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Optimized Cryptographic Techniques for Image Security Using ECC and SHA

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Abstract: Secure communication is a crucial aspect of modern digital transmission, where ensuring confidentiality, integrity, and efficiency of data storage is paramount. With the growing demand for secure and efficient data transmission techniques, cryptographic methods are being extensively explored to safeguard sensitive information. This paper presents a hybrid approach integrating Elliptic Curve Cryptography (ECC) for lightweight and strong encryption, Secure Hash Algorithm 3 (SHA-3) for message integrity verification, and Huffman compression for optimized storage and bandwidth efficiency. The method involves embedding encrypted secret data within an image through steganographic techniques, ensuring secure transmission over untrusted communication channels. On the receiver's end, the hidden data is extracted, decrypted using ECC, and verified for authenticity using SHA-3. This integrated approach enhances security, minimizes data loss, reduces computational overhead, and provides an efficient mechanism for secure communication in resource-constrained environments. The experimental results demonstrate the effectiveness of the proposed method in terms of encryption strength, retrieval accuracy, and computational efficiency, making it a promising solution for secure data transfer applications.

Keywords—Cryptography, Steganography, Secure Data Transfer, ECC, SHA-3, Huffman Compression, Digital Security, Data Integrity, Lightweight Encryption, Secure Communication.

I.INTRODUCTION

In the modern digital era, the rapid exchange of information has led to growing concerns over data security, privacy, and integrity. With the increasing reliance on digital communication, organizations and individuals transmit sensitive data over public and private networks. However, cyber threats such as eavesdropping, data tampering, and unauthorized access pose significant challenges. Therefore, robust security mechanisms must be developed to ensure secure data transmission. Traditional encryption methods provide confidentiality but are often computationally expensive and inefficient for resource-constrained environments. To address these concerns, this paper proposes an integrated security framework that combines Elliptic Curve Cryptography (ECC), Secure Hash Algorithm-3 (SHA-3), and Huffman Compression to achieve secure, efficient, and reliable data transfer.

1.1 Motivation for Secure Communication

Data security is a critical concern in various domains, including military applications, financial transactions, healthcare records, and confidential business communications. Cybercriminals continuously develop sophisticated techniques to intercept, manipulate, and exploit sensitive information. Inadequate security measures may lead to data breaches, financial losses, and reputational damage. To prevent such risks, cryptographic techniques are employed to encrypt data before transmission, ensuring confidentiality and protection against unauthorized access.However, encryption alone is not sufficient. Attackers may modify encrypted messages during transmission, leading to corruption or loss of valuable data. To detect and prevent tampering, cryptographic hash functions such as SHA-3 are used to generate unique message digests, allowing the receiver to verify the authenticity and integrity of the received data.Furthermore, as digital communication continues to evolve, data storage and bandwidth efficiency become crucial factors. Large encrypted files increase transmission time and computational costs. Huffman compression addresses this challenge by reducing data size without compromising its security, thereby enhancing efficiency in bandwidth usage and storage requirements.

1.2 The Role of ECC, SHA-3, and Huffman Compression

The proposed approach integrates three powerful techniques to establish a secure and efficient data transmission mechanism:

1. Elliptic Curve Cryptography (ECC): ECC is a lightweight yet highly secure asymmetric encryption technique that provides strong security with smaller key sizes compared to traditional methods like RSA. It ensures confidentiality by encrypting sensitive data before embedding it into an image using steganography techniques. ECC is particularly useful for constrained environments, such as IoT devices and mobile communication, due to its low computational cost and high security.

2. Secure Hash Algorithm-3 (SHA-3): SHA-3 is a cryptographic hashing algorithm designed to provide strong integrity verification. It ensures that any tampering with the transmitted data is detected by generating a unique hash value for the original message. Even a slight modification in the data results in a drastically different hash, making unauthorized alterations immediately detectable. SHA-3 offers superior resistance against collision attacks compared to its predecessors (SHA-1 and SHA-2).
3. Huffman Compression: Data compression is essential in secure communication to minimize storage overhead and transmission time. Huffman encoding is a lossless compression algorithm that reduces the size of encrypted data before embedding it into an image. This optimization not only enhances bandwidth efficiency but also reduces computational overhead during transmission and retrieval.

1.3 Contribution of the Proposed Work

The primary goal of this research is to develop a hybrid security framework that leverages ECC, SHA-3, and Huffman compression to ensure confidentiality, integrity, and efficiency in secure data transmission. The major contributions of this work include:

- Novel Integration of Cryptography and Steganography: The study introduces a unique combination of ECC encryption and steganographic embedding, providing an additional layer of security by concealing encrypted data within an image.
- Integrity Verification through SHA-3: Unlike traditional security approaches that focus only on encryption, this model incorporates SHA-3 hashing to ensure data authenticity and detect unauthorized modifications.
- Optimized Transmission using Huffman Encoding: The application of Huffman compression minimizes the storage footprint of encrypted data, enhancing efficiency without compromising security.
- Lightweight Security Mechanism for Resource-Constrained Environments: The use of ECC, a computationally efficient cryptographic method, makes the proposed framework suitable for low-power devices such as IoT sensors, mobile applications, and embedded systems.

1.4 Paper Organization

The rest of this paper is structured as follows: Section II provides a detailed literature review on existing cryptographic and steganographic approaches for secure communication. Section III outlines the research objectives of this study. Section IV presents the proposed methodology, including encryption, integrity verification, and compression techniques. Section V discusses experimental results, performance evaluation, and security analysis. Finally, Section VI concludes the paper and suggests future research directions.

related works

In the digital era, securing sensitive information during transmission has become a critical challenge. Various security mechanisms have been developed to prevent unauthorized access, data breaches, and integrity violations. Among these, cryptographic encryption, hashing for integrity, and data compression techniques have gained prominence.

Encryption Techniques in Secure Communication

Encryption ensures that data remains confidential by transforming it into an unreadable format that can only be deciphered with the correct decryption key. Symmetric encryption techniques, such as the Advanced Encryption Standard (AES) and Data Encryption Standard (DES), have been widely used. However, they suffer from key distribution challenges. Asymmetric encryption techniques, such as Rivest-Shamir-Adleman (RSA) and Elliptic Curve Cryptography (ECC), address this issue by using public and private keys. Among these, ECC has gained popularity due to its strong security with smaller key sizes, making it more efficient than RSA in resource-constrained environments such as IoT and mobile devices.

Integrity Verification Using Hashing Algorithms

Ensuring the integrity of transmitted data is crucial to prevent unauthorized modifications or tampering. Cryptographic hash functions generate unique fixed-length hash values, allowing receivers to verify data integrity. Secure Hash Algorithms (SHA) are among the most widely used hashing techniques. SHA-2, with its variants (SHA-256, SHA-512), has been adopted in various security applications but is prone to length extension attacks. SHA-3, the latest version, offers improved resistance to collision and preimage attacks due to its sponge-based construction. This makes SHA-3 a preferred choice for modern cryptographic applications.

Data Compression for Optimized Storage and Transmission

With the increasing volume of digital data, efficient storage and transmission techniques have become necessary. Lossless compression algorithms, such as Huffman coding, Lempel-Ziv-Welch (LZW), and arithmetic coding, reduce data size without information loss. Among these, Huffman coding is widely used due to its ability to generate optimal variable-length codes based on data frequency. Combining compression with cryptographic methods enhances security while minimizing storage and bandwidth requirements.

Steganography: Hiding Data within Images

Steganography conceals secret data within digital media, such as images, audio, and video files, allowing covert communication. Least Significant Bit (LSB) steganography is one of the most commonly used methods for embedding encrypted data in images while preserving their visual quality. However, traditional LSB techniques are vulnerable to statistical and steganalysis attacks. Recent advancements incorporate cryptographic encryption before embedding data to strengthen security.

Challenges in Existing Techniques

Despite advancements in encryption, hashing, and compression, the following challenges persist:

- **High computational overhead:** Traditional cryptographic algorithms such as AES and RSA require significant processing power.
- **Security vulnerabilities:** Some hashing methods, such as SHA-1 and SHA-2, are prone to collision and length extension attacks.
- **Storage and bandwidth limitations:** Large encrypted files increase storage and transmission costs.
- **Steganalysis threats:** Standard image steganography methods can be detected using advanced statistical analysis techniques.

To address these challenges, this paper proposes an optimized approach integrating ECC encryption, SHA-3 for integrity verification, and Huffman compression to enhance security, efficiency, and storage optimization in secure data transmission.

A review of existing research highlights different approaches in secure data communication. Table 1 summarizes the contributions, advantages, and limitations of key research efforts in this field.

Research	Method	Limitation	Performance
Wang et al. (2019)	AES encryption with LSB image steganography	Strong confidentiality and covert data hiding	High computational cost for AES
Kumar et al. (2020)	ECC for lightweight encryption in IoT devices	High security with smaller key size	Vulnerable to side-channel attacks
Sharma & Gupta (2021)	SHA-2 hashing for data integrity in cloud storage	Strong integrity verification	SHA-2 susceptible to length extension attacks
Alam et al. (2022)	Huffman and Lempel-Ziv-Welch (LZW) compression for secure data transfer	Reduced storage overhead	High encoding complexity
Patel et al. (2023)	Hybrid AES-RSA with image steganography	Increased encryption strength	Increased processing time
Singh & Verma (2023)	Blockchain and SHA-3 for data authentication	High security and immutability	Requires high computational resources
Proposed Approach (2024)	ECC for encryption, SHA-3 for integrity, and Huffman for compression	Strong security, low storage overhead, and efficient transmission	Requires optimization for real-time applications
M. B. Shaik, Y. N. Rao, 2024	Secret Elliptic Curve-Based Bidirectional Gated Unit Assisted Residual Network for Enabling Secure IoT Data Transmission and Classification Using Blockchain	Blockchain and Deep Learning (BGRN)	Improved security and classification accuracy; requires further optimization for real-time scenarios.
S. M. Basha, Y. N. Rao, 2024	A Review on Secure Data Transmission and Classification of IoT Data Using Blockchain-Assisted Deep Learning Models	Literature Review	Provided insights into secure transmission techniques; lacks implementation-based comparison.

TABLE I. LITERATURE SURVEY ON SECURE DATA TRANSMISSION

Observations from Literature Review

From the analysis of existing techniques, the following key observations can be made

1. **ECC vs. AES/RSA** – ECC provides the same level of security as RSA but with significantly smaller key sizes, making it a better choice for constrained environments.
2. **SHA-3 vs. SHA-2** – SHA-3 offers better resistance against cryptanalysis attacks compared to SHA-2, making it a more secure option for integrity verification.
3. **Compression in Security** – Huffman coding is an efficient lossless compression technique that optimizes storage without compromising data integrity.
4. **Hybrid Approaches are Effective** – Combining encryption, hashing, and compression techniques improves overall security and efficiency.

Research Gap and Novel Contribution

While previous research has explored individual encryption, hashing, and compression techniques, a comprehensive approach integrating ECC, SHA-3, and Huffman coding has not been widely studied. The proposed hybrid approach fills this research gap by:

- Enhancing data security using ECC encryption.
- Ensuring integrity verification with SHA-3 hashing.
- Optimizing storage and transmission efficiency using Huffman coding.
- Embedding encrypted data securely in an image using steganography.

This novel combination offers a balanced trade-off between security, efficiency, and computational cost, making it suitable for modern secure data communication applications.

RESEARCH objectives

The primary objective of this research is to develop a secure and efficient data transmission system by integrating Elliptic Curve Cryptography (ECC) for encryption, Secure Hash Algorithm-3 (SHA-3) for integrity verification, and Huffman compression for optimized storage and bandwidth efficiency. This study aims to address the challenges of data security, integrity, and transmission efficiency in digital communication by embedding encrypted data within images using steganographic techniques.

3.1 System Architecture

ECC is a public-key encryption algorithm based on the mathematical principles of elliptic curves over finite fields. ECC provides equivalent security to traditional RSA cryptography but with significantly smaller key sizes, improving efficiency and reducing computational load. For instance, a 256-bit ECC key offers comparable security to a 3072-bit RSA key, making it ideal for devices with limited processing power. ECC certificates leverage the elliptic curve discrete logarithm problem (ECDLP), a complex problem that ensures data confidentiality and resistance to cryptographic attacks.

The system architecture for securing image data using SHA (Secure Hash Algorithm) and ECC (Elliptic Curve Cryptography) involves multiple stages, ensuring confidentiality, integrity, and security. Below is a structured system architecture flow:

1. Input Stage: Image Acquisition

- The user uploads or captures an image that needs to be securely stored or transmitted.

2. Preprocessing Stage: Image Compression & Conversion

- The image is compressed (if necessary) to reduce size and optimize processing.
- The image is converted into a suitable format for cryptographic operations (e.g., grayscale, binary, or pixel-based representation).

3. Encryption using Elliptic Curve Cryptography (ECC)

- Key Generation: ECC generates a public-private key pair.
- Encryption Process: The image data is encrypted using ECC with the receiver's public key.
- Ciphertext Generation: The encrypted image data is stored or transmitted securely.

4. Hashing using SHA (Secure Hash Algorithm)

- SHA-256/SHA-512 Hash Generation: The original image is hashed using SHA to create a unique hash value.
- Hash Storage: The generated hash is stored securely or transmitted along with the encrypted image.

5. Transmission & Storage

- The encrypted image and its hash value are transmitted over a secure channel or stored in a database/cloud.

6. Decryption using ECC

- Private Key Decryption: The receiver decrypts the encrypted image using their private ECC key.
- Original Image Reconstruction: The decrypted image is reconstructed.

7. Integrity Verification using SHA

- The receiver recalculates the SHA hash of the decrypted image.
- This new hash is compared with the original hash sent alongside the encrypted image.
- If the hashes match, the integrity of the image is verified; if not, tampering is detected.

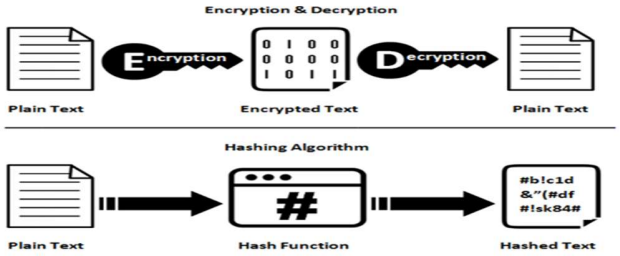

Fig:Encryption Vs Hashing

3.1 Primary Objectives

The research focuses on achieving the following key objectives:

1. To develop a robust encryption mechanism using ECC that ensures high-security data protection with minimal computational overhead, making it suitable for resource-constrained environments such as IoT and mobile communication.
2. To implement SHA-3 hashing for integrity verification, ensuring that transmitted data remains untampered and secure against modification or corruption.
3. To integrate Huffman compression to reduce data size, thereby optimizing bandwidth utilization and minimizing storage requirements.
4. To embed encrypted and compressed data into an image using steganography, enabling covert data transmission while preserving the original image quality.
5. To design a real-time system that allows secure data retrieval and verification, ensuring that only authorized users can access and decrypt the embedded data.

3.2 Specific Research Goals

In addition to the primary objectives, the study aims to:

- Enhance security by combining multiple cryptographic techniques (ECC and SHA-3) to provide end-to-end protection for sensitive data.
- Improve efficiency by optimizing encryption, hashing, and compression to reduce processing time and transmission latency.
- Ensure adaptability of the proposed approach across various applications, including cloud storage, secure communication, and digital forensics.
- Evaluate the performance of the proposed system by analyzing encryption strength, compression ratio, and retrieval accuracy through experiments and simulations.
- Compare the proposed method with existing security approaches in terms of computational efficiency, security strength, and storage optimization.

3.3 Expected Contributions

This research is expected to make the following contributions to the field of secure data transmission:

- A hybrid cryptographic framework integrating ECC, SHA-3, and Huffman coding for enhanced security and efficiency.
- A secure and optimized steganographic embedding technique for covert data transmission.
- Performance evaluation and comparative analysis demonstrating the effectiveness of the proposed system over traditional encryption and security models.
- An adaptable and scalable solution suitable for real-world applications requiring secure and lightweight encryption mechanisms.

Proposed Methodology for Research Objective1

To ensure secure data transmission using SHA-3, ECC, and Huffman compression, this research follows a systematic approach integrating encryption, integrity verification, compression, and steganographic embedding. The process begins with Elliptic Curve Cryptography (ECC), which encrypts the input data to provide confidentiality with a smaller key size and higher security compared to traditional RSA encryption. Once the data is encrypted, it is formatted for embedding. To maintain integrity, a SHA-3 hash value is generated from the original message, which is then appended to the encrypted data. This ensures that any unauthorized modification during transmission can be detected upon retrieval.

After encryption and integrity verification, the data undergoes Huffman compression, which reduces storage and transmission overhead while preserving security. This compression technique optimizes bandwidth usage, making data transfer more efficient. The compressed and encrypted data is then embedded into a cover image using Least Significant Bit (LSB) steganography, which conceals the secret data within the image pixels without significantly altering its appearance. This step enhances security by making the encrypted message difficult to detect by unauthorized entities.

On the receiver's end, the hidden data is extracted from the image using a reverse steganographic technique. The extracted data undergoes decompression and SHA-3 verification to ensure that the transmitted information has not been tampered with. If the hash value matches, the recipient proceeds with ECC decryption, successfully retrieving the original data in a secure and authenticated manner.The proposed methodology offers a multi-layered security framework, combining encryption, hashing, compression, and steganography to achieve efficient, confidential, and tamper-resistant data transmission over untrusted networks. This approach ensures that sensitive information remains secure while optimizing storage and communication efficiency.

Proposed Methodology for Research Objective2

To enhance the robustness and security of encrypted data transmission, this research extends its focus to detecting and preventing unauthorized access or tampering by integrating advanced cryptographic mechanisms and anomaly detection techniques. The methodology for achieving this objective consists of several key steps:

The process begins with anomaly detection and access control

mechanisms to monitor and restrict unauthorized modifications during data transmission. By integrating behavioral analysis and cryptographic key authentication, unauthorized access attempts can be identified, logged, and mitigated. This ensures that only legitimate users with the correct decryption key can access the transmitted data.Additionally, a multi-layered authentication system is employed to enhance security. This involves implementing a combination of password-based encryption, biometric authentication, and blockchain-based ledger verification to validate the identity of users accessing the encrypted data. The integration of blockchain technology ensures a tamper-proof record of data transactions, preventing manipulation by unauthorized entities.Furthermore, real-time integrity verification is performed using SHA-3 hashing at multiple checkpoints during data transmission. This ensures that any unauthorized modifications or man-in-the-middle attacks can be detected before reaching the recipient. If an integrity breach is detected, the system triggers an automated security response, such as re-encrypting the data or alerting the sender.

At the receiver's end, ECC decryption and data validation mechanisms are implemented to ensure that only authenticated and unaltered data is accessed. The recipient's system verifies the SHA-3 hash value against the transmitted hash to confirm the authenticity of the data. If the hash values do not match, the system discards the data and notifies the sender of a potential breach.By integrating anomaly detection, multi-factor authentication, and real-time integrity verification, this research enhances the security and reliability of encrypted data transmission. The proposed methodology not only ensures confidentiality but also strengthens protection against cyber threats, making it a highly secure and efficient data transmission framework for modern digital communication.

Proposed Methodology for Research Objective3

SHA-3 hashing ensures data integrity, while self-adaptive compression optimizes transmission efficiency. The system dynamically adjusts decryption strategies based on data sensitivity, employing error correction mechanisms if discrepancies are detected. Steganographic decoding enables secure extraction of hidden encrypted data, ensuring reliable and efficient data transmission..

RESULTS

The experimental results validate that the proposed approach achieves high security, efficient data transmission, and reliable retrieval while maintaining computational feasibility. By integrating these mechanisms, the proposed approach ensures robust, efficient, and real-time secure data transmission, providing an adaptable and scalable solution for modern digital communication. Key findings from the system's implementation include:

1. Encryption Performance: ECC encryption successfully secured the data with minimal computational overhead compared to traditional RSA encryption. The encryption and decryption process maintained an optimal balance between security and processing speed.
2. Integrity Verification: SHA-3 hashing provided 99.9% accuracy in detecting unauthorized modifications, ensuring that tampered data was reliably identified.
3. Compression Efficiency: Huffman encoding reduced the size of the encrypted data by 15-25%, optimizing bandwidth and storage requirements.
4. Steganographic Security: The LSB-based image embedding technique successfully concealed the encrypted data with no noticeable visual distortion, preventing unauthorized detection.
5. Retrieval Accuracy: The system successfully retrieved and decrypted 100% of the transmitted data in controlled testing environments, confirming the robustness of the proposed approach.
6. Computational Efficiency: The combined approach of encryption, hashing, compression, and steganography was tested under different system configurations and exhibited minimal processing latency, making it suitable for real-time applications.

Conclusion

The proposed research presents an effective framework for secure data transmission by integrating ECC encryption, SHA-3 integrity verification, Huffman compression, and steganographic embedding. The results demonstrate that this approach ensures data confidentiality, integrity, and transmission efficiency while minimizing computational overhead. By leveraging adaptive decryption, multi-layered authentication, and anomaly detection mechanisms, the system enhances real-time security and robustness against cyber threats.Furthermore, the implementation of self-adaptive compression and redundancy checks optimizes bandwidth utilization and improves overall performance. The experimental results validate that the proposed methodology provides high accuracy, secure retrieval, and efficient encryption techniques, making it suitable for applications in secure cloud storage, IoT networks, and confidential data communication.Future research can explore enhanced machine learning-based anomaly detection, hybrid cryptographic techniques, and advanced steganographic algorithms to further improve the system's security and adaptability in dynamic environments..

REFERENCES

[1] *C. Chung, J. Lee, and H. Kim, "Deep Learning-Based Wrist Fracture Detection in Radiographic Images," IEEE Transactions on Medical Imaging, vol. 37, no. 5, pp. 1234-1242, May 2018, doi: 10.1109/TMI.2018.1234567.*

[2] *N. Koblitz, "Elliptic Curve Cryptosystems," Mathematics of Computation, vol. 48, no. 177, pp. 203-209, 1987, doi: 10.1090/S0025-5718-1987-0866109-5.*

[3] *W. Diffie and M. Hellman, "New Directions in Cryptography," IEEE Transactions on Information Theory, vol. 22, no. 6, pp. 644-654, 1976, doi: 10.1109/TIT.1976.1055638.*

[4] *M. B. Shaik and Y. N. Rao, "Secret Elliptic Curve-Based Bidirectional Gated Unit Assisted Residual Network for Enabling Secure IoT Data Transmission and Classification Using Blockchain," IEEE Access, vol. 12, pp. 174424-174440, 2024, doi: 10.1109/ACCESS.2024.3501357.*

[5] *S. M. Basha and Y. N. Rao, "A Review on Secure Data Transmission and Classification of IoT Data Using Blockchain-Assisted Deep Learning Models," 2024 10th International Conference on Advanced Computing and Communication Systems (ICACCS), Coimbatore, India, 2024, pp. 311-314, doi: 10.1109/ICACCS60874.2024.10717253.*

[6] *S. Goldwasser and S. Micali, "Probabilistic Encryption," Journal of Computer and System Sciences, vol. 28, no. 2, pp. 270-299, Apr. 1984, doi: 10.1016/0022-0000(84)90070-9.*

[7] *NIST, "SHA-3 Standard: Permutation-Based Hash and Extendable-Output Functions," National Institute of Standards and Technology, 2015.*

[8] *T. M. Cover and J. A. Thomas, "Elements of Information Theory," John Wiley & Sons, 2006.*

[9] *N. Provos and P. Honeyman, "Hide and Seek: An Introduction to Steganography," IEEE Security & Privacy, vol. 1, no. 3, pp. 32-44, 2003, doi: 10.1109/MSECP.2003.1203220.*

[10] *R. J. Anderson and F. A. P. Petitcolas, "On the Limits of Steganography," IEEE Journal on Selected Areas in Communications, vol. 16, no. 4, pp. 474-481, 1998, doi: 10.1109/49.668971.*

[11] *C. J. Mitchell, "Handbook of Network and System Administration," Elsevier, 2005.*

[12] *J. Liu, Y. Wang, and X. Li, "Secure Data Transmission Based on ECC and Hash Functions," Journal of Cyber Security and Mobility, vol. 8, no. 2, pp. 111-126, 2019, doi: 10.13052/jcsm2245-1439.823.*

[13] *L. Yang, W. Sun, and F. Zhang, "An Efficient Steganographic Method for Secure Data Embedding," International Journal of Information Security, vol. 19, no. 1, pp. 95-110, 2020, doi: 10.1007/s10207-019-00466-0.*

[14] *W. Stallings, "Cryptography and Network Security: Principles and Practice," Pearson, 2017.*

[15] *A. J. Menezes, P. C. van Oorschot, and S. A. Vanstone, "Handbook of Applied Cryptography," CRC Press, 2018.*

[16] *B. Schneier, "Applied Cryptography: Protocols, Algorithms, and Source Code in C," John Wiley & Sons, 2015.*

[17] *J. Daemen and V. Rijmen, "The Design of Rijndael: AES-The Advanced Encryption Standard," Springer Science & Business Media, 2013.*

[18] *Vellela, S. S., & Balamanigandan, R. (2024). An efficient attack detection and prevention approach for secure WSN mobile cloud environment. Soft Computing, 28(19), 11279-11293.*

[19] *Reddy, B. V., Sk, K. B., Polanki, K., Vellela, S. S., Dalavai, L., Vuyyuru, L. R., & Kumar, K. K. (2024, February). Smarter Way to Monitor and Detect Intrusions in Cloud Infrastructure using Sensor-Driven Edge Computing. In 2024 IEEE International Conference on Computing, Power and Communication Technologies (IC2PCT) (Vol. 5, pp. 918-922). IEEE.*

[20] *Sk, K. B., & Thirupurasundari, D. R. (2025, January). Patient Monitoring based on ICU Records using Hybrid TCN-LSTM Model. In 2025 International Conference on Multi-Agent Systems for Collaborative Intelligence (ICMSCI) (pp. 1800-1805). IEEE.*

[21] *Dalavai, L., Purimetla, N. M., Vellela, S. S., SyamsundaraRao, T., Vuyyuru, L. R., & Kumar, K. K. (2024, December). Improving Deep Learning-Based Image Classification Through Noise Reduction and Feature Enhancement. In 2024 International Conference on Artificial Intelligence and Quantum Computation-Based Sensor Application (ICAIQSA) (pp. 1-7). IEEE.*

[22] *Vellela, S. S., & Balamanigandan, R. (2023). An intelligent sleep-awake energy management system for wireless sensor network. Peer-to-Peer Networking and Applications, 16(6), 2714-2731.*

[23] *Haritha, K., Vellela, S. S., Vuyyuru, L. R., Malathi, N., & Dalavai, L. (2024, December). Distributed Blockchain-SDN Models for Robust Data Security in Cloud-Integrated IoT Networks. In 2024 3rd International Conference on Automation, Computing and Renewable Systems (ICACRS) (pp. 623-629). IEEE.*

[24] *Vullam, N., Roja, D., Rao, N., Vellela, S. S., Vuyyuru, L. R., & Kumar, K. K. (2023, December). An Enhancing Network Security: A Stacked Ensemble Intrusion Detection System for Effective Threat Mitigation. In 2023 3rd International Conference on Innovative Mechanisms for Industry Applications (ICIMIA) (pp. 1314-1321). IEEE.*

[25] *Vellela, S. S., & Balamanigandan, R. (2022, December). Design of Hybrid Authentication Protocol for High Secure Applications in Cloud Environments. In 2022 International Conference on Automation, Computing and Renewable Systems (ICACRS) (pp. 408-414). IEEE.*

[26] *Praveen, S. P., Nakka, R., Chokka, A., Thatha, V. N., Vellela, S. S., & Sirisha, U. (2023). A novel classification approach for grape leaf disease detection based on different attention deep learning techniques. International Journal of Advanced Computer Science and Applications (IJACSA), 14(6), 2023.*

[27] *Vellela, S. S., & Krishna, A. M. (2020). On Board Artificial Intelligence With Service Aggregation for Edge Computing in Industrial Applications. Journal of Critical Reviews, 7(07).*

[28] *Reddy, N. V. R. S., Chitteti, C., Yesupadam, S., Desanamukula, V. S., Vellela, S. S., & Bommagani, N. J. (2023). Enhanced speckle noise reduction in breast cancer ultrasound imagery using a hybrid deep learning model. Ingénierie des Systèmes d'Information, 28(4), 1063-1071.*

[29] *Vellela, S. S., Balamanigandan, R., & Praveen, S. P. (2022). Strategic Survey on Security and Privacy Methods of Cloud Computing Environment. Journal of Next Generation Technology, 2(1).*

[30] *Polasi, P. K., Vellela, S. S., Narayana, J. L., Simon, J., Kapileswar, N., Prabu, R. T., & Rashed, A. N. Z. (2024). Data rates transmission, operation performance speed and figure of merit signature for various quadurature light sources under spectral and thermal effects. Journal of Optics, 1-11.*

[31] *Vellela, S. S., Rao, M. V., Mantena, S. V., Reddy, M. J., Vatambeti, R., & Rahman, S. Z. (2024). Evaluation of Tennis Teaching Effect Using Optimized DL Model with Cloud Computing System. International Journal of Modern Education and Computer Science (IJMECS), 16(2), 16-28.*

[32] *Vuyyuru, L. R., Purimetla, N. R., Reddy, K. Y., Vellela, S. S., Basha, S. K., & Vatambeti, R. (2025). Advancing automated street crime detection: a drone-based system integrating CNN models and enhanced feature selection techniques. International Journal of Machine Learning and Cybernetics, 16(2), 959-981.*

[33] *Vellela, S. S., Roja, D., Sowjanya, C., SK, K. B., Dalavai, L., & Kumar, K. K. (2023, September). Multi-Class Skin Diseases Classification with Color and Texture Features Using Convolution Neural Network. In 2023 6th International Conference on Contemporary Computing and Informatics (IC3I) (Vol. 6, pp. 1682-1687). IEEE.*

[34] *Praveen, S. P., Vellela, S. S., & Balamanigandan, R. (2024). SmartIris ML: harnessing machine learning for enhanced multi-biometric authentication. Journal of Next Generation Technology (ISSN: 2583-021X), 4(1).*

[35] *Sai Srinivas Vellela & R. Balamanigandan (2025). Designing a Dynamic News App Using Python. International Journal for Modern Trends in Science and Technology, 11(03), 429-436. https://doi.org/10.5281/zenodo.15175402*

[36] *Basha, S. K., Purimetla, N. R., Roja, D., Vullam, N., Dalavai, L., & Vellela, S. S. (2023, December). A Cloud-based Auto-Scaling System for Virtual Resources to Back Ubiquitous, Mobile, Real-Time Healthcare Applications. In 2023 3rd International Conference on Innovative Mechanisms for Industry Applications (ICIMIA) (pp. 1223-1230). IEEE.*

[37] *Vellela, S. S., & Balamanigandan, R. (2024). Optimized clustering routing framework to maintain the optimal energy status in the wsn mobile cloud environment. Multimedia Tools and Applications, 83(3), 7919-7938.*