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Multiple potential energy savings exist for wireless sensor networks.

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ABSTRACT

Many sensor nodes, connected wirelessly, are spread out throughout a given region to collect data and process it locally depending on what they find. While it is possible to replace or recharge the batteries in each network node, this begs the question: "how to prolong the network lifetime to such a long time?" Due to their ad hoc deployment in potentially dangerous environments, sensors cannot be readily replaced or recharged, making it a significant issue in WSN to maximize network lifespan while reducing energy consumption. We will review the most common methods for reducing sensor network power consumption, since this is now one of the most discussed issues in wireless sensor networks. In this article, we concentrate on data-driven ways that may be utilized to increase energy efficiency, and we also discuss duty cycle schemes, which represent the most suitable methodology for energy savings. Finally, we'll take a look at a few other sensor network communication protocols that have been suggested.

KEYWORDS

Wireless sensor networks,Energy saving, Data driven,Duty cycling

1. INTRODUCTION

Micro sensors have been developed as a result of recent developments in micro-electro-mechanical systems (MEMS), low power, and highly integrated digital electronics [1,17]. Sensor nodes in a wireless sensor network are dispersed throughout a region to collect data on environmental conditions such as temperature, humidity, vibrations, seismic activity, and so on [2]. Sensor nodes are typically small devices that include a sensing subsystem to collect data from the physical environment, a processing subsystem to do any necessary data processing and storage locally, and a wireless communication subsystem to transmit the collected data. In addition, the gadget receives the energy it needs from a power source to carry out the predetermined actions. The battery that provides this electricity often has a restricted capacity. Wireless sensor networks' initial inspiration came from military uses, such as battlefield monitoring. Due to its low cost, compact size, light weight, and ad hoc deployment; each sensor's limited energy, WSNs are increasingly employed in numerous civilian application areas, including environmental and habitat monitoring. Furthermore, nodes may be installed in a hostile or unsuitable area, making it unpleasant to recharge the battery. The goal at the network layer is to increase the lifespan of the network by discovering methods for energy-efficient route creation and reliable relaying of data from the sensor nodes to the sink. Sensors in a wireless sensor network are notoriously power-hungry compared to their standard wireless network counterparts. In addition, the reliability of the network has a significant impact on how well sensor network applications function [16].When the first sensor fails, we use it as the universal lifespan definition. The notion of lifespan suggested in [3] is commonly used in the study of sensor networks. The point at which a certain fraction of the network's nodes are completely powerless is one definition of the lifespan. Based on this definition,

in many ways it's quite close to the system we use here. A well-designed network's sensors all act in the same way to provide a stable energy supply. When a sensor fails, its neighbors will have to pick up the slack, and because we estimate the lifespan of several months to be several years, we may expect them to run out of energy pretty soon. Therefore, in constructing long-lasting wireless sensor networks, it is essential to minimize energy consumption. The remainder of the article is structured as follows: Section 2 covers the broad strokes of how sensor nodes may save energy (duty cycle, data-driven), as well as the most common ways that WSNs lose power. The duty-cycling method and energy-efficient MAC protocols in WSN are discussed in Section 3, and the data-driven methods are discussed in Section 4. The last chapter provides some final thoughts and addresses any remaining questions or concerns.

MAIN ENERGY-DRAINING PROCESSES IN WSNS

Such sensor systems have a limited supply of energy, which must be carefully controlled in order to keep the sensor nodes operational for the length of a given mission. A sensor node's energy consumption may result from either "useful" or "wasteful" causes. Data transmission and reception, query processing, and query and data forwarding to nearby nodes all use useful energy. The following are some of the many possible causes of unnecessary energy usage. Energy is wasted for two main reasons: first, collision (when a node receives multiple packets at once, these packets are termed collided), even if they only partially coincide, and second, idle listening (listening to an idle channel in order to receive possible traffic). The collision results in the loss of all packets and the need to retransmit them, both of which increase power consumption. Overhearing (when a node gets packets that are meant for other nodes) is another source of wasted energy. The fourth is due to control-packet overhead (only as many as are necessary for a given data delivery). Finally, over-emitting is wasteful from an energy perspective since it occurs when a message is sent before the receiving node is prepared to receive it. Given the above, it's clear that avoiding these energy leaks requires careful protocol design.

Thirdly, overarching strategies for conserving energy

Given the aforementioned problem and power breakdown, many strategies need to be used, sometimes all at once, to cut down on the amount of energy used by wireless sensor networks. At a high level, we single out two primary enablers: duty cycling and data-driven methods. The networking stack is the primary target of duty cycling. When communication is not necessary, the radio transceiver should be placed into sleep mode (which uses very little power). When no more data needs to be sent or received, the radio should be turned off and turned back on when a new data packet is ready to be sent or received. As a result, nodes respond to network activity by periodically going into an active and inactive state. The percentage of a node's lifespan that it is actively processing data is known as its duty cycle. Data-driven methods, which will be discussed in further depth in the coming sections [18], may be leveraged to further enhance energy efficiency.

3.1. duty-cycling

Transmission, reception, idle listening, and sleep are the four normal modes of operation for a sensor radio. According to the data collected, transmission accounts for the most of the energy used, although standby use is often quite close to that of reception. The opposite is true during sleep mode, when energy usage drops significantly. There are two methods that work together to accomplish duty-cycling. On the one hand, sensor networks' characteristic node redundancy may be used by selectively activating a small number of nodes for the sake of preserving connection. For specific uses

For many sensor network applications (e.g., event detection), the infrequency of actual occurrences means that most of the time, sensors are doing nothing. This has a negative impact on both the networks' longevity and their value. If a node is not presently required to maintain connection, it may enter a sleep state to save power. Topology control is the process of determining the minimum number of nodes required to ensure network connection. While passive nodes must always have their radio on, active nodes (those chosen by the topology control protocol) may turn it off when not in use. When there is no network activity, they may turn the radio off (or into a low-power sleep mode), allowing it to periodically sleep and then wake up. Power management is defined throughout as duty cycling performed on live nodes. Thus, duty cycling may be implemented with varying degrees of fineness via topology control and power management. It is possible to implement power management protocols as standalone sleep/wakeup protocols riding atop a MAC protocol, or as part of the MAC protocol itself. It is possible to employ a number of criteria to determine when and which nodes should be activated or deactivated. This allows us to classify topology control techniques into two basic categories: Protocols based on location determine when and which nodes should be activated. Geographic Adaptive Fidelity (GAF) [4], often called Geographic Random Forwarding (GeRaF) [5,19], is a forwarding scheme that takes into account the physical locations of sensors. To ensure network connection or full sensing coverage, connectivity-driven protocols dynamically activate and deactivate sensor nodes. On-demand protocols like Adaptive Self-Configuring Sensor Networks Topologies (ASCENT)[20]; location-driven topology and Span [6] are examples of connectivity-driven protocols that adaptively elect "coordinators" of all nodes in the network. It is essential for control protocols to be able to identify where sensor nodes are located. In most cases, this is accomplished by installing a GPS receiver on the sensor. The greatest common sense approach to power management is found in on-demand protocols. A node should only become active when it receives a request for communication from another node. The fundamental issue with on-demand schemes is how to alert a sleeping node that other nodes are ready to start talking to it. In order to do this, such strategies often use a pair of radios, one with a low data rate and low power for signaling and the other with a high data rate and higher power consumption for data transfer. Setting up prearranged meetings is another viable option. Scheduled rendezvous systems are predicated on the assumption that nodes should all awaken at the same time. To maintain connectivity with their neighbors, most nodes wake up at predetermined intervals and stay up for a brief period of time. They then retire for the night until the next scheduled meeting time. The last possible option is to implement an asynchronous sleep/wakeup protocol. Such protocols allow a node to wake up whenever it pleases while maintaining connectivity with its peers. This is accomplished via the sleep/wakeup scheme's assumed features, thus no direct communication between nodes is required. Nodes participating in on-demand schemes are only roused from sleep when they are expected to receive a packet from a close-by node. As a result, on-demand systems are well suited for low-duty-cycle sensor network applications (such as fire detection, machine failure monitoring, and more broadly; any event-driven situations) due to their low energy requirements. In conclusion, many criteria may be utilized to determine the states of individual nodes and the timing of their activation or deactivation. Therefore, there are essentially two types of topology control protocols: the first location-driven; the position of sensor nodes is considered to be known and is used to choose which node to activate and when [23]. Second, in order to maintain network connectivity, connectivity-driven sensor nodes are dynamically activated and deactivated [24, 25]. The implementation of such schemes typically necessitates two channels: a data channel for regular data communication and a wakeup channel for reawakening nodes as needed. The wakeup signal and data packet transfers in Sparse topology and Energy Management (STEM) [7] are sent over two separate radios. For reasons having to do with varied broadcast ranges, the wakeup radio is not a low power radio. This is why the wakeup radio has a non-synchronized duty cycle. Every node activates its wakeup radio at regular intervals of tactive every T seconds. In order for one node (the source) to talk to another (the target), they will send out a series of beacons at regular intervals on the

alarm clock TV. After being alerted by a beacon, the destination node activates its data radio and responds with a wakeup acknowledgment. STEM-B[22] is a beacon-based method; in, the authors offer a variation (STEM-T) that use a wakeup tone instead of a beacon. The key distinction is that STEM-T activates all neighboring nodes rather than just the one. Topology control procedures may be employed with either STEM-B or STEM-T.It presents a Pipelined Tone Wakeup (PTW) technique to strike a balance between power efficiency and wakeup latency. Similar to STEM, PTW[21] employs a wakeup tone to rouse nearby nodes and utilizes two independent channels to broadcast wakeup signals and packet data. Therefore, any node near the originating node will be awoken. All nearby nodes must awaken at the same time for a rendezvous strategy to function properly. Every so often, a node will awaken to check for incoming signals before falling back to sleep until the next scheduled rendezvous. The primary benefit of such methods is that it is assured that all neighboring nodes are awake while any given node is awake. Broadcast messages may then be sent to all nearby neighbors [8]. On the other hand, nodes must be synchronized in order to wake up at the same moment in planned rendezvous systems. In WSNs, power management via node napping has been the subject of substantial research. There are three distinct types of power management systems now in use. In the first group, you'll find TDMA techniques like TRAMA [26] and DRAND. Unfortunately, TDMA networks are inefficient for applications that have stringent and dynamic delay requirements since each node must wait for its time slot to broadcast. Synchronous duty cycling procedures, including S-MAC and T-MAC, are the focus of the second group. The main problem with these protocols is that they need regular synchronization of node sleep cycles, which may cause unnecessary energy consumption and communication delays. Asynchronous channel polling protocols, such as B-MAC and X-MAC[27], are the third category of power management strategies; nodes in these protocols awake at regular intervals to check the channel for activity. The energy consumption of the nodes is significantly affected by the medium access control (MAC) protocol, which controls the communication module directly. There are five main causes of energy waste, and academics have suggested several MAC protocols to increase energy efficiency and extend the lifespan of networks. The following are characteristics of a good media access control (MAC) protocol for WSNs. Network lifespan may be increased by prioritizing three characteristics: energy efficiency, scalability, and flexibility. The network's connection and topology should be able to be restored quickly and efficiently despite fluctuations in network size, node density, and topology caused by the MAC protocol. Latency, throughput, and bandwidth utilization are also crucial, although they may take a back seat in sensor networks [9].

1.1. ENERGY EFFICIENT MAC PROTOCOLS FOR WSNS

Depending on the channel access policy, the various energy-efficient MAC protocols are briefly discussed and placed into one of four broad categories: contention-based, TDMA-based, hybrid, or cross-layer. The benefits and drawbacks are then briefly discussed. There is no need for coordination between the nodes using the channel when using a contention-based MAC protocol, such as the Carrier Sense Multiple Access (CSMA) or Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA). When a node wants to transmit data, it will battle with other nodes for access to the available wireless channel. When two or more nodes try to access the same channel at the same moment, a collision occurs. S-MAC (Sensor-MAC), T-MAC (Timeout-MAC), and U-MAC (Utilization-MAC) are the most common contention-based MAC protocols. Multiple Access Channel Protocols Based on Time Division Multiple Access The scheduling-based TDMA approach, in contrast to contention-based MAC protocols, provides an inherently collision-free system by designating a distinct time slot for each node to transmit and receive data. The first benefit of TDMA is that it eliminates the potential for interference between neighboring wireless networks. As a result, the power lost due to packet collisions is diminished. Since TDMA allows for transmission from nearby nodes during separate time slots, the hidden terminal issue may be addressed without incurring any additional message cost. Energy-efficient MAC (E-MAC), Dynamic Energy-efficient MAC (DEE-MAC), and Slot Periodic Assignment for Reception MAC (SPARE MAC) are three of the most important TDMA-based MAC protocols. Some hybrid MAC protocols, which combine the benefits of contention-based MAC with TDMA-based MAC, have been developed in recent years. All of these protocols use a split-in-two structure for the access channel. Data packets are sent via the planned access channel, whereas control packets use the random access channel. Hybrid MAC protocols outperform both contention-based and TDMA-based MAC protocols in terms of energy efficiency, scalability, and adaptability. In particular, Z-MAC (Zebra MAC), A-MAC (Advertisement-based MAC), and IEEE 802.15.4 [9] make up the hybrid MAC protocols.At the conclusion of this part, we are given a concise explanation of the most significant energy wasters in a MAC protocol for WSNs. Collision: When a packet is damaged during transmission, it must be deleted and subsequent retransmissions of data packets and control packet overhead increase energy usage. In addition, less-important data packets may be sent. Energy is wasted when a node is idle and listens to network traffic when it has not transmitted any packets. This happens when the node picks up packets that are meant for other nodes.

1.1.1. S-MAC

In any given time period, you may be either awake or asleep. The energy-wasting issues are effectively addressed by S-MAC[28] by the use of a method that involves periodic listening and resting. A node is more likely to be sleeping than to be actively monitoring the channel while it seems to be inactive. By allowing the node to enter periodic sleep mode, S-MA shortens the duration of the listen phase.

Figure 1. Periodic Listen and Sleep

There are two methods that may be utilized to make S-MAC resilient to synchronization failures. To begin, no absolute timestamps are ever sent around, just relative ones. Second, in contrast to TDMA techniques with relatively small time slots, the listen period is much greater than the clock error or drift. S-MAC calls for much less precise synchronization between adjacent nodes. Here's a quick rundown of the procedure: S-MAC's primary objective is to lessen the load on the electricity grid, and it does so in three ways: This protocol avoids collision and overhearing by having nodes go to sleep when they detect an RTS or CTS packet, with the duration field in each packet indicating how much time is left in the current transmission. Figure 2 depicts this type of communication between senders as a form of message passing.

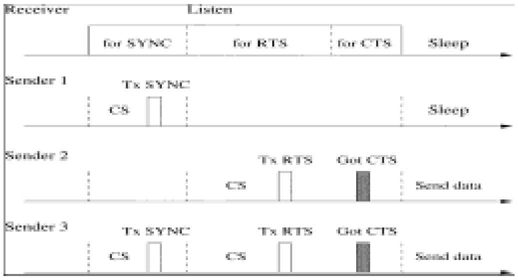

Figure 2. Investigate CTS and RTS Packet

A SYNC packet is used to synchronize schedules on nearby nodes, which is necessary for the listen/sleep scheme. Due to the findings of this study, the effectiveness of the algorithm suffers with varying traffic loads since sleep schedules and listen times are predetermined and fixed, hence reducing energy loss caused by idle listening. Sleep schedule announcements have the potential to eliminate the burden of global time synchronization while also reducing the energy loss caused by idle listening, making the sensor MAC protocol an attractive option. The S-MAC has a constant active time, or a constant duty cycle. The situation is sub-optimal. a) Even if the message rate is low, there is still energy loss due to passive listening. b) The method is less effective when the traffic load varies since the sleep and listen durations are fixed. c) The high cost of the long listening time, during which nobody transmits unless absolutely necessary. d) Constant time-syncing burden, even when no users are online, and f) Data transmission overhead caused by RTS/CTS and ACK

1.1.2. T-MAC

T-MAC [29] is an extension of the previous protocol which adaptively adjusts the sleep and wake periods based on estimated traffic flow to increase the power savings and reduce delay. TMAC also reduces the inactive time of the sensors compared to S-MAC. Hence, it is more energy efficient than S-MAC.

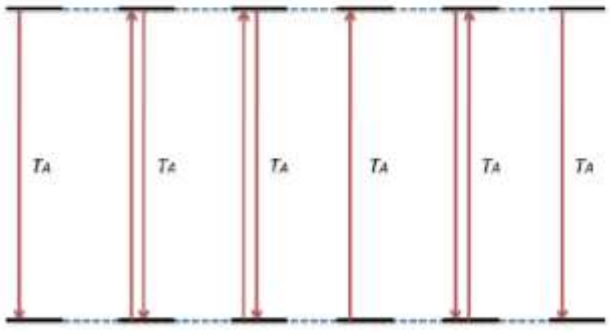

Figure 3. The Basic T-MAC Protocol Scheme with Adaptive Active Times

This protocol has proposed to enhance the poor results of S-MAC protocol under variable traffic load that listen period ends when no activation event has occurred for a time threshold TA

.Reduce idle listening by transmitting all messages in bursts of variable length, and sleeping between bursts and the end of advantage this type of MAC is times out on hearing nothing.

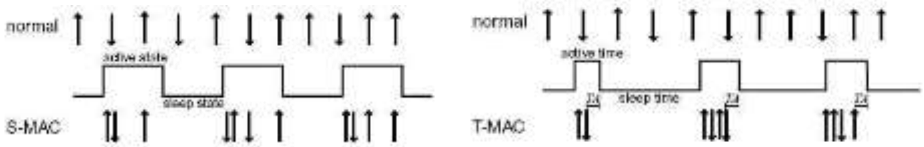

Figure 4. Comparison of S-MAC and T-MAC

Can be said that T-MAC gives better result under variable load and suffers from early sleeping problem, node goes to sleep when a neighbor still has messages for it.

1.1.3. U-MAC

U-MAC [30] provides a method to enhance the efficiency of energy use in several wireless sensor network programs. As illustrated in Figure 5, a communication in U-MAC may cease at either the planned listen time (represented by "a") or the scheduled sleep time (represented by "b"). The node will continue listening until the next planned sleep time d if a transmission terminates at the scheduled sleep time b, resulting in wasted energy between b and the next scheduled listen time c. U-MAC is derived from the S-MAC protocol and offers three key enhancements over S-MAC: a wider range of duty cycles, adjusting of duty-cycle depending on usage, and selective sleeping after transmission. Each node is given a duty cycle and communicates with its neighbors and peers at regular intervals to coordinate its schedule. Additionally, the time of a node's next sleep is tacked onto the end of ACK packets. It prevents RTS retransmission due to neighbors failing to provide updated schedules..

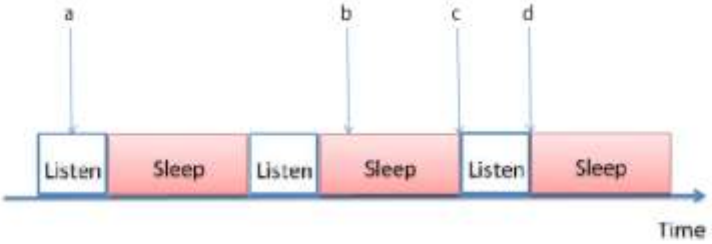

Figure 5. A transmission may end at scheduled sleep time or listen time

1.1.4. µ-MAC

To achieve large sleep ratios while keeping communication latency and dependability within reasonable bounds, the -MAC [31] is suggested. The -MAC, seen in Figure 6, presupposes the use of a single time-slotted channel. The protocol operates in cycles of contention and non-contention. During the contention phase, the network's architecture is established and transmission sub-channels are set up for the first time. The -MAC classifies subchannels into two types: regular traffic and sensor data. The contention phase in the -MAC protocol is time-consuming and resource-intensive.

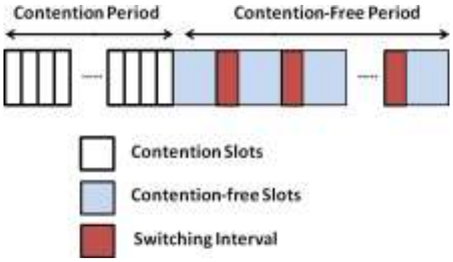

Figure 6. Time Slot Organization

1.1.5. DEE-MAC

DEE-MAC [33] is a method for conserving energy by putting sleeping idle listening nodes in sync with the cluster master. The radios in sensor networks may be switched off during non-transmission periods to save power, making MAC protocols based on time division multiple access (TDMA) a logical option. Furthermore, clustering is a powerful distributed approach used by massive WSNs. It is possible to combine clustering strategies with TDMA-based methods to lessen the financial burden of unnecessary listening. Like the LEACH system [14], DEE-MAC operates in iterative "rounds." A round is the amount of time that elapses between when a node broadcasts its interest in an event and when it gets a response from the event. Each cycle consists of a clustering phase and a transmitting phase. These two stages make up the whole of DEE-MAC activities. There is a period of cluster formation followed by a phase of transmission in each cycle. During cluster creation, a node evaluates its remaining power and selects whether or not to become the cluster leader. The strongest node in the cluster is chosen to serve as the group's leader. With each subsequent iteration, the network's structure and node power dynamics evolve to accommodate a new cluster of nodes with a new set of nodes. The transmission phase begins after a cluster leader has been elected. In this stage, there will be several sessions, each of which will have a contention period and a data transmission period. During the contention phase, all nodes in the cluster maintain an active radio and signal their desire to transmit data to the node in the center of the cluster. After this time has passed, the node with data to transmit will be identified by the cluster head. The cluster master creates a TDMA schedule and sends it out to all of the nodes. In each session, one data slot is allotted to each node. Each node that has data to transmit or receive is woken up in accordance with the schedule that has been published. Reducing the cost of idle listening in massive wireless sensor networks is rationally addressed by clustering and TDMA based techniques. The DEE- MAC, on the other hand, is built for "event-driven" software. Energy savings may be increased further by using inter-cluster communication through nodes rather than only the cluster heads, and by assessing the mistake potential in a packet during the contention phase.

1.1.6. SPARE-MAC

SPARE MAC is a MAC protocol that uses TDMA to disseminate information among WSNs. SPARE MAC's basic concept is to save energy consumption by suppressing unnecessary listening and traffic overhearing. To do this, SPARE MAC employs a distributed scheduling method, which works by allocating certain radio resources (i.e., time slots) to each sensor node for reception, and then communicating this information to surrounding nodes. As a result, the RS of a receiving node may trigger the activation of a sending node [9,10].

1.1.7. Z-MAC

Z-MAC [32] is one of the most intriguing hybrid protocols. Z-MAC initiates an initial configuration phase during which the primary transmission control method is defined. Through the use of neighbor discovery, every node is able to compile a list of its closest neighbors. Finally, a distributed slot assignment mechanism is used to rule out the possibility of two nodes in the two-hop neighborhood sharing a slot. Therefore, it is assured that no two-hop neighbor's transmission will be disrupted by a one-hop neighbor's broadcast. The purpose of the local frame exchange is to settle on a time period. Z-MAC does not use a universal frame size that is the same for every node in the network. When a topological shift happens, it will be exceedingly difficult and costly to adapt. Z-MAC, on the other hand, enables each node to keep its own local time frame independent of its disputing neighbors. Each node reports its local slot allocation and timing constraints to its two-hop neighbors. As a result, every node knows the reference slot and frame of every node in its immediate two-hop neighborhood. The transmission control process is now in effect, and the nodes may begin accessing the channel. There are many possible states for nodes. There are two types of conflict levels: low (LCL) and high (HCL). If a node has not received an Explicit Contention Notification (ECN) during the current TECN period, it is included in the LCL. When nodes are experiencing heavy congestion, they will send out ECNs. Only the current slot's owner and their one-hop neighbors may engage in contention for the channel in HCL. In LCL, both owned and non-owned nodes may vie for use of every available transmission time slot. But owners get preference over those who aren't. Since a node in Z-MAC may simply transmit whenever the channel is free, it can take advantage of the high channel even when congestion is minimal. Z-MAC uses a combination of TDMA and CSMA. ZMAC uses TDMA to enhance contention resolution, with CSMA serving as the foundation MAC scheme. The idea of a "owner slot" is fundamental to Z-MAC. Each node is assured access to its own slot (TDMA style) and subject to slot contention (CSMA style) for all other slots. By doing so, we can cut down on both energy use and collisions. Z-MAC is made up of two primary parts. Local framing and synchronization and neighbor discovery and slot assignment are two such methods.

1.1.8. A-MAC

A-MAC is a newly suggested medium access control that is tailored to long-term monitoring and surveillance tasks in order to offer collision-free, non-overhearing, and low-idle-listening transmission services. In such uses, nodes stand guard and are otherwise dormant until something triggers their action. While A-MAC will significantly extend the lifespan of a network, it will also introduce some delay at an acceptable level. The main benefit of AMAC is that it alerts nodes in advance of their turn as packet recipients. Only while acting as a transmitter or receiver does a node remain awake; otherwise, it just goes to sleep. Overhearing and pointless listening are both eliminated as potential sources of wasted energy.

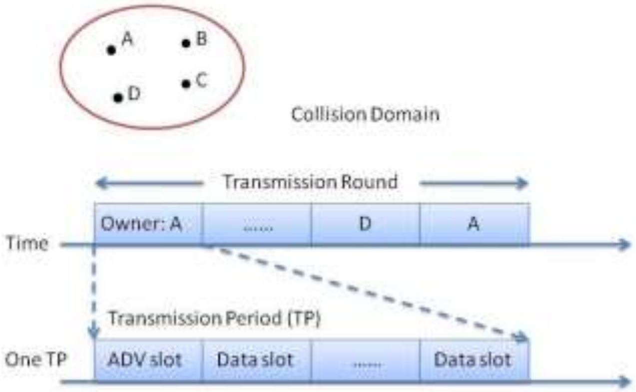

Figure 7. Structure of A-MAC

1.1.9. WiseMAC

In this protocol [34], all nodes defined to have two communication channels: data channel uses TDMA and control channel uses CSMA, preamble sampling used to decrease idle listening time. Sample nodes have the medium period to see if any data is going to arrive that is shown in figure 8.

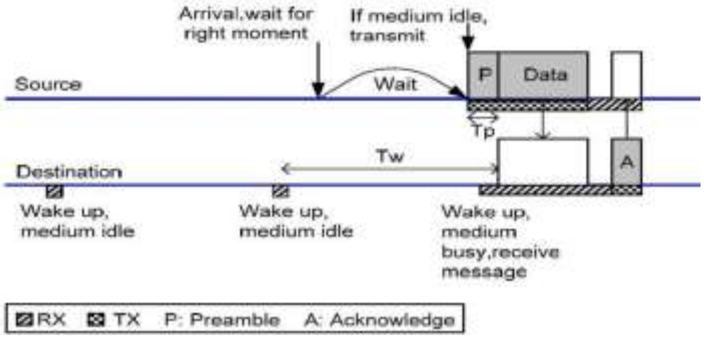

Figure 8. Structure of WiseMAC

This protocol has several features that we describe briefly: At first, the preamble length adjustment is dynamic that causes the better performance. Secondly, conflict, when one node starts to send the preamble to a node that is already receiving another node’s transmission where the preamble sender is not within the range; another problem in this protocol is hidden terminal problem.

2. DATA-DRIVEN APPROACHES

Data-driven methods may further enhance energy efficiency. There are two ways in which data sensing affects the power needs of sensor nodes: Excessive sampling. The power consumption of the sensing subsystem may be reduced since most samples exhibit significant spatial and/or temporal correlations [11]. This eliminates the need to send redundant information to the sink. When the sensor itself is a power hog, cutting down on communications is not enough. In the first scenario, unnecessary samples lead to wasted energy and communications, even if the sampling costs are small.The second problem arises when the power used by the sensor subsystem is significant. Methods that are data-driven may be broken down into those that use data reduction strategies to deal with excess samples,

whereas the primary focus of energy-efficient data collecting techniques is to lessen the load on the sensor network. In-network processing and data prediction, two subsets of data reduction, will be explored in depth below. Data aggregation (such as calculating the average of certain variables) is performed at intermediary nodes in the network on the way from the sources to the sink as part of in-network processing. This reduces the total quantity of data that must be sent over the network on its route to the sink. To anticipate data, one must first construct an abstraction of the phenomena being sensed, such as a model defining the development of the data. The model resides at the sink as well as the sensors so that it may make predictions about the data observed by the nodes with a certain margin of error. If the accuracy requirements are met, the model may be used to assess user requests at the sink without retrieving the precise data from the nodes.

2.1. Data Prediction approaches and in-network processing

Data prediction methods provide a model of the perceived phenomena, allowing for questions to be addressed without access to the raw data itself. As many pairs of models as there are sources exist in the network, with one located at the sink and the other at the source nodes. Database researchers have created many query methods for sensor networks including TinyDB and Cougar. In addition to these examples, several academic papers have explored methods for query processing in sensor networks. A few examples include energy-efficient routing protocols, in-network query processing methods, approximate data query processing, strategy adaptive methods, and plan optimization over time. The vast majority of these research have focused on improving the performance of only one very lengthy query. The impact of various route trees on data aggregation was investigated by Demers et al. The network nodes do several query optimizations in this effort. This procedure should determine when and how queries may exchange partial data and how redundant data can be removed along the way. The smallest possible amount of data is sent to the base station by using an appropriate encoding algorithm [14].One strategy is the first formal paradigm for optimizing numerous queries in sensor networks. In this particular effort, we focus on aggregating queries that are geographically specific. Instead of instantly sending queries to the nodes, the query optimizer at the base station groups requests sharing the same aggregation operator into batches. The primary concept behind this strategy is to reduce down on the number of regions needed to run the queries by combining linear reduction and a combinational approach. The optimization of many queries was seen by Muller at el [35,36] as a rewriting and merging queries challenge. The goal of this strategy is to allow numerous queries to make use of the same sensor network. In this configuration, the base station houses a processing unit responsible for aggregating individual inquiries into a unified network request. The user's query has to be narrower than the network's. This means that every possible user query must be included in the network query. In addition, the network query's sampling frequency must equal the quotient of the users' individual query sampling frequencies. The base station receives the network result from the nodes once the query has been inserted into the network. Then, the individual users' extracted results are sent to them. The primary benefit of this approach is that there is only ever one parent and one channel for any given result to spread via any given network node. Separating inquiries into "backbone" and "non-backbone" categories is another method [38]. Normal query propagation means that the backbone queries' partial results should be shared with the non-backbone set queries. The primary objective of this technique is to find the optimal number of nodes in the backbone tree so as to reduce the overall amount of messages sent throughout the network. The issue is tackled by transforming it into a Max-Cut problem. Based on the queries, a network is constructed with each query represented by a vertex and the amount of reduced messages shared between two questions represented by the edge weight. In order to pick the optimal subset of backbone queries, a heuristic approach is applied on the generated network. Taboo-Aware Indexing and Querying Protocol [37]

query optimization technique that sorts queries to get the best possible combination. The first kind of data prediction methods derives from an initial stochastic characterisation of the phenomena, especially in terms of probabilities and statistical features. The following are two primary methods in this vein. One might use a probability density function (PDF) to transform data into a random process. Combining the calculated PDFs with the observed samples yields data prediction. A good example of this strategy is the Ken solution [12]. The basic idea is the same as what was presented at the beginning of this section; there are probably many models, and each is copied at the source and sink. In this scenario, the foundational model is probabilistic, meaning that, during training, an attribute-specific probability density function (PDF) is generated. The source node refreshes the model and sends a set of samples to the sink when it is no longer valid, allowing the sink to refresh the relevant instance. Second, it is common practice to model time series using moving averages (MA), autoregressive models (AR), or auto-regressive moving averages (ARMA) for forecasting purposes. The simplicity of these devices belies their usefulness in a wide range of applications where they perform well. While more complicated models (such as ARIMA and GARCH) have been created, their incompatibility with wireless sensor networks limits their use. In the end, we employed the presented models and algorithms for data prediction in wireless sensor networks. They all employ algorithms to make predictions based on heuristic or behavioral descriptions of the observed occurrences. The most influential methods of this kind are discussed below. Stochastic approaches employ a broad and sound approach and provide us the tools to carry out complex tasks like aggregation. The fundamental problem with these methods is that they need too much processing power for most modern sensors.When several high-powered sensors are accessible, such as Stargate nodes in a heterogeneous wireless sensor network, stochastic techniques may become more practical. Possible developments in this area might concentrate on creating streamlined distributed models to achieve the appropriate balance between computational complexity and accuracy. However, when using low-order AR/MA models, time series forecasting methods may still achieve sufficient accuracy. This makes their incorporation into sensing devices easy and portable. Furthermore, most cutting-edge methods, including [13], do not need the transfer of all sensed data until a model is produced. In addition, they enable us to spot anomalies and discrepancies in our models. However, the model utilized is one that is well-suited to portraying the occurrence in question.A-priori validation is needed for this, which isn't always possible. Taking a multi-model approach is an exciting new development. Since this method has not been thoroughly investigated, there is opportunity for more study and enhancements. Finally, algorithmic methods must be evaluated individually, since they are often case-dependent. In order to determine whether or not a certain solution is effective for a given category of applications in the actual world, research might be directed in that direction.

3. CONCLUSIONS

For WSNs, energy is a crucial resource. The majority of published papers on WSN routing highlight energy efficiency as a key performance indicator. However, energy efficiency alone is insufficient to successfully extend the lifespan of a network. Network partitioning and a poor coverage ratio are common outcomes of uneven energy depletion, both of which have a negative impact on performance. In recent years, there has been a lot of focus on finding ways to reduce energy consumption in wireless sensor networks, which has its own set of issues compared to more conventional wired networks. To overcome these restrictions, researchers have put in a lot of time and effort designing strategies to maximize output with the same input. In this work, we provide a brief overview of the literature concerning energy-efficient sensor technologies. networks. Many of these methods for conserving energy show promise, but there are still significant obstacles to be overcome before they can be widely used in sensor networks. Therefore, further study is needed. crucial for dealing with similar scenarios.

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