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EC-MAC: Energy-Aware Cooperative MAC Protocol in Wireless Sensor Network

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ABSTRACT

Nowadays, cooperative communication algorithms have been utilized in Wireless Sensor Network (WSN) to enhance the overall network performance. As is well known, a WSN needs to consider a number of important factors, such as the energy effectiveness and the longevity of the sensor nodes. The energy-aware cooperative medium access control (EC-MAC) protocol is a novel protocol proposed in this paper for usage in WSNs. EC-MAC protocol allows the source nodes to use the intermediate nodes as relays that can be used to transmit the source's data to the access point (AP). This paper demonstrates how the suggested relay selection method can be used by the EC-MAC protocol to choose the best relay node. After channel state information (CSI) has been calculated and acquired, the best relay should have the highest residual energy and the quickest transmission time. Then, by establishing suitable cooperative links, data transmission from a source node to an AP can be carried out. The effectiveness of the EC-MAC protocol in terms of system energy efficiency is examined in this study using the MATLAB simulation tool and compares the outcomes with other cooperative protocols like Modified Cooperative Access MAC Protocol (MCA-MAC) and Throughput and Energy aware Cooperative MAC Protocol (TEC-MAC) and the performance of WSNs employing the suggested EC-MAC protocol is examined in this research for both ideal and dynamic channel conditions. EC-MAC protocol achieved energy efficiency improvements of 20%, and 40% respectively, more than MCA-MAC and TEC-MAC protocols. The results indicated that EC-MAC protocol offers a higher level of energy efficiency for the WSN than other cooperative protocols currently in use.

1. Introduction

The wireless sensor network (WSN) has been hailed as a notable technological achievement due to its high demand in a variety of applications, such as target tracking, fighting, and fire detection [1-3]. A large quantities sensor nodes make up a WSN to keep an eye on a particular environment and report to the access point (AP). These sensor nodes have the capacity to self-configure the network

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and organize themselves. They are also capable of creating and sustaining communication among themselves. However, before putting their plans to improve network performance into action, WSN designers must consider a number of challenges [4,5]. At the top of these difficulties is the energy efficiency of sensors. Battery power is typically used to power the sensor nodes. They are said to function under severe energy restrictions. Due to that, reducing the overall energy consumption of the WSN is a main required design challenge [6]. Also, the wireless environment can cause some drawbacks such as the signal noise, the interference, the delay in the data delivery, and reducing in the overall throughput w.r.t distance through the wireless medium. To address the aforementioned issues, cooperative communication methods among sensor nodes are proposed. The basic concept of cooperative communication is based on two factors which are the wireless broadcast advantage (WBA) and the wireless cooperative advantage (WCA). According to WBA and WCA, the neighbouring sensor nodes can act as relays to each other. Data packets emitted from a source node can be heard by the nearby sensor nodes. These neighbouring sensor nodes can help forwarding the data packets to the specific destination node with lower power consumption and higher data rate. So, the source nodes can use the neighbouring sensor nodes as relay nodes to route the transmitted data packets to the AP. This may aid in lowering the WSN's energy usage and transmission delay [7]. The single relay strategy and the multiple relay strategy are the two cooperative communication techniques. The multiple relay technique is more difficult to deploy than the single relay strategy and has a higher cooperation overhead. Therefore, the single relay cooperative communication technique is taken into consideration by WSN designers [8,9]. The information sharing stage and the cooperative transmission stage are the two steps that make up the cooperative communications process, on the other hand. The WBA and WCA are fully utilized in the implementation of these two stages. For the cooperative MAC protocols to be successfully designed, three crucial considerations must be made. These concerns revolve around when, with whom, and how to interact. In order to activate only beneficial cooperation and choose the appropriate relay, all three issues must be properly managed (s).activate only beneficial cooperation and choose the appropriate relay, all three issues must be properly managed (s).This paper's goal is to create and implement a new cooperative MAC protocol to increase the energy efficiency of WSNs. The proposed protocol in this paper is called the Energy-aware Cooperative MAC (EC-MAC) protocol that has been applied in WSN. In EC-MAC protocol, a cross-layer scheme has been proposed which includes both the physical layer and the MAC layer. On other hand, EC-MAC protocol introduces a data transmission algorithm that depends on both the data rate of the wireless channel and source nodes. Using the available MAC and physical layer information, the transmission mode in EC-MAC protocol will be adaptively selected from two modes which are the data packet direct transmission mode or the cooperative transmission mode. Because of the changing between these two cooperative modes, the overall performance of WSNs has been improved. For source nodes that can transmit data at faster speeds, direct transmission (or non-cooperative) mode is appropriate. The source node transmissions data direct to the AP of direct transmission mode. For source nodes that can transmit data at faster speeds, direct transmission (or non-cooperative) mode is appropriate. The source node transmissions data direct to the AP of direct transmission mode.

The proposed EC-MAC protocol for WSN makes some contributions, which are described below:

i. Development of an analytical model to evaluate the EC-MAC protocol's performance, which considers some parameters such as the channel conditions, multi-rate, cooperative transmission, and saturated traffic load.
ii. To route the data packets from the source sensor node to the AP, a relay node selection method is proposed. It will choose the best relay node with the highest residual power

and the shortest transmission time.

iii. Adaptive change between transmission modes, use of fewer control packets and overhead across transmission.

Six sections make up the remainder of this paper. Some of the related works are listed in Section II after that. The overall communication system is explained in Section III. The suggested EC-MAC protocol for WSN is described in Section IV. The analytical model for the suggested EC-MAC approach is provided in Section V. The simulation findings from a comparative examination of the suggested protocol have been discussed in section number VI. The conclusions of this work and recommendations for additional research are presented in Section VII.

2. Literature Review

To enhance the effectiveness of WSN, several papers suggested and examined cooperative communication techniques. In [10], the authors suggested a Wireless Sensor Cooperative-MAC (WSC-MAC) protocol of MAC layer. The primary goal of this protocol is to disseminate the physical layer cooperative communications technique and the proper MAC layer strategy for WSN in order to increase the WSN's overall reliability. In the WSC-MAC protocol, each sensor node produces a link-state database to keep track of the link quality between nearby sensor nodes. Link quality between the relay node and the access point, which had to be better than the direct source and destination of link quality, was taken into consideration while selecting the relay node. Wireless Sensor Networks (WSNs) consist of many tiny sensors deployed in a monitoring environment to gather data about physical phenomena. The sensors are typically battery-powered, and energy conservation is a critical concern in the design of WSNs. To conserve energy, the Medium Access Control (MAC) protocol is an essential component of the WSN protocol stack, responsible for controlling access to the shared wireless channel and reducing energy consumption. The standard MAC protocols used in WSNs, such as the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) protocol, are designed for traditional wireless networks and are not well suited to the specific requirements of WSNs. As a result, researchers have proposed various energy-aware MAC protocols that are tailored to the characteristics of WSNs. One such protocol is the energy-aware cooperative MAC (EAC) protocol, which combines the features of both cooperative communication and energy-awareness to improve the energy efficiency of WSNs. The EACO protocol is based on the concept of cooperative communication, which enables nodes to work together to transmit data over a shared wireless channel. In cooperative communication, nodes act as relays to forward data between source and destination nodes, thus reducing the transmission power required for data transmission. In the EACO protocol, nodes that are located within a certain distance of each other are grouped together into a cooperative cluster. The cluster head is elected based on a combination of energy and communication quality metrics, and it is responsible for transmitting data on behalf of its cluster members. The EACO protocol also incorporates energy-awareness, which is designed to reduce energy consumption by controlling the transmission power of nodes. In the EACO protocol, nodes monitor their energy levels and adjust their transmission power accordingly. If a node has a low energy level, it reduces its transmission power to conserve energy, whereas if a node has a high energy level, it increases its transmission power to improve communication quality. The EACO protocol also implements a dynamic clustering mechanism, which enables nodes to join or leave a cluster based on changes in network conditions. For example, if a node has a low energy level, it can leave the cluster to conserve energy, while if a node has a high energy level, it can join a cluster to improve communication quality. This dynamic clustering mechanism helps to improve the energy efficiency of the WSN by adjusting the size of the clusters based on network conditions. One of the key benefits of the EACO protocol is that it reduces the energy consumption of the WSN by reducing the transmission power required for data transmission. This is achieved by allowing nodes to work together as relays to forward data between source and destination nodes, thus reducing the transmission power required for data transmission. The EACO protocol also improves the communication quality of the WSN by enabling nodes to adjust their transmission power based on their energy levels, which helps to reduce the impact of fading and interference on data transmission. In addition to energy conservation and communication quality, the EACO protocol also provides improved scalability and reliability compared to standard MAC protocols. This is achieved by allowing nodes to join or leave a cluster based on changes in network conditions, which helps to reduce the impact of node failures and congestion on the WSN. The EACO protocol also provides a simple and efficient mechanism for cluster head election, which enables nodes to work together to transmit data in a cooperative manner. In conclusion, the energy-aware cooperative MAC (EACO) protocol is a promising approach to improve the energy efficiency and communication quality of Wireless Sensor Networks (WSNs). The EACO protocol combines the features of cooperative communication and The authors in [11] presented the Underwater Cooperative MAC protocol (UCMAC) cooperative MAC protocol for underwater WSNs (UWSNs). First, a source node must identify the suitable cooperators through the cooperators' list while also specifying their proximity to the destination. Then, the best one of the selected cooperators sends the data packet that it successfully received from the source node or from the other cooperators. If an error is received for a data packet, the destination requests from the cooperators to re-transmit the data in the first nearest way. System latency, throughput, and energy efficiency were assessed for UCMAC. The results showed that the UCMAC protocol outperformed other existing cooperative schemes. A throughput and energy-aware cooperative MAC technique for WSNs was presented by the authors in [12], where (TEC-MAC). TEC-MAC allowed the sensor nodes with higher data rates to act as relays to the source nodes with lower data rated using the multi-rate capability feature of the IEEE 802.11. On the other hand, the relay can transmit its own data packets while transmitting the source node’s data packets. In TEC-MAC, each node periodically listens to running transmissions on the channel to create and maintain a list or relay table and this process wastes a lot of time. In [13], the authors designed a MAC-layer protocol to enhance the data transmission performance in WSN. A channel allocation technique for nodes in this protocol was presented and is based on the maximum of channel gain. The proposed protocol aimed to minimize from the transmission collision, so the authors proposed a retransmission scheme. This scheme was based on the multiple access carrier sensing system with a collision avoid approach. According to the simulation results, the suggested protocol increased accessing fairness and had a greater chance of transmission in WSNs. The authors of [14] offered two methods for energy-saving cooperation: a cooperative power allocation method and a relay selection method. These two methods were created to be used with Energy Harvesting WSNs (EH-WSN). The authors used a simple heuristic algorithm which helped in enhancing the energy efficiency of sensor nodes in EH-WSN which was based on a clustering scheme. First, the authors assessed how cooperative communication affected EH-WSN performance. The energy sustainability of each sensor node was also taken into account. The results of the simulation shown that the suggested approach performs admirably in the transmitting power distribution for node allocation and average working utility. A cooperative Medium Access Control (MAC)-layer technique for WSNs, named (MCA-MAC), was created by the work in [15]. MCA-MAC protocol helped to enhance some important metrics that have a great effect on the performance of WSNs such as throughput, delay, and energy efficiency. With this protocol, the source sensor nodes can use the middle neighbour nodes as relays. These relays have the ability to transmit source's data to the AP. The authors also presented that algorithm for choosing the best relay based on its shortest time of transmission for the given source-destination pair. The simulation results analysed the performance of a WSN after using MCA-MAC protocol and by comparing the results with other existing schemes such as TEC-MAC protocol, MCA-MAC surpassed TEC-MAC in terms of throughput, energy efficiency, and packet latency. However, these two protocols have some limitations such as, each node must listen to the current transmission to build the relay list and that may waste a large time. Also, there is no solution presented if the selected relay was busy. The EC-MAC that is suggested in this study helps to overcome the issues and difficulties that the TEC-MAC [12] and MCA-MAC [15] protocols encountered. For instance, in EC-MAC, a well-distributed method that doesn't necessitate a lot of overheads selects the best relay node. The chosen relay in EC-MAC is determined by a number of factors in addition to CSI, including transmission time and residual energy.

3. Communication System Description

This study made the assumption that the WSN contains 150 static sensor nodes. These nodes have an even distribution. One physical wireless channel was used for data transfer. In order to maintain the channel conditions constant while transmitting the MAC frame, a slow fading channel is also used. The source and relay node signals are both monitored and heard by the AP. Due to wireless channels' broadcast nature, it also receives their signals. The IEEE 802.11b standard is the foundation for the WSN proposed in this work. Known data transfer rates offered by the IEEE 802.11b protocol are 11, 5.5, 2, and 1 Mbps [12,16,17].The direct transmission mode and the cooperative relaying mode are the two data transmission methods, as was previously indicated. Since the data is sent directly from the source to the destination, only the source and destination nodes are involved in the transmission process when using the direct transmission mode (AP). The suggested relay selection technique is used by the source node to choose the optimal relay node during the first of two phases that make up the cooperative relaying mode. The second phase covers the whole routing path from the source node to the destination through the relay node as well as the overall data transmission procedure. The relay node then delivers this data to the destination as the source node begins transmitting its "DATA-S" data to it. Finally, EC-MAC protocol enables the relay to send its own data to the AP after sending the source's data which saves more time and power consumption. Figure 1 gives a description of the system communication.

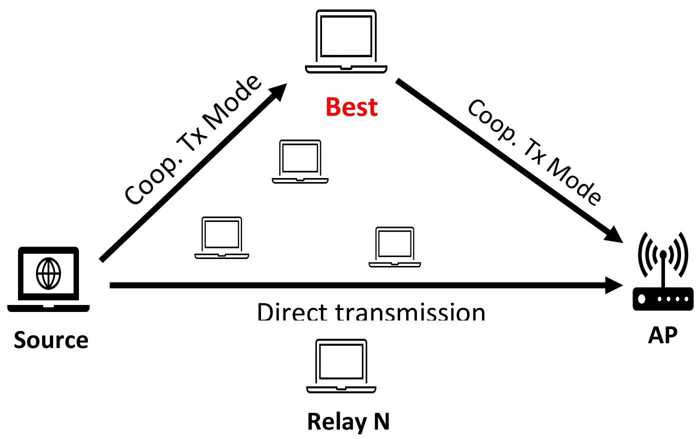

Fig. 1. The communication system description

4. Proposed EC-MAC Protocol

This section provides examples of the fundamental concept and specifics of the proposed EC-MAC protocol for WSN. In this part, an introduction to the IEEE 802.11 MAC protocol has also been included. Relay selection algorithm and relay transmission protocol are the two components that make up the cooperative relaying transmission mode in the proposed EC-MAC protocol. The proposed optimum the data transmission algorithms and relay selection algorithm are now thoroughly detailed of next section.

4.1 The Proposed Relay Selection Algorithm

Without taking into account any other significant sensor node-related parameters, such as the total transmission time and the residual energy of the sensor nodes, the majority of relay selection approaches rely solely on the channel state information (CSI) of the source to AP, source to relay, and relay to AP channels. In order to save energy and select the best relay node for a high network performance, the EC-MAC protocol's architecture focuses on minimizing the number of control packets that are sent between sensor nodes. [12,15], The optimal relay is chosen based on three factors: the CSI, the amount of residual energy (RE), and the transmission time of the data packet. In this paper, the proposed relay selection algorithm passes through some steps. First, the source node with data need to transmit must send a Need to Send (NTS) packet. Once the neighbouring sensor nodes received this NTS packet, they deduce the CSI of the channel to AP then compares it with a predefined threshold value (TH). The neighbour is regarded as a potential relay if the measured CSI is above this cutoff; otherwise, the neighbour concludes that it is unable to improve the direct transmission and quietly departs. Second, every last neighbour may successfully relay the data packet to the AP. Now, the best relay must be selected from the remaining nodes set (M) according to the least end-to-end delay and the highest residual energy. So, to become the relay node, each potential relay computes an $R_{Backoff}$ value using the following equation:

$$R_{Backoff} = \frac{1}{\alpha\, CSI + \delta\, RE + \beta \frac{1}{T_{srd}}} \tag{1}$$

Where α, δ, a nd β are three coefficients that used to normalize the value. On the other hand, T_{srd} is the cooperative transmission time for a source node (i) employing a relay node. The direct data transmission time can be calculated as follows:

$$T_{sd} = 8L\, R_{S-D} \tag{2}$$

L stands for packet length, and R_{S-D} stands for source to destination data rate. On the other hand, it is possible to determine the data transmission time for transmission of cooperative of source node, however, we can determine it by summing the transmission times from source to relay node and the transmission times from relay node to the AP (i). The cooperative transmission time can be estimated as in Eq. (3):

$$T_{srd} = 8L\, R_{sr} + 8L\, R_{rd} \tag{3}$$

Where R_{sr} is the data rate of the sending from the source node to the relay node. And R_{rd} is the transmission's data rate from the relay node to the AP. If a neighbour relay node j is concerned, it must meet the requirement that Tsrd < Td to be chosen as a relay node. For this source-AP pair, the chosen relay node that achieves the shortest transmission time from the source to the AP is designated as an optional relay node. The algorithm for relay selection is depicted in a flow diagram in Figure 2.

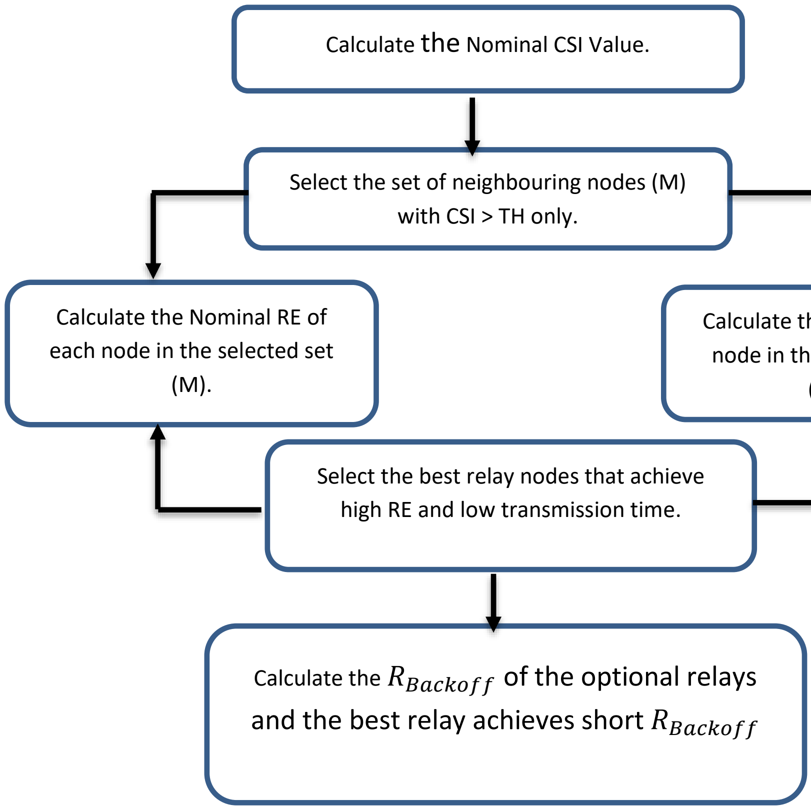

Fig. 2. Flow diagram of relay selection algorithm

4.2 Overview of IEEE 802.11 MAC Protocol

The majority of cooperative MAC protocols require RTS/CTS/ACK of the Distributed Coordination Function (DCF) of 802.11. The source node that has to transmit a packet uses sensing to find the channel. The channel backs off for a random amount of time after being found to be idle for the distributed inter-frame space (DIFS) length before transmitting a request-to-send (RTS) packet. If the intended node successfully received the RTS packet, it will transmit a CTS packet to acknowledge the channel reservation and get ready for the incoming data packet after a brief inter-frame space (SIFS) time. When RTS and CTS packets are exchanged, communication between the source node and the destination node is established, and parameters are initialized. The neighbour nodes within the communication range of the source node and the destiny node update their NAV durations by deleting the duration fields from RTS and CTS packets. The source node transmits the data packet for SIFS after the channel reservation is complete. The source node watches for an ACK packet sent by the destination node.

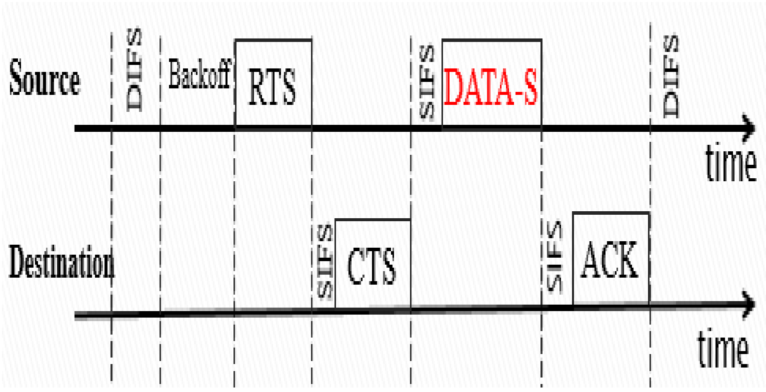

Fig. 3. The handshake mechanism timing of 802.11 RTS/CTS/ACK

4.3 EC-MAC Data Transmission Algorithm

As mentioned above, the cooperative relaying transmission mode and direct transmission mode are the two data transmission modes supported by the EC-MAC protocol. This section explains these two modes in detail.

4.3.1 Cooperative relaying data transmission mode

This strategy used only for frame with long lengths. The source node sends its data frame via a relay node to AP. When a frame with large data's coming from the source node to broadcast (one that exceeds the RTS threshold), it waits for a random back-off time before sending an NTS packet to the AP. The AP waits for Short Inter-Frame Space Time (SIFS) after receiving the NTS packet before responding with a Clear To Send (CTS) packet and waiting for Ready To Relay (RTR) packets from neighbouring nodes. The relay node delivers an RTR packet to the source and AP as it becomes available. Only the relay node receives the data packets that the source node sends at the data rate (R_{sr}). At the same time, it receives a data packet from the source node, the data packet at data rate (R_{rd}) that transmitted broadcasts from relay node to AP. The AP responds to both source and relay with Cooperative Acknowledgement (C-ACK) after successfully obtaining data packets from the relay and the source. The source node will employ the direct transmission strategy if the relay node is unavailable. The handshake for cooperative data transmission relaying is illustrated in Figure 4.

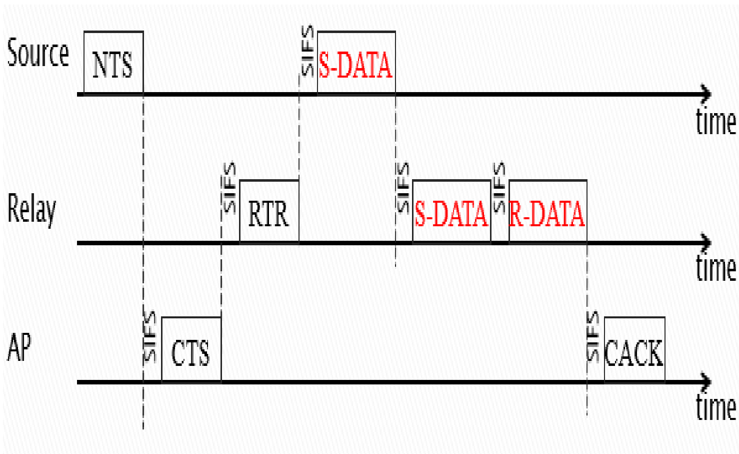

Fig. 4. The cooperative relaying data transmission handshake

4.3.2 Direct transmission mode

When relay of node become down or packet of data falls or less threshold values, that mode used. The source node transmits a Need to Send (NTS) packet to the AP and nearby sensor nodes when it has a large data frame to send (relays). The source and relay nodes receive a CTS packet in response from the AP. Data from source node is sent directly to AP after waiting the SIFS period and not receiving a Ready to Relay (RTR) relay node send packet refer to that unavailable. Source node receives a response from the AP in the form of an ACK packet. When the source's data frame length is smaller than the RTS threshold, it uses the IEEE 802.11 DCF RTS/CTS protocol to transmission its packet of data direct to AP [18]. Direct transmission mode's steps are shown in Figure 5.

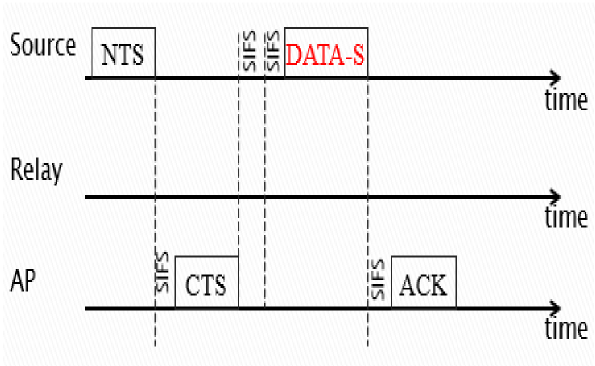

Fig. 5. The direct transmission handshake

5. The Mathematical Model of EC-MAC Protocol

The mathematical model for the estimation of the performance of WSN using EC-MAC protocol has been introduced in this section. The performance is measured in terms of energy efficiency under ideal and dynamic channel conditions.

5.1 Markov Chain Model

The EC-MAC protocol chose an analytic Markov chain as its expansion of the chain Bianchi suggested in It is a chain model in two dimensions that takes frame retry restrictions into account. Backoff counter value "k" and Backoff stage “i" are these parameters in IEEE 802.11b that characterize the state of a node. When sending a packet for the first time, “i” is initially adjust value to become 0 after that increasing by 1 every time, up to the maximum value of m, there occurs a collision. And "k," which is started by a random number between [0,W_i−1] is selected, while counter range is W_i is . $\tilde{\iota}_i$ represents to likelihood of node “i” that will transmission data in random time slot. While backoff counter nears to be 0, the medium is accessible by node irrespective of value of the backoff stage. The Markov chain model takes into account both the likelihood of errors and collisions. The Markov chain is shown in Figure 6. In [11,12,18], the likelihood of errors and Markov chain parameters are discussed in-depth. As a result, we have the back off stage as follows:

$$W_j = \begin{cases} 2^j W_o\,, & j \leq m \\ 2^m W_o, & j \geq m \end{cases} \quad (4)$$

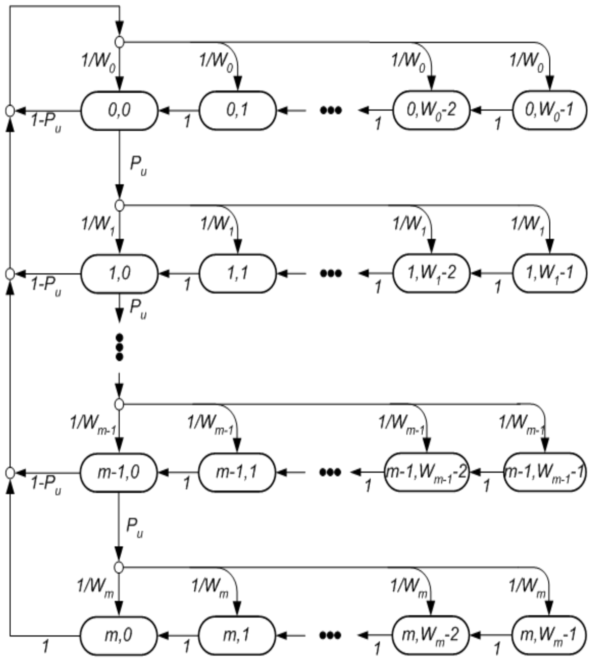

Fig. 6. The Markov chains

5.2 Energy Efficiency Expression Derivation

For Ideal the EC-MAC protocol network, the energy consumption through period of backoff $E_B^{(i)}$, energy consumption through period of collision $E_C^{(i)}$ and energy consumption through transmissions of overhearing $E_O^{(i)}$ are calculated in [12]. Then, energy consumption through transmission of successful $E_S^{(i)}$ of node that intended calculated as a below:

$$E_S^{(i)} = E_S^d + E_S^c \tag{5}$$

Which E_S^d is a direct transmission that successful and calculated as a below:

$$E_S^d = P_{TX}\left(T_{RTS} + \frac{8L_s}{R_{sd}} + T_{PLCP}\right) + P_{RX}T_{CTS} + P_{IX}(T_{ACK} + 3T_{SIFS} + T_{DIFS} + 4\Delta) \tag{6}$$

Which E_S^c is a cooperative transmission that successful and calculated as a below:

$$E_S^c = P_{TX}\left(T_{MRTS} + \frac{8L_S}{R_{sd}} + T_{PLCP}\right) + P_{RX}\left(T_{MCTS} + T_{RTH} + \frac{8(L_S+L_r)}{R_{rd}} + 2T_{PLCP}\right) + P_{IX}(T_{ACK} + 6T_{SIFS} + T_{DIFS} + 7\Delta) \tag{7}$$

Let E1,E2,E3, …., E5 are consumption of energy that node observed through durations T1,T2, …., T5 respectively that calculated as same as concept

For cooperative and direct transmission schemes [12], So consumption of energy through erroneous transmissions $E_E^{(i)}$is given by:

$$E_E^{(i)} = \sum_{i=1}^{N} N_i^d E_i^d + \sum_{i=1}^{7} N_i^c E_i^c \tag{8}$$

Which N_i^d and N_i^c are the numbers of average retries due to depravity of data packet and control in cooperative and direct transmission schemes respectively. That given by:

$$N_i^d = E[N_r]\frac{(1-P_{c,i})P_{ej}^d}{P_{u,i}}, \quad j = 1, 2, 3, 4. \tag{9}$$

$$N_i^c = E[N_r]\frac{(1-P_{c,i})P_{ej}^c}{P_{u,i}}, \quad j = 1, 2, 3, 4. \tag{10}$$

Which the average number of retries $E[N_r]$ that the node of intended before transmitting packet successfully will do it and will be presented in [12].

For non-ideal the EC-MAC protocol network, an expression for energy efficiency is derived in this subsection. The proportion of successfully sent packet bits to the network's overall energy consumption is known as ε, which stands for energy efficiency. Energy is used by nodes during the following operations: backoff $E_B^{(i)}$, transmission overhearing $E_O^{(i)}$, collision $E_C^{(i)}$, successful transmission $E_S^{(i)}$, and transmission errors $E_E^{(i)}$. When not engaged in any transmission or reception processes, nodes go into a sleeping mode to conserve power. The terms "PTX," "PRX," and "PIX," relate to the transmission power needed, reception, and (inactive or sensing) hence in addition, Eq. (8) [12] can be used to express the entire network energy efficiency. The reference [12] provides an explanation of how to calculate $E_B^{(i)}$, $E_O^{(i)}$, $E_C^{(i)}$, $E_S^{(i)}$, and $E_E^{(i)}$.

$$\varepsilon = \frac{8L\sum_{i=1}^{N} P_{s,i}(1-P_{e,i})}{\sum_{i=1}^{N}(E_B^{(i)}+E_C^{(i)}+E_O^{(i)}+E_E^{(i)}+E_S^{(i)})} \tag{11}$$

6. Results and Discussion

MATLAB has been used to assess the effectiveness of the suggested EC-MAC protocol to demonstrate the effects of several elements, including the quantity of sensor nodes and packet size. Which simulation software produced the results of the energy efficiency of WSN utilizing the suggested EC-MAC protocol have been taken. According to the results below, it was determined that the performance of EC-MAC protocol fared better than the TEC-MAC and protocols. The benchmark values of parameter values for simulation are displayed in Table 1 below.

Table 1
The standard values of parameters for simulation

Parameter	Value	Parameter	Value
MAC header	28 bytes	Slot time	9 µsec
PHY header	24 bytes	SIFS	16 µsec
RTS	44 bytes	DIFS	50 µsec
CTS	38 bytes	MRTS	50 bytes
ACK	38 bytes	MCTS	38.25 bytes
RTH	38 bytes	CW_{min}	15
CACK	38.25 bytes	CW_{max}	1023

Effectiveness of EC-MAC protocol for nodes with different data rates is evaluated in this research. Additionally, we examine our protocol in the following two cases:

6.1 Impact of Ideal Channel Environment

Figure 7 shows the energy of EC-MAC protocol and MCA-MAC protocol and TEC-MAC protocol in relation to the number of sensor nodes in an ideal channel environment. The energy of MCA-MAC and TEC-MAC reduces as the number of nodes rises, as Figure 7 illustrates. An increase in the likelihood of collisions is the cause of this. The EC-MAC protocol significantly exceeds the substitute in terms of performance. Overall, the EC-MAC protocol outperformed the MCA-MAC protocol and TEC-MAC protocol by 20% and 40%, respectively, in terms of energy savings. This is because the best relay was chosen, which speeds up cooperative transmission. Thus, it lowers energy use and boosts energy effectiveness.

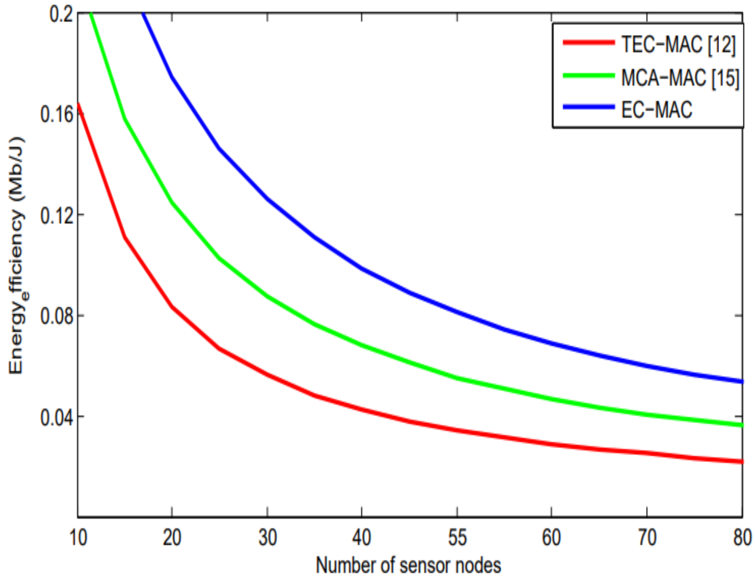

Fig. 7. Energy versus number of nodes with ideal channel condition

Under ideal channel conditions, Figure 8 illustrates the energy of EC-MAC protocol and MCA-MAC protocol and TEC-MAC are tracked with the packet length. Due to the specifications set forth in the EC-MAC protocol and MCA-MAC protocol and TEC-MAC, the packet size ranges from 400 to 1300. This figure demonstrates how the energy of three protocols grows as packet sizes increases. These happen because the overhead decreases as packet length grows. The EC-MAC protocol, however, performs a great deal better than the other transmission protocols.

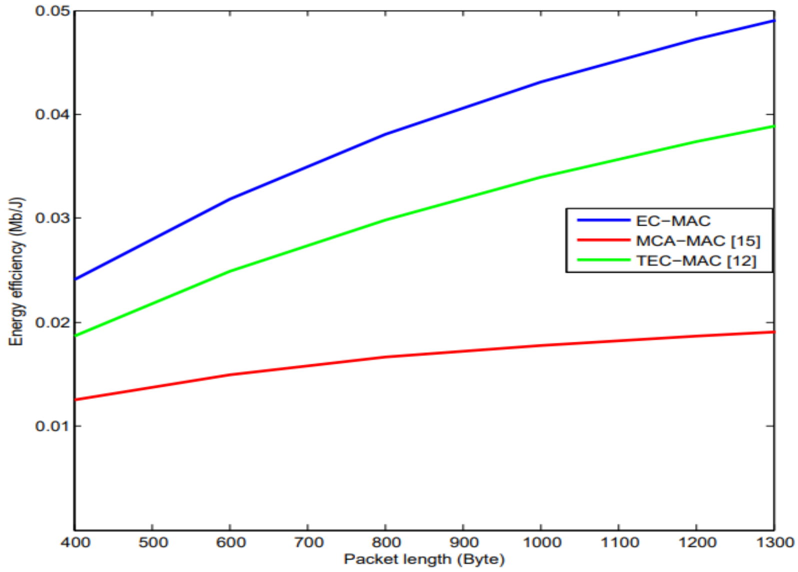

Fig. 8. Energy versus packet length with ideal channel condition

6.2 Impact of Non-Ideal Channel Environment

Figure 9 and Figure 10 show that the energy efficiency of EC-MAC protocol and MCA-MAC protocol and TEC-MAC protocol with the packet length and number of sensor nodes respectively. Shown that in the Figures, Energy efficiency of networks using EC-MAC can perform energy efficiency more than others using MCA-MAC protocol and TEC-MAC protocol under non-ideal channel condition. As illustrated in Figures 9 and 10, the proposed EC-MAC protocol is better than MCA-MAC protocol and TEC-MAC protocol in achieving more energy efficiency under defective channel environment.

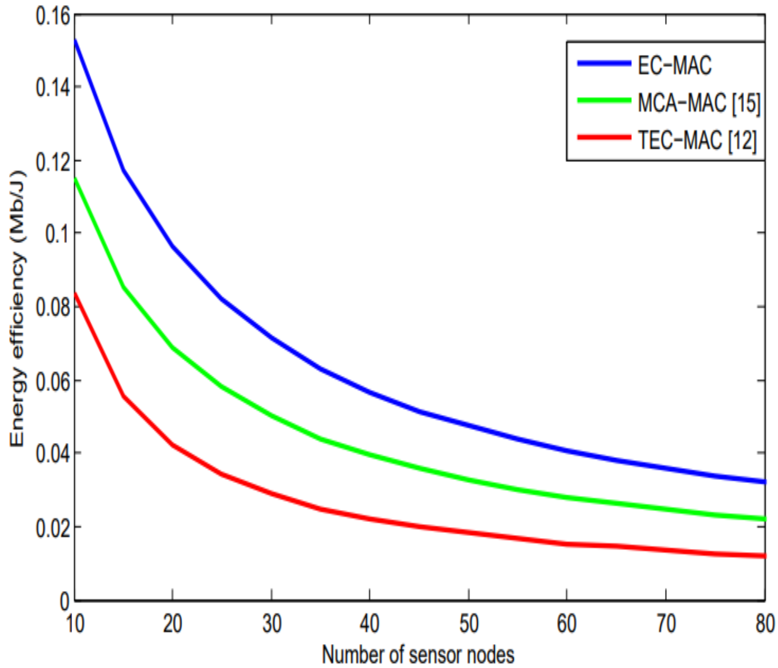

Fig. 9. Energy versus sensor nodes with non-ideal channel condition

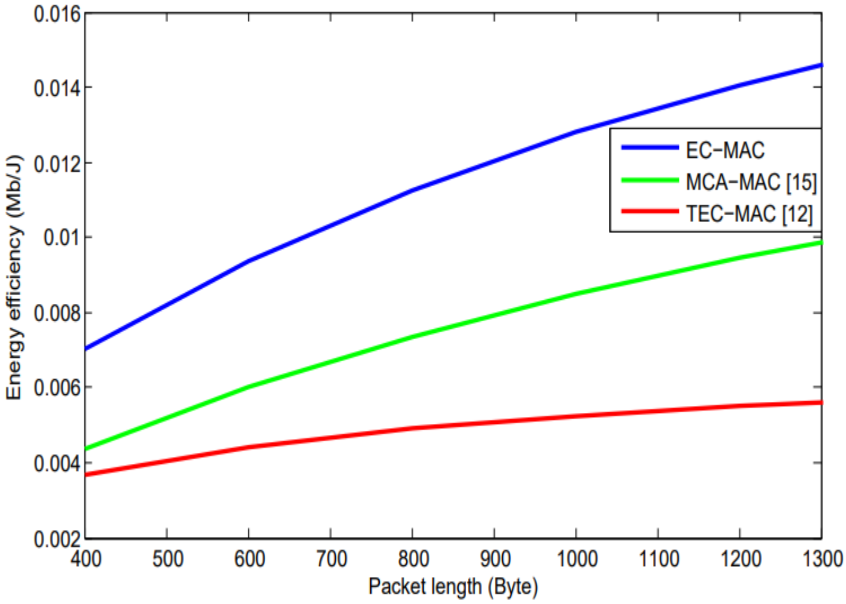

Fig. 10. Energy versus packet length with non-ideal channel condition

7. Conclusions and Future Work

For centralized wireless sensor networks, the EC-MAC protocol, a novel MAC layer protocol, has been suggested in this work. The network is improved by this protocol through using technology for cooperative communication, using a relay selection method, each wireless sensor node chooses the relay that will provide the greatest benefits for the high residual energy and short transmission time. The EC-MAC protocol also suggests a viable cooperative technique that let the relay node to use the channel without requiring a handshake to submit its own data packets. The suggested protocol was created in order to assess how well the EC-MAC performed in both dynamic and ideal channel settings. The MATLAB simulation results show that the proposed EC-MAC protocol may significantly improve energy efficiency by 20%, 40% respectively when compared to the MCA-MAC and TEC-MAC cooperative MAC protocols. Future research will find it fascinating to examine the EC-MAC protocol's system performance in real-time applications, such medical applications. Additionally, it will be beneficial to examine how the EC-MAC protocol performs in unsaturated environments that use more intricate traffic simulations, like the Markov Modulated Poisson Process model.

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