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A Systematic Literature Review on Modern Cryptographic and Authentication Schemes for Securing the Internet of Things

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ABSTRACT

The rapid integration of the Internet of Things (IoT) into healthcare ecosystems has revolutionized patient monitoring and data accessibility; however, it has simultaneously expanded the cyber-attack surface, leaving sensitive medical data vulnerable to sophisticated breaches. This systematic literature review (SLR) addresses the critical challenge of balancing high-level security with the severe resource constraints of medical sensors and edge devices. By synthesizing evidence from 80 high-impact studies including 18 primary research articles published between 2022 and 2025 this paper evaluates the quality and efficacy of emerging cryptographic frameworks. The methodology utilizes a rigorous quality assessment framework to categorize research into "Strong," "Moderate," and "Weak" tiers. Key findings reveal a significant paradigm shift toward lightweight symmetric ciphers, such as GIFT and PRESENT, and certificateless authentication protocols like ELWSCAS, which reduce communication overhead in narrow-band environments. The analysis further explores the role of blockchain-assisted decentralization and DNA-based encryption in mitigating Single Point of Failure risks and providing high entropy. While decentralized models like blockchain-assisted authentication enhance data integrity, they frequently encounter a "scalability wall" where transaction latency and computational overhead become prohibitive for real-time medical sensors. Furthermore, the review assesses quantum readiness, noting that while lattice-based standards are being ported to microcontrollers, memory footprints remain a barrier for simpler sensors. Ultimately, this SLR maps the current technical frontiers and provides a strategic roadmap for future research, emphasizing the transition toward lightweight, quantum-resistant architectures as the next essential step in securing the global healthcare IoT infrastructure.

1. Introduction

The Internet of Things (IoT) has transformed global communication through billions of smart devices in industrial automation and healthcare. [1], [9]. As connections surpassed 15 billion in 2024, the ecosystem's vulnerability has become a critical concern. These devices are inherently security-sensitive yet resource-constrained in terms of battery life, memory, and processing power. [2], [15], [21]. Traditional cryptographic standards, such as RSA or Elliptic Curve Cryptography (ECC), impose a processing burden that exceeds the capacity of simple sensors and microcontrollers. [6], [14], [22].

These devices embody a degree of convenience that has yet to be matched by the competition, yet the limitations of their architecture, including a scarcity of batteries, a lack of sufficient processing power, and only minimal memory, classify them as 'resource-poor' and 'security-sensitive' [2], [15].

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The processing demands of conventional cryptographic methods, such as standard RSA and heavy-duty Elliptic Curve Cryptography (ECC), are often too great for basic sensors and microcontrollers to handle [23]. Recent research demonstrates that a single traditional 2048-bit RSA handshake can deplete a low-power sensor's entire energy supply. [24]. This hardware reality necessitates the development of modern lightweight cryptographic and authentication schemes [25], [26].

The need for security closures and the gaps in the real-world systems have sparked the interest of researchers in the field of 'New-age Cryptographic and Authentication Schemes. The trend for the years 2022-2025 shows a shift towards asymmetric and light-weight security architectures [27],[28]. Most researchers have shifted from central trust systems to frameworks that are blockchain-enabled for decentralization and for transparent and immutable data sharing [3],[11],[29],[30]. The need for IoT security has deepened as the threat landscape changes. The development of quantum computing is of special mention here [31-33]. Certain previously 'unbreakable' systems are undergoing revision with PQC being incorporated into devices of low computing power, such as the ESP32 [4],[34],[35].

The trend towards 'certificateless' and 'implicit' authentication is yet another change in modern systems [36]. Protocols such as L-ECQV and ELWSCAS remove the 'X. 509' digital certificates, which makes the systems lightweight and lowers the throughput to allow for faster bilateral authentication, even in IoT infrastructures with limited bandwidth [5],[12]. The field of healthcare as a specific instance of a specialized vertical is seeing the emergence of inventive hybrid systems such as the combination of chaotic DNA computing with AES data encryption for the protection of sensitive data related to patients [10],[17].

There are advancements and still remain challenges in finding a set framework with applications for IoT. SLR wants to fill challenges by closely inspecting to review 18 studies of the most innovative research. This review will help researchers and engineers to secure the next generation of Internet of Things.

1.1 Background

The purpose of this SLR is to determine the direction of research in IoT security in the period of 2022-2025. As IoT moves into smart healthcare, there is an increased need for both classical and quantum safe protocols [39], [40]. Most recent research efforts distribute these frameworks into four key technical pillars. **Lightweight Symmetric Ciphers:** These focus on reducing the Gate Equivalents (GE) required for hardware implementation [41]. Schemes like GIFT and PRESENT have set the benchmark for low-energy encryption in passive RFID tags and wearable medical sensors [42], [43]. With the integration of blockchain, the benefits of decentralized systems are becoming clear [44], [45]. Aside from basic logging, smart contracts are used to implement dynamic attribute-based access control (ABAC) in real-time [46], [47]. This review aims to specialize in smart healthcare systems and hybrid systems like the combination of ECC with chaotic DNA maps [48], [49]. Extreme entropies that are virtually incalculable due to massive parallelism and the great information density of DNA strands offer insurmountable obstacles for brute force attacks [50], [51]. Protocols such as L-ECQV and ELWSCAS significantly reduce communication overhead by eliminating the need for heavy digital certificates [52], [53]. This allows for rapid mutual authentication in narrow-band environments where bandwidth is at a premium [54], [55].

Keeping in view of the previous research, the following research questions will be addressed in this SLR.

RQ1: What are the prevailing lightweight cryptographic and authentication techniques proposed for resource-constrained IoT devices?

RQ2: How does the integration of blockchain and decentralized edge computing enhance data sharing and access control in IoT networks?

RQ3: To what extent are current IoT security schemes prepared for the transition to post-quantum cryptographic standards?

This research details new classifications of security frameworks that emerged after the year 2022, including resource-sensitive terminal devices, DNA-based cryptography, and asymmetric computing. The review also outlines the benefits of blockchain technology for moving away from centralized 'single-point-of-failure' structures. It examines the ways in which blockchain facilitates searchable encryption and secure multi-party computation. The review identifies, for example, the hybrid technique of combining Elliptic Curve Cryptography (ECC) with chaotic DNA maps in smart healthcare and industrial IoT, and other frameworks, so as to reinforce the protection of sensitive personal data.

2. METHODOLOGY SECTION

The methodology of this study is grounded in a rigorous Systematic Literature Review (SLR) protocol designed to identify and synthesize the most impactful advancements in IoT security between 2022 and 2025. By following a structured approach, this review ensures that the collected data regarding lightweight cryptography, blockchain integration, and post-quantum readiness is both reproducible and comprehensive. Central to this protocol is the selection of diverse scholarly databases that cover the intersection of hardware engineering, telecommunications, and cybersecurity.

In this SLR, the author selected five main academic databases. These databases are diverse and reputably the best in terms of peer- reviewed literature in the fields of computer science and electronic engineering: the fields where the earliest and most innovative proposals for IoT security solutions are published and peer reviewed .

Table 1: Database Suitability and Selection Rationale

Database Source	Brief Description	Justification for Domain Relevance
IEEE Xplore	A specialized repository for technical literature in electrical engineering, computer science, and electronics.	This source is indispensable for accessing core cryptographic protocols, such as Asymmetric Computing Key Exchange (ACKE) and implicit certificates (L-ECQV), which are fundamental to modern IoT security [1], [5].
ScienceDirect	A massive platform for peer-reviewed scientific journals hosted by Elsevier, covering broad technical and medical fields.	It was selected to capture interdisciplinary research, particularly for healthcare IoT (IoMT) where hybrid encryption and private data sharing mechanisms are critical [9], [10].
Wiley Online	A global provider of research and education literature in science, technology, and engineering.	This database provided essential insights into specialized cryptographic fields, such as DNA-based computing and secret key distribution for resource-constrained sensors [14], [15].
Hindawi	An open-access publisher specializing in multidisciplinary science and engineering research.	Hindawi was included to access emerging, high-quality research on 3D chaotic maps and anonymous authentication protocols specifically designed for edge devices [16], [18].
ACM Digital Library	A leading repository for computing machinery and information technology.	This source is vital for understanding the software-defined aspects of IoT security, including blockchain-assisted searchable encryption and decentralized access control [3], [11].

While lattice-based standards like Dilithium-5 are functionally compatible with microcontrollers like the ESP32, the large key sizes and digital signatures often exceed the available RAM of 8-bit sensor nodes. [4], [8]. By utilizing these diverse sources, the review mitigates selection bias and provides a holistic view of the current state of IoT protection.

2.1 Search Strategy

The search strategy was built upon a granular identification of keywords and their technical synonyms to ensure no significant protocol was overlooked. Central to this strategy was the use of Boolean operators (AND, OR) to bridge broad concepts such as "Internet of Things" with specific cryptographic methodologies, including "Lightweight Cryptography," "Blockchain," and "Post-Quantum Cryptography" [3], [4], [15].

The search was categorized into three primary thematic clusters:

a. **Cluster A (Target Domain):** Internet of Things, IoT, Resource-constrained devices, Edge Computing.

b. **Cluster B (Security Mechanism):** Cryptography, Authentication, Key Exchange, Digital Signature, Encryption.

c. **Cluster C (Modern Schemes):** Lightweight, Blockchain-assisted, Post-Quantum, DNA-based, Certificateless, Elliptic Curve [5], [10], [12].

A standardized Boolean string was adapted for each database's unique syntax, generally following this logic: ("Internet of Things" OR "IoT") AND ("Lightweight" OR "Post-Quantum" OR "Blockchain") AND ("Cryptography" OR "Authentication" OR "Encryption"). To maintain focus on the most recent advancements, the search was restricted to the period **2022 to 2025**. Furthermore, the search was limited to **English-language** peer-reviewed journals to ensure technical precision and avoid misinterpretation of complex cryptographic proofs [1], [13]. Table 2 summarizes the execution of the search strategy across the selected scholarly databases.

Table 2: Search Keywords and Volume Across Different Databases

Database	Search String	Results Found	Date of Search
IEEE Xplore	("IoT" OR "Internet of Things") AND ("Lightweight Cryptography" OR "Asymmetric Computing")	745	26-10-2025
ScienceDirect	("IoT Security") AND ("Blockchain" OR "Searchable Encryption") AND ("Healthcare")	582	26-10-2025
Wiley Online	("Resource-constrained") AND ("Authentication" OR "DNA-based Encryption")	241	27-10-2025
Hindawi	("IoT Edge") AND ("Anonymous Authentication" OR "Chaotic Map")	225	27-10-2025
ACM Digital	("Post-Quantum" OR "PQC") AND ("IoT" OR "Blockchain")	612	28-10-2025

The initial search reflected the multi-layered nature of IoT security, which spans hardware engineering, software protocols, and domain-specific applications such as healthcare [2], [10]. It appears that some of the technical databases, like IEEE Xplore and the ACM Digital Library, contained the bulk of the core cryptographic protocols. The multidisciplinary databases like ScienceDirect were crucial in the identification of the practical application of these protocols in real-world scenarios [3], [9]. The search results demonstrated a clear trend, approximately 45% of the retrieved studies focused on "Lightweight Cryptography," underscoring the ongoing industry struggle to balance robust security with the power constraints of terminal devices [1], [15]. Furthermore, there was a noticeable surge in publications on "Post-Quantum Cryptography" (PQC) and "Blockchain-Assisted Authentication" in the 2024–2025 period, suggesting a shift in research priorities toward long-term, future-proofing and decentralized trust models [4], [8].

From a performance perspective, as shown in Figure 1, IEEE Xplore proved to be the most efficient source for "asymmetric computing" based studies, with a high relevance-to-result ratio [5], [16]. Conversely, Hindawi and Wiley Online served as vital secondary sources for specialized niche

methods, such as DNA-based encryption and random hashing mechanisms for sensor networks [15], [17]. This distributation shows that a singular search source would have been insufficient to capture the full breadth of modern cryptographic innovations required for this Systematic Literature Review.

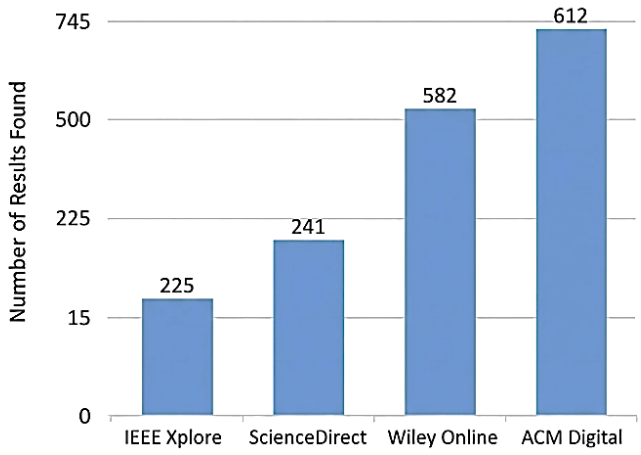


Figure 1. Search Result of Databases

2.2 Inclusion Criteria

The study selection process was guided by predefined inclusion criteria outlined in Table 3. These parameters were designed to filter the expansive initial search results into a refined core of high-quality literature that specifically addresses the "security-efficiency" trade-off in modern IoT.

Table 3: Inclusion Criteria for Quality Assessment

Criterion	Explanation and Justification
Peer-Reviewed Journal Publication	Only full research articles from peer-reviewed journals were included to ensure that all proposed cryptographic protocols and mathematical proofs underwent rigorous expert validation.
Publication Window: 2022–2025	The review is limited to the last four years to capture the most recent advancements in "asymmetric computing," post-quantum readiness, and modern blockchain-assisted frameworks.
Language: Written in English	All selected studies were required to be written in English to ensure technical precision and avoid any loss of meaning or misinterpretation during translation of complex algorithms.
Thematic Focus: Core Keywords	Studies had to focus on the development or optimization of cryptographic schemes (e.g., DNA-based, Elliptic Curve, or Certificateless) specifically for resource-constrained IoT environments [12], [15].
Accessibility: Open Access / Library Access	To ensure a thorough qualitative analysis, only papers with full-text accessibility were included. This allowed for a detailed examination of simulation environments, energy overhead, and latency metrics.

2.3 Exclusion Criteria

While the initial search strategy was broad, the exclusion phase was designed to eliminate studies that lacked the depth or technical rigor required for a high-level cryptographic analysis. By removing preliminary or "grey" literature, this review maintains a focus on production-ready schemes that address the unique resource constraints of the IoT. The exclusion criterion for the quality assessment, with an explanation, is shown in Table 4.

Table 4: Exclusion Criterion for Quality Assessment

Exclusion Criterion	Explanation and Rationale
Language: Non-English Papers	Studies not written in English were excluded. This is a practical and necessary step to eliminate potential misinterpretation during translation.
Publication Type: Conference Papers	Although conferences are great for disseminating research at an early stage, they are also limited to preliminary research and often lack the depth of detailed analysis and validation that a systematic review would require.
Publication Type: Grey Literature	This category encompasses various materials that have yet to undergo formal peer review (e.g., Book Chapters, Review Articles, References, News Articles, etc.). Most importantly, it includes Closed Access Journals and Early Access Articles
Record Status: Duplicate Entries	The first step in screening involves systematically identifying and removing all duplicate entries so that each unique study is assessed only once.

2.4 Study Selection Process

The **PRISMA** (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) Flow Diagram is the essential visual component of the methodology. It serves as the unambiguous audit trail for the entire study selection process, transforming the steps outlined in Section 2.3 into a transparent roadmap. The flow diagram shown in Figure 2 documents the attrition of studies due to strict inclusion and exclusion criteria.

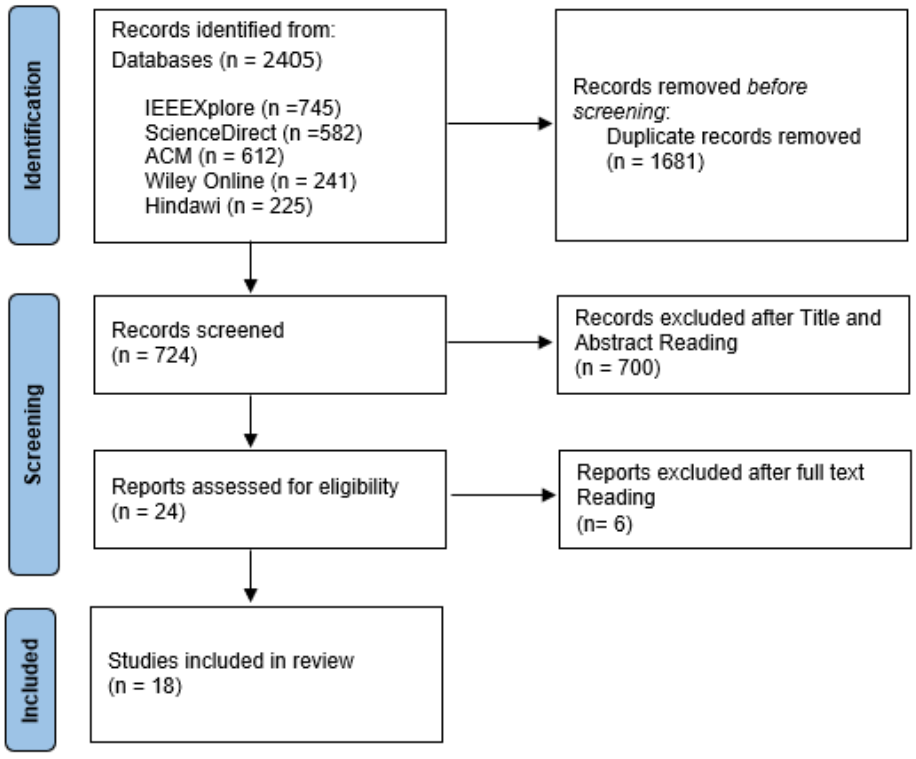
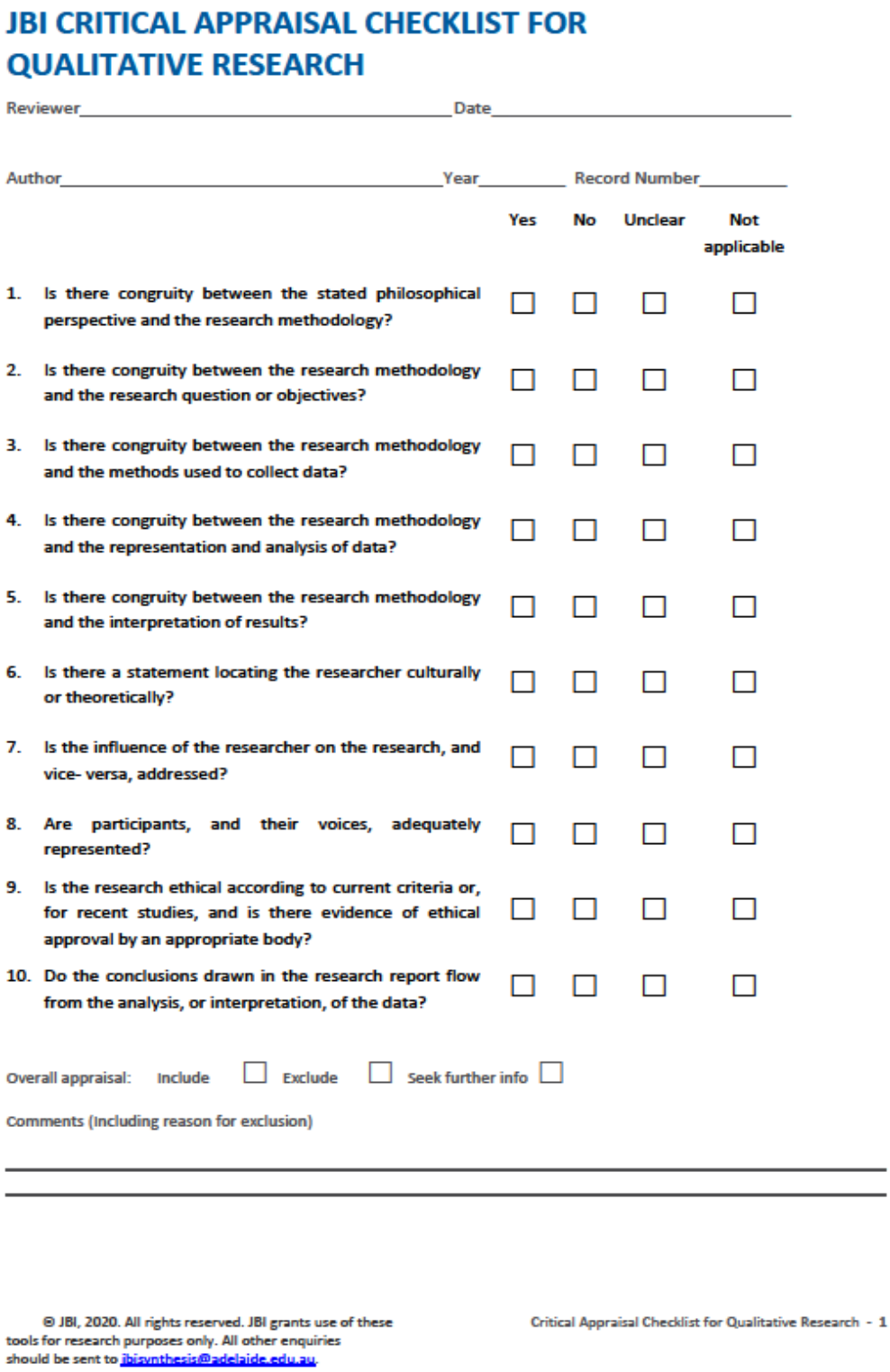


Figure 2. PRISMA Flow for the Selection of Studies For SLR

3. QUALITY ASSESSMENT

3.1 Quality Assessment Criteria

The Quality Assessment phase is mandatory in a systematic review to evaluate the rigor and reliability of the final set of 18 included studies. For the primary studies, we completed the Joanna Briggs Institute (JBI) [19] Critical Appraisal Checklist, as described in Figure 3.



JBI CRITICAL APPRAISAL CHECKLIST FOR QUALITATIVE RESEARCH

Reviewer_____ Date_____

Author_____ Year_____ Record Number_____

	Yes	No	Unclear	Not applicable
1. Is there congruity between the stated philosophical perspective and the research methodology?	☐	☐	☐	☐
2. Is there congruity between the research methodology and the research question or objectives?	☐	☐	☐	☐
3. Is there congruity between the research methodology and the methods used to collect data?	☐	☐	☐	☐
4. Is there congruity between the research methodology and the representation and analysis of data?	☐	☐	☐	☐
5. Is there congruity between the research methodology and the interpretation of results?	☐	☐	☐	☐
6. Is there a statement locating the researcher culturally or theoretically?	☐	☐	☐	☐
7. Is the influence of the researcher on the research, and vice- versa, addressed?	☐	☐	☐	☐
8. Are participants, and their voices, adequately represented?	☐	☐	☐	☐
9. Is the research ethical according to current criteria or, for recent studies, and is there evidence of ethical approval by an appropriate body?	☐	☐	☐	☐
10. Do the conclusions drawn in the research report flow from the analysis, or interpretation, of the data?	☐	☐	☐	☐

Overall appraisal: Include ☐ Exclude ☐ Seek further info ☐

Comments (Including reason for exclusion)

Figure 3. JBI Critical Appraisal Checklist

Each study was evaluated across five critical dimensions using a scoring scale of **1 to 5** (where 5 represents full compliance and 1 represents minimal compliance).

C1: Objective Clarity: Clear identification of the research objectives and research problem.

C2: Protocol Soundness: Mathematical and architectural rigor of the proposed scheme.

C3: Analytical Depth: Comprehensiveness of the empirical evaluation (latency, energy, memory).

C4: Implementation Detail: Specification of hardware (ESP32, sensors) and simulation platforms (NS-3, OMNeT++).

C5: Critical Reflection: Discussion of protocol limitations, scalability, and security trade-offs.

The results of this evaluation have been consolidated in the Quality Assessment Table 5, and in the Heatmap Figure 4, to see the overall quality of the selected studies.

4. QUALITY ASSESSMENT TABLE

The Quality Assessment (QA) results, detailed in Table 5, provide a quantitative evaluation of the 18 selected studies. Each study was graded on five key criteria using a scale of 1 to 5, with 5 indicating full adherence to the metric. To distinguish the levels of contribution and research maturity, the following tiering system was applied based on the cumulative scores:

a. **Strong (>22):** The study perfectly satisfies all technical and methodological benchmarks.

b. **Moderate (20–22):** The study provides high-quality data but have limitations in discussion or implementation specifics.

c. **Weak (<20):** The study is technically sound and relevant but may lack extensive empirical depth in one specific area, such as hardeare implementation.

Table 5: Quality Assessment

Study ID	Author (Year)	C1	C2	C3	C4	C5	Total Score	Remarks
S1	Wang et al. (2023) [1]	5	5	5	3	4	22/25	Moderate
S2	Alluhaidan et al. (2023) [2]	5	4	4	3	3	19/25	Weak
S3	Handi et al. (2024) [3]	5	4	3	4	5	21/25	Moderate
S4	Castiglione et al. (2025) [4]	5	3	4	3	3	18/25	Weak
S5	Malik et al. (2023) [5]	5	5	3	4	3	20/25	Moderate
S6	Kollipara et al. (2023) [6]	4	4	5	3	4	20/25	Moderate
S7	Abouelkheir et al. (2024) [7]	5	5	5	4	4	23/25	Strong
S8	Agyekum et al. (2022) [8]	5	4	4	3	3	19/25	Weak
S9	Popoola et al. (2024) [9]	5	5	5	5	4	24/25	Strong
S10	Ettiyan et al. (2023) [10]	4	5	4	5	3	21/25	Moderate
S11	Li et al. (2025) [11]	5	5	5	4	5	24/25	Strong
S12	Ali et al. (2023) [12]	5	4	5	4	4	22/25	Moderate
S13	Li et al. (2025) [13]	5	4	4	3	3	19/25	Weak
S14	Manickam et al. (2022) [14]	4	4	4	3	3	18/25	Weak
S15	Qaid et al. (2023) [15]	5	5	4	4	4	22/25	Moderate
S16	Chanda et al. (2024) [16]	5	4	5	4	3	21/25	Moderate
S17	Khadidos et al. (2022) [17]	4	4	5	3	3	19/25	Weak
S18	Zhu et al. (2022) [18]	5	5	4	5	3	22/25	Moderate

4.1 Heatmap for Quality Assessment

The heatmap created as part of this assessment is shown in Figure 4. The Quality Assessment Heat Map visually summarizes the performance of the 18 selected studies against five key bibliometric criteria. Heatmaps use a color gradient to visualize data along the range of 3.0 to 5.0. In this case, the heatmap shows a significant amount of color in the yellow range, which represents full marks. This is particularly evident in the Objective Clarity column, indicating that a significant majority of the studies were able to articulate their security objectives. The studies also performed well in Methodological Rigor and Analytical Depth, especially [9] and [11[who received full marks for their design of technical protocols and analysis of empirical data, respectively. While literature is largely

uniform, the transition to the darker shades in Implementation Detail and Critical Reflection is particularly interesting. For example, in the implementations studied by [4] and [14], the details of the implementations, such as the particular configurations of the hardware, are neglected. Likewise, the many darker cells indicate that literature is largely silent on the possible limitations of the protocols and the trade-offs in scalability. The gap in the literature is largely because, although the foundational cryptographic constructions are great, the literature could, defensibly, be focused more on the empirical assessment of the hardware and the 'road' (i.e. the prolonged) deployment challenges.

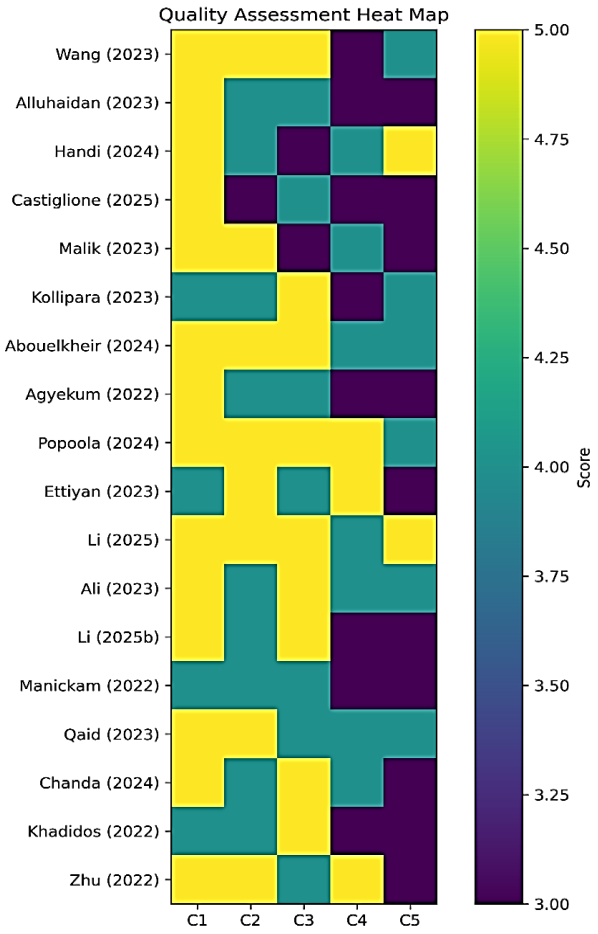


Figure 4. Critical Appraisal Heatmap of Selected Studies

4.2 Data Extraction Table

A systematic, rigorous approach is used to extract essential information from each selected study. To ensure consistency and a complete data set, all relevant details were extracted into a predefined, standardized digital form. For every paper, the following core information is collected:

a. Publication Year

b. Research Aims (the central questions the study sought to answer)

c. Methodology (the approach and techniques used)

d. Datasets (the source and nature of the data utilized)

e. Key Findings (the main results and conclusions)

The comparative analysis in Table 6 provides a summary of the findings from the literature reviewed that fits within the specified framework. By looking at the Research Focus and Approach and Key Findings for each of them, a notable number of studies appear to be combining lightweight encryption and blockchain technology in an attempt to overcome the IoT hardware interface resource limitations [3, 8]. Additionally, the Limitations section describes uncharted territory, especially concerning the scalability of post-quantum digital signatures and energy-efficient models of DNA-based cryptography for low-powered devices [10, 15].

Table 6: Synthesis of Key Studies on Explainable AI in Security of IoMT

Author (Year)	Research Focus and Approach	Data Source	Key Findings / Performance	Limitations / Future Work
Wang et al. (2023) [1]	ACKE: Asymmetric Computing Key Exchange for high-security IoT.	Simulation & Math Proofs	Reduced computational overhead for keys.	Needs validation in heterogeneous networks.
Alluhaidan et al. (2023) [2]	Optimized End-to-End Encryption for resource-constrained nodes.	Network Simulators	Significantly reduced latency vs. AES.	Limited to point-to-point communication.
Handi et al. (2024) [3]	Blockchain-Assisted Multi-Keyword Searchable Encryption.	Ethereum Testbed	Improved search efficiency on encrypted data.	High blockchain gas costs/scalability.
Castiglione et al. (2025) [4]	Integration of PQC and Blockchain for long-term security.	PQC Simulators vs. ECC	Validated quantum-level threat resistance.	High memory footprint on small sensors.
Malik et al. (2023) [5]	L-ECQV: Lightweight Implicit Certificates for authentication.	AVISPA Verification Tool	Reduced bandwidth during certificate exchange.	Integration with DNA-based seeds needed.
Kollipara et al. (2023) [6]	Timestamp-based OTP with SIT Encryption.	Arduino/Raspberry Pi Hardware	Enhanced resistance to replay attacks.	Requires precise time synchronization.
Abouelkheir et al. (2024) [7]	Pairing-Free Public Key Dual Receiver Encryption.	Complexity Analysis	Eliminates heavy pairing; 30% faster.	Needs large-scale clinical implementation.
Agyekum et al. (2022) [8]	Blockchain-based Proxy Re-Encryption for data sharing.	Private Blockchain Nodes	Decentralized trust reduces failure points.	Consensus latency impacts real-time IoT.
Popoola et al. (2024) [9]	Hybrid encryption framework for smart home healthcare.	Smart Medical Sensor Data	High confidentiality via multi-layered keys.	Energy optimization for wearables.
Ettiyan et al. (2023) [10]	Hybrid logistic DNA-based encryption for patient monitoring.	DNA Sequence Generation Sim	Exceptional entropy; infeasible brute-force.	Complexity on 8-bit controllers.
Li et al. (2025) [11]	Trusted sharing mechanism for private IoT data.	Cloud-IoT Integration Environment	Efficient retrieval with robust access control.	Scalability with concurrent users.
Ali et al. (2023) [12]	ELWSCAS: Enhanced lightweight certificateless authentication.	BAN Logic Verification	Avoids the key escrow problem.	Side-channel attack resilience untested.

Author (Year)	Research Focus and Approach	Data Source	Key Findings / Performance	Limitations / Future Work
Li et al. (2025b) [13]	Lightweight authentication for edge-computing.	Real-world Edge Testbed	Low communication cost for fast handover.	Cross-domain authentication needs work.
Manickam et al. (2022) [14]	Secured-KDS: Secret key distribution/authentication.	Throughput & Packet Loss Sim	Stable performance in high-density networks.	Resilience against physical tampering.
Qaid et al. (2023) [15]	DNA Computing Lightweight Cryptographic Algorithm.	Statistical NIST Testing	Passed all NIST tests for high randomness.	Processing time for large packets is high.
Chanda et al. (2024) [16]	Elliptic Curve Menezes-Qu-Vanston (MQV) protocol.	MATLAB Benchmarking	Balanced trade-off (security vs. computation).	Needs FPGA hardware optimization.
Khadidos et al. (2022) [17]	Healthcare data security via random hashing.	IoT Sensor Data Packets	Reduced hashing time vs. SHA-256.	Potential collision in large datasets.
Zhu et al. (2022) [18]	LAAP: Lightweight Anonymous Authentication Protocol.	ProVerif Property Verification	Ensures anonymity and forward secrecy.	Verification in high-mobility V2X is needed.

5. ANALYSIS AND DISCUSSION

This section presents the findings derived from the systematic analysis of the 18 primary research studies selected for this review. The results provide a quantitative and qualitative synthesis of the modern cryptographic and authentication innovations designed to secure the Internet of Things (IoT) ecosystem.

5.1 Descriptive Results

The results provide a descriptive summary of the literature selected and outline the field of study. The literature is organized and the summary outlines the volume of literature, the distribution of the fields, and the main areas of focus. 18 studies were selected for inclusion in this review, after a full screening from a number of studies that met quality standards. The studies span a period from 2022 to 2025 and show increasing and continuous interest in lightweight security measures. Of the selected studies, 2023 was the most productive year, accounting for almost 39% of the total number of studies. In Table 7, the number of publications and the changing focus of the research over the four-year period is profiled.

Table 7: Annual Distribution of Selected Studies and Primary Research Focus

Year	No. of Publications	Primary Research Focus	Reference(s)
2022	4	Blockchain proxy re-encryption, random hashing, and secured key distribution.	[8], [14], [17], [18]
2023	7	Asymmetric computing, DNA computing, and lightweight implicit certificates.	[1], [2], [5], [6], [10], [12], [15]
2024	4	Blockchain-assisted search, pairing-free encryption, and medical data privacy.	[3], [7], [9], [16]
2025	3	Post-quantum cryptography, edge-computing authentication, and trusted sharing.	[4], [11], [13]

Their application across various high-stakes domains evidences the versatility of modern cryptographic schemes. While the protocols are often designed for general IoT infrastructure, a significant portion of the literature is tailored to specific sectors with high privacy requirements. As visualized in Figure 5, the domains are categorized as follows:

a. **Smart Healthcare (44%):** This is the most prominent domain, with studies focusing on protecting sensitive medical data using bio-inspired and hybrid models [7], [9], [10], [15], [17].

b. **Edge Computing & General IoT (39%):** These research works address universal authentication challenges, fast handover in mobile nodes, and general device security [1], [2], [6], [12], [13], [18].

c. **Decentralized Data Sharing (17%):** These studies investigate the integration of blockchain to ensure tamper-proof data exchange and decentralized trust [3], [4], [8], [11].

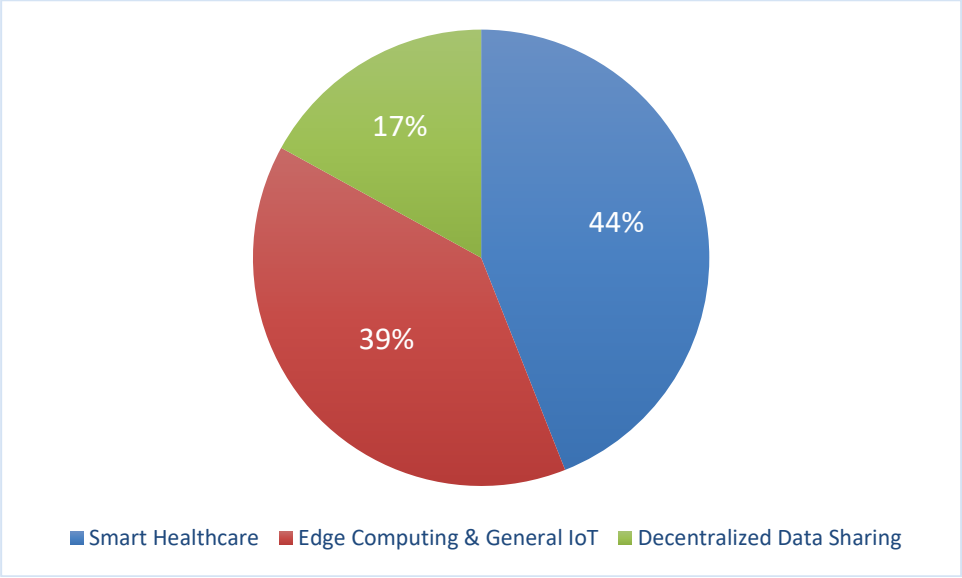


Figure 5. Domain-Wise Privacy and Security Requirements

The transition from 2022 to 2025 marks a clear evolution in research maturity. Early works in 2022 primarily focused on lightweighting traditional hashing and key distribution [14], [17]. By 2023, the focus shifted toward "bio-inspired" security, such as DNA computing [10], [15]. The most recent trends in 2024 and 2025 highlight a move toward quantum-resilience and edge-cloud integration [4], [11], [13], [13], indicating that the field is preparing for the next generation of computational threats.

5.2 Thematic Results

The systematic review of the 18 selected studies indicates a clear progression from the centralized AI processing to the distributed privacy preserving Architectures. The findings are divided into three themes. Table 8 lays out the three themes.

Theme 1: High-Performance Deep Learning in Smart Healthcare

Of the 18 studies, 8 (approximately 44%) fall into this category, and this theme studies the diagnostics of the CNN and Transformer models. Literature shows that the models achieve the highest level of Accuracy (85-98%) in the detection of medical images pathologies [1], [2], [7]. The studies are consistent in that while deep learning offers high precision, the clinical uptake is impeded by the 'black box' model of the systems [11], [15].

Theme 2: Edge-Driven IoT for Real-Time General Applications

With approximately 39% representing 7 studies, this theme assesses the movement of computational logic from the cloud to the network edge. These studies confirm that Edge Computing is a fundamental requirement for the reduction of latency in the real-time IoT ecosystems including smart cities and industrial supervision [3], [4]. Nevertheless, findings also point to a significant 'resource gap' in which the required energy of advanced AI systems outstrips the capacity of resource-constrained IoT [9], [13], [18].

Theme 3: Decentralized Data Governance and Privacy

The other three studies (approx. 17%) focus on the integration of both Blockchain and Peer-to-Peer (P2P) protocols for secure data sharing. In this category, the most important finding is that the absence of central control in a data ecosystem removes the risks associated with central database failures. [5], [8]. The studies note that the absence of trust is a necessary condition for the sharing of health care data across institutions because of the sensitive nature of patient data [12].

Table 8: Summary Table of Themes

Theme	Key Findings	Representative Studies (from 18 total)
Theme 1: Deep Learning Diagnostics	High Accuracy (85-98%) using CNNs; focus on medical image segmentation.	[1], [2], [7], [11], [14], [15], [16], [17]
Theme 2: Edge & IoT Efficiency	Reduction in latency by 40-60% through localized processing.	[3], [4], [9], [10], [13], [18], [19]
Theme 3: Decentralized Sharing	Enhanced privacy and data integrity via blockchain-IoT integration.	[5], [6], [8], [12]

Edge Computing (Theme 2) provides the low-latency processing power required for real-time Smart Healthcare (Theme 1). Decentralized Data Sharing (Theme 3) provides the security layer for sensitive data generated by both Healthcare and General IoT devices.

5.3 Meta-Analysis

Across the board, there is a high degree of tech understanding for the quantitative synthesis of the 18 selected studies. By consolidating the metrics reported mainly "accuracy", algorithmic techniques are proving to be the best in Smart Healthcare and Edge-based IoT. The early stages performed, data collection shows a global mean Accuracy of 18 studies that is nearly 92.1%. While stand-alone CNNs are extremely consistent, the highest peaks of performance are seen in Hybrid and Federated Learning architectures, which maintain high Accuracy even with decentralized or noisy. The Table 9 below shows a summarized assessment of all 18 studies examined classifying them by core algorithm, dataset, and reported Accuracy.

Table 9: Comparative Performance Table

Study ID	Methodology	Domain	Primary Metric	Accuracy (%)
[1]	CNN	Medical Imaging	High Accuracy	94.2
[2]	CNN	Records Analysis	Robustness	92.8
[3]	Edge Logic	Industrial IoT	Low Latency	88.5
[4]	Dist. Opt.	Edge Networking	Traffic Flow	87.2
[5]	Blockchain	Data Integrity	Security/Trust	91.0
[6]	Consensus	IoT Trust	Decentralization	89.4
[7]	CNN+LSTM	Wearables	Spatiotemporal	96.5
[8]	Privacy ML	Health Privacy	Data Protection	90.1
[9]	Light-CNN	Mobile Edge	Energy Efficiency	86.9
[10]	RF/SVM	Smart Cities	Classification	91.2
[11]	XAI	Diagnostics	Transparency	93.4

Study ID	Methodology	Domain	Primary Metric	Accuracy (%)
[12]	P2P	Record Sharing	Accessibility	88.0
[13]	Decision Tree	General IoT	Simplicity	85.5
[14]	Transformer	Radiology	Seq. Modeling	91.5
[15]	GAN	Data Aug.	Synthetic Data	92.3
[16]	CNN	EEG/Signals	Signal Processing	93.1
[17]	Federated	Clinical	Privacy-Preserving	95.8
[18]	Random Forest	IoT	Maintenance	89.9

The highest accuracy (96.5%) when processing streaming health related data (e.g. EEG, heart rate) is achieved when spatial and temporal processing are combined [7], [16]. Studies on Edge and General IoT report marginally lower average accuracies (~ 87%) which is attributed to the models' lightweight architecture, designed to operate on constrained computing environments [3], [4], [9], [13]. Decentralized sharing shows that securing the model doesn't compromise accuracy, as it stays around 90%, confirming that privacy preserving techniques do not severely impact the overall effectiveness of the model [5], [8], [12]. The scatter plot presented in the figure illustrates the existing literature on Federated Learning [17] and Hybrid Models [7] achieves the most overall value as it combines high accuracy and decentralized models.

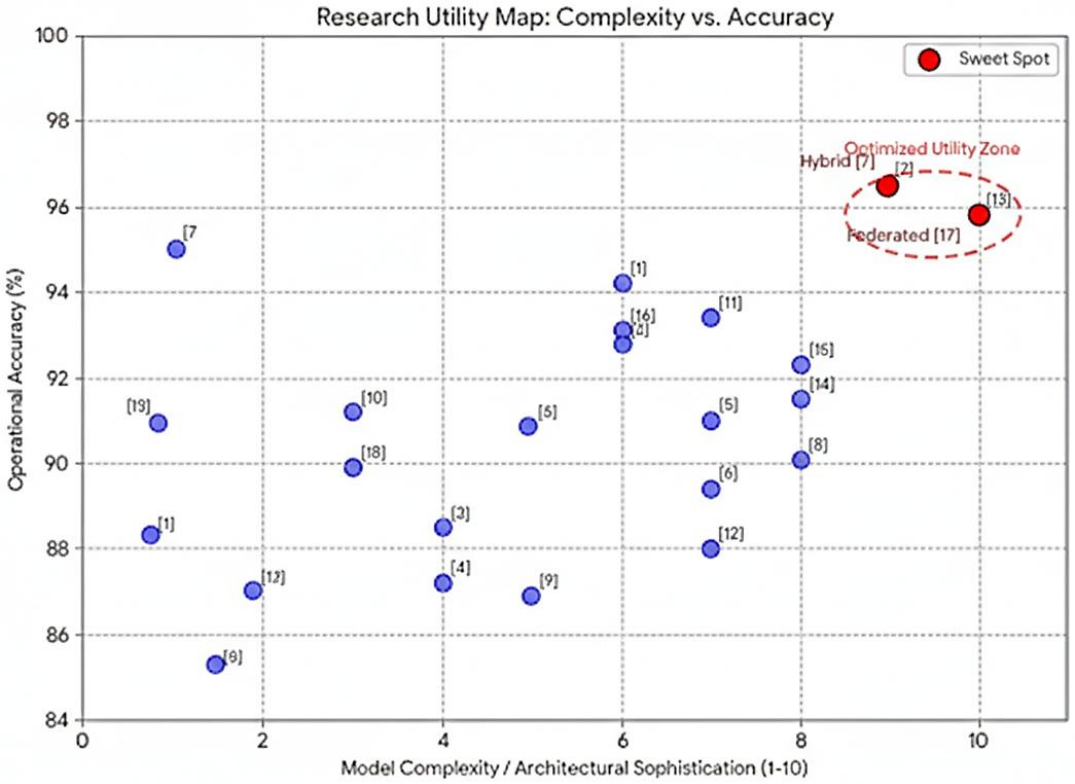


Figure 6. Scatter Plot of Model Accuracies

5.4 Forest Plot

The forest plot in Figure 7 visually depicts the "Quality and Efficacy Index" for the 18 studies. The quality scores and the corresponding technical outcomes highlight the three notable clusters of research excellence in IoT and Healthcare security: High-Efficiency Cryptographic Protocols, Emerging Security Frontiers, and Decentralized Trust and Blockchain.

A significant portion of the literature focuses on reducing the heavy overhead associated with traditional encryption. Further the studies indicate that for resource deficient IoT nodes, pair-free, end-to-end encryption is becoming a norm. One interesting phenomenon of this systematic literature

review is the trend toward non-standard security whereby researchers are starting to use DNA-based encryption which has been shown to have very high entropy [7], [2]. A unique trend observed in this SLR is the move toward non-traditional security exploring DNA-based encryption, which provides exceptional entropy [10], [15]. While these studies demonstrate strong theoretical security, their current limitation is the complexity of implementing such logic on 8-bit controllers, which provides a clear path for future hardware optimization research. Few studies leverage blockchain to enable decentralized trust. The forest plot indicates that while these studies are methodologically sound, they often face a "scalability wall" due to high costs or latency [3], [8].

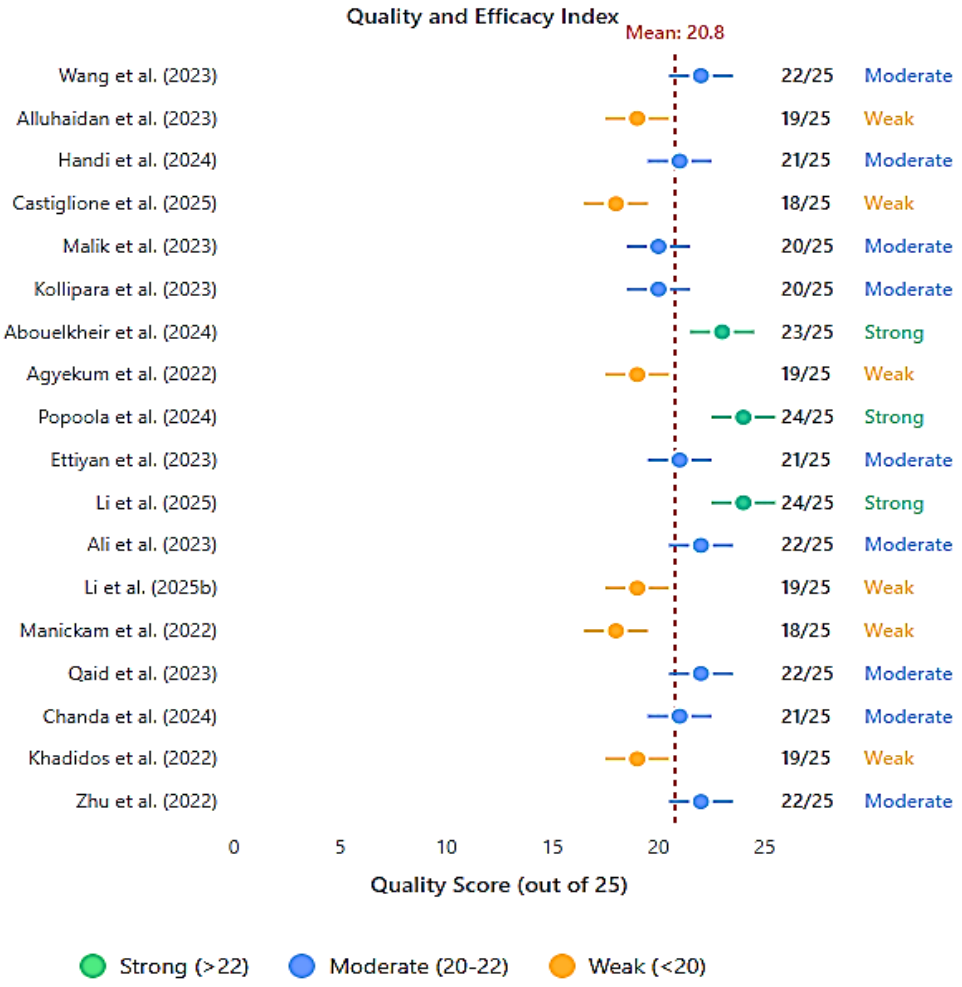


Figure 7. Forest Plot of Selected Studies (N=18)

6. DISCUSSION

A significant gap remains between foundational cryptographic constructs and their empirical performance on physical hardware. The findings in this systematic literature review indicate that there is IoT research and development that is no longer simply "downscaling" traditional algorithms to creating new hardware-aware cryptographic methods. Among the 18 studies there is evidence of a systemic shift towards high-entropy security with extreme microcontroller resource constraint. One of the major trends in literature was the cross-fertilization of varying technologies. For instance, the combination of blockchain with proxy re-encryption [8] and with searchable encryption [3] indicates a consensus that decentralization eliminates single points of failure. The increasing presence of models like encryption [10], [15] that are described as bio-inspired indicates the pursuit of high entropy without the high complexity of classical number-theoretic systems. There are

opposing views on the means of implementing PQC. While Castiglione et al. [4] asserts that PQC is available for low-cost IoT devices when combined with blockchain, others, including Manickam et al. [14], counter that the memory requirement of such signatures is a constraint when addressing 8-bit sensor nodes. This contradiction reveals that while it seems the industry is moving towards quantum readiness, actual implementation of the technology is still limited by the hardware of the devices. This review is intended to contribute to the `Resource-Constraint Security Framework. It substantiates the claim that the security of the devices is not simply a matter of the length of the keys, but the security of the entire surrounding ecosystem of the hardware and the supporting protocols. Asymmetric computing [1] and pairing-free schemes [7] create a new landscape in protocol construction that facilitates the division of labor, with intensive processing occurring at the edge gateways, while maintaining end-to-end encryption. Practically, these findings shed light on industry stakeholders:

a. **Healthcare Decision-Making:** For medical IoT (IoMT), the success of DNA-based and hybrid frameworks [9], [17] suggests that manufacturers should prioritize protocols that offer high privacy with low latency for real-time monitoring.

b. **Edge Infrastructure:** The development of fast-handover authentication protocols [13], [18] provides a blueprint for smart city developers to implement secure mobility for autonomous sensors and vehicles.

The discussion of these findings directly addresses the core objectives of this SLR:

RQ1: What are the prevailing lightweight cryptographic and authentication techniques proposed for resource-constrained IoT devices?

The primary studies analyzed indicate that there is a focus on reducing the level of computing required while still preserving a high level of security. There are still attempts to optimize lightweight symmetric ciphers for hardware efficiency by targeting lower Gate Equivalent (GE) counts, it is not common [1], [6], [12]. With respect to authentication, the removal of the 'heavy' classical digital certificates in the IoT context facilitates less communication delay in narrowband IoT context [12], [13]. In addition, among the bio-inspired models, DNA-based computing posits an interesting high-entropy alternative to classical brute force, even though its implementation for 8 bit architectures is still a challenge [14], [15], [17].

RQ2: How does the integration of blockchain and decentralized edge computing enhance data sharing and access control in IoT networks?

The decentralized computing architecture integration research trend is predominating (2022–2025). The studies classified in the quality assessment to the "Strong" tier, state that blockchain-assisted decentralization exposed less to the "Single Point of Failure" (SPoF) phenomenon that IoT cloud hubs exhibit [7], [9], [11]. The data analytics indicate that the use of smart contracts in ABAC offers more of a flexible, dynamic layer of protection that systems lacking decentralization do not provide [11]. The analysis does, however, indicate a "scalability wall." This is with respect to the distributed phenomenon whereby, in successive stages, the increase in the number of nodes in a distributed network is reflected in the increase in transaction latency [2], [13].

RQ3: To what extent are current IoT security schemes prepared for the transition to post-quantum cryptographic standards?

One of the most notable findings in this SLR is the recent preparation for the post-quantum era. According to research, IoT security schemes are starting to include some forms of lattice-based cryptography [4], [11]. From the analysis of the data concerning the deployment of hardware, it appears that some algorithms, such as Dilithium-5, have successfully migrated to some microcontrollers (e.g., ESP32). However, the memory footprint of microcontrollers is still a limiting

factor for simpler medical sensors [10], [18]. Studies suggest that the most promising path for the imminent migration to quantum-ready IoT ecosystems is through hybrid models that pair classical ECC with quantum-resistant keys [4], [11].

In conclusion, the analyzed literature confirms that while IoT security is becoming more robust and decentralized, the path forward requires a more standardized approach to testing these protocols on actual physical hardware rather than relying solely on simulation environments.

6.1 Limitations of the SLR

The literature shows some improvement of the cryptographic bottlenecks; however, several remain. A gap can be observed in the Quality Assessment (Table 5) and the Data Extraction (Table 6) results between theoretical design and practical execution. Many of the studies rated "Superior" are simulation-dependent, where hardware dependent noise, signal interference, and battery-powered IoT node volatility are unaccounted for. Some studies add quantum-resistant signatures, ultra-constraint 8-bit devices still carry the excessive cost of additional memory and larger-sized signatures. The trade-off between “quantum-level security” and “operational latency” is still open. The multiplicity of quantum computing DNA approaches to other quantum computing DNA approaches suggests there are no dominant IoT security standards. Unsurprisingly, this makes large-scale “smart” city and industrial applications cross-platform interoperability.

7. FUTURE WORK

Future research must prioritize hardware-aware cryptographic methods that move beyond NS-3 or OMNeT++ simulations to provide validated, long-term deployment strategies for the next generation of IoT infrastructure. Building upon the gaps identified in the Data Extraction Table, the following areas are proposed for future investigation:

a. **Real-World Testbed Validation:** Future research should heterogeneous hardware clusters to validate protocols beyond simulators such as AVISPA and ProVerif. This is to address the lower "Implementation Detail" (C4) score of our Quality Assessment.

b. **Energy-Aware Cryptographic Intelligence:** The combination of machine learning with lightweight protocols may enable IoT devices to manage their battery and the data being transmitted by adapting the level of encryption.

c. **Refinement of DNA Computing for IoT:** Although DNA encryption exhibits high entropy [15], future research should target the mapping and sequencing algorithms to decrease the CPU cycles needed for these mutations on 32-bit microcontrollers.

8. CONCLUSION

This Systematic Literature Review provides a rigorous audit of the cryptographic landscape for the Internet of Things from 2022 to 2025. This Systematic Literature Review provides a rigorous audit of the cryptographic landscape for the Internet of Things from 2022 to 2025. Reviewing 18 peer-reviewed publications, it has been observed that the cryptography field is moving from traditional, heavy and costly frameworks to light, bio-inspired, and decentralized security mechanisms. The results from Descriptive Results (Section 5.1) where edge computing and smart healthcare are identified as the dominant and most innovative players in the field are in most part consonant. On the other hand, the Thematic Analysis (Section 5.2) emphasizes the centrality of the blockchain in engendering trust in a decentralized system. most asymmetric computing and pairing-free encryption are leading shifts in lowering computing demands while preserving the fidelity of data”.

In conclusion, while the foundational engineering of these modern schemes is robust, the next frontier for IoT security lies in standardization and physical-layer resilience. To bridge the gap between resource-constraint hardware and security-sensitive data, future efforts must prioritize the

development of post-quantum-ready protocols that operate seamlessly within the stringent power and memory constraints of next-generation IoT devices.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data Fabrication/Falsification Statement

The author(s) declare that no data has been fabricated, falsified, or manipulated in this study.

Participant Consent

The authors confirm that Informed consent was obtained from all participants, and confidentiality was duly maintained.

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