National Journal of Antennas and Propagation, ISSN: 2582-2659 Vol. 6, No. 3, 2024 (pp. 69-74)
RESEARCH ARTICLE
HTTP://ANTENNAJOURNAL.COM

Development of an RFID-Based Supply Chain Management System using Blockchain and Machine Learning

Moti Ranjan Tandi[1], Ragini Kushwaha[2]
[1,2]Assistant Professor, Department of CS & IT, Kalinga University, Raipur, India.

KEYWORDS:
Radio-Frequency Identification,
Supply Chain Management,
Security,
Encryption.

ARTICLE HISTORY:
Received 23.09.2024
Revised 15.10.2024
Accepted 11.11.2024

DOI:
https://doi.org/10.31838/NJAP/06.03.09

Abstract

Products are transferred from supplier to customer via a supply chain management (SCM) system. The information and material movement from supplier to manufacturer, wholesaler, retailer, and customer is integrated and coordinated by it. Product availability when needed is guaranteed by an efficient supply chain management system. In this sense, the supply chain's use of Radio-Frequency IDentification (RFID) technology guarantees that the appropriate products are available where they are needed. RFID increases the supply chain's accuracy and boosts its overall dependability and efficiency. By incorporating the greatest technologies available, businesses are attempting to address supply chain bottlenecks. Cloud-based supply chain management (SCM) solutions have been flooding the market in recent years. Cloud-based SCM is thought to face significant security challenges. The current RFID-based security protocols are examined, compared to known security flaws, and their effectiveness in relation to the active RFID tag is assessed in this research project, which focusses on authentication problems in the various processes of cloud-based supply chain management applications where objects are tagged with an active RFID tag. Numerous RFID protocols now in use have been shown to be computationally demanding. This inspired us to offer safe RFID authentication methods that use less processing power from the RFID tag and don't require a reliable third party for cloud-based supply chain management.Mutual authentication between the participating entities, transferring the reader's rights to another authenticated reader by removing reader-to-reader communication, creating an ownership transfer protocol to stop counterfeit goods and give the customer verifiability, and creating an object tracking protocol for when RFID-tagged objects are in transit are the primary goals of this research project.

Author's e-mail: ku.MotiRanjanTandi@kalingauniversity.ac.in, ku.RaginiKushwaha@kalingauniversity.ac.in

How to cite this article: Tandi MR, Kushwaha R. Development of an RFID-Based Supply Chain Management System using Blockchain and Machine Learning. National Journal of Antennas and Propagation, Vol. 6, No. 3, 2024 (pp. 69-74).

Introduction

Information and networking technologies have a direct impact on the supply chain management concept's ongoing evolution. A supply chain management system is a collection of software programs designed to control the movement of information and items as a product or service from its starting point to its destination.[1] The information and material movement from supplier to manufacturer, wholesaler, retailer, and customer is integrated and coordinated by it. Product availability when needed is guaranteed by efficient supply chain management. These days, cloud computing makes it possible to use robust analytics to make more informed choices. The healthcare, manufacturing, logistics, and food and beverage industries can all benefit from supply chain management's aspects, including relationships with suppliers, compatibility, specifications and standards, delivery, and after-sales service. The process of SCM is intricate and requires a lot of knowledge (Bi and Mu 2010; Reyes 2011). The products must be tracked to guarantee their availability in an effective way in order to solve the inventory and logistics issues in SCM. Benefits of supply chain management (SCM) are attained by using the right tools and tactics to assist in managing the increasingly complicated supply networks of today. The movement of information and objects across the course of an object's

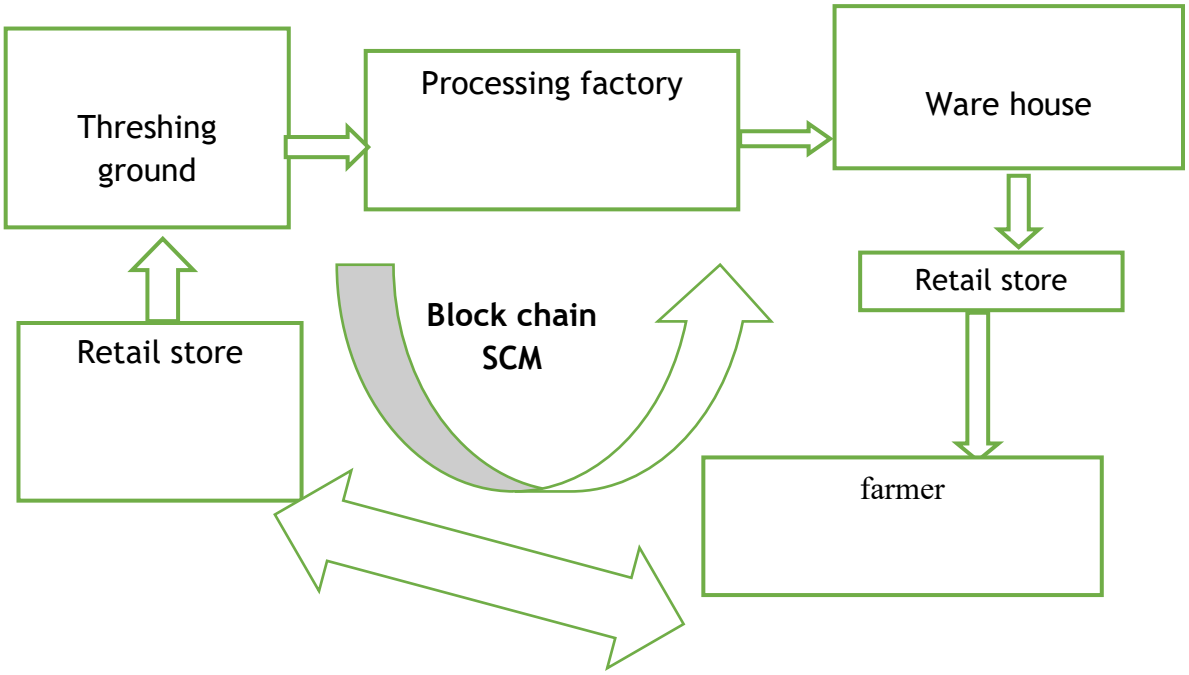

Fig. 1: A Novel Blockchain-Enabled Supply-Chain

life cycle is handled by SCM systems. Cloud storage is used to share and secure the flow of information. When an RFID tag is connected to an object, it allows for safe tracking of its movement both while storage and during transportation.[2] The problem is effectively addressed by this comprehensive strategy. An SCM application with cloud storage and RFID-assisted object attachment is the solution under consideration for the research project. The following are some of the many benefits of the RFID system in supply chain management: it keeps track of the condition of the item, prevents counterfeit goods from entering the market, removes human error in counting, and enhances accessibility. SCM applications that use cloud storage benefit from distributed data, anytime, anywhere access, and stakeholder satisfaction with data security. Additionally, supply chain firms benefit from distributed storage because it offers data availability, scalability, efficiency, and the capacity to use advanced analytics to make better decisions. It also speeds up logistics and improves the accuracy and efficiency of the product flow.[3]

RFID in SCM Application

RFID technology is one of several automated technologies that businesses can use to better meet their demands. The use of RFID in the supply chain guarantees that the appropriate products are available where they are needed.[4] It significantly increases the supply chain's accuracy and boosts its overall dependability and efficiency. Additionally, it facilitates faster communication throughout the supply chain. The performance of the RFID technology is enhanced by its use in a variety of fields.[5] The tag, reader, and server are the three parts of an RFID system in supply chain management. The tags are divided into two categories: active and passive. While a passive tag lacks an internal power source and can only be read at very close ranges, an active tag can be read and written to.[16] Product information and confidential information for safe communication are contained in an active tag. Data can be read from the tag and sent to the server thanks to readers, which establish a connection between the tag and the server. To verify the information, a reader scans the tag and connects to the cloud server. The reader may be a portable electronic device. The data must be processed and stored by the server. An authenticated reader can update the tag data.[7] A distinctive RFID tag is affixed to a product after it has been made. After passing via a warehouse and a retail location, the product is delivered to a customer.[6] RFID tags are used in the warehouse to verify an item's availability. Following purchase, the customer can use the product's RFID tag in any new RFID application. The service provider logs the product service history in the tag during after-sales support. It is occasionally necessary to follow a thing for the duration of its existence. RFID is a significant technology that offers business owners countless advantages. Every product has an RFID tag, which makes it simple for business owners to keep track of their stock. Because RFID tags offer greater visibility, they will significantly increase supply chain efficiency by identifying order abnormalities as they happen and allowing staff to promptly fix errors.

Additionally, it makes tracking simpler and more reliable, giving business owners constant control and visibility over their items. RFID chips can save operational expenses, streamline the supply chain, and eliminate the possibility of errors because they offer computerised product management.[15]

Overview of Proposed Framework

SCM is managing inventory more effectively since the introduction of RFID technology. RFID delivers real-time information and guarantees that the right products are available in the proper location. But this flexibility also creates privacy and security issues. An opponent may use unfair competition and the introduction of counterfeit goods into the market as a result of supply chain system threats. Sticking an RFID tag to an object and using an RFID reader to read the tag's ID number is a straightforward and well-known technique for RFID authentication. In these current approaches, the tag initiates communication as soon as it receives a message and does not confirm the reader. A denial of service attack could result if the reader is fraudulent.[9] An attacker may be able to acquire the stock details if they manage to compromise the reader, which could provide a risk to the information assertion. In order to obtain access or compromise the RFID readers and force them to authenticate to phoney tags, attackers can also alter the data in the tags. It is almost impossible to incorporate reader-to-reader communication and trustworthy third parties into the design of many of the current delegation and ownership transfer protocols for SCM. Therefore, it is imperative that appropriate security procedures be designed for SCM.It is crucial and difficult to build security protocols for RFID-enabled supply chains that meet the crucial security requirements with fewer tag computations.

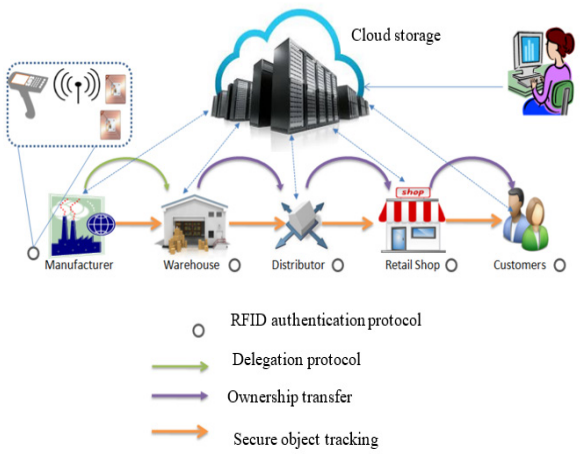

Fig. 2: Schematic diagram of object flow and security protocol

Existing RFID-based security mechanisms for ownership transfer, delegation, and mutual authentication are examined and evaluated against known security flaws. Their effectiveness in relation to RFID tag calculations is also examined. Numerous protocols have been shown to be computationally demanding, and some of them fail to meet crucial security requirements. Additionally, some protocols are difficult to deploy because they require a Trusted Third Party (TTP) in their design.[8]

Machine learning models

This inspired us to develop safe RFID authentication methods that require no reliable third parties and require less processing power from RFID tags. Some SCM applications have made use of passive tags. Passive tags might not be appropriate for many applications since they lack power and storage. The SCM for moving chemicals and medications, for instance, must maintain specific standards for temperature, moisture content, ambient light, closeness, and orientation. Sensors are to be installed in the tags in these situations in order to detect and record the data. Active tags are therefore appropriate for these uses. Additionally, an active tag's interrogation range is more similar to that of passive tags. Therefore, active tags are taken into consideration in this study rather than passive ones.[10]

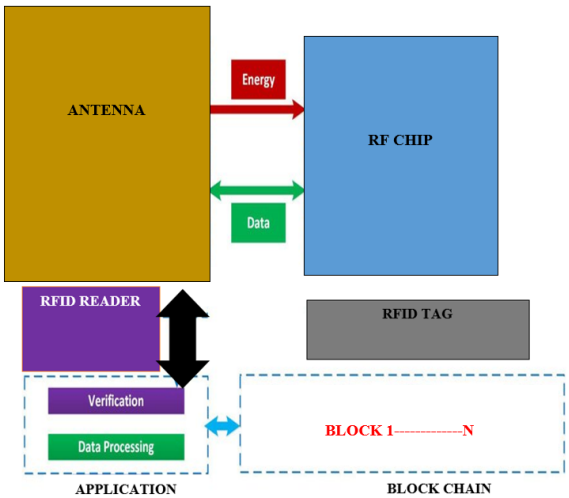

Fig. 3: Integration of RFID system with blockchain for supply chain process

Businesses should invest in the appropriate technologies to assist them manage their operations as supply chains get more intricate and globalised. There are a lot of documents being electronically shared between the company, suppliers, and purchasers as a result of the growing size and complexity of the supply chain.

Therefore, having effective document storage and anytime, anywhere access is crucial. A cloud server is more appropriate in this situation. These papers can be kept in one place thanks to the cloud. Data coordination and consolidation are offered by the cloud server. Additionally, it relieves some of the strain on supply chain planning and management while offering increased flexibility and response. Cloud servers are therefore taken into consideration in this analysis. Figure 3 shows the object flow schematic diagram and the required security protocols for each SCM level.

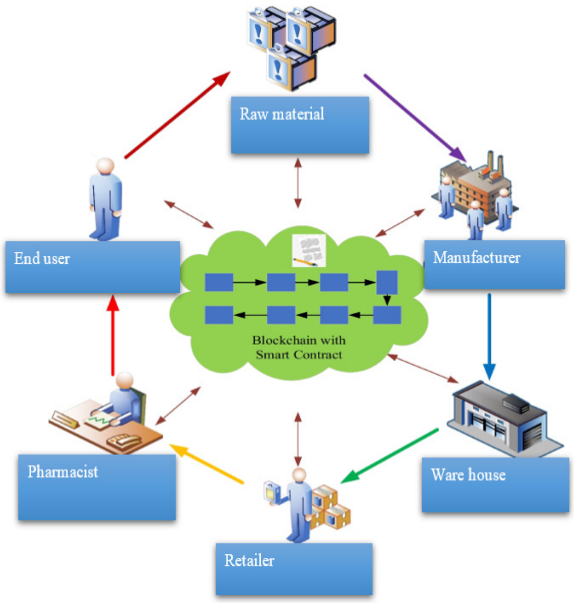

Figure 4: System architecture

Machine learning models: DNN

The term artificial neural network (ANN) refers to the input and output layers of a deep neural network (DNN) are made up of many layers. Although there are many different kinds of neural networks, all of them share the following elements: neurones, synapses, weights, biases, and functions that can mimic those of the human brain. They can also be learnt, much like any other machine learning algorithm. For instance, a DNN trained to recognise dog breeds. After reviewing the given image, DNN calculates the likelihood of correctly identifying the breed of dog in it. Here, the user can examine the findings, select the probabilities (such as above a certain threshold, etc.) in which the network should be shown, and return the suggested label. Complex DNN is considered a "deep" network since it involves many layers, each of which is referred to as mathematical manipulation. DNNs are capable of creating intricate non-linear associations.[17] The object can be expressed as a layered composition of primitives in compositional models produced by DNN architectures. Furthermore, compared to similarly functioning shallow networks, extra layers enable the composition of features from lower layers, potentially representing complicated data with fewer units. DNNs, for instance, demonstrated their ability to exponentially simplify the approximation of sparse multivariate polynomials. In contrast, there are a number of variations of the fundamental techniques used in deep architectures, each of which has been shown to be important in a certain sector. Comparing the performance of different designs is possible, but only if the same dataset is used for evaluation.

The green line shows the delegation process within the company, the purple line shows the ownership transfer process when the products are sold, the yellow line shows the object tracking process when the products are in transit, and the bubble shows the RFID reader to tag mutual authentication protocol. Additionally, the cloud server is used for storing during the task, which lowers the reader's storage needs and boosts scalability. As shown in Figure 4, a variety of protocols are devised and examined in this research project. GNY logic (Gong et al. 1990), a formal technique for protocol verification, is used to demonstrate the mutual authentication property of the suggested protocols.[12] It is demonstrated using the ProVerif tool that the protocol execution does not reveal the secret parameters, and different results are interpreted accordingly.The primary goals of this research project are to enable mutual authentication between the involved parties, share the session key upon successful authentication, transfer ownership by preventing counterfeit goods, assign a reader's rights to another authenticated reader, and track RFID-tagged items while they are in transit.[14]

Results and Discussion

Designing RFID security protocols for cloud-based supply chain management systems is the main goal of this research project (figure 5). This is done by

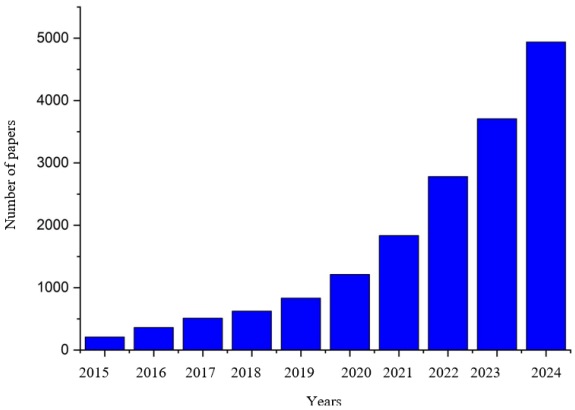

Fig. 5: Research trend plot in 2024

removing trusted third parties, cutting down on RFID tag computations, and maintaining security standards. The security analysis of the suggested protocol and a comparison of its features with those of the current ownership transfer methods are covered in this section. This section provides an informal analysis of security requirements for ownership transfer protocols in distributed environments.

Proposition 1: Double spending is avoided by the suggested ownership transfer process. Proof: The blockchain records each transition in this system. From the beginning of its existence, blockchain keeps a time-stamped, chronologically ordered transaction record. It is impossible to change the entry made in the ledger once it has been made. Confirming the object's condition shows that it isn't being sold to anyone else concurrently. Verifying the block transaction data will guarantee this, and the non-owner cannot assert ownership (figure 6).

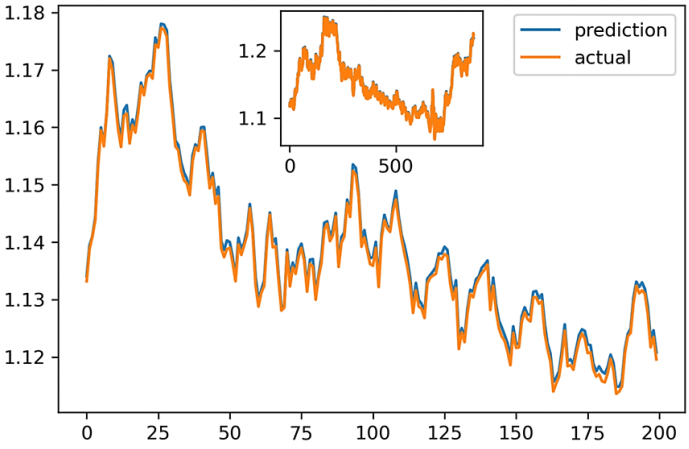

Fig. 6: Predicted results

Proposition 2. Accountability property is achieved by the suggested ownership transfer mechanism.

Proof: The ownership is successfully transferred when all the verifications are accurate; if not, the protocol is terminated.

Proposition 3: Verifiable property is satisfied by the suggested protocol.

Proof: The buyer is guaranteed to receive the original product thanks to this attribute. The customer can trace the product's life and confirm the product's uniqueness by verifying the full blockchain.

Proposition 4. Mutual authentication is a feature of the suggested protocol.

Proof: Authentication is provided by the buyer and seller via a digital signature. Phase 2 identification of the RFID tag and the buyer's reader are crucial once the product is delivered.

Proposition 5: Data integrity, trust, and fairness are achieved by the ownership transfer protocol. Proof: The blockchain data is hashed and saved, which further ensures data integrity. Data integrity is also guaranteed by the block's structure. The buyer confirms the block BCID that is recorded in both the distributed ledger and the tag (figure 7).

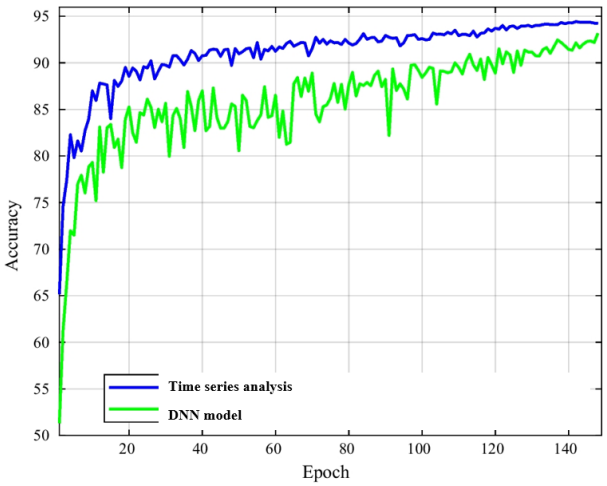

Fig. 7: Prediction accuracy of DNN

The tag just has to run the one-way hash function once and store the details of the current block. Computation for the tag is quite low when compared to the current protocols. TTP and reader-to-reader communication are not necessary for this protocol. While the conventional OT protocols operate in a centralised setting, it can operate in a distributed one. The buyer can verify the product's provenance with the help of the suggested process. In the event of a disagreement, the accountability attribute can also be demonstrated. Although mutual authentication is provided by the current ownership transfer protocols, characteristics like verifiability and accountability are not addressed. Additionally, standard methods do not work in distributed environments.

Conclusion

RFID is a useful technology for supply chain object tracking. When RFID is quickly implemented in a heterogeneous supply chain, security and privacy concerns surface. One of the most crucial security requirements for cloud-based supply chains is authentication. For an agile supply chain, a protocol that is safe, effective, and scalable is required. In the first effort, an informal security analysis is conducted and an RFID authentication protocol with tag reader association is developed. The tag entity is the subject of performance analysis.

Distributed ledgers, a feature of blockchain technology, are changing ownership tracking. Blockchain technology is used to create the RFID-based ownership transfer protocol in a distributed setting. The protocol meets security standards and was designed in two stages. In order to stop counterfeiting, this allows customers to confirm the product's ownership and place of origin. It is demonstrated that additional security features are satisfied by comparing the suggested protocol with current relevant systems.

References

[1] Kowsalya, K., R. Paritala Jhansi Rani, Malika Bhiyana, Manisha Saini, and Pravin P. Patil. "Blockchain-Internet of things-Machine Learning: Development of Traceable System for Multi Purposes." In *2023 3rd International Conference on Advance Computing and Innovative Technologies in Engineering (ICACITE)*, pp. 1112-1115. IEEE, 2023.

[2] Baygin, Mehmet, Orhan Yaman, Nursena Baygin, and Mehmet Karakose. "A blockchain-based approach to smart cargo transportation using UHF RFID." *Expert Systems with Applications* 188 (2022): 116030.

[3] Yuan, Guanghui, Shan Wu, and Bin Wang. "Supply chain management model based on machine learning." *Neural Computing and Applications* 35, no. 6 (2023): 4319-4335.

[4] Mishra, Ayaskanta, Sayan Karmakar, Ankita Dutta, Ankush Bose, and Manaswini Mohapatro. "Design and deployment of IoT enabled blockchain based resilient Supply-chain management system using ethereum." *International Journal of Computing and Digital Systems* 12, no. 1 (2022): 1029-1050.

[5] Muralidharan, J. "Machine Learning Techniques for Anomaly Detection in Smart IoT Sensor Networks." *Journal of Wireless Sensor Networks and IoT* 1.1 (2024): 10-14.

[6] Miyaji, A., Rahman, M.S., &Soshi, M. (2011). Efficient and low-cost RFID authentication schemes. *Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications, 2*(3), 4-25.

[7] Chen, Huilin, Zheyi Chen, Feiting Lin, and Peifen Zhuang. "Effective management for blockchain-based agri-food supply chains using deep reinforcement learning." *IEeE Access* 9 (2021): 36008-36018.

[8] Prasath, C. Arun. "Energy-Efficient Routing Protocols for IoT-Enabled Wireless Sensor Networks." *Journal of Wireless Sensor Networks and IoT* 1.1 (2024): 1-5.

[9] Varriale, Vincenzo, Antonello Cammarano, Francesca Michelino, and Mauro Caputo. "Sustainable supply chains with blockchain, IoT and RFID: A simulation on order management." *Sustainability* 13, no. 11 (2021): 6372.

[10] Raza, Syed Asif. "A systematic literature review of RFID in supply chain management." *Journal of Enterprise Information Management* 35, no. 2 (2022): 617-649.

[11] Unhelkar, Bhuvan, Sudhanshu Joshi, Manu Sharma, Shiv Prakash, Ashwin Krishna Mani, and Mukesh Prasad. "Enhancing supply chain performance using RFID technology and decision support systems in the industry 4.0–A systematic literature review." *International Journal of Information Management Data Insights* 2, no. 2 (2022): 100084.

[12] Kavitha, M. "Advances in Wireless Sensor Networks: From Theory to Practical Applications." *Progress in Electronics and Communication Engineering* 1.1 (2024): 32-37.

[13] Naidu, TM Praneeth, Chandra Sekhar, and Pradeep Kumar Boya. "Low Power System on Chip Implementation of Adaptive Intra Frame and Hierarchical Motion Estimation in H. 265." Journal of VLSI Circuits and Systems 6.2 (2024): 40-52.

[14] Arvinth, N. (2024). Integration of neuromorphic computing in embedded systems: Opportunities and challenges. *Journal of Integrated VLSI, Embedded and Computing Technologies, 1*(1), 26-30. https://doi.org/10.31838/JIVCT/01.01.06

[15] Mostafizur Rahman, M. (2019). Effectiveness of RFID Technology in Library Management System in Bangladesh. *Indian Journal of Information Sources and Services*, *9*(3), 21–29. https://doi.org/10.51983/ijiss.2019.9.3.637

[16] Rizwan, Ali, Dimitrios A. Karras, Jitendra Kumar, Manuel Sánchez-Chero, Marlon Martín Mogollón Taboada, and Gilder Cieza Altamirano. "An internet of things (IoT) based block chain technology to enhance the quality of supply chain management (SCM)." *Mathematical Problems in Engineering* 2022, no. 1 (2022): 9679050.

[17] Yonis, E. G. (2024). The Effect of Thickness on the Thermal Conductivity Coefficient and Some Mechanical Properties of Acrylic Material Used in the Manufacture of Dentures. *International Academic Journal of Science and Engineering*, 11(2), 8–14. https://doi.org/10.9756/IAJSE/V11I2/IAJSE1143

[18] Van, C., Trinh, M. H., & Shimada, T. (2025). Graphene innovations in flexible and wearable nanoelectronics. *Progress in Electronics and Communication Engineering*, 2(2), 10–20. https://doi.org/10.31838/PECE/02.02.02

[19] Mohammed Shabeeb, A. T., & Kokila, G. (2024). Attendance verifying system based on QR. *The SIJ Transactions on Computer Science Engineering & Its Applications*, 12(2), 1–8.