A Review on Clustering Protocol for Enhancing Energy Efficiency in the Wireless Sensor Network

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***Abstract*—**In the present days, Wireless Sensor Network (WSN) is an important and powerful technology that is used for the several applications such as surveillance systems, intelligent transport system, and military. A WSN is a specific wireless network made up of several sensor nodes and at least one Base Station (BS). The WSN is known to be a highly resource-constrained class of network, where energy consumption is one of the major concerns. In the WSN, sensor nodes have limited battery power, transmission range and storage capability. The clustering protocols helps in less energy consumption and to increase network lifetime. Hence, it is necessary to design effective and energy-aware protocol in order to maximize the lifetime of network. The clustering is a key algorithm employed to a sensor network by decreasing energy consumption. This paper presents a relative study of different energy efficient clustering protocols. The primary problems in the WSNs are network lifetime and energy consumption.

Keywords*—Base Station; Energy Consumption; Routing Protocol; Sensor Node and Wireless Sensor Network.*

I. INTRODUCTION

A WSN is a specific wireless network made up of several Sensor Node (SN) and at least one Base Station (BS). The major difference between the WSN and conventional wireless networks is that sensors are tremendously sensitive to an energy consumption. Energy consumption is a vital problem in designing the WSNs [1]. The WSN consist of a number of autonomous sensor nodes equipped with sensing capabilities, wireless communication boundaries, energy resource and limited processing. Many BS act as a final destination of the data. The WSN is utilized for the distributed and cooperative sensing of the physical phenomena. Energy consumption is required to pass sensory data to the final destination for every node, which is the main concern when designing the WSN routing protocol [2]. Clustering is one of a better technique to reduce energy consumption and to deliver stability in the WSNs [3] [4]. The clustering helps to prolong the lifetime of WNSs in an environment where battery replacement of individual sensor nodes is not an option after their deployment. But, the clustering overheads such as cluster size, cluster formation, cluster head rotation and cluster head selection directly affects the WSN lifetime [5].

The nodes or sensors having much load of data transmission and reception need more energy and become a dead node when nodes lost their energy. So, a clustering technique is employed to overcome this issue. There are two types of the clustering techniques such as Static Clustering and Dynamic Clustering used for less the energy consumption in WSN. In the static clustering technique, the cluster size is fixed and nodes send their data to fixed Cluster Head (CH) where their whole energy get saved through dynamic clustering [6]. A selection of clustering protocols implemented to address the energy efficiency issues in the various network scenarios. But, the most of the conventional clustering protocols don't consider the node's movements after clustering [7], [8]. In WSN, the energy consumption is an important aspect of retrieval technology and reduce energy consumption to increase the lifetime of the research process to the WSN. In this paper, a detailed review on the clustering protocol used for improving energy efficiency in the WSN done in order to analyse the performance and issue of the existing technologies. This review work motivates the researchers to do further research to improve energy efficiency in the WSN.

II. MAJOR ADVANTAGE OF THE CLUSTERING TECHNIQUE

- The clustering technique reduce the distance of nodes; through which data has to travel sent by the normal node. Hence, it conserves a large amount of energy for the normal nodes.
- The Clustering has a limited amount of redundant data in the network as data aggregation is performed at the Cluster Heads (CHs), which consumes energy and uses the bandwidth effectively [9].
- The clustering help in decreasing the number of exchanged communication in the WSN, which results in less consumption of the battery power of SNs.

III. CLUSTERING OVERVIEW

The clustering is a major technique of splitting a network into sub-networks, which is called a cluster [10]. Each cluster has its own CH that maintains a whole information about the cluster. The cluster structure consists of three types of nodes such as CH, cluster member and cluster gateway node [11]. The figure 1 shows the structure of the cluster.

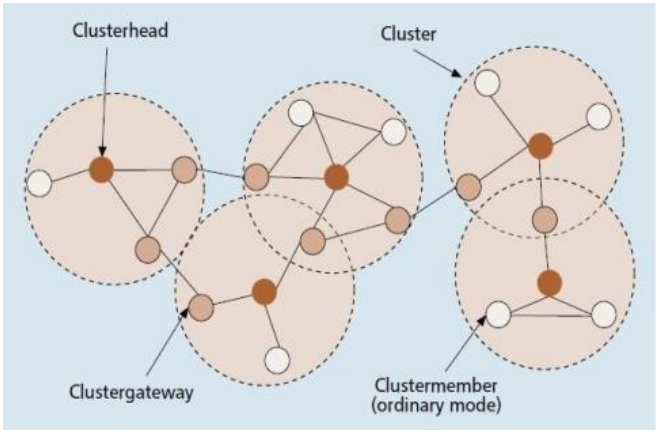

Figure.1. Structure of the Cluster [11]

1). Cluster Node:

Every cluster has a CH, which coordinates entire the nodes within the cluster. A different technique is introduced for selecting a CH in the cluster.

2). Cluster member:

Ordinary nodes transmit data or information to their CH, which compresses this data and forward it to other CH.

3). Cluster Gateway Node:

Non-cluster head node uses for making interaction among various clusters and forward information between clusters.

A. *Clustering Formation*

The regions are formed in dynamic clustering, but nodes are not fixed. The nodes send their data to the CH, which is a minimum distance from that node and consumed less energy. The initial step of clustering formation is to take BS as a center. So, its coordinates are taken as a reference point to form concentric squares. Entire region separate into n concentric squares, which have three squares Internal Square I_s, Middle Square M_s and Outer Square O_s [12].

Coordinate of the top right corner of $I_s, T_r(I_s)$

$$T_r(I_s) = \left(C_p(m)+d, C_p(n)+d\right) \quad (1)$$

Coordinate of both bottom right corner of $I_s, B_r(I_s)$

$$B_r(I_s) = \left(C_p(m)+d, C_p(n)-d\right) \quad (2)$$

Coordinate of left corner of $I_s, T_i(I_s)$

$$T_1(I_s) = \left(C_p(m)-d, C_p(n)+d\right) \quad (3)$$

Coordinate of both bottom left corner of $I_s, T_i(I_s)$

$$B_1(I_s) = \left(C_p(m)-d, C_p(n)-d\right) \quad (4)$$

Here, d represents the distance from reference point and d is multiplied by a factor α , which is one for I_s two for M_s and O_s take top and bottom rightthe the of the I_s as reference point,

$T_r = \left(I_s(m+d,n)\right)$ and $B_r = \left(I_s(m+d,n)\right)$ forms non-corner region 2 (5)

$T_1 = \left(I_s(m,n+d)\right)$ and $T_r = \left(I_s(m,n+d)\right)$ forms non-corner regions 3 (6)

$T_1 = \left(I_s(m-d,n)\right)$ and $B_1 = \left(I_s(m-d,n)\right)$ forms non corner region 4 (7)

$B_r = \left(I_s(m,n-d)\right)$ and $B_1 = \left(I_s(m,n-d)\right)$ forms non corner region 5 (8)

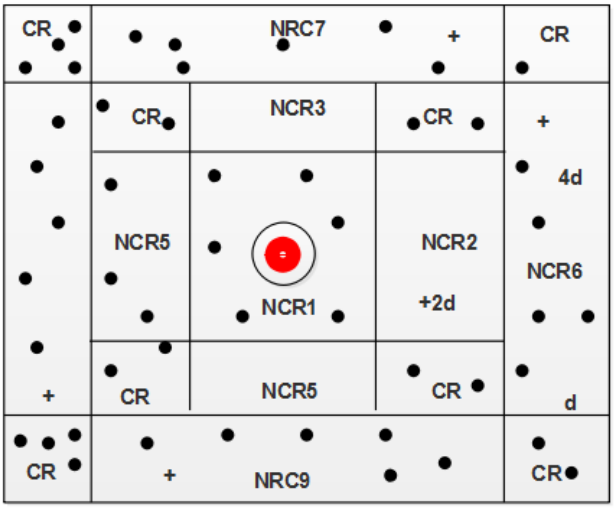

Figure.2. Block diagram for structure of region

The areas left between internal meddle square forms a corner region (like corner region 2, 3, 4 and 5). Similarly for division between middle and outer square take T_r and B_r of the middle square as a reference for forming non-corner region 6, T_r and T_1 to form non-corner region 7. T_1 and B_1 forms non corner region 8, B_r and B_1 forms non corner region 9. The areas left between meddle and out square forms corner regions. The figure .2 shows the block diagram of structure of region. In the figure 2, CR- Corner Region, NCR- Non Corner Region, +- CH, d- Reference Distance and ⊙ -BS.

B. *Energy Consumption Model*

This section describes how energy is consumed in various regions of the network field. Equation 9, 10 shows the energy cost of transmitting energy T_E and reception energy R_E respectively for a single bit of data over d distance.

$$T_E = \begin{Bmatrix} \{E_{elec} + \varepsilon_{fs} D^2, if\ D^2 < D_0 \} \\ \{E_{elec} + \varepsilon_{amp} D^4, if\ D^4 \geq D_0 \} \end{Bmatrix} \quad (9)$$

$$R_E = (E_{elec}) \quad (10)$$

*1)*Energy Consumption in I_s

To compute the area and energy consumption of I_s by using equation (11) and (12). Each side of I_s is two- d in length and width hence, area of I_s, $A(I_s)$ form the figure 2.

$$A(I_s) = 4d^2 \quad (11)$$

$$\text{Number of nodes in } I_s, N(I_s) = 4\rho d^2 \quad (12)$$

Here, ρ represents node density per Unit Area. Nodes of I_s transmit data directly to BS, hence their energy consumption. E_{Ix}^{Tx} is given by following equation (13).

$$E_{Ix}^{Tx} = 4\rho d^2 T_E \quad (13)$$

*2)*Energy Consumption in Corner Regions

In the figure 2, d is the reference distance for the formation of the non-corner region. Hence, the area of CR, $A(CR)$ is given by using equations (14),

$$A(CR) = d^2 \quad (14)$$

Number of nodes,

$$N(CR) \text{ in } CR : N(CR) = \rho d^2 \quad (15)$$

Nodes of (CR) may transmit data to the BS based on the minimum distance, so their energy consumption E_{CR}^{Tx} for sending data to the BS is followed by equation (16)

$$E_{CR}^{Tx} = (1-P)\rho d^2 T_E \quad (16)$$

Here, P represents the probability of sending data, and $(1-P)$ represents the probability of transmitting data to the BS.

*3)*Energy Consumption in the M_s

At the initial stage, compute energy consumption of normal nodes. Area of the each and every NCR in M_s is $2d^2$. There are 4-NCRs and 4-CRs. Every CR node may connect with one of the NCR's CH. An energy consumption of normal nodes in M_s, and per NCR, $E_{\frac{MS}{NCR}}^{Tx}$ is shown by the following equation (17).

$$E_{\frac{MS}{NCR}}^{Tx} = (2\rho d^2 - 1)T_E \quad (17)$$

Here, energy consumption of the CHs is computed. There are total four CHs in the 4-regions. Every CH saves energy in transmit E_{Ms-CH}^{Tx}, aggregation (φ), and receive E_{Ms-CH}^{Rx} process. Hence, their energy consumption is computed individually [12].

*4)*Energy Consumption in O_s

In DR protocol the area of every NCR maximizes from inner to the outer square. The area of NCR of O_s increases in the following approach. Length of one side of $M_s^{'}sNCR = 2d$. Length of one side of $O_s^{'}sNCR = 4d$ etc. A width of the entire regions remains same that is d. Considering this value of width and length into account, area of every NCR of $O_s^{'}$ can be computed as $4d^2$. Taking area into account can compute the total energy consumption, E_{Os}^{Tot} of O_s from the following equation (18).

$$E_{Os}^{Tot} = E_{Os-node}^{Tx} + E_{Os-all-CH}^{Tx} + E_{Os-all-CH}^{Rx} \quad (18)$$

C. Existing Clustering Protocol Technique

Some energy efficient clustering protocols like LEACH, PEGASIS, UCMR and CAWT discussed and explained the merits and demerits of that technique in the following section.

*1)*Low Energy Adaptive Clustering Hierarchy (LEACH)

The major goal of the LEACH clustering protocol technique is to enhance the lifetime of the network by equally allocating the energy consumption between all nodes and decreasing the energy consumption by creating a data aggregation. In the LEACH, load balancing is performed by CH in the cluster [13], [14], [15]. The disadvantage of LEACH protocol is that the selected CH may focus on a single part of the network. This technique is not suitable for networks organized in large regions.

*2)*Power Efficiency Gathering in Sensor Information System (PEGASIS)

The PEGASIS protocol makes a chain between the nodes. The data pass through the node to node. A new chain will be made whenever one node dies in the network. The PEGASIS algorithm distribute the energy equal to the load between the SNs within the network. The chain is made by the nodes. This algorithm gets information about the location of all the nodes and locally calculate the chain by employing the greedy algorithm [16], [17]. The transmitting distance of the node is less in the PEGASIS which is the major advantage of PEGASIS compared to LEACH protocol. As every node gets chosen once, energy dissipation is balanced between the SNs [18].

*3)*Unequally Clustered Multi-hop Routing (UCMR)

such a most of the clustering algorithm offers an equal cluster size. In UCMR protocol, each cluster incorporates a various cluster size based on its distance with reference to the BS. When the distance from BS increases then the cluster size also increases [19] [20].

*4)*Clustering Algorithm via Waiting Timer (CAWT)

The CAWT algorithm provides proximity-connectivity to create clusters. Nodes are used in the network; each node transmit a hello message to the neighbor node to show the existence. A node that has a number of hello messages organize into clusters then other nodes wait to form clusters.

IV. LITERATURE WORK

Several techniques are suggested by researches on clustering protocol for energy efficiency in WSN. In this scenario, a brief evaluation of some important contributions to the existing methods is presented below. A map dynamic harmony search-based fuzzy clustering protocol for energy-efficient wireless sensor networks.

Author	Methodology	Advantage	Disadvantage	Performance Measure
Subhashree, V. K., C. Tharini, and M. Swarna Lakshmi [21]	A Quality of Service (QoS) aware modified LEACH (M-LEACHM) clustering algorithm used for WSNs. In the M-LEACH, the CH selection was done by BS in each re-clustering period	In this literature work, a modified LEACH algorithm was presented to increase the lifetime of the network. The CH selection by the BS in the MLEACH saves more energy and maximize cluster formation time, which reduced the failure rate compared to the LEACH protocol	This proposed M-LEACH algorithm has achieved a packet delivery ratio only 0.9985	Energy efficiency Round trip time
Kour, Harneet, and Ajay K. Sharma [22]	Heterogeneous- Hybrid Energy Efficiency Distributed Protocol (H-HEED) for WSN. Here, the CH was selected based on the fraction of residual energy to the highest energy possessed by SNs.	The H-HEED protocol gained more lifetime and effective data packets compared to the HEED protocol.	The limitation of the H-HEED cannot perform well in the homogeneous environment	Energy efficiency Data Packet Lifetime
Padmanabhan, K., and P. Kamalakkannan [23]	The modified algorithm of Energy Enhanced Base station Controlled Dynamic Cluster Protocol (EEBCDCP) used in WSN. This algorithm selects a CH based on the residual energy of the SNs. The CHs were selected by the BS.	The EEBCDCP algorithm improved the clustering protocol to reduce energy consumption and increase network lifetime.	The EEBCDC's network topology is not suitable for the large scale network.	Energy Efficiency Network lifetime
Lee, Jin-Shyan, and Tsung-Yi Kao [24]	This paper has proposed a Hybrid Hierarchical Clustering Approach (HHCA) by considering a hybrid of centralized gridding used for Head Selection at upper levels and dispersed clustering used for HS at low levels	The proposed HHCA performed better in balancing energy consumption of each SNs in the Network. So, HHCA is stable compared to the Three Layer LEACH algorithm	In this proposed research work, some CHs specifically near the sink, it might die earlier due to the CHS has been a large workload	Lifetime Energy Consumption Packet Ratio
Sohn et al. [25]	The LEACH protocol used for the WSN, which employ a distributed cluster formation on Affinity Propagation (AP)	The proposed LEACH-AP protocol does not need extra hardware functionality for the position information and doesn't need to pre-determine the optimal number of clusters	This LEACH protocol doesn't suitable for networks organized in large regions.	Alive node Total number of received bits lifetime Energy Consumption
Singh et al. [26]	An enhanced energy efficiency BBO- based PEGASIS protocol in the WSN	The BBO implements an effective technique to create a short chain. This algorithm keeps the energy balanced to prolong the lifetime of the WSN	The performance parameter of the BBO-PEGASIS was not compared with the other optimization approach	Energy consumption Data Packet Transmit and receive energy.
Meenu, and Vandana [27]	Modified PEGASIS protocol improved energy efficiency in the WSN	The proposed PEGASIS hierarchical methods reduced energy consumption and maximize network lifetime. So, that presence of live nodes allows more nodes to exist.	The simulation performances of the proposed method were not clear. The SNs die early in the PEGASIS protocol	Energy Consumption Number of the live nodes and dead node
Leu et al. [28]	Energy Efficient Clustering	The EECS has made balance	The EECS protocol has	Network lifetime

	Scheme (EECS) used to prolong the life time of the WSN with Isolated Nodes (INs)	point between Intra- Cluster energy consumption and Inter-Cluster communication load based on distance and energy. The proposed method has improved the CH selection process and solved the problem of node isolation	produced additional overhead at the time of CH selection and allocation.	Network stability
Jadhav, Shruti S., and Vaishali Bodade [29]	Hybrid Energy Efficiency Distributed Cluster (HEED)Protocol for WSN	The HEED protocol doesn't create an assumption about node distribution and doesn't need special node capabilities.	The proposed HEED protocol suffers from a subsequent overhead.	Throughput Packet delivery ratio
Garg, Anshul [30]	This paper proposed Distance Adaptive Threshold sensitive Energy Efficient Network (DAPTEEN) based on TEEN and Adaptive Periodic TEEN protocols used for removing data redundancy	The DAPTEEN scheme overcome the problem of energy consumption due to redundant data transfer in the APTEEN and TEEN, thus extending the network survivability	The DAPTEEN protocol was not useful for the routing overhead because it insist the change of proposed protocol.	Average power balance Distance

V. CONCLUSION

Energy consumption is one of the major challenge in the clustering protocol of the WSNs. The energy utilization of the sensor is dominated by data transmission and reception. Hence, the proposed clustering protocols has to be energy efficient to prolong the life time of the individual sensors. Clustering is the best technique to reduce energy consumption and provide stability in the WSNs. There are different types of clustering protocol discussed in the above sections, each technique has their individual advantages and disadvantages. This paper presents the idea of some efficient protocols based on the clustering. This clustering protocol techniques aims to reduce the energy consumption and enhance the lifetime of the nodes. Several clustering protocol have been implemented in the past years, but still improvements are needed in the clustering protocol in terms of Quality of Service parameters. In the above mentioned protocols LEACH shows an improvement when compared to the other protocols. In future, a hybrid clustering protocol will be developed for reducing the energy consumption in WSN.

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