Journal of Harbin Engineering University
ISSN: 1006-7043

Vol 44 No. 9
September 2023

S-Mac Based Algorithm to Save Power and Optimise Energy in Wireless Sensor Networks

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Abstract—SMAC, also known as Sensor-MAC (Medium AccessControl), is a contention-based MAC protocol created for wirelesssensor networks (WSNs) to communicate in an energy-efficient manner. Its major goal is to reduce idle listening and collisionsin order to minimize energy usage and extend the network'slifespan. The sleep-wake cycle technique used by SMAC involves nodes switching back and forth between the active and sleeping states. Nodes disable their radios when they are sleeping to save energy. Using a recurring beacon signal sent by a specific node, synchronization is kept across nodes. Nodes are able to modify their sleep-wake cycles because to this synchronization.When it comes to channel access, the protocol uses a contention-based strategy, with nodes first listening to the channel before sending data. Nodes use adaptive listening, adjusting the length of their listening period in response to the presence of transmissions. To prevent collisions, SMAC additionally uses randomized back off timings. In wireless sensor networks, SMAC lowers need- less communication overhead, increases network longevity, and conserves energy by providing a framework for energy-efficient communication. This paper provides an overview of various power-saving and energy optimization techniques that can beused in WSNs.

Index Terms—S-MAC, C-MAC, WSN, Optimization**.**

I. Introduction

Wireless Sensor Networks (WSNs) have grown into a vital tool with a number of functions, including industrialautomation, healthcare, and environmental monitoring. WSNs consist of many small, low-power devices called sensors that can communicate wirelessly with each other to collect and transmit data [1]. However, one of the biggest problems with WSNs is their limited battery life, which is due to the energy constraints of the sensors [2]. This limitation has led to the need for power-saving and energy optimizationtechniques to maximize the lifespan of WSNs and make them more efficient and sustainable. Sensor MAC (Medium Access Control) protocols are essential for managing communication among sensors in wireless sensor networks (WSNs). These protocols play a major role in minimizing energy consumption.The primary objective of sensor MAC protocols is to enable efficient and reliable communication while conserving energy. By controlling access to the shared wireless medium and coordinating the network with the medium, they are able to accomplish this goal. Data packet transmission and receptionby controlling when and how nodes access the channel, sensorMAC protocols help reduce collisions, idle listening, and over- hearing, which are common causes of energy wastage.Several techniques are employed by sensor MAC protocols to optimizeenergy consumption they are Duty Cycling, Low Power Lis- tening (LPL), Synchronization, Adaptive Duty Cycling, Data Aggregation, Power Control.The sharing and access rules for different devices to a shared communication medium, such as awireless channel, are set forth by the Medium Access Control (MAC) protocol, a crucial part of a communication system. By controlling access to the channel and avoiding collisions between simultaneous transmissions, the MAC protocol is essential in ensuring effective and reliable data delivery. It specifies guidelines for packet transmission, synchronization, addressing, and channel access. [3].

II. Related Work

Provided a comprehensive survey use in WSNs of energy- efficient routing techniques. It goes over various routing techniques, including hierarchical, location-based, and cluster-based routing protocols, and evaluates their energy efficiency in terms of the stability, scalability, and overhead of the network [4]. Surveys various data aggregation techniques in WSNs, which aim to conserve energy by reducing the amount of data delivered. The paper discusses Various forms of data aggregation, such as geographical and temporal aggregation, are compared for how effective they are in terms of energy use, latency, and accuracy [5]. Presented a congestion- aware MAC protocol called C-MAC, which aims to reduce energy consumption in WSNs by avoiding unnecessary transmissions during congested periods. The protocol dynamically adjusts the contention window size based on the degree of network congestion and adapts to changes in traffic patterns. Vari- ous clustering algorithms in WSNs, which aim to prolong a network's lifespan by grouping sensors into clusters and minimizing the energy consumption of communication within and between clusters. The paper discusses different clustering criteria and compares their effectiveness considering network durability, energy effectiveness, and scalability [6]. Provideda comprehensive review of energy- efficient techniques in WSNs, including power- saving techniques and energy opti-

mization techniques. The study evaluates numerous methods, including duty cycling, sleep scheduling, data aggregation, and adaptive transmission power control, and contrasts how effective they are in terms of energy usage, network longevity, and network performance. Presented various data gathering schemes in WSNs, which minimise your sensor nodes en- ergy consumption during data collection. The paper discusses different data gathering approaches, such as mobile sinks, directional antennas, and multiple sinks, and evaluates their effectiveness in terms of power usage, network longevity, and data dependability [7]. Discussed the importance of WSNs in smart grid systems, highlighting their being able to control and monitor energy production, transmission, and consumption in real-time. It also reviews various communication protocols used in WSNs, such as ZigBee and Wi-Fi, and evaluates their suitability for smart grid applications. The paper also discusses the challenges associated with using WSNs in smart grid systems, such as limited energy resources of the sensor nodes, security issues and the need for reliable communication in harsh environments. The paper evaluates various solutions proposed in the literature to address these challenges, such as energy harvesting techniques, secure communication protocols and redundancy techniques [8]. Provided a comprehensive survey of energy-efficient communication protocols for Wire-less Sensor Networks (WSNs). It discusses the design goals and requirements of energy-efficient protocols, reviews the classification and characteristics of existing protocols, and compares the performance of different protocols in terms of energy efficiency, delay, and scalability [9]. Presnted the state-of-the-art security solutions for Wireless Sensor Net- works (WSNs). It discusses the security threats and attacks in WSNs, reviews the existing security solutions including au- thentication, confidentiality, integrity, availability, and privacy,and evaluates the performance and limitations of different solutions. The paper also identifies the research challengesand future directions focused on the use of Wireless Sensor Networks (WSNs) in precision agriculture in the area of WSNsecurity [10]. It discusses the challenges and opportunities of precision agriculture, reviews the applications of WSNs in precision agriculture such as crop monitoring, environmental monitoring, and irrigation management, and evaluates the performance and limitations of different WSN-based solutions. The paper also identifies the WSNs for precision agriculture research challenges and future approaches [11]. Keeping in mind actual transmission situations, such as adaptable and the features of the TMAC and SMAC protocols were examined in relation to transmission bit rate, dynamic topology, and mobile sensors in networks.Using duty cycle by using TMAC energy can be optimized SMAC uses more energy than thatof TMAC Nodes they themselves put their self to sleep.In this article, the most recent advancements in Multi-Agent Systems (MASs) are reviewed.To

make it easier to design and model agents, predict their behaviour, include AI approaches, and create communication protocols Very simple model, based on multi-agent system.It is user friendly.It can be accessed easily. Limited to basic seller and buyer agents and auction-
based markets . Due to the extensive use of cluster systems in numerous applications, such servers were designed with regard to performance, scalability, and service quality (QoS) inmind.Used For the cluster link together, a simulation test bed that simulates switches DVS and buffer energy consumption has been developed [12]. As buffer use rises as a result of DVS, this experimentation must be inspected concurrently. In the study, a simple network-applicable technique is suggested.Nodes keep an eye on their neighbourhood and work along with their closest neighbours to restore the network to its Pre-crash operational state. We divide this into three sections. Monitoring intruders the suggested set of guidelines can be a useful tool for creating future sensor networks that are more re- liable and secure as well as for enabling additional study in the field. Notifying the intrusion to the base station or lowering the link's quality estimate so that it will gradually loose its route and dependability. The wireless application proposed in this paper makes use of network clusters that converse utilising the PMAC protocol for a multicast communication pattern. They implement power management scheme in the proposed android application by extracting the features of PMAC protocol power consumed is minimal as the application utilizes the features of PMAC protocol for efficient power management It works on offline mode [13]. Comparing energy-saving technologies S-MAC and T-MAC,Combining S-MAC yields the lowest possible energy consumption, however the findings for S-MAC reveal that it has over-provisioning issues.Although T- MAC's results are acceptable they lag behind of S-MAC's with low-power listening. The methods employed therefore take into account those difficulties and include extending the weaker nodes' sleep cycles, optimal listening, overhearing, packet collision prevention, and concealed terminal problem elimination.The main aim is to increase throughput, decrease delay, and increase energy efficiency.Simulation's performance is best, according to the results, in terms of average throughput, average energy use, and total packets received at sink [14].

III. Methodology

SMAC is an energy-efficient protocol that uses a slotted medium access mechanism to conserve power.

A. *Node creation*

The process of creating individual devices that may link to form a network forgathering and transmitting of data.Typically, each sensor node in the network is made up of a tiny micro controller, a wireless transceiver, a power source (such as a battery), and the development of one or more sensors to monitor the unknown physical processes. The design and development of the sensor node's hardware and software constitute node creation. The hardware components include the micro controller, the wireless transceiver, and the sensors, which are chosen based on the specific application require-ments. The software components include the firmware and the communication protocol to make sure the node has ability to communicate with other network nodes.

B. *Initialization*

Refers to the process of setting up the parameters and configuration of the network. This is an essential step in ensuring that the network operates efficiently and conserves energy. During initialization, each sensor node is configured with the necessary network parameters such as the Super frameDuration (SD), the Active Period (AP), the Sleep Period (SP), and the Contention Window (CW). These parameters are used by the Medium Access Control (MAC) a protocol to control how nodes can access the shared communication channel. The initialization process also involves setting the network topology, selecting the routing protocol, and configuring the security mechanisms if required. One common MAC protocol used in WSNs is the Sensor MAC (SMAC) protocol. During initialization, the SMAC protocol sets the SD to define the duration of a super frame, which is divided into an AP and an SP. The AP is used for active communication, while theSP is used for low- power sleep. Another important aspect of initialization is the clocks on the nodes are coordinated.. In WSNs, nodes operate on low-power sleep cycles to conserve energy. The synchronization mechanism ensures that the nodes wake up and transmit simultaneously, lowering the chance of collisions and enhancing network performance.

C. Packet Transmission

A key component of wireless communication, particularly that of Wireless Sensor Networks (WSNs), is packet transmis- sion.In WSNs, packet transmission relates to the act of sending data packets from a sink or from one sensor node to another for additional processing. The transmission process typically involves multiple stages, including packet creation, packet forwarding, and packet reception. When a sensor node detects a physical phenomenon, it creates a data packet that includes the sensed data and the destination address. The packet isthen forward to a subsequent hop towards the destination node using a routing protocol. Until the packet reaches the last node, the procedure is repeated often referred to as thesink node. Packet transmission in WSNs is a challenging issue because of the low power, bandwidth, and computing capabilities of the sensor nodes. Therefore, efficient routing protocols and transmission schemes are need to reduce energy use and increase network lifetime. Routing protocols are sev- eral commonly used in WSNs, including geographic routing, hierarchical routing, and data-driven routing. These protocols aim to find the most efficient path to send data packets with thesource's and destination's ,least amount of energy and packet loss feasible. Another important aspect of packet transmission in WSNs is packet collision avoidance. Due to the shared communication medium and the limited bandwidth, multiple nodes may try to transmit data simultaneously, leading to packet collisions and energy waste. To avoid collisions, MAC protocols such as Sensor MAC (SMAC) and Time Division Multiple Access (TDMA) are used to regulate access to the communication channel.

D. Delay Control

Delay control is an essential component of wireless com- munication, such as Wireless Sensor Networks (WSNs). In WSNs, delay control refers to the ability to control and manage the time it takes for data packets to reach their destination. In WSNs, data packets can experience significant delays dueto the constrained processing and power of the sensor nodes. Therefore, delay control is crucial to ensure timely delivery of data packets and to enable real-time applications such as surveillance, monitoring, and control. One of the primary mechanisms used for delay control in WSNs is the use of Quality of Service (QoS) metrics. QoS metrics provide a way to quantify the network's dependability, throughput, latency, and packet loss characteristics. By configuring suitable QoS parameters, such as the maximum delay and the packet loss rate, it is possible to control and manage the delay in the network. Another mechanism used for delay control in WSNs is the use of delay-tolerant routing protocols. These protocols aim to find the most efficient path to transmit the data packets while taking into account the delay constraints. For example, the Spray and Wait routing protocol uses a combination of flooding and controlled replication to ensure that the data packets reach their destination within a specific delay bound. In addition, several techniques are used to reduce the delay in WSNs, including data aggregation, prediction, and compression. To reduce the amount of transmissions, data aggregation involves combining several data packets into a single packet and, thus, the delay. Prediction techniques use historical data to forecast the network's potential future behaviour and adjust the transmission schedule accordingly. Compression techniques reduce the size of the data packets, which reduces the transmission time and, thus, the delay. To minimise the amount of transmissions, data aggregation involves combining several data packets into a single packet. And thus, the delay.

E. Base Station Operation

Base station functions include a wireless sensor network's central node (WSN), collecting and transmitting data from sensor nodes to a cloud server or sink node.The base station, which controls the network and regulates inter-user com- munication, is the root of the problem. Sensor nodes, and performing data analysis and processing. The base station operates by sending control messages to the sensor nodes, such as polling messages to request data transmission, synchroniza- tion messages to coordinate the timing of data transmission, and routing messages to instruct the nodes on the path to forward the data. When the base station gathers the data after receiving it from the sensor nodes, analyses it, and applies data processing algorithms to extract meaningful information. The base station may also perform data compression to limit the transmission of data to the sink node or the cloud server, which can save energy and bandwidth. The base station also monitors the status of the sensor nodes, including their amount of energy, connectivity, and reliability. It may dynamically adjust the network topology or routing paths to optimize the

network performance and prolong the network lifetime. The base station is a crucial component of the WSN that manages the network, collects data from the sensor nodes, and performs data analysis and processing. Its operation involves sending control messages, aggregating and processing data, monitoring the network status, and optimizing the network performance.

F. Energy Optimization

Energy optimization is important for wireless sensor net- works (WSNs), as their nodes frequently depend on batteries and have limited energy resources. To extend the lifetime of WSNs, energy optimization techniques are essential. These methods seek to lower the nodes energy usage without com- promising the nodes performance. network's performance and quality of service (QoS). The SMAC algorithm used in this project incorporates numerous methods to increase the energy effectiveness of the network. One of the primary energy optimization techniques used in SMAC is the duty cycle approach. The nodes in SMAC spend most of their time in sleep mode to conserve energy. They wake up only at scheduled intervals to transmit and receive data. This approach reduces the idle listening time, which is a significant source of energy consumption in WSNs. Another energy optimization technique used in SMAC is the randomized back off mech- anism. The back off mechanism is used to avoid collisions among the nodes and reduce the energy consumption caused by retransmissions. The back off timer is selected randomly from a range of values based on the contention window size, which is dynamically adjusted based on the network's traffic load and energy availability. Additionally, SMAC incorporates energy-aware routing techniques that select the most energy- efficient route for transmitting data.The energy-aware routing algorithms consider the remaining energy of the nodes along the path and select the path that minimizes the energy con- sumption.

IV. Smac Implementation

The Sensor-MAC (SMAC) protocol is a contention-based medium access control (MAC) for Wireless Sensor Networks (WSNs) protocol to reduce energy consumption by enabling when they are not sending or receiving data, the nodes go to sleep. The SMAC protocol is a simple and efficient protocol that uses a combination of scheduling, randomization, and back off mechanisms to reduce collisions and energy consumption. In this project, the SMAC algorithm is used to control the delay and power consumption during the packet transmission process. The SMAC protocol uses a schedule- based approach to determine the nodes wake-up and sleep cycles. The nodes synchronize their schedules using a shared beacon signal broadcast by the base station. The beacon signal contains the information about the schedule interval and the wake-up time. When a node wakes up, it checks if there is any pending packet to transmit. If there is a packet to transmit, the node initiates a contention period during which the competing nodes for access to the channel.The contention period is divided into multiple contention slots, each with

a randomly selected back off timer. The back off timer is used to reduce the probability of collisions and improve the fairness among the nodes. The node with the smallest back off timer wins the contention and transmits its packet. If there are multiple winners, the node with the highest priority wins. After the packet transmission, the node goes to sleep until its next wake-up time. The SMAC protocol reduces the energy consumption by minimizing the idle listening time and the collisions. By dynamically altering the scheduling interval, the quantity of traffic, and the energy supply, that in turn impacts how big the contention window is, the protocol also adjusts to the changing network conditions. The Sensor-MAC (SMAC) protocol uses a contention-based approach to schedule the node's wake-up and sleep cycles based on the traffic load and energy availability. The SMAC protocol uses two main parameters to control the node's sleep schedule, the time between being active and asleep. The active time frame is the time during which the node sleep period is the time when the node goes to sleep to conserve energy, the node stays up to send and receives the data. The SMAC protocol calculates the active and sleep periods using the following formula:

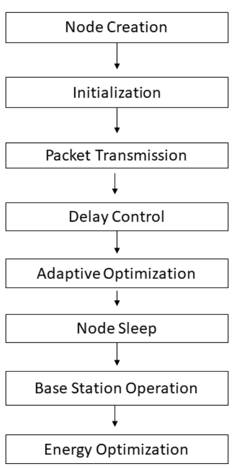

Fig. 1. Overall Workflow

$Activeperiod = (2^{BE} + 1) * UnitBackoffPeriod$

$Sleepperiod = SLEEPTIME - Activeperiod$

where BE is the back off exponent, which determines thesize contention window size and the number of retries, and Unit_Backoff_Period is the duration of a single back off slot. SLEEP TIME is the total sleep time, which is the sum of the active and sleep periods. The SMAC protocol uses a randomized back off mechanism to avoid collisions among the nodes. The back off timer is selected randomly from a range of values based on the contention window size. The contentionwindow size is calculated using the following formula:

$CW = 2^{BE} - 1$

where CW is the contention window size, and BE is the back off exponent. The SMAC protocol dynamically adjusts the back off exponent based on the network's traffic load and energy availability. When the network is busy, the back off exponent is increased to reduce collisions and improve the activity among the nodes. When the network is idle, the back off exponent is decreased to reduce the delay and improve the throughput.

V. Overall Workflow

Network startup and the base station's transmission of the beacon signal initiate the SMAC protocol procedure. When nodes awaken as planned, they look for any waiting packets to transmit before starting a period of contention to get access to the channel. In order to reduce delays and increase throughput, the protocol dynamically modifies the back off exponent and contention window size based on the amountof network traffic and energy available. The schedule interval and contention window size are two additional ways that the protocol adjusts to shifting network conditions. The nodes

go to sleep after packet transmission until their subsequent wake-up time. The base station minimises energy usage while collecting transmitted data and carrying out important tasks.

collisions, and improved throughput by dynamically adjusting the network's load and energy availability, determine the size of the contention window and the back off exponent. The project also demonstrated the effectiveness of adaptive optimization in adjusting the schedule interval and contention window size based on changing network conditions. These findings have significant implications for the creation of wireless sensor networks that use less energy,which can help address the growing demand for sustainable and reliable IOT applications.The coordination component of SMAC guarantees that nodes retain a shared time reference by using a beacon sig- nal. By effectively scheduling and coordinating transmissions, this synchronisation increases energy efficiency and lessens collisions.SMAC's contention-based channel access method has shown promising results in terms of cutting down on idle listening and enhancing overall network performance. Nodes compete for channel access by keeping an eye out for transmissions that are already in progress and sending data when the channel is empty. By allowing nodes to modify their listening length based on the presence or absence of transmissions, the adaptive listening feature aids in energy conservation. Additionally, SMAC's use of randomised back off timers has been successful in reducing collisions. The protocol lowers the likelihood of simultaneous reprises by introducing randomness in the restoration attempts, improv- ing overall network efficiency.In wireless sensor networks, SMAC's multiple advantages—including energy conservation, synchronization, contention-based access, adaptive listening, and collision avoidance—help to improve network perfor- mance, extend network lifetime, and increase energy effi- ciency. These outcomes make SMAC an advantageous MAC protocol option in situations where network durability and energy conservation are top priorities.

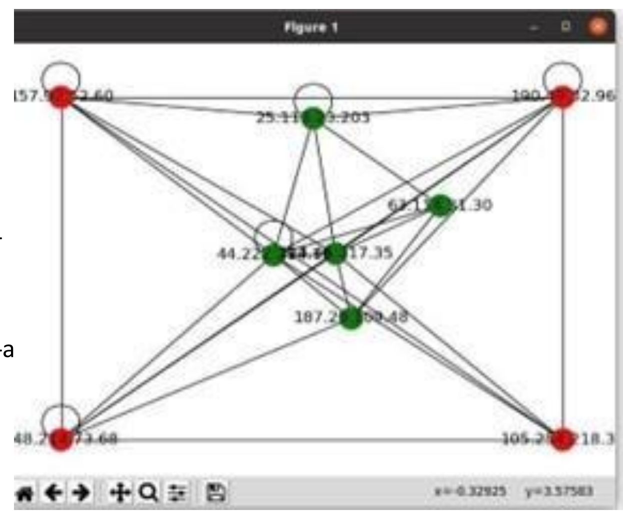

Fig. 2. sensor and anchor nodes

Algorithm 1 Modified S-MAC Algorithm

```
import numpy as np
from sklearn.ensemble import
RandomForestRegressor
max_iterations = 100
initial_config = generate_initial_configuration()
evaluated_configs = []
best_config = None best_performance = float('-inf')
for i in range(max_iterations) do
    X = get configuration space(evaluated configs)
    y = get performance values(evaluated configs)
    surrogate_model = RandomForestRegressor()
    surrogate model.fit(X, y)
    suggested config = sug- gest _ configuration(surrogate model, evaluated configs)
    performance = evalu-a
    evaluated_configs.append((suggested_config, performance))
    if performance > best_performance then
        best config = suggested config
        best performance = performance
    end if
end for
return best_config
```

VI. RESULTS AND DISCUSSION

The overall project in an effort to increase energy efficiency and throughput Using SMAC a wireless sensor network pro- tocol. The results showed that the SMAC protocol reduced energy consumption by minimizing idle listening time and

In the Fig. 2. the sensor nodes interact with the anchor nodes. The red ones are the anchor nodes and the green ones are the
sensor nodes the nodes can be changed on requirement ,the nodes listen to their neighbour nodes and then perform the action.

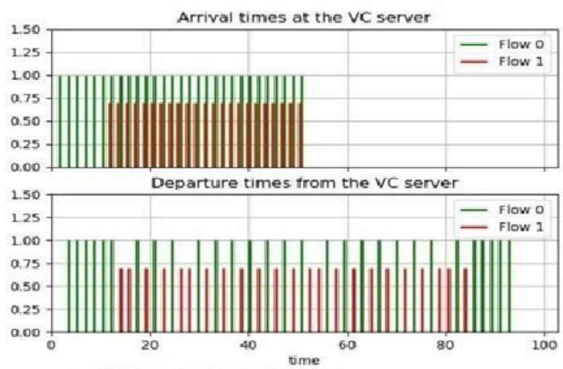

Fig. 3. Arrival and Departure

The graph depicts the arrival and departure times at the server.The x-axis represents the time, and the y-axis represents the number of requests. The green line shows the arrival times, and the orange line shows the departure times. The graph shows that there are spikes in the arrival times, indicating periodsof high demand. The departure times follow a similar pattern, but with a slight delay due to processing time. The graph can be used to analyze the server's performance, identify peak periods, and optimize resource allocation to ensure smooth and efficient operation.

VII. Conclusion

In conclusion, this study attempted to apply the SMAC protocol to improve wireless sensor network performance and energy efficiency. The protocol was intended to minimise delay and maintain high network throughput while lowering energy consumption of sensor nodes. The project involved several stages, including the initialization of the network and setting up the base station to broadcast the beacon signal periodically. The nodes wake up at their scheduled time and check for any pending packet to transmit. If there is a packet, the node initiates a contention period during which the nodes compete to access the channel. The SMAC protocol dynamically adjusts the back off exponent and contention window size based on the network's traffic load and energy availability to reduce the delay and improve the throughput. It also adapts to the changing network conditions by dynamically adjusting the schedule interval and the size of the contention window dependent on energy availability and traffic volume. Data supplied by the nodes is collected by the base station and carries out the required tasks, like aggregation, compression, and analysis. The SMAC protocol reduces energy consumption by minimizing idle listening time and collisions. The projects outcome showed that the implementation of the SMAC pro- tocol significantly improved the network's performance and energy efficiency. The arrival and departure times of packets atthe VC server indicate that the protocol effectively reduces the delay and improves the throughput. In conclusion, the SMAC protocol is a promising method for raising the effectiveness of wireless sensor networks in the area of efficiency and energy. Success of the project demonstrates the importance of developing energy-efficient and adaptive network protocols for wireless sensors to support their wide-ranging applications in various fields, including environmental monitoring, smart cities, and industrial automation.

VIII. Future Enhancement

The details gathered by the nodes could be used to train machine learning models for predictive maintenance and fault detection. This could help identify potential problems before they become critical and allow for proactive maintenance. As wireless sensor networks are often used in critical infrastruc- ture systems, ensuring the security of the network is of utmost importance. Enhancing the SMAC protocol with encryption and authentication mechanisms would make it more secure and less vulnerable to attacks. The information gathered from the nodes could be sent to cloud platforms for storage and analysis, allowing for better scalability and flexibility. This would enable more sophisticated data analysis techniques to be applied to the data, potentially leading to more valuable insights.The incorporation of sophisticated scheduling meth- ods into SMAC is one area that will see future improvement. Even while SMAC uses a contention-based strategy, adding components of scheduled-based access could have additional advantages. To ease congestion and improve channel utilisa- tion, strategies like time slot distribution and reservation can be investigated. The protocol may provide predictable access and reduce collisions by allocating dedicated time slots to nodes, which improves overall network performance.The addition of artificial intelligence and machine learning methods to SMAC is another potential improvement. These methods can give nodes the ability to dynamically modify their contention characteristics and sleep-wake cycles in response to shifting network conditions. Machine learning algorithms may analyse traffic patterns, energy consumption trends, and environmental data to optimise the protocol's parameters in real-time, increas- ing the protocol's adaptability and energy efficiency.

References

[1] P. Rawat, K. D. Singh, H. Chaouchi, and J. M. Bonnin, "Wireless sensor networks: a survey on recent developments and potential synergies," *The Journal of supercomputing*, vol. 68, pp. 1–48, 2014.

[2] V. C. Gungor and G. P. Hancke, "Industrial wireless sensor networks: Challenges, design principles, and technical approaches," *IEEE Trans- actions on industrial electronics*, vol. 56, no. 10, pp. 4258–4265, 2009.

[3] O. D. Incel, L. Van Hoesel, P. Jansen, and P. Havinga, "Mc-lmac: A multi-channel mac protocol for wireless sensor networks," *Ad Hoc Networks*, vol. 9, no. 1, pp. 73–94, 2011.

[4] K. Akkaya, M. Demirbas, and R. S. Aygun, "The impact of data aggregation on the performance of wireless sensor networks," *Wireless Communications and Mobile Computing*, vol. 8, no. 2, pp. 171–193, 2008.

[5] A. Abbasi and M. Younis, "A survey on clustering algorithms for wireless sensor networks," *Computer communications*, vol. 30, no. 14- 15, pp. 2826–2841, 2007.

[6] M. Faheem and V. C. Gungor, "Mqrp: Mobile sinks-based qos-aware data gathering protocol for wireless sensor networks-based smart grid applications in the context of industry 4.0-based on internet of things," *Future Generation Computer Systems*, vol. 82, pp. 358–374, 2018.

[7] R. Ma, H.-H. Chen, Y.-R. Huang, and W. Meng, "Smart grid commu- nication: Its challenges and opportunities," *IEEE transactions on Smart Grid*, vol. 4, no. 1, pp. 36–46, 2013.

[8] 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, 2019.

[9] Al Zaid, E. Foo, and J. Gonzalez Nieto, "Secure data aggregation in wireless sensor network: a survey," in *Proceedings of the Sixth Australasian Information Security Conference (AISC 2008)*, pp. 93–105, Australian Computer Society, 2008.

[10] P. K. Singh and A. Sharma, "An intelligent wsn-uav-based iot frame- work for precision agriculture application," *Computers and Electrical Engineering*, vol. 100, p. 107912, 2022.

[11] T. Samant and A. Datta, "Analysis and comparison of smac and tmac protocol for energy efficient dynamic topology in sensor network.," *International Journal of Electrical & Computer Engineering (2088- 8708)*, vol. 6, no. 5, 2016.

[12] J. Lakshmi, M. Ghonge, and A. J. Obaid, "Cloud based iot smart healthcare system for remote patient monitoring," *EAI Endorsed Trans- actions on Pervasive Health and Technology*, vol. 7, no. 28, pp. e4–e4, 2021.

[13] N. Kumar, D. Lohani, and D. Acharya, "Vehicle accident sub- classification modeling using stacked generalization: A multisensor fu- sion approach," *Future Generation Computer Systems*, vol. 133, pp. 39–52, 2022.

[14] P. Joshi, G. Singh, and A. Raghuvanshi, "Comparative study of different routing protocols for ieee 802.15. 4-enabled mobile

sink wireless sensor network," in *Advances in VLSI, Communication, and Signal Processing: Select Proceedings of VCAS 2018*, pp. 161–170, Springer, 2020.

[15] P. Mohan and M. Nikitha, "Ranking of sensor nodes by optimizing sensor data in energy harvesting wireless sensor network," in *2022 IEEE International Conference on Data Science and Information System (ICDSIS)*, pp. 1–6, IEEE, 2022.

[16] P. Rawal and P. Mohan, "Threshold based activation of energy harvest- ing framework in wsn using cooja," in *2022 IEEE North Karnataka Subsection Flagship International Conference (NKCon)*, pp. 1–6, IEEE, 2022.

[17] Inchana and S. K. BJ, "Double circle localization for the detection of jamming attack in wireless sensor network," in *2022 IEEE North Kar- nataka Subsection Flagship International Conference (NKCon)*, pp. 1–5,IEEE, 2022.

[18] C. Gujjar, S. Sunil, and A. Mukhopadhyay, "A survey on wireless ad- hoc implementations in android-based smartphones," in *2017 Interna- tional Conference on Communication and Signal Processing (ICCSP)*, pp. 0894–0899, IEEE, 2017.