A BRIEF SURVEY OF ENERGY BASED CONSTRAINTS FOR IMPROVISING ITS EFFICIENCY IN WIRELESS SENSOR NETWORKS

M. Sajitha, S.Veni*

Abstract

Wireless sensor networks (WSNs) contains a potentially large number of wireless networked sensors, sufficient for full-time task operations without human interference in a possibly hostile environment. A sensor node is usually a miniature component system comprising four principal components: a sensing unit for data collection, a local data processing microcontroller with some memory operations, a communication unit to facilitate data transmission/receipt from and to other connected devices. It could be used in various applications, including targeting surveillance, environmental control, device monitoring, health monitoring, or hostile environment exploration. The purpose is to recognise and record any occurrence in the area of interest for data collection that constitutes the critical aspect for WSN applications. Apart from an external human influence after initial implementation, the device scenarios for WSNs frequently require long-term active battery-driven structure nodes. Since the nodes will exhaust a battery within a few days, in the absence of energy-saving techniques. Many researchers have established protocols that are capable of reducing energy usage. In this article, a comprehensive survey was performed for WSN, and numerous issues were addressed in terms of various scenarios and energy efficiency methods. This survey aims to raise understanding of the various energy management systems for the researcher's group. We define energy storage in WSNs according to different energy source mechanisms for the sensor node, such that a complete insight is obtained into the topic. Then we address various methods and the protocol conceptions centred on energy usage. Instead of addressing each protocol individually, this paper focuses on a general description of the effective methods adopted by many protocols, such as Duty cycling, Data-driven methods, or approaches focused on mobility. To precisely define the features of each system, our discussion is split into these three key parts.

Department of Computer Science,
Karpagam Academy of Higher Education, Coimbatore, Tamil Nadu, India
*Corresponding Author

Keywords: Wireless Sensor Network, Energy Efficiency, Duty Cycling, Data-Driven Approaches, Mobility based Approaches

I.INTRODUCTION

A WSN is a series of a variety of spatially distributed remote processing modules in a specific region. WSN's act as network relays and data processors and can detect (estimate), manipulate, and convey data among many different sink nodes. Application developers or admins will then create assumptions in a given situation and react to incidents. WSN's are very compact and highly economical. It could calculate the conditions of the atmosphere and perhaps some metrics, such as pollution levels, wind speed, vibration, intensity and moisture, then transmit this data to a specific basis for proper processing.

A WSN could have been expected to distribute many very tiny modules assembled and programmed for a collective vision. Services of Sensor networks involve and are never restricted to frontline protection, sustainable development, emergency preparedness and recovery, accurate and informed livestock, pharmacy and medical services, ecosystem structures, highway regulation, and target detection. Figure 1 shows various application usage through WSNs.

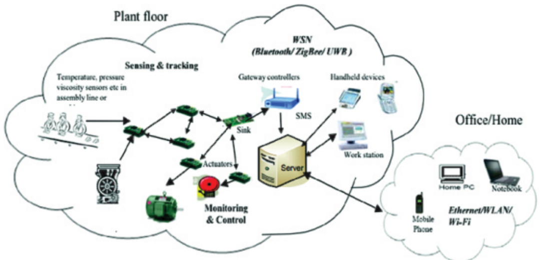

Figure 1: WSNs Types of Application

Types of green surveillance and target detection could be subterranean mining monitoring for any patterns to ensure the protection and position of mineworkers at all times. In contrast with conventional networks, WSNs are implemented at low prices. They will adapt dynamically to changes in their environments and respond actively to topological changes in the network.

Core elements of the WSN are as follows

(i) Modules for Sensing the Surroundings

(ii) Modules for Processing the Information

(iii) Modules for Energy Supplies

(iv) Modules for Transmitting/Receiving the Information

The numerous elements that build up the WSN [1] were shown in Figure 2. The modules for sensing was provided based on the application to analyse atmospheric factors that accompany the sensor and converts the external energies into electrical signals. In processing the information by the processor module, information on activities occurring in the vicinity of the sensor is gathered, and data is transmitted via a radio transmitter (RT) through intermediated nodes to the specific destination node. A battery is usually the power source for sensor nodes that were not replaceable or rechargeable, particularly if the sensor nodes are to run for a more extended period without any human interference.

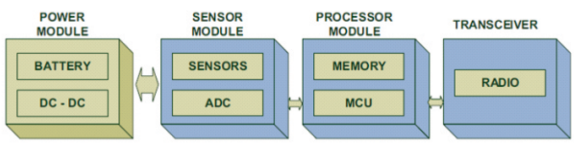

Figure 2: Node's Architecture in WSN

Specialised mesh topology routing protocols allow the sensing nodes to establish a broad range of communication and bind the virtual world to the environment in operation. Scientific advancement has culminated in decreased sensor size and costs and has triggered enthusiasm in the usage of broad unsupervised abandonment sensing groups. In the past several years, a comprehensive study has been conducted on the prospect of sensor cooperation in the data storage and measurement, tracking and management of sensing operations and data transfer to the target node. Sensors that communicate via wireless connections could create an ad-hoc network, which is natural to the distribution of collective sensors.

The network communication based on the wireless framework is organised in an adaptive way in which sensor nodes may coordinate themselves with little proper organisation. This is seen in most WSNs implementations. The task of sensing modules is to sense and collect data from a sensor area, measure data and return it to a central location via a radio module [2].

A single-hop transmission method is needed, followed by each sensing node transmitted directly to the sink-node. Multi-hop communication is an alternate method of sending data packets to the sink-node by utilising intermediate-nodes [3]. A routing method computes if the intermediate node sets are chosen, determining routes for sending information to its sink. Routing protocols may be categorised according to how the data was sent to the nodes to the destination-node.

In the development of WSNs, effective infrastructure administration is a key concern. This is possible with Energy-Efficiency technologies such as Energy Harvest, Radio Optimization, Energy Efficient routing protocols, Sleep or Wake-up and Data Reduction [4].

As sensing nodes energy is mainly used for receiving information and transfer [5], the conventional strategies for routing are primarily concerned with how to use the shortest possible route for transferring data from the source-node to the destination-node. Even though a significant volume of the information is transferred via the energy-contracted sensor network by "multiple-to-single" mode from a source node, quickly creating severe problems with the "philter influence" and the "power void". This means that nodes on the shortest path or sink-node consume much faster energy than another, leading to energy imbalances and lesser network existence.

Moreover, the "multiple-to-single" mode can start causing communication delays. For example, in the case of the main event, the nodes would have to send a significant volume of data to the sink-node in a limited period, resulting in congestion. Packet loss can lead to the removal of many data packets, which reduces wireless communication consistency. In the meantime, the network would contribute to excessive electricity usage and a delay in data delivery, thus reducing the use of resources. Any congestion research typically utilises such metrics to monitor the inflow rate. At the same time, traffic has been detected, and the upstream-node cannot manage the downstream-node flow rate for congestion avoidance. Numerous routing techniques are often used to minimise congestion favoured by idle-nodes. However, nodes may drain power according to routes [6].

This research concentrates on energy-efficient routing protocols, an approach to saving energy required to find routes for data transfer between source-node and destination-node. Some of the newly published reports dealing with communications related to energy-efficiency were published in [7]. The structure of the network architectures must therefore address the possible compromise for various network applications at the expenditure of energy-efficiency.

II. RELATED WORKS

In 2015, the authors in [8] suggested using route theory based on fuzzy, FuzzyLogic based EnergyOptimizedRouting (FLEOR) techniques, which showed a practical subjectivity when determining the weight of attributes, which means that the rules of the fuzzy were artificially determined. The lack of objectivity could not lead to the final decision being optimal. The theory of evidence by DempsterShafer (DS) is easy to estimate and reduced demands on previous information. It could even merge the multi-faceted characteristic of the sensor nodes with an acceptable theoretical and practical derivation and get a great decision. In the meantime, the theory of DS evidence is easier to compute and short in previous knowledge demand. This can also be used as a satisfactory interpretation to merge multiple sensor node characteristics and get excellent performance.

In 2016, the authors in [9] described an energy-efficient protocol for routing which reviews and classified the protocols according to sensor nodes' features. Participants have surveyed several forms of energy-efficient routing protocols.

In 2017, the authors in [10] presented a recent survey of network lifetime maximisation techniques to look back at new developments in WSNs that cover infrastructures, restrictions for deployment and forecast models for its lifetime.

In 2018, the authors in [11] proposed that the lowest power consumption tree should be established, then proposing the "cut-edge" method to sustain the load among nodes so that power can be used and the network's life gets extended. However, the software uncertainty and the overall communication requirements of the two algorithms are considerable and might well be in practical applications that consume too many resources. However, single-hop communication or a simple mathematical model in routing decision-making is not sensible, and different network attributes must also be considered extensively.

In 2019, the authors in [12] chose the nearby node with the lesser hops as the relay from a source-node to the sink-node and used the available bandwidth as its determinant if multiple tracks are available with the lowest hops. Thanks to this simple mechanism, the nodes can be placed, but it is not possible in scalability.

Although these surveys are far behind significant developments because of the lack of comprehensive evaluation data and frameworks, here in this survey, the general models for minimising energy usage have to be presented and addressed with a comprehensive review.

III. METHODOLOGIES

In WSNs, energy management is a series of principles for controlling different energy supply processes and then effective use of energy supplied in the sensor node. The ultimate target here is to control resources such that no node is energy deficient and the device continues to function. The practical energy management framework for the limited supply is essential for the sensor node, and the necessity for usage should be controlled according to the vital source of energy.

Energy is regarded as a limited power source for a node sensor, especially when a node is installed in a distant area. While usable energy is exhausted, supply energy is almost impossible[1]. However, balancing the energy management between supply and load is required to stop energy shortages in a network.

This survey intends to increase understanding of the different energy management systems within the research community. It defines the energy-efficiency in WSNs on two key aspects to providing an outline of the discussions. Initially, it addresses concerns about multiple sensor node energy distribution processes and briefly examines various methodologies and collection of energy-based protocol designs. The WSN Energy Management structure is shown in Figure 3.

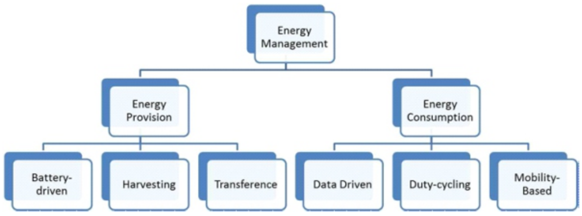

Figure 3: WSN Energy Management

Although in addition to processes for energy supply, diverse methods and protocols for energy-efficient usage have to be explored on each node. Many energy-efficiency initiatives in publications rely primarily on the energy use of active nodes. That objective would be to utilise techniques that understand the restricted supplies limitations and to create an application that consumes minimal resources. Therefore, the integration of power sources and energy utilisation leaves the door open for further successful and productive methods in WSN energy management.

This study describes the general design strategies for energy administration and provides a deeper understanding of how to improve efficiency in energy management. This survey results will conclude that adequate energy usage consumption must be considered before some energy storage mechanism is proposed other than energy sources. The present activities throughout this aspect will help even further to boost the experiment pattern. This survey may be beneficial in designing more successful energy control systems for this reason. Besides, also it promises a framework for improving the new energy efficiency schemes.

3.1 ENERGY PROVISION

For a sensor node, the most popular power supply is a battery that can be recharged or replaced depending on the condition it is being implemented. Numerous authors discovered alternative energy source pathways by environmental energy usage because of insufficient battery supplies. A sensor network will run almost perpetually by collecting ambient energy. Consequently, energy-based methods are constrained, as there may be situations in which a node get damages from a reduced potential of storage relative to its storage capacity. An energy deficiency node may therefore impact the entire system output in such scenarios. Recently, methods focused on energy conversion, where energy may be transmitted to an energy-deficient node in the region, are proposed. Such energy-deficient nodes are used in areas with minimal environmental storage possibilities. The transmission of wireless energy is now known as the most significant innovation.

The electricity supply systems may also be categorised as battery energy, environmentally-based energy and energy transport schemes. The battery-driven nodes are often graded according to either the battery source or the battery rechargeable. The collected energy differs even from lots of sources, typical of thermal, wind, solar. Mainly with the disintegration of energy transmission dependent supply, the latest development in WSNs has grown. LASER energy is the basis for energy transmitting schemes, including resonance of magnetic, reflection from solar and RadioFrequency (RF)/ microwaves. Every innovation aims to scoop potential sources for energy to have the maximum possible excess energy to maximise the system's existence.

3.2 ENERGY CONSUMPTION

Owing to its minimal energy consumption nodes and versatility, WSNs have been attracting significant attention in recent years. However, scientists are also still dissatisfied, and more attempts are being made to maximise energy usage by improving the reliability of the sensors powered by batteries. This article addresses many methods the research group has embraced to maximise the performance of battery-driven equipment to maintain the network on an ongoing basis. This research would have a fair overview of the main methods influenced by various protocols rather than addressing every other protocol individually. To precisely define the features of each system, we split our survey into three key subsections.

3.2.1 APPROACHES BASED ON DUTY CYCLING (DC)

DC is seen as a more productive way to improve the existence of the network. There is a wide range of algorithms wherein nodes change their DC to minimise battery usage by switching between sleep and wake-up modes. The concept will be to put the node in a low-power mode if no data connectivity is enforced. This avoids energy loss, as the nodes wake up whenever communication is required. These methods will extend the entire existence of the network while the battery is awake. DC-based techniques were segmented by different protocols considering minimal DC, such as topology based Control, Sleep and Wake up and MAC-based protocols.

(i) Protocols based on Topologies

Protocols that are based on topological apply to schemes that adhere to domain criteria of complex network topology. The plan is to establish a sleeping mode for specific nodes while retaining the network working and increasing the network's longevity as location-driven. Connectivity-oriented is two categorisations in this protocol.

In location-driven approaches, nodes are modelled on their role to sleep or wake up. The node's position is supposed to be identified. Nodes may collaborate to determine which node should be deactivated within a specified location without impacting their protected area. In connectivity oriented, it was a static structure where the administrator can preplan the model. The schemes to control the topologies attempt to minimise the topology and conserve it for the survival of the topology. Much of the activities in this direction are in the field of ConnectedDominatingSet (CDS) or the backbone to establish a reduced topology for other network nodes.

(ii) Protocols based on Sleep/wake-up

The protocols based on Sleep/Wake-up are classified as Scheduled Rendezvous, Asynchronous and On-Demand.

(a) Scheduled Rendezvous:

This helps nodes wake up in a scheduled manner and settle functional for a short moment, and afterwards, it triggers it to sleep-mode before another event arises rendezvous. Though these protocols it is feasible and synchronisation among nodes is essential. These systems often lead to some disadvantages as regards increased maintenance synchronisation.

(b) Asynchronous:

A node will then wake up regardless of the remaining nodes and always connect with all its neighbours. Access to the network even under very complex environments is simpler to install and assured. They are claimed to be much less energy-efficient such that higher DC than synchronous nodes is also accomplished.

(c) On-Demand:

This has been utilised in event-driven situations, in which nodes are expected for communication to wake-up. SparseTopology and EnergyManagement (STEM), PipelineTone Wakeup (PTW) and RadioTriggered (RT) sleep wake-up systems are typical examples of these systems. Multiple radios fix the problem of reminding an inactive node for waking up for signalling and more efficient for transmitting data with low-rate through low-powered radio. The protocol is optimal, but a wake-up device that is caused by radio would not function. It can be found only in cases when nodes are similar to one another. Moreover, the usage of a separate radio sounds impractical.

(iii) Protocols based on MAC:

An alternate DC method is by utilising low-powered protocols based on MAC. It was categorised as Contention-Based, Time-Division Multiple-Access (TDMA) and Hybrid-MAC.

(a) Contention-Based:

Instead, DC succeeds by the incorporation of the sleep or wake-up phase of a medium access feature. These methods are stable, flexible, and sustain a lower latency than other protocols, but they involve higher power usage due to disagreement and collisions.

(b) TDMA:

The DC in the nodes is only enabled if the connection to a channel is necessary. Each node is allocated a set time slot, and the expended energy is limited only to the corresponding time frame. The TDMA-based systems have energy efficiency since nodes switch on their radios in their time frames. These mechanisms are modular and versatile, but they are also closely coordinated and susceptible to interruption. These techniques are worse than contention-based methods and are thus only found in WSNs under limited traffic patterns.

(c) Hybrid-MAC:

This method resembles contention-based and TDMA, which combine properties for both protocols. This gets to function as a Contention-Based method while the contention level among the nodes was minimal, and if when the contention level was maximum, it gets to function as a TDMA. This is a complicated method that can only be executed when high node numbers are introduced.

3.2.2 APPROACHES BASED ON DATA-DRIVEN

Approaches based on Data-Driven were usually concentrated on growing the sample volume, thereby retaining a reasonable degree of sensors precision. These strategies may be categorised as schemes to minimise data and to obtain energy-efficient data. The programs for reducing the data will resolve unwanted samples. Data prediction is an additional categorisation for reducing a data process that relies on the development of abstraction of sensor information or that is a design towards predicting the data for future purposes.

Methods based on predicting the data be even further categorised into time-series, stochastic and algorithm-based methods. These methods engage at the cost of large computing expenditures in high-level calculations as aggregation. This is possible in circumstances that involve more significant battery sizes, whereby potent sensor connections are accessible on the network. In the time-series prediction, various historical values are derived from periodic samples and then used in the same series to estimate a potential value. These protocols presume that the node's sensing sub-system absorbs more resources than the sub-systems that are communicating. Such structures are also classified into Adaptive-Sampling, Hierarchical-sampling and Model-Based Active-Sampling.

(i) Sampling Based on Adaptive:

The primary objective is to lessen the quantity of information collected mainly from a transmitter by spatially or temporally correlating the data. Such systems were more extensive and more effective and are mostly centrally applied, needing high calculations.

(ii) Sampling Based on Hierarchical:

Various sensor types are mounted on nodes in this process. These systems seem to be quite energy-efficient yet even primarily applicable. The added transmitter costs could be higher is a significant disadvantage.

(iii) Sampling Based on Model-Based:

These are analogous to applications for data forecasting. The purpose is to minimise the number of information observations by utilising measured methods and resources by gathering data.

3.2.3 APPROACHES BASED ON MOBILITY

The usage of very few mobile nodes within the infrastructure will accomplish by the mobility-based approaches. In this, the mobile-nodes, depending on their actions, may be of two kinds. They are either entirely controllable or robotic in general, as part of a communications framework. These nodes could adopt a consistent mobility pattern. On the other side, the mobility of the nodes may be uncontrollable and unpredictable in the setting. In certain situations, though, they may adopt a trend of mobility which in general is either predictable or unpredictable. Algorithms focused on mobility may be split into two groups.

(i) Mobile-Sink based approach:

A mobile-sink is used to gather data from the field sources and maximise the network's lifespan. It has been seen to increase networks' lifespan 5 to 10 times over utilising mobile sink-nodes than with static sink-nodes. However, this could be considered the delay probability correlated with the arrival of data to the sink-node.

(ii) Mobile-Relay based approach:

For the retrieval of data from source nodes, the message ferry is used. In the region, these messages ferries gather the data, transport it, and forward it to the target node. Mobile transfers have almost the same characteristics as VANET data methods under which cars routinely access a data collection network. However, specific problems have to be resolved, such as sensors in the wake-up mode required for waiting for the vehicle to gather information. To fix how long a vehicle would have to wait for information from both the static-nodes and vice versa, it is essential to specify the transmission schedule whenever a sensor can forward data collected to the mobile element.

IV. DISCUSSION OF THE STUDY

In the energy consumption-based management systems, numerous energy-efficiency strategies the DC energy management approaches are proposed by numerous. In addition to DC, the latest technology also identifies with Data-Driven and Mobility-Based schemes. Topology management systems focused on DC are the newest energy-saving techniques, offering high energy quality and extended network lifespan. The advantages and disadvantages of the survey methods are given in Table 1.

METHODS	ADVANTAGES	DISADVANTAGES
Duty-Cycling	• The far more powerful means of boosting the network's battery life for Sleep/Wake-up modes. • Wastage of Energy is prevented since nodes just wake-up when a wireless transmission or reception is needed.	• Much command signal is required to preserve the connection of a distribution route. • These command signals use much further bandwidth and higher energy usage.
Data-Driven	• It is classified as energy-efficiency and data-reduction systems. • Future data forecasting based on a data processing model.	• The added transceiver expense could be viewed as a downside for these schemes. • Over-head infrastructure is a barrier.
Mobility-Based	• They may be either entirely controllable or robotic in general inside the network infrastructure. • These nodes might adopt a consistent mobility pattern.	• In certain instances, though, a mobility sequence that is either erratic or spontaneous in general can be followed. • Sensors must be in the wake-up phase constantly.

Table 1:Energy-Efficient Methods Advantages and Disadvantages

Almost all of the current initiatives, though, are still centred on energy quality dependent recycling. The efficient energy production of the devices, algorithms, software and sensor protocol was helpful, but they would inevitably yield when the batteries attached are exhausted. For example, an energy-efficient protocol dependent on spatial-temporary sensing operations may contribute to the deterioration of device functionality to extend network existence.

Thus this result showed that green technology is safer than utilising fixed energy at the point of network launch. It is already integrated with the node. The higher point of view in topological structure will improve the network's lifetime by adding it up with renewable energy sources and minimising the consumption of WSNs. This survey will be beneficial for the WSNs research community.

V. CONCLUSION

This survey article provided a detailed review of numerous WSN energy-management methods. This system was categorised into two types: provision for energy supply and consumption of the energy. Energy supply studies the characteristics of energy sources and builds architectures dependent on the abundance of energy, mostly on sensing elements. By comparison, schemes focused on energy usage apply to algorithms and protocols which would not include the energy supply of the node into account. The whole research focuses primarily on defining the ability of various protocols for energy management and attempts to use them effectively. A wide-ranging energy-efficient protocol could help handle its service when keeping the supply and usage of nodes into account. Thus it concludes by concentrating more on topological structures in tandem to construct an energy-efficient algorithm for the research group. Alternatively, environmental sources of energy and wireless techniques also need more development. Established supplies need increased energy management and recognition of the capacity for the discovery of new sources. The network existence may also be extended utilising a composite strategy composed of all resources (battery, ecological condition and wireless modules). Consequently, it would still be a matter of accessible science, and a great deal of work is needed to obtain a constant WSN.

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