A Review: Threshold Based Clustering Schemes of Routing Protocols for Heterogeneous Wireless Sensor Networks

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Summary
The threshold based clustering schemes are a new era of clustering techniques. The threshold based clustering scheme offers a process of optimal cluster formations. The optimal utilization of the energy by using threshold-based clustering scheme network lifetime by process of making clusters. The outset of optimal threshold based clustering is new research area in heterogeneous routing protocols. This study presents the review of the threshold based clustering schemes used in various routing protocols such as soft threshold, hard threshold, hierarchical clustering, two-level threshold and three level threshold schemes. The concept threshold based energy efficient routing schemes provide a variety of routing algorithms. The characteristics and properties of widely known threshold based scheme clustering protocols are compared and scrutinized by several attributes and aspects. Furthermore, challenges and discussion on possible future research areas for threshold based clustering schemes presented in this paper. Moreover, this paper discusses and presents future research, challenges, and issues for threshold based clustering the scheme based routing algorithms for heterogeneous wireless sensor networks.

Key words:
Networks, Communication protocols, Threshold, Energy, Heterogeneous

1. Introduction

The recent technological evolutions in the technology of wireless networks contain rapid developments by small, cost-effective, lower energy consumption and smart sensor nodes in the heterogeneous wireless sensor networks. The wireless sensor networks are extensively used in several applications such as army applications, health-related, industrial and environmental automation. Due to harsh environment and requirement of the application requires sensor nodes to be randomly deployed in vast quantities and operate separately [1]. Those unattended networks of the sensors which cannot be consistently replaced and battery charged. Consequently, the issues of the energy restrictions and consumption are the most important issue to be resolved. Normally network routing protocols can be classified into three main categories flat, hierarchical and location-based routing protocols. The hierarchical routing protocols are also called as cluster-based routing protocols. To gather and aggregate the data from the whole network, sensor nodes are divided into a number of groups which are known as clusters [2]. The clusters present in the network are having one special node which is called cluster-head and other nodes are called member nodes. The formation of the cluster contains the cluster-head (CH) and member nodes where the sensor nodes broadcast their data towards the corresponding cluster-head. The cluster-head is aggregating data from the network and eventually transmit it towards the base-station (BS). The cluster-head are required transmit data towards high distance as compared to other members therefore, CHs spends higher rate of energy [3, 4]. The common solution for the problem of energy depletion is to balance the energy consumption among the nodes by the election of the cluster-heads [5]. The reduction in the energy consumption can be achieved by efficient clustering formation. The clustering approaches and techniques are employed in various clustering algorithms and routing protocols [6]. The current research trends are using adaptive weight based clustering technique for the improvement of performance in terms of energy for the wireless sensor networks. Since all the member and cluster-head nodes are not having the same energy in the network which is called heterogeneous wireless sensor networks. The clustering techniques are extended by two level or three level weight based clustering techniques. The threshold based clustering technique employs various factors considered for the election or selection of the cluster-heads such as distance, energy, and mobility. The threshold based clustering technique is based on a threshold for the improvement in the quality pertaining to the clustering technique. The threshold based clustering algorithms are using two level and three level threshold levels for the selection of efficient cluster-heads among the member nodes of the cluster. The clustering techniques are very useful for encountering energy depletion issues and network lifetime in heterogeneous wireless sensor networks.

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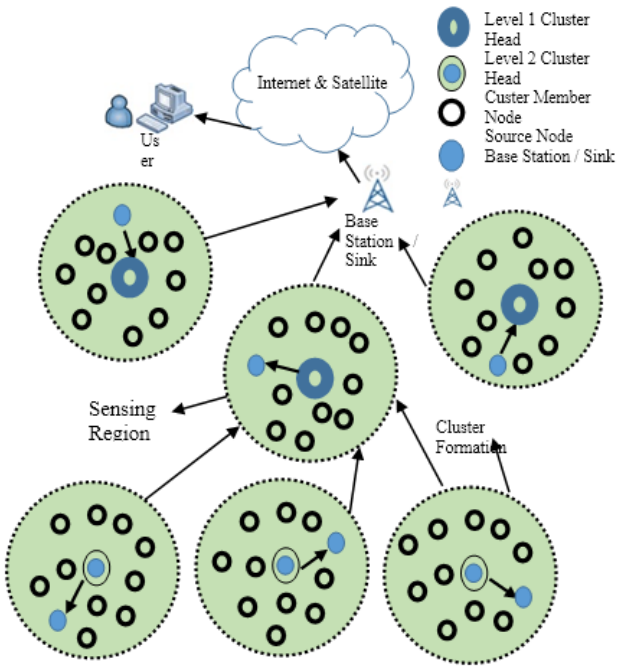

Fig. 1 Common clustered wireless sensor network topology

The Fig 1. depicts the typical topology of the clustering based routing protocol. Moreover, the threshold based clustering schemes are used for cluster-head selection which is efficient as compared to the other member nodes in the network [7, 8]. The various threshold based schemes are present in multiple proposed algorithms and routing protocols.

2. Network Design factors and Routing Issues in HWSN

The HWSNs are facing various constraints and issues pertaining to network reliability, topology dynamics. The various resources of networks such as bandwidth, energy consumption, memory storage, processing and hardware size. There are some important design issues which should be considered while designing routing algorithms which are following.

Constrained Processing Capability: The network member sensor nodes are having limited memory, low battery capability, a limited processor for data processing and sensing, transmission and communication. These constrained and limited capabilities of sensor nodes affect the processing of sensor node. The routing protocol or algorithm should take into count the effective usage of the resources in the network.

Limited Battery Power: The network member sensor nodes are having a limited energy source for sensing and communication. The routing algorithm should be efficient for power consumption to increase the lifetime of sensor nodes. The sensor nodes while they are idle they should be assigned sleep mode to save the energy.

Deployment Area or Sensing Region: The location and tracing are important for the sink node and base station to data propagation, therefore the sensors should be deployed in the sensing region in a way to keep them in range of the base station (BS).

Random deployment: The sensor nodes are deployed in vast number in the deployment area. To achieve the optimal clustering in the network to reduce the energy consumption the deployment should be uniform and rationale.

Heterogeneity of Network: The communication network can be heterogeneous or homogeneous. The heterogeneity of network means the nodes in the network are having different levels of the energy. The clustering approach uses a cluster head selection and election mechanism takes into count the factor of energy levels.

Velocity and Mobility: The network member nodes can be mobile and moving with variable or a fixed velocity to sense a particular region. The link between the sensor nodes and sink depends on velocity and location. This issue is the important due high usage of mobility in sensor nodes.

Data acquisition: The member node of the network is sensing in the region and collecting data from the particular area. The sensor nodes are responsible to collect data and transmit them toward the sink node. The data acquisition is a significant issue in the routing protocol design.

Scalability: The number of nodes is not certain or limited during the establishment of the network. Therefore, the network is able to be scale, eventually the issues of scalability become important in the routing algorithm design considering the performance of the overall network.

Packet Delay: The packet delay which is also referred as latency is a delay of packet transmission which occurs between sender and receiver. The lower delay is beneficial for attaining the optimum throughput for enhancing the lifetime of the network. The routing protocols design is ought to be designed in a fashion to encounter the delay issues.

Node Failure: The node failure is also an important issue in routing algorithm design because it's crucial for the algorithm to enable a lifetime of network reducing redundancy by coping node failure.

Reactive Fault Tolerance: The routing protocol design also faces issues of fault tolerance which arises in the event of failure of the nodes. The routing algorithm design is to be designed in a way to deal the fault tolerance for an optimum lifetime of the communication network.

3. Heterogeneous WSN Routing Protocols

The heterogeneous wireless sensor networks are variable in terms of topology and networking properties which brings significant performance related issues during the design of routing algorithms or routing protocols dedicated to heterogeneous wireless sensor networks. The HWSN routing protocols are made to establish communication of nodes among the network for data dissemination based on certain procedure and rules. The routing protocol design is an important issue in HWSNs due low power source, limited hardware capabilities, limited bandwidth and link which is prone to errors. The suitable routing protocol for the HWSN should guarantee the packet delivery in an efficient way with low power consumption towards the destination node. In the earlier times the network communications were performed simple and direct manner. The sensor nodes were aggregating and propagating data towards the base station. This method of communication nodes contained errors related to node failure due to the distance between the source and destination which overall affects the network lifetime [9]. Furthermore, the multi-hopping technique was developed where the every sensor node had direct transmission towards sink node, by sending the data towards the neighbor nodes which eventually transferred to the sink node. The transfer of data between sensor nodes is performed to reach the nearest node of the sink and finally it arrives at sink node. The disadvantage of this method was the node which is close to the sink node is prone to node failure due to staying continuously active by transmitting or receiving the data from the source to the sink node or base station.

The energy efficiency is most important norms during the design process of the routing algorithm for HWSNs. Therefore, the clustering approach is used for achieving the optimal energy utilization in the routing algorithms. The clustering technique which divides the whole network into the chunks, which are called a cluster. The nodes inside the cluster are called member nodes and one of them is selected or elected as cluster-head (CH). The key aim behind the selection of cluster-head is to route all the data from member nodes towards the base station via cluster node. The cluster-heads are assigned responsibility for aggregating data from the member nodes of the cluster, which is eventually transmitted towards sink node. Consequently, some nodes of the whole network are transmitting data over the distant base station with other nodes transmitting data over short distance resulting in low energy consumption for increasing the lifetime of the network. In heterogeneous and homogenous WSNs clustering approach is widely used for network formation [10]. The network in which all the member nodes are having the same energy level is known as homogenous wireless sensor networks. The common basic routing protocol proposed is LEACH for the homogenous WSNs network. The cluster head selection is easy to process because all the sensor nodes possess the same level of energy. In contrast, those networks which member nodes are not having the same level of energy and different nodes are having different levels of energy is called heterogeneous wireless sensor network. Additionally, the levels of energy can be two, three or multi-level pertaining to the deployment of the network. The heterogeneous routing protocols designs are containing the technique of clustering which is based on the specific criteria and weight for achieving optimum performance of the network. The homogenous network after formation and data dissemination turns into the heterogeneous network where the formation or clustering becomes important for the design of heterogeneous routing algorithms.

4. Literature Review and Background

The wireless sensor networks can be classified into two kinds which are having properties of the homogeneous and heterogeneous. There are various routing protocol and routing algorithms proposed in available literature pertaining to the heterogeneous wireless sensor networks. In this study we have focused on some well-known heterogeneity based routing protocols. Moreover these routing protocols design is considered for the heterogeneity of the network. The main important goal of these routing protocols is to prolong the overall network lifetime and increase the performance of the network. Most of routing protocols are employing the clustering approach and choosing cluster-heads for the data dissemination and propagation. These routing protocols are having a threshold based scheme for achieving optimal performance of the sensor network. Some important and significant routing protocols, routing algorithms and threshold-based clustering schemes are following.

4.1 TEEN

The threshold sensitive energy efficient (TEEN) routing protocol presented in [11] is important routing protocol which is based on a threshold for energy efficiency in the network. This protocol employs hierarchical clustering approach and data-centric for the formation of the network. This protocol pertains to the category of reactive routing protocols. The important aim of this routing protocol is to sense and gather data from sensing region afterward transmit it towards sink node. The TEEN routing protocol contains clustering topology which two-tier with two types of threshold is known as a soft and hard threshold. The hard threshold is triggered in the shape of a threshold value for sensed data; since the transmitter is switched on in the case when data is ought to be acquired for transmission towards cluster-head (CH). The soft

threshold is triggered for a small chance of the value sensed for the attribute where the sensor nodes transmit data towards cluster-head by turning on the transmitter if the values have changed according to the soft threshold. The CH in TEEN transmits to member nodes the information of soft and hard threshold. This method makes sure that the nodes are permitted according to the hard threshold for transmission of data in case of sensed data is valuable, which considerably reduces the transmission events. The sensor node determines if the sensed data value is out of the hard threshold then it compares the attribute changes with the requirements of the soft threshold for the transmission which eventually turns on the transmitter for data transmission to the cluster-head.

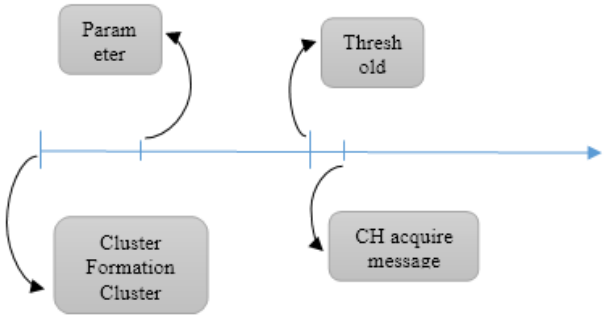

Fig. 2 The timeline of the TEEN routing protocol

The Fig 2. illustrates the working timeline regarding TEEN routing algorithm. The main advantage of the TEEN routing protocol is the data broadcast is estimated and controlled based on two thresholds. The main disadvantage of the TEEN is the sensor node must meet the soft or hard threshold value otherwise transmission will not occur. Moreover this protocol is not very suitable for the real-time applications in which the data aggregation and transmission is occurring frequently.

4.2 APTEEN

The adaptive threshold sensitive energy efficient (APTEEN) routing protocol proposed in [12] is enhanced version of TEEN. This routing protocol contains the properties of the reactive and proactive network which is also known as a hybrid network. The APTEEN uses a system which is based on a query which has three types: constant, historical and on-time which are utilized in the hybrid network. The cluster-head in the APTEEN is broadcasting various information such as physical location attributes, soft and hard threshold, TDMA time-slot scheduling and transmission time. The main advantage of this routing protocol energy efficiency and increasing network lifetime. This routing algorithm has higher overhead and complexity.

4.3 SEP

The SEP is mentioned in [13], A Stable Election Protocol for clustered heterogeneous wireless sensor networks is famous routing algorithm which provides stability in the field of HWSNs by incorporating multiple heterogeneous attributes and characteristics related to the HWSN network which increases the lifetime of the network with the help of utilizing energy levels set for the member nodes of the cluster. The constrictions of the levels are based on the energy by having member nodes as advance nodes with a fraction of m and residual energy holding normal nodes. The stability in the HWSNs sensing field is enhanced with the usage this approach for a reduction in the power consumption. The SEP routing algorithm uses (1 + axm) to increase the energy to balance the energy among the nodes which are advanced for the selection of cluster-head as compared to the normal nodes. The probabilistic equation used in the SEP contains 1/popt (1+axm) with the epoch for providing the increased energy. The Popt is set for the probability for the election of the cluster-head in the network. The following is equation used in SEP for making probabilities.

$$P = \frac{P_{opt}}{P + am} \text{ Normal sensor node} \quad (1)$$

The Popt is the probabilistic node which will be selected as the cluster-head. The normal nodes are having less energy as compared to the advance nodes. The following is given the probability of the advanced nodes

$$P = \frac{P_{opt}(1+a)}{(a+am)} \text{ Advance sensor node} \quad (2)$$

The advance nodes are having (1+a) more energy as compared to the normal nodes. The two-level heterogeneity provides a probabilistic selection of the cluster head for achieving optimum cluster-head election.

4.4 TSEP

The threshold-sensitive stable election protocol (TSEP) which is proposed in [14] that is threshold-based routing protocol uses threshold approach for the cluster-head selection. The TSEP is reactive fashion routing protocol where the transmission energy consumption is controlled by the introduction of the three-level based threshold of heterogeneity. Considering the energy model it makes clusters by computation with the help of three energy levels namely normal, intermediate and advance nodes. The advance nodes are possessing higher energy as compare to all present member nodes in the network and advance nodes are having lower energy level as compared to the advance nodes, whereas, the normal nodes are

having normal energy levels. The TSEP is utilizing reduced energy dissipation by using the heterogeneity of the energy. The algorithm starts making clusters with CH broadcasting the specific parameters such as report time, attributes, hard and soft threshold. The probabilities for the cluster head selection in this routing protocol are as follows.

$$P_{nrm} = \frac{P_{opt}}{(1+\alpha.m)+b\mu} \text{ Normal sensor node} \quad (3)$$

$$P_{\text{int}} = \frac{P_{opt.(1+\mu)}}{(1+m.\alpha+b\mu)} \text{ Intermediate sensor node} \quad (4)$$

$$P_{\text{adv}} = \frac{P_{opt.(1+\alpha)}}{(1+m.\alpha+b\mu)} \text{ Advance sensor node} \quad (5)$$

From calculations of the above given equations the threshold probability equations are calculated.

$$T_{nrm} = \begin{cases} \dfrac{P_{nrm}}{1-P_{nrm}(\text{r}.\text{mod}\dfrac{1}{P_{nrm}})0} & \text{If } N_{\text{nrm}} \in G \end{cases} \quad (6)$$

$$T_{\text{int}} = \begin{cases} \dfrac{P_{\text{int}}}{1-P_{\text{int}}(\text{r}.\text{mod}\dfrac{1}{P_{\text{int}}})0} & \text{If } N_{\text{int}} \in G \end{cases} \quad (7)$$

$$T_{adv} = \begin{cases} \dfrac{P_{adv}}{1-P_{adv}(\text{r}.\text{mod}\dfrac{1}{P_{adv}})0} & \text{If } N_{\text{adv}} \in G \end{cases} \quad (8)$$

This algorithm contains three levels of heterogeneity threshold which has normal, intermediate and advance nodes. The probabilistic selection of the cluster-head in this way provides more energy for the network.

4.5 DEEC

The distributed energy efficient clustering algorithm (DEEC) is reported in [15], which is based on the probabilistic clustering scheme incorporating routing algorithm. The DEEC is selecting and electing cluster heads by gaining the information ratio among the member nodes for their pertaining available or residual energy for all nodes with average available energy into the network. The requiring this information about the residual energy also requires energy between the sensor nodes. The cluster-head (CH) is chosen on the basis of the sensor node available energy as compared to the average energy in the network. The DEEC uses two levels of the energy by naming normal and advance nodes. The probabilistic equation used in DEEC is as follows

$$P = \frac{P_{opt}E_i(\text{r})}{(\text{P}+\text{am})\,\text{E(r)}} \text{ Normal sensor node} \quad (9)$$

$$P = \frac{P_{opt}(1+a)E_i(\text{r})}{(1+\text{am})\,\text{E(r)}} \text{ Advance sensor node} \quad (10)$$

This routing protocol employs advance nodes and normal nodes for the threshold where the residual energy and average energy is counted in the equation. This routing protocol assumes that the HWSNs is having the energy levels for different nodes. The cluster-heads are elected based on their residual energy level.

4.6 BEENISH

The balanced energy efficient network integrated super heterogeneous routing protocol is reported in [16] which utilizes the threshold based energy scheme for the level which is containing a threshold for the energy pertaining to the member sensor nodes of the network. This routing protocol adopts four levels of the energy for member sensor nodes. The cluster-head (CH) is selected on the available energy into the power source of the sensor nodes. The concept of the DEEC is implemented in the BEENISH for cluster-head selection which is depending on the levels of energy for the member nodes according to average network energy. The DEEC is consisting of only two types of the sensor member nodes advance and normal. Contrary, BEENISH is using four types of the sensor node energy levels namely advance, normal, ultra-super and super. The routing protocol enables network with stability and lifetime by providing higher energy conservation. The probability of the threshold used in this algorithm is as follows.

$$P_i = \begin{cases} \dfrac{P_{opt}E_i(r)}{(1+m(a+m_0(-\text{a}+\text{b}+\text{m}_1(-\text{b}+\text{u}))))\,\text{E(r)}} s_i \text{ is the normal node} \\ \dfrac{P_{opt}(a+a)E_i(r)}{(1+m(a+m_0(-\text{a}+\text{b}+\text{m}_1(-\text{b}+\text{u}))))\,\text{E(r)}} s_i \text{ is the advance node} \\ \dfrac{P_{opt}(1+b)E_i(r)}{(1+m(a+m_0(-\text{a}+\text{b}+\text{m}_1(-\text{b}+\text{u}))))\,\text{E(r)}} s_i \text{ is the super node} \\ \dfrac{P_{opt}(1+u)E_i(r)}{(1+m(a+m_0(-\text{a}+\text{b}+\text{m}_1(-\text{b}+\text{u}))))\,\text{E(r)}} s_i \text{ is the ultra node} \end{cases} \quad (11)$$

The above-mentioned equation values are put into the threshold equation to achieve the cluster head selection by dividing them into four levels namely normal, advance, super and ultra-nodes.

4.7 REECH-ME

The regional energy efficient cluster heads based on maximum energy (REECH-ME) presented in [17] routing protocol provides sink mobility with the threshold energy approach for the election and selection of the cluster-head

for increasing the lifetime of the network with optimal utilization of the energy. The heterogeneity is incorporated into this routing algorithm. The clustering approach is used to fetch the sensed data from the sensing region and transmitted towards the base station. This routing protocol utilizes the energy in the full coverage area by dividing the network area into the sub-regions. Each region contains a fixed number of nodes with the sink node located at the center of the area. The following is the energy equation used in the REECH-ME routing protocol.

$$E_{Tx}(k, d) = E_{elec} * k + \in_{mp} * K * d^4 \quad (12)$$

$$E_{Rx}(k) = E_{elec} * k \quad (13)$$

The E_{elec} assumed the dissipated energy which is being consumed by the transmitter for the communication or propagation of the data. The cluster-head selection is achieved by the probability for optimal cluster head selection. Minimum energy consumption is provided within the coverage area to provide stability and lifetime of the network. In this routing protocol the unattended areas are coverage hole.

4.8 SCEDH

The efficient stochastic clustering in WSN with energy distributed heterogeneity (SCEDH) is presented in [18] which uses probabilistic and stochastic clustering approach for HWSN for cluster head selection and dividing the nodes in terms of their energy levels. This routing protocol employs three levels of the threshold for optimal usage of the energy for transmission and propagation in the network by the member nodes. The three levels of the threshold are namely super, advanced and normal nodes. This clustering algorithm applies clustering approach by using energy heterogeneity for the nodes. The nodes are assigned initial energy at the beginning all the nodes are having the same energy. The algorithm contains multi-level energy for the sensor nodes, where some percentage of nodes are having more energy as compared to the other sensor nodes. This routing protocol is aimed for the extending the lifetime of the network with re-energizing the nodes. This routing protocol incorporates following equation for the energy conservation.

$$P_{enh} = p_i + P_{opt}\frac{E_i(\mathrm{r})\,\mathrm{d}_{\mathrm{toBS}}}{\overline{E_{tk}}\,\overline{d_{toBS}}} \quad (14)$$

$$d_{toCH} = \frac{M}{\sqrt{2k\pi}} \quad (15)$$

The equation of probability (14) showing the total residual energy for the nodes. Whereas the equation (15) is calculating the average distance between the cluster members and the cluster head. The random topology is assumed in the network where the nodes are having restricted energy in the battery.

4.9 TCES-MIEEPB

The threshold based chain-leader election scheme for mobile sink improved energy-efficient PEGASIS-based routing protocol mentioned in [19] which is enhanced version of MIEEPB routing protocol which is based on PEGASIS routing protocol. The threshold base chain-leader selection scheme is implemented in the routing protocol where the sink is mobile. The energy efficiency is achieved by introducing the three-level heterogeneity in the sensor nodes. Initially the network sensor nodes are having uniform energy level but after transmission and communication the sensor nodes are having versatile energy among them. The energy levels which are used in this routing protocol are namely normal, strong and herculean nodes. This routing protocol also considers distance and proximity into consideration while electing cluster-head. The clustering approach which is based on the chain is used in this routing protocol for the formation of the cluster. The equation used for the energy in the TCES-MIEEPB is given below.

$$P_i = \begin{cases} \dfrac{Popt\,Ei(r)}{(1+m.(a+mab))\bar{E}(r)} = \dfrac{Popt.Etotal(1-\frac{r}{R})*\frac{dsi}{D0}}{(1+m).(a+mab))\,\bar{E}(r)} & if\ si\ is\ normal node \\ \dfrac{Popt\,(1+a)\,\bar{E}i(r)}{(1+m.(a+mab))\bar{E}(r)} = \dfrac{Popt(1+a).Etotal(1-\frac{r}{R})*\frac{dsi}{D0}}{(1+m).(a+mab))\,\bar{E}(r)} & if\ si\ is\ strong\ node \\ \dfrac{Popt\,(1+b)\,Ei(r)}{(1+m.(a+mab))\bar{E}(r)} = \dfrac{Popt(1+b).Etotal(1-\frac{r}{R})*\frac{dsi}{D0}}{(1+m).(a+mab))\,\bar{E}(r)} & if\ si\ is\ herculean node \\ 0 & otherwise \end{cases} \quad (16)$$

The probabilistic three level threshold based cluster-head selection scheme is used in this algorithm. The sink node is comparing the distance between the nodes and the perform election of the node for the transmission of the data.

4.10 DECV

The delay effective and correlative velocity (DECV) routing protocol for threshold based cluster head selection in heterogeneous WSN is presented in [20] which is threshold-based routing algorithm for the heterogeneous wireless sensor network. This routing protocol considers the velocity threshold for improving the overall

performance of the network where the mobility of nodes is very high. The higher velocity of sensor nodes makes network failure because of nodes becoming out of range of broadcast. The clustering approach is used in this algorithm where the cluster-head is selected on the basis of the threshold levels for reducing routing overhead and delay. This routing protocol reduces the packet drop and delay with introducing adaptive approach named as a velocity threshold cluster-head election. The nodes are classified into the priorities by their specific velocities for selecting the cluster-head for the smooth transmission and propagation of the sensed data.

$$P_i = \begin{cases} \dfrac{P_{opt}\,T(r)}{\overline{T}(r)(1-k.(\sigma+k_o.\gamma))} \\ \dfrac{(1-\sigma)P_{opt}\,T(r)}{\overline{T}(r)(1-k.(\sigma+k_o.\gamma))} \\ \dfrac{(1-\gamma)P_{opt}\,T(r)}{\overline{T}(r)(1-k.(\sigma+k_o.\gamma))} \end{cases} \quad (17)$$

This routing protocol embeds the threshold based scheme for choosing optimal cluster-head among the member nodes. The algorithm grants the sensor nodes ability to select cluster head by adding parameters of current location and probabilistic location of the sensor nodes.

5. Comparative Analysis and Discussions

The wireless sensor networks are embedding into our daily life. The cluster formation approach is widely used for the data acquisition and transmission in the form of data packets into the wireless sensor networks. The clustering approach enables wireless sensor network to enhance the capabilities in terms various performance metrics. The cluster-heads are collecting data from the member sensor nodes in the cluster then transmit it towards the base station (BS). The various protocols discussed in this study assumes the heterogeneity factors of velocity and energy for uplifting the network lifetime with reducing the chance of network failure. The threshold based techniques discussed in this study has used heterogeneity in their routing algorithms. Consequently, the heterogeneity attributes of the WSN prone to various performance related issues. In this paper we have explained in detail the threshold based clustering schemes for the heterogeneous wireless sensor networks. The comparison of the different routing protocols according to their properties and attributes are as follows.

Table 1: Comparison of different HWSNs routing protocols

CH factors	*CH*	*Mobility*	*Size of cluster*	*Type of network*	*Energy*	*PDR*
TEEN	CH based	Static	No	Reactive	Low	Good
APTEEN	CH based	Static	No	Reactive	Moderate	Good
SEP	CH based	Static	No	Proactive	Low	Lower
TSEP	CH based	Static	Yes	Proactive	Moderate	Moderate
DEEC	CH based	Static	No	Reactive	Low	Lower
BEENISH	CH based	Static	Yes	Proactive	High	Good
REECH-ME	CH based	Static	Yes	Proactive	Moderate	Good
SCEDH	CH based	Static	No	Proactive	Moderate	Lower
TCES-MIEEPB	CH based	Mobile	No	Proactive	High	Good
DECV	CH based	Mobile	No	Proactive	High	Moderate

The table 1. shows a comparison of various factors of different routing protocols. This study is helpful for understanding the basic principles and working of the well-known routing algorithms anticipated for the heterogeneous wireless sensor networks. In this study important routing protocols are mentioned and discussed for suitability of their threshold based schemes.

Table 2: The Advantages and limitations of various Routing Protocols

Authors	Routing	Advantages	Limitations
A. Manjeshwar., D.P. Agrawal [11]	TEEN	This is clustering approach based algorithm which has a threshold. It has a good lifetime in the clustering	This routing algorithm is suitable for the wireless sensor networks.
A. Manjeshwar., D.P. Agrawal [12]	APTEEN	This is enhanced version of the TEEN. This has higher energy efficiency as compared to TEEN	The data aggregation is done by the specified sensor node in the region
G. Smaragdakis, I. Matta and A. Bestavros [13]	SEP	This routing algorithm is also based on the clustering scheme. This routing protocol is good in Energy consumption.	The energy in the cluster head might be decreased during transmission towards the base station.
A. Kashaf, Nadeem Javaid, Zahoor Ali Khan, and Imran Ali Khan [14]	TSEP	It is an extension of the SEP algorithm which extends the stability of the network.	The network lifetime is improved by the dead nodes.
L. Qing, Q. Zhu, and M. Wang [15]	DEEC	This algorithm provides good energy balancing among nodes.	The path and distance are not considered.
T. N. Quereshi, N. Javaid, A. H. Khan, A. Iqbal, E. Akhtar and M. Ishfaq [16]	BEENISH	The network lifetime is extended by using threshold levels of the lasting power source of nodes.	Nodes mobility is not incorporated in this algorithm
A. haider, M. M. Sandhu, N. Amjad, S. H. Ahmed, M. J. Ashraf, A. Ahmed, Z. A. Khan[17]	REECH-ME	This algorithm counters the node failure by the preservation of the energy.	The scalability of nodes is not considered in the protocol design.
M. Yebari and M. Essaaidi [18]	SCEDH	The overhead of communication is reduced and lifetime is extended.	This algorithm has load balancing issues
Kang Wei-Xin, Raja Asif Wagan, Li Jingde and Zhang Chengcheng [19]	TCES_MIEEPB	This routing algorithm uses threshold scheme with sink node mobility.	This routing protocol is based on MIEEPB protocol
Kang Wei-xin; Raja Asif Wagan; Saifullah Adnan; Li Jingde [20]	DECV	This algorithm focus on delay. The algorithm considers mobility.	This algorithm is focusing less on parameters energy.

The routing algorithms are compared according to their cluster formation and cluster-head selection approach. This study analyzes various routing protocols according to their robustness, reliability, network lifetime and energy etc. The routing protocols are compared on the quantitative and qualitative basis for their performance of communication. The table 2. demonstrates the major advantages and disadvantages of the important routing protocols pertaining to the heterogeneous WSN. The limitations and advantages of the routing protocols are highlighted to understand the basic principles of these routing protocols.

Table 3: The comparative table of routing protocols

Name	Network lifetime	Delay	Scalability	Energy	Heterogeneity
TEEN	Medium	Low	Low	Moderate	2
APTEEN	High	Low	Medium	High	3
SEP	Low	Moderate	High	Moderate	2
TSEP	Medium	Low	High	High	3
DEEC	High	High	High	High	2
BEENISH	Medium	Moderate	Medium	High	4
REECH-ME	High	High	High	Moderate	3
SCEDH	High	High	High	Moderate	2
TCES-MIEEPB	Medium	Moderate	Low	High	3
DECV	High	Low	High	Moderate	3

These routing protocols are showing their efficiency in terms of the various factors and properties. The Table 3. Shows the comparative analysis of the various aspects of those routing protocols in terms of scalability, energy and heterogeneity.

6. Conclusion and Future work

In this study, the efficiency and performance of the routing protocol according to its threshold based routing scheme for HWSNs discussed. This approach contains cluster-head selection based on various thresholds for achieving optimal performance. There are various factors affecting the threshold weight such as distance, residual energy and velocity. The reduced data communication energy consumption and overhead, neighbor discovery and cluster-head election are established. The network connectivity is achieved by establishing communication through the cluster heads to fetch the data from the cluster. The optimal parameters were used for cluster formation. This study provides a general overview of the available threshold based clustering schemes for the heterogeneous wireless sensor network based routing algorithms. Various researchers studied on different issues and problems to achieve efficient communication by designing specific routing protocols for HWSNs. The routing protocol design is heavily depending on various threshold based clustering schemes for reducing energy consumption and increasing network lifetime. There are various threshold

based techniques proposed with complexity, efficiency and effective communication. Each routing protocols working principle, advantages and disadvantages are also highlighted. The various characteristics and properties of routing protocols are compared and analyzed for their performance in a communication network. The research issues, challenges and future research directions are highlighted in this study.

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