RESEARCH ARTICLE

SAMRIDDHI Volume 14, Issue 3, 2022 Print ISSN: 2229-7111 Online ISSN: 2454-5767

Energy Efficient Medium Access Control (MAC) Layer Protocol for Wireless Sensor Network

Akant K. Raghuwanshi*, Virendra S. Chaudhary

Electronic and communication, RKDF University, Bhopal, Madhya Pradesh, India

Abstract

The primary concern in the design of Wireless Sensor Network Media Access Control protocols is energy efficiency. As a result, when constructing Wireless Sensor Network nodes, energy efficiency must be taken into account. Most sensor network applications necessitate energy management and sufficiency over the node's lifetime, which might be several years. They must work together for common applications such as environmental monitoring and data collection. Each component consumes the least amount of power, ensures the average successful transmission rate, minimizes the average data packet waiting time, and reduces the average energy consumption. The wireless sensor network's lifetime is totally determined by the energy consumption of the nodes. As a result, the sensor nodes must spend their energy wisely. Media Access Control methods created for Wireless Sensor Networks sought to greatly reduce the ensuing energy waste when compared to existing protocols. The Media Access Control protocol is introduced as a novel routing protocol to promote energy economy and extend the lifetime of the wireless sensor network by providing load balance. This paper discusses and examines Media Access Control techniques designed for energy savings in Wireless Sensor Networks. Actual results, such as the limitations of Media Access Control protocols and existing methods that can be improved, will be obtained at the end of the study. Furthermore, the protocols used by Wireless Sensor Networks were explored in depth, as were the protocols that avoid energy waste in the Media Access Control layer. At the completion of the study, it is to find the best Media Access Control protocol for reducing energy waste and to provide opinions to help eliminate the protocol's flaws.

Keywords: MAC, Routing Protocol, RTS-CTS Handshaking, Wireless Network, Sensor Network.

SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology (2022); DOI: 10.18090/samriddhi.v14i03.05

Introduction

Wireless Sensor Networks (WSNs) are wireless devices that use sensors to monitor physical or environmental conditions such as light, heat, pressure, pollution, humidity, sound, noise level, vibration, and asset mobility in various locations.[1] Sensors are used by WSNs to keep track of physical and environmental conditions. These are wireless networks composed of self-contained devices distributed according to their location. These self-contained devices, also known as sensor nodes (SN), are connected to routers and a gateway to form a unique WSNs system. Each node comprises a processing capacity (microcontroller), numerous types of memory, an RF transceiver and power supply (battery, battery), and various sensors and actuators. After propagating in ad hoc mode, nodes connect wirelessly and self-organize. When it comes to the way people live and work, WSN's systems might be described as revolutionary.

A WSNs system is an ideal application to provide a solution by spreading the findings to be obtained due to the physical conditions of the environment and climate measurements over the long term. Wireless sensors for utilities such as electricity and water grid and street lights offer low-cost methods by collecting healthy data to reduce energy use and better manage resources. In addition, WSNs are used to monitor highways, bridges, and tunnels effectively. A typical UCA consists of dozens of small but effective ADs that self-organize in wireless environments, provide interconnection, and exchange data.[2] With the advancement of technology, small, energy-consuming, and multifunctional ADs have been developed. One of the most important problems encountered when designing UWA is energy waste. Energy waste can be seen as the soft belly of WSNs because the battery can run out at any moment.

Corresponding Author: Akant Kumar Raghuwanshi, Electronic and communication, RKDF University, Bhopal,Madhya Pradesh, India, e-mail: akantthakur7@gmail.com.

How to cite this article: Raghuwanshi AK, Chaudhary VS. (2022). Energy Efficient Access Control MAC Layer Protocol over Wireless Sensor Network SAMRIDDHI : A Journal of Physical Sciences, Engineering and Technology, 14(3), 270-279.

Source of support: Nil

Conflict of interest: None

Moreover, ADs, whose power source is a battery, have minimal energy. Therefore, preserving, maximizing and saving this energy is the most critical issue in WSNs; Media Access Control (MAC, Medium Access Control) protocols have been developed to deal with this situation;[2] because the energy expenditures of ADs are also affected by the existence of the WSNs. Therefore, the most beneficial use of the energies of ADs has a vital value in the continuation of the tasks of the WSNs numerous studies have been conducted in the literature for the efficient and effective use of energy.

The main purpose of this study is to contribute to the management of increasing energy efficiency. This article will be presented in the following order: Section 2 explains system architecture in UCAs. In section 3, comprehensive information about sensor nodes is presented. In Section 4, the MAC protocol structure is mentioned in UCAs. In section 5, the general view of the UACs and the MAC structure will be examined. While comparisons are mentioned in MAC protocols in section 6, in section 7, energy efficiency comparison has been made in the protocols and summarized in a table. Relevant results are given in section 8.

Wireless Sensor Network

WSNconsists of a large number of distributed small ADs created to measure physical parameters such as temperature, pressure or relative humidity and to monitor the system. ADs have limited computing power, memory capacity, and limited communication capability. WSNs are highly preferred because of their ease of use and ability to reach everywhere. Advances in wireless systems have made it possible to create low-cost, less energy-consuming, multifunctional small detection devices. Through thousands of aforementioned tools, "ad-hoc" networks are occurring. These devices are scattered over an immense area, resulting in an "ad-hoc" environment merger without a physical connection. The randomly placed "ad-hocs" and the sensor forming the network create a detection network system by cooperating.[1-4] Sensor networks make it possible to access data instantly and comfortably from anywhere. It performs these by performing various operations on the data. In this way, WSNs is used very effectively. UCAs can consist of many SNs that do not need maintenance and repair, do not require human intervention, and can work independently from each other collectively. Even if the coverage area of only a single node is small, densely distributed SNs work simultaneously and on the principle of cooperation, thus extending the scope of the network.[5] SNs spread around the environment and created an automatic topology. ADs carry out data flow to the main node (sink) and the base station via the gateway. The network infrastructure is directly connected to the application. SN's large macro detectors provide excellent efficiency, unlike conventional sensor systems, because in traditional systems, cables have to be used until the user. Such that; if a macro sensor fails or its work is interrupted; while the sensor's function completely collapses in the area where the sensor is located in the traditional system, SNs continue to create data even if a small part of the micro-sensor in the same area fails; because fault tolerance is possible in SNs. In addition, each SN is built competently with wireless connectivity and hardware enough to transmit data with signal processing. Due to the limited energy, processing power, and communication resources, it is essential to use many SNs for high efficiency regardless of the area.[6]

Assuming that the battery of an SN is depleted or broken, or another obstacle intervenes, moreover, communication is interrupted due to this obstacle, after the sensor network setup is made, other sensors sending or waiting for data to that SN will understand the situation and organize the reorganization of the topology in that area. In other words, all information that will pass through the corrupted SN is redirected, and all connections with the broken SN are broken.

Sensor Nodes

The general structure of SNs consists of detection, processing, receiver/transmitter, and power units.[7] Figure 1 shows the general structure of the SNs, where the microcontroller processes the data and controls the functionality of other components in the SNs.[8] The transceiver uses the ISM (SBT, scientific and medical device band) band of SNs. The power supply calculates the energy consumption in the SNs. While energy expenditure is higher for data communication in SNs, it is less for detection and data processing. It can say that the energy level required to transfer one kilobyte of data to a distance of one hundred meters is approximately equal to the energy needed to process 3 million commands on a processor that processes one hundred million instructions per second.[9]

The sensing unit detects physical units such as humidity, pressure, and temperature and converts them into quantitative signals that the processing unit can grasp. The processing unit is the part that manages the SN. The Transceiver unit offers the possibility of communication between SN and WSN. The power unit is the most important part of the SN. It is used to meet the power requirement of other units in the SN (See Figure 1).

Sometimes a battery is added for the power unit to last longer or maintain sensor node. In some implementations, a routing unit is required to process the detected data. The envisaged routing protocols show that the routing system is a requirement in SNs. On the other hand, it is also recommended to use relocations for moving SNs. An energy-efficient MAC protocol aims to minimize the four main problems that cause energy waste: idle listening, overhearing, collision or distortion, and control packet load.

Important Causes Of Energy consumption

Some of Major issues has discussed below,as stated for excessive energy consumption in the MAC layer, is mostly caused by the number of packets and unnecessary listening

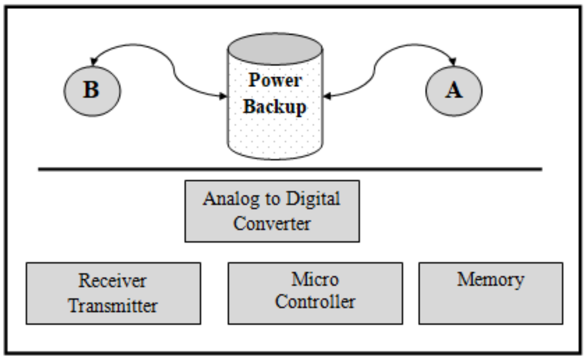

Figure 1: General structure of Sensor Node

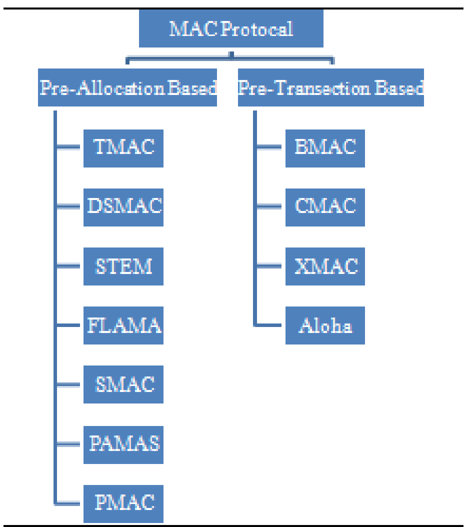

Figure 2: Classification of MAC protocols

of the environment, unnecessary data acquisition, and most importantly, conflicts. Unnecessary listening to the environment causes a huge amount of energy wastage.[3] It is the case of unnecessary SNs who overhear the environment instead of going to sleep and receiving data involuntarily. In other words, all SNs in the cluster receive and transmit messages unrelated to them. This means wasting energy. In addition, it is usual to have situations that consume too much energy, such as a collision of received packets during sending. As a result, the life of SN decreases rapidly; accordingly, it will be exhausted on the WSN.

Idle listening: When nodes have nothing to send or receive, the nodes remain active and listen to the network in vain. This process also consumes an equal amount of energy as when sending or receiving. Thus, it causes energy waste.

- **Idle Listening:** When nodes have nothing to send or receive, the nodes remain active and listen to the network in vain. This process also consumes an equal amount of energy as when sending or receiving. Thus, it causes energy waste.
- **Collision or Distortion:** Normally, a collision can occur when neighboring nodes compete for a free environment, and the lossy channel causes the transmitted packets to be corrupted. When one of the two situations occurs, the corrupted packets must be resent; this increases energy consumption.
- **Overhearing:** Occurs when a node receives some packets directed to other nodes.
- **Control Packet Load:** The exchange of control packets between the sender and the receiver also consumes energy.

Protocol Structure of Wireless Sensor Networks

Figure 2 illustrates the protocol structure utilized in WSN. "The protocol framework incorporates elements such as energy management and route discovery. The protocol is structured into physical, data link, network, transportation, and application layers, as well as a power management plane, a motion management plane, and a task management plane.[10] The physical layer, as illustrated in Figure 2, is responsible for frequency selection, modulation, data encryption, and transmission. The data connection layer is in charge of MAC error checking, and data stream multiplexing. Due to the mobile noise and SNs present in a wireless environment, it is critical to avoid MAC protocol clashes with power management and neighbor broadcasts.

The network layer deals with the routing of data transmitted by the transport layer. The transport layer controls the data flow. Thanks to the detection processes, different types of applications can be developed. These applications are used thanks to the application layer.[10] In the protocol architecture behind these layers are motion, power and division planes. Thanks to these planes, the detection processes of SNs will be shaped, and energy consumption will be minimized. The power management plane manages the power usage of the SN. After the SN receives the packet from any neighboring node in the same cluster, the RF is turned off. Thus receiving the same packet again will be prevented. If the energy level of the SN falls below the lower threshold value, it can send a message to the neighboring SNs to report that it is at a critical level. In this way

SN uses its remaining energy only for the sensing process. The motion management plane detects and records the movements of the SN. This way, the neighboring SNs and the return path can be found easily. Knowing neighboring SNs also balances the SN's task and power management. The task management plane shares the detection tasks that the SNs will do in the detection area.

Media Access Controls With Wireless Sensor Networks

MAC is a mechanism that enables an efficient sharing of wireless transmission media between nodes. The MAC layer covers processes such as data packet fragmentation, error recovery, motion management, power conservation and encryption. MAC addresses are low-level bases that handle Ethernet-based networks. Each network card has a unique MAC address. Packets sent over Ethernet always come

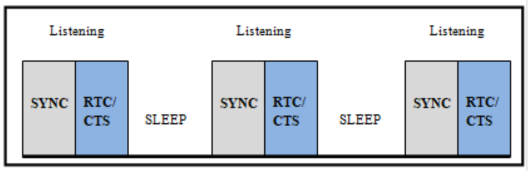

Figure 3: S-MAC Protocol

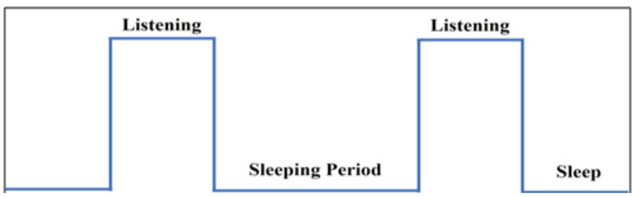

Figure 4: T-MAC Protocol

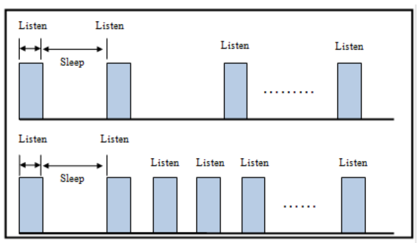

Figure 5: T-MAC Protocol

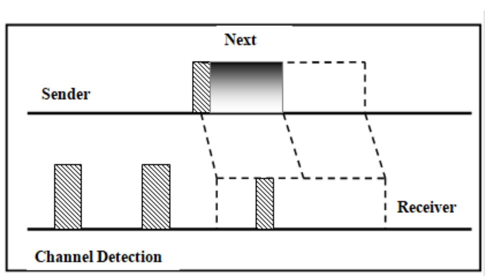

Fig ure 6: Wise-MAC protocols

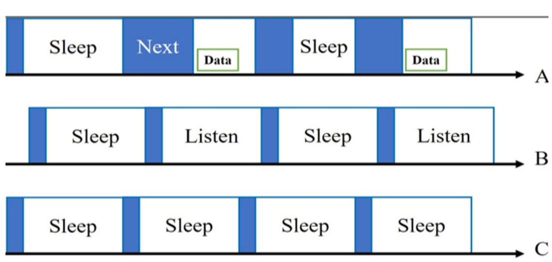

Figure 8: Wise-MAC protocols

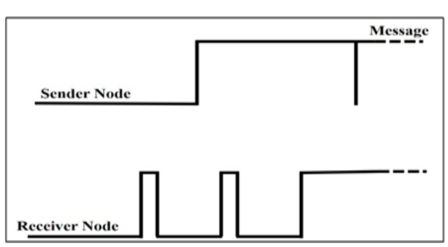

Figure 9: Aloha Architecture

from a MAC address and are sent to a MAC address.[11] If a network adapter receives a packet, it compares the packet's destination OEK address with the adapter's own MAC address. If the addresses match, the package is processed; otherwise, the package will be dropped. There is not yet a standard MAC protocol in WSN. Most of the energy use in WSN is consumed by RFs, so turning off RFs during communication is important for savings. In Fig ure 4, a classification is made based on the prefix parameter. Here, exactly how the protocols developed for energy efficiency in MAC perform data communications and how they benefit.[12]

Media Access Control Layer Protocols

MAC Layer protocols are supposed to accomplish the following duties in a wireless sensor network: Establishing infrastructure and connecting sensors for data transfer allows sensor nodes to share network communication resources. The MAC layer is in charge of sharing media. It enables nodes to make decisions about when to access shared material. MAC Protocols can be divided into the following categories:

- **Determined:** It is based on the TDMA protocol (Time Division Multiple Access). The channel is separated into time periods in this technique. The frame refers to a complete cycle of these periods. Because ZBCE protocols lose packets to Collision, Idle Listening, and Over-Listening, they naturally save energy.
- **Random:** Based on the Carrier Sense Multiple Access Control Protocol (CSMA / CD, Carrier Sense Multiple Access and Collision Detection), this is how you can control multiple devices at the same time. In random access protocols, the channel can be shared by nodes when they want to. In this case, if the nodes compete for the channel and find the channel free, the transmission will start immediately. Otherwise, it will wait until it is idle and can see the channel to get a chance to send the channel.

Media Access Control Protocols applied on Wireless Sensor Networks

Low Energy Adaptive Clustering Hierarchy (LEACH): The first subset style routing protocol in WSN[13-15] is LEACH. LEACH conserves energy by utilizing data compression techniques as well as subset dynamic routing technologies. The LEACH algorithm has two states. (a) Setup Status: At this point, a cluster title has been chosen for this tour. (b) Stable State: Nodes submit data to the cluster header at this stage. The cluster header node is chosen at random; the network load is balanced v. The chance that a node is a cluster node is calculated as follows: Y is the proportion of the total cluster head, t is the number of rounds available, t mod (l / Y) each cluster in one cycle is chosen as the number of nodes, Z, and cluster header node set is not chosen. The following are some of LEACH's flaws: In the following round of recycling, the likelihood of a node selected as a cluster header becoming a cluster head node again after a specified amount of time

Table 1: Comparison of MAC Protocols

Protocol name	Basis sasic	Control pack	Plan diagram	Simulation	Prefix operation
Streamer	Tdma	-	Planned	Yes	No
Pamas	Csma	Rts / cts	Unplanned	Yes	No
Smac	Csma	Rts / cts	Planned	Yes	Yes
Dsmac	Csma	Rts / cts	Planned	Yes	No
Bmac	Csma	-	Unplanned	Yes	Yes
Aloha	Aloha	-	Planned unplanned	Yes	Yes
Xmac	Csma	-	Planned	Yes	Yes
Cmac	Csma	Rts / cts	Planned	Yes	Yes
Tmac	Csma	Rts / cts	Planned	Yes	No
Stem	Csma	-	Unplanned	Yes	No
Zmac	Csma, tdma	-	Planned	Yes	No
P-mac	Csma	Rts / cts	Planned	Yes	No
Wise-mac	Csma	-	Planned	Yes	Yes

Table 2: Simulation Parameters

Parameters	Value
Simulator	Ns2(ver2.34)
No of nodes	10, 50,100,150
Routing protocol	Aodv
Pause time	15,30,60,120,240,480 Sec.
Traffic type	Cbr(constant bite rate)
Simulation time	300 M sec.
Simulation area	800mx600m
Range of node	250 M
Traffic connections	Tcp/udp
Maximum speed (m/s)	35

is l / y. When a node is chosen as the cluster header, the beginning energy of each node is considered equal, as is the energy consumption.

Multiple Parent Method

The Multi-Parent approach has the advantage of minimising data latency while using the wake timing method to reduce energy consumption. Parental determination for any node in the network, on the other hand, is an algorithm that requires numerous processing cycles.

(a)P-MAC

The Pendulum-MAC (P-MAC) system is divided into layers, and nodes in each tier are allotted periods when they are awake to submit data to AD. An awake schedule is followed by ADs distributed around the geographic area for monitoring.[14]

Table 3 Comparative Performance Evaluation on mobility 25m/sz

Routing protocol	Pdr (%ile)				Routing load (no. Of packet)				Energy consumption (in joule)			
	10	50	100	150	10	50	100	150	10	50	100	150
Tmac	72.96	71.6	69.2	70.5	2827	3887	5294	6346	1401	1589	1899	2001
Bmac	70.15	69.5	67.9	65.8	3529	4579	5765	6595	1501	1602	1872	2057
Pmac	89.95	81.6	82.9	78.3	2988	3789	5476	6499	1287	1489	1802	2013
Aloha	83.16	81.8	79.1	76.3	2798	3897	5187	6199	1197	1407	1684	2056
Cmac	72.25	74.5	72.2	70	3810	4798	5892	6806	1581	1684	1989	2051

Table 4: Comparative Performance Evaluation on mobility 15m/s

Routing protocol	Pdr (%)				Routing load (no. of packet)				Energy consumption (in joule)			
	10	50	100	150	10	50	100	150	10	50	100	150
Tmac	74.81	73	72.3	73.9	2654	3798	5076	6197	1321	1465	1792	1909
Bmac	75.22	76.6	71.2	70.1	3376	4395	5578	6401	1423	1514	1779	1979
Pmac	86..01	84	86	85	2843	3623	5316	6337	1189	1401	1718	1946
Aloha	86.21	84.1	82.2	82	2619	3736	5029	6078	1002	1325	1591	1991
Cmac	75.76	77.1	74.3	73.2	3698	4632	5756	6759	1479	1592	1893	1952

Table 5: comparative performance evaluation on mobility 5m/s

Routing protocol	Pdr (%ile)				Routing load (no. Of packet)				Energy consumption (in joule)			
	10	50	100	150	10	50	100	150	10	50	100	150
Tmac	75.09	75	74.1	76	2601	3712	5008	6054	1304	1325	1735	1865
Bmac	76.28	77.2	73	73.2	3299	4308	5472	6309	1402	1517	1723	1914
Pmac	86..92	84.1	86.9	85.6	2608	3698	5286	6285	1104	1365	1667	1877
Aloha	87.01	85	86	83.1	2587	3683	4982	5979	1000	1265	1523	1906
Cmac	79.16	78	76.2	74.1	3614	4598	5678	6702	1425	1543	1821	1845

This means that ADs will decide when to wake up and sleep based on their location. However, it contradicts this technique, which has the primary disadvantage of delaying data collection over long periods. It also necessitates a particular level of density in order to function; it necessitates a denser network in order to establish a connected network. As a result, it is unsuitable for small networks.

(b)S-MAC

Sensor MAC is a contention-based protocol developed specifically for wireless sensor networks. Its fundamental principle is based on CSMA / CD. It employs a "Listen and Sleep" strategy on a regular basis to avoid idle listening and save energy loss. As shown in Figure 3, each node monitors a periodic sleep and listening schedule. During the listening phase, the node discovers the network and listens to and talks with other nodes if it finds it idle. When the sleep period arrives, the node switches off the radios and enters sleep mode. This drastically minimizes the amount of time spent listening while doing nothing. Nodes communicate using RTS (Ready to Send), CTS (Clear to Send), and Data Acknowledgement (ACK) in this protocol. When a node detects an RTS or CTS packet intended for another node, it enters sleep mode.[15] This is a recurring process. S-MAC advises operating at a low duty cycle to save energy. The frame is a complete cycle of the listening and sleeping periods. If possible, the node will turn off its radio during sleep. Large quantities of energy consumption from unneeded idle listening can thus be avoided, particularly when traffic is light.

Nodes in the network form virtual clusters with their neighbors and share a synchronization schedule for the listening and sleeping periods. As a result, a network can have several clusters. Periodic SYNC packets are used by nodes in different clusters to locate their neighbors. This is referred to as PNK (Periodic Neighbor Discovery). Furthermore, the Sensor MAC protocol employs message delivery to mitigate the latency that may result from a collision for WSNs. Because of message transmission, big packets can be sent in little pieces. Furthermore, coordinated preparation is carried out to avoid any potential disputes. Depending on whatever application is executing in SNs, the delay becomes significant. The data will be very low if there is no incoming or outgoing flow. As a result, ADs are generally empty. Very good synchronization is essential for nodes to work cooperatively and shop.

S-MAC protocol, energy problem reduction Listening on a regular basis, keeping a sleep routine, and avoiding idle listening. Overhearing troubleshooting is avoided by employing channel signaling to put each node into a sleep state using periodic SYNC messages to prevent collision. S-MAC uses a pair of RTS / CTS for message relay, but each track requires an ACK. This control significantly reduces package load.

(c)T-MAC

T-MAC (Timeout Medium Access Control- Timeout Media Access Protocol) is a TDEK-based protocol.16 It's based on the S-MAC protocol. T-MAC reduces idle listening for WSNs regardless of whether a duty cycle of the same length decides whether an active cycle will continue to run or not.[17] In other words, if no one hears anything on the channel, the task is canceled.

T-MAC sends all communications in variable duration bursts, with a sleep/wake time interval between them. This is done to cut down on idle listening. The node wakes up on a regular basis to connect with its neighbors, and it employs the RTS and CTS Data Validation schemes to assure collision avoidance and reliable transmission.[18] Messages are kept in a buffer here, and then a frame is established to which a message is transmitted during an active time, as shown in Figure 4. When there are no active events during the TA period, the active time expires, and the node falls into sleep mode. At the moment, heavily loaded nodes interact incessantly while remaining awake. Early sleep deprivation can be viewed as a negative.

(a)DSMAC

DSMAC (Medium Access Control with a Dynamic Duty Cycle for Sensor Networks) protocol is inspired by the S-MAC protocol. DSMAC provides a good trade-off between two performance metrics without facing much overhead.[19] In addition, DSMAC can adjust business cycles in changing traffic conditions without the need for previously recorded data of application requirements. If a SYNC packet does not arrive until the end of the period, nodes in DSMAC can freely choose their desired plan here, assuming it is the only active sensor in the channel. Accordingly, they send SYNC packages to other ADs in the environment to implement their own plans. ADs maintain a SYNC table for neighboring nodes. Nodes send their preserved SYNC table to other nodes on the opposite channel to avoid a collision. Nodes have sleep and wake times in these SYNC tables. As soon as the nodes hear the SYNC packet signal, they update their synchronization table and set their timer to the SYNC packet generator. The minimum delay of the receiving node is equal to all current hop delay values in the current SYNC period. DSMAC protocol (See Figure 5) uses a dual-stage tuning module. Apart from this, each receiving node also keeps track of its energy consumption efficiency and average delay.

(b)B-MAC

B-MAC (Berkeley Medium Access Control Protocol) is a protocol that uses TDEK. To achieve low power functionality, B-MAC employs an adaptive prefix sampling approach. In this manner, duty cycle and idle listening can be reduced to a bare minimum. Once the B-MAC begins processing, it still permits configuration and provides a bi-directional interface for performance adjustment.[20] For message transmission, the B-MAC protocol has an extremely lengthy prefix. Because of the large front end, the optimal interchange will occur in terms of delay. TKG (Clean Channel Assignment, Clear Channel Assessment), packet retraction for channel resolution, link layer acknowledgment for security, and a low power listening technique for low power communication are all used by B-MAC. Following the initial pullback, the TKG contradicting value algorithm is activated. When a channel is unsuitable for traffic, an incident notifies the service of the congestion backoff time. If the withdrawal period is not specified, the tiny random withdrawal is preferred. The favored technique in B-MAC is the same as the prefix sampling technique in Aloha, but it has been modified to different radio characteristics.[21] A threshold value for the utilization of signal intensity is specified in the B-MAC protocol to reduce energy consumption. The initial prefix length synchronizes to the range of comprehension if an activity has occurred in the channel to acquire information in a secure state. One of the issues with this protocol is the concealed terminal problem, which exists in regular wireless networks.

(c)Wise-MAC

WiseMAC requires no setup signals, does not require network-wide synchronization, and adapts to the load of traffic. It offers very low power consumption in low traffic conditions and high energy efficiency in high traffic conditions. This design brings the receiver nodes to a position to receive the data packet with the initial signal, as in the AED (listening with minimum energy, low power listening) in the initial phase. Destination nodes receiving the data packet send the "received" packet in response,[22] as shown in Figure 8. This "received" packet carries information about the next sampling time of the node beyond the information that the data was properly received. Thus, the node sending the packet starts sending the next start signal just before the node starts sampling by calculating this time and possible clock deviations, and immediately after making sure that it has warned the node, it starts to send the normal data packet. Thus, the power consumption on both the receiver and transmitter sides is reduced. In cases where there is more than one sender to the same recipient, collisions may occur in data packets. To prevent this, sending nodes to send a random length start signal immediately after the start signal they send for wake-up purposes. The data that sends the longest duration signal is entitled to send a data packet.

(d)STEM

Two different channels are used in the Sparse Topology and Energy Management (STEM) protocol. These are Call and Radio channels. Often, only the call channel is used, as the network is expected to be in monitoring. For example, in an emergency, the path used in the information channel, communication occurs using known wireless protocols and is active throughout the network. In STEM, the call channel listens systematically during the time needed to obtain the call packet, and the application is performed through the receiver. STEM does not maintain capacity, thus making it possible to use considerably less energy and create a possible negative in routing. The most noteworthy feature of the mentioned protocol is that the nodes can be in idle rest mode in a non-dependent state. In order to prevent excessive use of energy in the STEM protocol, a neighboring AD in sleep mode is activated by a short message and saving energy. When the two ADs establish a link to activate their radios, the link is active and available for subsequent packets. In order not to interfere with the current data transmission wake-up protocol, STEM uses a different frequency band; that is, it uses different RF for each band.[23]

(e)Pre-Sampling with Aloha

The Aloha prefix sampling protocol is a protocol that combines the Aloha protocol and the prefix sampling method.[24] The purpose of the pre-sampling method is to allow the RECEIVER to remain in sleep mode most of the time while the channel is empty. This includes a certain length of a prefix transfer in front of each packet. A receiver wakes up periodically at set times and checks the activities in the channel. If the channel is empty, the receiver will sleep again. If a pre-existing channel is present, the receiver remains awake and continues listening until the packet is received, as shown in Figure 9. Combining the characteristics of Aloha and foreground sampling, the environment minimizes the time spent on unnecessary listening.[25] In other words, the sending node waits for a message from the recipient to determine whether the transmission is successful or not. The problem with the Aloha protocol is that the environment is unnecessarily resting and wasting energy.[26] The solution is to take advantage of the low-power listening method. In order to sample incoming messages, the header in the message uses a prefix to identify the recipient of subsequent messages. If the transmitted prefix is not heard by the receiver, then RF is not used until the next sample arrives. The prefix sampling method is the protocol that informs that the channel is loaded.

Comparison in Mac Protocols

Preventing energy waste and using energy efficiently is an important and necessary issue in WSN. When the MAC protocols are examined in detail, the importance of energy efficiency is once again understood. In this study, as a result of examining and comparing energy-efficient MAC protocols one by one, it is understood that many different mechanisms are used for the related protocols for energy efficiency. The protocols shown in Table 1 have been compared according to the parameters they are based on and whether they use the prefix or not. It is understood that most of the protocols implemented at the MAC layer adopt the TDFE method; however, it is obvious that the protocols using the prefix in recent years have benefited from the ZBCE management. Some protocols either provided synchronization within their own plans or within the plans they obtained, preventing energy wastage and providing energy efficiency. While all of the protocols shown in Table 1 have simulations, most of them cannot process in the foreground. It is very important to achieve energy efficiency with its frontend. This is why the protocols in this study are divided into two parts. These protocols try to achieve energy efficiency by using a prefix and that try to achieve without a prefix. In this way, it can be understood which protocol follows what method in MAC.

Environmental setup and Comparative analysis

This study compares TMAC, BMAC, CMAC, Aloha, and PMAC routing methods in diverse sensor network settings. The systems' performance was compared using characteristics like PDR, RL, and energy consumption (EC). Using OTCL and TCL simulation script files, NS-2 was used to compare the performance of the Routing protocol in four different network scenarios (Tables 2, 3, 4, and 5). The packet delivery ratio measures the success rate of various traffic sources in delivering network frames (data, control, or acknowledgment). As seen in equation 1, a higher packet delivery ratio is required for optimal MAC protocol.

$$pdf = \frac{\sum Packet\ Recived\ by\ Destination}{\sum Packet\ generated\ by\ traffic\ sources} \ldots\ldots\ldots\ldots(1)$$

The packet delivery ratio of the Routing protocol significantly varies with node density and mobility.

TMAC acquires approximately 69.21 %- 72.96 % at 25m/s node mobility, BMAC acquires approximately 65.84 %- 70.15 %, PMAC acquires approximately 78.25 % -89.95 %, ALOHA acquires approximately 76.28 %- 83.16 %, and CMAC acquires approximately 69.98 % - 74.49 % packet delivery ratio over various network scenarios as shown in Table 3.

TMAC acquires approximate 72.27 %- 74.81 %, BMAC acquires approximate 70.13 % - 76.59 %, PMAC acquires approximate 83.98% -85.99%, ALOHA acquires approximate 81.98 %- 86.21 %, and CMAC acquires approximate 73.18 %- 77.09 % packet delivery ratio over

TMAC acquires approximately 74.08 %- 76.01 %, BMAC acquires approximately 72.96% -76.28 %, PMAC acquires approximately 84.08 %- 86.92 %, ALOHA acquires approximately 83.06 % - 87.01 %, and CMAC acquires approximately 74.12 %- 79.16 % packet delivery ratio over various network scenarios, as shown in Table 5.

On the other hand, a routing load is an administrative overhead required to initiate a route from source to destination and establish an end-to-end connection. As demonstrated in equation 2, any optimal routing protocol must have a lower routing load.

$$rl = \frac{\sum Control\ packet\ generated\ by\ traffic\ source}{\sum Total\ packet\ generated\ by\ traffic\ source} \ldots\ldots\ldots\ldots(2)$$

TMAC uses approximately 2827-6346 control packets as routing overhead at 25m/s node mobility, while BMAC uses approximately 3529-6595, PMAC uses approximately 2988-6499, ALOHA uses approximately 2798-6199, and CMAC uses approximately 3810-6806 control packets, as indicated in Table 3. As demonstrated in Table 4, at 15m/s node mobility, TMAC uses about 2654-6197, BMAC uses approximately 3376 - 6401, PMAC uses approximately 2843-6337, ALOHA uses approximately 2619 - 6078, and CMAC uses approximately 3698-6759 control packets as routing overhead. As demonstrated in Table 5, at 5m/s node mobility, TMAC uses about 2601 -6054, BMAC uses approximately 3299-6309, PMAC uses approximately 2608-6285, ALOHA uses approximately 2587-5979, and CMAC uses approximately 3614-6702 control packets as routing overhead.

On the other hand, energy consumption refers to the amount of battery power consumed by any node to complete a transmission. Higher energy consumption reduces the network's survival, whereas lower energy consumption ensures the network's life over a longer period of time. As stated in equation 3, any optimal conduction network requires a longer lifespan.

$$\psi_{sn\omega} = \frac{\sum_{i=1} \varphi_n}{\xi_n \quad \xi_i} \ldots\ldots\ldots\ldots(3)$$

where, $\psi_{sn\omega}$ is represent energy consumption over the sensor network, φ_n^i denote initial energy of nodeand ξ_n^i denote resident energy of node

The Routing protocol's energy consumption increases as node density and mobility increase. TMAC consumes approximately 1401-2001 joule energy at 25m/s, BMAC consumes approximately 1501-2057 joule energy, PMAC consumes approximately 1287-2013 joule energy, ALOHA consumes approximately 1197-2056 joule energy, and CMAC consumes approximately 1581-2051 joule energy during communication overhead over various network scenarios, as shown in Table 3 and Figure.[14]

TMAC consumes approximately 1321-1909 joule energy during communication overhead at 15m/s, BMAC consumes approximately 1423-1979, PMAC consumes approximately 1189-1946, ALOHA consumes approximately 1002-1991, and CMAC consumes approximately 1479-1952 joule energy during communication overhead over various network scenarios, as shown in Table 4 and Figure.[17]

TMAC consumes approximately 1304-1865 joule energy during communication overhead at 5m/s, BMAC consumes approximately 1402-1914, PMAC consumes approximately 1104-1877, ALOHA consumes approximately 1000-1906, and CMAC consumes approximately 1425-1845 joule energy during communication overhead over various network scenarios, as shown in Table 5 and Figure.[20]

It is noticed that when node density and mobility increase over the network, the PDR of the routing protocol drops, yet routing load and energy consumption increase. On the other hand, when mobility is reduced from 35 to 5 m/s, PDR increases significantly while routing load and energy consumption decrease, creating an excellent environment for sensor networks. Because the mobility of a Sensor network is typically lower than that of a mobile ad-hoc network, our suggested method and result are appropriate for Sensor networks.

After analyzing the performance of the Routing protocol in various network conditions, it was discovered that PMAC had a higher PDR ratio. ALOHA, on the other hand, spends the least amount of time routing overhead packets, allowing it to dramatically boost network survival while using the least amount of battery power. PMAC and TMAC, on the other hand, show modest performance across the network.

Conclusion

With the extensive usage of WSNs, energy efficiency in routing has become critical. The adoption of routing that is energy-efficient has a direct impact on the life of WSNs. The majority of the research in the literature has been on boosting energy efficiency. The focus of this research is on energy-sensitive PEC procedures. The goal is to determine which protocol will save the most energy. All of the routing protocols examined are concerned with preventing collisions, reducing latency, and finding solutions to current energy-sensitive problems. Despite these advancements, there are no standard routing protocols for WSN, and there is still much work to be done in this area. It also looks for novel techniques and strategies to reduce energy waste.

Furthermore, efforts are being undertaken to reduce transmission delays in delay-resistant applications. The proposed routing protocols in WSNs, as observed in the paper, are classified into two types: contention-based and centralised. The number of studies on this topic is growing all the time, and new methodologies are being developed. Because maintaining energy efficiency in the WSN is a major issue for researchers, a complete assessment of the studies in this field and showing the differences between them will be a source for future studies in this sector.

References

[1] M. Shafiq, H. Ashraf, A. Ullah, and S. Tahira, "Systematic literature review on energy efficient routing schemes in wsn – a survey," Mobile Networks and Applications, vol. 25, pp. 882–895, Jun 2020.

[2] M. F. Othman and K. Shazali, "Wireless sensor network applications: A study in environment monitoring system," Procedia Engineering, vol. 41, pp. 1204–1210, 2012. International Symposium on Robotics and Intelligent Sensors 2012 (IRIS 2012).

[3] S. Yadav and R. S. Yadav, "A review on energy efficient protocols in wireless sensor networks," Wireless Networks, vol. 22, pp. 335–350, Jan 2016.

[4] J. Yan, M. Zhou, and Z. Ding, "Recent advances in energy-efficient routing protocols for wireless sensor networks: A review," IEEE Access, vol. 4, pp. 5673–5686, 2016.

[5] K. Kredo and P. Mohapatra, "Medium access control in wireless sensor networks," Comput. Netw., vol. 51, p. 961–994, Mar. 2007.

[6] R. Valarmathi, "Secure data transfer through audio signal with lsa," Indian Journal of Science and Technology, vol. 8, p. 17, 01 2015.

[7] K. Sohraby, D. Minoli, and T. Znati, Medium Access Control Protocols for Wireless Sensor Networks, pp. 142–196. 2007.

[8] K. Sohraby, D. Minoli, and T. Znati, Introduction and Overview of Wireless Sensor Networks, pp. 1–37. 2007.

[9] L. J. G. Villalba, A. L. S. Orozco, A. T. Cabrera, and C. J. B. Abbas, "Routing protocols in wireless sensor networks," Sensors (Basel, Switzerland), vol. 9, no. 11, pp. 8399–8421, 2009. 22291515[pmid].

[10] M. R. Senouci and A. Mellouk, "1 - wireless sensor networks," in Deploying Wireless Sensor Networks (M. R. Senouci and A. Mellouk, eds.), pp. 1–19, Elsevier, 2016.

[11] S. Jung, J. Kim, and S. Kim, A Study on MAC Address Spoofing Attack Detection Structure in Wireless Sensor Network Environment, vol. 199, pp. 31–35. 08 2011.

[12] W. Fang, Z. Liu, and F. Liu, "A cross-layer protocol for reliable and efficient communication in wireless sensor networks," International Journal of Innovative Computing, Information and Control, vol. 8, 10 2012.

[13] K. Guleria and A. K. Verma, "Comprehensive review for energy efficient hierarchical routing protocols on wireless sensor networks," Wireless Networks, vol. 25, pp. 1159– 1183, Apr 2019.

[14] S. Tyagi and N. Kumar, "A systematic review on clustering and routing techniques based upon leach protocol for wireless sensor networks," Journal of Network and Computer Applications, vol. 36, no. 2, pp. 623–645, 2013.

[15] Razaque, M. Almiani, M. J. khan, M. N. Kakenuly, and Y. Jararweh, "Energy efficient medium access control protocol for wireless sensor networks," in 2018 6th International Renewable and Sustainable Energy Conference (IRSEC), pp. 1–6, 2018.

[16] S. Sarode and A. Sakhare, "Review on leach: A protocol for energy efficient wireless sensor network," in 2015 2nd International Conference on Electronics and Communication Systems (ICECS), pp. 1021–1026, 2015.

[17] R. Singh, B. K. Rai, and S. K. Bose, "A novel framework to enhance the performance of contention-based synchronous mac protocols," IEEE Sensors Journal, vol. 16, no. 16, pp. 6447–6457, 2016.

[18] Ramasamy and R. Thangavel, "A survey on mac protocols for

wireless sensor networks," pp. 121–126, 06 2017.
[19] D. Dang, Q. Ngo, H. Dang-Ngoc, and C. S. Hong, A Multi-channel MAC Protocol with Power Control for Wireless Ad Hoc Networks, pp. 63–73. 03 2016.
[20] D. Ngom, P. Lorenz, and B. Gueye, "A distributed scheduling algorithm to improve lifetime in wireless sensor network based on geometric placement of sensors with coverage and connectivity constraints," 08 2015.
[21] J. A. Msumba and H. Xu, "Throughput optimization mac scheme for cognitive radio networks: A pomdp framework," in 2013 Africon, pp. 1–5, 2013.
[22] G. Binu and K. Jacob, "Performance comparison of two different energy conservation mac protocols," Procedia Technology, vol. 4, p. 207–214, 12 2012.
[23] C. M. Garc´ıa Algora, V. Alfonso Reguera, N. Deligiannis, and K. Steenhaut, "Review and classification of multichannel mac protocols for low-power and lossy networks," IEEE Access, vol. 5, pp. 19536–19561, 2017.
[24] P. Hurni and T. Braun, "Evaluation of wisemac on sensor nodes," International Federation for Information Processing Digital Library; Wireless and Mobile Networking;, vol. 284, 08 2008.
[25] C. Schurgers, V. Tsiatsis, and M. Srivastava, "Stem: Topology management for energy efficient sensor networks," in Proceedings, IEEE Aerospace Conference, vol. 3, pp. 3–3, 2002.
[26] Y. Chu, P. D. Mitchell, and D. Grace, "Reinforcement learning based aloha for multi-hop wireless sensor networks with informed receiving," in IET Conference on Wireless Sensor Systems (WSS 2012), pp. 1–6, 2012.
[27] Chau , J. Dawson, and P. Mitchell, "Directional hub slotted aloha medium access control protocol for wireless sensor networks with directional antennas," in 2021 55th Annual Conference on Information Sciences and Systems (CISS), pp. 1–6, 2021.
[28] V. Loginov, I. Kargin, E. Khorov, and A. Lyakhov, "Study of fast multi-hop aloha with instant forwarding," in 2018 IEEE 29th Annual International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC), pp. 1–6, 2018.