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Review

Dew Computing: Survey

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Abstract: Dew Computing (DC) has recently emerged as a complementary computing paradigm that extends cloud, fog, and edge computing by enabling autonomous, local-first computation directly at end-user devices. Unlike traditional distributed models that rely on centralized or near-edge infrastructures, Dew Computing emphasizes offline-capable, low-latency, and resilient processing at the extreme edge, while maintaining synchronization with fog and cloud layers when connectivity is available. This paper presents a systematic and comprehensive review of Dew Computing based on a structured literature analysis, covering its conceptual foundations, architectural models, and operational mechanisms. The study analyzes key Dew-based architectures, including cloud–dew and hybrid edge frameworks, highlighting their role in reducing latency, improving fault tolerance, enhancing energy efficiency, and supporting privacy-preserving local processing. In contrast to existing surveys, this work provides a critical synthesis of current approaches by identifying their strengths, limitations, and deployment trade-offs across different application scenarios. Furthermore, the paper examines major application domains such as Internet of Things (IoT), smart healthcare, smart agriculture, and cyber-physical systems, where Dew Computing demonstrates advantages in real-time responsiveness and operational resilience. Security and privacy challenges are also analyzed, focusing on recent solutions such as blockchain-based trust management, federated learning, lightweight cryptographic protocols, and AI-driven intrusion detection, while highlighting unresolved issues related to scalability and resource constraints. Unlike prior works, non-computing interpretations such as meteorological dew-point modeling are excluded or clearly distinguished to avoid conceptual ambiguity. Finally, the survey identifies open research challenges, adoption barriers, and future research directions, positioning Dew Computing as a key enabler for decentralized, user-centric, and resilient next-generation computing systems.

Keywords: Dew Computing; Internet of Things (IoT); Resource Management; Security and Privacy; Decentralized Computing; Local-First Computing

1. Introduction

The rapid evolution of distributed computing paradigms has led to the emergence of Dew Computing (DC) as a complementary computing model alongside cloud, fog, and edge computing. Unlike traditional cloud-centric approaches that concentrate computation in remote data centers, Dew Computing emphasizes localized processing at end-user devices while maintaining interoperability with higher-layer infrastructures. By leveraging local computing resources such as personal computers, mobile devices [1], and Internet of Things (IoT) nodes, Dew Computing enables low-latency, resilient, and reliable computation under intermittent or unstable network conditions [2–5].

Dew Computing is formally defined as a paradigm that places computation, storage, and control at the lowest level of the network hierarchy, directly on end-user devices or local nodes, allowing autonomous operation with optional collaboration with fog and cloud layers [5–7]. This paradigm was introduced to address limitations of centralized cloud computing, particularly in scenarios requiring ultra-low latency, offline operability, enhanced privacy, and system resilience. Ray [6] initially conceptualized Dew Computing as a complementary layer extending computational intelligence to user devices, while Wang [5] refined this concept by introducing two core principles: independence (autonomous local operation) and collaboration (selective synchronization with higher layers). Historically, the evolution of Dew Computing is closely linked to the proliferation of IoT devices, mobile platforms, and cyber-physical systems (CPS), which require localized processing and real-time responsiveness [8]. This shift reflects a broader transition from centralized computing toward decentralized and user-centric intelligence, where computation is pushed closer to data sources to improve responsiveness and reliability.

The significance of Dew Computing is further underscored by its applicability in domains such as smart environments, real-time control systems, personalized computing, autonomous vehicles, robotics, agriculture, and energy-efficient systems [9,10]. Pan and Luo [11], along with Wang et al. [12], positioned Dew Computing as a natural progression in Internet computing, emphasizing decentralization and local autonomy. Utomo and Falahah [13] and Ray [14] further highlighted its role in reducing dependence on network connectivity by enabling autonomous local computation with selective cloud synchronization. Tyagi [15] extended this vision by framing Dew Computing as a transformative paradigm for future computing infrastructures. Despite these advancements, existing studies remain largely descriptive and lack comprehensive comparative evaluation across architectures [16], applications as Cyber-Physical Systems and IoT [17], and performance trade-offs [18]. In addition, prior surveys such as Gusev [19] and Sharma et al. [20] provide general overviews but do not offer a unified taxonomy combined with systematic critical analysis across domains. This limitation motivates the need for a more structured and analytical survey. The increasing demand for latency-sensitive applications has exposed limitations in centralized cloud architectures, including bandwidth constraints, response delays, and reliability challenges [16]. In response, Dew Computing has emerged as a paradigm that pushes computation to the extreme edge, enabling local autonomy and offline operation [11, 12, 14]. **Figure 1** illustrates the workflow of a cloud–dew application, demonstrating how local dew nodes process data independently and synchronize with cloud services when connectivity is available. This workflow highlights the practical advantages of Dew Computing in real-time and resource-constrained environments.

The motivation for this study stems from the increasing demand for decentralized, scalable, and resilient computing frameworks capable of reducing network latency, improving fault tolerance, and supporting real-time applications. Although cloud and fog computing provide substantial computational capabilities, they face challenges related to latency sensitivity, dependence on stable connectivity, and resource contention. Dew Computing addresses these limitations by enabling localized processing, reducing communication overhead, and improving system responsiveness while maintaining integration with cloud infrastructures.

Moreover, despite the growing body of research on Dew Computing, several critical gaps remain:

1. Security and Privacy: While prior studies have explored dew-assisted IoT environments, integrated frameworks combining intrusion detection, privacy preservation, and trust management remain limited and lack scalability analysis.
2. Resource Management: Existing approaches for task scheduling and resource allocation often fail to address dynamic and heterogeneous dew environments effectively.
3. Standardization and Interoperability: The absence of standardized architectures, protocols, and APIs impedes seamless interoperability among heterogeneous systems.
4. Performance Evaluation: There is a lack of rigorous empirical evaluation and benchmarking across dew, fog, and cloud paradigms under realistic deployment conditions.
5. Applications and Deployment: Many application scenarios remain conceptual, with limited real-world validation and comparative performance analysis.

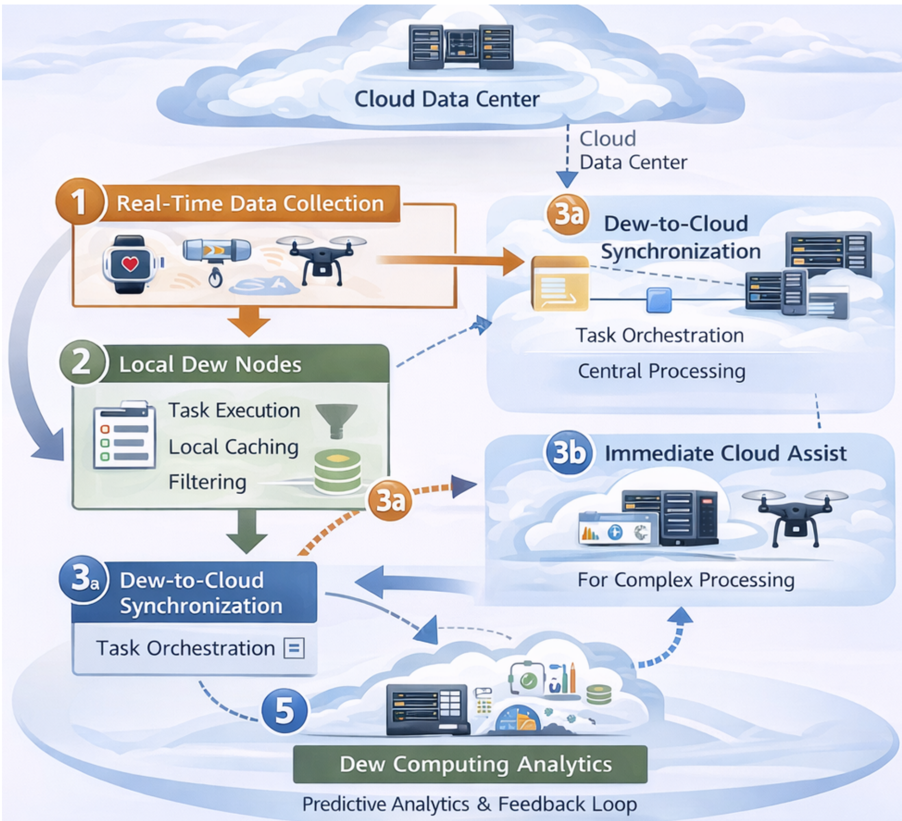

Figure 1. Workflow of a Cloud-Dew Application.

In light of the identified gaps, this work addresses the following research questions:

1. How does Dew Computing compare with cloud and fog computing in terms of latency, reliability, and resource efficiency?
2. What mechanisms can ensure security, privacy, and trust in dew-enabled IoT ecosystems?
3. How can task scheduling, resource allocation, and hybrid cloud–dew workflows be optimized for performance and energy efficiency?
4. Which application domains benefit most from Dew Computing, and what limitations remain in practical deployments?

In this regard, the main contributions of this work are as follows:

1. A systematic and structured review of Dew Computing based on a rigorous literature analysis, covering architectures, operational models, and integration with cloud and edge paradigms.
2. A comparative and critical analysis of existing approaches, highlighting strengths, limitations, and trade-offs across applications and system designs.
3. Identification of key research challenges and future directions, with emphasis on security, resource management, and real-world deployment constraints.

The remainder of this paper is structured as follows: Section 2 presents background concepts and definitions of Dew Computing. Section 3 describes the systematic literature review methodology. Section 4 provides a comprehensive literature analysis. Section 5 introduces the taxonomy of Dew Computing. Section 6 discusses applications, followed by challenges and open issues in Section 7. Section 8 presents critical discussion and future directions, and Section 9 concludes the paper.

2. Literature Review

Early research on Dew Computing primarily focused on conceptual definition and positioning within distributed computing hierarchies. Ray [6] provided the initial formalization of Dew Computing as a user-centric, device-level computing paradigm. Wang [5] later refined this model by classifying Dew systems into standalone and collaborative operational modes, establishing the foundational operational dichotomy in the literature. The notion of "dew computers" was introduced [8] as physical computing entities operating at the lowest layer of distributed systems, while Skala et al. [8] further formalized Dew Computing within a hierarchical architecture beneath fog and cloud layers, emphasizing its role as an extreme-edge computing layer. Subsequent studies transitioned Dew Computing from theory to implementation. Gushev [17] proposed a Dew-based architecture for cyber-physical systems and IoT environments, while Gusev [18] demonstrated its applicability in IoT streaming and real-time data processing scenarios. More recent work [19] addressed scalability constraints in large-scale dew deployments, and Sharma et al. [20] provided a systematic analytical review, confirming Dew Computing as a distinct and emerging distributed paradigm. Overall, across these foundational studies, Dew Computing is consistently characterized by device-level autonomy, offline operability, and reduced dependence on centralized infrastructure [6,8].

2.1. Comparative Paradigm Studies

Pan and Luo [11] conducted one of the earliest systematic comparisons among cloud, fog, and dew computing, demonstrating that Dew Computing provides advantages in latency-sensitive and intermittently connected environments. Ahammad et al. [21] extended this analysis by incorporating roof computing, proposing a four-layer taxonomy for IoT-based systems. Gusev [22] critically examined whether Dew Computing should be considered a subset of edge computing or an independent paradigm, concluding that it is fundamentally distinct due to its autonomy- and offline-first design principles. Ageed et al. [23] provided a historical evolution from grid and cloud computing toward fog, edge, and dew computing, positioning Dew Computing as part of a broader shift toward decentralized computing intelligence.

2.2. State-of-the-Art and Research Challenges

Tyagi [15] presented a comprehensive review of Dew Computing applications in smart systems, healthcare, sustainable IoT, and AI-enabled edge intelligence, while identifying key challenges in scalability, interoperability, and security integration. Roy et al. [24] introduced sustainability-oriented evaluation metrics, emphasizing energy efficiency and environmental impact alongside performance indicators such as latency. Ray [14] revisited the conceptual evolution of Dew Computing and emphasized the need for standardization, interoperability frameworks, and industrial adoption to support long-term scalability and practical deployment.

2.3. Evolution of Dew Computing

Wang et al. [12] described Dew Computing as part of a broader transition toward decentralized Internet computing paradigms. Ristov et al. [25] formalized Dew architecture as an extension of the client–server model with cloud as a backend layer, while Patel et al. [26] further characterized Dew Computing as a tightly coupled extension of cloud systems, emphasizing bidirectional dependency between Dew and cloud layers.

2.4. Dew Computing vs. Edge and Fog Computing

Gusev [22] critically evaluated whether Dew Computing is a subset of edge computing and concluded that it is a distinct paradigm defined by offline-first operation and device autonomy. Ahammad et al. [21] compared cloud, fog, roof, edge, and dew computing within IoT environments and identified Dew Computing as the most decentralized computing layer. Ageed et al. [23] traced the evolution from grid and cloud computing toward fog, edge, and dew paradigms, positioning Dew Computing as the endpoint of decentralization in distributed systems.

Based on all the above discussion, **Figure 2** illustrates the Cloud–Fog–Dew hierarchy, showing cloud as the centralized layer, fog as the intermediate processing layer, and dew as the end-user device layer enabling local execution and autonomy. As well as **Table 1** shows the Comparison among the Cloud, Fog, Edge, and Dew Computing.

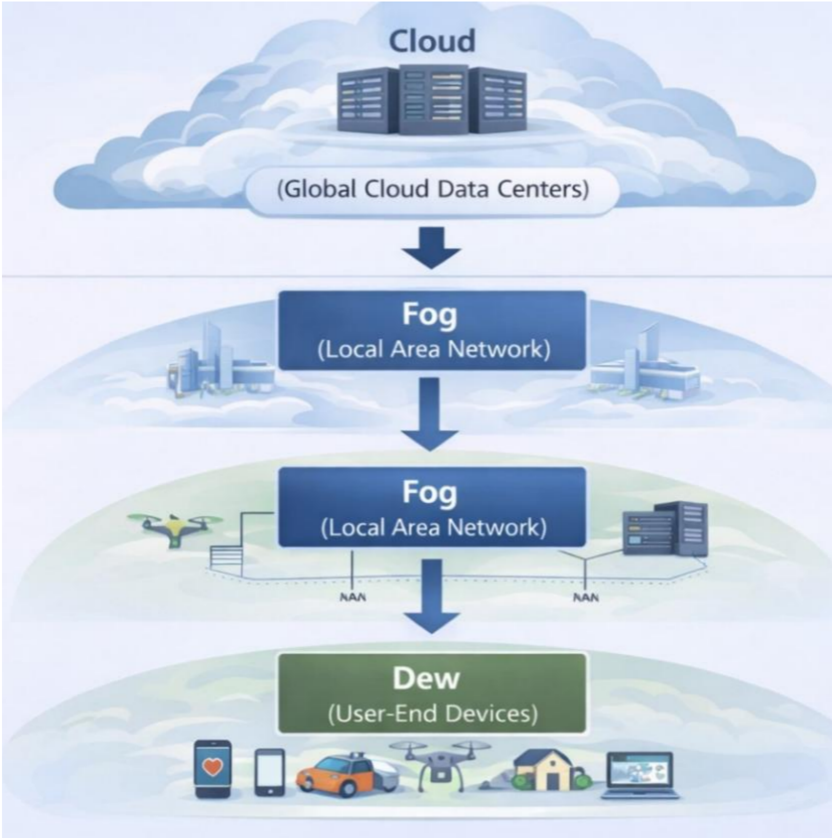

Figure 2. Cloud-Fog-Dew Hierarchy.

Table 1. Comparison of Cloud, Fog, Edge, and Dew Computing.

Computing Paradigm	Location of Computation	Latency	Scalability	Security Features	Typical Applications
Cloud Computing [5,6,8]	Remote centralized data centers	High, network-dependent	Very high	Centralized security; exposed to network-based threats	Big data analytics, enterprise systems, cloud storage
Fog Computing [8,10,17,27,28]	Intermediate nodes (gateways, routers)	Medium	Moderate	Distributed security with local filtering	Smart cities, industrial IoT, traffic systems
Edge Computing [9,17,18]	On-device or near-device	Low	Limited by device capacity	Lightweight device-level security	Autonomous vehicles, drones, healthcare monitoring
Dew Computing [11,12,19,20]	End-user devices (on-premises)	Very low, offline-capable	High via local resource utilization	Privacy-preserving, local authentication, blockchain-enabled trust mechanisms	Smart agriculture, personal IoT, offline services

2.5. Formal Models and Theoretical Foundations

Gusev and Wang [29] proposed a formal implementation-independent model of Dew Computing aimed at unifying heterogeneous interpretations under a generalized theoretical framework. Their model emphasizes abstraction, hardware independence, and cross-domain applicability, providing a basis for taxonomy design and standardization efforts. Earlier, Wang [30] introduced the Cloud–Dew architecture, formally defining dew servers as locally operating service entities that synchronize with cloud services when connectivity is available, a formulation that remains widely adopted in subsequent research.

2.6. Dew Computing in IoT and Agriculture

Sarkar et al. [31] investigated Dew Computing in the context of the Internet of Agricultural Things (IoAT), focusing on localized sensor processing, cloud-assisted analytics, and improved energy and bandwidth efficiency in rural deployments. Sarkar et al. [31] proposed a hybrid dew–edge–cloud cooperative execution model, improving computational efficiency, reliability through distributed task allocation, and operational flexibility in heterogeneous IoT environments.

2.7. Cross-Study Analytical Synthesis

This subsection synthesizes the reviewed studies to provide cross-paper analytical insights beyond descriptive reporting. Across the literature, hybrid architectures (Cloud–Dew and Dew–Fog–Cloud) dominate, reflecting a shift toward cooperative and hierarchical computing models. In contrast, fully standalone Dew systems are less frequently implemented in real-world scenarios, despite their conceptual importance for offline-first operation. From an application perspective, most studies focus on IoT-driven domains, including smart agriculture, healthcare monitoring [32], Estimation of Natural Gas Dew Point Temperature [33] and mobile systems. However, these works commonly lack standardized evaluation frameworks, limiting objective comparison across implementations. A recurring limitation is the insufficient integration of security, privacy, and trust mechanisms within Dew architectures. Moreover, energy efficiency and resource optimization are rarely evaluated under realistic conditions. Overall, the literature demonstrates strong conceptual development but reveals gaps in unified benchmarking, large-scale validation, and consistent architectural design principles.

3. Research Methodology

This survey adopts a Systematic Literature Review (SLR) methodology to ensure a rigorous, transparent, and reproducible analysis of Dew Computing research. The methodology follows established guidelines for systematic reviews in distributed computing and is inspired by previous structured survey frameworks such as Sharma et al. [20].

3.1. Review Framework and Scope

The review is based on a structured analysis of peer-reviewed scholarly literature retrieved from major digital libraries, including IEEE Xplore, ACM Digital Library, SpringerLink, ScienceDirect (Elsevier), MDPI, Wiley Online Library, arXiv, and Google Scholar. The scope is limited to studies published between 2015 and 2026 in which Dew Computing is explicitly introduced as a primary concept or a significant architectural contribution. The selected literature covers key research dimensions including architectural design, application domains, task scheduling mechanisms, and security and privacy considerations in Dew Computing environments. For systematic analysis, the studies were categorized into four main dimensions:

- Architectural design.
- Application domains.
- Performance objectives.
- Security and privacy considerations.

To ensure methodological rigor, the review employs comparative analysis, taxonomy construction, and structured synthesis tables to organize and interpret findings. Additionally, foundational works such as Tyagi [15] and Ray [14], were included to ensure coverage of core Dew Computing paradigms, while recent studies [21,23], and domain-specific applications in healthcare and AI-enabled systems [32] were used to enhance diversity and depth.

Backward and forward citation tracking was also applied to improve completeness and reduce publication bias.

3.2. Search Strategy

A structured and reproducible search strategy was employed to identify relevant studies on Dew Computing. The search was performed across the following databases: IEEE Xplore, ACM Digital Library, SpringerLink, ScienceDirect (Elsevier), MDPI, Wiley Online Library, arXiv, and Google Scholar. A set of predefined keywords and Boolean operators was used to ensure systematic coverage of the literature. Core search terms included:

- "Dew Computing".
- "Cloud–Fog–Dew".

- "Local-first Computing".
- "Edge–Dew Computing".
- "Dew-based Cyber-Physical Systems".

These were combined using Boolean expressions such as:

- ("Dew Computing" AND "IoT" AND "Security").
- ("Dew Computing" AND "Edge Computing").
- ("Dew Robotics" OR "DewROS2").

No strict time limitation was applied; however, emphasis was placed on studies published between 2015 and 2026 to capture both foundational and recent advancements.

Study Selection Process

To improve transparency, reproducibility, and systematic rigor, the study selection process should be explicitly structured as follows: in the stage 1, the Title Screening: A total of 312 papers were excluded at this stage due to irrelevance to Dew Computing or absence of direct conceptual alignment with distributed/decentralized computing paradigms. While, in the stage 2, the Abstract Screening: From the remaining studies, 89 papers were excluded because they did not present sufficient technical depth, architectural contribution, or methodological relevance to Dew Computing frameworks. And then stage 3, the Full-Text Eligibility Review: An additional 12 papers were excluded after full-text evaluation due to incomplete methodological descriptions, lack of performance evaluation, or absence of measurable validation criteria. After completing all screening stages, the final set of studies was retained for detailed qualitative and quantitative synthesis.

3.3. Inclusion and Exclusion Criteria

The study selection process was guided by predefined eligibility criteria and systematically applied across all screening stages to ensure reproducibility, consistency, and reduction of selection bias.

Inclusion Criteria:

- Peer-reviewed journal and conference papers.
- Studies explicitly addressing Dew Computing or related paradigms.
- Works focusing on architecture, algorithms, applications, or security.
- Publications written in English.

Exclusion Criteria:

- Non-peer-reviewed articles, editorials, or blog posts.
- Studies unrelated to Dew Computing or distributed architectures.
- Papers lacking technical depth or evaluation.
- Duplicate publications or extended versions of earlier work.

3.4. Data Extraction and Synthesis

Each selected study was systematically analyzed using a structured data extraction process covering:

- Bibliographic metadata (authors, year, venue, DOI).
- Dew Computing focus (architecture, domain, Dew/Fog/Cloud layer).
- Employed techniques (security, scheduling, resource management, AI/ML).
- Performance metrics (latency, energy, bandwidth, scalability, accuracy).
- Identified research gaps and recommendations.

Synthesis was conducted through:

- Tabular comparison of Cloud, Fog, Edge, and Dew paradigms.
- Thematic analysis of recurring concepts such as decentralization, resilience, low latency, and energy efficiency.
- Quantitative synthesis highlighting performance improvements attributable to Dew Computing.

3.5. Analysis Approach

The final analysis employed:

- Comparative evaluation to assess Dew Computing advantages over other paradigms.
- Gap analysis to uncover unresolved challenges in security, resource management, and AI integration.
- Trend-based recommendations to identify promising directions for future research.

This methodological framework ensures a rigorous, replicable, and comprehensive review of the Dew Computing landscape, providing both theoretical insight and practical relevance.

3.6. PRISMA-Inspired Flow Diagram

The study selection process follows a PRISMA-inspired framework to ensure transparency and reproducibility. The workflow includes identification, screening, eligibility, and inclusion phases as shown in **Figure 3**, as well as the following.

- Total records identified: 1,050.
- Records after duplicates removed: 650.
- Records screened: 650.
- Records excluded: 400.
- Full-text articles assessed: 250.
- Full-text articles excluded: 122.
- Studies included in qualitative synthesis: 128.
- Studies included in quantitative synthesis: 90.

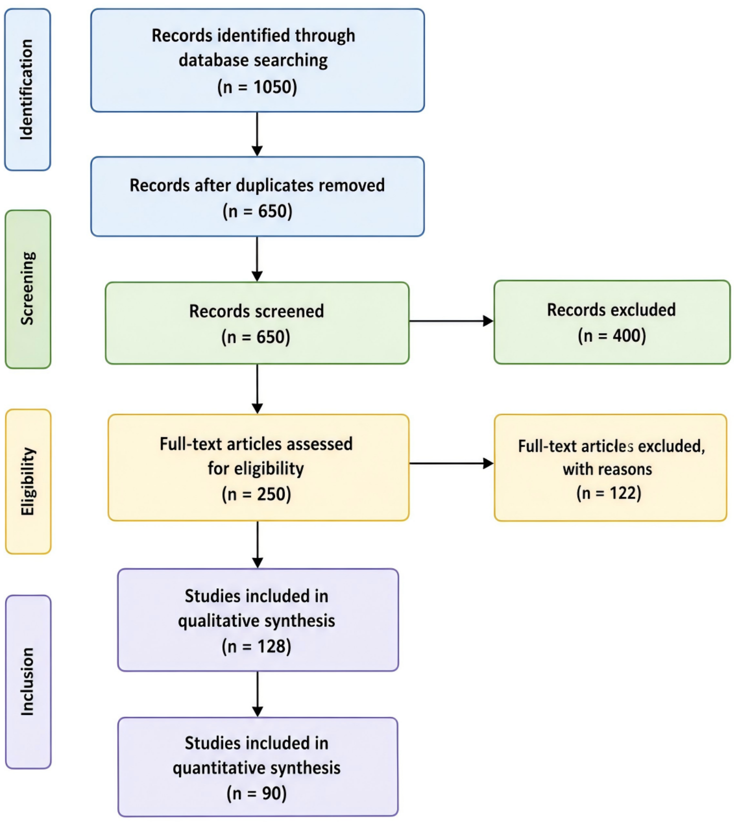

Figure 3. PRISMA Flow Diagram.

This study may be subject to selection bias due to database coverage limitations. Additionally, publication bias may affect the representation of negative results in the surveyed literature.

4. Applications of Dew Computing

Dew Computing has emerged as a distributed computing paradigm designed for real-time processing, local autonomy, resilience, and reduced cloud dependency. It enables computation closer to data sources while maintaining controlled integration with fog and cloud layers. Unlike earlier descriptive studies, this section organizes applications into a structured taxonomy based on domain, dew role, and system benefit to improve analytical clarity. **Table 2** shows the summary of Dew Computing Applications.

Table 2. Executive Summary of Dew Computing Applications.

Domain	Dew Role	Key Benefit	References
Industrial & Process Systems	Neural-based dew-point estimation, predictive modeling for industrial gas/process control	Improves safety by preventing hydrate formation and operational instability	Ghanbari et al. [33], Hernandez-Torres et al. [34], Haji-Savameri et al. [35], Daneshfar et al. [36], Khan et al. [37], Kaydani et al. [38]
IoT & Cyber-Physical Systems	Local control, preprocessing, edge–dew coordination for IoT/CPS environments	Ultra-low latency, real-time processing, reduced offloading cost	Mishra et al. [39], Savyanavar and Ghorpade [40], Rajareddy et al. [41], Mahapatra et al. [42], Zhang et al. [43]
Hybrid Computing Architecture, Scheduling & Resource Management (Cloud–Fog–Edge–Dew Systems)	Cloudlet–fog–edge–dew architectural integration, task scheduling, resource allocation, benchmarking, and system optimization across distributed layers	Improved scalability, optimized workload distribution, reduced latency, and efficient resource utilization in hybrid computing environments	Pan et al. [44], Ganesh et al. [45], Moussa and Alazzawi [46], Pinzón Castellanos [47], Alkhudhayr and Ardah [48]
Security, Cryptography & IoT Implementation in Dew Systems	Cryptographic protocol analysis, authentication schemes, and IoT-based Dew computing system implementations for secure cyber-physical environments	Improved authentication security, enhanced cyber-physical protection, and secure Dew-enabled IoT deployments	Cao and Liu [49], Chukwuocha et al. [50], Jeyaraj et al. [51], Amjad [52]
Healthcare & Home Care	Local patient data processing, personal health record (PHR) support, monitoring systems	Privacy preservation, low latency, real-time monitoring	Salam et al. [32], Medhi and Hussain [53], Manocha et al. [54], Manocha et al. [55], Khan et al. [56], Risteska Stojkoska et al. [57], Dabbs et al. [58], Becker et al. [59]
Smart Environments & Cities	Edge–dew integration, local analytics for smart infrastructure	Energy efficiency, resilience, reduced cloud dependency	Sojaat and Skalaa [9], Dogo et al. [60], Lipić and Skala [61], Andriulo et al. [62], Mane et al. [63]
Mobile & Consumer Devices	On-device computation and cache-based processing in smartphones and consumer devices	Energy efficiency, improved responsiveness	Mane et al. [63], Hirsch et al. [64], Adhikary et al. [65], Mateos et al. [66]
Cloud–Fog–Dew Integration	Hierarchical task distribution across cloud, fog, and dew layers	Optimized scheduling, reduced latency	Ahammad et al. [67], Wang and Skala [68], Lynn et al. [69], Srivastava et al. [70], Axak et al. [71]
Cybersecurity & Authentication	Dew-based intrusion detection, Zero Trust and secure authentication models	Enhanced trust, localized security enforcement	Frincu [72], Mishra et al. [73], Verma and Sohani [74], Singh and Mishra [75], Ma et al. [76]
Edge Applications & Services	Dew-enabled applications for disaster, healthcare, and smart systems	Improved resilience, decentralized data validation	Kar et al. [77], Harris and Wang [78], Simpson and Quist-Aphetsi [79], Ghosh and Nath [80]
Energy & Environmental Systems	Dew-based environmental modeling, dew point and climate optimization systems	Energy savings, optimized resource utilization	Beysens et al. [81], Ghosh et al. [82], Cui et al. [83], Lekouch et al. [84]
Robotics & Vehicular Systems	Autonomous dew nodes for robotics, UAVs, and vehicular systems	Low latency, fault tolerance, autonomous decision-making	Stanco et al. [85], Dey et al. [86], Ghosh [87], Stanco et al. [88]
Machine Learning & AI	Edge–dew learning models (ANN, ESN, reinforcement learning, ANFIS)	Real-time prediction and adaptive intelligence	Moussa and Alazzawi [89], Valladares et al. [90], Alizamir et al. [91], Qasem et al. [92], Mohammadi et al. [93], Mohammadi et al. [94]
Blockchain Systems	Lightweight distributed ledgers and trust mechanisms on dew nodes	Tamper resistance, secure distributed trust	Karmakar et al. [95], Wang and Gusev [96], Alorf [97], Wang [98]
Research & Education	Simulation platforms and experimental testbeds for dew computing systems	Validation and prototyping of dew architectures	Wang and Skala [68], Plakhteyev et al. [99]
Scientific Computing	CFD and physical simulation models at dew level	Reduced cloud dependency, local computation efficiency	Beysens et al. [81]
Agriculture & Smart Farming	IoT sensing, UAV monitoring, smart irrigation systems	Real-time monitoring, improved resource efficiency	Ghosh et al. [82], Dey et al. [86]
Multimedia & IoT Systems	On-device media processing, caching, and IoT content distribution	Reduced latency and bandwidth usage	Gusev [18], Roy et al. [100]

Figure 4 illustrates an IoT and cyber-physical system architecture where dew nodes perform local computation, reducing latency and improving system resilience through partial cloud synchronization.

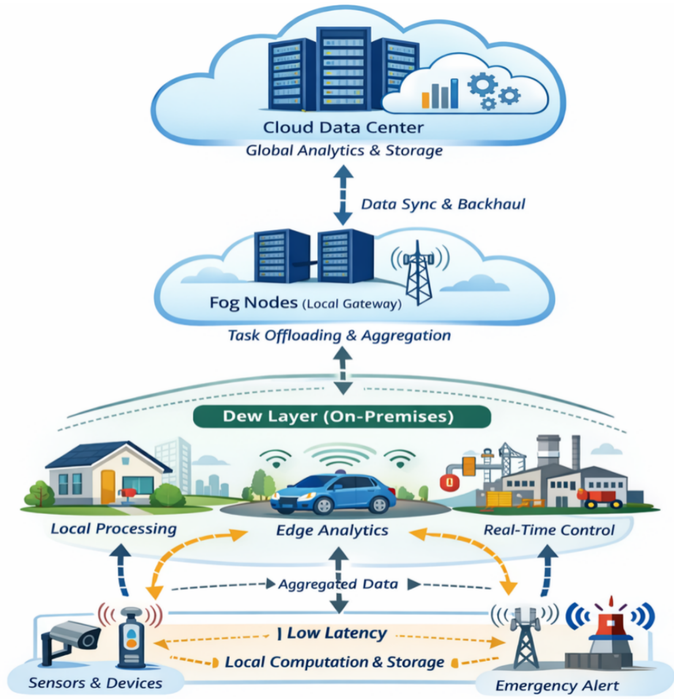

Figure 4. IoT and Cyber-Physical Systems.

Figure 5 presents a vehicular dew computing architecture (AdHocVDew), where mobile dew nodes interact with fog and cloud layers to support low-latency vehicular communication and mobility-aware computing.

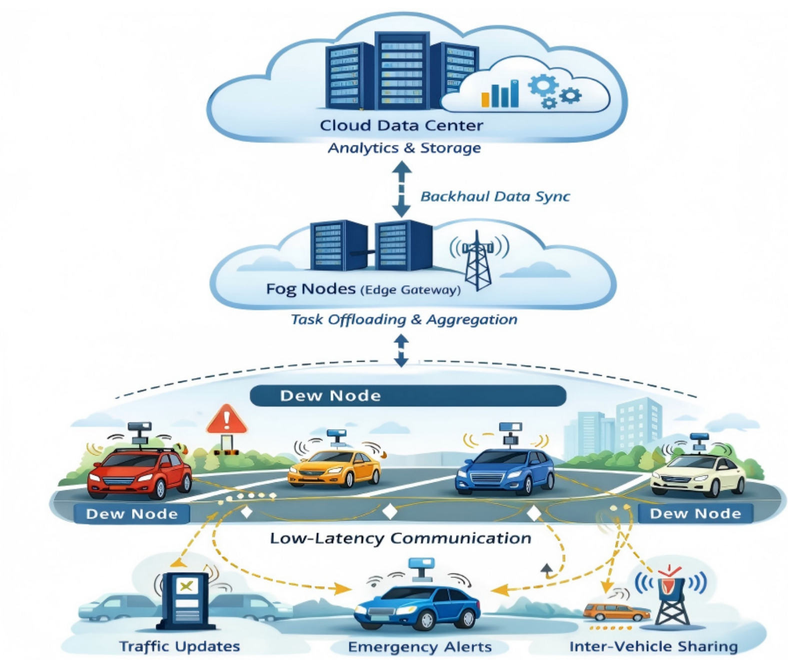

Figure 5. Dew-Enabled Vehicular Networks (AdHocVDew).

Figure 6 shows a hybrid machine learning–dew framework for intrusion detection using deep learning models such as LSTM-AE and CNN, enabling real-time anomaly detection at the edge.

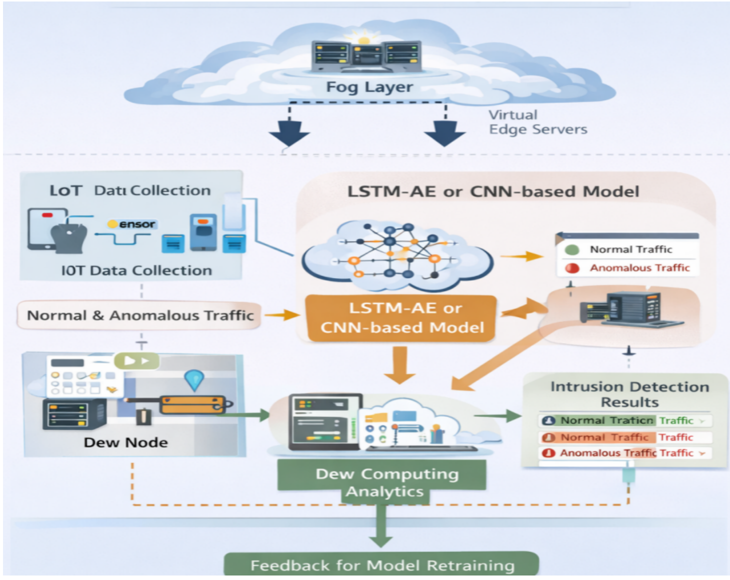

Figure 6. Hybrid ML-Dew Framework for Intrusion Detection.

Figure 7 illustrates a dew-enabled robotics architecture (DewROS/DewROS2), highlighting local task execution, reduced cloud dependency, and distributed control in robotic systems.

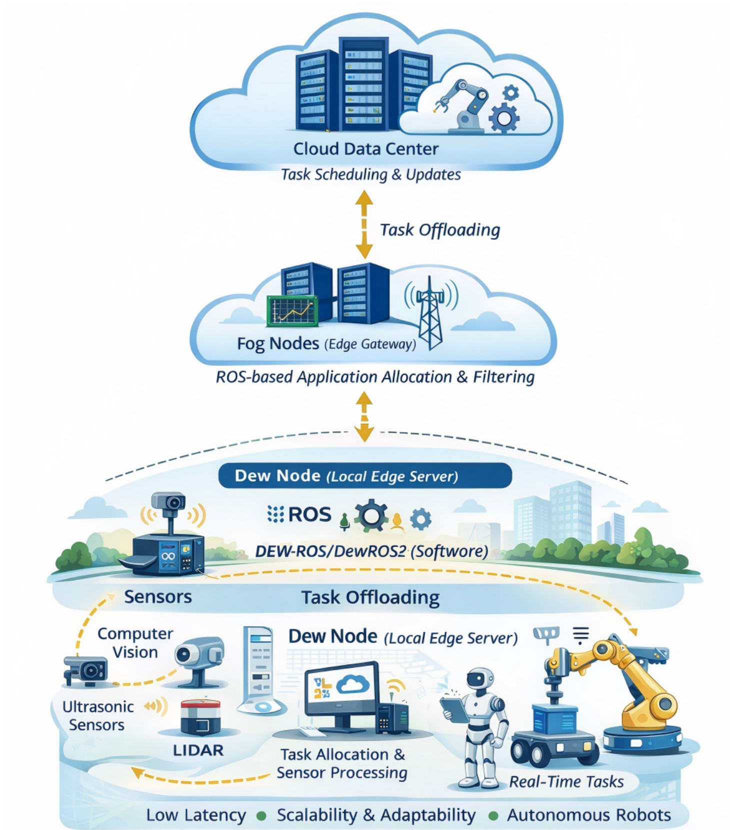

Figure 7. Dew Robotics Architecture (DewROS/DewROS2).

Figure 8 demonstrates application-specific implementations of Dew Computing in agriculture, smart cities, and environmental monitoring, emphasizing domain adaptation and real-time responsiveness.

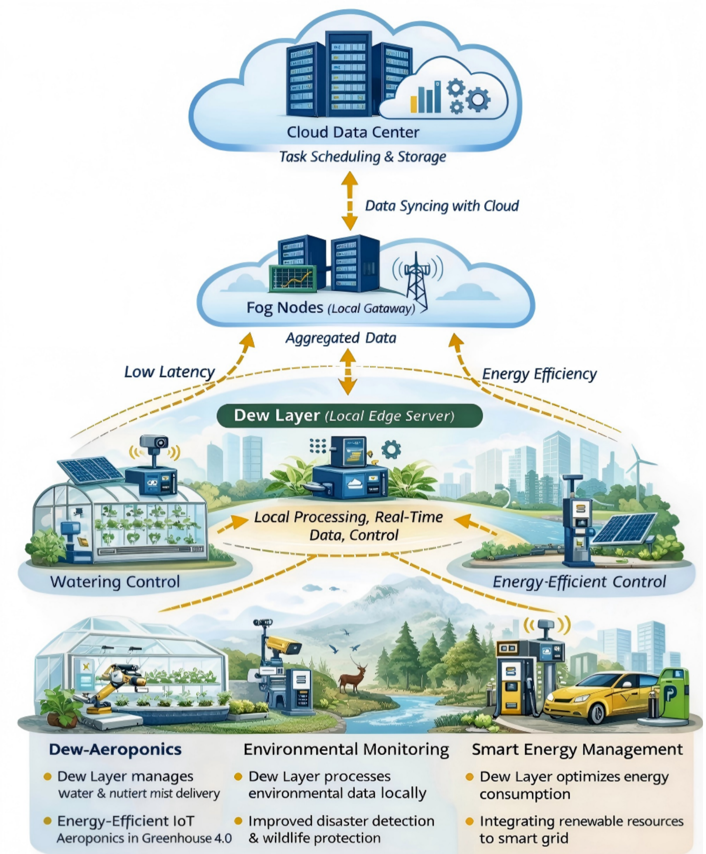

Figure 8. Dew Computing for Agriculture and Smart Cities.

Figure 9 presents predictive modeling approaches for dew-point estimation using soft computing techniques such as neural networks, extreme learning machines, and genetic programming.

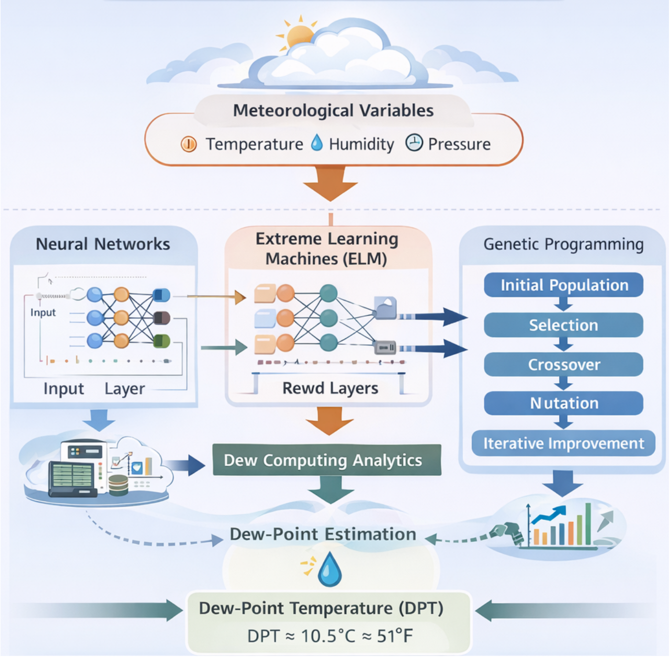

Figure 9. Predictive Modeling for Dew-Point Estimation.

The reviewed applications confirm that Dew Computing effectively supports offline-first and latency-sensitive environments. However, most implementations remain domain-specific and lack generalizable design frameworks. In addition, performance benchmarking and cross-domain adaptability are insufficiently addressed.

5. Challenges and Open Issues

Despite its numerous advantages, Dew Computing faces several significant challenges that limit its large-scale adoption and full operational maturity:

5.1. Security and Privacy

End-device intelligence introduces vulnerabilities such as physical tampering, decentralized trust management, and exposure of sensitive data. Ray [6] emphasized these risks, while distributed security mechanisms in Dew environments [101–103] further highlight the need for robust encryption, access control, and localized intrusion detection. These challenges are further exacerbated by the heterogeneity of Dew nodes and their exposure to untrusted environments, which increases the attack surface compared to centralized systems. To provide a clear overview of known security challenges and possible solutions using blockchain, federated learning, and other methods as shown in **Table 3**.

Table 3. Security Challenges and Solutions in Dew Computing.

Challenge	Threat Type	Mitigation Technique
Data interception [7]	Eavesdropping/Man-in-the-middle attacks	End-to-end encryption, secure communication protocols
Unauthorized access [8,9]	Identity theft, credential compromise	Lightweight authentication schemes, multi-factor authentication
Distributed denial of service (DDoS) [10,11]	Service disruption	Traffic monitoring, rate limiting, federated intrusion detection
Privacy leakage [9,12]	Exposure of sensitive user data	Data anonymization, differential privacy, blockchain-based access control
Malware injection [8,11]	Device-level compromise	Anti-malware agents, code integrity verification
Resource misuse [10,13]	Unauthorized computational exploitation	Resource allocation policies, secure task offloading in dew-fog-cloud environment
Network partitioning [11,14]	Communication failure between layers	Localized decision-making at dew layer, redundancy, decentralized protocols

Figure 10 provides a visual representation of how blockchain, federated learning, and other security measures protect dew nodes and IoT devices, emphasizing a layered defense architecture that mitigates both internal and external threats in distributed environments.

5.2. Scalability and Performance

Managing large-scale heterogeneous Dew nodes presents a critical scalability issue. Gusev [19] and subsequent studies [104–106] noted that resource coordination, task distribution, and system responsiveness can degrade as the network grows. This degradation becomes more pronounced under high mobility and dynamic workload conditions, where real-time decision-making is required across distributed nodes.

5.3. Interoperability and Standardization

The absence of unified protocols and reference architectures across Dew–Fog–Cloud layers remains a barrier. Wang [5], Skala et al. [8], and other works [11, 25, 26, 29, 30] emphasize the need for standardized frameworks to enable seamless integration and predictable operations. The lack of standardization also limits cross-platform compatibility and increases system integration overhead in heterogeneous environments.

5.4. Resource Constraints and Energy Efficiency

Dew devices, particularly smartphones and IoT nodes, suffer from limited battery life, memory, and computational capacity. Hirsch et al. [64] and others [30, 64, 107, 108] stress the importance of energy-aware design, efficient task allocation, and sustainable operation. Energy constraints are further intensified by continuous sensing, communication, and local processing requirements inherent in Dew paradigms.

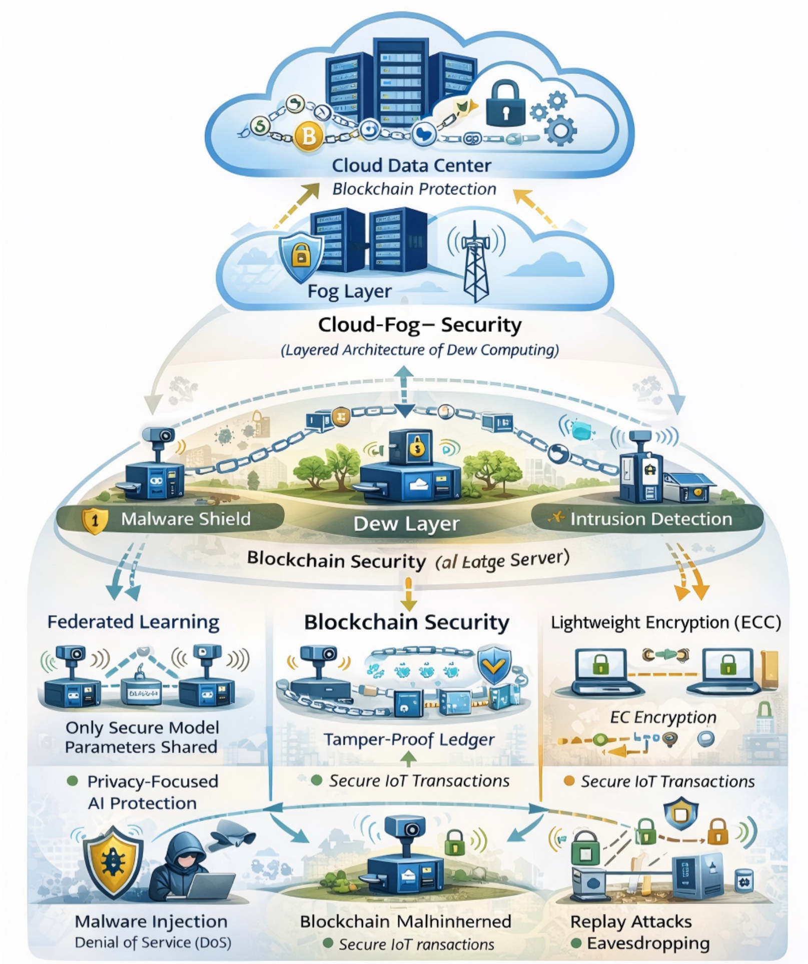

Figure 10. Security and Privacy in Dew Computing.

5.5. Scheduling and Load Balancing

Traditional scheduling approaches are insufficient for Dew environments due to dynamic workloads and mobility. Javadzadeh et al. [108] and further studies [64,107] highlight the need for new mathematical models and adaptive scheduling strategies to optimize task execution. **Table 4** summarizes MRU/FRU caching, task offloading, and scheduling techniques in Dew-enabled systems.

Table 4. Resource Management Techniques for Dew Systems.

Technique	Target Resource	Advantage	Limitation
MRU/FRU Caching [8,14]	Computational & storage resources	Reduces latency, improves local resource utilization	May lead to cache misses for unpredictable workloads
Task Offloading to Fog/Cloud [9]	CPU/GPU cycles	Balances load, minimizes device energy consumption	Network dependency may increase latency in low-connectivity scenarios
Mobility-Aware Scheduling [10,11]	Mobile dew devices (vehicles, drones)	Ensures task continuity in dynamic networks	Complex scheduling logic, requires real-time monitoring
Priority-Based Workflow Scheduling [12,14]	CPU/GPU cycles, memory	Optimizes important or time-critical tasks	May starve low-priority tasks
Dynamic Node Allocation [9,11]	Computational nodes in Dew–Fog–Cloud stack	Efficient utilization of available nodes, reduces congestion	Overhead in frequent reallocation decisions
Hybrid Learning-Based Resource Management [15]	CPU, memory, network bandwidth	Adapts to changing workloads, improves overall system performance	Requires training data and processing overhead

These scheduling challenges are further complicated by unpredictable node availability and intermittent connectivity in real-world deployments.

5.6. Paradigm Confusion and Conceptual Overlap

The distinction between Dew and Edge Computing remains unclear. Gusev [22] and Pan and Luo [11] noted overlapping concepts, which complicates system design and theoretical understanding. This conceptual ambiguity also affects the development of unified frameworks and slows down academic consensus on system boundaries.

5.7. Reliability, Offline Support, and Network Dependency

Ensuring dependable operation during intermittent connectivity and minimizing internetwork dependency without compromising consistency remains challenging [14,109]. Maintaining data consistency in offline-first scenarios remains a critical unsolved issue in highly distributed Dew environments.

5.8. Integration with Emerging Technologies

Incorporating AI, ML, and blockchain into Dew systems is desirable but increases complexity and may affect latency and resource usage [110,111]. Additionally, integration overhead may counteract the low-latency advantage that Dew Computing aims to achieve.

5.9. System Complexity

Heterogeneous node management, multi-layer orchestration, and diverse application requirements exacerbate complexity [15,112,113]. This complexity introduces significant challenges in system debugging, monitoring, and lifecycle management.

5.10. Sustainability

Optimizing energy consumption and environmental impact in Dew Computing is essential for long-term viability [24]. Sustainability concerns also extend to large-scale deployment of battery-powered edge and Dew nodes, requiring greener computing strategies. The Summary of the Dew Computing Challenges, and open issues as shown in **Table 5**.

Table 5. Summary: Dew Computing Challenges.

Challenge	Description
Security & Privacy [16]	Local vulnerabilities, trust management, and sensitive data handling
Scalability [17]	Coordination and resource management of large numbers of Dew nodes
Standardization [18]	Lack of unified frameworks and reference architectures
Energy Efficiency [19]	Battery, CPU, and memory limitations; sustainable operation
Scheduling & Load Balancing [20]	Dynamic task allocation for mobile and heterogeneous nodes
Paradigm Confusion [21,22]	Ambiguity between Dew and Edge computing
Reliability & Offline Support [3,23]	Offline operation and minimizing network dependency
Emerging Tech Integration [24,25]	AI, ML, blockchain incorporation with low latency
System Complexity [26]	Multi-layer orchestration and diverse node management
Sustainability [27]	Energy and environmental impact optimization

This analysis indicates that despite diverse architectural approaches, there is no consensus on standardized design or evaluation criteria. This fragmentation limits interoperability and slows the transition from conceptual models to real-world deployments.

6. Dew Computing Landscape: Taxonomy and Classification

Dew Computing has evolved as a distinct layer in distributed computing, bridging local devices with fog and cloud infrastructures. Multiple taxonomies and classification schemes have been proposed to capture its structural, functional, architectural, and sustainability dimensions, reflecting its increasing heterogeneity and application scope.

6.1. Structural Taxonomy

Foundational classification by Wang [5] distinguishes Dew systems based on autonomy and collaboration: Standalone Dew Systems—Fully autonomous, offline-capable devices, in addition to Collaborative Dew Systems—Dew nodes synchronized with cloud or fog layers. Skala et al. [8] further integrated Dew Computing as a structural layer within hierarchical distributed architectures, highlighting its role in multi-layered computing systems. This integration formally positions Dew as the closest computational layer to end-users in the Cloud–Fog–Dew continuum. The structural taxonomy is shown in **Table 6.**

Table 6. Structural Taxonomy.

Category	Description	Ref
Standalone Dew	Independent operation	Wang [5]
Collaborative Dew	Cloud/Fog synchronized	Wang [5], Skala et al. [8]
Hierarchical Dew	Integrated into multi-layer systems	Skala et al. [8]

Ahammad et al. [21] expanded the IoT computing taxonomy into four layers: Cloud, Fog, Roof, and Dew, while Ageed et al. [23] positioned Dew as the final stage of computing decentralization. Wang et al. [12] framed Dew within the broader evolution of Internet computing paradigms. Collectively, these works emphasize Dew Computing as an essential terminal layer in hierarchical distributed architectures. To illustrate the evolution of the Dew Computing paradigm, **Figure 11** presents a historical timeline from early Dew Computing proposals to recent IoT and AI-integrated architectures, highlighting key milestones in its development.

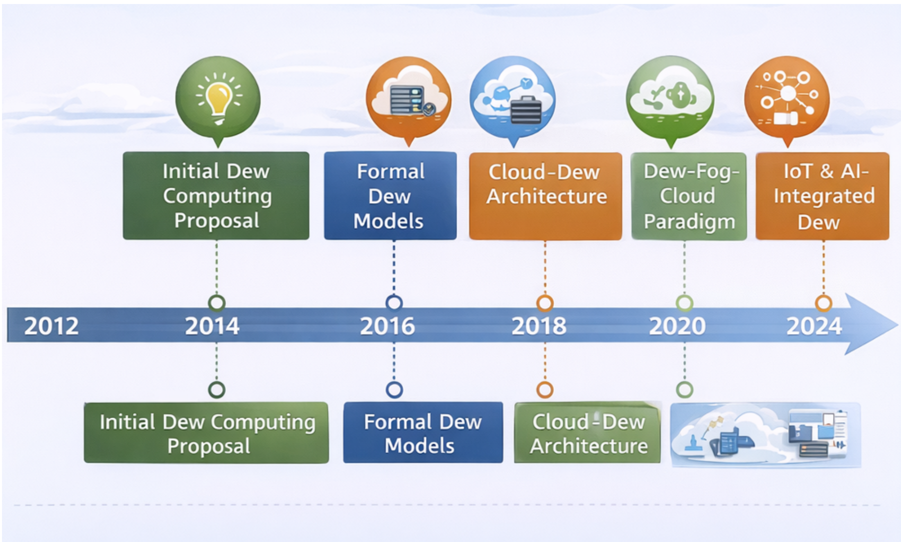

Figure 11. Timeline of Dew Computing Development.

6.2. Functional Classification

Based on Wang and Leblanc [114], Dew Computing can be categorized functionally as:

- Web in Dew (WiD): SaaS/SaaP services embedded in Dew nodes.
- Device-Centric Dew: User hardware serving as primary computational units.
- Service-Oriented Dew (DaaS): Dew-as-a-Service model [101].

Sustainability-aware Dew introduces an additional classification dimension [24]:

- Performance-Oriented Dew—Optimized for computational efficiency.
- Energy-Aware Dew—Designed for low power consumption.
- Sustainable Dew—Balances performance with environmental impact.

The classification of functional and sustainability aspects of Dew systems is shown in **Table 7**, while **Table 8** illustrates the Expanded Layered Model of Dew systems.

Table 7. Functional & Sustainability Classification.

Dimension	Category	Ref
Service Model	DaaS	Singh et al. [101]
System Goal	Sustainable Dew	Roy et al. [24]
Security Model	Secure Dew Architecture	Ray and Skala [115]
Application Focus	Drone-based Dew	Mukherjee et al. [116]

Table 8. Expanded Layered Model.

Model Layer	Layer	Function	Ref
Dew	User devices	Autonomous processing	Wang et al. [12], Ahammad et al. [21]
Roof	Near-user aggregation	Local coordination	Ahammad et al. [21]
Fog	Network edge	Regional processing	Ahammad et al. [21]
Cloud	Data centers	Centralized analytics	Pan and Luo [11], Ageed et al. [23]

This layered abstraction reinforces Dew Computing as the closest computational tier to end-user environments, enabling localized intelligence and reduced dependency on centralized infrastructure.

6.3. Architectural Taxonomy and Models

Architectural variants highlight Dew's integration with cloud and edge paradigms: Standalone Dew Computing—Fully independent offline computing [14,117], Cloud–Dew Architecture—Cooperative cloud-synchronized Dew systems [103], and the Dew–Fog–Cloud Architecture Multi-layer hybrid models [32,54]. The architectural models of Dew systems are detailed in **Table 9**.

Table 9. Architectural Models.

Model	Description	Ref
Formal Dew Model	Abstract, implementation-neutral	Gusev and Wang [29]
Cloud–Dew	Local Dew servers synchronized with cloud	Wang [30]
Edge–Cloud–Dew	Hierarchical hybrid computing	Yu [112]
Cloud–Fog–Dew	Multi-layer orchestration	Gordienko et al. [113]
Serverless Dew	Infrastructure-less execution	Gusev [105]

Moreover, **Table 10** presents application-specific architectural models.

Table 10. Application-Specific Models.

Model	Function
Dew-enabled Agriculture [31,118,119]	Localized IoT computation for farm management
Hybrid Dew–Edge–Cloud [31]	Collaborative task execution
Reinforcement Learning-based Dew Scheduling [120,121]	AI-driven task distribution
Mobile Edge Dew Microservices [122]	Q-learning-based microservice execution

6.4. Emerging Functional Perspectives

Local Computation & Services:

- Task execution at device level [64,108].
- Data caching for offline access [106,117].
- Security services including IDS, blockchain, and privacy preservation [98,101,103].
- Simulation and performance modeling [102].

Serverless and Device-less Dew Computing:

Gusev [105] introduces serverless and device-less Dew computing, which eliminates dependence on fixed infrastructure, enabling:

- Opportunistic computation.
- Infrastructure-less execution.

- Adaptability in disconnected or highly dynamic environments.

Industry 5.0 Applications:
Subbiah et al. [104] position Dew Computing within Industry 5.0 paradigms, emphasizing:

- Human-centric system design.
- Decentralized resilience.
- AI-driven local autonomy.

The analysis highlights a lack of consensus on standardized design and evaluation criteria across existing architectural approaches. This fragmentation significantly constrains interoperability and delays the transition from conceptual models to scalable real-world implementations.

7. Case Studies and Practical Use Cases

The practical deployment of Dew Computing across multiple domains demonstrates its feasibility, effectiveness, and measurable impact on latency reduction, local autonomy, and distributed intelligence. These case studies collectively validate Dew Computing as a viable complementary paradigm to Cloud and Fog architectures.

7.1. IoT, CPS, and Multimedia Applications

Applications of IoT, CPS, and multimedia systems using Dew Computing are summarized in **Table 11**.

Table 11. IoT, CPS, and Multimedia Applications.

Case Study	Domain	Key Outcome	Ref
Dew-based CPS	IoT/CPS	Improved responsiveness and real-time processing	Gushev [17]
IoT Streaming Dew Server	Multimedia IoT	Reduced latency in media delivery	Gusev [18]
Smart Living Environments	Smart Homes	Enhanced user-centric autonomy	Sojaat and Skalaa [9]

These applications demonstrate that Dew Computing significantly improves real-time responsiveness by shifting computation closer to data generation sources.

7.2. Healthcare, Security, and Mobile Systems

Healthcare, security, and mobile applications of Dew Computing are summarized in **Table 12**.

Table 12. Healthcare, Security, and Mobile Systems.

Case	Domain	Outcome	Ref
Healthcare Monitoring	Medical IoT	Secure, low-latency local processing	Salam et al. [32]
Intrusion Detection	Cybersecurity	Faster detection of anomalies	Singh et al. [101]
Smartphones as Dew Nodes	Mobile Systems	Feasible on-device execution	Hirsch et al. [64]
Real-time IoT Scheduling	Industrial IoT	Deadline-aware task execution	Javadzadeh et al. [108]

These use cases highlight the critical role of Dew Computing in enabling privacy-preserving and latency-sensitive applications in healthcare and security domains.

7.3. Specialized IoT and Drone Use Cases

Specialized IoT and drone-based applications are summarized in **Table 13**.

Table 13. Specialized IoT and Drone Use Cases.

Case	Domain	Result	Ref
DewDrone	IoDT	Reliable UAV operations with local processing	Mukherjee et al. [116]
DewMusic	Music IoT	Efficient crowdsourcing and low-latency content handling	Roy et al. [100]
Asthma Prediction CPS	Healthcare	Early detection of respiratory conditions	Manocha et al. [55]
Indoor Health Monitoring	Smart Buildings	Localized anomaly detection	Manocha et al. [54]
Blockchain Dew Node	FinTech/IoT	Lightweight decentralized computation	Chukwuocha et al. [50]

These applications demonstrate the adaptability of Dew Computing in mobility-intensive and real-time critical environments.

7.4. Advanced Dew Platforms and Frameworks

Advanced platforms and frameworks are summarized in **Table 14.**

Table 14. Advanced Dew Platforms and Frameworks.

Case Study	Domain	Contribution	Ref
DC-Health	Healthcare IoT	Offline diagnostics for patient monitoring	Medhi et al. [117]
DewDrone	Drones	Delay-tolerant UAV IoT operations	Mukherjee et al. [116]
DewMusic	Multimedia	Crowdsourced music IoT platform	Roy et al. [100]
Vehicular Dew	Transportation	Low-latency vehicular data processing	Zhao et al. [106], Khatua et al. [123]
Secure Dew Hotspots	Networking	Secure local computing architecture	Sahoo et al. [103]
Formal Dew Model	Theory	Generalized framework for Dew Computing	Wang et al. [29]

7.5. Smart City, Industry, and Elderly Care

Applications in smart city infrastructure, industrial systems, and assisted living environments are summarized in **Table 15.**

Table 15. Smart City, Industry, and Elderly Care.

Case Study	Domain	Contribution
Smart Parking [112]	Smart City	Low-latency urban service delivery
MedGini [100,124]	Healthcare	Sustainable Dew-enabled health monitoring
Industry 5.0 Dew [104]	Industry	Human-centric decentralized manufacturing
Elderly Care Ecosystem [113]	Ambient Assisted Living (AAL)	Non-obtrusive on-device care systems
Cognitive Dew Health [125]	Healthcare AI	Enhanced disease prediction using local computation

7.6. Agriculture, IoT, and Edge Integration

Agricultural and IoT-integrated Dew applications are summarized in **Table 16.**

Table 16. Agriculture, IoT, and Edge Integration.

Case Study	Domain	Contribution	Ref
Consumer Electronics IoAT	Agriculture	Dew-enabled IoT devices for sustainable farming	Sarkar et al. [31]
Hybrid Dew–Edge–Cloud	IoT	Cooperative computational grid for multi-tier execution	Sarkar et al. [31]
Task Scheduling via RL	Hybrid IoT	AI-driven resource optimization	Sanabria et al. [120]
Smart Tomato Storage	Agriculture	Zone-wise local Dew-layer computation	Kasera and Acharjee [118]
Sustainable Agriculture	Agriculture	Real-time processing and decision-making	Singh et al. [119]
Dew-IoT Agriculture System	Agriculture	Sub-platform localized computation for IoT	Bera et al. [126]

Across these domains, Dew Computing consistently improves real-time decision-making and reduces reliance on centralized cloud resources.

7.7. Workflow and Resource Management Analysis

Figure 12 illustrates MRU/FRU caching, task offloading, and scheduling across Dew–Fog–Cloud nodes, emphasizing performance optimization and energy efficiency in distributed environments.

Table 17 presents a workflow analysis of a Cloud–Dew application, showing task distribution across layers along with processing time, data transfer, and observed latency.

7.8. Performance Evaluation and Comparative Analysis

Table 18 compares key performance metrics across Cloud, Fog, and Dew Computing, highlighting latency, bandwidth efficiency, energy consumption, and scalability.

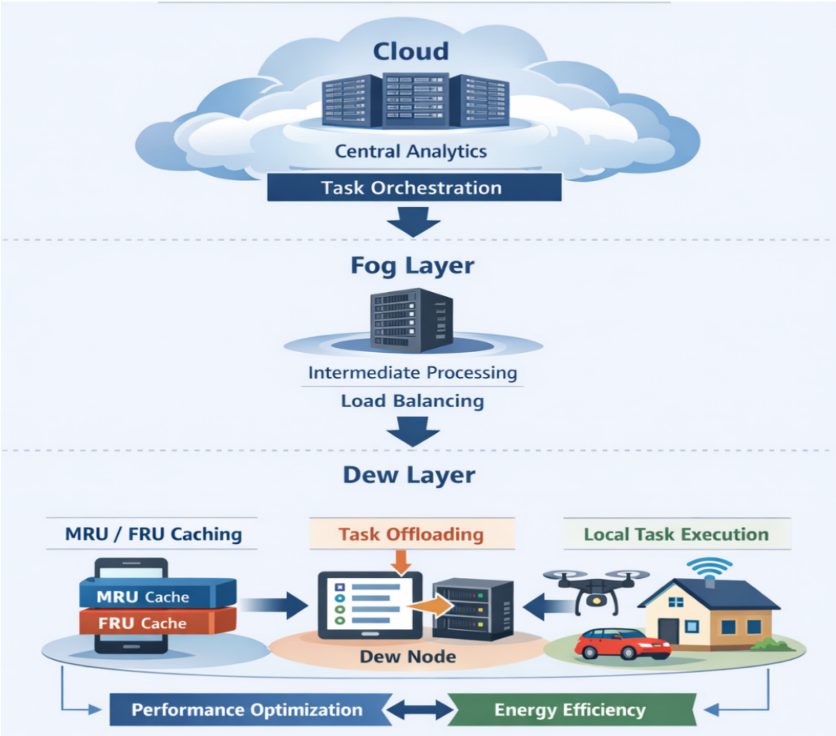

Figure 12. Resource Management in Dew-Enabled Systems.

Table 17. Workflow Analysis of Cloud–Dew Application.

Task	Layer (Dew/Fog/Cloud)	Processing Time (ms)	Data Transfer (MB)	Observed Latency (ms)
Sensor Data Acquisition [5,6]	Dew	5	0.5	6
Local Preprocessing & Filtering [6,8]	Dew	15	0.2	17
Edge Aggregation [8,17]	Fog	30	5	35
Machine Learning Inference [9,10]	Cloud	120	20	150
Feedback/Control Signal [5,8]	Dew	10	0.1	11
Data Storage & Backup [10,18]	Cloud	80	50	100
Anomaly Detection [8,17]	Dew/Fog	25	2	28

Table 18. Performance Evaluation and Comparative Analysis.

Metric	Cloud Computing	Fog Computing	Dew Computing	Improvement with Dew	Ref.
Latency (ms)	150–250	50–100	5–20	Up to 95% reduction	Wang [5]; Ray [6]; Skala et al. [8]
Bandwidth Utilization	High	Moderate	Low	40–60% reduction	Wang [5]; Skala et al. [8]
Energy Consumption (per node)	High	Moderate	Low	30–50% savings	Skala et al. [8]; Gushev [17]
Response Time (s)	1–2	0.5–1	0.05–0.2	80–95% faster	Ray [6]; Skala et al. [8]; Gushev [17]
Resource Usage Efficiency	Centralized	Semi-distributed	Local computation	Up to 3× improvement	Skala et al. [8]; Šojat and Skala [10]
Reliability/Fault Tolerance	Moderate	High	Very High (autonomous/self-healing)	Increased resilience	Skala et al. [8]; Sojaat and Skalaa [9], Šojat and Skala [10]
Scalability	Cloud-dependent	Edge-limited	Hybrid flexible scaling	User-level scalability	Sojaat and Skalaa [9], Šojat and Skala [10]

Overall, this comparative analysis quantitatively confirms that Dew Computing significantly outperforms Cloud and Fog paradigms in latency reduction, energy efficiency, and localized resource optimization.

In addition to providing a more structured and comparative evaluation of existing Dew Computing studies, a quantitative analysis is conducted across representative works. The comparison considers key performance and architectural attributes, including latency behavior, energy efficiency, offline capability, dataset characteristics, and identified limitations. This analysis highlights the heterogeneity of existing approaches and reveals the absence of standardized benchmarking practices across studies. It also emphasizes that while most architectures achieve acceptable performance in isolated scenarios, there is limited evidence of consistent evaluation under unified experimental conditions. The Comparative Analysis of representative Dew Computing Studies is summarized in **Table 19**.

Table 19. Comparative Analysis of Representative Dew Computing Studies.

Study	Architecture Type	Application Domain	Key Limitation	Research Gap Identified
Wang [30]. Gusev and Wang [29]	Standalone Dew	General Systems	Limited real-world validation	Need for deployment studies
Ray [6,14]	Cloud–Dew	IoT Systems	Weak security mechanisms	Trust-aware architectures
Skala et al. [8], Šojat and Skala [10]	Dew–Fog–Cloud Hybrid	Distributed Systems	High system complexity	Simplified architecture models
Zhang et al. [106]	Edge–Dew Integration	Smart Agriculture	Limited scalability analysis	Large-scale performance evaluation

The case studies demonstrate the practical feasibility of Dew Computing under controlled conditions. Nevertheless, challenges related to scalability, interoperability, and standardized evaluation persist, particularly in large-scale and heterogeneous environments.

8. Insights and Future Directions

Based on the reviewed literature, Dew Computing is transitioning from a conceptual distributed computing paradigm into a deployable and scalable architecture with practical adoption across IoT, CPS, healthcare, industrial systems, and emerging intelligent infrastructures. This evolution is driven by increasing demand for ultra-low latency processing, offline capability, and decentralized intelligence at the network edge.

8.1. Key Insights

The analysis reveals that Dew Computing is not merely an extension of Edge or Fog computing but represents a distinct architectural paradigm emphasizing user-level autonomy, offline resilience, and decentralized service continuity. This distinguishes it fundamentally from latency-optimized edge models and cloud-dependent hybrid systems.

- Dew Computing is a fundamental enabler for ultra-low latency, offline-capable, and near-device processing systems in distributed environments.
- It operates as a complementary layer rather than a replacement for Cloud and Fog Computing, forming a hierarchical multi-layer computing continuum.
- It is inherently aligned with IoT and CPS evolution, enabling localized decision-making and autonomous system behavior.
- Dew systems are increasingly integrated with AI techniques, enabling intelligent edge-level inference and adaptive processing.
- Mobile and resource-constrained devices are emerging as primary Dew execution environments, supporting service-oriented models such as Dew-as-a-Service (DaaS).
- Healthcare remains a dominant application domain, particularly for privacy-preserving, real-time monitoring and distributed medical analytics.
- Dew Computing is expanding toward blockchain, UAV systems, and creative computing domains, indicating convergence with decentralized and intelligent technologies.
- Energy efficiency and sustainability are becoming core design objectives in next-generation Dew architectures.
- Security, trust management, and decentralized authentication mechanisms are critical enablers for large-scale Dew deployment.

Overall, these insights indicate that Dew Computing is evolving into a foundational layer for intelligent distributed systems rather than a peripheral extension of edge computing.

8.2. Research Gap

To systematically summarize the limitations identified across the reviewed literature, a consolidated research gap analysis is presented. This synthesis highlights recurring methodological, architectural, and evaluation deficiencies in existing Dew Computing studies. The identified gaps serve as the foundation for defining future research directions and emerging opportunities in the field. **Table 20** illustrates the Research Gaps and Recommended Directions in Dew Computing.

Table 20. Research Gaps and Recommended Directions in Dew Computing.

Research Area	Observed Limitation	Impact on Field	Recommended Direction
Standardization	Lack of unified frameworks and benchmarks	Prevents fair comparison across studies	Development of standardized evaluation metrics
Security & Privacy	Weak integration of trust and security models	Risk in real-world deployment	Design of secure Dew architectures with trust management
Scalability	Most studies limited to small-scale experiments	Restricts industrial adoption	Large-scale real-world deployment studies
Interoperability	Fragmented architectures across systems	Limits cross-platform integration	Hybrid and interoperable Dew frameworks
Energy Efficiency	Limited evaluation under realistic conditions	Reduces sustainability assessment	Energy-aware Dew computing models
Real-world Validation	Heavy reliance on simulation environments	Gaps between theory and practice	Deployment in real IoT and CPS environments

8.3. Future Research Directions

Based on the above synthesis, several critical research gaps are identified:

- Lack of standardized benchmarking frameworks for Dew systems.
- Limited integration of security and privacy mechanisms.
- Insufficient large-scale real-world deployment studies.
- Poor interoperability across heterogeneous environments.
- Limited focus on energy-efficient Dew architectures.

8.3.1. AI-Driven and Intelligent Dew Systems

Future Dew systems are expected to be deeply integrated with artificial intelligence techniques:

- Development of Dew-native AI architectures leveraging federated learning and distributed model training.
- Cognitive Dew systems for healthcare diagnostics, smart environments, autonomous robotics, and adaptive decision-making frameworks [125,127].
- Lightweight on-device inference models optimized for constrained Dew nodes.

8.3.2. Energy Efficiency and Sustainability

Energy-aware design is a critical research direction for large-scale Dew deployment:

- Energy-aware Dew architectures incorporating predictive energy consumption models for IoT and mobile devices [128].
- Development of green Dew computing frameworks focusing on reduced carbon footprint and sustainable resource utilization [24].
- Integration of renewable energy–powered Dew nodes in distributed environments.

8.3.3. Standardization and Interoperability

A major barrier to adoption is the lack of standardized frameworks:

- Development of unified Dew–Fog–Cloud integration standards and formal APIs.
- Definition of clear conceptual and architectural boundaries between Dew and Edge Computing to reduce ambiguity [29,30].
- Creation of interoperability frameworks for heterogeneous IoT and CPS ecosystems.

8.3.4. Security, Privacy, and Trust Management

Security remains a core research challenge in Dew environments:

- Security-by-design Dew architectures supporting decentralized trust management and authentication [115].

- Integration of blockchain and federated learning for secure distributed computation.
- Privacy-preserving analytics for sensitive domains such as healthcare and smart cities.

8.3.5. Emerging Applications and Paradigms

Dew Computing is expanding into several high-impact application domains:

- Autonomous UAV and robotic systems leveraging local real-time Dew computation.
- Industry 5.0 environments enabling human-centric, resilient, and decentralized manufacturing systems [104].
- Serverless and infrastructure-less Dew architectures for rural, remote, and intermittently connected environments [105].
- Dew-enabled digital twins for real-time monitoring, simulation, and predictive analytics [103,116].

Table 21 shows the gaps of the research and the Future Directions in Dew Computing.

Table 21. Research Gaps and Future Directions in Dew Computing.

Gap	Potential Solution	Research Focus
Limited AI/ML integration for predictive scheduling	Hybrid ML, reinforcement learning, predictive analytics	Optimized task offloading and dynamic resource allocation in Dew environments
Security vulnerabilities in distributed Dew networks	Blockchain, federated learning, lightweight encryption	Authentication, intrusion detection, privacy preservation
Lack of benchmarking standards	Simulation frameworks and experimental testbeds	Comparative evaluation of latency, energy, and scalability
Limited real-world deployments	Pilot studies and industrial validation	Smart cities, vehicular networks, industrial automation
Energy efficiency challenges	Energy-aware scheduling and renewable-powered nodes	Carbon reduction and operational efficiency
Interoperability limitations	Standard APIs and protocol definitions	Seamless integration in hybrid computing architectures
Task distribution uncertainty in robotics	Adaptive and intelligent scheduling algorithms	Latency reduction and reliability improvement in autonomous systems

8.4. Summary of Emerging Trends

As summarized in **Table 22**, emerging trends in Dew Computing include the integration of IoT, edge and fog computing, artificial intelligence, and blockchain technologies. Current research focuses on intelligent resource management, enhanced security, real-time processing, and decentralized service delivery across various domains, including healthcare, agriculture, transportation, and smart environments, demonstrating the increasing maturity and practical adoption of Dew Computing.

Table 22. Summary of Emerging Trends.

Trend	Description	Ref.
AI-enabled Dew	On-device intelligence and cognitive processing	Salam et al. [32], Singh et al. [101], Afaq and Manocha [125], Manocha and Masoodi [127]
Mobile Dew Platforms	Smartphones and IoT devices as primary computing nodes	Hirsch et al. [64], Singh et al. [101]
Service-Oriented Dew	DaaS and localized SaaS integration	Singh et al. [101]
Healthcare-Centric Dew	Real-time, privacy-preserving medical monitoring	Salam et al. [32]
Sustainable Dew Systems	Green computing and energy-aware architectures	Roy et al. [24], Longo et al. [128]
Security and Blockchain Integration	Trust management and decentralized security frameworks	Wang [98], Ray and Skala [115]
Serverless Dew Computing	Infrastructure-less and opportunistic computation	Gusev [105]
Industry 5.0 Systems	Human-centric decentralized manufacturing	Subbiah et al. [104]
Dew-based Digital Twins	Real-time predictive modeling and monitoring systems	Salam et al. [32], Singh et al. [101], Afaq and Manocha [125], Manocha and Masoodi [127]

9. Conclusions

Dew Computing has matured from a conceptual extension of cloud–fog–edge paradigms into a practical decentralized computing model that emphasizes local-first execution, offline capability, and seamless synchronization with higher-tier infrastructures. This survey highlights its growing relevance in enabling resilient, low-latency, and user-centric computing across distributed environments. The analysis of architectures such as cloud–dew and dew–fog–cloud demonstrates that integrating local device intelligence with hierarchical computing layers significantly improves system responsiveness, fault tolerance, and operational efficiency. These advantages make Dew Computing particularly suitable for latency-sensitive and connectivity-constrained domains, including IoT ecosystems, cyber-physical systems, smart infrastructure, healthcare, and autonomous systems. Despite these advancements, several challenges remain unresolved. Key issues include the lack of standardized frameworks, interoperability constraints across heterogeneous environments, and the need for more robust security and privacy mechanisms. Additionally, efficient resource orchestration and energy-aware computation remain critical for large-scale adoption. Recent research trends indicate increasing reliance on machine learning, federated learning, blockchain, and lightweight cryptographic techniques to enhance task scheduling, trust management, and decentralized decision-making. However, empirical validation in real-world large-scale deployments is still limited. In brief, Dew Computing represents a significant step toward fully decentralized and resilient computing ecosystems. Its integration with emerging technologies positions it as a promising foundation for next-generation distributed systems. Future research should prioritize standardization, scalable security frameworks, and practical deployment models to bridge the gap between theoretical development and industrial adoption.

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Institutional Review Board Statement

Not applicable. This study is a survey of existing literature and does not involve human participants, animals, or any form of identifiable personal data; therefore, ethical approval was not required.

Informed Consent Statement

Not applicable. This study is based solely on a survey of previously published literature and does not involve human participants or the collection of personal data; therefore, informed consent was not required.

Data Availability Statement

This study is based on a survey of previously published literature. All data supporting the findings are available within the article and its cited references.

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Conflicts of Interest

The authors declare no conflict of interest.

AI Use Statement

The authors confirm that no artificial intelligence tools were used to generate the manuscript content, including any sections, sentences, or paragraphs. ChatGPT was only utilized as a language support tool to rephrase selected sentences and paragraphs for clarity and to improve the linguistic quality of the manuscript.

References

1. de Matos, F.; Rego, P.A.L.; Trinta, F. Improving Mobile Device Efficiency through Dew Computing and Multi-Language Communication. In Proceedings of the ICC 2025 - IEEE International Conference on Communications, Montreal, QC, Canada, 8–12 June 2025; pp. 5853–5858.
2. Ur Rehman, W.; Al-Ezzi Sufyan, M.M.; Salam, T.; et al. Cooperative Distributed Uplink Cache over B5G Small Cell Networks. *PLoS One* **2024**, *19*, e0299690.
3. Al-Ezzi Sufyan, M.M.; Ur Rehman, W.; Salam, T.; et al. Duplication Elimination in Cache-Uplink Transmission over B5G Small Cell Network. *EURASIP J. Wirel. Commun. Netw.* **2021**, *2021*, 185.
4. Al-Ezzi Sufyan, M.M.; Ur Rehman, W.; Salam, T.; et al. Distributed Uplink Cache for Improved Energy and Spectral Efficiency in B5G Small Cell Network. *PLoS One* **2022**, *17*, e0268294.

5. Wang, Y. Definition and Categorization of Dew Computing. *Open J. Cloud Comput.* **2016**, *3*, 1–7.
6. Ray, P.P. An Introduction to Dew Computing: Definition, Concept and Implications. *IEEE Access* **2017**, *6*, 723–737.
7. Rai, S.; Chawla, R.; Vashishath, M.; et al. EW YOLO: Edge Computing IoT and YOLOv11 Setup for E-Waste. *Appl. Sci.* **2026**, *16*, 2152.
8. Skala, K.; Davidovic, D.; Afgan, E.; et al. Scalable Distributed Computing Hierarchy: Cloud, Fog and Dew Computing. *Open J. Cloud Comput.* **2015**, *2*, 16–24.
9. Sojaat, Z.; Skalaa, K. The Dawn of Dew: Dew Computing for Advanced Living Environment. In Proceedings of the 2017 40th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), Opatija, Croatia, 22–26 May 2017; pp. 347–352.
10. Šojat, Z.; Skala, K. Views on the Role and Importance of Dew Computing in the Service and Control Technology. In Proceedings of the 2016 39th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), Opatija, Croatia, 30 May–3 June 2016; pp. 164–168.
11. Pan, Y.; Luo, G. Cloud Computing, Fog Computing, and Dew Computing. *ZTE Commun.* **2017**, *15*, 1.
12. Wang, Y.; Skala, K.; Rindos, A.; et al. Dew Computing and Transition of Internet Computing Paradigms. *ZTE Commun.* **2017**, *15*, 30.
13. Utomo, P.; Falahah. Dew Computing: Concept and Its Implementation Strategy. In Proceedings of the Fifth International Conference on Informatics and Computing (ICIC), Gorontalo, Indonesia, 3–4 November 2020; pp. 1–6.
14. Ray, P.P. Minimizing Dependency on Internetwork: Is Dew Computing a Solution? *Trans. Emerg. Telecommun. Technol.* **2019**, *30*, e3496.
15. Tyagi, A.K. Dew Computing: State of the Art, Opportunities, and Research Challenges. In *Machine Learning Algorithms Using Scikit and TensorFlow Environments*; IGI Global: Hershey, PA, USA, 2024 ; pp. 332–345.
16. Cao, Z.; Ye, H. Comment on “Efficient Design of an Authenticated Key Agreement Protocol for Dew-Assisted IoT Systems”. *J. Supercomput.* **2025**, *81*, 149.
17. Gushev, M. Dew Computing Architecture for Cyber-Physical Systems and IoT. *Internet Things* **2020**, *11*, 100186.
18. Gusev, M. A Dew Computing Solution for IoT Streaming Devices. In Proceedings of the 40th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), Opatija, Croatia, 22–26 May 2017; pp. 387–392.
19. Gusev, M. Scalable Dew Computing. *Appl. Sci.* **2022**, *12*, 9510.
20. Sharma, S.; Sharma, C.; Sharma, K.; et al. Exploring Paradigms of Computing: An Analytical Retrospection of Dew Computing. *SN Comput. Sci.* **2025**, *6*, 566.
21. Ahammad, I.; Khan, A.R.; Salehin, Z.U. A Review on Cloud, Fog, Roof, and Dew Computing: IoT Perspective. *Int. J. Cloud Appl. Comput.* **2021**, *11*, 14–41.
22. Gusev, M. What Makes Dew Computing More than Edge Computing for Internet of Things. In Proceedings of the IEEE 45th Annual Computers, Software, and Applications Conference (COMPSAC), Madrid, Spain, 12–16 July 2021; pp. 1795–1800.
23. Ageed, Z.S.; Zeebaree, S.R.; Sadeeq, M.A.; et al. Comprehensive Study of Moving from Grid and Cloud Computing through Fog and Edge Computing towards Dew Computing. In Proceedings of the 4th International Iraqi Conference on Engineering Technology and Their Applications (IICETA), Najaf, Iraq, 21–22 September 2021; pp. 68–74.
24. Roy, S.; Panda, D.; Kim, B.-G.; et al. DewMetrics: Demystification of the Dew Computing in Sustainable Internet of Things. In *Dew Computing*; Springer: Singapore, 2023 ; pp. 3–39.
25. Ristov, S.; Cvetkov, K.; Gusev, M. Implementation of a Horizontal Scalable Balancer for Dew Computing Services. *Scalable Comput. Pract. Exp.* **2016**, *17*, 79–90.
26. Patel, H.M.; Chaudhari, R.R.; Prajapati, K.R.; et al. The Interdependent Part of Cloud Computing: Dew Computing. In *Intelligent Communication and Computational Technologies*; Springer: Singapore, 2017; pp. 345–355.
27. Al-Sarori, M.H.; Al-Ezzi Sufyan, M.M.; Al-Asaly, M.; et al. BERT and Beyond: A Comprehensive Survey of Natural Language Processing Techniques for Information Retrieval. *J. Intell. Commun.* **2025**, *4*, 93–114.
28. Ahmed, M.; Okba, K.; Harous, S.; et al. Synergizing Generative AI and the Internet of Things: Fundamentals, Challenges, and Opportunities. *KSII Trans. Internet Inf. Syst.* **2025**, *19*, 3440–3469.
29. Gusev, M.; Wang, Y. Formal Description of Dew Computing. In Proceedings of the 3rd International Workshop on Dew Computing, Toronto, ON, Canada, October 2018; pp. 8–13.

30. Wang, Y. Cloud-Dew Architecture. *Int. J. Cloud Comput.* **2015**, *4*, 199–210.
31. Sarkar, S.; Sengupta, A.; Das, A.; et al. Dew Computing Enabled Consumer Electronics for Sustainable Internet of Agricultural Things. In *Dew Computing*; Springer: Singapore, 2023; pp. 317–345.
32. Salam, T.; Ur Rehman, W.; Ud Din, I.; et al. Cooperative Dew Computing for Computational Offloading in Healthcare Monitoring. *IEEE Access* **2024**, *12*, 170041–170056.
33. Ghanbari, A.; Kardani, M.N.; Moazami Goodarzi, A.; et al. Neural Computing Approach for Estimation of Natural Gas Dew Point Temperature in Glycol Dehydration Plant. *Int. J. Ambient Energy* **2020**, *41*, 775–782.
34. Hernandez-Torres, J.A.; Torreglosa, J.P.; Sanchez-Herrera, R.; et al. Development of an Optimized Non-Linear Model for Precise Dew Point Estimation in Variable Environmental Conditions. *Appl. Sci.* **2024**, *14*, 10508.
35. Haji-Savameri, M.; Menad, N.A.; Norouzi-Apourvari, S.; et al. Modeling Dew Point Pressure of Gas Condensate Reservoirs: Comparison of Hybrid Soft Computing Approaches, Correlations, and Thermodynamic Models. *J. Pet. Sci. Eng.* **2020**, *184*, 106558.
36. Daneshfar, R.; Keivanimehr, F.; Mohammadi-Khanaposhtani, M.; et al. A Neural Computing Strategy to Estimate Dew-Point Pressure of Gas Condensate Reservoirs. *Pet. Sci. Technol.* **2020**, *38*, 706–712.
37. Khan, M.R.; Kalam, S.; Tariq, Z.; et al. A Novel Empirical Correlation to Predict the Dew Point Pressure Using Intelligent Algorithms. In Proceedings of the Abu Dhabi International Petroleum Exhibition and Conference, Abu Dhabi, United Arab Emirates, 11–14 November 2019.
38. Kaydani, H.; Mohebbi, A.; Hajizadeh, A. Dew Point Pressure Model for Gas Condensate Reservoirs Based on Multi-Gene Genetic Programming Approach. *Appl. Soft Comput.* **2016**, *47*, 168–178.
39. Mishra, K.; Rajareddy, G.N.; Ghugar, U.; et al. A Collaborative Computation and Offloading for Compute-Intensive and Latency-Sensitive Dependency-Aware Tasks in Dew-Enabled Vehicular Fog Computing: A Federated Deep Q-Learning Approach. *IEEE Trans. Netw. Serv. Manag.* **2023**, *20*, 4600–4614.
40. Savyanavar, A.S.; Ghorpade, D.V.R. Resource Allocation Scheme for Dew Computing Paradigm Using Mobile Grids. *Int. J. Innov. Technol. Explor. Eng.* **2019**, *8*, 199–203.
41. Rajareddy, G.N.; Mishra, K.; Majhi, S.K.; et al. M-SOS: Mobility-Aware Secured Offloading and Scheduling in Dew-Enabled Vehicular Fog of Things. *IEEE Trans. Intell. Transp. Syst.* **2025**, *26*, 4851–4864.
42. Mahapatra, A.; Mishra, K.; Pradhan, R.; et al. Next Generation Task Offloading Techniques in Evolving Computing Paradigms: Comparative Analysis, Current Challenges, and Future Research Perspectives. *Arch. Comput. Methods Eng.* **2024**, *31*, 1405–1474.
43. Zhang, G.; Band, S.S.; Ardabili, S.; et al. Integration of Neural Network and Fuzzy Logic Decision Making Compared with Bilayered Neural Network in the Simulation of Daily Dew Point Temperature. *Eng. Appl. Comput. Fluid Mech.* **2022**, *16*, 713–723.
44. Pan, Y.; Thulasiraman, P.; Wang, Y. Overview of Cloudlet, Fog Computing, Edge Computing, and Dew Computing. In Proceedings of the 3rd International Workshop on Dew Computing, Toronto, ON, Canada, 29–30 October 2018; pp. 20–23.
45. Ganesh, A.; Sree Divya, K.; Sasikala, C.; et al. Optimizing Task Scheduling: Exploring Advanced Machine Learning in Dew-Powered Cloud Environments. *Scalable Comput. Pract. Exp.* **2024**, *25*, 3701–3714.
46. Moussa, M.M.; Alazzawi, L. Cloud-Dew Computing Cyber Attack Detection Using Asynchronous Training for Distributed LSTM-AE. In Proceedings of the IEEE World AI IoT Congress (AIIoT 2023), Seattle, WA, USA, 7–10 June 2023; pp. 649–655.
47. Pinzón Castellanos, J. Contributions of Dew Computing Architecture to the Internet of Things: Comparisons between Pilot Implementations of Both Architectures. Master's Thesis, Autonomous University of Bucaramanga, Bucaramanga, Colombia, 2018. (in Spanish)
48. Alkhudhayr, H.; Ardah, H. Mitigating Cyberphysical Risks in IoT-Enabled Smart Transport Infrastructure. *J. Supercomput.* **2025**, *81*, 446.
49. Cao, Z.; Liu, L. A Note on "Authenticated Key Agreement Protocols for Dew-Assisted IoT Systems". *Cryptol. ePrint Arch*. **2023**, 1497.
50. Chukwuocha, C.; Thulasiram, R.K.; Thulasiraman, P.; et al. Ensuring Resource Availability with MRU/FRU Caching: A Dew-Blockcloud Model. In Proceedings of the 43rd International Convention on Information, Communication and Electronic Technology (MIPRO), Opatija, Croatia, 28 September–2 October 2020; pp. 1927–1933.
51. Jeyaraj, R.; Balasubramaniam, A.; Ma, A.K.; et al. Resource Management in Cloud and Cloud-Influenced Technologies for Internet of Things Applications. *ACM Comput. Surv.* **2023**, *55*, 242.

52. Amjad, H.R.S.M.M. IoT Based Cyber-Physical System in Automobile Devices with Dew Computing Architecture. 2024 . Available online: https://www.researchgate.net/publication/363382940_Print_IoT_Based_Cyber-Physical_System_in_Automobile_Devices_with_Dew_Computing_Architecture (accessed on 13 January 2026).
53. Medhi, K.; Hussain, M.I. Role of Dew Computing in Smart Healthcare Applications. In *Dew Computing*; Springer: Singapore, 2023; pp. 225–239.
54. Manocha, A.; Sood, S.K.; Bhatia, M. IoT-Dew Computing-Inspired Real-Time Monitoring of Indoor Environment for Irregular Health Prediction. *IEEE Trans. Eng. Manag.* **2023**, *71*, 1669–1682.
55. Manocha, A.; Bhatia, M.; Kumar, G. Dew Computing-Inspired Health-Meteorological Factor Analysis for Early Prediction of Bronchial Asthma. *J. Netw. Comput. Appl.* **2021**, *179*, 102995.
56. Khan, F.A.; Rahman, A.; Alharbi, M.; et al. Awareness and Willingness to Use PHR: A Roadmap towards Cloud-Dew Architecture Based PHR Framework. *Multimed. Tools Appl.* **2020**, *79*, 8399–8413.
57. Risteska Stojkoska, B.; Trivodaliev, K.; Davcev, D. Internet of Things Framework for Home Care Systems. *Wirel. Commun. Mob. Comput.* **2017**, *2017*, 8323646.
58. Dabbs, A.D.V.; Myers, B.A.; Mc Curry, K.R.; et al. User-Centered Design and Interactive Health Technologies for Patients. *CIN Comput. Inform. Nurs.* **2009**, *27*, 175–183.
59. Becker, J.T.; Dew, M.A.; Aizenstein, H.J.; et al. Concurrent Validity of a Computer-Based Cognitive Screening Tool for Use in Adults with HIV Disease. *AIDS Patient Care STDS* **2011**, *25*, 351–357.
60. Dogo, E.M.; Salami, A.F.; Aigbavboa, C.O.; et al. Taking Cloud Computing to the Extreme Edge: A Review of Mist Computing for Smart Cities and Industry 4.0 in Africa. In *Edge Computing: From Hype to Reality*; Springer Nature Switzerland: Cham, Switzerland, 2018; pp. 107–132.
61. Lipić, T.; Skala, K. The Key Drivers of Emerging Socio-Technical Systems: A Perspective of Dew Computing in Cyber-Physical Systems. In Proceedings of MIPRO 2017, Opatija, Croatia, 22–26 May 2017.
62. Andriulo, F.C.; Fiore, M.; Mongiello, M.; et al. Edge Computing and Cloud Computing for Internet of Things: A Review. *Informatics* **2024**, *11*, 71.
63. Mane, T.S.; Solutions, T.A.; Agrawal, H.; et al. Enhancing Usability of Cloud Storage Clients with Dew Computing. *Dew Computing* **2018**, 14.
64. Hirsch, M.; Mateos, C.; Zunino, A.; et al. A Task Execution Scheme for Dew Computing with State-of-the-Art Smartphones. *Electronics* **2021**, *10*, 2006.
65. Adhikary, F.; Paul, S.K.; Obaidat, M.; et al. Cache Computing for Dew Devices at the Edge Networks. In *Dew Computing*; Springer: Singapore, 2023 ; pp. 41–60.
66. Mateos, C.; Hirsch, M.; Toloza, J.; et al. Motrol 2.0: A Dew-Oriented Hardware/Software Platform for Batch-Benchmarking Smartphones. In Proceedings of the IEEE 45th Annual Computers, Software, and Applications Conference (COMPSAC), Madrid, Spain, 12–16 July 2021; pp. 1772–1777.
67. Ahammad, I.; Khan, M.A.R.; Salehin, Z.-U. Advancement of IoT System QoS by Integrating Cloud, Fog, Roof, and Dew Computing Assisted by SDN: Basic Framework Architecture and Simulation. *Int. J. Ambient Comput. Intell.* **2021**, *12*, 132–153.
68. Wang, Y.; Skala, K. The 3rd International Workshop on Dew Computing. In Proceedings of the 28th Annual International Conference on Computer Science and Software Engineering, Markham, ON, Canada, 29–31 October 2018; pp. 357–358.
69. Lynn, T.; Mooney, J.G.; Lee, B.; et al. *The Cloud-to-Thing Continuum: Opportunities and Challenges in Cloud, Fog and Edge Computing*; Springer International Publishing: Cham, Switzerland, 2020.
70. Srivastava, S.; Tadepalli, S.K.; Wang, Y.; et al. Dew Text Application Development. In Proceedings of the DEWCOM 2018, Toronto, ON, Canada, 29–30 October 2019.
71. Axak, N.; Rosinskiy, D.; Barkovska, O.; et al. Cloud-Fog-Dew Architecture for Personalized Service-Oriented Systems. In Proceedings of the IEEE 9th International Conference on Dependable Systems, Services and Technologies (DESSERT), Kyiv, Ukraine, 24–27 May 2018; pp. 78–82.
72. Frincu, M. Architecting a Hybrid Cross Layer Dew-Fog-Cloud Stack for Future Data-Driven Cyber-Physical Systems. In Proceedings of the 40th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), Opatija, Croatia, 22–26 May 2017; pp. 399–403.
73. Mishra, D.; Pursharthi, K.; Singh, M.; et al. Construction of Post Quantum Secure Authenticated Key Agreement Protocol for Dew-Assisted IoT Systems. *Int. J. Inf. Secur.* **2025**, *24*, 19.
74. Verma, U.; Sohani, M. An Efficient Lightweight Authentication Scheme for Dew-Assisted IoT Networks. *Secur. Priv.* **2024**, *7*, e360.
75. Singh, M.; Mishra, D. Security and Privacy Aspects of Authorized and Secure Communications in Dew-

Assisted IoT Systems. In *Dew Computing*; Springer: Singapore, 2023; pp. 79–101.
76. Ma, Y.; Ma, Y.; Cheng, Q. Cryptanalysis and Enhancement of an Authenticated Key Agreement Protocol for Dew-Assisted IoT Systems. *Secur. Commun. Netw.* **2022**, *2022*, 7125491.
77. Kar, B.; Sahu, U.; Thomas, C.; et al. HybridGuard: Enhancing Minority-Class Intrusion Detection in Dew-Enabled Edge-of-Things Networks. *Comput. Netw.* **2025**, *276*, 111966.
78. Harris, A.; Wang, Y. Disaster-Resilient Messaging Using Dew Computing. In Proceedings of the 15th International Conference on ICT Innovations, Skopje, North Macedonia, 24–26 September 2023; pp. 79–93.
79. Simpson, G.; Quist-Aphetsi, K. A Centralized Data Validation Approach for Distributed Healthcare Systems in Dew-Fog Computing Environment Using Blockchain. In Proceedings of the International Conference on Cyber Security and Internet of Things (ICSIoT), Accra, Ghana, 29–31 May 2019; pp. 1–4.
80. Ghosh, T.; Nath, I. Zero Trust Authentication for Dew Computing: Enhancing Cloud Security. *SSRN Electron. J.* **2025**.
81. Beysens, D.; Cooke, R.; Crobu, E.; et al. Computational Fluid Dynamics Study of a Corrugated Hollow Cone for Enhanced Dew Yield. *J. Hydrol.* **2021**, *592*, 125788.
82. Ghosh, B.; Roy, S.; Ahmed, N.; et al. Dew Aeroponics: Dew-Enabled Smart Aeroponics System in Agriculture 4.0. In *Dew Computing*; Springer, 2023; pp. 261–287.
83. Cui, X.; Chua, K.; Yang, W.; et al. Studying the Performance of an Improved Dew-Point Evaporative Design for Cooling Application. *Appl. Therm. Eng.* **2014**, *63*, 624–633.
84. Lekouch, I.; Lekouch, K.; Muselli, M.; et al. Rooftop Dew, Fog and Rain Collection in Southwest Morocco and Predictive Dew Modeling Using Neural Networks. *J. Hydrol.* **2012**, *448*, 60–72.
85. Stanco, G.; Botta, A.; Gallo, L.; et al. DewROS2: A Platform for Informed Dew Robotics in ROS. *Robot. Auton. Syst.* **2024**, *182*, 104800.
86. Dey, S.; Mukherjee, A.; Karmakar, A. Architecture of Fault-Tolerant Dew-Flash: Future of Agricultural Drone. *IETE J. Res.* **2025**, *71*, 2676–2685.
87. Ghosh, S. AdHocVDew: Graph Theory Based Dew Enabled 5G Vehicular Ad Hoc Network. *Mob. Netw. Appl.* **2024**, *29*, 1853–1871.
88. Stanco, G.; Botta, A.; Ventre, G. DewROS: A Platform for Informed Dew Robotics in ROS. In Proceedings of the 2020 8th IEEE International Conference on Mobile Cloud Computing, Services, and Engineering (MobileCloud), Oxford, UK, 3–6 August 2020; pp. 3–6.
89. Moussa, M.M.; Alazzawi, L. Distributed Hybrid DL Cyber-Attacks Detection Using Data Parallelism in Cloud-Dew Computing. In Proceedings of the 2023 IEEE Transportation Electrification Conference & Expo (ITEC), Detroit, MI, USA, 21–23 June 2023; pp. 1–6.
90. Valladares, S.; Toscano, M.; Tufiño, R.; et al. Performance Evaluation of the Nvidia Jetson Nano Through a Real-Time Machine Learning Application. In Proceedings of the International Conference on Intelligent Human Systems Integration, Palermo, Italy, 22–24 February 2021; pp. 343–349.
91. Alizamir, M.; Kim, S.; Kisi, O.; et al. Deep Echo State Network: A Novel Machine Learning Approach to Model Dew Point Temperature Using Meteorological Variables. *Hydrol. Sci. J.* **2020**, *65*, 1173–1190.
92. Qasem, S.N.; Samadianfard, S.; Sadri Nahand, H.; et al. Estimating Daily Dew Point Temperature Using Machine Learning Algorithms. *Water* **2019**, *11*, 582.
93. Mohammadi, K.; Shamshirband, S.; Motamedi, S.; et al. Extreme Learning Machine Based Prediction of Daily Dew Point Temperature. *Comput. Electron. Agric.* **2015**, *117*, 214–225.
94. Mohammadi, K.; Shamshirband, S.; Petković, D.; et al. Using ANFIS for Selection of More Relevant Parameters to Predict Dew Point Temperature. *Appl. Therm. Eng.* **2016**, *96*, 311–319.
95. Karmakar, A.; Ghosh, P.; Skala, K.; et al. Blockchain-Based on Dew Computing for Unreliable Network. In *Dew Computing*; Springer: Singapore, 2023; pp. 117–132.
96. Wang, Y.; Gusev, M. Decentralized Hardware Ownership Control: Dew Computing with Blockchain. In Proceedings of the 4th International Workshop on Dew Computing (DEWCOM 2019), Online, 9–10 November 2019; pp. 8–13.
97. Alorf, A. Blockchain and Dew Computing for Secure Energy Trading in Smart Grids: A Profit-Aware Approach. *SSRN Electron. J.* **2022**.
98. Wang, Y. A Blockchain System with Lightweight Full Node Based on Dew Computing. *Internet Things* **2020**, *11*, 100184.
99. Plakhteyev, A.; Perepelitsyn, A.; Frolov, V. Edge Computing for IoT: An Educational Case Study. In Proceedings of the 2018 IEEE International Conference on Dependable Systems, Services and Technologies, Kyiv, Ukraine, 24–27 May 2018; pp. 130–133.

100. Roy, S.; Sarkar, D.; De, D. DewMusic: Crowdsourcing-Based Internet of Music Things in Dew Computing Paradigm. *J. Ambient Intell. Humaniz. Comput.* **2021**, *12*, 2103–2119.
101. Singh, P.; Kaur, A.; Aujla, G.S.; et al. DaaS: Dew Computing as a Service for Intelligent Intrusion Detection in Edge-of-Things Ecosystem. *IEEE Internet Things J.* **2020**, *8*, 12569–12577.
102. Hirsch, M.; Mateos, C.; Rodriguez, J.M.; et al. DewSim: A Trace-Driven Toolkit for Simulating Mobile Device Clusters in Dew Computing Environments. *Softw. Pract. Exp.* **2020**, *50*, 688–718.
103. Sahoo, S.; Panigrahy, S.; Bhat, M.S.; et al. A Comprehensive Study on Leveraging Serverless Dew Computing for Advanced Data Privacy. *Trans. Emerg. Telecommun. Technol.* **2025**, *36*, e70193.
104. Subbiah, P.; Nagappan, K.; Bellam, K. Dew Computing for Industry 5.0. In *Next Generation Data Science and Blockchain Technology for Industry 5.0: Concepts and Paradigms*; John Wiley & Sons Inc.: Hoboken, NJ, USA, 2025; pp. 235–272.
105. Gusev, M. Serverless and Deviceless Dew Computing: Founding an Infrastructureless Computing. In Proceedings of the 2021 IEEE 45th Annual Computers, Software, and Applications Conference (COMPSAC), Madrid, Spain, 12–16 July 2021; pp. 1814–1818.
106. Zhao, L.; Li, H.; Zhang, E.; et al. Intelligent Caching for Vehicular Dew Computing in Poor Network Connectivity Environments. *ACM Trans. Embed. Comput. Syst.* **2024**, *23*, 1–24.
107. Sanabria, P.; Montoya, S.; Neyem, A.; et al. Connection-Aware Heuristics for Scheduling and Distributing Jobs under Dynamic Dew Computing Environments. *Appl. Sci.* **2024**, *14*, 3206.
108. Javadzadeh, G.; Rahmani, A.M.; Kamarposhti, M.S. Mathematical Model for the Scheduling of Real-Time Applications in IoT Using Dew Computing. *J. Supercomput.* **2022**, *78*, 7464–7488.
109. Olabisi, D.; Abubakar, S.K.; Abdullahi, A.T. Demystifying Dew Computing: Concept, Architecture and Research Opportunities. *Int. J. Comput. Trends Technol.* **2022**, *70*, 39–43.
110. Pal, M.N.; Sengupta, D.; Tran, T.A.; et al. Machine Learning-Based Sustainable Dew Computing: Classical to Quantum. In *Dew Computing*; Springer: Singapore, 2023; pp. 149–177.
111. Sosu, R.N.A.; Babu, C.N.; Frimpong, S.A.; et al. The Relevance of Blockchain with Dew Computing: A Review. In Proceedings of the 2020 43rd International Convention on Information, Communication and Electronic Technology (MIPRO), Opatija, Croatia, 28 September–2 October 2020; pp. 1934–1940.
112. Yu, Y.-C. Smart Parking System Based on Edge-Cloud-Dew Computing Architecture. *Electronics* **2023**, *12*, 2801.
113. Gordienko, Y.; Stirenko, S.; Alienin, O.; et al. Augmented Coaching Ecosystem for Non-Obtrusive Adaptive Personalized Elderly Care on the Basis of Cloud-Fog-Dew Computing Paradigm. In Proceedings of the 2017 40th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), Opatija, Croatia, 22–26 May 2017; pp. 359–364.
114. Wang, Y.; Leblanc, D. Integrating SaaS and SaaP with Dew Computing. In Proceedings of the 2016 IEEE International Conferences on Big Data and Cloud Computing, Social Computing and Networking, Sustainable Computing and Communications, Atlanta, GA, USA, 8–10 October 2016; pp. 590–594.
115. Ray, P.P.; Skala, K. Internet of Things Aware Secure Dew Computing Architecture for Distributed Hotspot Network: A Conceptual Study. *Appl. Sci.* **2022**, *12*, 8963.
116. Mukherjee, A.; De, D.; Dey, N. DewDrone: Dew Computing for Internet of Drone Things. *IEEE Consum. Electron. Mag.* **2021**, *12*, 52–57.
117. Medhi, K.; Ahmed, N.; Hussain, M.I. Dew-Based Offline Computing Architecture for Healthcare IoT. *ICT Express* **2022**, *8*, 371–378.
118. Kasera, R.K.; Acharjee, T. A Dew Computing-Based Smart Tomato Storage Monitoring Framework. *J. Ambient Intell. Smart Environ.* **2025**, *18*, 18761364251372647.
119. Singh, P.D.; Saini, G.; Singh, K.D.; et al. Dew Computing in Smart Agriculture to Improve Real-Time Data Processing and Decision-Making Capabilities for Sustainable Farming. In *Sustainable Computing and Intelligent Systems*; Springer: Cham, Switzerland, 2024; pp. 245–253.
120. Sanabria, P.; Tapia, T.F.; Neyem, A.; et al. New Heuristics for Scheduling and Distributing Jobs under Hybrid Dew Computing Environments. *Wirel. Commun. Mob. Comput.* **2021**, *2021*, 8899660.
121. Sanabria, P.; Tapia, T.F.; Toro Icarte, R.; et al. Solving Task Scheduling Problems in Dew Computing via Deep Reinforcement Learning. *Appl. Sci.* **2022**, *12*, 7137.
122. Chakraborty, S.; De, D.; Mazumdar, K. DoME: Dew Computing Based Microservice Execution in Mobile Edge Using Q-Learning. *Appl. Intell.* **2023**, *53*, 10917–10936.
123. Khatua, S.; Manerba, D.; Maity, S. Dew Computing-Based Sustainable Internet of Vehicular Things. In *Dew Computing*; Springer: Singapore, 2023; pp. 181–205.

124. Karmakar, A.; Banerjee, P.S.; De, D. MedGini: Gini Index Based Sustainable Health Monitoring System Using Dew Computing. *Med. Nov. Technol. Devices* **2022**, *16*, 100145.
125. Afaq, Y.; Manocha, A. Dew Computing-Assisted Cognitive Intelligence-Inspired Smart Environment for Diarrhea Prediction. *Computing* **2022**, *104*, 2511–2540.
126. Bera, S.; Dey, T.; Ghosh, S.; et al. Internet of Things and Dew Computing-Based System for Smart Agriculture. In *Dew Computing*; Springer: Singapore, 2023; pp. 289–316.
127. Manocha, A.; Masoodi, Z.S. Exploring the Potential of Dew Computing for Smart Healthcare: A Comprehensive Review. In Proceedings of the 2023 10th International Conference on Computing for Sustainable Global Development, New Delhi, India, 15–17 March 2023; pp. 1384–1389.
128. Longo, M.; Hirsch, M.; Mateos, C.; et al. Towards Integrating Mobile Devices into Dew Computing: A Model for Hour-Wise Prediction of Energy Availability. *Information* **2019**, *10*, 86.