A Survey on Stable Routing Protocols for Wireless Sensor Networks

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***Abstract*— Wireless sensor networks is one of trending technology in wireless communication. A sensor is a device that responds to and detects input from physical or environmental conditions, such as pressure, heat, light, etc. The sensor nodes communicate one another via variety of wireless strategies. These communication strategies are managed by routing protocols. Wireless Sensor Networks Routing Protocols has been classified in three main categories based on routing information, network structure, and protocol operation. Among them, Stable routing protocols maintain consistent and reliable communication paths in a computer network. The idea of this paper is to give a summary of stability-based routing protocols for heterogeneous and homogeneous sensor nodes with its merits and demerits.**

Keywords*— *Wireless Sensor Networks, Routing Protocols, Stability

I. Introduction

Sensing is a methodology used to collect data on a physical object or process, such as the occurrence of events (i.e., changes in state like a drop in temperature or pressure). An object which performs these sensing tasks is called as sensor.

Wireless sensor nodes are set of four major components: a computing unit, a sensor unit, a transceiver unit, and a power unit. The sensors connect to controllers and processing stations directly (e.g., using LAN), an increasing number of sensors communicate the collected data through wireless to a centralized processing station. Thus, a Wireless Sensor has not only a sensing component, but also has on-board processing, communication, and storage capabilities. With these enhancements, a sensor node is often not only responsible for data collection, but also for in-network analysis, correlation, and fusion of its own sensor data and data from other sensor nodes. Sensor nodes interacts with each other and also with Base Station (BS)using their wireless radio signals, enables them to transmit their sensor information to distant processing, visualization, analysis, and storage systems. There are two sensor fields which monitors two different geographic regions and connecting to the Internet using their base stations.

Sensors are usually deployed randomly in inaccessible zone; if one of the sensors consumes its energy, replacing the power supply becomes difficult or impossible in some environments, and energy holes emerge. Moreover, the energy of sensor nodes goes down during the transmission of data. Therefore, routing is an important factor in WSNs, and proper selection of effective routing protocols can preserve energy and prolong network lifetime.

For the realization of WSN based applications, many routing techniques have been proposed over the years like Low Energy Adaptive Clustering Hierarchy routing protocol (LEACH), Power Efficient Gathering in Sensor Information Systems (PEGASIS), Sensor Protocol for Information via Negotiation (SPIN), Hybrid Energy Efficient Distributedrouting (HEED), Geographic Adaptive Fidelity routing protocol (GAF), etc.. Since, Wireless Sensors have limited power supply, energy efficient routing remains the major research issue which is been discussed based in the paper based on their stability. On the basis of structure of the network, WSNs routing protocols are broadly categorized into three classes: based on routing information, based on network structure and based on protocol operation.

In WSN's the stable routing methods act a crucial role in maintaining the network's efficiency, reliability, and overall performance. It aims to establish stable routes for data transmission among the sensor nodes while adapting to dynamic network conditions and resource constraints. The metrics, node stability and residual energy, must be taken into account while designing routing protocols that synchronize the tradeoff between the stability of a node and its minimum energy consumption. The unstable routes poses a problem in many network structures such as Internet border gateway routers [14], ad hoc networks, and mobile ad hoc networks [12].

Routing protocols in Wireless Sensor Networks can indeed be categorized based on various criteria, including the homogeneity and heterogeneity of sensor nodes. Let's break down each aspect:

i. Homogeneous Networks: In a homogeneous sensor network, all sensor nodes have similar capabilities, such as processing power, communication range, and energy levels. This makes the network more straightforward to manage, as all nodes follow the same set of rules and protocols.

ii. Heterogeneous Networks: In a heterogeneous sensor network, sensor nodes have different capabilities. Nodes may vary in terms of processing power, comminication range, energy storage, and sensor types. Heterogeneous networks can be more complex to handle but can offer benefits like increased network flexibility and better resource allocation.

II. ROUTING CHALLENGES IN SENSOR NETWORKS

The design task of routing protocols for WSN is quite challenging because of multiple characteristics, which differentiate them, from wireless infrastructure-less networks. Several types of routing challenges involved in wireless sensor networks. Some of important challenges are listed below:

Energy Consumption : As sensor nodes in WSN have limited battery power, it becomes challenging to perform computationand transmission while optimizing energy consumption[1]. In fact the transmission of one bit of data consumes more energy than processing the same bit of data. Sensor node lifetime strongly depends on its battery life.

Node Deployment : Sensor nodes are usually densely deployed in the field of interest depending on application thus influencing the performance of a routing protocol. The deployment can be either deterministic or self-organizing. In selforganizing systems, sensor nodes are scattered randomly creating a topology in an adhoc manner[4].

Data Delivery Models : Data delivery models can be time driven, data driven, query driven and hybrid (combination of delivery models) depending on the application of sensor nodes and time criticality of data reporting. These data delivery models highly influence the design of routing protocols especially with regard to reducing energy consumption[5][6].

Node Capability : Depending on the application, a sensor node can have different role or capability such as relaying, sensing and aggregation since engaging all these functions on the same node would drain the energy of that node more quickly. Different capabilities of sensor nodes raise multiple issues related to data routing and makes routing more challenging[7][8].

Network Dynamics : Most of the network architectures assume that sensor nodes are static but the mobility of base stations and sensor nodes is necessary in some applications [8]. Routing packets in such dynamic architectures becomes challenging in addition to minimizing energy consumption and bandwidth utilization.

Data Aggregation : Since sensor nodes generate redundant data, cluster heads or base stations may receive similar packets from multiple nodes and these packets need to be aggregated before being forwarded to the base station. Signal processing methods can also be used for data aggregation[9].

III. RELATED RESEARCH WORKS

Stability remains a burning question in wireless networks. The stability in routing is considered as the majoy weakness in Wireless Sensor Networks. In WSNs, the nodes are typically resource-constrained, energy-efficient, and often deployed in harsh environments, a stable routing protocol is of utmost importance. The routing protocol should be capable to adapt to the dynamic network topology, conserve energy, and ensure reliable data delivery. The routing algorithms should be stable under all possible circumstances. The recent research works based on routing protocols for heterogenous and homogeneous networks in relation with the stability of nodes during routing is discussed in this section eloborately.

Figure 1, address stability constraints with respect to heterogeneous and homogeneous networks. Further the comparison is done for the heterogeneous and homogeneous networks based on their merits and demerits. Low-Energy Adaptive Clustering Hierarchy (LEACH) [21], Threshold sensitive energy efficient sensor network protocol (TEEN) [25] protocols are widely used for homogeneous WSNs.

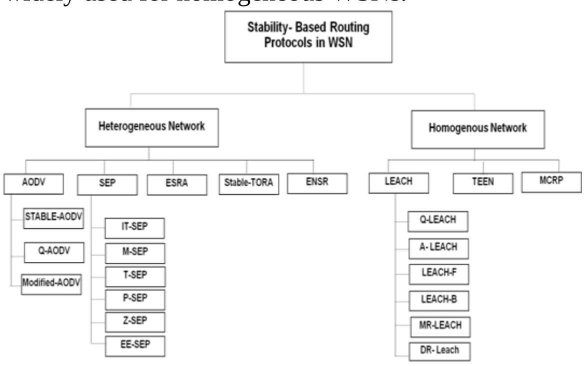

Fig. 1. Classification of Routing Protocols based on Stability

Ad-hoc On-Demand Distance Vector (AODV), Stable Election Protocol (SEP), Efficient Node Stable Routing Protocol (ENSR), Stable TORA, Efficient Stable Routing Algorithm (ESRA) protocol are widely used for heterogeneous WSN WSNs

3.1. Stable Routing Protocols For Heterogeneous Networks

The routing protocols such as Ad-hoc On-Demand Distance Vector (AODV), Stable Election Protocol (SEP), Efficient Node Stable Routing Protocol (ENSR), Stable TORA, Enhanced Stable Routing Algorithm (ESRA) is discussed briefly in the following sections.

3.1.1. AODV (Ad-hoc On-Demand Distance Vector) and its Variants

AODV is a reactive routing protocol that establishes routes on-demand as needed. While not specifically designed for WSNs, it can be adapted for such networks and offers stability in dynamic scenarios. AODV is one of the most commonly used routing protocols for both MANETs and WSNs. But in WSNs, when the mobility is high, AODV needs to find new paths to the destination frequently as the already established links breaks because of node movement.

Priyanka Pandey *et.al* [30], designed an Efficient and Stable-AODV (EFST-AODV) routing scheme for an improvement over AODV to establish a better quality route between source and destination. In this method, modified the route request and route reply phase. During the route request phase, cost metric of a route is calculated on the basis of parameters such as residual energy, delay and distance. In a route reply phase, average residual energy and average delay of overall path is calculated and the data forwarding decision is taken at the source node accordingly.

The performance of this routing protocol is described in terms of routing load. The load in the case of the suggested EFST-AODV is 9.66% less as compared to AODV. Similarly, the control message overhead is also reduced by 8.46 % as compared to AODV. This is because; the proposed approach discards those control packets that are coming from either an efficient node or a link.

Jian Xu,[31], proposed an modified AODV protocol by introducing the idea of ant colony algorithm. It provides multiple optional routes, reduces the flooding probability, and can protect low-power nodes, which is more suitable for WSN networks. Simulation results show that the modified AODV protocol reduces the energy consumption of nodes, prolongs the life of nodes, and effectively improves the stability and communication efficiency of the network.

Ranjita Joon, Parul Tomar[32], introduced Energy aware Q-learning AODV (EAQ-AODV) routing. The proposed EAQ-AODV uses Q-learning based reward mechanism for cluster head selection and AODV enabled routing protocol based on different parameters such as Residual Energy, Common Channel, Number of Hops, Licensed Channel, Communication Range and Trust Factor to establish the routing path. The experimental study shows that the proposed EAQ-AODV routing achieves an improved performance in terms of average end-to-end delay, average energy consumption and network lifetime when compared with the existing techniques. The performance of the proposed protocol's average stability for varied is obtained as 0.61 0.77, 0.82 and 0.88 using ESAC, ERP,EACRP and Proposed EAQ-AODV approaches, respectively. Thus proposed approach selects the more stable gateway and hence it improves the energy consumption performance.

3.1.2. Stable Election Protocol and its Variants

SEP[15] (Stable Election Protocol) provides longer stability period and higher average through put than current clustering heterogeneous-oblivious protocols. So every sensor node in a heterogeneous two-level hierarchical network independently elects itself as a cluster head based on its initial energy relative to that of other nodes. SEP is based on weighted election probability. Each normal node becomes a cluster head once every x rounds per epoch [26].

$$x = \frac{1}{p_{opt}}.(1 + \alpha.m)$$

Each advance node becomes a cluster head (1+ α) times in every x rounds per epoch. Initial energy of node is assigned randomly so the nodes are divided into two types advance and normal nodes. The normal and advanced nodes thresholds are as follows:

$$T_{s_{nrm}} = \begin{cases} \dfrac{P_{nrm}}{1 - P_{nrm}\left[r.mod\ \dfrac{1}{P_{nrm}}\right]} & if\ S_{nrm} \in G' \\ \text{Otherwise } 0 \end{cases}$$

$$T_{s_{adv}} = \begin{cases} \dfrac{P_{adv}}{1 - P_{adv}\left[r.mod\ \dfrac{1}{P_{adv}}\right]} & if\ S_{adv} \in G' \\ \text{Otherwise } 0 \end{cases}$$

In the last $1/Pr_{nrm}$ and $1/Pr_{adv}$ round where the normal and advanced nodes are not set as CHs are denoted by G' and G''.

To increase performance of SEP protocol an extension of SEP is proposed [25], in which nodes are divided into three levels, normal node, intermediate node and advance node. In TSEP cluster head selection is based on threshold and three types of nodes are divided. By using three thresholds the stability of network is better than SEP protocol. Simulation results have shown that stability period of Z-SEPis increased by approximately 50% and throughput by almost tenfold when compared to SEP, by just varying the network architecture. The network lifetime of TSEP is increased twofold than SEP because of its reactive nature.

Khushboo Yadav [17], designed an Zonal-Stable Election Protocol (Z-SEP) for heterogeneous WSNs. In this protocol, some nodes transmit data directly to base station while some use clustering technique to send data to base station as in SEP. The author implemented Z-SEP and compared it with traditional Low Energy adaptive clustering hierarchy (LEACH) and SEP. Simulation results showed that Z-SEP enhanced the stability period and throughput than existing protocols like LEACH and SEP.

Jeevan L J Pinto, Manjaiah D [27], put forth an extension of SEP considers three types of nodes; normal nodes, intermediate nodes and advance nodes. Where, advance nodes are in a fraction of total nodes with an additional energy as in SEP and a fraction of nodes with some extra energy greater than normal nodes and less than advance nodes, called intermediate nodes, while rest of the nodes are normal nodes. From the simulation and result analysis author proposed that M-SEP is more stable and effective than SEP as well as M-SEP provides a longer stability period on an average of 9% extra than SEP.

Paola G. Vinueza Naranjo. *et. al*.[28], proposed, a modified Stable Election Protocol (SEP), named Prolong-SEP (P-SEP) is presented to prolong the stable period of Fog-supported sensor networks by maintaining balanced energy consumption. P-SEP enables uniform nodes distribution, new CH selecting policy, and prolong the time interval of the system, especially before the failure of the first node. P-SEP

Liquan Zhao, and Qi Tang [34], came up with an improved energy efficient routing protocol named Improved Threshold-Sensitive Stable Election protocol (ITSEP) for heterogeneous wireless sensor networks. an optimal route with minimum energy consumption for cluster heads has been selected throughout data transmission. Simulation results show that this algorithm has achieved a longer lifetime than the stable election protocol algorithm, modified stable election protocol algorithm, and threshold-sensitive stable election protocol algorithm for the heterogeneous wireless sensor network.

Deepak Kumar Sharma *et. al* [35], designed an optimizing the probability of selection of the cluster heads of the clusters taking into account various energy factors. The proposed protocol shows improvement in the network lifetime, period of stability, and the throughput of the wireless network in comparison to SEP and LEACH protocol. The EISEP has 41.8% improvement in the network lifetime, 10.6% improvement in the stability period, and 73.23% improvement in the packets sent to the base station over the conventional SEP. It shows significantly better results than the LEACH protocol also with 20% more stability period, 332% more lifetime, and 66.3% more packets sent to base station. The significant improvement of results exhibits the importance of the factors of energy in the choice of selection of the cluster head.

3.1.3. Enhanced Stable Routing Algorithm (ESRA)

Biswa Mohan Sahoo *et. al* [18] proposed an ESRA protocol which improved stability period and network lifetime. The cluster-based routing has not only acquired network longevity but also has helped in the energy balancing in the network.

In this algorithm, two levels of energy heterogeneity is considered; normal nodes and advanced nodes. The proposed formula of probability for normal nodes for becoming CH is given by below equation.

$$P_{nrm} = \frac{P_{opt}}{(1 + am) * E_i\,(n)}$$

The proposed work introduced the distance factor in the threshold-based equation with the predefined condition if the nodes are located within the average distance of all the nodes to the sink given by D_{avg} as shown in equation.

$$T\,(S_{nrm)} = \begin{cases} \dfrac{3\ *\ P_{nrm}\,(i) * E_{avg}(r)}{(1 - P_{nrm}\left(r\ mod\ \left(\dfrac{1}{s *\ P_{nrm(i)}}\right)\right) * E_i(n)} & if\ S(i) \in G \\ 0\ otherwise & \end{cases}$$

3.1.4. Efficient Node Stable Routing Protocol (ENSR)

ENSR minimizes energy consumption and selects more stable nodes for packets forwarding. Stability becomes the most important factor that qualifies the node's centrality. A node’s stability is characterized by residual energy, link quality, and number of hops needed to reach the destination from the node.

In [14], Suzan Shukry, proposed ENSR, at first, some nodes will be selected as the stable forwarding nodes, usually with maximum SBC between their neighbors within a limited communication radio range of a particular region. Furthermore, each stable forwarding node then broadcasts its identity, including SBC, to the source node separately. The source node can compute a stable path to forward packets to the corresponding stable forwarding node, based on a proper designed stable path routing metric (SPRM). Then, this table forwarding node will behave as a new source node and start another stable path routing process until the packets are forwarded and reached to the destination node.

3.1.5. Stable TORA

Sajjad Jahanbakhsh Gudakahriz *et. al* [19], Routing procedure in Stable-TORA protocol would ignore repeated packets during sending route query packets to discover distinct node routes. Also each node calculates its remaining energy percentage and also the lifetime of the link between it and the previous node when it receives a route query packet. Simulation results showed that the Stable-TORA protocol acts better in terms of packet delivery ratio, end to end delay, routing overhead, and network lifetime compared to TORA protocol, which is due to discovery and use of high quality routes.

3.2. Stable Routing Protocols for Homogeneous Networks

Low-Energy Adaptive Clustering Hierarchy (LEACH) [21], Threshold sensitive energy efficient sensor network protocol (TEEN) [25] and MCRP[34] is discussed briefly in the following sections.

3.2.1. Low-Energy Adaptive Clustering Hierarchy (LEACH) and its Variants

LEACH is a hierarchical clustering algorithm introduced by Georgios Smaragdakis *et.al*[15]. The main idea behind LEACH protocol is to select cluster heads randomly from WS nodes and then uniformly rotate this role for equal energy consumption. The LEACH operation is divided into two phases: Setup phase to form clusters and to select respective CHs; steady state phase to transfer data to the BS. Though, LEACH can increase the network lifetime, it also possesses few limitations. LEACH assumes that each node has enough power to transmit data to BS if needed and that each node can support MAC protocols. Cluster head is selected from the cluster on probabilistic manner as:

$$T(n) = \frac{P}{1 - \left[P * \left(rmod\left(\frac{1}{P}\right)\right)\right]} \quad n \in G$$

$$T(n) = 0 \qquad Otherwise$$

The cluster head selection probability is denoted by pr, the current round number is r_o and in the last 1/pr rounds the nodes which are not elected as CHs are denoted by the set GH.

Kalyan, B.S [16] proposed a Quadrature-LEACH (Q-LEACH) for homogenous networks which enhances stability period, network life-time and throughput quiet significantly. According to this approach sensor nodes are deployed in the territory. In order to acquire better clustering author have partition the network into four quadrants. Doing such sort of partitioning better coverage of the whole network is achieved. Additionally, exact distribution of nodes in field is also well defined.

A-LEACH protocol was developed by Abdellah *et al.*[10], proposes the protocol emphasis on increasing the existence time before the death of the first node (which is known as the stable region) and decreasing the deteriorate probability of sensor nodes using heterogeneous parameters specifications. This protocol includes two stages: the setup phase and the steady state phase.

Reshma I. Tandel [21] proposed F-LEACH, a protocol for securing node to node communication in LEACH-based network. It used random key pre-distribution scheme with symmetric key cryptography to enhance security in LEACH. F-LEACH provides authenticity, integrity, confidentiality and freshness to node-to-node communication. But it is vulnerable to node capturing attack [21].

Sina Einavi Pour [22] presented, a new energy aware CH selection algorithm is proposed which selects CHs based on the residual energy, the position and centrality of nodes. It uses a variable range upon which the centrality and the number of neighbors of each node are calculated. Simulation results show that the proposed algorithm outperforms LEACH, Multi-hope Routing with LEACH (MR-LEACH) and Enhanced Multi-hop LEACH (EM-LEACH) in terms of reducing energy consumption, increasing network lifetime and improving network reliability.

Mu Tong and Minghao Tang [23], developed B-Leach based on the analysis of defect in LEACH including the fluctuation of the number of cluster heads and the ignorance of the nodes residual energy. In the proposed protocol B-LEACH, at each round, after the selection of the cluster head according to LEACH protocol, a second selection is introduced to modify the number of cluster head in the consideration of node's residual energy. As a result the number of cluster head is constant and optimal for every round.

Syed Umar *et.al* [24], proposed a new cluster based Re-Leach dynamic Protocol Dynamic Re-clustering based Leach protocol (DR-Leach), the expansion of the lattice energy consumption and reduce the age. The idea is that the energy cluster leader's next production cluster to balance in each round, the same number of nodes is maintained for the network lifetime. It calculates the optimum amount of CHS in each round, and the optimum amount for each cluster. The results showed that the improvement of reliability protocols proposed frame and the total energy consumption than BCDCP Leach and protocols.

3.2.2. TEEN (Threshold-sensitive Energy Efficient sensor Network protocol)

Brijesh L. Kundaliya *et.al*, [25] designed a protocol specifically for sensing the sudden changes in the environment like temperature monitoring. There are two versions of this protocol: one is Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN) and the other is Adaptive Periodic Threshold Sensitive Energy Efficient Sensor Network Protocol (APTEEN).

In TEEN [25], the data is not transmitted very frequently to the BS but the sensing operation continues at all time. For the implementation of TEEN, two thresholds are maintained for the selection of CH: soft threshold and hard threshold. Hard threshold allows the sensor nodes to transmit data only if the sensed attributes are in the range of interest. After sensing hard threshold, the data is transmitted only if sensed attribute is equal to or larger than soft threshold. The limitation of TEEN is taken care by APTEEN, which can be used for applications requiring periodic updates.

3.2.3. MCRP: Multiple Chain Routing Protocol

Husam Kareem et. Al [34], designed the MCRP protocol with the major objectives to increase the lifetime of WSNs by reducing the data transmission path to minimize energy consumption in WSN, and to maximize the network stability period by distributing the load evenly among all the nodes.

The MCRP works within two stages: the initialization stage and the data transmission stage. Simulation results demonstrate that the presented algorithm MCRP achieves its design goals and outperforms the existing work such as Chain-Chain based routing protocol (CCBRP), and Two-stage chain routing protocol (TSCP) algorithms in terms of Network lifetime, FND and LND (first node and last node died), Network stability period, and Energy consumption. The length of the stability period in MCRP algorithm is the highest one compared to CCBRP and TSCP algorithms. The improvement of the MCRP algorithm is almost 4% and 35% over TSCP and CCBRP algorithms respectively in term of stability period.

Thus the stable routing algorithms play a crucial role in maintaining efficient communication and data transfer in computer networks. The choice of algorithm depends on the specific network requirements, scale, and the level of the stability needed. It's also worth noting that stability is just one aspect to consider, and factors like convergence speed, scalability, and overhead are also important considerations when selecting a routing algorithm.

IV. DISCUSSIONS

Table 1 summarizes the recent works results of Ad-hoc On-Demand Distance Vector (AODV) and its variants, Stable Election Protocol (SEP) and its variants, Efficient Node Stable Routing Protocol (ENSR), Stable TORA, Efficient Stable Routing Algorithm (ESRA) based on the performance metrics, network stability period and energy consumption of heterogeneous networks.

TABLE I. SUMMARY OF STABLE ROUTING PROTOCOLS FOR HETEROGENEOUS NETWORKS

Author, Year	Routing Protocols	Network Stability	Performance	Merits	Demerits
Priyanka Pandey *et.al* 2021 [30]	Stable-AODV	Medium	Better throughput Higher performance in packets received	Constructs a stable route by focusing on signal power, delay and distance parameters.	An energy conservation technique can be incorporated No security features is added
Jian Xu, 2019 [31]	Modified AODV	High	Improved Packet Delivery Fraction Less Average delay	Performs better when the number of connection increase	Self Depletion of battery
Ranjita Joon, Parul Tomar, 2022 [32].	EAQ-AODV	Medium	Minimizes the energy consumption High throughput	It provides stable performance	It does not support mobility
Brijesh L. Kundaliya *et.al*, 2019 [25]	T-SEP	High	Greater network lifetime and improved stability	Perform well in small as well as large sized networks	Complex calculation at each node
Khushboo Yadav 2017 [17]	Z-SEP	High	Stability period is increased by 50% when compared to SEP and LEACH Increased in throughput by 18%	The best route is selected. It attains security and balanced energy consumption.	It incurs additional overhead due to the collection of network data and the calculation of cluster size.

Jeevan L J Pinto, Manjaiah, 2018 [27].	M-SEP	Very high	Increasing the stability period of the typical network approximately by 9%, longer than SEP.	It has increased network durability and stability	Variation of the constancy period of the sensor network
Paola G. Vinueza Naranjo. *et. al*, 2016 [28].	P-SEP	Moderate	Increases the stability period Increases packet transmission	Reducing the energy consumption and extends the lifetime of the network	It needs balancing improvements
Liquan Zhao, and Qi Tang, 2019 [34]	IT-SEP	High	Better packet delivery ratio Decreasing the average power consumption by 34%	Consumes the least amount of energy	Path stability depends on average value of residual lifetime which is not efficient
Deepak Kumar Sharma *et.al*, 2019 [35]	EI-SEP	High	Stability period is 20% more than LEACH 10.6% more than SEP 73.23% improvement in the packets delivery	Energy Consumption is reduced and throughput is increased.	No clustering feature is added
Biswa Mohan Sahoo *et. al*, 2019 [18]	ESRA	Medium	The stability period by ESRA is enhanced by 15.43%, 64.39% and network lifetime by 30.95%, 73.16% as compared to P-SEP and DSEP protocols	It has uniformity of energy consumption	It lacks flexibility
Suzan Shukry, 2021 [14]	ENSR	Very high	Increasing the packet delivery ratio by 16% Decrease the ATD by approximately 6.46%	Preserve node energy consumption, by mitigating “hot spots”. It reduces transmission cost between sensor nodes and increases network longevity	Table maintanance cost rise as the number of nodes grows.
Sajjad Jahanbakhsh Gudakahriz *et.al*, 2018 [19]	Stable- TORA	Medium	Increased in the quality of packet delivery ratio and network lifetime It has better end to end delay and routing overhead.	Suitability for large and dense WSN	The cost of link calculation is high for large number of nodes.

Table 2 summarizes the recent works results of Low-Energy Adaptive Clustering Hierarchy (LEACH) and its varients [21], Threshold sensitive energy efficient sensor network protocol (TEEN) [25] and MCRP[34] based on the performance metrics, network stability period and energy consumption of homogenous networks.

TABLE II. SUMMARY STABLE ROUTING PROTOCOLS FOR HOMOGENEOUS NETWORKS

Author, Year	Routing Protocols	Network Stability	Performance	Merits	Demerits
Kalyan, B.S. 2022 [16]	Q-LEACH	High	It provides stable performance. Reduced in Delays, Collisions and Signal interference.	Load balancing among sensor node strictly depicts network life-time	There is no mechanism for data aggregation
Fakhrosadat Fanian et. Al, 2016 [20]	A-LEACH	Moderate	Save energy and load balancing	Increased network stability and reduced energy consumption.	There is no concern for distance to the BS, resulting in the premature mortality of distant nodes.
Reshma I. Tandel, 2016 [21]	F-LEACH	High	It has high energy efficiency and very good scalability.	It attains security and balanced energy consumption	Qos and Time constraints are not considered.
Sina Einavi Pour, 2021 [22]	MR-LEACH	Moderate	Total network lifetime has increased by 32% Reduce energy consumption	It allows for scalability and considers both transmission power and minimum battery power.	Overhead is caused It has a lower performance gain due to the tiny field size.
Mu Tong; Minghao Tang, 2020 [23]	B-LEACH	Very low	Increase network lifetime Balanced cluster distribution	To maintain the network’s quality of life, the protocol assures that the cluster partitioning is balanced and homogeneous.	Dynamic clustering generates overhead
Syed Umar et.al, 2017 [24]	RE-LEACH	Moderate	Increase in energy efficiency	It provides reduced latency, simple	It has large number of unused nodes that are below the threshold.

			Moderate cluster scalability	clustering method and load balancing.	
Brijesh L. Kundaliya, 2019 [25]	TEEN	High	It maximizes network longevity and provides excellent energy efficieny. Low Scalability	It has improved performance and fewer transmissions. Good load balancing	Cluster formation causes overhead. Only reactive communication is possible.
Husam Kareem et. Al, 2019 [34]	MCRP	High	Increase in network lifetime of MCRP about 9% and 19% over TSCP and CCBRP algorithms respectively.	Nodes establish direct communications with the base station. The best route is selected	Lack of data aggregation at the sink node and causes data flooding.

V. CONCLUSION

Network life time and stability period of sensor nodes is a major challenge in the wireless sensor networks. The requirement of stable routing techniques for each sensor network differ based on the applications, it is infeasible to design a routing technique which satisfies the requirements in all scenarios of WSNs. These protocols are used for enhancing the energy efficiency of the network. There are many research works that have been done in the area of stability in different aspects such as node deployment, energy consumption, nature of nodes and coverage. This paper presents a comprehensive survey of stable routing protocols in wireless sensor networks. From the discussions and summary of the heterogeneous and homogeneous networks based on stability, heterogeneous networks have better stability in all aspects. Furthermore researchers continue to develop and refine routing techniques to address the challenges posed by different WSN scenarios and application domains.

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