VOL. 13, NO. 14, JULY 2018 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

A REVIEW ON ENERGY OPTIMIZATION TECHNIQUES USED IN WSN

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ABSTRACT

From decades the issue of energy optimization in Wireless sensor networks (WSNs) has been resolved using various technologies ranging from physical modification to the network nodes or sensors to the software solutions such as changes to routing protocol, dealing with various optimizations on the network parameters and so on. There were many protocols proposed to increase the lifetime of the sensor node and with this Wireless energy transfer (WET) has been considered a favorable technique for extending the lifetime of WSN. However energy conservation on the network is also achievable if we compress the data flow in the network, reduce communication overheads and wireless energy transfer.

Keyword: energy optimization, wireless energy transfer, routing protocol, node lifetime, communication overheads.

INTRODUCTION

A wireless sensor network (WSN) is usually defined set of collaborative sensors that are deployed to sense various parameters of the geographical area such as temperature, humidity, pressure and so on. These sensors comprehend the data which their neighbors and interpret if for the purpose of their deployment. The important components of the WSN are sensors and these sensors compose of a sensing element, processing element and the power source. The power source and memory of the sensors are always the points of concern as they are minimalistic in nature and critical for usage. Thus they have to be preserved to make the sensor networks accurately. When we compare memory and power source, we have to leverage more on power source as they are the core critical element of the network. There is enormous amount of research done to conserve energy in the sensor networks and these works are broadly classified into:

a) Developing a protocol to optimize energy. LEACH, PEGASIS, Low energy adhoc sensors. Delay aware routing protocol, TDMA protocols
b) Devising a hardware solution to optimize energy. (Design level optimization) (MIMO)
c) Dedicated sensors to optimize task on each sensor. (Load balancing)
d) Clustering approach to resolve energy consumption in the network. (EECS), HEED
e) Introducing cloud to optimize the operation and storage in sensors.
f) Optimization achieved through altering the data packet parameter (packet size optimization)
g) Optimization achieved through varying sensor parameters. (Target coverage)
h) Energy optimization using nature inspired algorithms. (ANT, swarm)
i) Hybrid algorithms. (hybrid)
j) Energy reduction using miscellaneous methods. (Relay data mules).
k) Wireless Energy Transfer (WET)
l) Genetic algorithms

The rest of the paper is organized to cover the following 11 point in the literature survey and methodology (comparison of work) consequently. Finally a conclusion based on the following work will be given at the conclusion section.

LITERATURE SURVEY

Developing a protocol to optimize energy

This method has been identified to build a routing protocol that ensures energy efficiency through optimization some of the case studies are made on the following protocols and the discussions are discussed as follows:

a) TDMA
b) LEACH
c) PEGASIS
d) DARA

TDMA: Time division multiple access protocol

The very first work that has been considered is the “Energy Aware Routing for Low Energy Ad Hoc Sensor Networks [1], where there are optimal paths drawn to preserve the processing and connecting overheads during any transmission in the network. There is also a simulation work done that shows the improvisation in the network throughput when this method was employed. The next approach that is considered is introduction of Time Division Multiple Access (TDMA) protocols to preserve energy. The work “Energy-Efficient TDMA MAC Protocol for Wireless Sensor Networks Applications [2]” suggests effective TDAM, MAC approach in railway application to optimize communication overheads in the network. In this paper the MAC layer has been redesigned to suit the TDMA protocol that is implanted on the network and also the clustering heads are placed in the railway wagons. This work is also compared with the Bit-Map assisted Protocol (BMA).

LEACH: Low energy adaptive clustering hierarchy

The other approach to conserve energy through routing protocol is a major breakthrough in the research which was considered the best possible solution. This method is called Low Energy Adaptive Clustering Hierarchy (LEACH) [3]. LEACH proposes the following technique which is randomized variation of the high-energy cluster-head position to exchanges between the sensors to reduce the load on one sensor. By this there is equal load distributed in the network and there is a cluster head that is elected to ensure the following methods are preserved in the entire network. In LEACH protocol the iterations are considered as round and in each of such a round the clusters are formed in set up phase which is to initialize the transfer and steady phase to transmit. After this framework is done the data will be sent form source to BS.

PEGASIS: Power-efficient gathering in sensor information systems

PEGASIS: Power-Efficient Gathering in Sensor Information Systems [4], chain-based protocol where each node links to nearby node and transfers the data to the sink. The node that is near to the BS takes the initiative to transmit the data. The nodes are randomly placed with a weight and a chain is formed according when a data has to be transmitted.

DARA

DARA [5], the next approach for energy preservation is a proactive routing algorithm. DARA reflects the end-to-end delay for packets. Hence the packets are routed between router and the gateway. The protocol proposes that any routing path should consist of (1) each user must be associated with a router at the footprint and (2 there should always be a path defined from the incoming node in the router to the gateway. Now it is the choice of the user to choose the nearby router and its footprint but the user must decide on only router to avoid ambiguity.

Devising a hardware solution to optimize energy

In this approach the problem of energy conservation has two approaches: they are:

a) Design level optimization
b) New hardware development

Design level optimization [6]

It is also a proven method to reduce the energy consumed by sensors during the transmission. The details of this can be understood as follows:

Devising a new hardware

The research paper "A Cooperative MIMO Framework for Wireless Sensor Networks [7]", provides a new perspective to optimize energy through communication optimization. The author has proposed a cooperative multi-input multi-output (MIMO) communications to prolong the lifetime of WSN. Single-antenna sensor nodes are bunched so as to form virtual antenna arrays which becomes virtual MIMO (VMIMO) nodes. Here the author has designed a distributed cooperative cluster protocol (CCP) to select nodes in the cluster to balance the load and thus optimize the communication overhead and also energy. These elected nodes will be called the cooperating nodes (CN) and an algorithm to find the optimal CN is written.

Dedicated sensors to optimize task on each sensor

The available method is "Load balancing Based Approach to Improve Lifetime of Wireless Sensor Network [8]", provides dedicated sensors to optimize task on each sensor. This approach accepts heterogeneous network which is formed by the sensor nodes with different energy levels and processing power. Cluster are made such that at least one high computing node is deployed nearby each other node. Initially the nodes with high energy level and processing power are nominated. Consequently a cluster head (CH) is elected and designated a communication range. The nodes with minimum energy are asked to sleep and the information of those nodes will be maintained with the CH. This repeats until the CH nodes energy reaches a threshold value, post which the CH activates sleeping nodes. Thus the energy is optimized through load balancing

Clustering approach to resolve energy consumption in the network

There are two methods discussed which follows clustering approach to solve the problem of energy optimization, they are:

a) EECS
b) HEED

EECS: An energy efficient clustering scheme in wireless sensor networks [9]

It is a research paper that focuses on energy optimization based on the pure clustering approach. The EECS protocol works similarly to the LEACH protocol. Here the entire network is divided into groups and each group is having a CH. The CH and BS communicates within single hop. To initiate the data transfer the nodes send an initial message to the group to check the power level and once the data is received the nodes are assigned with workload and cluster formation in the network.

HEED: Hybrid energy efficient distributed [10]

This protocol is a clustering protocol. It makes use of the residual energy as main parameter and the network topology features that are considered as secondary. The primary assumption is that all the nodes are homogenous i.e. with same amount of energy initially.

S. No	Design level	Optimization
1	Architecture-level	In the Architecture-level optimization we have connecting which enables data transmission to distant clients existing various locations of the network. This connection is nothing but overlapping a sensor network with slices of the IP network.
2	Component-level	The component level design optimization is achieved through COTS sensor nodes deliver optimization prospects at this level through tunable parameters whose standards can be focused to meet erratic application necessities such as sensing, power. Storage and so on. This level focuses on sensing unit, processing unit, transceiver unit, storage unit, actuator unit, location finding unit and the power unit. All of these components are considered for the optimization.
3	Data Link-level	In the Data link-level the design optimization is provided by majorly in the presence of the QoS parameters. Some major techniques that are identified are, channel access plan, message size, duty cycle, and receiver power off, dying nodes, self-organization and failure recovery. The approaches that are followed are: 1. Load Balancing and Throughput Optimizations 2. Power/Energy Optimizations
4	Network-level	Immediately after the data link layer we have shift our focus onto network layer. This layer deals with the transfer of packets from source to destination and in WSN it has to sense the data from the environment in which it is deployed and transfer the data. Here the implementation of energy efficient routing protocol is critical to save the node energy spent on routing. Preferably, data distribution and routing protocols should mark energy efficiency, toughness, and scalability. The approaches that are followed here are: 1. Query Dissemination Optimizations 2. Real-Time Constrained Optimizations 3. Network Topology Optimizations 4. Resource Adaptive Optimizations
5	Operating System-level	In a sensor node the operating system (OS) offers optimization trials because the operations of the sensor nodes lies between the single and general applications that run on multiple platforms. It is the job of the OS in the sensor node to manage I/o, Processor, memory, hardware, power and so on. Hence the approaches that are discussed here are: 1. Event-Driven Optimizations 2. Dynamic Power Management 3. Fault-Tolerance

In the paper the influence of heterogeneity in terms of node energy is studied. That is there will be sensors that have slightly higher energy those other nodes to form the heterogeneity. The lifetime of sensor nodes in the networks is inadequate; we have to re-energize the sensor network by adding more nodes.

Introducing cloud to optimize the operation and storage in sensors

The other possible method that is applicable for energy optimization is integrating sensor networks with the cloud [11]. Design and Optimization of Traffic Balance Broker for Cloud–Based Telehealth Platform speaks about the following idea. In this architecture the cloud broker manages the requests from the server and also the memory allocation

Optimization achieved through altering the data packet parameter

Optimization achieved through altering the data packet parameter (packet size optimization) is explained well in the paper "Energy Efficiency based Packet Size Optimization in Wireless Sensor Networks [12]". In the WSN, noticing events, processing the sensed data and communicating with neighbor nodes are the important functions. The energy constraint has led to the consideration of the QoS parameters to improve the above said functions and this paper presents consumption characteristics and channelization to handle the parameters instead of the traditional Forward Error Correction mechanism.

Optimization achieved through varying sensor parameters

Target coverage mechanism has also been a method of energy optimization that is discussed in the paper "Energy -Efficient Target Coverage in Wireless Sensor Networks [13]", to increase the network lifetime, the sensor nodes are divided into a number of sets, so as to each set covers all the targets. These sensor sets are triggered consecutively, so that only one set is active at a time. The sensors from the active set are either in the active state or in the deep state based on the requirement. The transition from active mode to sleep mode will increase the network longevity.

Energy optimization using nature inspired algorithms

Optimization of Energy Consumption in Wireless Sensor Networks based on Nature-Inspired Algorithms [14], proposes a new way to optimize energy using Modified Particle Swarm Optimization (MPSO) and Ant Colony Optimization (ACO) algorithms. These are the

Nature-inspired algorithms that change the way the stereotyped algorithms are build and come examples for these are Particle Swarm Optimization (PSO), Bee Colony Optimization (BCO) and Ant Colony Optimization (ACO) have been introduced. Here an advanced algorithm has been proposed to the existing algorithms to increase the efficiency.

Hybrid algorithms

Minimizing the Energy Consumption in Wireless Sensor Networks [15] is a work that considers the following points to reduce the energy consumption: mobile base stations, data mules, and mobile relays. Here the Mobile Base Station gathers the data and to stabilize the transmission load, multiple hop transmission is required. The base station calculates the data from the visited nodes and the battery life gets exhausted very quickly.

Energy reduction using miscellaneous methods

The improvised form of the mobile stations which collects the data from the sensor nodes and send it to the BS are called the Data Mules. They perform like the polling officers that poll the station frequently to check if some data is available. Henceforth they also form a path which can sense the mobility of the data and hence optimize on the same. Similarly Data relays are alos a form of replacement on mobile stations.

Wireless energy transfer

The paper "Throughput Optimization for Massive MIMO Systems Powered by Wireless Energy Transfer", proposes a promising way of energy optimization, Wireless Energy Transfer (WET). Far-field wireless energy transfer (WET) serves the power-limited devices in wireless networks [1]. WET refers to the use of radiative electromagnetic (EM) wave produced from a power transmitter to transport energy to a power receiver. The EM frequency decline rapidly over spaces, to understand WET in exercise, the EM energy needs to be focused into a thin ray to attain effectual broadcast of power, also mentioned to as energy beam forming.

Genetic algorithms

Usage of genetic algorithms has also been in practice to serve the purpose of energy optimization in WSN. One such genetic algorithm inspired energy optimization protocol is GAEEP [16]. The jest of paper is grouping sensor nodes to form clusters in order to achieve the network scalability and to exploit the network lifetime.

Metrics tabulation based on the above discussed work to justify the clustering approach is written below:

S. No	Domain in focus	Parameters	Complexity	Research weightage	Merits	Demerits
I	Developing a protocol to optimize energy.	• Packet Throughput • Delay • Energy	Moderate	High	Efficient way to conserve energy and reduce overheads	Energy localization is not given preference
II	Devising a hardware solution to optimize energy	Hardware parameters	High	Low	Effective approach that gives a new hardware and it can be used to specific purpose	Not cost efficient as it requires new infrastructure
III	Dedicated sensors to optimize task on each sensor	• Load • Energy Dissipation • Delay	Moderate	Moderate	Effective load balancing method	Not effective in identify energy drop-offs
IV	Clustering approach to resolve energy consumption in the network	• Load • Energy Dissipation • Delay • Throughput	Moderate	High	Energy localization with energy drop offs are identified	Needs improvement in scheduling and prioritizing packet transaction
V	Introducing cloud to optimize the operation and storage in sensors	• Memory • Energy • Throughput	High	High	Energy optimization is effective due to usage of cloud	Does not solve the energy problem but only subsides the issue
VI	Optimization achieved through altering the data packet parameter	• Packet size • Packet delivery ratio • Energy • Delay	Low	High	Effective way to optimize energy by altering packets	Stereotyped and over exploited method.

VII	Optimization achieved through varying sensor parameters.	• Energy Dissipation • Load • Throughput	Low	Moderate	Efficient solution to precise problem	No scalability to higher range of networks
VIII	Energy optimization using nature inspired algorithms.	• Energy Dissipation • Load • Throughput • Delay	High	Moderate	Energy localized and optimized	Complex methods and cost ineffective
IX	Hybrid algorithms.	• Energy Dissipation • Load • Throughput • Delay	High	Moderate	Parameterized energy saving done	Complex methods and cost ineffective
X	Energy reduction using miscellaneous methods.	• Energy Dissipation • Load • Throughput Delay	Moderate	Low	Multiple parameters considered to reduce energy consumption	No energy localization is done
XI	WET	• Energy Dissipation • Load • Throughput • Delay	High	Low	New approach to transmit energy	No energy localization is done
XII	Genetic Algorithms	• Energy Dissipation • Load • Throughput • Delay	High	Low	Multiple parameters considered to reduce energy consumption	Complex methods and cost ineffective

Derivational model on pure clustering and comparison study

The method that is pervasively used to find the solution for energy optimization in the WSN is clustering. The approach of clustering in the implementing a routing protocol is a proven method to overcome the problem of node lifetime and hence a critical routing protocol with an adequate algorithm to serve the purpose. The option that can be chosen in this regards is the hierarchal routing [18]. The following term are clustering taxonomy [20] which will be used in the rest of the paper:

Node

1. Ordinary node: It is node that does not participate in the clustering activities and it would just sniff around the network to analyses the incoming and outgoing packets.
2. Gateway: This node is responsible from transmission of packets from source to destination.
3. Cluster Head: The node that will be elected in the cluster to be a head to initiate the process of communication and monitor the cluster.

Clustering attributes of clusters

1. Cluster count: It is the number of clusters that are present in the network and based on the cluster count we can categories the clustering schemes as :

a. Fixed cluster: The scheme is called to be fixed if the number of clusters are fixed and predetermined by the CH.

b. Variable cluster: The scheme is called to be variable if the number of clusters is not predetermined and the CH forms a cluster randomly.

2. Cluster size: It refers to the number of nodes in the cluster. There is classification of the network based on this as:

a. Uniform Clusters: The networks are formed by clusters which have equal number of nodes in all the clusters.

b. Non-Uniform Clusters: The networks are formed by clusters which have unequal number of nodes in all the clusters.

3. Intra cluster schemes: It speaks about the data dissemination from source to destination in WSN that incorporated clustering. There are 2 schemes in this, namely:

a. Single hop intra cluster routing: Here the data is transmitted from source to CH directly.

b. Multi hop intra cluster routing: Here the data is transmitted to CH through multiple hops.

4. Inter cluster communication: Here the communication is between the CH and BS directly which is single hop communication.

Capabilities of CH

1. Agility: It refers to the movement of clusters and here the classification is made as:

a. Mobile clustering: Here the CH moves around the cluster and hence the cluster structure has to be preserved.

b. Stationery clustering: Here the CH is fixed and moves only in the limited area.

2. Functionality: It describes about the functions that are performed on a cluster and they are:

a. Transmission of data by the CH

b. Aggregation of data by the CH

c. Management of data by the CH

d. Maintaining structure of data by the CH

3. Consistency in energy: It is about the energy distribution in the cluster. There are 2 classification which are:

a. Homogenous energy cluster where the energy distribution is equal in the cluster and election of CH is random.

b. Heterogeneous energy cluster where the energy distribution is unequal in the cluster and hence CH election is predetermined.

Clustering activities that are scheduled from initial to final phase of the network are

1. Construction cluster: This is about how the clusters are formed in the network and there are also schemes related to this. They are:

a. Distributed Cluster formation: A cluster is formed in the network which is a result of all the nodes and their equal participation.

b. Centralized Cluster formation: Here the clusters are formed by the CH alone.

c. Hybrid Cluster formation: It is a combination of the above said methods.

2. Cluster head selection: The selection of the cluster head can be done is these two possible ways:

a. Prior assigned: CH is elected out of various parameters of cluster

b. Random: CH election is done in random.

3. Clustering mechanism : The formation of the cluster is can be done as:

a. Active: Where the nodes and sensors are in sync.

b. Passive: It contradicts active.

c. Hybrid: It is a mix if both methods.

4. Objectives: The main objective of clustering is to attain :

a. Robust connectivity in the cluster and the network.

b. Improving nodes lifetime.

c. Making the network more fault tolerant.

Clustering algorithm characteristics

a) Convergence Rate: Here the algorithms are classified based on the convergence time i.e., more the number of nodes converge to the time at the same time more constant is the rate and for variable it is contradictory to the above statement.

b) Distribution estimation: Here the classification is made on the coverage of nodes in the cluster, based on which it is either termed as probabilistic od iterative.

Classification of clustering

In clustering we have numerous techniques. It can be broadly classified into inter cluster routing and intra cluster routing based on the location of the configuration of the cluster. Since we focus on the energy optimization within the cluster, the routing scheme that is opted is intra clustering. In the intra-cluster routing the regions are divided into the intensity based region and the non-intensity based region. In the intensity region the network is identified to consume more energy due to high data rate and transactions. The energy optimization should be applied in this section itself. The routing strategy opted here is multi-hop routing and this saves the energy as the data which has to be sent is not sent to the destination directly but sent to the nearest node and then the packet is routed to the actual destination. In the intensity based region the TDMA approach is followed and in the Non intensity region the CSMA/CA is followed. Now the concern is about the cluster head selection and to do this the approaches followed are LEACH and LEACH-C, In LEACH-C the cluster head and cluster flushes the information to the sink of the network and the sink is responsible for the scheduling and synchronization of the data. The process of cluster head selection happens when the remaining energy in the node is capable to complete the entire cycle.

The classification of the hierarchical clustering done on the WSN is described in 4 categories:

a) Chain based routing
b) Tree based routing
c) Grid based routing
d) Area based routing

Chain based hierarchical routing:

The algorithms that are identified are:

S. No	Category and name	Description	Advantages	Disadvantages
1	Hierarchical- Chain Based	The data transmission happens when there is a chain constructed and the data is finally delivered by the leader node. The node with the highest residual energy will be elected as the cluster head and transmission follows the path: node to cluster head to base station. There will be only mode that communicates to the base station	The simplicity in the topology helps to configure the node faster and the energy is conserved as there is no communication overhead. It provides the small transmit distances to cover and hence easily reconfigurable.	Due to chain management there is huge delay is packet routing and since the network information is just maintained by the leader node thee structure becomes less robust
2	Hierarchical-tree based	In this structure a tree like structure is created to build the topology and the parent node is responsible for data dissemination and aggregation. The parent node communicates the leaf node and the network is likewise created.	The simplicity in the topology helps to configure the node faster and t energy is conserved as there is no communication overhead.	Due to chain management there is huge delay is packet routing and since the network information is just maintained by the leader node thee structure becomes less robust. The energy consumption is also uneven due to construction of trees.
3	Hierarchal -grid based	In this structure a grid like structure is created to build the topology and the location aware routing is followed by the node for data dissemination and aggregation. The parent node communicates the leaf node and the network is likewise created.	The topology is simple and hence data delivery is made efficient.	The main issue is with the load balancing and overload. Since the networks are formed by grids and the location aware sensors always transfer the data to the nearest node the energy management is uneven.
4	Hierarchical- area based	This structure is the most efficient one. It creates the area based on the load of the network and hence there is no uneven energy distribution. Once such areas are created the dFata collection from the nodes start from one end. The nodes that are ON will transmit the data and the nodes at the sink start collection of data. Thereby load balancing is done.	The advantages are that the topology formed are very simple and the there is even energy distribution of load throughout the network. The energy consumption is also less as the network collects that data from the nodes that are ON. The key feature is the load balancing done on the network.	The disadvantages are high capital investment cost. The topology is simple yet robust to implement and hence costly to implement. This structure is also less scalable due to the specific region identification requires more information.

If we consider the hierarchical routing for the clustering approach in WSN the following parameter play a vital role to select an appropriate algorithm. They are:

a) Energy efficiency
b) Data delivery
c) Algorithm complexity
d) Implementation cost

The comparison of the above said protocols are done based on the following parameters and are tabulated as follows:

S. No	Protocol	Energy efficiency	Data delivery	Algorithm complexity	Implementation cost
1	Chain Based	Low	Slow	Simple	High
2	Tree based	Low	Medium	Simple	High
3	Grid Based	Medium	Medium	Moderate	High
4	Area Based	High	Fast	Moderate	Moderate

CONCLUSIONS

The comparison of all the above said work leads to the conclusion that there is a vast research done the derivation of a new routing protocol that helps the energy optimization in the WSN. All the categories discussed so far end up giving an algorithm at the end by implanting the various parameters that are discussed. Thus it is

considered to develop a new routing protocol that suffices the present condition using clustering approach.

ACKNOWLEDGEMENTS

I would like to thank my guide for her constant support and endurance without which this work stands incomplete. I also would like to mention that the Christ University and VIT Univeristy have helped me throughout my research work. Above all these I feel previlaged to mention the support and adherence of my parents and family, without them the research would have been just conception.

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