It leads to balanced distribution of energy consumption in the whole network. Besides, it decreases intra-cluster tasks so that the CH saves more energy. Therefore the proper amount of energy could be dedicated to inter-cluster communication. Parent nodes transmit aggregated data to CH either directly or via other parent nodes in the same cluster. Afterwards, CHs transmit the received data to the BS in a single-hop or multi-hop manner depending on their distance to the BS. Fig. 1 shows the multi-layered structure of network protocol. Following, some assumptions and the radio model of the proposed protocol and the formation steps are expressed.

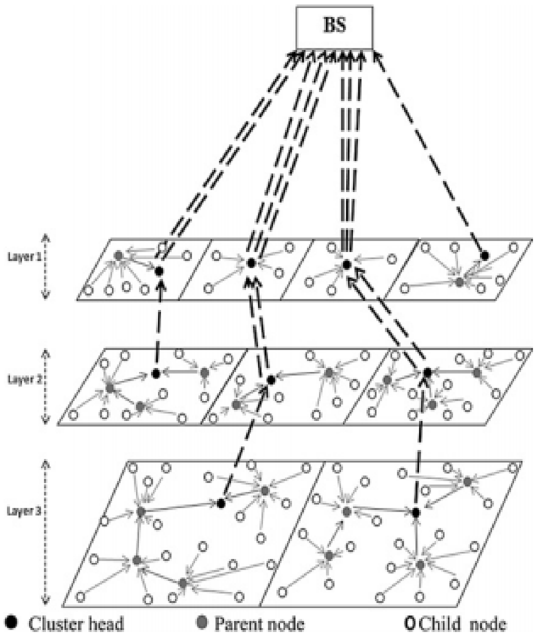

Figure 1. Multi-layered structure of network

Model assumptions:-

The considered assumptions for the proposed protocol are described as follows:

(1) All nodes are distributed randomly and uniformly in a square area as M × M × (M2).
(2) The BS is located stable and far from the network without any energy, processing and memory constraints.
(3) All nodes are the same in terms of resources, processing, communication, the initial energy and so on.
(4) All nodes are stable after deployment and sense the environment and do have data to send.
(5) The nodes are considered as dead nodes when their energy is over.
(6) Every round consists of a complete cycle for selecting the CH and parent nodes, the formation progress and data phase.
(7) Nodes do not know their location and BS location, and they are not equipped with a global positioning system.
(8) Every sender node considering its distance to receiver can adjust its sending power level.
(9) Every node can estimate its distance to sender considering the receiving signal power.

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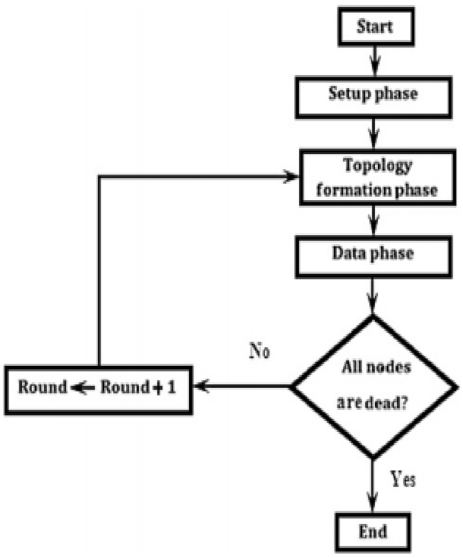


Figure 2. Overall steps of the proposed protocol

Protocol phases:-

This protocol is composed of three phases: 1) setup, 2) topology formation and 3) data phase

Setup phase:-

In this phase, the BS broadcasts a Hi-MSG to the whole network and each node calculates its distance to BS dBs based on received signal power. Then, each node broadcasts an elementary-MSG message to the whole network and other nodes calculate their distance to this transmitter node. Each node calculates its CH radius with respect to its distance from the BS using below equation. In below equation, Rmin is the minimum cluster size and speedchange-rate is radius variation speed rate. They are protocol parameters. dBS min is the distance of closest node to the main station and dBS max is the distance of the furthest node to the BS.

$$R_{\text{size}} = R_{\min} * \left[1 + \left(\frac{d_{\text{BS}} - d_{\text{BS}\min}}{d_{\text{BS}\max} - d_{\text{BS}\min}} \right) * \text{speed}_{\text{change-rate}} \right]$$

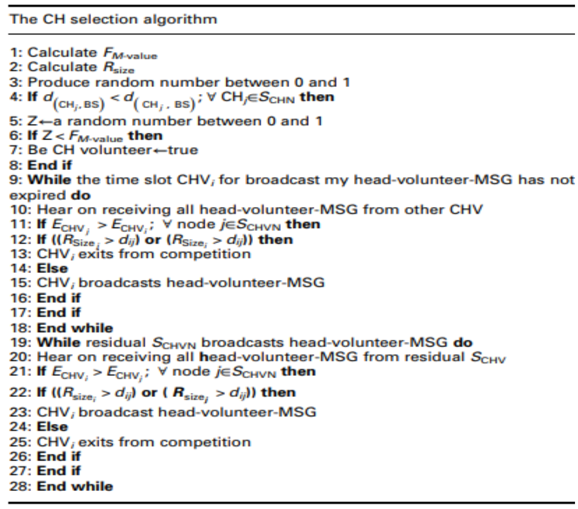
Topology formation phase:-

In this phase protocol topology is formed. This phase consists of four sub-phases including CH selection, parent selection, intra-cluster communication and inter-cluster communication

CH selection sub-phase:-

In this sub-phase, CHs are determined by the steps of which are depicted in Table 1. Lines 1–2 were specified in the setup phase for each node. In lines 3–8, each node generates a random number between zero and one. If the generated number is less than the normalized FM-value of the node, the node will consider itself as a CH candidate. In lines 9–18, each node which has considered itself as CH candidate waits for its time slot when it can introduce itself as CH candidate via head-volunteer-MSG. Till then it listens to all messages of this type which are transmitted by other candidates. If among candidates a candidate j is found such that its residual energy ECHVj is higher than candidate i and simultaneously one or two of them has Rsize larger than the distance between them, dij candidate i leaves the competition and will not send its head-volunteer-MSG. In contrast, if one or both of the above-mentioned conditions are not met candidate i will send its head-volunteer-MSG. In lines 19–26 the CH candidate node, which has introduced itself as a candidate CH via head-volunteer-MSG and listens to all messages of this type as it was doing before. If there is not any other node, which satisfies the aforementioned criteria, the candidate node considers itself as a CH; otherwise, it withdraws its claim for being CH. Then, CHs announce their selection as CH by transmitting a head-MSG including ID and spreading code. Afterwards, other nodes select the closest CH as their corresponding one according to received signal powers.

Table 1. Intra-cluster formation algorithm



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The CH selection algorithm
1: Calculate $F_{M\text{-value}}$
2: Calculate $R_{\text{size}}$
3: Produce random number between 0 and 1
4: If $d_{(\text{CH}_j,\text{BS})} < d_{(\text{CH}_i,\text{BS})}$; ∀ $\text{CH}_j \in S_{\text{CHN}}$ then
5: Z←a random number between 0 and 1
6: If $Z < F_{M\text{-value}}$ then
7: Be CH volunteer←true
8: End if
9: While the time slot $\text{CHV}_i$ for broadcast my head-volunteer-MSG has not
expired do
10: Hear on receiving all head-volunteer-MSG from other CHV
11: If $E_{\text{CHV}_j} > E_{\text{CHV}_i}$; ∀ node $j \in S_{\text{CHVN}}$ then
12: If (($R_{\text{Size}_i} > d_{ij}$) or ($R_{\text{Size}_j} > d_{ij}$)) then
13: $\text{CHV}_i$ exits from competition
14: Else
15: $\text{CHV}_i$ broadcasts head-volunteer-MSG
16: End if
17: End if
18: End while
19: While residual $S_{\text{CHVN}}$ broadcasts head-volunteer-MSG do
20: Hear on receiving all head-volunteer-MSG from residual $S_{\text{CHV}}$
21: If $E_{\text{CHV}_i} > E_{\text{CHV}_j}$; ∀ node $j \in S_{\text{CHVN}}$ then
22: If (($R_{\text{size}_i} > d_{ij}$) or ( $R_{\text{size}_j} > d_{ij}$)) then
23: $\text{CHV}_i$ broadcast head-volunteer-MSG
24: Else
25: $\text{CHV}_i$ exits from competition
26: End if
27: End if
28: End while
```

Parent selection sub-phase:

In the proposed protocol, first off, each non-CH node generates a random number and compares it with Nthreshold-PVN (which is the same for all nodes and is considered as a protocol parameter). With respect to the generated number, the node selects whether it could be a parent volunteer or not. Then each parent candidate node transmits a parent-volunteer-MSG including its own ID and its CH's ID to inform other nodes. Each parent volunteer node (PVN) counts PVNs in its RPN radius considering the received power of parent-volunteer-MSG and comparing its CH to the CH of each message. The number of these neighbors is denoted by NPVN-radius. Subsequently, each parent candidate transmits a PVN-energy-MSG which consists of its ID, its CH's ID, its residual energy and NPVN-radius value to its CH. Receiving this information, each CH utilizes the following fuzzy logic algorithm and normalized inputs of residual energy and NPVN-radius to prioritize its parent candidates. Then, some of the parent candidate nodes with low priority are eliminated using (11). Each CH transmits parent-ID-MSG and informs its parent nodes about the ID of all parent nodes considering its distance to the furthest PVN. Each parent node, then, broadcasts a parent-MSG including its ID and its CH's ID to announce its position as parent.

$$N_{\text{PN-final}} = N_{\text{PVN}} * \text{delete-rate}$$

Intra-cluster communications formation sub-phase:

In this sub-phase, a sub-tree topology is formed in each cluster. The steps of this sub-phase are illustrated in Table 2 algorithm and are explicated in the following paragraphs. According to lines 1–2 if a CH does not have any parent node, each node considers a CH as its next hop. In lines 3–4, each CN selects the closest parent node. Then, it transmits a join-child-MSG message including its own ID and its parent ID to the corresponding CH. In lines 5–17, parent node i determines its next hop, which might be either another parent node in the cluster or it's CH. According to lines 7–8, first the parent node i selects parent node j which is the closest parent node among those parent nodes which are closer to the CH than node i. In lines 9–15, if the distance of the parent node i to its CH d (PNi, CH) is less than the distance between nodes i and j d PNi, PNj, the CH would be the next hop of parent node i; otherwise, j would be its next hop. Now each parent node informs its CH about its next hop using a join-parent-MSG which includes its own ID and the ID of its next hop. Each CH transmits a schedule-MSG message to each node so that it could inform them about the time slot number of each node for time division multiple access data transmission.

Table 2. Intra-cluster formation algorithm

```
The next hop determination

1: If there is no PN then
2: My next hop is my CH
3: Else if node $i$ is a CN then
4: My next hop is the nearest PN
5: Else if the node $i$ is PN then
6: While my next hop is not determined do
7: If $d_{(PN_j, CH)} < d_{(PN_i, CH)}$; $\forall PN_j \in S_{PN}$ then
8: Select my nearest $PN_j$
9: If $d_{(PN_i, CH)} < d_{(PN_i, PN_j)}$ then
10: Next hop for $PN_i$ is CH
11: My next hop is determined
12: Else
13: Next hop for $PN_i$ is $PN_j$
14: Next hop is determined
15: End if
16: End if
17: End while
18: End if
```

Inter-cluster communications formation sub-phase:

In this sub-phase, the data path from CH to BS is determined. The steps are presented in Table 3. Nodes whose distance from BS are less than relay-radius form, the first layer and are called send direct (SD) nodes. The nodes inside other layers are called multi-hop send (MHS) nodes. According to lines 1–10 if CH i CHi is MHS, it transmits its own aggregated data and the data received from other CHs (which are even further from the BS) to the CH which is closer to the BS. As a result, data reaches to BS step-by-step. In lines 3–5, first, the cluster head j CHj is selected among the CHs which are closer to the BS than CH i. CHj must be the closest CH to i and it would be chosen as the next hop. Otherwise in lines 6– 8, if there is a SD CH in the first layer, CH i chooses a CH among those SD ones such that the sum of energy consumption in i and the selected CH is minimized. The optimal CH is called CHoptimal. In lines 9–11, if there is not a SD CH in the first layer, CH i sends its data to BS directly. When the next hop of MHS CH is determined, the MHS CH broadcasts a next-hop-MSG, which includes its own ID and the ID of the next hop. In lines 14–15 if the CH is SD type it transmits its own data as well as data received from other MHS CHs directly to the BS.

Table 3. Next hop determination algorithm

```
The next hop determination

1: If $CH_i$ is MHS type then
2: While next hop is not determined do
3: If $d_{(CH_j, BS)} < d_{(CH_i, BS)}$ ; $\forall CH_j \in S_{MHS}$ then
4: My next hop for $CH_i$ is my nearest $CH_j$
5: Next hop is determined
6: Else if $S_{SD}$ is not empty Then
7: My next hop for $CH_i$ is $CH_{optimal}$
8: Next hop is determined
9: Else if $S_{SD}$ is empty Then
10: My next hop is the BS
11: Next hop is determined
12: End if
13: End while
14: Else if $CH_i$ is SD type Then
15: Their data are sent directly to the BS
16: End if
```

Data phase:

In this phase, each parent node or CH aggregates received data from other CNs or other parent nodes by its own sensed information and sends them via single-hop or multi-hop communication to the BS.

III. CONCLUSION

In this paper, a multi-layered distributed cluster protocol for ad hoc networking with variable cluster size and conjointly a unique intra-cluster communication theme has been projected for the sake of energy potency. because the result in contestable, the projected protocol accrued the network life cycle dramatically by forty eight and 12% in small-scale networks and 283 and a hundred and sixtieth within the large-scale network as compared with LEACH and DSBCA protocols, respectively. What is more, the projected protocol offers a far better distribution of the nodes leading to considerably improved balanced energy consumption throughout the network and decreased risks of Associate in nursing instability amount. Our results show the overall residual energy of network for the projected protocol is1.8% when the primary node is dead, whereas it's twenty one and eight for LEACH and DSBCA, severally, indicating improved load balancing conditions as a results of virtually higher distribution in CHs. These values square measure eleven, 47, and forty first for the large-scale situation

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