A Survey on Energy Efficient Routing Protocols in Wireless Sensor Networks

1Raghavendra Y M, 2Asha M
1,2 Asst.Professor, ECE DEPT
GSSSIEETW, Mysore
raghavendra@gsss.edu.in
asha.m@gsss.edu.in

Abstract: **Wireless Sensor Network (WSN) refers to a group of spatially dispersed and dedicated sensors for monitoring and recording the physical conditions of the environment and organizing the collected data at a central location. In many WSN applications, the sensor nodes are battery driven and they are often very difficult to recharge or change the batteries. The energy consumption in WSN depends on Sensor nodes, Architecture and Communication Protocols utilized. Energy efficient routing is one of the most effective ways to save energy in WSNs. Energy efficiency is the first and foremost issue in designing a routing protocol. An energy efficient routing protocol is needed to ensure network performance and prolonging network lifetime. A number of energy efficient routing protocols were proposed. Here some of the routing protocols in WSN are discussed. WSN has become an emerging area of research in recent years**

Keywords: **WSN, energy efficiency, routing protocol, network lifetime.**

I.INTRODUCTION

Wireless sensor networks are equipped with autonomous sensor nodes with a major motive to sense the environmental and physical conditions and route to the master sensor node that is base station that has uninterrupted power supply and is generally fixed. Energy is a limited resource in wireless sensor networks. In fact, the reduction of power consumption is crucial to increase the lifetime of low power sensor networks. As most of the energy consumption is originated by sensing, data processing and communication, these operations are the basis for identifying and exploiting energy saving potentials. The relation between energy consumption and communication range [1] in WSNs is $E = kd^n$, where E is the energy consumption, d is the communication range, and $2<n<4$, k is a constant. From the formula, we see that the longer the range, energy consumption is more. The major limitation is limited buffer size, limited energy supply, limited computing power, and limited bandwidth. So researchers are all involved in designing the energy efficient routing protocols or doing amendments in existing energy saving protocols for the energy conservation of sensor nodes. Several energy conservation approaches have been proposed for WSN.

In addition, the sensor network should have a lifetime long enough to fulfill the application requirements. But not only it is important to manage existing resources correctly in order to avoid wasting them and reserve some of them for critical situations, but also regenerating or harvesting consumed energy as much as possible, to make network live longer. The routing protocols are used to find a path from source to target destination. Depending on the network structure, routing in the wireless sensor networks can be divided into three types: flat routing, location-based routing and hierarchical routing. So an energy efficient routing protocol is required to make sensor nodes live longer.

This paper is organized as follows: Section II describes on routing factors in WSN design. Section III exhibits on different routing techniques.

Section IV on review of related papers in WSN. Section V is on comparison of protocols. And finally conclude the paper in section VI.

II.ROUTING FACTORS IN WSN DESIGN

The design of routing protocols in WSN is influenced by many challenging factors. To achieve effective communication in WSNs these parameters should be taken care properly. Some of these parameters are discussed as below [2][3].

Energy consumption: Sensor nodes can use their limited supply of energy performing computations and transmitting information in a wireless environment. As such, energy conserving forms of communication and computation is essential. Sensor node lifetime shows a strong dependence on the battery lifetime.

Node deployment: Performance of the routing protocols depends on the node deployment. It may be in deterministic or random fashion. In deterministic method, sensor nodes are placed manually and data is passed through predetermined paths. In random method, nodes are scattered randomly in an adhoc manner. Now a days sensor nodes are equipped with Global Positioning System.

Fault tolerance: In the event of node failure, routing protocol must provide new paths. So that data transmission or reception process should not get affected. Failures may be due to physical damage, environmental disturbance or lack of power.

Scalability: In most of the sensing applications hundreds or thousands of sensor nodes are deployed. Routing protocols should be able to work with these huge number of nodes. Sometimes nodes may go to sleep mode and awake on demand. So nodes should be extremely scalable.

Data aggregation: Sensor nodes may provide redundant data. Aggregation technique is used to eliminate redundant

data. While aggregating data similar kind of packets are discarded and only the aggregated data is transmitted. This is also one of the energy efficient techniques in routing protocols.

Quality of service: Sensor networks may have different Quality of Services (QOS) based on their application like latency, packet loss. Hence routing protocol must take care of their QOS requirements for particular application.
By considering all these factors in WSN, routing techniques are developed and discussed in the next section.

III ROUTING TECHNIQUES

The routing protocols are used to find a path from source to target destination. Depending on the network structure, routing in the wireless sensor networks can be divided into three types: I) Flat based routing, II) Location-based routing and III) Hierarchical routing. Depending on the protocol operation, routing protocols are classified as Multipath routing, Query based routing, negotiation based routing and QOS based routing. Fig1 shows the classification of routing techniques.

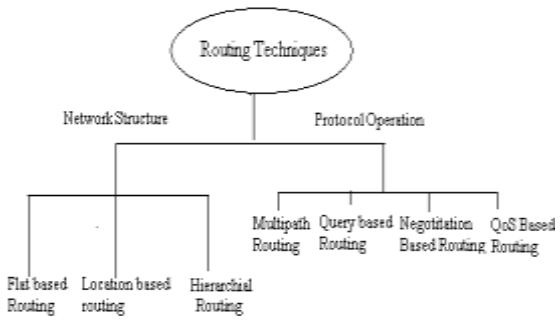

Fig1: Routing Techniques

Flat based routing (Flooding):
In flooding all sensor nodes have equal functionality in flat based routing i.e. all nodes collaboratively perform sensing task. Since large number of sensor nodes, assigning global identifier is not feasible to each node. This leds to data centric routing. Where BS sends queries to collect data from selected sensors in certain region. SPIN[4] and directed diffusion[5] are the examples of this routing.

Hierarchical based routing (clustering): In the network, if sensor nodes play different roles that type of technique is known as hierarchical based technique. Hierarchical routing is mainly used for scalability and energy efficient communication. Here low energy nodes can be used to sense the data and high energy nodes are used for processing and sending the data.

Location based routing (Geographic): In the network, if sensor node positions are exploited to route data is known as location based technique. Based on the signal strength distance between neighboring nodes is calculated. To save energy many nodes goes to sleep state.

Multipath routing: To enhance network performance multipath routing is used instead of single path. Due to this in any condition if main path fails, there exists always an alternate path.

Query based routing: In this routing, the destination nodes propagate a query for data, from a node through the network and a node having this data sends the data which matches the query back to the node, which initiates the query.

Negotiation based routing: Through negotiation based method redundant data's are eliminated or suppressed. Based on the resources available communication decisions takes place.

QOS based routing : Sensor network has to satisfy some quality of services while sending data to base station. Services are bandwidth, delay, packet loss, energy etc.

IV RELATED WORK

Enormous papers are published based on the routing protocols. These protocols are based on network structure or based on protocol operation or application needed. An approach is done to list some of these papers.
Low energy adaptive clustering hierarchy **(LEACH)** [6] is one of the most popular algorithms. LEACH forms the clusters based on the received signal strength. LEACH uses local cluster heads as routers to the sink. The transmission of data is done only through these cluster heads rather than all the sensor nodes in the network. This will save energy as only cluster heads are responsible for transmission of data towards sink. These cluster heads change randomly over time depending on energy dissipation of the sensor nodes. This decision is made by the node choosing a random number between 0 and 1. The node becomes a CH for the current rotation, if the number is less than the threshold value. Data from cluster nodes to BS achieves through CH.

A **Time division multiple access (TDMA)** scheduling scheme has balanced energy and end-to-end delay of wireless sensor networks. This balance achieves with appropriate scheduling of the wake-up intervals. From sensors to gateway it takes one sleep interval for data transmission. **TDMA scheduling algorithm** [7] scheduling reduces sleep mode delay in WSN. TDMA algorithm initially builds the transmission schedule. Transmission schedule is flooded back to the sensor nodes, allowing them to know when they can transmit or receive a packet. Energy-saving phase determines sleep and wake-up periods using initial transmission schedule.

Memetic algorithm (MA) [8] is a dynamic optimal design algorithm. Memetic algorithm optimized the design based on the battery level threshold values for each operating modes of sensors. The MAapproach is materialized through local search and threshold update schemes. Local search initialize the threshold values of battery levels for each three possible operating modes are CH, Higher Sensor Range (HSR), and Lower Sensor

Range (LSR) defined. If battery level is below its threshold, then operating mode is changed to lower mode until its corresponding threshold value becomes lower.

Geodesic sensor clustering (GESC) [9] is a Distributed clustering algorithm and designed for multi-hop networks. Clustering creates the hierarchical base structure. Network management technique uses the residual energy for selecting cluster head. The clustering protocol is divided into two major procedures: the clustering formation procedure (CFP) and the network operation procedure (NOP). The duration of the clustering formation procedure is the time interval needed to cluster the network, while the duration of the network operation procedure is the time interval between two subsequent intervals. The clustering protocol is divided into rounds where at the beginning of each round CFP is triggered. The NOP follows the CFP when data transferred from the nodes to cluster heads and it will forward through multi-hop paths to the information sink.

Geographical Adaptive Fidelity [10] is an energy-aware routing protocol primarily proposed for MANETs, but can also be used for WSNs because it favors energy conservation. The design of GAF is motivated based on an energy model that considers energy consumption due to the reception and transmission of packets as well as idle (or listening) time when the radio of a sensor is on to detect the presence of incoming packets. GAF is based on mechanism of turning off unnecessary sensors while keeping a constant level of routing fidelity.

Reliable and Energy Balancing Multi-Path Routing [11] Algorithm for Wireless Sensor Networks. The REMP protocol guarantees the mentioned quality of service parameters in wireless sensor networks and balances the energy consumption in all sensor nodes. By means of simulations, the authors have evaluated and compared the performance of these routing protocols with the MCMP (Multi-Constraint Multi-Path) and EQSR (Energy Efficient and QoS aware multipath routing protocol) routing protocol.

Receiver-driven medium access control (RMAC) [12] is a type of TDMA based scheduling scheme. Unlike other MAC protocol, each node in its time slot will receive message from other nodes. To avoid simultaneous message transmission from multiple nodes to the receiver node, each receiver node will have a sender node on its scheduled time period. When compared with other Receiver MAC protocol, it is having time stealing mechanism. If the sender node is not transmitting any message on the time slot of receiver node, then the allotted time slot will be traced up by nearby sender node to transmit its message to the receiver node.

Multi Layer -MAC [13] is a distributed contention-based and self organizing MAC protocol, where nodes discover their neighbours based on their radio signal level. ML-MAC divides sensor nodes into layers. Layers are randomly chosen by nodes and its time period of each layer is divided into number of frames. Each frame decides its listen and sleep periods. The listen periods of nodes in different layers are non-overlapping. A node in the ML-MAC protocol wakes up only at its assigned layer's listen period. ML-MAC reduces the energy consumption than other protocols by reducing the wake up time of each node through layered architecture.

Adaptive service provisioning mechanism [14] proposed the adaptive service provisioning for enhanced energy efficiency. The flexibility of wireless sensor networks is achieved through novel service binding strategies that automatically adapt application behavior. Adaptation mechanism is divided into three parts: energy-aware selection, shared service invocations, and adapting the network topology changes. Selecting the provider is to choose the one that result in the application having the smallest energy footprint. Service sharing enables multiple service execution requests can be combined into one execution of the service.

Optimal wake-up frequency assignment algorithm (OWFA) [15] exhibits both centralized and distributed mechanism. OWFA assigns optimal wake up frequency to all nodes in the data gathering tree. OWFA has three procedures as: Alpha procedure, Combine-Node procedure and Assign frequency procedure. Alpha calculates optimal wake-up frequency by summing the overhead energy values and data transmission energy values of all child nodes. Combine-Node procedure recursively calculates the combined energy consumption coefficient of the root node. The root node assigns the wake-up frequency of each node.

Energy efficient cluster node (EECL) data transmission [16] is distributed over the sensors which forms optimal clusters. The cluster has been created and the data transmission is fixed with TDMA scheduling. Sensors nodes have to send the data during its allocation transmission time to the CH. After allocating transmission time for each node, the radio of CH node is turn to off. When wake-up time CH receives data from remaining nodes and the data has been aggregated. The data has sent through energy efficient CH to BS.

Network coding-based cooperative ARQ (NCCARQ MAC) protocol [17] is a network coding technique. NCCARQ correlates the transmissions between a set of relay nodes that supports a bidirectional communication among pair of nodes. NCCARQ-MAC enables wireless workstations to request cooperation of neighboring nodes for correct reception of a data packet. It allows the helper nodes to perform network coding techniques to the packets to be transmitted before relaying the packets. The relay store, a copy of any captured data packet until it is acknowledged by the intended destination. The error mechanism, such as Cyclic Redundancy Code is applied to perform error control for receiving messages.

Cluster based routing protocol (EADC) [18] is a cluster-based routing protocol. EADC calculates average residual energy and waiting time of each node. If a node has not receive any header message from remaining nodes within the waiting time, then it elects as a CH. The other nodes are joined as members to CH. CH broadcast the schedule to its cluster members. During its

schedule, nodes transmit the data to CH. If the distance between the CH to BS is less than the calculated threshold, then it will have BS as next hop. Otherwise, it will forward to next CH node having higher residual energy.

Improved LEACH protocol (WLEACH) [19] that is **Wise Low Energy Adaptive Clustering Hierarchy** by three improved sides: the first side is adding considering of energy ,the second aspect is adding multi-jump routing between nodes, and the third aspect is adding dormancy of cluster head node. Considering the first side, known that LEACH protocol limits the node times to become the cluster head, which can avoid node's death based on cluster-head node' more energy-using, they also become low-energy and easy to die. In order to solve this problem, it is necessary to limit the energy a node become cluster-head. Now there has been some theory about energy threshold, such as initial node's energy, the average energy of whole cluster and the average energy of whole network.

LEACH Centralized with Chain protocol is a hierarchical protocol [20]. Where each node makes autonomous decisions that result in all the nodes being placed into clusters, this protocol offers no guarantee about the placement and/or number of cluster-head nodes. Since the clusters are adaptive, obtaining a poor clustering set-up during a given round will not greatly affect overall performance of LEACH. However, using a central control algorithm to form the clusters may produce better clusters by dispersing the cluster-head nodes throughout the network. Then a chain routing between cluster-heads is established to reduce the amount of nodes which communicate with the base station. Further improvement in energy cost for data gathering can be achieved if only one cluster-head transmits to base station and if each cluster-head transmits only to local neighbor cluster heads in the data fusion phase.

Virtual Backbone and ERPMT Techniques[21] used to increase lifetime of network .In VBS Method Instead of creating a single backbone we are creating a multiple overlapped backbones to work alternatively. This would increase the lifetime of WSN comparably. In ERPMT Method we divide the node energy into two ratios; one for the sensor node originated data and the other one is data relays from other sensors. The performance is evaluated by considering the QoS parameters like data rate, packet loss ratio, Bandwidth and SNR value.

Big Bang Big Crunch (BBBC) based metaheuristic algorithm [22] is proposed for the selection of Cluster Head in such a way so that its energy is used uniformly with delayed disintegration of network. The Big Bang and Big Crunch theory is introduced by Erol and Eksin, which is based upon the analogy of universe evolution where two phase of evolution is represented by expansion (Big Bang) & contraction (Big crunch). This algorithm has a low computational time and high convergence speed. In fact, the Big Bang phase dissipates energy and produces disorder and randomness. In the Big Crunch phase, randomly distributed particles are arranged into an order by way of a convergence operator "center of mass". The Big Bang–Big Crunch phases are followed alternatively until randomness within the search space during the Big Bang becomes smaller and smaller and finally leading to a solution.

K-Hop based algorithm [23] is proposed for formulate a huge clustering can effectively handle energy efficiency parameter. But in sensor networks some sensor nodes may interrupt to other cluster range. This function is called cluster overlapping problem. In traditional clustering algorithm each and every node will belong to only one cluster. But in this algorithm a single node may belong to more than one cluster. The key idea of this algorithm is that it considers bidirectional links. So this is better choice for a network which has huge number of sensor nodes.

PDORP-PEGASIS DSR (Dynamic Source Routing) optimized routing protocol[24], optimally utilizes proactive and reactive routing model. They have observed that extra energy is consumed by the nodes in the role of CH. Therefore the number of cluster heads should be optimized. Another challenge is to receive the data from trust worthy sensor nodes so that hidden or malicious nodes could not disrupt the route. The PDORP algorithm has decreased the communication distance between the nodes so that less energy is consumed. When a node becomes more aggressive at the time of data transfer, the other node is bound to receive a packet from it and in such a way it can cause damage to existing routes. The proposed solution creates a trust for the first time in each round on the basis of the parameters allocated to the nodes. After every round, the trust list is updated and after a certain number of rounds, the trust would not be checked to avoid time delays.

V COMPARISION OF FEW ROUTING PROTOCOLS

Table 1 compares the different energy efficient routing protocols with respect to their energy consumption.

Table1: Comparison of different routing Protocols.

SL No	Author	Year	Protocols	Energy Consumption
1	Heinzelman et.al	2000	LEACH	HIGH
2	Intanagonwiwat, C et al.	2000	Direct Diffusion	LIMITED
3	A.Manjeshwar et.al	2001	TEEN	HIGH
4	J. Kulik et.al	2002	SPIN	LIMITED
5	Lindsey et.al	2002	PEGASIS	MAXIMUM
6	O. Younis et.al	2004	HEED	LOW
7	Sangho Yi	2007	PEACH	LIMITED
8	A.Manjeshwar	2009	APTEEN	HIGH
9	Sinchan et.al	2010	GAF	LIMITED
10	Laiali Almazaydeh	2012	VGA	LOW
11	Dr.T.V.U kiran et.al	2013	VBERPMT	LOW
12	Archana et.al	2014	BBBC	LOW
13	Manikandam. K et.al	2015	KOCA	LOW

14	Gurbinder S B et.al	2016	PDORP	LOW

VI CONCLUSION

In this paper, we have reviewed many research papers which mainly concentrate on energy efficient routing protocols in WSN. It is difficult to compare them directly because each method is distinct with different underlying assumptions. But still energy efficient and network lifetime prolongation routing protocols are required.

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