Routing Protocol Based on Energy Consumption and Network Lifetime in WSN: A Review

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Abstract: The WSN consists of diverse number of sensor nodes for communication sensing and computation. Due to their small nature they have limited energy source since they are battery operated, recharging and replacing these batteries is very difficult and have several energy efficiency problems for which there are equivalent solution that can optimize the cost of routing and metric calculation, approaches to Load Balancing, Data Forwarding. The life of battery can be extended by designing an efficient routing protocol and algorithm which will overcome the drawbacks in WSN efficiently. Here we are doing a comparative study on the different routing techniques and algorithm to access the productivity of the technique, which helped researchers device various solution to the drawbacks in routing packets to their destination.
Keywords—WSN, Protocol, Routing, Chain Based, Tree Based, Energy consumption, Network lifetime.

Introduction

Sensors help to locate and send a signal based on the input received they are very sensitive ,there are various use of sensors in real time like monitoring ,controlling homes, health care, target sensing ,intruder detection etc. it collects the data and computes based on the computation it has been programmed to do. Sensors have numerable number of drawbacks like Range of the output signal is always limited, Non-linearity, Noise etc. The data which the sensors collect can be of any form based on the application like light, motion, heat .at the time of data capture the sensitivity of the sensors are improved, dissipation of transmission, continuous dynamic analysis. When data are analyzed on a real time the information received guarantees that processes are active and the implementation performance are most favourable.

Routing is the process of sending the data in the form of packets from one point to another to help establish basic communication. Routing is important in providing security, monitoring etc.

The types of routing in WSN are–**Static, Dynamic and Default**.

Static Routing is a method for manually setting up a router's routing table. Dynamic Routing is a method of updating automatically in response to network changes. By default routing, traffic is forwarded to a different network using a router's default gateway.

A router receives a packet as soon as it enters the network. The routing procedure is continued after the router consults the routing table and examines the packet header to determine the packet's destination. Less bandwidth-intensive routes are the most effective ones. Using a routing protocol is the most effective technique to select the most cost-effective route. It is capable of carrying out many duties, including load balance and traffic control.

The fundamental routing algorithm now in use is static routing. A routing table stores pre-defined routes. The routing table is used to choose the optimum path when a packet is transmitted. The most frequent and straightforward sort of routing is static routing. The first choice for network configuration is routing. The standard routing algorithm uses the first route in a routing table.

The algorithm tries to determine the next best route using the next HOP if the first route is not accessible. It uses the HOP to find a route if the next HOP is not accessible. When a network administrator wishes to provide every packet a distinct route, they employ this sort of routing.

Dynamic Routing is a procedure of dynamically moving fluid objects.The best path can be discovered using a routing table. Every time a packet is transmitted or received, the routing table is modified accordingly.

The performance of the network is affected by effective routing methods. It keeps the network operating effectively.

Designing a secure protocol for routing that can function in every context is the main challenge facing WSN. Security is important because it is one of the metrics used to evaluate routing protocols. We are examining the well-known protocols in this study to determine their weaknesses and advantages.

Over a large geographical area sensor nodes are dispersed randomly over a network, which are connected to sensor nodes. The 3 fundamental parts of each node are Communication component, processing unit, and sensory unit.

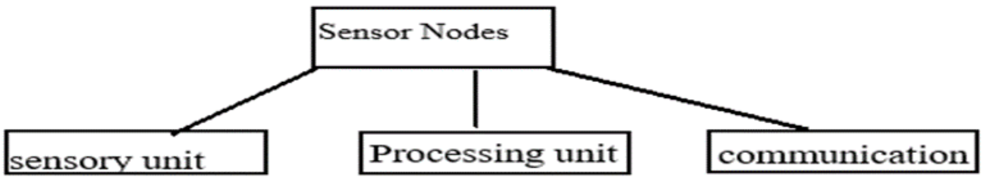

Fig1:- Sensor nodes basic components

Despite the wide range of applications, WSNs have a number of restrictions, including a constrained energy source, limited computer power, and a constrained bandwidth. Among other things, WSNs' ability to carry innovative data transfer while emphasising network lifetime and avoiding connectivity degradation is one of their primary design goals. To do this, they employ aggressive energy management measures. The difficulties and problems in design have an impact on the routing protocols used in WSN. Before a well-organized communication can be achieved in a wireless sensor network, the obstacles must be effectively overcome with the aid of good algorithms and protocols.

Challenges and design issues

Certain **challenges and design issues** that affect the routing process in WSNs are summarized [15].

Node deployment:[15] Application-specific node deployment options for WSNs include manual (deterministic) and random node deployment. When sensors are manually deployed, data is sent through pre-established paths and the sensors are manually positioned. In contrast, ad hoc routing infrastructure is created when sensor nodes are dispersed randomly during random node deployment. To enable connection and energy-efficient network operation, optimum clustering is required if the resulting node distribution is not uniform. Due to energy and bandwidth restrictions, inter-sensor communication often only occurs within limited transmission distances. As a result, it is very possible that a route will have several wireless hops.

Energy consumption without loss of accuracy: Wireless environment exhaust the stored energy for performing computation and information transmission. Conserving energy in any form is necessary for good communication and computation. There is interdependencies between sensor nodes and battery lifetime [33]. Power failure can cause malfunctioning of sensor nodes and may significantly affect the changes in topology of sensor nodes which leads to re-routing of packets and re-organisation of the network.

Data reporting method Application:[15] The time-criticality of the data drives the specific reporting of that data in WSNs. For data reporting, any of the following approaches may be used: time-driven, event-driven, query-driven, or a mix of these.. For applications that need for routine data monitoring, the time-driven delivery approach is appropriate. In order to perceive the surroundings and send the relevant data at regular intervals, Sensor nodes will periodically activate their transmitters and sensors. Both event-driven and query-driven techniques need sensor nodes to reply rapidly to queries from the BS or other network nodes or refers to abrupt changes in a detected attribute's value brought on by the happening of a particular event. These are thus ideal for applications that require quick response times. Combining the a forementioned techniques is also an option. The data reporting method significantly affects the routing protocol's energy consumption and route calculations.

Node/link heterogeneity: [15] Numerous studies made the assumption that all sensor nodes were uniformly distributed, which meant that they all had the same capacity for computing, communication, and power. A sensor node may, however, serve a specific purpose or perform a specific function depending on the application. In terms of data routing, the presence of a heterogeneous group of sensors presents a variety of technical problems. For instance, certain applications may need a variety of sensors to follow moving objects in photos or videos, identify movement using auditory signals, and monitor the temperature, pressure, and humidity of the immediate surroundings.. On the same sensor node, these specialised sensors may be deployed singly or in conjunction with additional functionality. Even the rate at which these sensors gather and report information can vary, and they may be subject to various QOS restrictions or use various data reporting formats These cluster heads might be chosen from the deployed sensors or they could be given a boost in terms of energy, bandwidth, and memory compared to other sensor nodes. Hierarchical protocols, for example, identify a cluster head node from the common sensors. Therefore, it is up to the cluster of cluster leaders to send information to the Base station.

Fault Tolerance: [15] Nodes in a WSN may not perform as planned owing to insufficient power, physical damage, or disturbance from the environment, but this shouldn't have an impact on the sensor network's overall task.When node failure rates rise, new links and routes will arise and be accommodated by the Medium Access control and routing protocol. The packets will be rerouted through such paths of the network if energy is abundant. By changing the transmitted power and signaling speeds on the active lines, energy consumption can be decreased. A fault-tolerant network needs numerous layers of redundancy.

Scalability:[15] In the sensing area, there are hundreds of thousands of sensor nodes distributed. To operate with hundreds of sensor nodes, an effective routing architecture is crucial. When an environmental event requires a specific response, it should have the scaling function; otherwise, the sensors may go into sleep mode, with the information gathered from the few remaining sensors being of low grade.

Network dynamics:[15] Many studies make the assumption that sensor nodes are stationary. However, in many cases, both BS and sensor nodes can be mobile. As a result, it becomes more challenging to route messages from or to moving nodes because issues with route and topology stability, as well as energy, bandwidth, and other considerations, become critical. Additionally, the incident might be mobile (for example, via a target detection/tracking application) [8]. Even though the majority of applications demand regular reporting to the base station while sensing dynamic events, when sensing fixed events, the network can function in a reactive manner (i.e., generate traffic when reporting) instead.

Transmission media: [15]A wireless medium connects the communicating nodes of a multi hop sensor networkThe performance of the sensor network may also be affected by common wireless channel problems (such as fading and high error rate). Typically, just a small amount of bandwidth—between 1 and 100 kb/s—will be needed for sensor data. The MAC's design is connected to the transmission media. Use of TDMA (time-division multiple access)-based protocols, This is one approach of MAC design for sensor networks, which saves more energy than contention-based protocols like CSMA (carrier sense multiple access) (e.g., IEEE 802.11). Additionally, Bluetooth technology [13] is an option.

Connectivity:[15] Due to the high node density, connectivity depends on how nodes are distributed. Sensor nodes are prevented from staying totally detached from one another, which in turn anticipates nodes to be connected. Nevertheless, this will not prevent the structure of the network from altering or the network's capacity from decreasing when nodes fail.

Coverage:[15] Since the physical diameter of the environment can only be covered by a specific amount of area coverage, each node only receives a guaranteed view of the surroundings that is constrained in terms of distance and precision.

Data aggregation:[15] Although sensor nodes could produce a lot of duplicate information, it is possible to aggregate comparable packets from different nodes to cut down on the amount of transmissions. The act of combining data from several sources in accordance with a specific aggregation function (such as duplicate suppression, minima, maxima, and average) is known as data aggregation. In several routing protocols, this strategy has been utilised to optimise data transport and achieve energy economy. Data aggregation can also be done using signal processing technique, It is known as data fusion in this situation when a node is able to provide a more accurate output signal by combining the signals that come in and lowering their noise levels using techniques like beam formation.

Quality of service: [15]In order for the data to be processed and turned into something meaningful, it must be sent from the sensors within a set amount of time, failing which the information becomes useless.

Routing techniques

Routing can be categorised as follows according to the network topology (Jamal Al-Karaki et al., 2004)[15]]. **Flat based routing, Hierarchical routing, Location-based routing**.

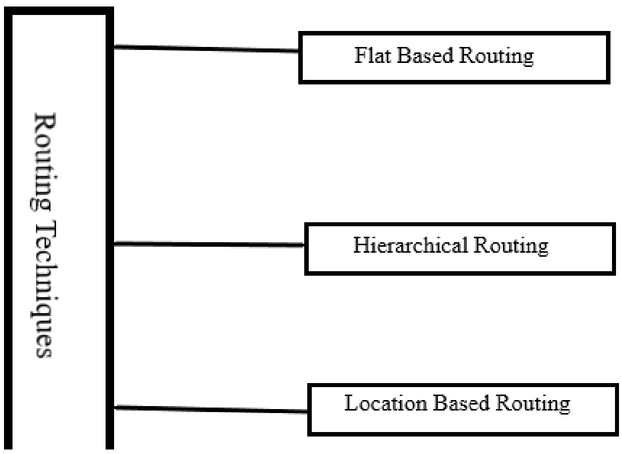

Figure 2. Classification of Routing Technique

Flat based routing protocol

Whenever a node needs to transfer data from one location to another, it first determines the optimum route to take before using the multi-hop approach to send the data. Every node has a task that needs to be completed. According to Qinbib He et al. [21], the flat routing protocol has certain drawbacks, featuring inefficient resource management, a self-organized complexity of cooperating nodes, and a sluggish network requiring the maintenance of large routing tables. Not appropriate for large wireless sensor networks. To improve the nodes' performance and survival rate, researchers have proposed the idea of hierarchical routing protocols.

Hierarchical routing technique

An IP address is split into a network portion and a host portion in the majority of Transmission Control Protocol/Internet Protocol (TCP/IP) routing schemes. Up until a gateway is reached that can transport an IP datagram directly, gateways only use the network component. The establishment of sub-networks results in the introduction of fresh levels of hierarchical routing. The most energy-efficient routing protocols for wireless sensor networks are recognised to be hierarchical routing systems.

Purpose

It is more challenging to centralise system management and operation due to the Internet system's global character. This necessitates a hierarchical structure for the system, with layers of organisation and various group loops connected to one another at each level.

The process of placing routers in a hierarchical order is called hierarchical routing. A company intranet would be a nice illustration. The majority of business intranets are built on a fast backbone network. Routers connected to this backbone in turn are connected to a specific functioning

Classification of hierarchical routing

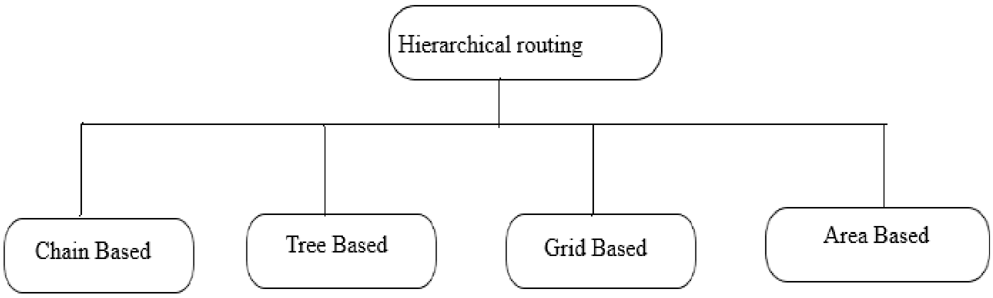

Figure 3. Classification of hierarchical routing Technique

The chain-based Routing protocol (CRP): is one method from Hierarchical routing protocols that lowers the amount of energy used by WSNs. But when the network includes lengthy links from the base station, there is a difficulty. The responsibility of gathering data is assigned to a leader, who then collects the information that's sent down the hierarchy.

The Tree Based Routing protocols (TRPs):A particular method from Hierarchical routing protocols that lowers the amount of energy used by WSNs. But when the chain includes lengthy links from the base station, there is a difficulty. A leader is chosen to carry out the data collection activity, and the leader node receives the data given along the chain. Using sensor nodes to build a logical tree, the links between the nodes are only governed by Parent-Child relationships. By doing away with path searching and avoiding the usage of lengthy broadcasts from leaf nodes to parent nodes, tree-based routing may accomplish minimal control overhead as well as excellent latency. According to T. S. Chenet et al. and S. Umar et al., tree-based protocols are more self-organized and efficient at conserving energy than cluster-based routing protocols.[29]

Grid based routing protocol (GBRP:)Routing linking source and sink through single-hop or multi-hop fashion is used to send the data from the source to the sink. There are various grids that split the entire network. Without using a routing table, routing operations are carried out.

Area Based Routing Protocol (ARP): Employed in Wireless Sensor Networks (WSN), which leverage nodes' locations to facilitate communication. Higher tier nodes, such as sensor nodes, are those that are assigned to a particular area. The size of the area can be changed based on the needs for load balancing..

Routing protocol

DS-EERA: (LIANGRUI TANG ET.AL)[17] **DEMPSTER–SHAFER ENERGY EFFICIENT AND RELIABLE ROUTING ALGORITHM**

Three attribute indices— For each node in the network, the transmission energy efficiency ratio, idleness level, and intensity of energy factor are developed. The entropy weight method is used to find what is happening in a particular situation where the weight of each index, and the blend of the two indices give rise to a BPA function. The dependable value of the index is then combined utilising the DS evidence fusion rule to get the optimum routing decision routing.. Based on the simulation results, DS-EERA gives good result for transmission reliability by effectively reducing network energy usage, extending lifetime of the network, and improving the amount of packets lost when opposed to the MCRP and FLEOR algorithm.

HCEH-UC (Bing Han et.al) [5]: Suggests a routing technique based on energy harvesting for continuous WSN target coverage. Nodes may accomplish environment-adaptive clustering based on their closeness to one another utilising the recommended hierarchical clustering algorithm. By doing so, the network's topological structure can be improved and the amount of energy required to transfer data inside the group can be reduced. The remaining energy of the node, the energy structure for data transfer, and the energy gathered necessary to develop a better HCEH-UC routing protocol are the three key energy harvesting elements that are taken into consideration while recommending a cluster head selection technique. In the end, by using the alternate operating-recharging mode of the cluster head node, it is possible to effectively define the dispersed channel of communication and topological relationship of the newly built node cluster.. As a result, it is able to continuously cover targets using energy harvesting.

PEGCRP (Fatima Bouakka et.al**) [9]** "**Power Efficient Grid-Chain Routing Protocol** in WSN" protocol to increase the network's life. The grid algorithm was used in the initial stage to partition the nodes into virtual cells. Then, the sensor nodes' locations are taken into consideration to form cells with grids, and minimises the radius of transmission by the use of multi-hop that instantly has an impact on reducing energy consumption. These data which are transmitted use chain transmission in intra-cluster and inter-cluster, where each and every node has communicates with their neighbour, protocol (PEGCRP). Cluster Heads selection is based on two criteria: the smallest distance from each zone's midpoint and the maximum residual energy. The simulation shows that our created protocol is the most reliable and uses less amount of energy, which helps in extending the network lifetime.

Chain based Hierarchical routing protocol

ICBCCP (Awadhesh Kumar Maurya et.al) [4] Improved Chain Based Cooperative Routing Protocol: An enhanced CBCCP technique has been devised that chooses the Cluster Head (CH) and Cluster Co-Coordinator (CC) based on energy, distance, and density. In Improved CBCCP, each cluster has one CH and several CC, and the network is separated into layers of fixed measures. The data are sent to CH via the single Hop method. In order to adjust the load on the node, each cluster head and cluster coordinator has the load of one cluster. Cluster coordinator is used for intra-cluster communication and inter-cluster communication to shorten transmission range.

In essencethe network is divided into smaller networks, and a set number of members are distributed at random throughout each smaller network.. From each CH, CCs are selected based on energy, node density, and distance. A CH and several CCs are present in each and every sub network. Every Cluster Co-ordinator is controlled such that it only handles one sub-network load. The cost of intra-cluster communication is reduced by applying path prediction cost measures. The strategy suggested by author Shilpa Mahajan et. al.[27] reduces energy utilization and extend the lifetime of networks. Energy consumption metric developed by Awadesh Kumar Maurya et al[4] ETx(1,d)=1If (d>d0), elect +1*Emp*d4 if ETX(1,d)=1.If (d>=d0), then *Elect+ 1*Efs*d2.

DCBRP: (Haydar Abdulameer Marhoon et.al**) [11]:** Deterministic Chain Based Routing Protocol is a brand-new routing protocol that is built on the minimalist Chain Based Routing protocol developed by Deter Bouakkaz et al. This includes the underlying building process, the Chain Head Selection (CHS), and the Next Hop Connection mechanism. According to the findings of an in-depth study, the DCBRP performs better than the CCM and TSCP in terms of both node energy consumption and Chain Head energy consumption. Deterministic Chain Based Routing Protocol additionally performs better than the TSCP and CCM with regard to network lifetime metric, on consideration we come to know that it is the primary metric to gauge lifespan in WSN. Energy *delay=Etotal Econs.in round r* Ddelay to deliver all data is the metric developed by Lindsey et al (2001) for DCBRP by Haydar Abdulameer Marhoon [11]. For the DCBRP, the average energy usage is 0.077.

ICCHR(Huarui Wu et.al)[12]: **Improved Chain Based Clustering Hierarchical Routing** energy efficiency and load balancing and the life span of network can be realized by using Hierarchical routing technique. The technique concentrate on studying the formation of clusters, cluster head election, chain formation, and data transmission process. The creation of clustering, CH election, chain formation, and data transmission procedure are all determined by a study of the ICCHR algorithm. Additionally, the suggested ICCHR algorithm improves the network lifespan and uses less energy than E-LEACH, PEGASIS-E, LEACH-1R PEGASIS, and P-LEACH algorithms. Huarui et al. computed the energy consumption as ETx (k,d)=kEelec+kEfsd2 d d0, kEelec+kEampd4 d >= d0.

Tree based Routing Protocol

LEAST (Low-Energy Adaptive Scalable Tree-based routing protocol) [1][3]: The LEAST protocol's clustering follows a basic tree architecture and is designed to be adaptable based on the proximity of the sensors. The lifetime of network and consumption of energy for this tree-based protocol are significantly longer than those of the current hierarchical techniques.

EADAT (Energy Aware Data Aggregation Tree)

Network lifetime can be increased by EADAT

It is important to comprehend how an EADAT [36] might impact the network lifetime. Simply count the sensors alive during a simulation to do this. The numerous sensors defined in the area are chosen at random,the packet rate is one pkt/s. A comparison between situations where the aggregate tree is used and those where it is not. Because sensors constantly exchange information when an event source is randomly situated in the observation region, most sensor nodes expire at a certain point in time without triggering the creation of a data aggregation tree. Because event sources are placed haphazardly around the monitored area, sensors are constantly busy transmitting and receiving data. Since the sensors are organised into an aggregation tree, they can last longer. Energy Conservation by EADAT

Under similar network conditions, the EADAT [36] protocol uses less energy than one without an aggregation tree, which increases the number of sensors that are alive. The lifespan of the network is extended by this energy conservation. The technique used must only activate non-leaf nodes in the aggregation tree to maintain the order of network traffic. All leaf nodes main concern is to conserve energy. The typical residual energy of all sensors alive diminishes much more slowly when EADAT is employed than it would if an aggregation tree weren't there.

HMBCR(SHAHA AL-OTAIB et.al)[25] Meta-heuristic hybridization for cluster-based routing The HMBCR technique employs an equation that accounts for energy, distance from other nodes, distance from the base station, and traffic in the network, among other four factors. The first phase involves using a clustering algorithm depending on the BSO-LD (BrainStorm Optimisation with Levy Distribution). A water wave optimisation with a hill-climbing WWO-HC (Water Wave Optimisation with a hill-climbing) based routing method is also used to select the best route.. To assure the long-term network resilience and energy saving of the HMBCR technology, an in-depth evaluation is conducted. The findings from the study demonstrated that, under a variety of conditions, the HMBCR approach would consistently beat the alternatives. The HMBCR technique has two operational phases: WWO-HC-based routing and BSOLD-based clustering. The nodes are initially spread out randomly across the target area. After setup, the nodes are used to collect information about nearby nodes. The BSO-LD approach is then used to identify the network's ideal set of CHs. The WWO-HC algorithm's selected inter-cluster paths are subsequently used for data transfer. A number of simulations were run to check the HMBCR method's effectiveness. With respect to energy efficiency, network longevity, PDR, ETE delay, and PLR, the study's results demonstrated that the HMBCR technique performed better than earlier solutions.

RSTR (Qinbin He et.al)[21]: **Robust Self-OrganisingTtree Based Routing** The sleep-wake cycle, local node density, and virtual potential energy are all integrated into the protocol. The recommended routing scheme works well and self-organizes. The protocol for routing lets nodes to proactively enter or exit the network and allows nodes to transmit data automatically through shortest route to a linked sink. In single-sink, multiple-sink, and three-dimensional WSN situations, the technique is applicable. The protocol concurrently enhances energy savings, greatly reduces overall network traffic, and is accountable for a sleep-wake-up process. The routing protocol establishes layer labels and minimum spanning trees to direct the nodes to convey data along the shortest path to the appropriate sink. By determining the nodes' direction of communication using their virtual energy sources, our method more evenly distributes the network's energy consumption. This significantly lengthens the network's survival time. RSTR doesn't require flooding, allowing the node to stay in touch with its contacted node until that node's energy consumption is low in order to establish the information-flow direction and create a tree .RSTR reduces energy consumption caused by data updates that occur too often by determining the optimum energy reserve of its adjacent nodes. It requires a lot of slumber nodes in a widespread WSN network, and more nodes are constantly needed to maintain the network operational. The paper describes the RSTR's sleep-wake-up process. The study specifically outlines the mechanism of REWUM. REWUM is a more advanced active wake-up technique. The lifetime of WSN's can be increased significantly by the effective use of REVUM. In a widespread WSN, the node closest to a sink will use energy more quickly. To keep the network operating efficiently, we constantly need to add nodes close to sinks.

A widespread WSN cannot use a single sink mechanism, in addition. A potential technique for a widespread WSN would be the use of many sinks or a mobile sink. If we don't continuously add nodes near sinks, the first WSN network ought not to be an arbitrary network either. Because of this, it is not apparent what kind of node arrangement and sleep-wake-up process ought to be utilized for WSNs or whether the entire network can achieve the longest survival span and most efficient energy utilisation. A dynamic network of WSNs can also make use of RSTR. Adaptive Wireless Sensor Networks are far more advanced than static wireless sensor networks.

Comparative study

Upon comparing the various routing protocols based on different parameters

Protocol	**Structure**	**Energy consumption**	**N/w Lifetime**	**Packet Loss Rate**	**Reliability**	**Author**
DS-EERA	NA	Reduced	Prolonged	Improved	Good	Tang.L.et.al 2020
PEGCRP	Grid-Chain	Less	Improved	Reduced	Good	Fatima Bouakkazetial et.al 2021
DSR &DYMO	NA	Reduced		Reduced		Pandey A.K et.al 2018

ICBCCP	Chain	Reduced	Prolonged	Improved	Good	Awadesh Kumar Maurya et.al
DCBRP	Chain	Reduced	Extended	Reduced	NA	Haydar Abdulameer Marhoon et.al 2016
ICCHR	Chain	Low	Extended	NA	NA	Huarui Wu et.al 2019
LEAST	Tree	Reduced	Improved	NA	NA	AmirMohamme d
HMBCR	Tree	Reduced	Maximized	Reduced	Good	Shaha-Al-Qtaibi et.al 2021
RSTR	Tree	Reduced	Extended	NA	NA	Qinbin He et.al
EADAT	Tree	Reduced	Extended	Reduced	NA	m.ding et.al 2022

Table 1. Comparison chart for routing protocol

Conclusion

WSN have extensive application in recent years. Researchers are continuously working upon to bring about the appropriate algorithm to overcome the drawbacks in WSN. Upon review of various routing techniques in WSN it is inappropriate to choose or say, with the various draw backs we have come across such as battery life, Bandwidth, Short communication Range etc., the best protocol with regard to power usage and network lifetime since they are interdependent they need to consider the structure and the packet loss rate. If consumption of energy is low there is going to be improvement in the lifetime of the network.

Every Research technique gives rise to a better modified algorithm since only upon implementation in real scenario do we come across the short comings of the algorithm designed. For future work planning on analyzing the various other drawbacks not taken into account in this research paper and come up with a good algorithm which will further improve one or two drawbacks in WSN.

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