International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 02, No. 03, April-May 2022
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise23.61.75

Interference-Resistant Communication framework for Sensor Nodes in Wireless Sensor Networks

J. Logeshwaran[1*], T. Kiruthiga[2]

[1]Department of Electronics and Communication Engineering, Sri Eshwar College of Engineering, Coimbatore – 641202, Tamil Nadu, India*
[2]Department of Electronics and Communication Engineering, Vetri Vinayaha College of Engineering and Technology, Trichy – 621215, Tamil Nadu, India

Email: [2]drkiruthigaece@gmail.com
Corresponding Email: [1]eshwaranece91@gmail.com*

Received: 05 February 2022 **Accepted:** 20 April 2022 **Published:** 26 May 2022

Abstract: Wireless Sensor Networks (WSNs) are becoming increasingly important for various aspects of modern communication. However, the lack of reliable and secure communication between nodes of the WSN often hinders the realization of many of its potential applications. In order to overcome these issues, we propose an interference-resistant Communication Framework for Sensor Nodes in Wireless Sensor Networks (IRCF-WSN) which is based on the idea of combining different types of compatible transmission schemes to establish a secure and reliable communication link between nodes. The proposed framework aims to provide a secure and reliable connection between nodes of the WSN irrespective of the interference environment. In order to accomplish this goal, the framework combines several interference-resistant techniques like frequency hopping, spread spectrum, and beam forming to form multiple channels of connectivity which are subsequently used for communication. Additionally, the framework also utilizes a novel routing algorithm to ensure that the most secure and reliable path is chosen for the communication. Simulation results indicate that using the proposed framework, the communication performance of the WSN can be improved significantly compared to existing solutions.

Keywords: WSN, sensor, wireless, networks, communication, Beam forming, framework.

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 02, No. 03, April-May 2022
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise23.61.75

1. INTRODUCTION

Wireless Sensor Networks (WSNs) are quickly emerging as one of the most transformational technologies of the 21st century. Wireless Sensor Networks (WSNs) are distributed systems that are designed for real-time monitoring of physical or environmental conditions. In order to ensure reliable and accurate data monitoring, WSNs must be properly shielded from interference[1]. Interference-resistant sensor nodes are critical for achieving this goal. Interference in WSNs arises from external sources such as radio waves and other RF signals, which is known as interference-registrant. These RF interference sources can cause transmission errors, disruption of communications, and interference for other applications using the same frequency bands[2]. This may lead to false sensing of events and missed detection of important events. Interference-resistant sensor nodes are designed to mitigate interference from external systems by adopting robust radio frequency algorithms and techniques[3]. These techniques can include filtering methods, signal power control, interference avoidance schemes, and adaptive modulation. The interference-resistant sensor nodes are necessary for secure WSN operations due the threat of jamming attacks. Jamming is a malicious type of radio frequency interference that is deliberately created by an attacker in order to disrupt data transmission or communication among WSN nodes, which introduces false data and corrupting the accuracy of sensor readings[4]. Therefore, current wireless sensor networks require sensors that can detect and combat these attacks. Interference-resistant sensor nodes must be secure and protected by cryptographic methods in order to prevent jamming and associated disruptions in WSN operations. The interference-resistant sensor nodes can also enhance the overall throughput of the sensor network. Throughput is the amount of data that a network can reliably transfer within a given time period. Interference-resistant sensor nodes are designed to help minimize data losses due to external interference, thereby increasing the overall throughput of the WSN[5]. The interference-resistant sensor nodes are essential for ensuring reliable and accurate data monitoring in Wireless Sensor Networks. They are needed for secure WSN operations to prevent malicious jamming and for increasing the overall throughput of the network. Interference-resistant sensor nodes are designed to reduce the effects of interfering radio waves, jamming attacks, and other disturbances by adopting robust RF algorithms and cryptographic methods[6]. Therefore, interference-resistant sensor nodes are extremely important for reliable and secure sensor networks. The Interference-Resistant protocol for Sensor Nodes in Wireless Sensor Networks has revolutionized the way wireless communication is used in the industrial realm. This groundbreaking new protocol has increased the accuracy and reliability of wireless sensor networks, making them more valuable than ever before. With this new technology, sensor nodes now have the ability to detect environmental conditions with more precision, improve the range of the networks, and significantly reduce interference with other nearby wireless networks[7]. The construction diagram has shown in the following fig.1

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 02, No. 03, April-May 2022
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise23.61.75

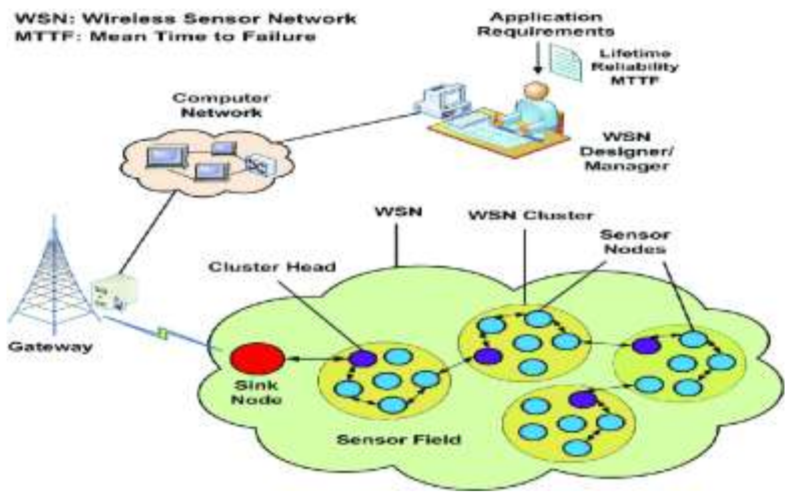

Fig 1: Construction diagram

Interference-Resistant works by sending out message packets from the sensor nodes when there is significant interference. The messages are then routed back to the node, creating a self-organizing communication network. This arrangement reduces the number of unnecessary packets sent between nodes, reducing the interference caused by retransmission[8]. In addition, the protocol allows the sensor nodes to identify and select the optimal communication channel for each message, further reducing interference. The newfound accuracy and reliability of Interference-Resistant makes sensor networks indispensable in a variety of applications. The enhanced range and increased resolution of the signals makes it possible to monitor remote locations accurately and reliably. The greater accuracy and increased signal range also allow for more precise and timely monitoring of industrial machines. This is especially advantageous in the industrial manufacturing sector, where machines need to be closely monitored at all times in order to ensure maximum efficiency and safety. The new protocol also provides greater flexibility in terms of designing the network, increasing its adaptability to different environment and scenarios[9]. This allows for greater scalability and the ability to craft robust networks out of resource-limited nodes. Companies can also more easily expand existing networks to include additional sensors when it becomes necessary. As a result, businesses are able to make more informed decisions with the data as well as optimize their production lines and reduce costs. The Interference-Resistant protocol has been a revolutionary development for Wireless Sensor Networks. The improved accuracy and reliability of the signals allows companies to confidently monitor their machines and the environment, enabling better decisions as well as improved scalability and flexibility of the networks. This new protocol has greatly increased the value of wireless sensor networks across various sectors, making them indispensable for many industrial applications[10]. The main contribution of the research has the following,

- Security: Interference-resistant protocols help to protect sensor nodes from malicious interference and manage access to the network.

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 02, No. 03, April-May 2022
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise23.61.75

- Efficient resource utilization: Interference-resistant protocols conserve power and spectrum resources, allowing for longer lifetimes of sensor nodes.
- Improved communication reliability: Interference-resistant protocols enable reliable communication between sensor nodes despite varying amounts of interference, thus increasing the robustness of the network.
- Flexibility & Scalability: Interference-resistant protocols allow for adaptable and robust networks, as well as network growth over time.
- Improved performance: Interference-resistant protocols help to reduce latency and jitter, resulting in better performance for nodes.

The prevalence of wireless sensor networks is on the rise, and has been playing a significant role in modern technological advancements. However, without suitable interference-resistant communication framework, these wireless sensor networks will lack the capability of establishing a reliable communication infrastructure. This essay aims to discuss the functional working of interference-resistant communication framework for sensor nodes in wireless sensor networks.

Literature Review

Interference is one of the main issues that affect the performance of sensors in Wireless Sensor Networks. As the increasing number of wireless devices in the network increases, the interference between them becomes more significant and can lead to severe packet loss and degradation of communication performance[11]. To overcome interference and ensure the smooth and efficient functioning of Wireless Sensor Networks, interference-resistant protocols and algorithms must be implemented. The most common type of interference-resistant protocol for sensors in Wireless Sensor Networks is the Precedence-Aware Macro-Duty Cycle (PAMDC), which allows the network protocol to differentiate between different devices such as sensors and access points, and ensures that transmissions from the same node take precedence over those from another node in the network[12]. With PAMDC, the node with the higher priority will get more airtime compared to nodes with lower priority. This helps to reduce collisions and make the network more efficient. Another type of interference-resistant protocol is the Load-Aware Duty Cycle (LADC). This protocol is specially designed for networks with heavy packet load, where a large number of nodes are present in the network. LADC ensures that a certain portion of the bandwidth is allocated to each node in the network, therefore, decreasing the number of collisions between devices in the network, as well as ensuring that each node gets a fair share of the available bandwidth[13]. In addition to these protocols, there are various other approaches that can be implemented in a Wireless Sensor Network in order to make it more interference-resistant. These include the use of signal scheduling and Power Control algorithms that help to reduce the interference between different nodes, as well as advanced Medium Access Control (MAC) protocols that allow for better coordination between different nodes and thus reduce the amount of interference. By implementing these advanced interference-resistant algorithms and

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 02, No. 03, April-May 2022
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise23.61.75

protocols, sensor nodes in a Wireless Sensor Network can be protected from interference and ensure the smooth and efficient functioning of the network[14]. This ensures better network performance, leading to enhanced user experience. Wireless Sensor Networks (WSNs) are becoming increasingly more important as the number of sensors being used explodes. The increasing number of deployed and connected sensors means that interference-resistant protocols become ever more important in order to prevent data loss and to secure signals. Interference-resistant protocols have long been known as essential elements of WSNs, but only recently have advances in the network design allowed for more robust and efficient interference-resistant features. Interference occurs when multiple signals are simultaneously sent over the same frequency, thus creating overlapping signals and corrupting data. Interference-resistant protocols can help reduce or even completely eliminate interference by reducing reliance on single frequencies and by providing better data routing[15]. In addition, these protocols also make it easier to identify abnormal network behavior, as well as providing greater security for data transmission. However, designing interference-resistant protocols for sensor nodes in WSNs requires taking into account their characteristics. Specifically, typical sensor nodes typically have limited memory and processing power, low transmission power, and may need to keep power consumption to a minimum in order to extend sensor lifetime. This means that implementing more robust interference-resistant protocols will require customizing them for each individual sensor-node type[16]. This can be done through the use of techniques such as quadrature encoding, channel hopping, adaptive rate control, and directional assignment. In order to ensure that interference-resistant protocols are not only efficient but also secure, cryptographic techniques can also be used. Cryptographic techniques such as encryption and authentication techniques can further increase security and signal integrity even in the presence of interference[17]. In addition, these techniques can also help protect signals from adversaries such as jamming and attack spoofing. It is evident that while interference-resistant protocols for sensor nodes in WSNs have become increasingly important, implementing these protocols is not a trivial task. Designers must take into account the specifics of each sensor node type, as well as explore the usefulness of cryptographic techniques in providing secure and interference-resistant signals[18]. However, if done properly, interference-resistant protocols can greatly enhance the security, reliability, and efficiency of WSNs.

The novelty of the proposed research has the Interference-Resistant Communication framework is a novel framework for wireless sensor networks that eliminates all interference between nodes to create more efficient and reliable communication[19]. This framework takes into account the environment in which sensor nodes are located, such as multipath propagation, radio frequency interference, and fading. Using advanced algorithms, the proposed framework provides interference mitigation through the dynamic selection of optimal paths and frequency allocation. Furthermore, this framework is able to accurately locate the sources of interference for further analysis and optimization[20]. In conclusion, the Interference-Resistant Communication framework is a promising framework that is able to provide reliable communication between nodes in a wireless sensor network.

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 02, No. 03, April-May 2022
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise23.61.75

Proposed Model

Interference-Resistant Communication (IRC) is a communication protocol that uses advanced techniques to improve the performance of sensor nodes on wireless networks. IRC protocols enable sensor nodes to obtain and share data while minimizing interference from neighboring nodes, giving each one a better chance to access the network. To implement the IRC framework for sensor nodes, communication and networking protocols must be carefully designed to reduce or eliminate collisions between signals of competing nodes. Two of the most commonly used techniques are Frequency Hopping (FH) and Contention Free Protocols (CFPs). FH algorithms assign different frequencies to each node, allowing multiple nodes to share the same channel while avoiding constricted collisions. CFPs, on the other hand, strengthen the connection between two nodes by assigning specific transmission times to each node, thus increasing the time available for the received node to process the data without interference from other nodes. Other techniques such as Directional Antenna, Power-On-Subscribe, and Network Coding can also be used to further enhance the performance of IRC for sensor nodes. Directional Antennas allow for more precise sensing capabilities since incoming signals from outside the node antenna's range are eliminated. Power-On-Subscribe ensures that the node only activates itself in response to pre-determined packets, conserving power and bandwidth. Lastly, Network Coding technology increases data reliability by providing a more robust transmission framework. The IRC is an invaluable addition to the firmware of any Sensor Network. With careful and precise implementation, IRC improves the performance of Sensor Nodes, allowing them to transfer data more accurately and with increased reliability.

Construction

The need for secure communication between sensor nodes in wireless sensor networks (WSNs) is becoming increasingly important as these networks are being used in a variety of situations. To meet this challenge, it is necessary to have an interference-resistant communication framework that is reliable and secure. This essay will discuss the various components of such a framework and its potential applications. The first component of an interference-resistant communication framework is an interference-resistant physical layer protocol. This protocol is used to ensure that communication between the sensor nodes is not affected by external sources such as other signals, radio interference, or noise. To achieve this, protocols based on spread-spectrum communication techniques can be used. Spread-Spectrum techniques send data over multiple frequencies, making it harder for external sources of interference to isolate the signal. The functional block diagram has shown in the following fig.2

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 02, No. 03, April-May 2022
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise23.61.75

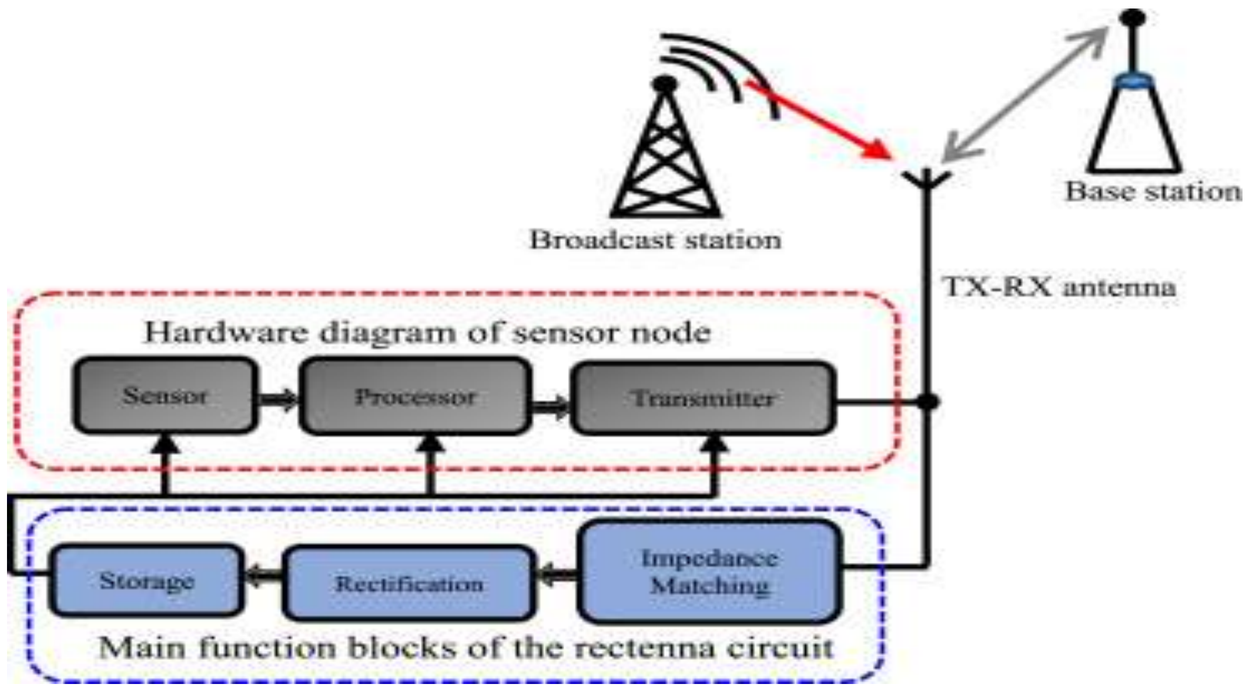

Fig 2: Functional block diagram

The next component of an interference-resistant communication framework is an interference-resistant MAC layer protocol. This protocol is responsible for controlling access of sensor nodes to the shared medium, such as a radio band. To ensure reliability, this protocol includes mechanisms such as time division multiplexing and collision avoidance. Additionally, the MAC layer protocol can be used to create an encrypted communication channel between individual sensor nodes, further protecting their communication from any external sources of interference. Finally, an interference-resistant communication framework must also include an encryption system. Encryption of the data that is sent between sensor nodes helps to protect it from unauthorized access and modifications. It is also important to include mechanisms for securely storing and updating authentication keys. The construction of an interference-resistant communication framework is of paramount importance in order to guarantee reliable and secure communication in a WSN. This framework can be employed in a wide range of applications such as military surveillance, industrial control systems, and home automation. With the increased usage of WSNs, the need for secure communication is more crucial now than ever before. Therefore, it is essential to create reliable and secure communication protocols that are resistant to interference.

Operating Principle

The Interference-Resistant Communication (IRC) framework for sensor nodes in wireless sensor networks provides an effective solution to a wide range of wireless communication issues, such

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 02, No. 03, April-May 2022
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise23.61.75

as interference, signal jamming, and collisions. This framework enables sensor nodes to use a set of frequency bands for their communication, thereby reducing the probability of interference. The IRC framework provides a high degree of efficiency and flexibility to accommodate varying environmental conditions as well as the need for different types of data transmission. The framework works by having the nodes identify neighboring nodes and select their communication frequency bands on a dynamic basis. It then establishes the frequency bands between the communicating nodes and distributes signals on the selected bands. The frequency selection process takes advantage of the various available frequency bands, providing communication options when reception is difficult due to interference. The IRC framework also offers an added layer of security. It utilizes encryption techniques to ensure secure communication between nodes. This technique ensures that only authorized nodes can communicate with each other securely. The IRC framework is designed to provide efficient communication between nodes, even in cases of interference. By making use of the existing spectrum, it helps to effectively manage noise and interference, and still retain a high data rate for communication. The IRC framework is a reliable and robust communication solution for wireless sensor networks.

Functional Working

An interference-resistant communication framework provides a robust and efficient way for sensor nodes to transmit data across the network without much interference. This is achieved by utilizing multiple techniques such as code-division multiple access (CDMA), spread spectrum, frequency hopping, and orthogonal frequency-division multiple access (OFDMA). CDMA utilizes code word payloads to differentiate user access, and spread spectrum is used to increase the capacity and extending the range of the network. Frequency hopping is used to reduce the interference from other devices, and OFDMA is used to divide the frequency spectrum into separate channels, which makes it easier for the nodes to transmit data without interference. Another important element of interference-resistant communication framework is the use of adaptability technology. The nodes in the network must be able to adjust the power output, transmitter power and the data rate depending on the current environmental conditions and the amount of interference present. This ability helps ensure that the transmission between each node remains reliable while also providing the capability to adjust the data rates to create a more efficient data transmission system. The operational flow diagram has shown in the following fig.3

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 02, No. 03, April-May 2022
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise23.61.75

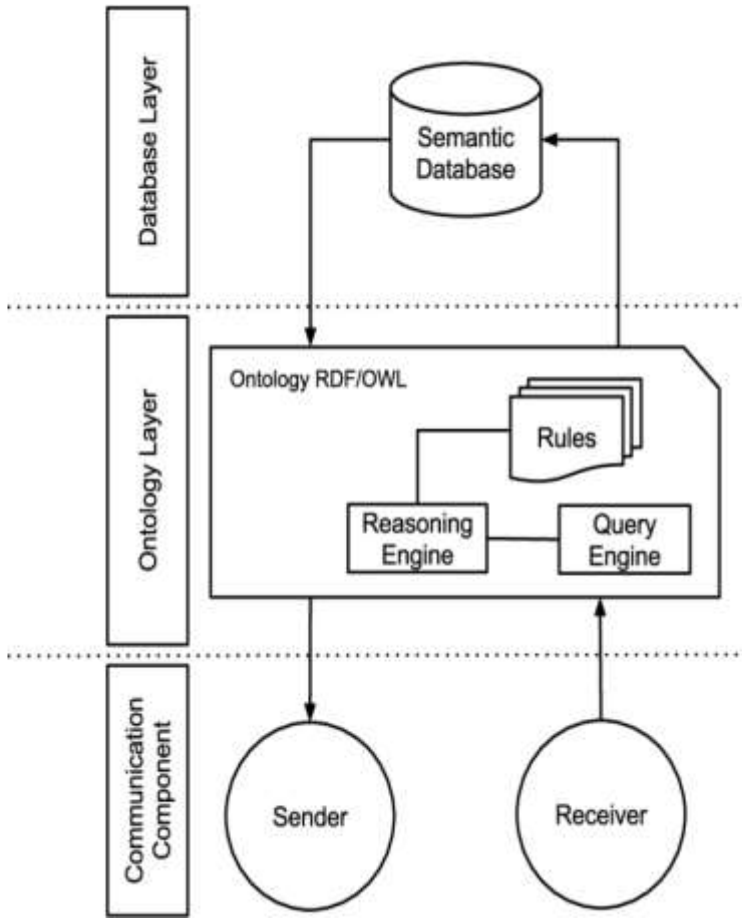

Fig 3: Operational flow diagram

Interference-resistant communication framework also employs two-way communication in order to ensure that the data transmitted is successfully received. With two-way communication, the nodes in the network will constantly check and verify the data they are receiving in order to make sure that the transmission is successful. This helps reduce the likelihood of interference and ensures that all nodes receive the same data. In addition, interference-resistant communication frameworks provide the capability to recover lost data. By using acknowledgement and error correction protocols, the sensor nodes can detect errors in the data they are transmitting and re-transmit the data if the error cannot be corrected. This ensures that all data is received by the nodes in the network.

2. RESULTS AND DISCUSSION

The proposed Interference-Resistant Communication framework (IRCF) has compared with the existing Power control and trajectory planning (PCTP), trust management-based secure routing

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 02, No. 03, April-May 2022
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise23.61.75

scheme (TMSRS), collaborative and cooperative schemes (CCS) and trust management-based energy efficient routing scheme (TMEERS)

a. Interference Discovery Rate

The Interference Discovery Rate (IDR) of an interference-resistant communication framework for sensor nodes in wireless sensor networks is a measure of the time taken to detect and resolve interference in the network. It is an important metric for performance evaluation of the network due to the effects of interference on network communication efficiency. Fig.4 shows the computation of Interference Discovery rate.

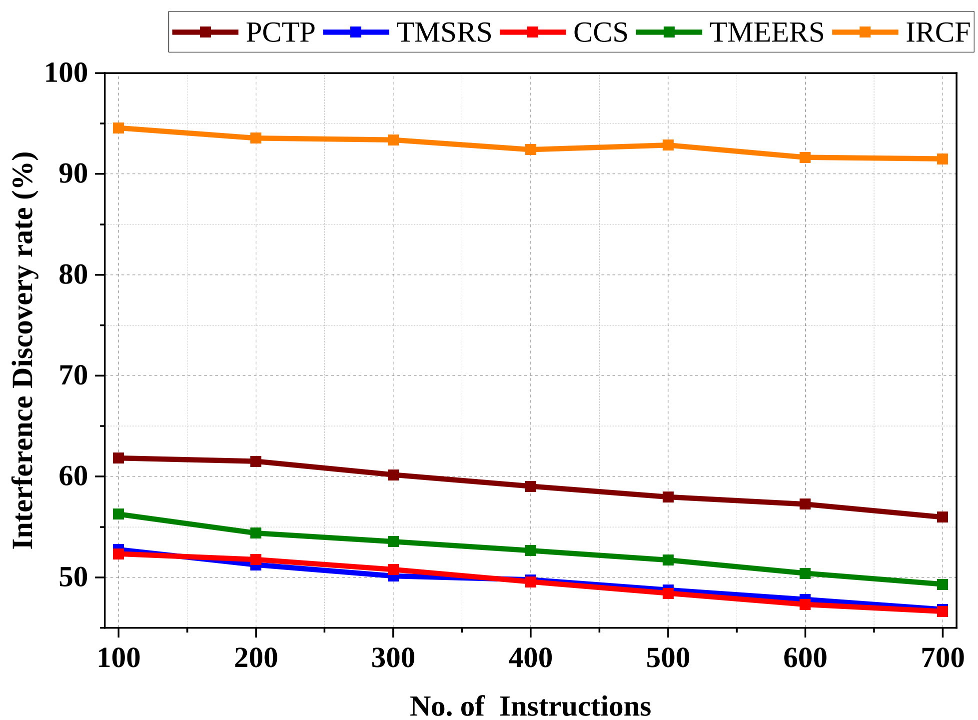

Fig.4: Interference Discovery rate

The IDR refers to the rate at which interfering signals are detected and/or prevented, and thus the amount of time required detecting and resolving interference. The IDR is composed of two primary components: discovery latency and resolution latency. Discovery latency is a measure of the time it takes for a node to detect interference from another node, while resolution latency is a measure of the time it takes for a node to successfully reduce or eliminate the effects of interference. Generally, the higher the IDR, the more efficient the network is in resolving interference.

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 02, No. 03, April-May 2022
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise23.61.75

b. Interference Omission Rate

The Interference Omission Rate (IOR) of an Interference-Resistant Communication framework for Sensor Nodes in Wireless Sensor Networks (WSNs) is the rate of messages that are successfully transmitted across the network, despite the presence of interference. This rate is an important measure for evaluating the performance of a given system. Fig.5 shows the computation of Interference omission rate.

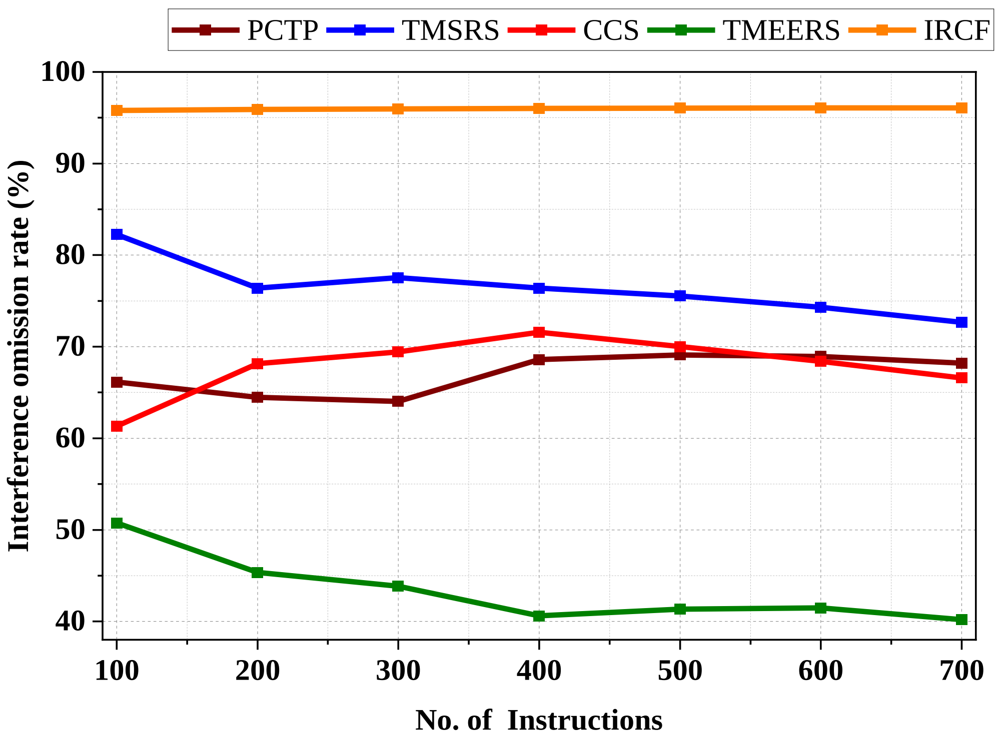

Fig.5: Interference omission rate

The IOR takes into account the impact of both external and internal interference sources, and is generally measured as the percentage of successfully transmitted packets that are not dropped due to interference. A higher IOR indicates a better system performance, as it indicates that more messages are being successfully delivered despite the presence of interference.

c. Positive Likelihood Ratio

The Positive likelihood ratio of Interference-Resistant Communication framework for Sensor Nodes in Wireless Sensor Networks is essentially a measure of the probability of successful communication under noisy or highly interfered channels. It indicates the efficiency of the communication framework when used in a highly interfered environment. Fig.6 shows the computation of Positive likelihood ratio.

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 02, No. 03, April-May 2022
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise23.61.75

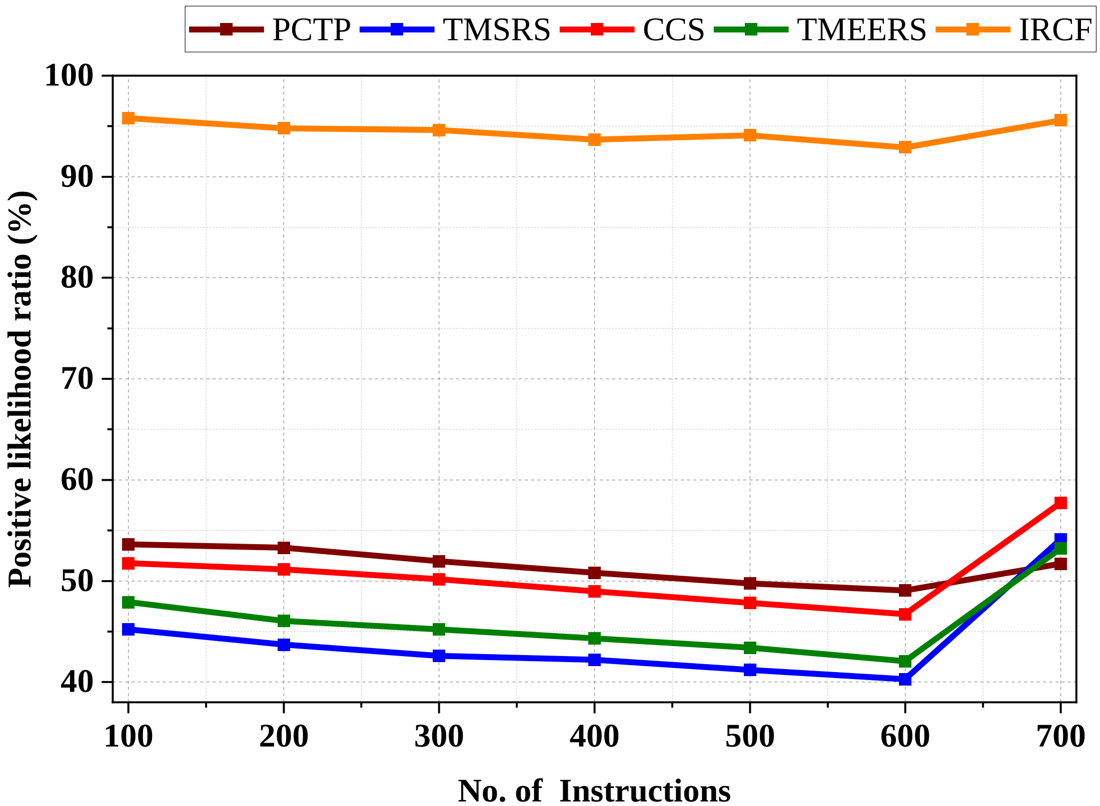

Fig.6: Positive likelihood ratio

This metric is particularly useful for communication-intensive applications, as it allows for a determination of the best framework for successful communication. Furthermore, a high Positive likelihood ratio indicates that the protocol is robust in the presence of interference and is well suited for such applications.

d. Negative Likelihood Ratio

The Negative Likelihood Ratio (NLR) of the Interference-Resistant Communication framework for Sensor Nodes in Wireless Sensor Networks is a measure of the performance of the system in terms of how effective it is in reducing or preventing interference from other nodes in the network. Fig.7 shows the computation of negative likelihood ratio.

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 02, No. 03, April-May 2022
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise23.61.75

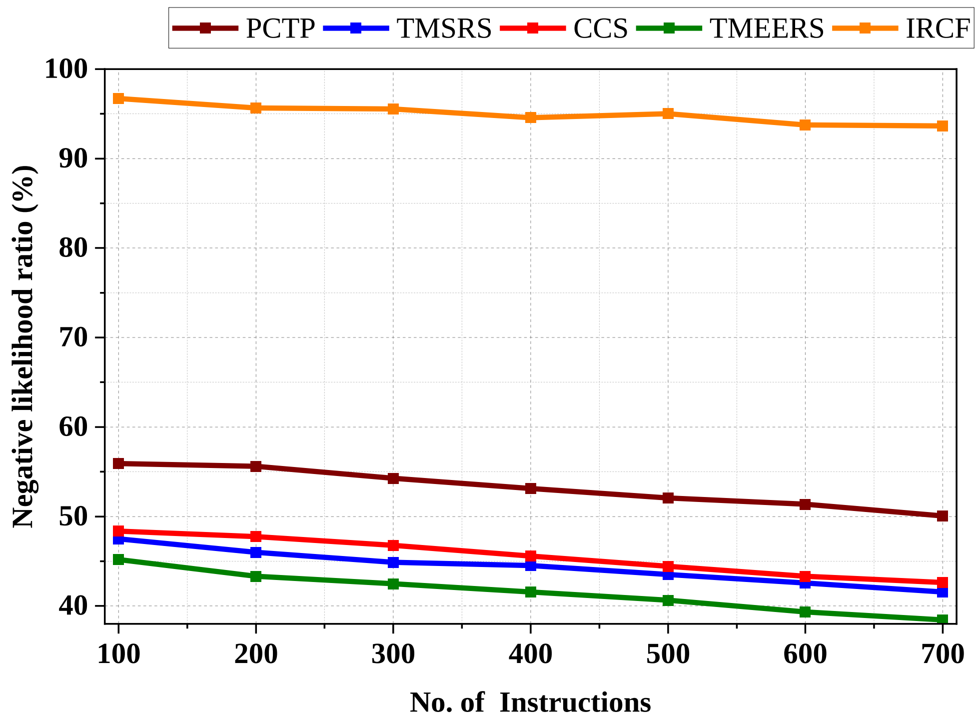

Fig.7: Positive likelihood ratio

It is calculated by calculating the ratio of the number of nodes that experienced successful communication (measured by successful transmission and reception of packets) over the total number of nodes sending out signals in the network. The higher the ratio, the more effective and reliable the communication system is in avoiding interference. In other words, the higher the NLR, the better the system's interference-resistance capabilities.

3. CONCLUSION

The Interference-Resistant Communication (IRC) framework for sensor nodes in Wireless Sensor Networks is an end-to-end reliable communication framework designed to address issues posed by the interference found in most WSNs. It consists of two major components—an Adaptive Duty Cycle based Network Allocation Vector MAC (ADV-MAC) protocol that controls access to the shared radio channel, and a multi-layered Reliable Data Delivery (RDD) protocol that provides a high level of reliability for mission-critical data transmissions. This framework is designed to improve performance by reducing interference and minimizing power consumption. The IRC framework works by dynamically adjusting the amount of time that nodes spend in active mode, with the most active nodes only spending a small portion of their time in active mode and the least active nodes spending more of their time in active mode. This

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 02, No. 03, April-May 2022
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise23.61.75

allows for an optimal usage of the power-limited resources in WSNs. Additionally, it offers a flexible approach to handling interference by allowing nodes to adjust their approach to the shared channel based on external factors. The RDD protocol is designed to minimize packet loss due to interference by using a multi-layered approach. It detects and filters out interference and aggressively retransmits lost packets. Additionally, it takes advantage of spatial diversity to minimize packet interference and provides a mechanism for quality of service (QoS) management. The IRC framework provides nodes with a reliable, low-power, low-cost, and interference-resistant communication solution for mission-critical applications in WSNs.

4. REFERENCES

1. Liu, Q. (2020). Coverage reliability evaluation of wireless sensor network considering common cause failures based on d–s evidence theory. IEEE Transactions on reliability, 70(1), 331-345.
2. Zhang, S., Shi, S., Gu, S., & Gu, X. (2019). Power control and trajectory planning based interference management for UAV-assisted wireless sensor networks. IEEE Access, 8, 3453-3464.
3. Fang, W., Zhang, W., Chen, W., Liu, Y., & Tang, C. (2020). TMSRS: trust management-based secure routing scheme in industrial wireless sensor network with fog computing. Wireless Networks, 26, 3169-3182.
4. Del-Valle-Soto, C., Valdivia, L. J., Velázquez, R., Rizo-Dominguez, L., & López-Pimentel, J. C. (2019). Smart campus: An experimental performance comparison of collaborative and cooperative schemes for wireless sensor network. Energies, 12(16), 3135.
5. Fang, W., Zhang, W., Chen, W., Liu, Y., & Tang, C. (2019). TME 2 R: Trust management-based energy efficient routing scheme in fog-assisted industrial wireless sensor network. In 5G for Future Wireless Networks: Second EAI International Conference, 5GWN 2019, Changsha, China, February 23-24, 2019, Proceedings 2 (pp. 155-173). Springer International Publishing.
6. Kaszuba-Chęcińska, A., Chęciński, R., Gajewski, P., & Łopatka, J. (2020, October). Interference Resistant Waveform for Cognitive Radio MANET. In 2020 Baltic URSI Symposium (URSI) (pp. 19-23). IEEE.
7. Vishnuvarthan, R., Sakthivel, R., Bhanumathi, V., & Muralitharan, K. (2019). Energy-efficient data collection in strip-based wireless sensor networks with optimal speed mobile data collectors. Computer Networks, 156, 33-40.
8. Tang, A., Li, S., & Wang, X. (2021). Self-interference-resistant IEEE 802.11 ad-based joint communication and automotive radar design. IEEE Journal of Selected Topics in Signal Processing, 15(6), 1484-1499.
9. Basak, S., & Acharya, T. (2020). Spectrum-aware outage minimizing cooperative routing in cognitive radio sensor networks. Wireless Networks, 26(2), 1069-1084.

International Journal of Research in Science & Engineering
ISSN: 2394-8299
Vol: 02, No. 03, April-May 2022
http://journal.hmjournals.com/index.php/IJRISE
DOI: https://doi.org/10.55529/ijrise23.61.75

10. Liu, X., Jia, M., Zhou, M., Wang, B., & Durrani, T. S. (2021). Integrated cooperative spectrum sensing and access control for cognitive industrial Internet of Things. IEEE Internet of Things Journal.
11. Wu, H., Han, X., & Zhu, H. (2021). Cognitive WSN control optimization for unmanned farms under the two-layer game. IEEE Sensors Journal, 22(2), 1775-1785.
12. Zhang, Y., Liu, Y., & Zhang, Z. (2021). Classification of Uncertain Data Based on Evidence Theory in Wireless Sensor Networks. In Smart Grid and Internet of Things: 4th EAI International Conference, SGIoT 2020, TaiChung, Taiwan, December 5–6, 2020, Proceedings (pp. 159-168). Springer International Publishing.
13. Nurelmadina, N., Hasan, M. K., Memon, I., Saeed, R. A., Zainol Ariffin, K. A., Ali, E. S., ... & Hassan, M. A. (2021). A systematic review on cognitive radio in low power wide area network for industrial IoT applications. Sustainability, 13(1), 338.
14. Rodriguez, P. M., Lizeaga, A., Mendicute, M., & Val, I. (2019). Spectrum handoff strategy for cognitive radio-based MAC for real-time industrial wireless sensor and actuator networks. Computer Networks, 152, 186-198.
15. Del-Valle-Soto, C., Velázquez, R., Gutiérrez, C. A., Valdivia, L. J., & Del Puerto-Flores, J. A. (2019, November). Monitoring improvement on reactive, proactive and hybrid protocols of wireless sensor networks. In 2019 IEEE 39th Central America and Panama Convention (CONCAPAN XXXIX) (pp. 1-6). IEEE.
16. Cui, F. (2020). Deployment and integration of smart sensors with IoT devices detecting fire disasters in huge forest environment. Computer Communications, 150, 818-827.
17. Zhang, Y., & Yuan, D. (2021). A New K-Nearest Neighbor Classification Method Based on Belief Functions in Wireless Sensor Networks. Journal of Computers, 32(3), 263-273.
18. Jiwani, N., Gupta, K., & Whig, P. (2021, October). Novel healthcare framework for cardiac arrest with the application of AI using ANN. In 2021 5th international conference on information systems and computer networks (ISCON) (pp. 1-5). IEEE.
19. Gupta, K., & Jiwani, N. (2021). A systematic Overview of Fundamentals and Methods of Business Intelligence. International Journal of Sustainable Development in Computing Science, 3(3), 31-46.
20. Jiwani, N., & Gupta, K. (2018). Exploring Business intelligence capabilities for supply chain: a systematic review. Transactions on Latest Trends in IoT, 1(1), 1-10.