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Energy Efficiency Enhancement Methods for Mobile Wireless Sensor Networks: A Survey

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Abstract: *Wireless Sensor Network consists of several resource constrained sensor nodes which are expected to operate autonomously for a long time, e.g., for months or even years. Due to limited availability of power supply, a major concern in WSN is energy conservation. During the earlier stages of the development of WSN, nodes were static and communication between any two nodes was done by using a multi-hop path. A lot of research was done and literature was available about various energy conservation schemes of static WSN. Later mobility is introduced, and it has been considered as an alternative solution for energy-efficient data collection in wireless sensor networks. Several issues regarding connectivity can be solved by introducing mobility in WSN. In this paper, we present mobility based energy conservation schemes, which can be classified depending on the nature of the mobile element, i.e. a mobile sink or a mobile relay, the energy efficient data collection methods like cross layer approaches, routing techniques and clustering schemes in Mobile Wireless Sensor Networks (MWSNs). A comparative analysis of the various energy efficient protocols is also done.*
Key Words: *Energy Efficiency, Mobile Wireless sensor Networks, Mobile Sink, Mobile Relay, Cross Layer, Routing, Clustering*

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I. Introduction

In the early stages of the development of WSN, nodes were static and communication between any two nodes was done by using a multi-hop path. Recently, mobility has been considered as an alternative solution for energy-efficient data collection in wireless sensor networks. There are different ways to accomplish the mobility of sensor nodes [1]. Instead of making each sensor node mobile, mobility can be limited to special nodes which are less energy constrained than the ordinary ones. Sensors can be placed on elements which are mobile of their own (e.g. vehicles or animals etc.). If all sensors are put into mobile elements, then all the nodes in the network are mobile. In another case only a limited number of special nodes can be placed on mobile elements, while the other sensors are stationary. In both these cases there is no additional energy consumption overhead due to mobility, but during the network design phase the mobility pattern of mobile elements has to be considered.

Several issues regarding connectivity can be solved by introducing mobility in wireless sensor networks. Mobility in wireless sensor networks (WSNs) can influence the network operation. The several parameters that are to be considered which affect the network performance are application diversity, network topography (topology), network connectivity and deployed node(s) or sensed event(s) location estimation. Mobility is also a serious issue if introduced in WSNs operations. It has advantages and disadvantages on different levels of the network operation. The advantages of introducing mobility to the network are as follows [2]. Introducing mobility to the network can enlarge the scope of applications to implement WSNs. Examples of applications are social activity monitoring, cattle monitoring, etc [3]. Since WSNs transfer their data in a multi-hop fashion, mobility can enhance the network operation by changing the location of the nodes leading to create different links to the destination required. If mobility is limited to special nodes, e.g., sink node(s), the stationary nodes then can be relieved in terms of links generated to the destination node. The sink node(s) can roam around through stationary nodes and gather the information sensed by sensor nodes. Mobile sink nodes can also enhance the network connectivity by minimizing the congestion that can happen during network traffic flow.

There are challenges to the operation of the deployed network due to mobility. If mobility is limited to special node(s), then adequate plan and calculations are required to estimate the optimum number and paths for the special node(s) to cover the deployed network [4]. If mobility is random, that leads to rapid changes in the network topology. It is also to be noted that quick variations in topology affects the connectivity of the nodes. Topology changes have an effect on the routing operation as the links need to be rebuilt frequently, which causes increased energy consumption of the nodes. Mobility affects the MAC protocol operation because the connectivity can suffer from broken connections due to the transmission range of the wireless interface. The location of the sensor node(s) in random mobility is an important attribute because the sensed event is attached to the location of the sensor node. In such cases, a localization mechanism becomes a frequent operation leading to an increment in node(s) energy consumption [5].

Sensor nodes in a WSN are examples of resource constrained devices, because the processing power, memory and energy supply of sensor nodes are limited [6]. Mobility is also useful for reducing energy consumption. Packets coming from sensor nodes traverse the network towards the sink by following a multi-hop path. When the sink is static, a few paths can be more added than others, depending on the network topology and packet generation rates at sources. The batteries of the nodes near the sink deplete quicker than other nodes due to the data traffic concentrating towards the sink [7]. If a designated mobile device is given the task for data collection as mobile data collector, the traffic flow can be altered. Other nodes wait for the passage of the mobile device and route messages towards it, so that the communication with mobile data collector takes place in directly or with a limited multi-hop traversal. This helps ordinary nodes for saving energy.

The rest of the paper is organized as follows. The reasons for the energy wastage are given in section 2. Classification of energy efficient methods for Mobile WSNs and recently published work under these categories are described in section 3. Section 4 shows performance analysis of various protocols. Then the conclusion of the paper is given in section 5.

II. Reasons for Energy Wastage

Identifying the different ways for energy wastage is the first step towards energy conservation. The following are the main reasons for energy wastage.

- Distance: Energy will be wasted, if the path chosen for communication is not the shortest one.
- Control packet overhead: The control information is used during transmission of data. Using more number of control packets will cause energy wastage.
- Collision: When a node receives more than one packet at the same time, there is a possibility of collision among these packets. All packets which are collided have to be discarded and the retransmissions of these packets are required. This leads to energy wastage.
- Overhearing: When a sender transmits a packet, all nodes in its transmission range receive this packet even if they are not the intended destination. Thus, energy is wasted when a node receives packets that are sent to other nodes.
- Idle listening: This happens when a node is listening to an idle channel in order to receive packets which may come through that channel. This is another reason for energy wastage.
- Interference*:* Each node located between transmission range and interference range receives a packet but cannot decode it.

III. Energy Efficient Methods for MWSNs

Research Work available about mobile sensor networks is limited. There are number of energy efficient techniques proposed in the literature for Mobile sensor networks. In this paper we focus on different categories of energy efficient data collection methods which are applied to Mobile Wireless Sensor Networks (MWSNs). The various methods are sensor node mobility based methods, cross layer approaches, routing techniques and clustering schemes. The classification of the energy efficient methods for the mobile wireless sensor networks is shown in figure 1.

3.1 Mobile Sink/Relay Based Methods

Sensor node mobility can be divided into two categories: limited mobility where there are specific nodes that roam around the network to perform an exclusive task (e.g., mobile sink nodes) and random mobility where the nodes (sensor nodes) roam around the area of deployment to collect the data needed for the application [8]. Mobility-based energy conservation schemes can be classified depending on the nature of the mobile element, i.e. a mobile sink (MS) or a mobile relay (MR) [9].

3.1.1 Mobile Sink Based Methods

Nodes closer to the sink are subject to premature energy depletion because they have to relay more packets even when techniques for energy conservation are applied. Mobile sinks can solve this problem by providing load-balanced data delivery/collection and achieve uniform-energy consumption across the network. SPAT (Set Packing Algorithm and TSP) is proposed in [10]. SPAT ensures the mobile sink to collect data from all sensor nodes. Data is gathered with minimum energy. It also ensures fairness by equally collecting data from all the sensor nodes.

In [11], Ring Routing, a hierarchical routing protocol for wireless sensor networks with a mobile sink is presented. The protocol imposes three roles on sensor nodes which are ring node, regular node and anchor node. Ring nodes form a ring structure which is a closed loop of single-node-width. The basis of Ring Routing is (i) advertisement of sink position to the ring, (ii) regular nodes obtaining the sink position information from the ring whenever necessary, and (iii) nodes disseminating their data via the anchor nodes, which serve as intermediary agents connecting the sink to the network. The sensor nodes can change these roles during the operation of the WSN.

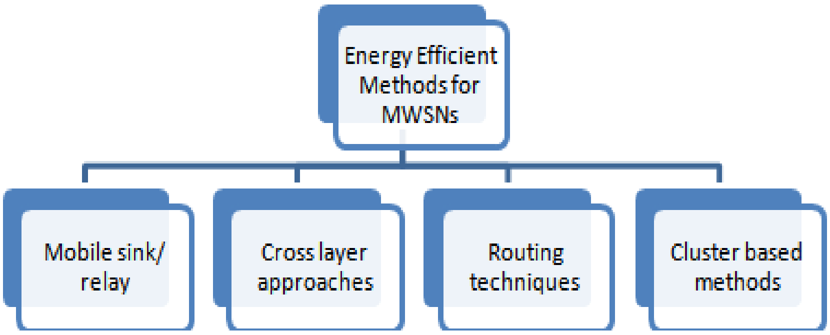

Figure 1: Energy Efficient Methods for MWSNs

Guangqian Xie *et al.* [12] proposed a tour-planning algorithm for the mobile sink to find shortest route by avoiding obstacles. The concepts of minimum spanning tree and TSP are combined to find the obstacle avoiding algorithm. Mobile sink starts the data-gathering route periodically from the starting site, then directly collects data from the cluster heads in a single-hop range, and finally returns to the starting site.

Table 1: Comparison of Energy Efficient Mobile Sink Based Methods

Author	Year	Contribution	Objective	Scope for further work
H Nakayama *et al.* [10]	2011	SPAT (Set Packing Algorithm and TSP)	Less energy consumption, fairness in data gathering.	Reducing data gathering time, using multiple sinks are to be considered
Can Tunca *et al.*[11]	2015	Ring Routing protocol to minimize the data reporting delays considering the various mobility parameters of the mobile sink	Energy efficiency, Increased network lifetime.	Multiple mobile sinks, data reporting delay to be considered
Guangqian Xie *et al.* [12]	2016	Obstacle avoiding algorithm with the concepts of minimum spanning tree and TSP	Increased network lifetime	Reduction of control overhead
J. Wang *et al.* [13]	2017	Energy-efficient cluster-based dynamic routes adjustment approach (EECDRA)	Increased network lifetime	Flooding of update message to be addressed

An energy-efficient cluster-based dynamic routes adjustment approach (EECDRA) which aims to minimize the routes reconstruction cost of the sensor nodes while maintaining nearly optimal routes to the latest location of the mobile sinks is presented in [13]. The network is divided into several equal clusters with one selected cluster head within each cluster. Cluster heads are selected based on the residual energy of each node. Route reconstruction process is managed using already set rules and a limited number of nodes are to readjust their data delivery routes toward the mobile sinks. The wireless sensor network lifetime is prolonged with optimal routes.

3.1.2 Mobile Relay Based Approaches

Optimal Mobile Relay Configuration (OMRC) in data-intensive WSNs is proposed in [14]. The total energy consumed by both mobility of relays and wireless transmissions is minimized which is in contrast to existing mobility approaches that only minimize the transmission energy consumption. The tradeoff in energy consumption between mobility and transmission is exploited by configuring the positions of mobile relays. It does not require complex motion planning of mobile nodes, so it can be implemented on a number of low-cost mobile sensor platforms. The proposed framework consists of three main algorithms. The first algorithm computes an optimal routing tree assuming no nodes can move. The second algorithm improves the topology of the routing tree by greedily adding new nodes exploiting mobility of the newly added nodes. The third algorithm improves the routing tree by relocating its nodes without changing its topology. This iterative algorithm converges on the optimal position for each node given the constraint that the routing tree topology does not change.

Table 2: Comparison of Energy Efficient Mobile Relay Based Methods

Author	Year	Contribution	Objective	Scope for further work
Fatme El-Moukaddem *et al.* [14]	2013	Optimal Mobile Relay Configuration (OMRC) in data-intensive WSNs	Energy consumed by both mobility of relays and wireless transmissions is minimized.	Handling constraints like mobility restrictions.
Hamid Mahboubi *et al.*[15]	2017	Energy-Efficient Target-Tracking Strategy to find optimal route with obstacles.	Energy efficient, reduced execution time.	Information exchange to be reduced, Reliability
Djamel Djenouri *et al.* [16]	2017	Energy-aware deployment model of relay nodes	Improved the network life time	Energy requirement in high data rate applications to be addressed.

In [15], an energy-efficient strategy is presented for tracking a moving target in an obstacles filled environment with a network of mobile sensors. The field is first divided into a grid and is then converted to a graph. The proposed technique with the help of shortest path algorithm searches for near-optimal locations for the sensors in different time instants to route information from the target to destination.

Djamel Djenouri *et al.* [16] proposed an energy-aware deployment model of relay nodes (RNs) to solve the problem of communication coverage for sustainable data forwarding in wireless sensor networks. A general environment has been considered, where two types of sensor nodes (SNs), energy rich nodes (ERNs) vs. energy limited nodes (ELNs) may be deployed. ELN is used for data reading while ERN is used for coverage. The problem has been reduced to finding the minimum weighted connected dominating set (MWCDS) in a vertex weighted graph. An integer linear program (ILP) has been derived as an optimal solution for the problem in terms of the number of RNs to be added.

3.2 Cross Layer Approaches

An adaptive and cross-layer framework for reliable and energy-efficient data collection in WSNs based on the IEEE 802.15.4/ZigBee standards was proposed in [17]. The framework involves an energy-aware adaptation module that captures the application's reliability requirements, and autonomously configures the MAC layer based on the network topology and the traffic conditions in order to minimize the power consumption. ADaptive Access Parameters Tuning (ADAPT), that can effectively meet the application-specific reliability under a wide range of operating conditions, for both single-hop and multi-hop networking scenarios.

Table 3: Comparison of Energy Efficient Cross Layer Approaches for MWSNs

Author	Year	Contribution	Objective	Scope for further work
Mario Di Francesco *et al.* [17]	2011	Cross layer energy-aware adaptation algorithm ADAPT (ADaptive Access Parameters Tuning)	Reliability and reduced power consumption.	Delay is to be addressed
Hsueh-Wen Tseng *et al*.[18]	2011	cross-layer detection and allocation (CL-DNA) scheme to solve the hidden device problem	Detection of hidden devices, reduces the power consumption of the network.	Control packet overhead to be minimized
Suleyman Cakici *et al.* [19]	2014	Cross-layer routing protocol (MACRO)	End-to-end delay, route reliability, reduced power consumption	Packet delivery ratio to be improved
Marwan Al-Jemeli *et al.* [20]	2015	Cross-layer operation model, which integrates four layers	Reduces the network's energy consumption, improves packet delivery ratio.	Selection of shortest routes to be considered.

A cross-layer detection and allocation (CL-DNA) scheme to solve the hidden device problem (HDP) in IEEE 802.15.4 is presented in [18]. In wireless networks, there is no guarantee that a device will hear signals from other devices. If signals transmitted from device A to device C cannot be sensed by device B, device B assumes that the channel is clear. As a result, device B might transmit data to device C at the same time. The overlapped signals cause the failure of device C to recognize either of the signals sent by device A or B. This is called the hidden device (or hidden terminal) problem. The HDP increases the chance of transmission failures which leads to retransmission procedures. As a result, the power consumption is high and the battery life of the sensors is shortened. The CL-DNA scheme reduces the power consumption of the network.

Suleyman *et al.* [19] proposed a cross-layer routing protocol (MACRO) for increasing packet transfer reliability in Mobile Sensor Networks based on a new cross-layer interaction approach. It primarily exploits the idea of interaction among the five layers application, transport, network, MAC and physical layers in one protocol. The protocol specifically designed for mobile networks, not only finding the available routes but also ensuring the route reliability suffering from topology changes. The MACRO tries to sustain the reliability of a route by adapting possible topology changes and channel conditions such as node failures and serious congestions. Although its primary goal is to increase end-to-end route reliability, it also tries to find the best routes that will experience minimal end-to-end delay and power consumption.

A cross-layer operation model, which integrates four layers (application (node location), network (routing), medium access control (MAC) and physical layers) in the network operation is proposed in [20]. The location of the mobile nodes is included in the routing operation after the route discovery process. The location information is then utilized by the MAC layer transmission power control to adjust the transmission range of the node. This is used to minimize the power used by the network interface to reduce the energy consumption of the node(s). The model deploys a mechanism to minimize the neighbor discovery broadcasts to the active routes only. Reducing control packet broadcasts between the nodes reduces the network's energy consumption. It also maintains a good packet delivery ratio.

3.3 Routing Techniques

The routing protocol should construct stable and efficient path between a source destination pair in the path discovery phase and maintain the constructed path in the maintenance phase adaptively. Most of the proposed routing protocols for WSN do not consider both mobile sensor nodes and mobile BS. Research work available about mobile sensor networks is limited. When the mobility is introduced in the sensor nodes, the topology becomes very dynamic and the task of finding out the stable routes (i.e., reliable and durable) under such circumstances becomes challenging. Moreover, it is difficult for the WSN nodes to cope up with the overhead of maintaining routing tables mainly due to memory constraints.

Table 4: Comparison of Energy Efficient Routing Techniques for MWSNs

Author	Year	Contribution	Objective	Scope for further work
L. Karim *et al.* [21]	2012	Location-aware and fault tolerant clustering protocol for mobile WSN (LFCP-MWSN)	Energy efficient and reliable.	Mobility of a cluster head (CH) out of its cluster is to be addressed.
Hiren Kumar Deva Sarma *et al.* [22]	2014	Energy-Efficient and Reliable Routing protocol for mobile wireless sensor network (E^2R^2)	Energy efficient and reliable.	During high data rate, throughput is to be improved.
Attea, B *et al.* [23]	2015	Non-Dominated Sorting Genetic Algorithm-II (NSGAII)	Coverage optimization, Increased network lifetime	Directional coverage problems and detection accuracy can be considered.
Tom Hayes *et al.* [24]	2016	Location aware sensor routing (LASeR)	High packet delivery ratio, reduced overhead, reduced energy consumption	End to end delay.

A location-aware and fault tolerant clustering protocol for mobile WSN (LFCP-MWSN) is is presented in [21]. LFCP-MWSN follows a simple range free approach to localize sensor nodes during cluster formation and every time a sensor moves into another cluster. Initially all sensors have the same energy and once a node is selected as a CH, it remains in the same cluster. A node in each cluster is equipped with GPS and work only for localization. This node is known as an anchors node. Sensors are heterogeneous in terms of their roles since they work as anchor nodes, cluster heads, and cluster members. In the steady phase, CHs assign timeslots to the member nodes using TDMA scheme. Member nodes of a cluster transmit data, receive acknowledgement from CH and count their movement inside and outside of the cluster at the allocated timeslot. Thus, no extra timeslot is required to calculate nodes mobility. However, one extra timeslot is assigned in each frame to allow a mobile node to send JOIN REQUEST message to the CH of a new cluster when that node moves out of a cluster. Keeping the updated location information of mobile nodes is a great challenge. In the LFCP-MWSN protocol, sensors are localised at the cluster formation phase and whenever a node moves out of a cluster to join a new cluster. LFCP-MWSN uses special packets, which are sent by member nodes of a cluster to CH when member nodes have no sensed event to send to CH but these special packets allow the LFCP-MWSN protocol to detect the mobility and failure of member nodes of a cluster. LFCP-MWSN protocol is energy efficient and reliable.

In [22], an energy-efficient routing protocol, which is called Energy-Efficient and Reliable Routing protocol for mobile wireless sensor network (E^2R^2), is proposed. The proposed protocol is hierarchical and cluster based. Each cluster consists of one cluster head (CH) node, two deputy CH nodes, and some ordinary sensor nodes. The mobility of the nodes is considered while routing decisions are made. The protocol is reliable in terms of data delivery at the base station (BS). The objective behind such routing is that the data packets need to move through suitable routes in spite of node mobility and in presence of subsequent link failures. The protocol is reliable in terms of data delivery at the base station (BS). Mobility in sensor nodes and in the BS is considered in this paper. The re clustering time and energy requirements have been minimized by introducing the concept of CH panel. At the initial stage of the protocol, the BS selects a set of probable CH nodes and forms the CH panel. Considering the reliability aspect of the protocol, it puts best effort to ensure a specified throughput level at the BS. Depending on the topology of the network, the data transmission from the CH node to the BS is carried out either directly or in multi hop fashion. Moreover, alternate paths are used for data transmission between a CH node and the BS. The notion of deputy cluster head (DCH) is used, which increases the lifetime of the network. The protocol ensures reliability in terms of data delivery at the BS; this is achieved through the use of multiple routes and switching of the routes as decided by the BS.

The Non-Dominated Sorting Genetic Algorithm-II (NSGAII), a cluster-based routing protocol is proposed in [23], finds solution to coverage as well as maximization of network lifetime. The location of a given number of mobile sensors needs to be re-decided such that the sensed data from the detected targets can be routed more efficiently to the sink and thus increasing the network lifetime. Each round of the proposed NSGA-II based routing protocol creates a set of solutions in which the sink can pick up and distribute the one with high coverage to form the clustered routes.

Location aware sensor routing (LASeR)[24] addresses the high reliability and low latency requirements of mobile wireless sensor networks (MWSNs). The protocol uses location information to maintain a gradient field even in highly mobile environments, while reducing the routing overhead. This allows the protocol to utilize a blind forwarding technique to propagate packets towards the sink. LASeR takes advantage of the available location information in order to route packets. LASeR uses blind forwarding to transmit packets, which means that the decision to forward a packet is made by the receiving node, rather than the transmitting node. Hence, when a node receives a packet it stores it in a queue until its next opportunity to transmit.

3.4 Cluster Based Methods

Mobility can effectively extend the clustering of nodes and balance the energy consumption, thus reducing the chance of energy hot spots. The data collection in WSNs with mobile element (ME)s was surveyed in [25]. Due to the mobility of a ME, path breakage may often occur during data transmission. As a consequence, mobility support needs to be explicitly accounted for to deliver streaming data in WSNs with MEs.

Table 5: Comparison of Energy Efficient Clustering Methods for MWSNs

Author	Year	Contribution	Objective	Scope for further work
S A B.Awwad *et al.* [26]	2011	Cluster based routing protocol for mobile sensor nodes (CBR-Mobile)	High packet delivery ratio	Control overhead to be reduced.
S. Deng *et al.* [27]	2011	Mobility-based clustering (MBC) protocol	Reduced packet loss.	Energy consumption, control overhead to be reduced.
Ruonan Zhang *et al.* [28]	2015	Node Density based Clustering and Mobile Collection (NDCMC)	Data collection from large-scale wireless sensor networks (WSNs) with increased energy efficiency	Scheduling the traveling paths of MEs, network partitioning and ME data collection
L Cheng *et al.* [29]	2015	Seamless streaming data delivery (SSDD) protocol, Inter cluster route construction algorithm	Improves the scalability and energy efficiency of inter cluster communication	Route maintenance overhead during the data transmission phase to be reduced

Cluster based routing protocol for mobile sensor nodes (CBR-Mobile) provide cluster based routing to support mobility of sensor nodes [26]. The sensor node utilizes its assigned timeslot(s) to send data. It will switch to sleep mode after data has been sent until the next scheduled timeslot. It will also go back to sleep mode, if it does not utilize its assigned timeslot. Some time slots are unused because these are occupied by sensor nodes which have no data to send or these nodes had gone out of the cluster. The CBR-Mobile uses adaptive scheduling algorithm which supports reassigning of time slots to sensor nodes that are awake or have recently moved into the cluster.

S. Deng *et al.* proposed a mobility-based clustering (MBC) protocol [27] for wireless sensor networks with mobile nodes. In MBC a sensor node elects itself as a cluster-head based on its residual energy and mobility. Each non-cluster-head node is allocated a timeslot for data transmission in ascending order in a time division multiple address (TDMA) schedule based on the estimated connection time. In the steady-state phase, a sensor node transmits its sensed data in its timeslot and broadcasts a joint request message to join in a new cluster and avoid more packet loss when it has lost or is going to lose its connection with its cluster head. MBC protocol can reduce the packet loss and energy consumption.

In [28], a Node Density based Clustering and Mobile Collection (NDCMC) approach which combines the hierarchical routing and ME data collection in WSNs is presented. NDCMC is proposed to collect data from large-scale wireless sensor networks (WSNs), with increased efficiency. CH selection scheme based on the node density is included because nodes which are surrounded by more deployed nodes are more likely to become CH. ME collects data from CHs, which are gathered from cluster members. Thus, the efficiency of both intra-cluster routing and ME data collection is improved. A low-complexity traveling track planning algorithm is designed for an ME to pass by all CHs. In addition, a simple Random Clustering and Mobile Collection (RCMC) scheme is introduced by which a number of CHs are selected randomly in a WSN.

A seamless streaming data delivery (SSDD) protocol for multi-hop cluster-based WSNs with MEs was proposed in [29] with focus on supporting mobility for continuous data delivery in hierarchical networks. A scalable and energy-efficient inter cluster route construction algorithm in multi-hop cluster-based WSNs is designed to improve the performance of inter cluster communication during route discovery. To support the mobility of MEs, a cross-cluster handover mechanism and a path redirection scheme is proposed so that SSDD maintains the end-to-end (E2E) connectivity between a source node and a ME efficiently, i.e., by avoiding the constant broadcasting of the location information as the ME moves across multiple clusters. It is demonstrated that the proposed SSDD protocol has high energy efficiency and low data delivery latency.

IV. Performance Analysis of Various Energy Efficient Protocols

Comparative analysis of various energy efficient protocols is given in the following table. The comparison is done based on mobility, approach, layers involved, type of routing and fault tolerance characteristics.

Table 6: Comparison of Various Energy Efficient Protocols for MWSNs

Protocol	Mobility	Approach	Layers involved	Type of routing	Fault Tolerance
ADAPT	Yes	Cross layer	MAC	NA	NA
CL-DNA	Yes	Cross layer	Physical MAC	NA	NA
MACRO	Yes	Cross layer, Routing	Application, Transport, Network, MAC, Physical	NA	NA
CLNOM	Yes	Cross Layer	Application, Network, MAC Physical	NA	NA
LFCP-MWSN	Yes	Cluster based Routing	NA	NA	Yes
E^2R^2	Yes	Cluster based Routing	NA	Hierarchical routing	Yes
NSGAII	Yes	Routing	NA	NA	NA
LASeR	Yes	Routing	NA	Location aware routing	NA
CBR-Mobile	Yes	Cluster based Routing	NA	Cluster based routing	NA
MBC	Yes	Cluster based Routing	NA	Cluster based routing	NA
NDCMC	Yes	Cluster based Routing	NA	Hierarchical routing	NA
SSDD	Yes	Cluster based	NA	Hierarchical routing	NA

V. Conclusion

Sensor nodes in a WSN are examples of resource constrained devices, because the processing power, memory and energy supply of sensor nodes are limited. In the earlier stages of development of WSN, nodes were static, but later mobility was introduced. Mobility in wireless sensor networks (WSNs) can influence the network operation. It is to be noted that quick variations in topology affects the connectivity of the nodes. Topology changes have an effect on the routing operation as the links need to be rebuilt frequently, which causes increased energy consumption of the nodes. So it is very important to find solution to the problem of how to reduce the energy consumption of sensor nodes. We surveyed the recent advances in the development of energy-efficient solutions for MWSNs. We introduced a new taxonomy of energy conservation schemes based on mobility. Mobility based energy conservation schemes like mobile sink based and mobile relay based methods are presented in this paper. Various energy efficient data collection methods like cross layer approaches, routing techniques and clustering schemes applied in Mobile Wireless Sensor Networks (MWSNs) are also discussed.

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