Middle-East Journal of Scientific Research 23 (10): 2603-2612, 2015
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2015.23.10.22797

A Survey of Energy Efficient Data Aggregation Schemes in Wireless Sensor Networks

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Abstract: Wireless sensor networks (WSN) are the collection of resource-constrained self-organized sensor nodes that are often deployed in hostile and inaccessible environments in order to monitor the environment. Applications of sensor networks are increasing day-by-day in all areas throughout the world. WSN suffers from many constraints like low computation, less storage, limited energy and communication capabilities. Energy limitation is one of the main concerns of any wireless sensor network application. Enormous research has been done in recent years, investigating different aspects like, less energy protocols, network topologies, routing protocol and coverage problems of wireless sensor networks. To overcome these limitations and achieve reliable data from sensor nodes, many data aggregation algorithms have been proposed. The main goal of these data aggregation algorithms is to reduce the energy utilization in data aggregation to improve the lifetime of the sensor networks. This paper presents a qualitative review of recent approaches in data collection techniques in WSN. The review classifies each of the considered techniques based on essential topology. The main focus of this paper is to survey the energy-efficient routing protocols for Wireless Sensor Network. A comparison of these techniques is provided for qualitatively evaluating these techniques. The review concludes with a discussion on limitations of the considered techniques.

Key words: Energy efficiency · Aggregation Tree · Clustering Algorithm · Scheduling algorithm · Wireless sensor networks

INTRODUCTION

A wireless sensor network consists of sensor nodes deployed over a surface area for monitoring environmental changes like temperature, humidity, vibrations and so on. Typically, a sensor node is a tiny device that consists of three components such as a sensing subsystem, a processing subsystem and a wireless communication subsystem. In addition, an energy source supplies the energy needed by the device to perform the environmental monitoring. Energy consumption is one of the biggest constraints of the wireless sensor networks.

Since the wireless sensor network is normally used for remote environment monitoring in areas where extending electrical energy is difficult. Therefore, the devices need to be powered by batteries and alternative energy sources discussed by Sandra Sendra *et al.* [1]. Since battery energy is limited, the use of different techniques for energy saving is one of the major research topic in WSNs. This energy source habitually consists of a battery with a limited energy resource. In addition, it could be able to recharge the batteries, because of the nodes are deployed in a remote environment. Moreover, the sensor network should have a more lifetime to satisfy the application requirements. In any case, energy is a very essential resource that must be used very sparingly. Therefore, energy conservation is a key issue in the design of systems based on wireless sensor networks.

WSNs have numerous applications such as, early detection of forest fire [2], security surveillance [3] and real-time target tracking [4]. These applications can be classified into two categories (i) event-driven and (ii) continuous data collection.

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In event-driven applications, it is very critical to deliver alarms about serious events in a timely manner so that an appropriate action can be taken in response. Meanwhile, in continuous data collection, it is important to provide a guarantee on the delivery time as well as increase of data collection rate and/or number of nodes in the network.

Energy Conservation Schemes: Sensor networks are organized in an ad hoc approach, with individual nodes enduring mostly inactive for lengthy periods of time. If something is fetched, then it becomes suddenly active. In general Sensor Networks are battery constrained. The following major analysis of the literature, we have decided that there are three components available in data aggregation protocol such as: (1) How data are aggregated, in which a suitable aggregation function; (2) Routing scheme, which characterize how the aggregated data are routed towards the base-station through a structure; (3) The aggregation schedule, which classifies how long a node has to wait in a couple of time before sending its data to its upstream node. In such a way that the existing solutions intend to optimize one of these components while assuming the other two components are predefined. In this paper, we survey the data aggregation scheduling elucidations that aim to schedule the aggregation process for a given structure and a given aggregation function. In this categorization, our analysis focuses on how long the nodes are scheduled to achieve data aggregation objectives, such that the data latency is minimized and the aggregation freshness is ensured. The energy efficiency of wireless sensor networks increased due to unnecessary operations like overhearing, retransmission due to collisions, redundant control packets broadcast and also listening to media when idle. In general a node may do useful operations like receiving or transmitting operations. Depending on the precise application, the energy efficient data aggregation protocols can be classified into the following categories[3-10]

Energy conservation Schemes

- Topology Control
- Tree based
- Cluster Based
- Connection-driven Sleep/wakeup protocols
- Scheduling algorithms
- Contention based
- MAC Protocols with Low Duty Cycle
- TDMA (Time Division Multiple Access)
- Hybrid
- Data Driven Approaches
- Data reduction and compression
- Algorithmic Approaches Energy –Efficient data Acquisition
- Mobility based

Topology Control: Topology Control Protocols: it is based on network redundancy. Mostly sensor networks have some degree of redundancy. So energy conservation is a very critical issue in wireless sensor network. Therefore more number of works has been done on the techniques of topology control. So that easily can put to a low power consuming state when the sensor nodes which are not in direct use, thus saving energy discussed by Banerjee *et al.* [11]. In many cases, network consumption is done at random [12].

There are more number of criteria can be used to choose which nodes are to be activated or deactivated and when. In this status of view, topology control protocols can be broadly categorized into two variations: Connectivity driven protocol and location driven protocol. Connectivity driven protocols in which activates or deactivates sensor nodes in such a way that network connectivity or complete sensing coverage [13] is fulfilled. Location driven protocol illustrates which node should be turned on and when, based on the location of sensor nodes which are measured to be known [13].

Tree Based Topology: We have listed and briefly explained few algorithms and their categories proposed by previous researchers.

Chen, P. *et al*. [5]. They proposed WST-LEACH algorithm. It's based on well-known LEACH protocol. These sophisticated the merits provided in LEACH protocol as well as spanning it. It has concerns for energy savings and determined a way of efficient data aggregation. Building a data sinking path is selected by cluster heads in its network. It's not done in random manner hence it focusing the remaining energy, distribution density of the nodes and the distance from cluster heads to the base station. Then these proposed work created a weighted spanning tree by using cluster heads which does the weighted calculation of the weighted value. This work of calculations represents factors such as the balanced amount of energy of the cluster heads, distribution of surrounding nodes and the distance to the other cluster heads. Then, after aggregating the data, it is sent to the base station through the tree. At last after aggregating the data, it is sent to the base station via tree.

Hussain, S. *et al*. [7]. They had found an effective routing of sensor network tree which would be save more energy and this will provide good structure of communication for data aggregation. This approach is a modification of a previously created algorithm called Minimum Spanning Tree (MST) search algorithm by Kruskal. Here the work of spanning tree is constructed in an undirected weighted simple graph, which is characterized by a weighted adjacency matrix. The input graph is preliminary clustered by recursive hierarchical clustering in two parts due to construct efficient search of the distributed spanning tree. These two parts be determined to minimize the intra-cluster distances and too maximize the inter-cluster distance.

Huangfu *et al*. [8], This includes the information about Cluster-based Minimal Spanning Tree with Degree-Constrained (CMST-DC). This is a hierarchical two layered structure which contains cluster structure and tree structure. The features of cluster based minimal spanning tree is robustness, less time taking to complete a round and low network. The concept of algorithm is clusters are formed and then cluster head is nominated in all clusters based on residual energy. Here the cluster heads create a routing tree simultaneously and create the second layer of the network and finally the base station receives data from cluster heads which is selected by some criteria. More number of design problems is considered before developing the structure of the algorithm that makes it a good approach. This algorithm guarantees maximum utilization of network energy which in turns gives longer lifetime.

Liehuang, *et al.* [10], The centre of attention of this paper is group key authentication for secure communication. The authors proposed key agreement protocols such as two-party and three-party keys. This group key agreement protocol is proposed which is created as novel tree based authenticated group key agreement protocol. It's not mandatory that all users to be authenticated in two-party and three-party authenticated key-agreement protocol. It is indicated that AKP (l, n) as n-party authenticated key agreement protocol with 1 users to be authenticated. Since AKP (2, 1) protocol, it is designed that A and B (considered users) need to be in agreement upon a common key and A wants to be authenticated by B. For AKP (2, 2), A and B need to be in agreement upon a common key and they need to be authenticated by each other. Similarly AKP (3, 3) and AKP (3, 2) are described. These protocols are done by the following some certain steps, based on bilinear pairing, for every type. After that the validated group key agreement protocol, which is indicated as AP3TGDH, is illustrated. It consists of three steps.

- To create the key tree and how all the nodes come into a final key authentication conclusion using either private or public key is illustrated.
- How it is going to contribute in the tree if any new node joins the tree.

If any node is leaves from the tree, then the entire tree is going to be refreshed and the agreement protocol may carry on.

Cluster Based Topology: In this approach, network is divided into a number of clusters. Each and every cluster has a cluster-head which is selected among cluster members. The cluster member sends the aggregate data and delivers the aggregated data to sink. The cluster based environments is to merge and shrink the data belonging to a single cluster is an important way to aggregate data. There are few issues involved with the process of clustering in a wireless sensor network. The researchers are dealt with many factors when applying a cluster based data aggregation in a network. There are, i) how many cluster to be formed to optimize the network performance parameters. ii) How many nodes should be taken to make a single cluster? iii) Which node has to select as a cluster head. To act as a cluster-head there are more energy is required in a network [14].

Enhanced Low-Energy Adaptive Clustering Hierarchy (ELEACH): E-LEACH [15] added better LEACH in two major aspects. E-LEACH proposes a cluster head selection algorithm for sensor networks and they have non-uniform starting energy level between the sensors. Most probably, this algorithm guesses that sensors have global information about other sensors. E-LEACH also categorized that, under certain assumptions, the square root of the total number of sensor nodes to minimize the total energy consumption required by cluster-heads. Other features of E-LEACH are the same as LEACH.

LEACH-Centralized (LEACHC): LEACH-C utilizes a centralized clustering algorithm and same steady-state protocol. Each node transfers data about current location and energy level to base station (BS) during the set-up phase of LEACH-C. The Clusters, CH node and non-CH nodes of each cluster is concluded by the base station.

The base station uses its global data of the network to provide enhanced clusters that require less energy for data transmission. In LEACH the number of CHs varies from round due to the lack of global coordination among nodes whereas, the number of CHs in each round of LEACH-C equals a predetermined optimal value.

Hierarchical PEGASIS: A conservatory to PEGASIS, called Hierarchical-PEGASIS was created to decrease the delay incurred for packets during transmission to the base station [16]. For this purpose, simultaneous transmissions of data are studied in order To avoid collisions via approaches that incorporate signal coding and spatial transmissions, when simultaneous transmissions of data are studied. H-PEGASIS recommends an elucidation to the data collecting problem by considering energy × delay metric. Simultaneous transmissions of data messages are pursued in order to reduce the delay in PEGASIS.

Energy Balancing PEGASIS (EB-PEGASIS): EBPEGASIS is energy based efficient chaining algorithm [17]. The node will think about the closest node is a far node when an average distance of formed chain. If the distance thresh is shorter than the distance from nearest node to its upstream node. In general the distance threshes can obtain from average distance of formed chain. If the closest nodes merge the chain, then it will emerge a long chain. In this case the far node will search a nearer node on formed chain. So the new protocol EB-PEGASIS avoids long chain effectively. EB-PEGASIS can assurances just about the same in get through energy of sensor nodes and avoid the dying of some of the nodes early than other nodes to prolong the lifetime of sensor networks. It saves energy on sensors and also balances the energy consumption of all sensor nodes.

Sleep/Wake up Protocols: The components (i.e. radio sub system) of the sensor node, without relying on connectivity are assumed as sleep/wake up scheme. The top of the MAC protocol (i.e. at the network or the application layer) has been carried out due to the creation of sleep /wake up scheme. This Independent sleep/wake up protocols can be auxiliary subdivided into three main categories: on-demand scheduled asynchronous and rendezvous schemes.

Scheduling Algorithms

Contention Based Protocols: Contention based protocols are used in wireless sensor networks which are the MAC protocols proposed for it. B-MAC (Berkeley MAC) contention based protocol one among the most used protocols, which has very low power MAC and low complexity moving with Tiny OS operating system. Little functionality like energy efficient process and channel access are provided by B-MAC. The most operation of B-MAC is basic channel access content features. The operations are lack of reference and accurate channel estimation facility and optional acknowledgements. Second thing is an asynchronous sleep/awake scheme which is based on periodic listening called low power. Listening can be used to achieve a low duty cycle B-MAC. To check the channel for activity can be done by the nodes through periodically wake up. Check interval is the period between consecutive wakeups. To detect the eventual ongoing transmission the nodes remain active for a wake up time, after it got wake up. The application is used to check the interval after the wake up time is finished.

A long pleasure and a pay load are used to make B-MAC. The check interval must be equal to preamble duration ongoing transmission during its check interval can be detected by every nodes synchronized nodes are not required in this approach. The preamble and then the payload can be activated and received when the node detects the channel activity. A scheduled rendezvous communication scheme can be adopted by the S-MAC (sensor-MAC) is called as MAC protocol for multi-hop sensor networks. To co-ordinate their sleep/wake up periods can be done by nodes exchange and synchronization of packets. In this random distributed algorithm is being used. The formula for that algorithm is establishment of own schedule or schedule of the neighbor can be done by each node.

To form a virtual cluster nodes are using same schedule. Both the schedule can be followed by the node if they do not overlap; so that the schedule is used as a communication bridge between different virtual clusters. The two-hop neighbor can forwarded local slot assignment and time frame of each node. A common reference slot has the information about synchronization details of node.

MAC Protocols with Low Duty Cycle: The fabulous and fast growth in sensors technology approved their application in various fields necessitating monitoring, such as, rare species surveillance, transportations, agriculture, medical field, military activities, etc. Several dedicated MAC protocols have been designed for wireless sensor networks due to their intrinsic constraints and limitations. The bandwidth optimization while keeping very low energy consumption is discussed by [18]. Increasing the communication range between sensors and their gateway, to make use of directive and adaptive phased arrays is recommended for the WSN gateways discussed by [19]. The main sources of energy consumption are idle listening, receiving and transmitting in wireless communication discussed by [20]. The majority of common MAC protocols are TDMA (Time Division Multiple Access) based, hybrid and contention-based.

TDMA Scheduling Algorithms: TDMA (Time Division Multiple Access) schemes obviously allow sensor nodes as channel access is done on a slot-by-slot basis. During their own slots, the energy consumption is ideally reduced to the minimum level required for transmitting/receiving data when the nodes need to turn on their radio. In general time is divided into frames in TDMA-based MAC protocols. And each frames contains of a few number of time slots. In TDMA-based MAC protocols, time is divided into (periodic) frames and each frame consists of a certain number of time slots. Each and every node is allocated to one or more slots per frame, based on a few scheduling algorithm and it uses such slots for transmitting/receiving packets to/from another nodes. The important energy efficient TDMA protocol for wireless sensor networks is TRAMA. TRAMA separates time into two parts, a scheduled access period, a random-access period. The scheduled access period is formed by a number of slots assigned to an individual node. Then the random access period is devoted to slot stipulation and is accessed with a contention-based protocol.

ISDA (Improved SDA) [21,22]: ISDA has a centralized algorithm proposed to enhance the time latency of SDA [23]. This algorithm creates a collision-free scheduling with an information latency upper-bound of $(7\Delta / \log2 (|N|)) \times (R - 1)$ for an aggregation tree, where R is the network radius, N is the number of nodes and Δ is the maximum node degree. The network is divided into equal cells in ISDA. Each and every cell can contain a set of nodes. By merging TDMA and measuring that parent's time slot is higher than the children' ones, ISDA ensures the aggregation freshness and data accuracy.

CIAS (Centralized Improved Data Aggregation Scheduling) [24]: CIAS is used to minimize the data aggregation latency by using CDS topology. The authors choose the network topology centre as the aggregation tree root instead of the base-station. This choice is made to reduce the upper-bound time latency of CIAS to a function of the network radius R, instead of the network diameter D. The time latency in CIAS is at most $16R+\Delta-14$. Due to the uses of TDMA scheduling and the parent's time slot is always higher than the children' ones the data accuracy and aggregation freshness are ensured in CIAS solution. However, this technique may increase the data latency and Bagaa et al. in [21] have also proved that the data latency upper-bound of CIAS is incorrect.

SAS (Sequential Aggregation Scheduling) [25]: The scheduling proposed in SAS is a centralized solution. This algorithm used a collision free schedule with a latency bound of $15R+\Delta-4$; where R is the network radius and Δ is the maximum node degree. SAS is working in two steps: The data aggregation scheduling and the aggregation tree construction. The use of CDS structure may increase the data latency by SAS. Sequential Aggregation Scheduling uses the same method proposed in [24]. Bagaa *et al*. [21] have proved that the data latency upper-bound of SAS is also incorrect. Finally, sync packets which contain a list of intended neighbour destinations for subsequent transmissions delivered by nodes. Nodes send out a synch packet containing a list of intended neighbour destinations for subsequent transmissions. As a result, nodes can be in agreement on the slots which they must be awake in. So the owners advertise the unused slots for being re-used by other nodes.

FLAMA (FLow-Aware Medium Access) is a TDMA MAC a protocol inherits from TRAMA and it is optimized for intermittent monitoring applications. The major plan is to avoid the overhead connected with the replace of traffic information. FLAMA first sets up flows, as the message flow in intermittent reporting applications is rather stable and then uses a pull-based mechanism, so the information's are delivered only after being explicitly requested.

TDMA Scheduling Algorithms: The level of contention in the networks can be adapted to the protocol behaviour in hybrid protocols. When the level of contention is high at that moment they behave as a contention-based protocols when the level of contention is low and switch to a TDMA scheme. Switching the protocol behaviour between TDMA and CSMA is the idea behind hybrid MAC protocols. Time slot and nodes are distinguished as owner and non-owners in PTDMA. Depending on the number of senders the protocol can adjust the access probability for the owners and non-owners. Depending on the level of contention is the networks can be adapted the MAC protocol to work as a TDMA or CSMA scheme. For a one- hop wireless scenario the PTDMA was conceived. Wireless sensor networks quire common have topology changes. Synchronization errors interference irregularities but there issues does not taken into account.

Z-MAC is one among the most interesting hybrid protocols in wireless sensor networks. Preliminary set up phase is the main transmission control scheme of Z-MAC. Lists of two-hop neighbours were built by each node by means of the neighbour's discovery process. Any two nodes are the two-hop neighbourhood are not assigned to the same slot this is called as distributed slot assignment algorithm which has been applied in this. No transmission from a node to any of its one-hop neighbour can be guaranteed through this algorithm. Aim of deciding the time frame can be done by local frame exchange. All nodes in the network of Z-MAC do not the global frame. When the topology change occurs this will be very difficult and expensive to be adapted. Depends upon the number of neighbour Z-MAC allows each node to maintain its local time of frame and avoids any conflicts with its connecting neighbours [26, 27].

ATC: Monitoring or event driven application are considered by distributed solution is called is Adaptive timing convert. Hop count h count and the number of its children which is the each node in the tree were assumed by each author.

EATA: EATA is called as centralized solution. (Effectiveness based aggregation time allocation algorithm for wireless sensor networks) published in [28]. The aim of monitoring applications EATA is aggregation of freshness and reduces the data redundancy. Assumption of EATA is shortest path tree is already created. EATA has the multi-hop broadcast communication and contention based MAC protocol which has a messages collision and energy consumption as a negative impact.

ZFDAT: ZFDAT is called as distributed solution (zone based fast data aggregation) published in [29]. ZFDAT and ATC used the same techniques to distribute the waiting time over cluster members. In terms of data accuracy, aggregation freshness and data latency and minimum message collision is ZFDAT can be guaranteed by use of weighted path adjusted interval and contention free MAC protocol. To allow the use of a contention free MAC protocol can be done through the network nodes synchronization based upon the assumption. Between the two nodes the clock is drifted that waked be prevented through above mechanism.

LODAT: LODAT is a distributed solution published in [30] called (Latency optimized data aggregation timing model for wireless sensor networks). This is used for monitoring the applications by managing the waiting time. To create and maintain the data aggregation tree LODAT used CTP (collision Tree Protocol). To create and update the data aggregation tree the CTP uses the written link quality. LODAT is greedy with respect to the energy consumption by many messages collision can occur due to the fact that LODAT employs CTP and beacons exchange. A positive impact in data latency, data accuracy and aggregation freshness will be the part of periodic update of waiting time and the use of weighted path adjusted interval.

Data Driven Approaches: By keeping the serving precision with in an acceptable level for the application the data driven techniques are designed to reduce the amount of sampled data. According to the difficulty they address the data driven approaches can separated. Reducing the energy spent by the sensing subsystem can be done by data-reduction scheme addresses in the case of unwanted samples, as energy-efficient data acquisition schemes [31].

Data reduction and Compression: One more classification level related to data reduction schemes are discussed over here. Data compression and data prediction are the techniques in network processing. The quantity of data to be delivered to the sink node is aim of the all these techniques. In the context of wireless sensor networks where nodes have limited energy and forwarded messages of different priorities are to develop selective message forwarding schemes this will be of stochastic tools tailored to those scenarios. And this is discussed by Arroyo valles *et al*. [32].

To reduce the amount of information sent by source nodes can be done through data compression. The node generates data. Then decode it at the sink and invokes encoding information in that particular node. Many mechanisms are available for data compression which Pradhan *et al*. [33], Tang *et al*. [34] and Xiong *et al*. [35] discussed in this paper.

Energy Efficient Data Acquisition: Sensing- constrained can be done through an emerging class of applications. In general statement that sensing is not related to an energy consumption standpoint. And it's bigger than the energy consumption of the radio or we can say that greater than the energy consumption of the rest of the sensor nodes [36]. This can be appropriate to more different issue as given below:

- Long acquisition time: it's may be in the order of hundreds of milliseconds or even seconds; and the sensing subsystem consumed energy in high.
- Active sensors: sensors gathered information about sensed phenomenon by using active transducers. For example sonar, laser rangers or radars. Sensors need to send probing signal based on acquire information about the observed quantity, as discussed by Ditzel et al [37].
- Energy hungry transducers: few sensors basically require more energy resources to perform their sampling task.

There are more number of energy-efficient data-acquisition techniques have been conceived for minimizing the radio energy consumption, below the assumption that the sensor consumption is negligible.

Mobility Based Schemes: Most of the sensor nodes such as mobile, mobility can be used as a tool for reducing energy consumption. Towards the sinks(s), the packets coming from sensor nodes track a multi-hop path in a static sensor network. In this case these may be a possibility to load more path than others and nodes are nearer to the sink and have no relay reduction as given by Mohapatra *et al*. [38]. The flow can be changed if mobile devices are responsible for data collection directory from static nodes if some of the nodes such as mobile. Communications takes place in proximity due to normal nodes waits for the channel of the mobile device and route message towards it. Based on the result, ordinary nodes can save energy because path length, forwarding overheads and contention are decreased as well. Moreover mobile devices enters into the network is extend more evenly the energy consumption due to communication. When it is excessive, there is need to attack nodes to entities such as buses or animal.

Mobility scheme can be characterized as mobile sink and mobile relay schemes when we think about mobile scheme. There is an important issue is the type of control the sensor network designer has on the mobility of nodes. The clear information on this point is presented by Jon *et al*. [39]. Generally mobile nodes can be categorized into the ways: they can be created as part of network infrastructure or they can be part of environment. The mobility can be fully controlled when they are part of the infrastructure. If it is in the case environment they might not controllable. Based on the reliability, if they follow a strict schedules then they have a predictable mobility. If not they may have a random behaviour.

Mobility sensor nodes are feasible and it can be accompanied in different ways as studied by Akyildiz *et al*. [40]. To change the location, the sensor can be equipped with the mobilizer. It's quite expensive from the energy consumption standpoint, adding mobility to sensor nodes may not be convenient. The resulting energy consumption may be greater than the energy gain because of the mobility itself. So, it's not necessary that making each sensor node mobile, mobility can be useful to the nodes, which are less energy constructed than the ordinary nodes. In this case, mobility is strictly tied to the heterogeneity of sensor nodes. On the other side, sensors can be placed on elements which are mobile on their own instead of providing mobilizers.

RESULTS AND DISCUSSION

The protocols surveyed have addressed several problems with the aims to resolve energy limitation issues of sensor networks. In network data aggregation and integration used by different scheduling algorithms under different topologies reduces energy consumption while data forwarding.

The existing data aggregation algorithms that are discussed in this article are categorized into four different topologies. Based on these topologies the energy efficient techniques have been implemented for aggregating data. The conclusion made over this study is all the tree based topology uses distributed way of data synchronization. And all the existing works discussed are concentrates on utilization of energy. But the limitations of the existing models motivate the research to find the better solution to resolve maximum issues in data aggregation. The tree based topology [7, 10, 22, 24] are resolved the energy issues but [7] is failed in data duplication, [22] fails in security and [10, 24] are failed in avoiding collisions. [5, 8, 15, 17] are the cluster based data aggregation that deals with energy issues and does not resolve the collision aggregation delay and data duplication issues. Hybrid topology represents a combined routing topology for data aggregation.

Table 1: Comparison of the energy efficient protocols

Paper Reference	Topology	Energy Saving Technique	Synchronization	Issues addressed	Limitations
WST-LEACH [5]	Cluster & Tree based	Data aggregation in efficient way	Distributed	Data aggregation, Energy efficiency	Collision
MST [7]	Tree based	Scheduling	Distributed	Collision, Energy efficiency	Data duplication
CMST-DC [8]	Cluster based	hierarchical two layered structure	Centralized	Energy efficiency	Aggregation delay
Party Key Agreement Protocols [10]	Tree based	group key agreement protocol	distributed	Security and energy efficiency	Collision
Block Cellular Automata [11]	Flat	Low power consumption	Centralized	Aggregation delay, Energy efficiency	Collision
DEMA [13]	Flat	connectivity driven protocols	distributed	Energy management schemes	Aggregation delay
E-LEACH [15]	Cluster based	Scheduling algorithm	distributed	Energy consumption, Aggregation delay	Collision
Hierarchical PEGASIS [16]	Cluster based	simultaneous transmissions	hierarchical	Collision, energy efficiency	Aggregation delay
EBPEGASIS [17]	Cluster based	energy efficient chaining algorithm	Distributed	Energy efficiency	Data duplication
ISDA [22]	Tree based	TDMA Scheduling	Distributed	Aggregation Delay, Collision	Data security
CIAS [24]	Tree based	CDS topology	Centralized	Data latency, accuracy	Collision
ATC [27]	Hybrid	Scheduling algorithm	Distributed	Energy efficiency, Aggregation freshness	Aggregation delay
EATA [28]	Hybrid	Contention-based MAC protocol	Centralized	Aggregation freshness, Reduce the data latency	Collision
ZFDAT [29]	Hybrid	Weighted path adjusted interval and contention-free MAC protocol	Distributed	Data accuracy, Aggregation freshness	Security

All the hybrid topologies discussed here are resolves the energy limitation issues as well as data aggregation freshness. But the main drawbacks of all the hybrid topology is that are suitable only for some specific application. All the energy efficient schemes that are discussed here used a scheduling algorithm to reduce the energy utilization. Table 1 depicts a comparison of the energy efficient protocols surveyed based on the issues addressed.

CONCLUSION

In this paper, the main approaches to energy conservation in wireless sensor networks have been surveyed. Special attention has been devoted to a systematic and comprehensive classification of the solutions proposed in the detailed survey. All the same, the discussion of the topics that have received wide interest in the past is not limited. It also stresses the importance of different approaches such as data-driven and mobility-based schemes. It is worth noting that the considered approaches need not be construed as alternatives. They should rather be exploited together. Even all the approaches achieved its objectives to reduce the energy utilization, it is highly recommended to the researcher community to approach the possibilities in renewable energy resources for sensor nodes.

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