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A Survey on Energy Efficient Routing in WSNs

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Abstract: *Devices that accesses the wireless channels are often portable and obtain energy from the local battery. This limits the amount of energy available to a node and affecting its lifetime. Protocol should therefore try to minimize energy dissipation to maximize node lifetime. Low energy routing protocols helps to extend the limited node energy and increases the lifespan of the whole system. So, the important challenge in the design of routing protocol is the key resource energy. In hierarchical routing architecture, sensor nodes self-configure themselves for the formation of cluster heads. In this way, hierarchical network structure optimize the network lifetime. In this paper, we have surveyed various routing protocols in Wireless Sensor Network (WSN).*

Keywords: *WSN, hierarchical routing,*

1. Introduction

Wireless Sensor Networks (WSNs) can be defined as a self-configured and infrastructure-less wireless networks to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to a main location or sink where the data can be observed and analyzed. A sink or base station acts like an interface between users and the network. One can retrieve required information from the network by injecting queries and gathering results from the sink. Typically a wireless sensor network contains hundreds of thousands of sensor nodes. The sensor nodes can communicate among themselves using radio signals [1].

A wireless sensor node is equipped with sensing and computing devices, radio transceivers and power components. The individual nodes in a wireless sensor network (WSN) are inherently resource constrained. They have limited processing speed, storage capacity, and communication bandwidth. After the sensor nodes are deployed, they are responsible for self-organizing an appropriate network infrastructure often with multi-hop communication with them [2]. Then the onboard sensors start collecting information of interest. Wireless sensor devices also respond to queries sent from a "control site" to perform specific instructions or provide sensing samples. The working mode of the sensor nodes may be either continuous or event driven.

1.1 Architecture of WSN

The most common architecture in WSN follows OSI Model. This architecture details are taken from [1]. We need five layers and along with it we have 3 cross layers planes as shown in figure 1.

1.1.1 Cross Layers

These layers are used to manage the network and to make the sensors work together in order to increase the overall efficiency of the network [2].

1.1.2 OSI Layers

- Physical Layer - It provides an interface to transmit bit stream over a physical medium. It is responsible for frequency selection, frequency generation, signal detection, modulation and encryption.
- Data Link Layer - It is responsible for multiplexing data streams, data frame detection, MAC and error control. It ensures reliability for point-to-point or point-to-multipoint communications.
- Network Layer - It is used for routing. The major challenges are in memory buffers and power saving. We have to deploy redundant sensors to achieve data aggregation and data fusion.
- Transport Layer – This layer is used to provide reliability and congestion avoidance. The protocols designed for these functions are either applied on upstream or downstream. They use different mechanism for loss detection and loss recovery. This is used when a system is organized to access other networks.
- Application Layer - It provides software for applications that converts data into understandable form and to send queries to collect information. It is responsible for traffic management.

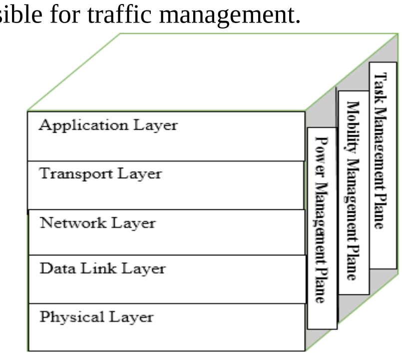

Figure 1: Architecture of WSN

1.2 Node Deployment

WSN is being applied everywhere in this world in different applications such as vehicle tracking, monitoring, earthquake observation, biomedical and health care etc. The effectiveness of WSN is influenced by the coverage of sensor deployment scheme as shown in figure 2. To achieve the collective information using routing WSN, coverage of deployment scheme becomes an essential part to make use of node deployment in order to get good connectivity and energy saving performance [3].

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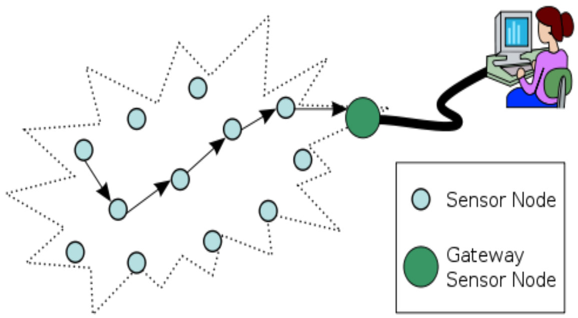

Figure 2: Nodes Deployment in WSN

There are two types of deployment found out through the researches done:-

1.2.1 Static deployment

In this, nodes do not change its position, it chooses the best location according to the optimization strategy and the location doesn't affect the lifetime in WSN. It includes the deterministic deployment and the randomly deployment [3].

In deterministic deployment, initially meshing of surveyed area is done and then the network node deployment is carried out. Algorithms used for it are Genetic algorithm, Watershed algorithm etc.

Randomly deployment is backed to the deployment of the robot. Sensor node needs to move to proper location and start working in order to increase sensor network's performance. Algorithms used for it are Virtual force algorithm, simulated annealing algorithm, Particle swarm optimization algorithm etc.

1.2.2 Dynamic deployment

In this, sensor nodes are initially located in the area randomly. These sensors change its position by using the knowledge of other sensors, if they are mobile. This leads to increase the coverage rate of sensors. Algorithms proposed for this problem are Artificial Bee Colony algorithm (ABC), Artificial Fish School Algorithm (AFSA) etc.

2. Literature Review

In [1], authors states that WANET (wireless ad hoc network) is expected to be deployed in a wide range of civil and military applications. In order to provide a better understanding of the research challenges of the energy-aware multicast routing, this article presents a systematical investigation of current state-of-the-art algorithms for these two classes of optimization problems. Taxonomy, comparison, and open research issues for each problem are also discussed, with an objective to inspire new research interests in this field. In paper [3], the author's first break down the energy consumption for the components of a typical sensor node, and discuss the main directions to energy conservation in WSNs. Then, the authors present a systematic and comprehensive taxonomy of the energy conservation schemes, which are subsequently discussed in depth. Special attention has been devoted to promising solutions which have not yet obtained a wide attention in the literature, such as techniques for energy efficient data acquisition. Finally the authors conclude the paper with insights for research directions about energy conservation in WSNs. In paper [4], authors analyze the design issues of sensor networks and present a classification and comparison of routing protocols. This comparison reveals the important features that need to be taken into consideration while designing and evaluating new routing protocols for sensor networks. In this paper [5], the authors present the challenges in the design of the energy efficient medium access control (MAC) protocols for the wireless sensor network. The authors describe several MAC protocols for the WSNs emphasizing their strength and weakness wherever possible. Finally, the authors discuss the future research directions in the MAC protocol design. Recently several medium access control protocols for the wireless sensor network have been proposed by the researchers. In [6], Authors described that to collect data from large-scale wireless sensor networks (WSNs) is a challenging issue and there are mainly two approaches to increase the efficiency: 1) by hierarchical routing based on node clustering and 2) by mobile elements (MEs). Since either method has pros and cons, this paper presents a hybrid approach, called node-density-based clustering and mobile collection (NDCMC), to combine the hierarchical routing and ME data collection in WSNs. In [7], the authors provided a detailed analysis on the relations between clustering and routing, and then propose a joint clustering and routing (JCR) protocol for reliable and efficient data collection in large-scale WSN. JCR adopts the back-off timer and gradient routing to generate connected and efficient inter-cluster topology with the constraint of maximum transmission range. The relations between clustering and routing in JCR are further exploited by theoretical and numerical analyses.

P. Nayak et. al. [8] proposed an energy efficient clustering algorithm for wireless sensor network using fuzzy logic concept. By selecting suitable fuzzy descriptors one Super Cluster Head is elected among the cluster heads who is the representative for delivering the message to a mobile base station. The idea of sink mobility along with the fuzzy logic increases the network life time dramatically. It is expected that it would be more useful in many practical applications like health care, agricultural field, disaster heat areas, military applications etc. Simulation result shows that the proposed protocol performs better than LEACH protocol in terms of first node dies, half nodes alive, last node dies, better stability and better network lifetime. In this paper [9], the authors have analyzed the problem of network lifetime optimization by balancing energy consumption at different CHs in a clustered WSN. Analysis revealed that the number of clusters and the number of MNs associated with each cluster have significant roles in the optimization of network lifetime by avoiding the energy hole problem. As a future extension of our work, the clustering strategy may be made more realistic by considering a three-dimensional environment. In this paper [10], a novel energy-efficient cluster selection algorithm for multi-level heterogeneous WSNs based on AP has been proposed, named as PECBA. Simulation results have shown that the PECBA

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has a better performance in balancing the energy consumption and prolonging the network lifetime compared with DEEC. This paper [11] proposed a fast, adaptive, and energy efficient data collection protocol in multi-channel-multi-path WSN. The protocol consists of two major phases. The first phase is the node-channel assignment that uses the graph coloring technique to resolve the issue of node overhearing and interference. The second phase is the scheduling and packet forwarding, in which a novel three-dimensional parallel iterative matching (3DPIM) algorithm is proposed to pair up sensor nodes in different time slots so as to enable collision-free multiple simultaneous data transmissions in every time slot. Simulation results show that our proposed protocol can achieve fast and energy-efficient data collection while being adaptive to the change of network traffic in WSN. The simulation results show that FAEM outperforms other existing data collection protocols in terms of lower end-to-end latency and packet loss. In this paper [12], the author proposed a new technique to resolve the problems due to limited energy sources. Using a quaternary transceiver (in the architecture on a sensor node), instead of a binary one, which will use the amplitude/phase, modulator/demodulator units to increase the number of bits transmitted per symbol. The system will reduce the consumption of energy in the transmission phase due to the increased bits transmitted per symbol. In this paper [13] the impact of selfish nodes on energy efficiency of cluster based routing algorithm of homogeneous WSNs is analyzed and studied. Packet throughput, network lifetime and packet retransmission attempts are the performance metrics used. The simulation results show that when the percentage of selfish nodes reaches the level of 75%, only 37% of packets reach the base station, network lifetime is reduced to 40% of rounds, and the number of packet retransmission attempts is close to 63%. In this paper [14], the authors have proposed network coding based clustering and routing protocol for sensor networks. The authors have tested our algorithms extensively and experimental results show that the proposed algorithm is much more efficient than LEACH with respect to network lifetime, energy consumption, packet delivery ratio and delay. The design issues of resource constrained sensor network include the use of efficient routing protocol which have significant impact on the energy dissipation of the network has been discussed. In this paper [15], the authors propose a multi-hop intra-cluster technique in uneven clustering, to minimizing the hot spot and intra-cluster communication problems. The BS divides the whole network into three types of unequal fixed square shaped Grids (clusters). In each cluster, the BS selects a Cluster Head (CH) based on number of hop or neighbour nodes and residual energy of the sensor nodes. Our proposed scheme uses both (centralized and distributed) methods for efficient routing in the network. The proposed method is semi-centralized, so the BS divides the entire network into unequal clusters and selects CH based on residual energy and maximum number of neighbour nodes, which saves the energy of sensor nodes. From the simulation results, it is clear that this scheme is energy efficient and it has less hot spot problem because it sustains up to more than 1000 round which is far better than the existing protocols. In our future work, the authors will concentrate on fully distributed clustering and try to simulate some other parameters for performance comparison.

3. Clustering in Wireless Sensor Network

Clustering is a key method used to decrease energy consumption in wireless sensor network. It also increases the scalability and lifetime of the network. Cluster head work as a fusion point for data aggregation, to reduce the amount of data transmitted to the base station. Clustering can be done in both homogenous and heterogeneous sensor network. The homogenous networks are those networks whose nodes have identical hardware and battery power. When static clustering (for the entire lifetime of the network one elected cluster head serves) is done in homogenous network the cluster head node will be over loaded with the data aggregation, network coordination and processing. Because of these reasons the cluster head node dies soon which affect the life time of the network. On the contrary, the heterogeneous sensor networks consist of two or more different type of nodes with varied battery power and hardware. The motivation for heterogeneous network is that the extra energy can be implanted in few nodes, thereby reducing the cost of the rest of the network [9].

- *LEACH (Low Energy Adaptive Clustering Hierarchy)*

LEACH [10] is one of the most popular clustering algorithms. The main idea behind leach is to form clusters based upon the signal strength of the sensors. Some of the nodes are randomly chosen as the cluster heads(CH) and a node is assigned to the CH based upon the signal strength received by that node from the CH. CHs have to do a lot more work than the normal nodes, hence they dissipate a lot more energy and may die quickly. In order to maintain a stable network, CHs keep on rotating, in every round. So, a node which had become CH may not get an opportunity to become CH again before a set interval of time. A node can become the cluster head for the current round if its value is less than the threshold T(n) where T(n) is given by –

$$T(s) = \begin{cases} \dfrac{p}{1 - p\left(r \bmod \dfrac{1}{p}\right)} & \text{...........} if \;\; s \; \varepsilon \; G \\ 0 \text{..................................} otherwise \end{cases} \quad \text{……………..(1)}$$

P is the percentage of cluster heads, r is the r^{th} round, G is the set of nodes which are not cluster heads in the last 1/P rounds.

Advantages:

• LEACH is completely distributed. LEACH does not require the control information from the base station, and the nodes do not require knowledge of the global network in order for LEACH to operate.

• LEACH reduces communication energy by 8 times as compare to direct transmission and minimum transmission energy routing.

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- *SEP (Stable Election Protocol)*

SEP (Stable Election Protocol) is proposed where sensor node are in a heterogeneous two-level hierarchical network. A node can independently elects itself as a cluster head based on its initial energy relative to that of other nodes. Nodes will have different reference value of probabilities which are given by equation (2). SEP protocol in heterogeneous network provides enhanced results than LEACH protocol [11].

$$p_i = \begin{cases} \frac{p_{opt}}{(1+a.m)} \text{.........if } s_i \text{ is the normal node} \\ \frac{p_{opt}(1+a)}{(1+a.m)} \text{.........if } s_i \text{ is the advanced node} \end{cases}$$

………………………(2)

Advantage:

• SEP does not require any global knowledge of energy at every election round.

Limitations:

• The drawback SEP method is that the election of the cluster heads among the two type of nodes is not dynamic, which results that the nodes that are far away from the powerful nodes will die first.

- *TEEN (Threshold Sensitive Energy Efficient Network)*

TEEN is also one of the hierarchical protocols. All the nodes report their sensed data to their sensor. The CH sends the aggregated information to higher level of CH until the information reaches to the sink. Thus, the architecture of TEEN is based upon the hierarchical grouping where closer nodes form clusters and this process goes on second level until the sink is reached (figure 3). It uses data-centric technique with hierarchical policy. TEEN is suitable for time critical sensing applications. Also message transmission takes more power than data sensing, so that energy consumption in TEEN protocol is less than the hierarchical protocol in proactive networks. However it is not suitable applications where periodic reports needed because user may not get any data at all if thresholds are not reached [11].

The main features of this scheme are as follows:

1. Time critical data reaches the user almost instantaneously. So, this scheme is eminently suited for time critical data sensing applications.
2. Message transmission consumes much more energy than data sensing. So, even though the nodes sense continuously, the energy consumption in this scheme can potentially be much less than in the proactive network, because data transmission is done less frequently.
3. The soft threshold can be varied, depending on the criticality of the sensed attribute and the target application.
4. A smaller value of the soft threshold gives a more accurate picture of the network, at the expense of increased energy consumption. Thus, the user can control the trade-off between energy efficiency and accuracy.
5. At every cluster change time, the attributes are broadcast afresh and so, the user can change them as required.

The main drawback of this scheme is that, if the thresholds are not reached, the nodes will never communicate; the user will not get any data from the network at all and will not come to know even if all the nodes die. Thus, this scheme is not well suited for applications where the user needs to get data on a regular basis. Another possible problem with this scheme is that a practical implementation would have to ensure that there are no collisions in the cluster.

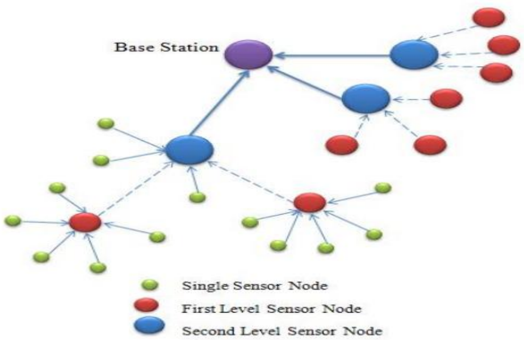

Figure 3: Clustering in TEEN protocol

- *DEEC (Distributed Energy Efficient Clustering)*

DEEC (Distributed Energy Efficient Clustering) is a heterogeneous clustering protocol in which cluster head is selected on the basis of probability of ratio of remaining energy of the node and average energy of the network. DEEC protocol is more competent than the SEP protocol because it does not fit for networks having more than two levels of energy [12]. In DEEC [12] protocol all nodes use the initial and residual energy level to define the cluster heads. DEEC estimate the ideal value of network lifetime to compute the reference energy that each node should expend during each round. In a two-level heterogeneous network, where we have two categories of nodes, m, N advanced nodes with initial energy equal to Eo.(1+a) and (1 − m).N normal nodes, where the initial energy is equal to Eo. Where a and m are two variable which control the nodes percentage types (advanced or normal) and the total initial energy in the network E_{total}.

•The value of Total Energy is given as

$$E_{total} = N.\ (1-m).E_o+N.m.E_o.(1+a) \quad (3)$$

•The average energy of rth round is set as follows

$$E(r) = (1/N)\ E_{total}\ (1-R) \quad (4)$$

R denotes the total rounds of the network lifetime and is defined as

$$R= E_{total} / E_{Round} \quad (5)$$

E_{Round} is the total energy dissipated in the network during a round, is equal to:

$$E_{Round} = L\ (2NE_{elec} + NE_{DA} + kE_{mp}d^4_{\ toBS} + NE_{fs}d^2_{\ toCH}) \quad (6)$$

k: number of clusters

E_{DA}: data aggregation cost expended in the cluster heads

dtoBS : average distance between the cluster head and the base station

dtoCH: average distance between the cluster members and the cluster head.

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Advantages:
• DEEC does not require any global knowledge of energy at every election round.
• Unlike SEP and LEACH DEEC can perform well in multi-level Heterogeneous wireless network.
Limitations:
• Advanced nodes always penalize in the DEEC, particularly when their residual energy reduced and become in the range of the normal nodes. In this position, the advanced nodes die rapidly than the other nodes.

4. Conclusion and Future Work

In this paper, we have surveyed WSN architecture, node deployment and various routing protocols of WSN. Sensor network nodes are limited with respect to energy supply, restricted computational capacity and communication bandwidth. Most of the attention, however, has been given to the routing protocols since they might differ depending on the application and network architecture. To prolong the lifetime of the sensor nodes, designing efficient routing protocols is critical. Even though sensor networks are primarily designed for monitoring and reporting events, since they are application dependent, a single routing protocol cannot be efficient for sensor networks across all applications. In future, we may propose a routing protocol which will be reliable and energy efficient.

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