Review-Comparison of Heterogeneous Clustering Protocols of Wireless Sensor Network

Kiranpreet Kaur, Amandeep Kaur

Department of Computer Science,
Guru Nanak Dev University, Regional Campus Jalandhar (Punjab), India

Abstract

Recent developments in wireless communication shows more interest on delivering sensitive information to its final destination under several constraints such as energy, reliability, latency, security and stability. Through the various developments in digital technology, Micro-Electro Mechanical Systems (MEMS) and wireless transceiver, it is possible to integrate sensing and computing units along with power supply and transceiver to a single unit called as Sensor Node (SN). The collection of SNs built a special type of network called as Wireless Sensor Networks (WSNs). Many pre-existing research proposals on WSNs have paid more attention on minimization of energy consumption during the process of sensing, computation, and transferring data to the Base Station (BS) using gateways. However clustering is the most important technique that is used to extend the lifetime of sensor network by reducing energy consumption as well as scalability, but node heterogeneity is another important aspect which can be used to save the energy consumption of SNs in the network field. In this paper, a survey of the state-of-the-art heterogeneous routing protocols in WSNs has been compared to find the merits and demerits among various parameters. These comparisons is done with respect to various performance evaluation parameters like CH Selection, Energy Efficiency, Application Specific and Security.

Keywords: Clustering, Heterogeneous sensor nodes, Node Heterogeneity, Routing, Wireless sensor Networks.

I. INTRODUCTION

In last two decades with advancements in wireless technologies, Wireless Sensor Networks (WSNs) become an essential part of our everyday life as these networks are being used in vast areas of applications. WSNs consist of Sensor Nodes (SNs) which are equipped with transceivers and low-power microcontrollers to perform various operations in the network. The Sensor Nodes collect the data from the regions in which these are deployed and then transfer to Cluster Heads (CHs) to the Base Station (BS). BS is the location, from which sensed data can easily be sent to the user by some physical medium. The connectivity among the Sensor Nodes can be of single or multihop. Both mechanisms provide overwhelm to BS as a number of Sensor nodes try to communicate directly with Base Station. Generally, this process is not used as their is a wastage of energy. However clustering is a better solution for saving energy of individual SN. Clustering is the mechanism in which all the major decisions of SNs are taken by some specialized nodes called as Cluster Heads. Clustering is a basic technique used to extend the life time of a sensor network by reducing energy consumption as well as network scalability. Clustering is based on single, and multihop communication respectively. Both single and multihop communications are having several pros and cons such as in single hop communication as the distance increases energy losses are also higher, whereas multihop communication suffers from energy hole problems.

There is large range of applications where WSNs can play an important role such as monitoring of environment, military operations, pollution control system, detection of earthquake, control of vehicle motion, surveillance system tracking of target and monitoring system for patients.

Although there exist many research proposals in the literature on these issues, but in this paper, we have concentrate on the heterogeneous WSNs as these can also play an important role in many real - time applications. There are numerous parameters based on which the performance of WSNs can be analyzed. Some of these parameters are as follows: the lifetime of the network field, type of deployment of SNs, packet delivery ratio, latency, connectivity, reliability, scalability, stability, minimization of cost of energy consumption and, energy efficiency.

For improvement of network lifetime, node heterogeneity is exploited in many research proposals. Node heterogeneity can be defined in terms of computation, communication and link connectivity. Depending upon the level of node heterogeneity, SNs of the network field can be classified into different categories. WSNs are classified into two broad categories as cluster and non-cluster based which are further subdivided into homogeneous or heterogeneous. Heterogeneity is further subdivided according to the computation, communication, and link connectivity as shown in Fig. 1.
Heterogeneous WSNs were proposed by Heinzelman et al. (2000) to address the issue of network uniformity. To resolve this issue, level two homogeneous environment is replaced by heterogeneous environment. Therefore, it does not perform well when considered the remaining energy of Sensor Nodes for CH (Cluster Heads) selection. In LEACH, Cluster Heads are responsible for transfer of data to Base Station, but do not consider the remaining energy of Sensor Nodes for CH selection. Therefore, it does not perform well when heterogeneous environment is replaced by heterogeneous environment. To resolve this issue, level two heterogeneous wireless sensor network was proposed by Smaragdakis et al. (2004) called as Stable Election Protocol (SEP) which includes two types of nodes. In SEP, CH selection was based on Weighted Election Probability (WEP). The main drawback of SEP was that it had substandard performance with respect to the stability of Sensor Nodes for multi-level heterogeneous WSNs. Distributed Energy Efficient Clustering (DEEC) algorithm was initiated by Qin et al. (2006) for multi-level heterogeneous WSN to prolong the life time of the network field. The selection of CHs in DEEC Protocol is based on computation between the mean value of total energy of network field and remaining energy per SN. It rotates the cluster-head role among all nodes to enhance energy uniformity.

As summarized in Table 1, although there exists many review on routing protocols for WSNs, but our work differs from various other cluster-based routing protocols developed for HWSNs.

- This review is an attempt to provide the analytical discussion on various cluster-based routing protocols.
- A detailed classification of routing protocols for Heterogeneous WSNs is survey in the proposal.
- Detailed comparative analysis of various existing routing protocols is provided with respect to various performance evaluation metrics.

Based on pre-existing literature survey in Table 1, it has been analysed that the most of the routing protocols have some characteristics such as deployment of SNs, data redundancy, energy consumption, size of SNs, security, reliability, and fault tolerance, but none of the existing routing protocols have considered the node heterogeneity with respect to various metrics. With respect to these points, in this paper, we have defined a complete taxonomy of different heterogeneous protocols with respect to various performance evaluation parameters.

Table 1: Summary of previous reviews of routing protocols for HSWN

<table>
<thead>
<tr>
<th>Authors</th>
<th>Paper</th>
<th>Merits</th>
<th>Demerits</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liliana &amp; Nidal</td>
<td>Comparison of clustering algorithm and protocol for WSN.</td>
<td>Good classification of clustering protocol.</td>
<td>Less parameters selected for comparison.</td>
<td>To extend the WSN lifetime.</td>
</tr>
<tr>
<td>Shafiullah et al</td>
<td>Energy efficient and QOS aware routing protocol for WSN.</td>
<td>Strength and weakness of each protocol explained.</td>
<td>Detailed comparison table is missing.</td>
<td>Energy efficiency, minimize bandwidth and latency</td>
</tr>
<tr>
<td>Katiyar et al</td>
<td>Clustering algorithm for WSN.</td>
<td>Type of heterogeneity included.</td>
<td>Less parameters selected for comparison.</td>
<td>Energy efficiency, System stability.</td>
</tr>
<tr>
<td>Wei et al</td>
<td>Clustering based routing protocols in WSN.</td>
<td>Challenges in clustering were highlighted.</td>
<td>Tabular classification was missing.</td>
<td>Accuracy based 3D network design.</td>
</tr>
</tbody>
</table>
Sha et al. (2013)
Multipath routing techniques in WSN.
Good qualitative comparison
Heterogeneity not considered while doing comparison
Optimisation of cluster size.

Gupta et al. (2014)
Clustering Protocols in WSN.
Good classification of routing protocols with tabular approach
All heterogeneities not considered
Selection of optimal routing path, energy efficiency.

Tyagi & Kumar (2015)
Clustering & routing techniques based upon LEACH protocol for WSN.
Good tabular as well as diagrammatic classification of each category.
All heterogeneities not considered
Cluster head selection
Load balancing.

Fig. 2. Taxonomy of various heterogeneous routing schemes

III. TAXONOMY OF HETEROGENEOUS WIRELESS SENSOR NETWORKS

There are various parameters based upon which cluster-based heterogeneous routing protocols are categorize. Fig 2 describes the classification of various heterogeneous protocols for WSNs in this paper. This taxonomy provides the detailed study of node heterogeneity - based routing protocols for WSNs. Main benefits of using node heterogeneity in WSNs is to increase the throughput of data transferred from a source to a destination and to decrease the latency. While using the heterogeneous nodes, there are much less number of hops between SNs, and sink. So, the end-to-end delivery rate is much higher in heterogeneous WSNs as compared to the homogeneous WSNs.

Furthermore, node heterogeneity in WSNs can be classified based upon the following: Energy heterogeneity, Link heterogeneity, and Computational heterogeneity. **Energy heterogeneity** means that battery of Sensor Nodes is easily replaceable. Among these three categories of node heterogeneity, the most popular is energy heterogeneity because resource consumption is much higher in both, link heterogeneity and computational heterogeneity as compared to energy heterogeneity. If there is no energy heterogeneity, link heterogeneities and Computational decrease the performance of WSNs. Computational heterogeneity means that the heterogeneous node has a more robust microprocessor and more memory in the heterogeneous node as compared to the normal nodes. More data storage and Complex data processing can be provided by the heterogeneous nodes possessing the robust computational resources. Link heterogeneity mainly focused on the distance between two SNs. For long distance network, transceiver of heterogeneous environment must have high bandwidth to achieve reliable data transmission. In this proposal, we have taken all the above three node heterogeneities into account. First, we discussed about energy heterogeneity, which is further divided into two different levels. At each level, we have taken four parameters as CH Selection, Energy efficiency, Application specific and Security for energy heterogeneity. Each parameter has been further subdivided into single or multihop.

Fig. 3. Two level classification on the basis of CH selection.

3.1. Energy Heterogeneity

Energy is an important resource during communication in WSN. So, energy heterogeneity plays an important role in the network because it can enhance the network lifetime. Energy heterogeneity can be further sub classified into two classes depending upon the percentage of energy carried by the nodes. There are two types of node classes which are type-1 and type-2 nodes, based upon percentage of nodes having different energy distribution.

3.1.1. Two Levels Energy Heterogeneity

3.1.1.1. Two levels’ CH selection

The classification of two levels is based upon the selection of the CH as shown in Fig 3. The selection of CH can be further classified in two types as single or multihop. In literature, many clustering protocols have been defined by considering single or multihop communication. In this proposed classification, we have considered both types of communication and discussed their merits and demerits with respect to the selection of CH. Detailed description of
Various protocols in this category are shown in Fig. 3 as follows:

**EDFCM** (Energy dissipation forecast and clustering management) is a stable selection and reliable transmission protocol proposed by Zhou et al. (2010). This protocol selects optimum number of clusters and provides reliable transmission in HWSNs. This protocol is designed on a method of energy dispersal among the SNs and clustering management and is known as EDFCM. It has examined the rate of energy consumption and residual energy of all SNs into account. Estimated lifetime of network field was given as follows:

\[ \frac{E_{total}}{E_{round-total}} = NE_0(1+\alpha m) \]

Objective of EDFCM was to maximize lifetime, and reliable data transmission over the network field. One step energy consumption predict was the base of CH selection in the EDFCM protocol. The optimal value for two different models was given as:

**K inexp** = M \[ \sqrt{\frac{N}{2\pi}} \left( \frac{1-m^2-m^2\alpha}{1-m\alpha} \right) \]

**K inexp** = M \[ \sqrt{\frac{N}{2\pi}} \left( \frac{1-m^2-m^2\alpha}{1-m\alpha} \right) \]

Here, \( \alpha \) is energy heterogeneity parameter and \( \beta \) is computational heterogeneity parameter.

**BCDEEC** (Balanced and Centralized Distributed Energy Efficient Clustering) is another clustering scheme for HWSNs proposed by Ben et al. (2011).

This protocol manages and distributes the energy of CHs to increase the network life time. The main objective of this protocol was to enhance the stability, and the energy efficiency of HWSNs. Estimated value of lifetime of network field was given as follows:

\[ R = \frac{E_{total}}{E_{round}} \]

\[ E_{total} = N(1-m)E_0 + (m-b)N(1+c)E_0 \]

\[ E_{round} = L[2N(1-b)E_{elec} + N(1-b)E_{Dh} + n(1-b)E_{fs}d_{BCNS} + kE_{mp}d_{BCNS}] \]

Here, \( b \) represents the energy heterogeneity parameter and \( p_{g}(t) \) represents the number of gateways (Ben et al., 2011). Two types of nodes are normal and advanced nodes both of which are different with respect to their energy levels. At the beginning of each round, every advanced sensor node (SN) elects itself as a gateway with probability \( p_{g}(t) \). If \( k_g \) denotes the expected number of Gateway nodes (GNs) for current round then the probability of a node becomes gateway in \( \tau_{BC} \) is computed as follows.

\[ p_{g}(t) = \frac{k_g}{N* m} \]

where, \( N* m \) is the number of advanced nodes in the network. Selections of CH exclude gateways and achieve optimal selection of clusters.

\[ k_{opt} = \sqrt{\frac{N(1-b)}{2n}} \frac{\varepsilon_{mp} M}{\varepsilon_{fs} d_{BCNS}} \]

Cost of energy is the threshold for the transmission of data either from CH to BS or from CH to gateway directly. Advantages of this protocol are effectiveness in increasing the network life time, energy efficiency, and enhancing the time period before the first node dies. This protocol performed better than DEEC and SEP in heterogeneous environments.

**EDC** (Event Driven controller) is a dynamic clustering scheme for urban scenarios proposed by Wen et al. (2004). EDC is an energy-aware protocol due to which clustering of multi-model SNs is possible. In multi-model SNs, two phases for clustering can be included viz.: Node re-positioning and Pre-cluster information. The main achievements of this protocol were: Improvement in quality of data fusion, energy efficiency and reduction in transmission power.

**SEP** (Stable Election Protocol) is a protocol proposed by Smaragdakis et al. (2004) to enhance the lifetime of network. SEP protocol was symmetrical to the LEACH protocol but main difference was of operating environment. The idea of WEP was used in Stable election protocol to achieve best load balancing in the formation of CH. SEP assured that a CH selection process is selected randomly and distributed according to the value of respective energy of individual SNs. Single level node heterogeneity has been contemplate in this protocol but it can further be extended to different levels of hierarchy and types of nodes. SEP has major advantage in the form of its scalability because global knowledge of energy is not required for each round. The main drawback of SEP was that it performed poorly in multi-level HWSN.

**DEC** (Diversity based Energy aware Clustering) is a protocol for HWSNs proposed by Tabatabaei et al. (2012) which uses different levels of energy of SNs for the selection of CHs. It also produces clusters with high diversity along with their members. In DEC protocol, fixed upper limit was set for number of CHs which includes dimensions of the network field (a, b), and the transmission range \( (\tau_{CH}) \) as follows:

Upper limits of CHs: \( \tau_{CH}, (\frac{N}{2}) \)

DEC was suitable for steady nodes and used single hop communication medium. It consists of four stages: Initialization, cluster joining, migration, and termination. First phase is initialization phase, in which each node broadcasts its information regarding residual energy. The node must waits for random amount of time \( (\tau_{1}) \) in order to avoid any collision. As there were many clusters in the range, in the cluster joining phase, the node will decides which cluster to join. After that, node joins the suitable cluster by sending the message and changed its status.
Third phase was the migration phase which equally divides the nodes among the cluster, based on their sensing capabilities. The termination phase is used to eliminate the coverage problem caused by random deployment of the nodes. DEC maximizes the sensor diversity within each cluster. With the use of DEC protocol better average energy level of CHs as compared to pre-existing routing protocols is achieved.

**DB-SEP (Distance Based Stable Election Protocol)** is an HWSNs protocol proposed by Benkriane et al. (2012). The objective of DB-SEP was to enhance the life time of network and to improve energy efficiency. CHs were selected based on the distance between BS and CH and initial energy. Uniqueness of DB-SEP was the distance based selection of WEPs. If \( d_i \leq d_{avg} \), then WEPs are as follows:

\[
p_{hrm} = \frac{p_{pt}}{1 + am} \left(1 - \frac{d_i}{d_{avg}}\right)
\]

\[
p_{avg} = \frac{(1 + a)p_{pt}}{(1 + am)} \left(1 - \frac{d_i}{d_{avg}}\right)
\]

whereas, if \( d_i \leq d_{avg} \), then WEPs will be

\[
p_{hrm} = \frac{p_{pt}}{1 + am}
\]

\[
p_{avg} = \frac{(1 + a)p_{pt}}{(1 + am)}
\]

where, \( d_i \) is the distance between the BS and node \( s_i \), \( d_{avg} \) is the mean value of distance between BSs and SN

The major advantages of this protocol are:

(i) DB-SEP was more efficient in energy consumption and an autonomous protocol.

(ii) Simulation results of DB-SEP protocol in comparison to the other clustering protocols show that it enhance the network lifetime much more efficiently.

But it have somedisadvantages like:

(i) Less energy is consumed by nodes which are at distance from BS as compared to nodes which are close to BS.

(ii) The probability of being selected as CH for current round is higher for SNs which is closest to the BS as compared to SNs which is far from BS. The confidentialand reliable information is given by the stable time metric, Therefore, it is important for the end user.

**EDL (Energy & Distance LEACH)** is a protocol proposed by Hou et al. (2009) in which remaining energy and distance of SNs are the key metrics for CH selection. The chances of becoming CH are more for SN with less distance in network andmore remaining energy. So, unnecessary energy loss is avoided that can be caused by too short distance between CHs. Selection of CHs was based on the thresholds such as:

\[
T_n = \begin{cases} 
\frac{p}{1 - p \left[ r_{max} \left(\frac{3}{p}\right)\right]} \frac{E_i(t)}{E_{reciv}(t)} & \text{if } n \in G \\
0 & \text{otherwise}
\end{cases}
\]

For data transmission, single hop communication is used for inter-cluster or intracluster communications. This protocol works well for, heterogeneous and homogeneous networks.

**WEP (Weight Election Protocol)**is a cluster based heterogeneous WSN proposed by Rashed et al. (2011) In this proposal, it is assumed that each SN has power control and can easily transmit data to other Sensor Nodes in the network. The protocol was depends on the hierarchical clustering process that uses various metrics of heterogeneity. These parameters were the additional energy factor between, normal and advanced nodes and the fraction of advanced nodes (\( m \)). Weight is estimated by ratio of initial energy of each sensor nodes to normal node. Individual CH cannot directly transmit data to BS but a chain was constructed with the use of greedy algorithm for selected CHs. Then, randomly selected chain leader was responsible for data transmission to base station. Intracluster data transmission was based on TDMA schedule assigned by respective CH. Main contribution of WEP was to enhance network lifetime and stability period.

**REEH (Residual Energy Efficient Heterogeneous)**is a clustered hierarchy protocol for WSNs proposed by Sehgal and Choudhary (2011) to improve the network lifetime. It was satisfactory for heterogeneous environment as compared to LEACH (Heinzelman et al.,2000) protocol. More Cluster Heads were selected based on the remaining energy of sensor nodes. REEH used LND, FND, and HNA as the performance evaluation metrics for life time enhancement. Du et al. (2007)put forward a security mechanism for HWSNs. In this protocol scheme, two types of node have been used in the cluster formation viz. Low end (L) and High end (H) sensors. H nodes were furnishwith tamper resistant hardware and L nodes were not, so these are not so secure like H nodes. H nodes were elected to communicate between BS and cluster.

The major advantages REEH protocol are:

(i) It has provided better security with low complexity.

(ii) Less storage was required

(iii) Security could be controlled with the usage of L nodes.

(iv) If key pool size is small, then there was high probability of security breach.

**GBHHR (Geography Based Heterogeneous Hierarchy Routing)**GBHHR (Geography Based Heterogeneous Hierarchical Routing) is a protocol for HWSNs proposed by Xi et al. (2008). It saves the energy during data collection and improve the lifetime of network. In this scheme, the concept of Hole Forewarning Routing (HFR) algorithm is used which solves the problem of energy hole during the transmission of data. Geographic routing is used to save the energy of sensor nodes and is found suitable for smaller memory SNs. Traditional geographical routing used the concept of greedy algorithm. GBHHR is an application specific protocol land the architecture of GBHHR used the multipath strategy route between the nodes. It has three phases viz.: start-up, running, and update. While comparing GBHHR with LEACH protocol and the results obtained show that there is less repetition during transmission of data which results in...
a more energy is saved in WSNs. It can be used for greater network range so that it gives higher energy efficiency than conventional hierarchical and geographical routing schemes.

**DCCCA (Double Cluster Head Topology Control Algorithm)** is a protocol based on energy threshold for heterogeneous WSN. In this protocol scheme, the concept of main CH (MCH) and the assistant CH (ACH) was used where, MCH do not have direct communication with BS. MCH collects the data and sends the same to ACH and then ACH transmits the data to the BS. The Operations of DCCCA are divided into two stages viz.: clustering and stable data transmission. Clustering stage includes selection of CH and cluster formation. The proposed algorithm selects the CH by the energy threshold and weighted value. After execution of every round, the rotation of CH depends upon the residual energy of CH. If the residual energy of MCH is less than the threshold value, then BS resets the energy threshold according to remaining energy of all CH. The authors of DCCCA found that it minimize the cost of CH energy and provided load balancing which increases the life time of network.

**LBGC (Load Balancing Group Clustering)** is a protocol for HWSNs Yaping and Yaming (2010) It selects the CH by unique procedure and performed route calculation based on energy distribution all over the network. It contains two stages such as: grouping and data transmission. Grouping stage was focused on the steady group clustering hierarchy (SGCH) protocol for HWSNs. LBGC has multithop environment for data transmission and used an uneven grouping to provide load balancing, because CHs nearer to the BS are of very less energy and die instantly. The distance between BS and Group Head (GH) is used as a parameter for grouping. Data transmission stage contains steady state phase and cluster formation. In cluster formation stage, the location of nodes plays an important role while selecting the CH node. Selection of node to become a CH was estimated by computing maximum EV value as:

\[
E_{\text{res}}(i) = \sum_{j=1}^{m} V_j E_{\text{residual}}, t = NT, \frac{E_a}{E_{\text{residual}}}
\]

where, Cost(i) is the communication cost of node i and \(E_{\text{res}(i)}\) indicates the residual energy. The communication cost can be reduced to

\[
\text{Cost}(i) = \sqrt{d_{\text{max}}^2(i) + d_{\text{min}}^2(i)}
\]

Where, \(d_{\text{max}}^2(i)\) and \(d_{\text{min}}^2(i)\) denote the maximum and minimum distance between the \(i^{th}\) node and the node in the corresponding group. Next hop node is selected on the basis of maximum \(E_{\text{res}}\) value, which can be calculated as:

\[
E_{\text{res}} = d^2(\text{CH}, \text{CH}_{\text{can}}) + d^2(\text{CH}_{\text{can}}, \text{BS})
\]

where, \(d(\text{CH}, \text{CH}_{\text{can}})\) denotes the distance between BS and CH candidate set. In steady state phase node sends data to CH then CH forward the total data in multi-hop routing to BS. This scheme balanced the energy consumption and provides the improvement in stability region of network.

**EAP (Energy Aware Routing Protocol)** is a protocol for long lived SNs. Major issue for WSNs was to save the energy of sensor nodes so as to satisfy the needs of applications. EAP has created load balancing in terms of energy to all SNs. By using this mechanism, the significant improvements in network life time can be achieved. For the establishment of unique route between source and destination, every SN maintains a neighborhood table. Variables of the table include remaining energy, identity and status of neighboring node. Cluster was formed with the estimation of mean value of broadcasting delay and remaining energy of cluster range as follows:

\[
E_{\text{res}} = \frac{\sum_{j=1}^{m} V_j E_{\text{residual}}}{m}, t = NT, \frac{E_a}{E_{\text{residual}}}
\]

Here, \(E_{\text{res}}\) represent the mean value of energy of cluster range of node \(V_j\), \(V_j\) is the neighbour node in the cluster range of \(V_j\), \(m\) is the no. of nodes in the cluster range, \(t\) is the broadcasting delay time, \(k\) is the real value from 0 to 1, \(T\) is the time taken for the selection of CH. In addition to clustering, it has also used a simple but efficient approach for intracluster coverage. EAP clusters SNs into groups and builds routing tree among CHs for energy saving.

**ECB (Energy Consumption Balancing)** is a protocol for HWSN proposed by Farruh et al. (2011). This mechanism was divided into three groups: load balancing, node deployment and energy mapping. Load balancing mechanism was responsible for network lifetime enhancements Node deployment was further classified into two categories: sensor, and sink node deployment. The monitoring and energy mapping mechanisms were concerned with drawing the outline for distribution of energy in the network. The main advantages of ECB were (i) enhancements of the network lifetime, (ii) equal energy consumption between nodes

Based upon the previous discussion, different protocols in two levels’ node heterogeneity are compared on the basis of several parameters such as, type of data transmission, CH selection, network lifetime, system reliability, network stability and the load distribution to the SNs and location of BS which are represented in Table 2 as follows

<table>
<thead>
<tr>
<th>Protocol</th>
<th>CH selection parameter</th>
<th>Data transmission</th>
<th>Life time</th>
<th>Reliability</th>
<th>Stability</th>
<th>Load Balancing</th>
<th>Location of BS</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDF CM</td>
<td>Energy and computatio</td>
<td>Single hop</td>
<td>Very good</td>
<td>Ye s</td>
<td>Very good</td>
<td>-</td>
<td>Center</td>
</tr>
<tr>
<td>EDF CM</td>
<td>nal heterogeneity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BC DEEC</td>
<td>No. of gateways</td>
<td>Single hop</td>
<td>Very good</td>
<td>-</td>
<td>Good</td>
<td>-</td>
<td>Center</td>
</tr>
<tr>
<td>ENS</td>
<td>Node having maximum</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Outside the network field</td>
<td></td>
</tr>
</tbody>
</table>
3.1.1.2. Two levels’ energy efficiency

The classification of routing protocols for Heterogeneous Wireless Sensor node based on two levels’ node heterogeneity is shown in fig 4. Efficient energy utilization per round of individual Sensor Node can be beneficial for enhancement of network lifetime, reliability stability of the nodes. Various protocols in this range are discussed as follows:

<table>
<thead>
<tr>
<th>DEC</th>
<th>SEP</th>
<th>Upper limit fixation</th>
<th>Single-hop</th>
<th>Yes</th>
<th>Outside the network field</th>
</tr>
</thead>
<tbody>
<tr>
<td>DB-SEP</td>
<td>Distance based WEP selection</td>
<td>Single-hop</td>
<td>Very good</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>EDL</td>
<td>Residual energy and distance</td>
<td>Single-hop</td>
<td>Good</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>WE P</td>
<td>WEP</td>
<td>Single-hop</td>
<td>Good</td>
<td>Excellent</td>
<td>Center</td>
</tr>
<tr>
<td>REEH</td>
<td>Residual Energy</td>
<td>Single-hop</td>
<td>Very good</td>
<td>-</td>
<td>Outside the network field</td>
</tr>
<tr>
<td>GBHHR</td>
<td>Threshold $T_e$ and virtual grid</td>
<td>Multihop</td>
<td>-</td>
<td>-</td>
<td>Center</td>
</tr>
<tr>
<td>CCACA</td>
<td>WEP and energy threshold</td>
<td>Multihop</td>
<td>Good</td>
<td>-</td>
<td>Outside the network field</td>
</tr>
<tr>
<td>LBCG</td>
<td>EV value and distance</td>
<td>Multihop</td>
<td>Good</td>
<td>-</td>
<td>Outside the network field</td>
</tr>
<tr>
<td>EAP</td>
<td>Average residual energy and broadcasting Range</td>
<td>Multihop</td>
<td>Very Good</td>
<td>Very Good</td>
<td>Yes</td>
</tr>
<tr>
<td>ECB</td>
<td>Residual energy and competition Range</td>
<td>Multihop</td>
<td>Very Good</td>
<td>-</td>
<td>Corner of network Field</td>
</tr>
</tbody>
</table>

Fig. 4: Two levels’ classification on the basis of energy efficiency

**AMCR (Adaptive Multi-Criteria Routing Protocol)** is a sensor network protocol proposed by Ramy and Mohamed (2011). The involvement of all SNs in AMCR is not required in the network field to maintain the routing table. The proposed scheme divides the SNs into two classes as resource, and designated nodes. Resource node did not take part in the construction of routing table and these nodes should be one hop away from a designated node which can be used as the gateway node. The Location-aware Affinity Propagation (LAP) protocol was used to build the routing table. AMCR also maintain event based monitoring in which an IWS (Index working set) was used to analyze which automatically updated as per the requirements of IWS. On the basis of priority of index, IWS is updated and if its value is found not comparable then data of IWS is rejected. A detailed structure of routing table of AMCR is given in Fig. 6. Various components used in Fig. 6 are explained such as. Identification Profile Table (IPT) contain information about identification of resources. Index definition table (IDT) has various type of information pertaining to indexing. Index routing table (IRT) contain information about the route construction and can also be used to avoid the flooding. IUT (Index Update Table) is used to diminish the redundancy of data. Response Routing Table (RRT) is used to keep records of route construction in the network field. Message Routing Table (MRT) provides messages to their destination groups. Performance parameters used in AMCR are route construction, index propagation, and message routing. The major advantages of AMCR are discussed as follow: preservation of node secrecy, how to optimize routing based upon specific application and Dynamic identification.

**EAERP (Energy Aware Evolutionary Routing Protocol)** is a routing protocol for dynamic clustering in WSNs. Primary objective of EAERP was to enlarge network life time, and to save energy. Cluster-based routing techniques and Evolutionary Algorithm (EAs) are interesting, and most popular techniques as these have utility in achieving scalable solutions and enhance network lifetime significantly. However, problem of
dynamic cluster formation is proved to be a NP-hard problem in this paper. EAERP used the design of clustering routing protocol based on EAs which can meet the largest stability period till First Node Dies (FND) for best network duration till LND. EAERP used an objective function that can be used by decreasing total degenerated energy in network as follows:

$$\phi_{EAERP}(J^c) = \left( \sum_{i=1}^{n_c} \left( \sum_{j \in C_i} E_{TX,CH_j} + E_{RX} + E_{DA} \right) \right) \text{\sum_{i=1}^{n_c} E_{TX,CH_i,B}}$$

where, \(n_c\) represents total no. of CHs, \(se \in C_i\) denotes non-CHs associated to ith CH node, \(E_{TX,CH_i}\) denotes energy degenerated for data transmission from s to CH\(i\), \(E_{RX}\) denotes receiving energy. The main advantages of this protocol are: (i) it enables to develop optimal clustered route, (ii) it provides better trade-off betweenstability and life time of network, and (iii) it also guarantees great distributed energy consumption.

**SRMCF (Source Routing for Minimum Cost Forwarding Protocol)** for Minimum cost forwarding and source based routing concepts for HWSNs proposed by Derogarian et al. (2011) SRMCF used BS optimally by assigning the responsibility to maintain topological information and routing table of every node. As according to Figs. 7–9 BS is responsible to update the routing table as per the suitable network topology. As shown in Fig. 7, minimum cost path between a specified node to BS. Packets are always generated from base station which includes header and payload as the overhead. Path tree segments, offset and pointer are the part of header. When the Pointer move to the other node, which is equal to the current position in routing table, it will decremented by one to the other node. Length of the path will be estimated by an beneficial to destination and offset only. Fig. 8 represents forward path information and ID allocation from BS to source node. Finally, Fig. 9 represents the updating of routing table at BS. In this protocol, packets always follow the optimal communication path with minimum cost

**HLAODV:** Jasmine and Paulraj Joseph (2010) proposed a cross layered routing protocol for pervasive HWSN based on location (HLAODV). HLAODV gives the best result as compared to DSR and AODV with respect to latency, energy efficient, load balancing, and congestion control. The main advantages of this protocol were latency, increment in network life time, and congestion control. Disadvantage of this protocol was that it cannot identify the minimum number of CH in order to get the optimal path.

**IDSQ (Information-Driven Sensor Querying)** is a routing protocol for adhoc WSN is proposed by Chu et al. (2002). The distributed SN is defined by variable data communication quality, limited battery power, and frequent node attrition. The proposed protocol mainly focused on intelligent collaboration among distributed sensors to increase tracking accuracy and to eliminate detection latency. As discussed above Main Benefit of the technique is to reduce node or link failure. IDSQ optimize sensor selection and CADR (Congestion Alleviation using Distance based Routing for WSN) take care of direct data routing. The major advantages of this protocol were (i) it
can drastically reduces latency in detection and tracking by application-aware optimal routing, (ii) scalability of sensor networks with an increase in SNs deployed (iii) the performance degrades graceful due to link failure.

3.1.1.3 Two level security:

Two levels’ node heterogeneity from security perspective is representation as shown in Fig. 10. Various protocols in this category are discussed such as. Du et al.(2007) proposed a security mechanism for HWSNs. In this protocol, two types of nodes were used in the cluster formation: Low (L) and High (H) end sensor nodes. Low end sensor nodes are secure like their counterpart as they don’t have tamper resistant hardware but High end sensor nodes are having tamper resistant hardware. High end nodes are selected to communicate between BS and cluster. The proposed protocol uses key management scheme for providing security to the network that is based on symmetric pre-distribution (AP). It mainly contains three phases: key pre-distribution phase, shared key discovery phase, and pair wise setup phase. In first phase, between the pool of keys, IDs of all keys are generated, then the H and L sensor are pre-loaded from the pool of keys with m and l keys. l keys form the ring. There is a special key associated with the H sensor which is known to the BS. The second phase starts after the cluster formation either in centralized or distributed way. In distributed way, every L sensors communicates with their neighbors for finding the shared key. In centralized way, each L sensor sends information to its cluster head in an un-encrypted key list containing the L sensor ID and then shares the same between H and L sensor nodes. After discovering the shared key between each pair of L sensors, H sensor should transfers the shared key message to L sensor. If distance between neighbouring nodes is less, then H and L sensors are neighbours, but it not true for all cases since there could be limitation between these two nodes. If the pair of L sensors do not share any key with their neighbours, then H first obtains the shared key between its neighbours and then H create a pair wise key for each pair and sends key to them in a secure manner. Probability that H can have at least one shared key When x is high, otherwise this scheme is used for setup pair wise key for x and y. Apart from this, there could be many security issues in HWSN like broadcast key setting, revocation of key for newly deployed Sensor Nodes key setting. L sensors are used as broadcast key to broadcast message in a very secure manner. U sends the packet to a neighbour v: $K_{u,v}^{l}$, where $K_{u,v}^{l}$ is the shared key between u and v. All L sensors need to called revoked when these have adversary effects. The major advantages of this protocol are (i) less storage was needed (ii) it ensure high security and the complexity is also low. However, the disadvantages of this protocol are (i) If key pool size is small, then there is high probability of security breach. (ii) security could be compromised with the use of L nodes.

3.1.1.4 Two level application Specific:

The classification of routing protocols based on two levels’ node heterogeneity is described in Fig. 11. This classification is primarily based on the network type, application type with type of data transmission. The selection of appropriate application specific protocol can reduce the communication cost. EDL, AMCR, DBSEP, GBHHR, and EAP protocols are application specific routing protocols and are already discussed in the earlier sections. Few protocols, those are exclusively selected for this segment are discussed as follows.

Fig.10: Two level classification on the basis of applications specific criterion.

where, A denotes sensing field area, $N_{RN}$ denotes the N random nodes that were deployed randomly.

The main advantage of this protocol was the better coverage, and connectivity with reduction in the cost of data transmission. A comparison on the basis of several characteristics such as- type of data transmission, selection of CH, network field, type of application is shown in Table 4.

Table 3: A brief comparison based on specific applications for two levels’ node heterogeneity.

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Data Transmission</th>
<th>CH Selection</th>
<th>Network Field</th>
<th>Application Type</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDL</td>
<td>Single hop</td>
<td>Residual energy and distance based threshold</td>
<td>Limited area</td>
<td>Actual monitorin g</td>
<td>Suitable for isomorphsic and heterogeneous Network</td>
</tr>
<tr>
<td>AMCR</td>
<td>Single hop</td>
<td>-</td>
<td>Large area</td>
<td>Target tracking through indexed propagati on</td>
<td>Route Construc tion and message routing</td>
</tr>
<tr>
<td>DBSEP</td>
<td>Single hop</td>
<td>Distance based</td>
<td>Small area</td>
<td>Tracking an object</td>
<td>-</td>
</tr>
<tr>
<td>GBHHR</td>
<td>Multi hop</td>
<td>Threshold and Virtual grid</td>
<td>Large area</td>
<td>Geographical based</td>
<td>HFR algorithm</td>
</tr>
</tbody>
</table>
**RKDM (Relay Node Deployment Strategy)** is a protocol for heterogeneous WSN. To overcome the problem of energy consumption in multihop network proposed by Kenan et al. (2005) RNDS has used three types of devices: SNs, Relay Nodes (RNs), and a BS. RNDS is suitable for large scale applications in WSN. The authors have considered three deployment solutions that addressed the issue that how to enhance the life time of the network and these are as follows: (i) connectivity oriented deployment, (ii) life time random deployment and (iii) hybrid deployment. When NNRN are deployed in the network field having area mod A, then the probability that any SN can reach at least one RN is given by

\[
p_T = 1 - \left( \frac{\pi s^2 A}{N} \right)^N
\]

where, \(A\) denotes sensing field area, \(NRN\) denotes the \(N\) random node that were deployed randomly.

### Three level’s energy heterogeneity

This section illustrates the detailed discussion on three levels’ node heterogeneity. As per the detailed structure of the taxonomy defined above, we are using the same classification parameters as used earlier for the discussion of two levels’ nodes heterogeneity.

#### Three level’s CH selection:

The classification of three levels’ protocols was based upon the selection of the CH and is given in Fig. 12. Similar to the earlier case, selection of CH was further divided into two categories: single, and multihop. A detail description of various existing routing protocols is given in Fig.Here, the SN can only communicate with the CH so that the traffic load as well as energy consumption in the network may reduce to some extent. To secure the CH communication among them, each CH established a secure pair wise key with other CH. This pair wise key was used for authentication purpose during communication among CH. Intra-cluster pair wise key establishment includes establishment of pair wise key between CHs and CMs. In this phase, SN sends its node ID, its stored CH ID to its physical CH, i.e., if SN \(s_i\) is the member of \(CH_j\) then (i) the SN \(s_i\) sends its ID and its stored CH IDs to its physical \(CH_j\) and \(CH_k\) to its physical \(CH_j\), (ii) key sharing takes place between \(CH_j\) and \(CH_k\), (iii) CH evaluates its associated polynomial, (iv) physical CH decrypts the encrypted message by the key between both the CHs. After performing these three phases, the secure hierarchical WSN was established where all communication in the network is secure with unique pair wise keys between both the communicating parties. IKDM as compared with some pre-key distribution schemes gives better mechanism improves three tier hierarchical architecture. This mechanism has three phases: key pre-distribution, inter-cluster pair wise establishment, and intra-cluster pair wise key establishment. In key per-distribution phase, the authors assume that there are \(n\) SN and \(m\) CH, and two different bi-polynomials viz.:

\[
f_{CH}(x, y)\text{ and } f_{EH}(x, y)
\]

These polynomials are used for establishment of pair wise key between CHs, for the calculation of secret value of CH respectively.

SNs CH is more powerful than ordinary SNs. CHs are having higher battery power, large memory size so that these can directly communicate with each other. Sink node has large memory storage capacity and communication range. A key distribution improve security for various wireless applications. It contains three nodes’ architecture: sink node, CHs,

![Fig.11:Three level classification on the basis of CH selection](image)

**IKDM (Improved Key Distribution Mechanism)** is a protocol for large scale hierarchical WSN to and SNs. Each SN directly connected to CH and there exists no communication path between different scalability, network throughput, and the communication overhead was much less than the random pre-distribution schemes. This protocol achieves better network throughput, and scalability and is well suited for large scale network.

**EEHC (Energy Efficient Heterogeneous Clustered)** is a protocol for HWSNs proposed by Dilip et al. (2009) The authors have used the energy efficient HWSN based on WEP of each SN. The election process of CHs can be modified correctly to deal with heterogeneous nodes. Major contribution of this protocol was to increase the network life time and scalability. It also includes the improvement in reliability of data and to decrease the latency of data transmission. Total initial energy in this protocol is:

\[
nE_0 (1 + m(\alpha + m_b\beta))
\]

The authors have used three categories of nodes as normal, advanced, and super. WEPs for these nodes are given as

\[
p_T = \frac{p_{opt}}{1 + m(\alpha + m_b\beta)}
\]
where, \( E_0 \) is the initial energy of type-1, and \( p_0, p_2 \) and \( p_3 \) are the respective WEPs.

**EEDCA (Energy Efficient Clustering and Data Aggregation)** is a protocol for HWSNs proposed by Kumar et al. (2011a). Hierarchical clustering and Data aggregation were used in this protocol to reduce the communication load. Total initial energy of network is computed as follows.

\[
E_{\text{total}} = \sum_{i=1}^{N} E_0 (1 + a_i)
\]

Similar to EEHE, WEPs for advance, super nodes and normal of EECDA can be calculated. This protocol has many advantages like unstable region is short, lifetime, higher energy efficiency, stability of the network, decrease in latency, and improved network reliability.

**H-HEED (Hybrid Energy Efficient Distributed Protocol)** is a protocol for HWSN proposed by Harneet and Ajay (2011) It was a hybrid protocol that has used the normal, super, and advanced node. In case of H-HEED, there is an increment in total energy by factor \((1 + m(a - m_0 (a - \beta)))\). Initially all nodes in H-HEED are having energy \( E_0 (1 + a_i) \) which could be \( a_i \) times greater than the \( E_0 \), therefore total initial energy is as follows

\[
E_{\text{total}} = \sum_{i=1}^{N} E_0 (1 + a_i)
\]

This protocol extends network life time and saves the energy.

**DBCP (Distance Based Cluster Protocol)** is a protocol for HWSNs proposed by Kumar et al. (2013a) in this scheme, clustering are of two types: Homogeneous clustering, and Heterogeneous clustering. Designing cluster based routing schemes for heterogeneous network is a difficult task. As a result most of the clustering schemes proposed for the WSNs were homogeneous such as HHEED and LEACH. DBCP is a protocol for single hop HWSNs which has used the average distance of the SNs from BS for the better system performances. This protocol selects a new CH based on the initial energy of nodes and mean value of distance from BS to SN. As discussed above in EEHE, DBCP also contains three categories of SNs. DBCP was an extension of DB-SEP. By taking full advantages of heterogeneity and these advantages are: (i) While comparing DBCP with pre-existing protocols of similar category, no. of alive nodes are found more, (ii) better life time, (iii) number of packets sent to Base Station was more in DBCP. Thus throughput of DBCP was more than LEACH and SEP. But this protocol works on single hop instead of multihop routing protocol. Furthermore this protocol can be extended to include some level of mobility in the network.

**DEESR (Dynamic Energy Efficient and Secure Routing protocol)** is a protocol for WSNs proposed by Mohammad et al. (2010). DEESR protocol maintained a sequence number and a routing table to calculate the next best hop in route. DEESR also maintains a Dynamic Trust Factor (DTF) that moderately isolates the malicious nodes and assure secure communication in the environment. Firstly, DEESR protocol uses the battery cost function to calculate the battery cost for each route and then selects the

\[
p_a = \frac{p_{opt}}{(1 + m(a + m_0 \beta))} (1 + \alpha)
\]

\[
p_b = \frac{p_{opt}}{(1 + m(a + m_0 \beta))} (1 + \beta)
\]

Based upon these WEPs, the authors have calculated threshold for these nodes this ensures that for every round in epoch each node will become a CH exactly once. From the results of this protocol, it was clear that the death of mean value of normal nodes was very fast in LEACH but in EEHC it was found very less.

**DEEC (Distributed Energy Efficient Clustering)** is an algorithm for HWSN proposed by Qing et al. (2006) The selection of CHs in the DEEC protocol was based on the probability which was calculated from the remaining energy of SN and mean value of energy of network. DEEC adjusts the rotating epoch of each node to its energy. Mean value of energy \( r \) at \( t_{\text{th}} \) time interval is computed as follows.

\[
\frac{E_i (r)}{N} = \frac{1}{N} \sum_{r=1}^{N} E_i (r)
\]

So, the average no. of CH per round per epoch (which is the optimal no of CH) is given by:

\[
p_{\text{opt}} \sum_{i=1}^{N} \frac{E_i (r)}{N} N_{nep}
\]

Here, the chances of nodes being selected as CH are more if they possess higher energy. The computation of WEPs for multi-level heterogeneous network is as follows

\[
p_{(a_i)} = \frac{p_{\text{opt}} (1 + a_i)}{N + \sum_{i=1}^{N} a_i}
\]

where, \( E_i \) denotes mean value of energy \( i \)th round, \( E_i (r) \) denotes the remaining energy of \( i \)th node at round \( r \). Author simulates DEEC in two scenarios as- two, and multi-level heterogeneous network. It has been found from the results obtained that it performs well in multilevel heterogeneous environment.

**EECHE (Energy Efficient Cluster Head Election)** is a protocol for HWSNs to increase the lifetime, energy efficiency, and stability of the network proposed by Dilip et al. (2009b). In this proposal, authors have considered three categories of nodes. Type1, and Type2, Type3 were set with \( \alpha \) and \( \beta \) times greater energy than Type 1. These nodes have initial energies \( E_1, E_2 \text{ and } E_3 \). The total initial energy of network field is computed as follows.

\[
Q = a - p (a - \beta)
\]

\[
E_i = nE_0 (1 + MQ)
\]

Estimated WEP for three categories of nodes is given by

\[
p_1 = \frac{p_{\text{opt}}}{(1 + MQ)}
\]

\[
p_2 = \frac{p_{\text{opt}}}{(1 + MQ)} (1 + \alpha)
\]

\[
p_3 = \frac{p_{\text{opt}}}{(1 + MQ)} (1 + \beta)
\]

Heterogeneous clustering and Heterogeneous clustering. Designing cluster based routing schemes for heterogeneous network is a difficult task. As a result most of the clustering schemes proposed for the WSNs were homogeneous such as H-HED and LEACH. DBCP is a protocol for single hop HWSNs which has used the average distance of the SNs from BS for the better system performances. This protocol selects a new CH based on the initial energy of nodes and mean value of distance from BS to SN. As discussed above in EEHE, DBCP also contains three categories of SNs. DBCP was an extension of DB-SEP. By taking full advantages of heterogeneity and these advantages are: (i) While comparing DBCP with pre-existing protocols of similar category, no. of alive nodes are found more, (ii) better life time, (iii) number of packets sent to Base Station was more in DBCP. Thus throughput of DBCP was more than LEACH and SEP. But this protocol works on single hop instead of multihop routing protocol. Furthermore this protocol can be extended to include some level of mobility in the network.

**DEESR (Dynamic Energy Efficient and Secure Routing protocol)** is a protocol for WSNs proposed by Mohammad et al. (2010). DEESR protocol maintained a sequence number and a routing table to calculate the next best hop in route. DEESR also maintains a Dynamic Trust Factor (DTF) that moderately isolates the malicious nodes and ensure secure communication in the environment. Firstly, DEESR protocol uses the battery cost function to calculate the battery cost for each route and then selects the

\[
\text{WEPs for multi-level heterogeneous network is as follows:}
\]

\[
p_{\text{opt}} \sum_{i=1}^{N} \frac{E_i (r)}{N} N_{nep}
\]

where, \( E_i \) denotes mean value of energy \( i \)th round, \( E_i (r) \) denotes the remaining energy of \( i \)th node at round \( r \). Author simulates DEEC in two scenarios as- two, and multi-level heterogeneous network. It has been found from the results obtained that it performs well in multilevel heterogeneous environment...

**DEEC (Distributed Energy Efficient Clustering)** is an algorithm for HWSN proposed by Qing et al. (2006) The selection of CHs in the DEEC protocol was based on the probability which was calculated from the remaining energy of SN and mean value of energy of network. DEEC adjusts the rotating epoch of each node to its energy. Mean value of energy \( r \) at \( t_{\text{th}} \) time interval is computed as follows.

\[
\frac{E_i (r)}{N} = \frac{1}{N} \sum_{r=1}^{N} E_i (r)
\]

So, the average no. of CH per round per epoch (which is the optimal no of CH) is given by:

\[
p_{\text{opt}} \sum_{i=1}^{N} \frac{E_i (r)}{N} N_{nep}
\]

Here, the chances of nodes being selected as CH are more if they possess higher energy. The computation of WEPs for multi-level heterogeneous network is as follows

\[
p_{(a_i)} = \frac{p_{\text{opt}} (1 + a_i)}{N + \sum_{i=1}^{N} a_i}
\]

where, \( E_i \) denotes mean value of energy \( i \)th round, \( E_i (r) \) denotes the remaining energy of \( i \)th node at round \( r \). Author simulates DEEC in two scenarios as- two, and multi-level heterogeneous network. It has been found from the results obtained that it performs well in multilevel heterogeneous environment.

**EECHE (Energy Efficient Cluster Head Election)** is a protocol for HWSNs to increase the lifetime, energy efficiency, and stability of the network proposed by Dilip et al. (2009b). In this proposal, authors have considered three categories of nodes. Type1, and Type2, Type3 were set with \( \alpha \) and \( \beta \) times large energy than Type 1. These nodes have initial energies \( E_1, E_2 \text{ and } E_3 \). The total initial energy of network field is computed as follows:

\[
Q = a - p (a - \beta)
\]

\[
E_i = nE_0 (1 + MQ)
\]

Estimated WEP for three categories of nodes is given by

\[
p_1 = \frac{p_{\text{opt}}}{(1 + MQ)}
\]

\[
p_2 = \frac{p_{\text{opt}}}{(1 + MQ)} (1 + \alpha)
\]

\[
p_3 = \frac{p_{\text{opt}}}{(1 + MQ)} (1 + \beta)
\]
route in which remaining battery is maximum. Here, a network infrastructure was also developed which in addition to the server also consists of three types of nodes namely SNs, CHs, and CNs. The main advantages of this protocol are: (i) this protocol provides privacy concern to the user and secured the network and less number of resources are used in participating nodes, (ii) this protocol is highly resilient with high, medium, and low mobility scenarios and also a very energy efficient, and (iii) DEESR protocol also have better packet deliver ratio as compared to other protocols.

**MCR (Multi-hop Communication Routing Protocol)** is a energy efficient routing protocol for HWSNs proposed by Kumar et al. (2011b) The major difference between MCR and other protocols is that MCR used multihop communication for the transmission of data from CH to BS. The major speciality of MCR protocol was that it does not require global knowledge of energy of every sensor node which was the main requirement of various existing protocols under the same category.

**MEEHC (Multi-hop Energy Efficient Heterogeneous Clustered)** is a protocol for HWSNs Selection of optimal path from source to destination is the main objective of MEEHC. A performance evaluation strategy of this protocol was similar to DBCP, EEHE. Similar to MCR, it has also used the concept of multihop communication. The mean value of number of CH per round per epoch is $CH_{average} = (1 + m(\alpha - m_0(\alpha - \beta)))mp_n$.

This protocol extends the network life time and was also stable. MEEHC can be expanded to deal with an energy efficient dissipation algorithm through data gathering in a mobile sensor network. Various protocols for three levels’ node heterogeneity are compared on the basis of different parameters such as type of data transmission, CH selection, network lifetime, network stability, system reliability and load distribution to the SNs designing any heterogeneous protocol for WSN. If the protocol is energy efficient, then eventually the lifetime of the entire network improves. Merits and demerits of three levels’ energy efficient heterogeneous protocol for HWSNs are discussed in brief so that the beginners can take the advantage for the selection of appropriate routing protocol as per their requirements. The comparison of three levels’ energy efficient heterogeneous routing protocols on the basis of various parameters is shown in Table 6.

### 3.1.2.2. Three levels’ energy efficiency

The taxonomy of three levels’ node heterogeneity based protocols focused on energy efficiency is shown in Fig. 13. In this taxonomy, we have taken both communication scenarios: single, and multihop. It has been observed that energy efficiency could be one of the vital issues while...

### Table 4: Comparison based on CH selection for three levels’ node heterogeneity

<table>
<thead>
<tr>
<th>Protocol</th>
<th>CH selection Parameter</th>
<th>Data Transmission</th>
<th>Life time</th>
<th>Reliability</th>
<th>Stability</th>
<th>Load Balancing</th>
</tr>
</thead>
<tbody>
<tr>
<td>IKDM</td>
<td>Higher resourceful node</td>
<td>Single-hop</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>EEHC</td>
<td>WEP</td>
<td>Single-hop</td>
<td>Very good</td>
<td>Yes</td>
<td>Very good</td>
<td>-</td>
</tr>
<tr>
<td>EDEEC</td>
<td>WEP and average energy</td>
<td>Single-hop</td>
<td>Excellent</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>EECDA</td>
<td>WEP</td>
<td>Single-hop</td>
<td>Very good</td>
<td>-</td>
<td>Good</td>
<td>-</td>
</tr>
<tr>
<td>H-HEED</td>
<td>Residual energy</td>
<td>Single-hop</td>
<td>Very good</td>
<td>Good</td>
<td>-</td>
<td>Yes</td>
</tr>
<tr>
<td>DBCP</td>
<td>WEP</td>
<td>Single-hop</td>
<td>Very good</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>DEESR</td>
<td>Dynamic trust factor</td>
<td>Multihop</td>
<td>Very good</td>
<td>-</td>
<td>Good</td>
<td>Yes</td>
</tr>
<tr>
<td>MCR</td>
<td>WEP</td>
<td>Multihop</td>
<td>Very good</td>
<td>Yes</td>
<td>Very good</td>
<td>Yes</td>
</tr>
<tr>
<td>MEEHC</td>
<td>WEP</td>
<td>Multihop</td>
<td>Very good</td>
<td>-</td>
<td>Good</td>
<td>Yes</td>
</tr>
</tbody>
</table>

![Three level Energy efficiency](image)

Fig. 12: Three levels’ classification on the basis of energy efficiency
Table 5: A comparison based on Energy efficiency for three levels’ node heterogeneity

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Energy Efficiency</th>
<th>Stability</th>
<th>Throughput</th>
<th>Latency</th>
<th>Scalability</th>
</tr>
</thead>
<tbody>
<tr>
<td>EEC DA</td>
<td>Very good</td>
<td>Good</td>
<td>-</td>
<td>Low</td>
<td>-</td>
</tr>
<tr>
<td>EDEC</td>
<td>Good</td>
<td>Good</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>HHE ED</td>
<td>Good</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>IKDM</td>
<td>-</td>
<td>-</td>
<td>Low</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>MCR</td>
<td>Very good</td>
<td>Very good</td>
<td>Very High</td>
<td>Low</td>
<td>-</td>
</tr>
<tr>
<td>DEES R</td>
<td>Very good</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MEE H</td>
<td>Very good</td>
<td>Good</td>
<td>Very High</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

3.1.2.3. Three levels’ security

The taxonomy for three levels’ node heterogeneity with respect to security aspect is shown in Fig. 14. The communication between the two parties can be authenticated, when security parameter was taken into consideration. It has been observed that security is and developing area which can be applicable in wide areas of applications. There are many mandatory situations during communication where security is necessary and should not be compromised at the time of designing of any protocol.

Fig. 13: Tree levels’ classification on the basis of security

3.1.2.4. Three levels’ application specific

The taxonomy of routing protocols based on three levels’ node heterogeneity and targeting on application specific criterion is shown in Fig. 14. This classification is primarily based on the application type, network type, with type of data transmission. The selection of appropriate application specific protocol could decrease the communication cost. DEEC and EECE, IKDM protocols are application specific routing protocols that are already discussed in the previous Sections. Brief summary of other application specific protocols is explained here along with comparison in Table 6 as shown below.

Fig. 14: Three level classification on the basis of applications

A Testbed for HWSNS called as WSNTB proposed by Jang-Ping et al. (2008). The testbed is divided into three layers architecture. Classification of these layers was based on the applications that includes, gateways with converters, servers and SNs respectively. Software resources and Real-time hardware and are effectively used by the end users from WSN through WSNTB. As WSNTB was designed for testbed applications, end users have the capability and freedom to use local mode and web based interface which is a special function of WSNTB. The software framework composes with three main layers as- core testbed layer, a combination of services interface layer, and resource access layer. This proposed approach can increases network life time and save time, money. It is reconfigurable, and provides expandable architecture so that users can perform experiment anytime and anywhere, used in real-time application.

Cheng et al. (2010) had proposed a Hierarchical Distributed Data Classification in WSNs. In this proposal, the authors have used an approach in which a judgement tree was maintained based on hierarchical distributed classification approach, where local classifiers are built by every leaf or intermediate node and then combined with routing path over intermediary nodes generating a spanning tree and a global classifier. Then, this local data was combined with pseudo-data to increase the classifiers. Various control factors were also used to enhance its effectiveness. The main advantages of this protocol are that (i) it has low communication overhead, (ii) it requires low storage, (iii) it saves more energy by reducing size of tree. But, the disadvantages of this protocol is reduction in accuracy. Table 7 shows the comparison of different application specific protocols with respect to various parameter.

Table 6: Comparison based on application specific criterion for three levels’ node heterogeneity

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Data Transmission</th>
<th>CH Selection</th>
<th>Network Field</th>
<th>Application Type</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDK</td>
<td>Single</td>
<td>Higher</td>
<td>Large</td>
<td>Data</td>
<td>Commun</td>
</tr>
</tbody>
</table>
3.2. Computational heterogeneity
In computational heterogeneity, node must have a memory and strong processor than normal node. Heterogeneous nodes could meet the requirement of rectified the storage issues and complicated data processing with strong computational resources. The Computational heterogeneity can degrade the processing latency in immediate nodes. So, higher end-to-end delivery rate is achieved by HWSN than the homogeneous sensor network. Computational heterogeneity imposes negative impact on the network if energy heterogeneity is not present in the network. Therefore, taking computational heterogeneity alone will decrease the network lifetime which is never required.

3.3. Link heterogeneity
The reliability in data transmission can be obtained from link heterogeneity. The concept of link heterogeneity is required to meet the requirement of communication over larger distance network and greater bandwidth. Because of this there can be decrease in waiting time for transmitting queue. Detailed summary of IDSQ (Chu et al., 2002), two levels’ protocol in which link heterogeneity is already discussed. Similar to computational heterogeneity, link heterogeneity is also an open area for designing a new protocol.

3.4. Hybrid category
Apart from computational, link and energy heterogeneity as discussed above, there are various other routing protocols which have been considered for hybrid categories. Therefore, a special segment was considered for these protocols in hybrid category. Brief description of each of these schemes are given as follows.

Optimal static multi-path routing strategy for a large scale WSNs was proposed by Lin et al. (2007). Data Packets have the sensed information that are sent from SNs to the BS either in a single or in a multihop manner. In optimal static multi-path routing strategy main focusing area is to model the dynamics of the energy consumption in WSN. This strategy utilizes the energy conserving technique, where energy queue works for the availability of at least one virtual packet. The energy source reload the used energy due to that virtual packet. Energy replenishment process can not be same for the entire time period, however, it may change according to the environmental conditions. Therefore, average energy replenishment rate is an important issue where, the key factors selected are, class, node and path. The packet can be routed properly through a path if all the nodes along the path have sufficient energy. Maximum utility factor is defined as:

$$M_{\text{max}} = \sum_{i=1}^{I} \left( \sum_{j=1}^{G} R_{ij} \cdot P_{ij} \right)$$

Where $R_{ij}$ is the pre-computed splitting probability and $P_{ij}$ denotes the blocking probability of class i packets on path j.

In order to control splitting probability ($P_{ij}$) distributed environment, the authors have used the following:

$$P_{ij} = \frac{1}{f \left( \sum_{j=1}^{G} R_{ij} \cdot P_{ij} \right) + \sum_{n=1}^{H} f \left( \sum_{j=1}^{G} R_{ij} \cdot P_{ij} \right)}$$

where, $k_{ij}$ is any non-decreasing and continuous function such $k_{ij}(p)>0$ for any $p>0$, an $R(i,j)$ is the set of nodes in path j of class i.

The major objective of the above said scheme was to find a static routing algorithm based on the optimal routing scheme for mobile environment, when the consumption of energy for every packet was minimum. The authors in Lin et al. (2007) have also proved that if a packet is assigned to a path that has optimal splitting, then the blocking was not possible in the static routing scheme. Towards the avoidance of blocking, they also proved that the energy replenishment rate must be greater than the arrival rate in the queue. The major advantages of this scheme are probability of admitting the packets under heavy load condition which leads to generate the optimal solution and the less overhead generation. Performance metric used by the author was distributed computation, interaction of classes and throughput comparison for static and dynamic schemes.

Based upon these metrics, the authors set the upper threshold for different classes with the utility factor as follows:

$$U_{i} = \log \left( \frac{t_i a + 1}{t_i + 1} \right)$$

where, $a$ denotes the total acceptance rate of class i and positive value of $t_i$ represents the concavity of utility function.

Clustering algorithm for maximizing the lifetime of WSN with energy-harvesting sensors was proposed by Zhang et al. (2013) Energy Harvesting (EH) nodes can be operated in three ways: as relay node, as CH and as relay between the non-CH and the CH nodes. The power required for CH and the node which are farthest from CH was given by

$$P_{CH} = \frac{E_{\text{elec}} \cdot \tau \cdot (N_s - 1) + E_{\text{DA}} + E_{\text{elec}} \cdot \tau \cdot N_s + E_{\text{elec}} \cdot \tau \cdot \text{temp} \cdot \delta_{\text{CH,Bs}}}{\text{area}}$$
Here, CH or $NCH$ die first, because they consume more energy than others, so the problem is to find the optimal location of CH. This algorithm may be expanded for distributed EH mechanism and also for the judging the behavior of the network after deploying the EH nodes. Long and Li (2013) proposed the enhance routing protocol for Large Scale HWSN. But, the major problem with existing algorithms such as TEEN and LEACH (Heinzelman et al., 2000) was that the nodes of the network in any position have to communicate to sink directly, so the scalability of the network may be limited and these protocols cannot work well for large-scale HWSNs. An enhanced routing protocol for large-scaled HWSNs named LEACH Region Divided Algorithm (LRDA) was proposed by the Long and Li, where, the square surveillance area is divided into small regions and each region must select a cluster head according to energy. In LRDA, the cluster head search for next hop after fusing data until the data is further transmitted to sink. The energy consumed by the node per second that will be acting as relay node is given by

$$P_{relay}(d) = (\alpha_1 + \alpha_2 d^n + \alpha_3 d^r)$$

where, $r$ is the relay rate. This equation can be further solved as

$$P_{relay}(d) = (\alpha_1 + \alpha_2 d^n)$$

The main advantages of this protocol are: (i) it increases the throughput of LEACH algorithm significantly, (ii) it extends the lifetime of WSNs, (iii) it was suitable for large-scale heterogeneous WSNS efficiently, but it increases the complexity of the network due to overheads included in managing several smaller cluster regions, (iv) the network scalability is also expanded with efficient energy consumption. Energy heterogeneity was explained under four category namely advance, normal, super, and ultrasuper nodes by Qureshi et al. (2013) and suggested Balanced Energy Efficient Network Integrated Super Heterogeneous Protocol (BEENISH) for WSNs. This protocol works on the concept of CH selection using the residual energy of specific node to the mean value of energy of entire network. By virtue of this, high energy nodes have high probability to be elected as cluster head as compared to low energy SNs which indicates the equal distribution of energy consumption among all sensor nodes. In this protocol, the average energy of $r$th round is computed as follows:

$$E_r(r) = \frac{1}{N} \sum_{r=1}^{R} (1 - \frac{r}{R})$$

where, $R$ is the total round from start of the network and can be calculated $R = \frac{E_{total}}{E_{round}}$

EEICCP (Energy Efficient InterCluster Coordination Protocol) is a protocol for HWSNs proposed by Rani et al. (2013) to manage energy load among SNs. EEICCP proposed cluster sensor nodes as an effective topology management for the energy constrained WSN by uniform distributing the energy among all the SNs and used themultihop approach for the cluster heads. EEICCP outperformed conventional protocols by distributing the network into layers of clusters in which each node has an equal responsibility of sending and receiving the data from all other nodes in the cluster, and transmit the aggregating signal to the BS. The evolution of nodes were uniform and it uses the line of sight of propagation to reduce the energy consumption and to reduce path loss exponent. EEICCP significantly decrease the energy consumption than LEACH. The main advantages of this protocol were: (i) EEICCP has an improvement over LEACH protocol in terms of network reliability, and scalability. (ii) EEICCP decreases the energy consumption of SNs. (iii) It equally distributes the energy load among the SNs and used the multihop approach. (iv) It exploits the benefits of the propagation channels for energy constrained network.

4. OPEN ISSUES:

In this paper, several heterogeneous routing protocols for WSNs by selecting different parameters have been discussed. As the taxonomy defined in the text, comparative study of different protocols is explained in multiple Sections. Although, we have elected different metrics which relate directly or indirectly application orientated, where WSNs can be used but, one can find several open issues which need to be investigated properly in this new emerging area:

- Link and computational heterogeneity have not been exploited to its full potential in WSNs. It has been observed that computation is main characteristic performed by every SN. Therefore, computational heterogeneity provides more memory space to SN which decrease the latency but on the other hand, data transmission rate could be increased with link heterogeneity from SN to BS.

- In order to obtain good performance from the environment, parameters of link heterogeneity need to be defined properly for the WSN where sensor nodes are deployed.

- Data aggregation mechanism for lifetime enhancement and energy efficiency of individual sensor node to whole network of WMN. During communication between two communicating parties, security is a most important for all the sensor nodes in the network. Due to limited resources availability with the SNs, standard security protocols may not be good for WSNs.

IV. CONCLUSION

This review paper mainly concentrate on node heterogeneity of various routing protocols for WSNs. A detailed taxonomy of node heterogeneity have been provided in the text. Among all the three heterogeneity discussed in this paper, energy heterogeneity plays a vital role in the network because it could increase the network lifetime. In WSNs, energy efficiency, selection of CH, security and application specific are very important criterion and must be selected optimally or suboptimally so that maximum outcome from the networkfield. One of the major drawbacks of individual SN is limited amount of battery. Similar to various previous approaches in the
same environment clustering is widely used for data transmission specially for large area HWSN. All heterogeneous routing protocols are explained with their significance according to their pros and cons. In this work is that it has we have selected the parameters such as: energy efficiency, security, reliability, load balancing, CH selection and network lifetime. From the literature review, we have analyzed that the above mentioned metrics cannot be ignored while discussing towards cluster based hierarchical routing protocol to be used either in HWSN or WSN. In the future, we will implement one of the above described protocols and evaluate its performance in comparison to the various existing benchmarked schemes in literature.

REFERENCES