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ANTMAC: Addressing Novel Congestion Technique Hybrid Model for Collision Control in IoT-based Environments using Contention-based MAC Protocol

Rabindra Kumar Shial
Department of Computer Science & Engineering, GIET University, Odisha, India
E-mail: rabindra.shial@giet.edu
ORCID iD: https://orcid.org/0009-0006-9606-9265

Premanshu Rath
Department of Computer Science & Engineering, GIET University, Odisha, India
E-mail: premansusekhararath@giet.edu
ORCID iD: https://orcid.org/0000-0002-5982-8983

Sudhir Ranjan Patnaik
Department of Computer Science & Engineering, NIST, Berhampur, Odisha, India
E-mail: sudhirpattanaik.oca@gmail.com

Sarat Chandra Nayak
Department of Computer Science, Yonsei University, South Korea
E-mail: saratnayak234@gmail.com; saratnayak234@yonsei.ac.kr
ORCID iD: https://orcid.org/0000-0003-0804-1264

Umashankar Ghugar*
Department of CSE, OP Jindal University, Raigarh, Chhattisgarh, India
E-mail: ughugar@gmail.com
ORCID iD: https://orcid.org/0000-0001-8508-9179
*Corresponding author

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Abstract: In the communication model of the OSI layer, the Media access control (MAC) layer has been given higher priority than other layers. It is a sub-layer of the data link layer, mainly controlling the physical equipment and interacting with the channels over the Internet of Things (IoT) sensor nodes. Mac layers have used two protocol types: contention-based and contention-free during transmission. These two protocols have controlled the physical equipment and data transmission for the last decade. Yet in the MAC layers transmission, some challenging issues are complicated to resolve. Data collisions are the significant changing issues at the MAC layer. As per the survey of researchers, the contention-based protocol is more affected by collision due to allowing the sharing of channels to all nodes over networks. As a result, it has got message delay, demanding more energy, data loss, and retransmission. The researcher always focuses on reducing collision during transmission to overcome these issues. They mainly evaluate the priority-based collision control using the contention-based protocol. In this ANTMAC model, we have considered the lower energy nodes' priority to enhance the likelihood that a node will gain access to the transmission channel before its power and batteries run out. Our recommended method ANTMAC outperforms ECM-MAC in terms of content retrieval time (CRT), total no of retransmission (TNR), total energy consumption (TEcm), throughput and network lifetime (NLT).

Index Terms: Collision, Contention Window, Contention Free, S-MAC, ECM-MAC, CRT.

1. Introduction

The concept of the Internet of Things (IoT) involves connecting sensors and actuators to networks and computers via the internet, enabling electronic monitoring and management of the physical world. Communication over IOTs is the most necessary for a human being in the current era. IOTs is constructed with several sensor nodes, which have less computational power and are tiny in size. Most of the time, nodes are deployed in unwanted places and accessed remotely. IOTs are low-cost and straightforward network architecture over wire networks. There are several applications in WSN such as environmental sensing, health monitoring, military surveillance, fire detection, weather forecasting, etc. [1]. In the OSI model, the data link layer is responsible for data transfer from node to node and the IEEE 802 standard also maintains it. This layer again works with two sub-layers such as MAC and Logical link control (LLC). The MAC has been prioritized due to its flexibility in controlling hardware equipment and data transmission. The MAC layer protocol has been divided into contention-based and contention-free. In contention-based protocol, it provides access to multiple channels at the same time and uses some set of rules for conducting smooth transmission during data flow. But still, there is some lacuna in data flow due to collision issues. Nowadays collision is a challenging issue in WSNs. When nodes access multiple nodes at the same channels, then it forms a collision, and that may result in a hidden terminal and overhearing problem [2]. Due to the collision, data are lost significantly. It is treated as a major drawback of the collision. After the collision, a regenerated process is required. As a result, extra energy and protocol performance. The priority-based collision control method is used to access the unauthorized with higher priority than other nodes' data. Priority can be managed by the different aspects such as signal levels of each node and data types. Those nodes, which have low energy and `essential data, must allow data transmission. In WSNs, energy consumption is the key factor during the transmission process, controlled by MAC protocol. Energy improvement is must necessary for improving the MAC protocol. The different facts of MAC protocol waste energy. As result hampers the lifespan of each node [3]. Several research papers have been published in this area, but still, energy consumption is a challenging issue in IOTs. There are two types of protocols such as contention-based and contention-free protocols. Another protocol, hybrid is a combination of the above two protocols [4]. Multiple users can transmit simultaneously across the same channel when using contention-based protocols. One of the leading causes of the protocols' poor performance is this media sharing. One of their most challenging problems is a collision. It causes several issues that impede the smooth transmission of signals, including latency, data and time loss, increased energy consumption, and many more. Collisions produce latency that slows messages and uses time and energy. Furthermore, a crash could result in the loss of crucial data, another enormous difficulty that must be fully overcome. Additionally, nodes occasionally attempt to re-transmit the data[5].

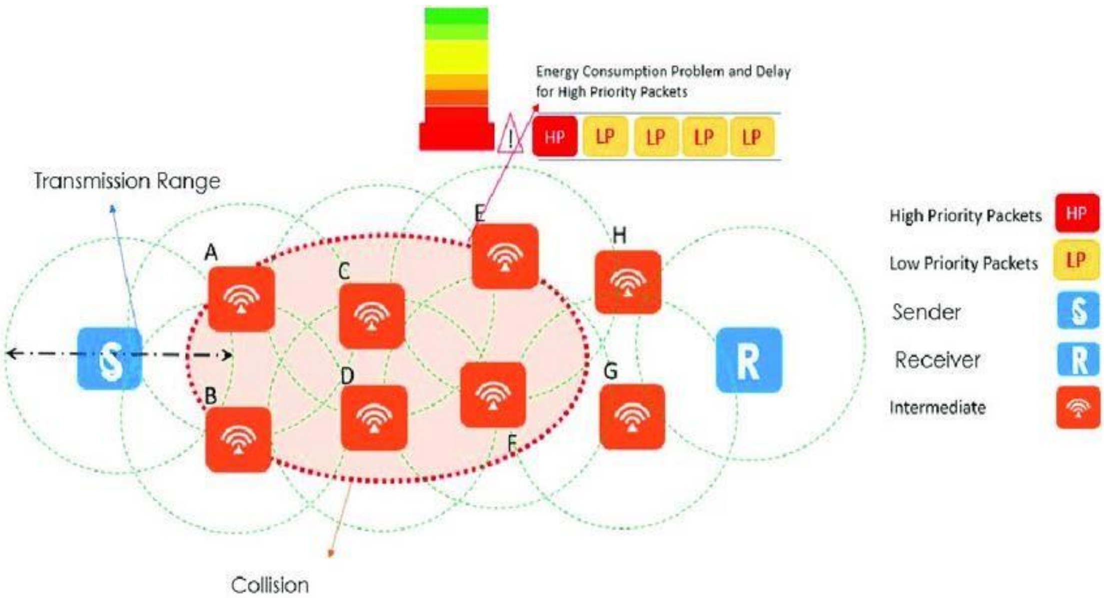

Fig.1. Collision and energy consumption problem scenario in IOTs [5]

The Objective of the ANTMAC Hybrid Model is as Follows

- To assess the effects of adjusting the data rates according to the probability of collisions and implementing priority-based collision control technique, which reduces collisions and enhances the efficiency of the protocol.
- Once a priority-based collision control technique is implemented in a contention-based protocol, it is essential to adjust the data rates, assess their impact on collision probability, and evaluate the protocol's collision rate and overall effectiveness of the MAC protocol.

- The proposed model will aid in reducing collision probabilities, enhancing the energy efficiency of the MAC protocol, and mitigating message delays caused by collisions. This would enable faster transmission rates and improve the overall quality of service of the protocol.

The paper has been organized as follows: Section 1 presents the introduction part and section 2 describes related work. Section 3 presents about problem and motivation section, sections 4 present the MAC architecture. Section 5 and 6 provides the ANTMAC model, and simulation and result analysis part. Finally, we have concluded the paper in section 7.

2. Related Works

To improve the quality of services and consumption of energy, most of the researchers have been working on the MAC protocol. In [6], the collision-free MAC protocol (CF-MAC) model, which uses the collision avoidance concept and reduce wasted time. Many nodes have participated in data transmission in WSN as results collision problem might be increases. The frame loss rate is decreased and the throughput is improved in [7] due to the implementation of a directional data transmission mechanism and a random-access method for collision avoidance. In [8], dynamic time slot has been allocated for adapting the rule for priority-based transmission. Here the performance is compared in term of energy requirement, throughput, and transmission speed. In this model, the authors have defined different types of priority such as energy data, on demand data and the periodic data and uses the different path to reduces the collision. In [9], during the data transmission process from node to base station, several collisions occur due to noise as results it lost the energy and packets. Here authors designed an algorithm, which is detect the data flow rate and indicates the collision of corrupted nodes. To overcome this problem, the initiator node has been implemented in this model. In iCore [10], proposed a collision free data collection model. In which, data has been dynamically forwarded to base station without any disturbance based efficient transmission scheduled, decreases the delay comprehensively and forwarding sequence optimization technique. In [11], the authors proposed a model, where distributed MAC based protocol has been implemented and uses the extension technique of CSMA over WSNs. Here, in the first phase, it has used filtration mechanism to differentiate the collision station and in second phase it detects the collision and improved as it is possible. Several collision detection methods have been used to improve the better quality. In [12], authors proposed Convergent MAC(CMAC) model, where it archive the inconsistent goals of low latency and energy efficiency and avoid the synchronization overhead. It also works at very low duty cycle at less traffic environments. The unicast method has been use forwarding the sensor nodes during the heavy traffic scenario, and it is coverage to unsynchronized duty cycle. In [13], the authors proposed a mode, where the uplink traffic has been restricted for the transmission simultaneously by using logical mechanism, and extend the CSMA/CA IEEE802.15.4 standard by using the probability concept of collision and retransmission limit. In [14], Markov chain model has been used to evaluate the energy efficiency, data rate and throughput. Here protocol is also used for making the node efficient energy and maintaining the low data rate. The large number of transmissions in networks, it hampers the data rate results and decreases the throughput.

In complex networks, the transmission is used for exponential backoff value. One of the deterministic backoff values represented CSMA/CA protocol is proposed, and each frame is the transmission with ACK. Set the protocol. Therefore, the start of the information and a proposed algorithm is run. Again, each ACK frame holds an extra bit with the back of represents representing the time slot wait time before the next transmission process. An efficient energy MAC protocol is proposed in [15] to find the active period of the nodes. In AP-MAC, nodes are active simultaneously with data transfer, increasing the probability of collisions. However, the random movement of nodes can reduce this probability and increase energy efficiency. In this scenario, both nodes must be aware of the active period before transmission can occur. AP-MAC creates a network environment that optimizes data transmission and collision avoidance. To further enhance this mechanism, a sleep scheduling mechanism that incorporates similarity measuring has been proposed in [16]. After the cluster construction, the data redundancy is checked using a fuzzy matrix. Similar sets of data nodes are seen at various stages. Nodes are placed in a sleep state to detect similarities. This method results in a transmission that is collision- free, error-free, and energy-efficient. The step towards the efficiency of collision in [17] is proposed due to data transmission at a time. LMAC (light weight MAC protocol) is a weight increase process avoid collision with increase energy efficiency. If there are more time slots than there are nodes, the network's value will change less, but collisions will be more likely to occur when there are less slots. The LMAC optimal number of time slots is a useful tool for preventing such problems. In [18], a number of strategies for lowering SMAC's power consumption due to collisions and delays are proposed. The SMAC algorithm handles different variable loads and contention windows according to data load. Various techniques are used to reduce collision based on the contention window. Before send the data, it will sense the medium then send. Hence reducing the crash and varying the contention window. The authors suggested that the proposed algorithm reduced collision as well as latency and consumed less energy as compared to other MAC protocols. The simulation time is less than 10 seconds; hence more time is needed to get the correct result. Many research works are going on energy efficiency in [19,20,21,22]. In Ad-hoc vehicular networks, researchers are currently concentrating more on intelligent transport systems. EDCAF is suggested as an analytical methodology to gauge IEEE 802.11's efficacy. The IEEE 802.11 standard's EDCAF, or enhanced multiple channel access function, is utilized in the MAC and physical layers to priorities the y-based quality of service. The ensuing relationship of EDCAF and its measures are investigated along with a theoretical method built on the Markov chain model. In VANETs with the issue of packet loss and collision, a new and effective MAC technique based on orthogonal frequency division multiple access is proposed [23,24].

3. Problems Scope and Motivation

Data transmission might be successful in this scenario. However, the issue of extra energy now arises. Since sensor nodes in IOTs are involved in sensing, processing, and other communication duties, optimizing a node's energy is a complex issue. Network collision in IOTs results in an energy concern. Serious network problems can result from excessive re-transmissions brought on by collisions, needless waiting for transmission retrieval, and excessive transmission of irregular and irrelevant data through low-powered nodes. The communication protocols used in IOT have a big impact on how much energy they use. Additionally, the erratic and unneeded awake time might lead to collision and energy problems. Periodic transmission over low-power sensor nodes can seriously impact the lifespan of the entire network, as well as result in data loss and delay problems.

The goal of this paper is to examine how well a contention-based MAC protocol performs by preventing and minimizing collisions. Multiple users can transmit data through the same channel simultaneously using contention-based protocols. Unfortunately, this sharing of channels is one of the reasons why the protocols can be inefficient. One of the biggest challenges that occur as a result of this is collisions, which can lead to issues such as latency, data loss, time loss, extra energy usage, and more, all of which can significantly hinder the smooth transmission of signals. Collisions resulting from contention- based protocols can cause latency, leading to delays in message transmission and a significant waste of time and energy. Additionally, the loss of important data due to collisions can be a major challenge that needs to be addressed. In addition, nodes may try to retransmit data, which is sometimes effective but results in increased energy usage for retransmissions and a large time loss that can have a detrimental influence on overall efficiency. The amount of power that nodes in a wireless sensor network use up is an important consideration. Due to the fact that nodes must perform sensing, processing, and communication functions, optimizing their energy consumption is a challenging problem. WSNs can run into serious power issues due to internal collisions. Serious problems might arise in a network because of, for example, an excessive number of retransmissions because of collisions, long retrieval times for transmissions, or the transmission of frequent but insignificant data by nodes with limited resources. The amount of power that nodes consume in WSNs is heavily reliant on the protocols used for communication between them. Collisions and energy waste might be exacerbated by unplanned waking periods. In addition, data loss and delays caused by periodic transmission through low-power sensor nodes can significantly impact the total network lifetime. To ensure optimal energy consumption and maximum network performance, these considerations must be baked into the design of communication protocols for WSNs from the get-go. According to the research on ECM-MAC and S-MAC methods. Here we have listed some important problems of ECM-MAC and S-MAC as follows:

- ***Complexity:*** The ECM-MAC protocol may be more complex than other collision mitigation strategies, which could make it more difficult to implement and maintain.
- ***Overhead:*** Using additional packets and procedures for collision detection and avoidance could increase overhead, negatively impacting network performance.
- ***Sensitivity to network conditions:*** The performance of the ECM-MAC protocol may be highly dependent on the specific network conditions and parameters, which could limit its effectiveness in certain situations.
- ***Scalability:*** The ECM-MAC protocol may not be scalable to very large networks or high- density environments, where the number of nodes and the amount of traffic could overwhelm the collision detection and avoidance mechanism.
- ***Limited scalability:*** The S-MAC protocol does not scale well to large networks, as it relies on frequent sleep-wake cycles for energy efficiency. As the number of nodes in the network increases, the overhead of managing these cycles also increases, reducing the protocol's efficiency.
- ***Latency:*** The sleep-wake cycles in the S-MAC protocol can lead to increased end-to-end latency, as nodes may be asleep when they need to communicate. This can result in delayed transmissions and increased energy consumption due to unnecessary retransmissions.
- ***Sensitivity to network traffic:*** The S-MAC protocol is sensitive to changes in network traffic patterns, as it relies on periodic beacon messages for synchronization. In high- traffic environments, the protocol may experience increased latency and reduced throughput.
- ***Limited support for QoS:*** The S-MAC protocol does not provide explicit support for Quality of Service (QoS) requirements, making it difficult to ensure that high-priority traffic is given preferential treatment. This can be a significant issue in applications where timely or critical data must be transmitted.

The final motivation for this study is to ultimately enhance the performance and operation of contention-based MAC protocols within any IoT device using WSNs. This is particularly important since collisions can have a significant negative impact on the overall efficiency and reliability of WSNs. By developing and implementing effective priority-based collision control techniques and data rate alteration strategies, this project aims to reduce and ultimately avoid collisions, thereby improving the overall performance of contention-based MAC protocols within WSNs. This work is expected to have positive implications for a wide range of applications that rely on WSNs, including environmental monitoring, healthcare, and industrial automation, among others. As per the survey of the related work, we learned that collision control at the MAC layer is a critical task for network transmission. Therefore, we have designed a model like ANTMAC Hybrid Model having some objectives.

4. Mac Architectures

The MAC (media access control) architecture in IoT (Internet of Things) is a crucial component of the communication protocols used in IoT networks. The MAC layer is responsible for controlling access to the shared communication medium and coordinating the transmission of data between nodes in the network. In IoT networks, the MAC layer must support low-power and low-bandwidth devices, as well as provide support for various network topologies, such as star, mesh and ad-hoc networks. Some popular MAC protocols used in IoT networks include CSMA/CA, TDMA, and hybrid protocols such as the combination of ECM-MAC and S-MAC. Additionally, the MAC layer must provide support for QoS (quality of service) requirements, such as priority-based queuing, to ensure that high-priority traffic is given preferential treatment during transmission. Overall, the MAC architecture in IoT is an essential part of the network infrastructure that enables the efficient and reliable communication between IoT devices and systems. We covered the categorization of MAC protocols in this part. The two basic MAC protocols are contention-based and contention- free. The hybrid category shows both types of characteristics [25].

4.1. Contention-based Protocol

PAMAS is a costly contention-based protocol that employs a bi-channeled strategy to reduce collisions. S-MAC makes use of the power-saving listen-sleep cycles; however, it has problems with latency and idle listening because the cycles are fixed. T-MAC and P-MAC employ adaptive duty cycles. On the other hand, T is detrimental to MAC's early sleep, whereas P is MAC's passive listening. Even though it has certain problems with collisions, routing-enhanced MAC works well for single-cycle communications. When the data rate is constant, Data Gathering MAC is optimal for converge-cast transmission. Bi-channeled wise-MAC is great for dynamic data rates, but it has a hidden terminal issue that might cause issues.

4.2. Contention-free Mac Protocol

TRAMA has been determined to be suitable for single-channeled transmissions among contention- free protocols. However, Y-MAC is helpful when there are many channels. However, Y-MAC requires an international time clock. DESYNC-TDMA should be considered as a solution to this time clock issue. However, it has the disadvantage of squandering bandwidth because of equal nodal slots. And LEACH is used in conjunction with clustering methods to overcome this problem with unequal nodal slots. Its disadvantages stem from the cluster head's constant activity and increased energy consumption. LMAC has sufficiently minimized the issue of physical layer overhead with the distributed method, but it must still deal with idle listening.

5. ANTMAC Hybrid Model

Our work provides a collision avoidance strategy for the MAC layer of WSNs that conserves energy by giving transmission preference to nodes with lower battery and energy levels. We solve the problem of packet collisions brought on by the nodes' waiting around at random intervals between transmissions. Our novel mechanism, ANTMAC Hybrid Model differentiates medium access based on the energy level of nodes to optimize Quality of Service (QoS) for devices with limited energy resources. By prioritizing lower energy nodes for transmission, the proposed mechanism aims to reduce energy consumption, and the overall efficiency of the proposed model is evaluated in terms of CRT, the total no of retransmission, total energy consumption, throughput analysis, and network lifetime.

5.1. Algorithm for ANTMAC Hybrid Model

i. Initialization:

- *Set the node to use ECM-MAC protocol for initial synchronization and collision avoidance.*
- *Once synchronization is established, switch to S-MAC protocol*

ii. Loop:

If the node is using S-MAC protocol: Periodically wake up and listen for incoming traffic.
If high-priority traffic is present:
Set node to ECM-MAC Protocol.
if collision present: Use Carrier Sensing Mechanism to detect and avoid collision
Set node to S-MAC protocol
Else

Transmit data based on ECM-MAC protocol.

iii. S-MAC protocol:

- *Set periodic wakeup intervals based on the network conditions.*
- *Set dynamic duty cycle adjustment based on the network conditions.*
- *Use neighbor synchronization to coordinate sleep-wake cycles.*
- *Set the node to use the S-MAC protocol.*

iv. ECM-MAC protocol:

- *During periods of high network traffic, switch back to ECM-MAC protocol.*
- *Use carrier sensing mechanism to detect collisions and avoid retransmissions.*
- *Use adaptive wakeup times and dynamic duty cycle adjustment based on the network conditions.*
- *Set the node to use the ECM-MAC protocol.*

v. QoS support:

- *Use priority-based queuing to ensure high priority traffic is given preferential treatment during transmission.*

5.2. Flowchart for ANTMAC

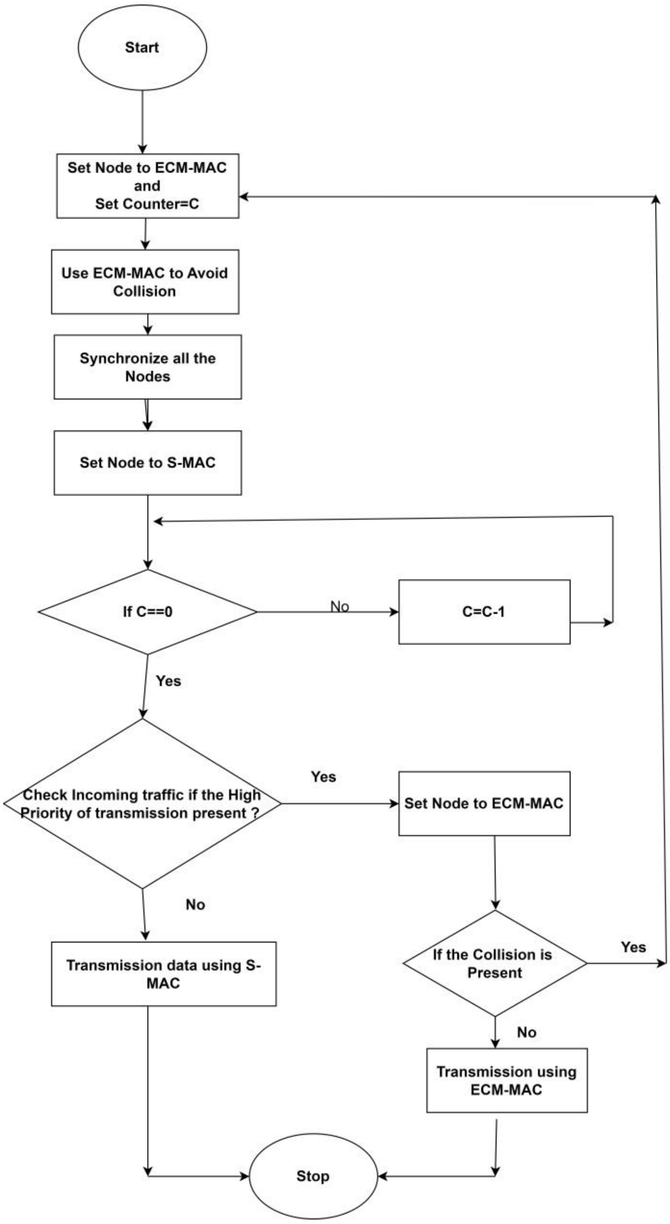

Fig.2. Flowchart of ANTMAC

6. Simulation and Results Analysis

This section evaluates the performance of our proposed protocol ANTMAC using various stimulation parameters and simulation matrices. ANTMAC was compared to native S-MAC and ECM-MAC protocols. Here we demonstrate the noticeable difference in implementing our protocol. We used MATLAB simulation tools in our proposed mechanism and applied them to our simulation environment's IEEE 802.15.4 MAC protocol standards.

Table 1. Simulation parameters

Parameters	Values
Transmission Media	Wireless
Size of the Networks	1000m*1000m
Physical Layer	Wireless Physical Layer
Medium Access Control	SMAC
CWmin	8-16
Simulation Time	20,40,60,80,100 Minutes
Number of Nodes	20,40,60,80,100
Energy Threshold	0-25%,25-50%,50-75%,75-100%
Number of sender/Receiver pairs	1,2,3,4
CRT	50
Nodes' Initial Energy	30J
Network Simulator	NS-2
Application	CBR
Simulation Run	10
Receiving Energy Consumption	0.3682 J
Transmit Energy Consumption	0.3682 J
IDLE State Energy Consumption	0.3442 J
Sleep State Energy Consumption	5.00E-05 J

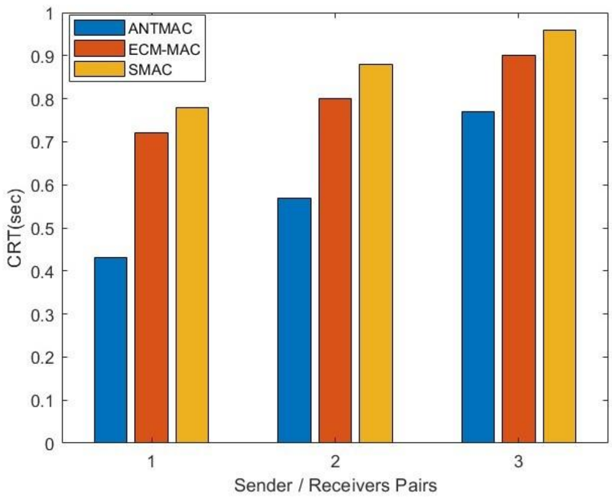

Fig.3. Content retrieval time (CRT)

In Figure 3, By measuring the number of senders and receivers on the X-axis and the Content Retrieval Time (CRT) on the Y-axis for each Mac protocol, we could assess its performance. The performance graph shows that, regarding CRT, ANTMAC performs the best. As we saw in the diagram, the ANTMAC managed the network's retransmissions, improving energy efficiency and lowering collision rates. Therefore, network accessibility and urgent network transmission lead to better CRT. The trends of the bar graph demonstrate that the CRT is more excellent with fewer sender and receiver pairs and lower with more sender and receiver pairs.

In figure 4, using the Total Number of Retransmissions performance matrix, we compare ANTMAC's performance to S-MAC and ECM-MAC (TNR). The value of the Y-Axis is TNR, while the value of the X-Axis is the total number of nodes. The graph shows that the ANTMAC performs better than S-MAC and ECM-MAC.

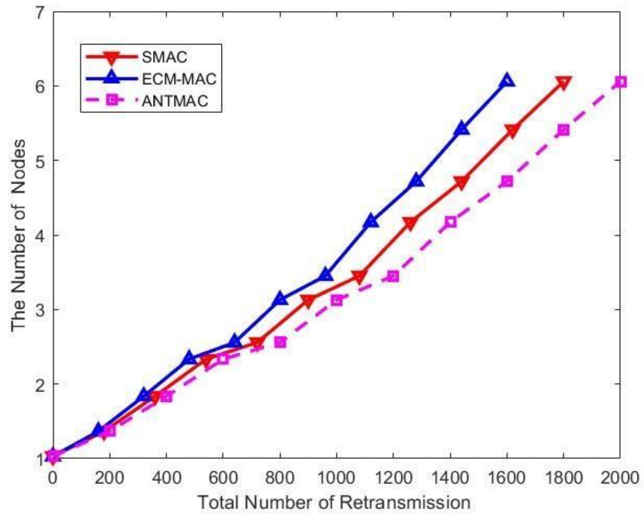

Fig.4. Total number of retransmissions (TNR)

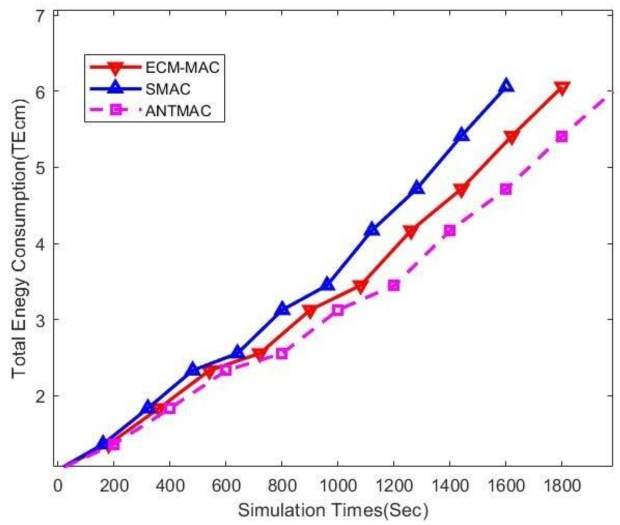

Fig.5. Total energy consumption (TEcm)

In figure 5, We compare the nodes' energy usage to the simulation times of 200, 400, 600, 800, and 1000 seconds. In this situation as well, ANTMAC performs better. Reduced retransmission rates and efficient CRT are directly correlated with the energy efficiency of ANTMAC. ANTMAC's priority mechanism well handles energy efficiency. This graph shows that all of the schemes—including ECM-MAC, S-MAC, and our suggested ANTMAC use less energy with shorter simulation times, and gradually spend more power with longer simulation times.

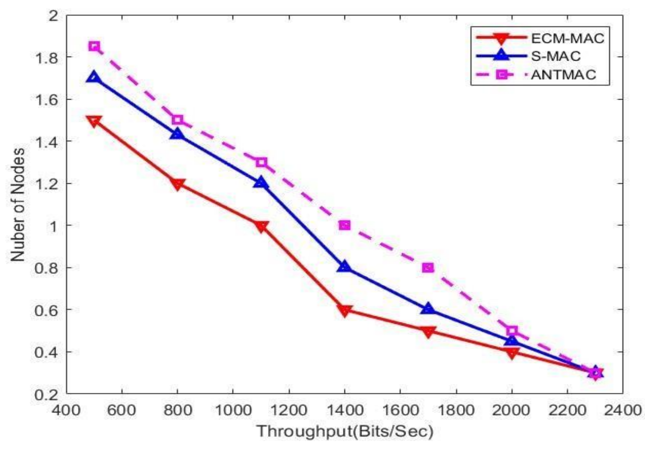

Fig.6. Throughput analysis

In figure 6, the simulation demonstrates the complete superiority of the ANTMAC architecture over SMAC and ECM-MAC. The transfer rate indicates the outcome, but actual consumption will also be comparable. One can send using a lower transmitter power or perhaps fewer pulses per bit with the ANTMAC protocol and still get the same transmission rate as with the other protocols. This discovery increases the protocol's energy effectiveness. On the other hand, it is essential to use alternative physical layer parameters to use the ANTMAC protocol.

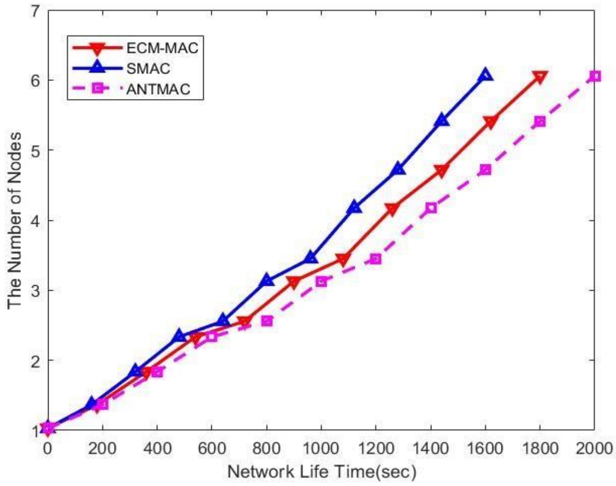

Fig.7. Network lifetime (NLT)

In figure 7, we assess ANTMAC's performance (NLT) using the Network Life Time performance matrix. Total Nodes is the value of the X-Axis, and NLT is the value of the Y-Axis. Here, there are 20 nodes, 40 nodes, 60 nodes, 80 nodes, and 100 nodes to experience varying traffic and packet densities. NLT should be lower if we want to share better performance. NLT and energy efficiency are directly related. The greater NLT, the more power and energy efficient the network is. Regarding NLT, ANTMAC performs better than the other comparable schemes, S-MAC and ECM-MAC.

7. Conclusion and Future Work

To evaluate priority-based collision control in a contention-based protocol is the primary focus of this model. In order to decrease collisions and maximize network longevity, nodes with the most crucial data or the lowest remaining energy will be prioritized for transmission. In the event of an excessive number of collisions, data flow will be intelligently decreased. Our simulation findings show that the ANTMAC protocol beats S-MAC and ECM-MAC in terms of total number of retransmissions, Content retrieval Time, Total Energy Consumption, Throughput Analysis, and Network Lifetime. When compared to the S-MAC and the ECM-MAC, the ANTMAC Model produces steadily higher TNR values. When the number of retransmissions reaches 2000, the density of the network increases to 80%. Compared to the S-MAC and the ECM-MAC, the energy consumption of TEcm is lower. Increasing the simulation time to 1800 seconds results in a reduction in overall power consumption. The ANTMAC model outperforms the S-MAC and ECM-MAC protocols in terms of both NLT and throughput. In the future work, we are planning to add trust-based management system in our proposed model.

Conflict of Interest

The authors declare no conflict of interest.

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Authors' Profiles

Rabindra Kumar Shial is working as Assistant Professor in the department of Computer Science and Batch Coordinator of B.Tech Program at National Institute of Science and Technology (Autonomous), India.I have done my M.Tech from Indian Institute of Engineering Science and Technology, Shibpur,Calcutta.I have done my BE in Electronics Engineering. from NIT,Bhopal.I have about 22 years of experience in academic, Administration as well as research.My area of interest includes Wireless Sensor Network, Computer networking.Currently I am pursuing my Ph.D at G I E T University,Gunupur, Odisha, India.

Premanshu Rath has done his Ph.D from Berhampur University .Currently he is working as Associate Professor in the department of Computer Science. GIET University, Gunupur.He has 12 year of Academic and research experience. His field of research interest includes Wireless Sensor Network, soft computing etc.

Sudhir Ranjan patnaik is working in the position of Professor and Head, Dept. of CSE, National Institute of Science and Technology (Autonomous), India.He has 15 years of experience in academic as well as research.His area of interest includes Wireless Sensor Network, Computer Network, Algorithm Design and Analysis,Soft computing.He is acting as reviewer of different journals in repute.He has 13 no of publications in his credit.

SARAT CHANDRA NAYAK received the M.Tech. degree in computer science from Utkal University,Bhubaneswar, India, in 2011, and the Ph.D. degree in computer engineering from the Veer Surendra Sai University of Technology (VSSUT), Burla, India, in 2016. He has 15 years of experience in teaching and research. Currently, he is associated with the Soft Computing Laboratory, Department of Computer Science, Yonsei University,South Korea, as a Postdoctoral Research Fellow with the Brain Korea 21 (BK21) Fellowship. He has more than 80 research articles in reputed international journals and conferences, one book, and 14 book chapters in his credit. His research interests include machine learning, data mining, soft computing, predictive systems, financial time series forecasting, computational intelligence,evolutionary computations, and Security.

Umashankar Ghugar earned his full-time doctoral degree from Berhampur University, Odisha, in 2021, and his M.Tech degree in Computer Science from Fakir Mohan University, Balasore, in 2012. and his B.E. degree in IT from Utkal University in 2006. He has ten years of teaching experience in different organizations and currently works as an Assistant Professor in the School of Technology, Department of CSE at GITAM University, Visakhapatnam. He has published 18 articles, including reputed journals and IEEE Transaction, book chapters, and conferences in international publishers. His research interests are in Computer Networks, Network Security in WSN,Cyber security, and VANET. He is a Reviewer of IEEE Access, IEEE Transaction on Education, IEEE Transactions on Neural Networks and Learning Systems, Security and Privacy (Wiley), International Journal of Communication Systems (Wiley), International Journal of Distributed Sensor Networks (Hindawi), International Journal of Knowledge Discovery in Bioinformatics (IGI Global), and International Journal of Information Security and Privacy (IGI Global) and a member of IEEE, IACSIT, CSTA, and IRED.

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