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Website: ijcs.stmikindonesia.ac.id | E-mail: ijcs@stmikindonesia.ac.id

A Review of Blockchain-Rooted Energy Administration in Networking

Patikiri Arachchige Don Shehan Nilmantha Wijesekara
nilmantha@eie.ruh.ac.lk
Department of Electrical and Information Engineering, Faculty of Engineering, University of Ruhuna, Galle 80000, Sri Lanka

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Abstract

Energy Administration (EA) in networking involves improving energy efficiency by managing energy. The blockchain framework involves a chain of associated blocks that obviously protects the genuineness, upholds accountability, and upholds disguised-anonymity of its transactions/entries with the help of peer-to-peer consensus techniques and cryptographic mechanisms. Driven by the fact that existing surveys do not focus on the EA in the broad scope of networking, we review diverse blockchain-rooted EA solutions, where we recognize 7 roles of blockchain in EA and explore them in detail with regard to EA techniques, EA approaches, blockchain-linked factors, network-linked factors, and such. We assembled a first-stage sample of 80 document citations by appraising the articles for qualification criteria hunted from E-libraries operating a detailed and prolonged process. Considering the review, in blockchain-rooted EA, blockchain can facilitate storing and exchanging data in a trustworthy manner, operate energy-efficient consensus approaches, act as an energy manager, provide authentication and access control for EA, facilitate secure offloading for EA, and provide automated EA tasks operating smart contracts. Detailed exploration shows that from blockchain-rooted EA, 32.5% operate blockchain to store and exchange data for an EA task, 95% operate uniform blockchain, 30% operate PoW consensus, 82.5% operate fully decentralized EA, 57.5% operate cross-layer EA, and 10% operate in IoT networks. Finally, we debate the possibilities and barriers to the conception of blockchain-rooted EA and then present guidance to vanquish them.

1. Introduction

Energy Administration (EA) is an important aspect of both energy-constrained networks, among others Wireless Sensor Networks (WSNs), mobile networks, etc., and in energy non-constrained networks, such as vehicular networks, wired networks, etc., in behalf of improving the energy efficiency of communication and save additional cost of energy [1]. However, in energy-constrained networks, EA is critical, as the network devices have a limited amount of energy, and that energy is required to be efficiently managed for the sake of reducing device failures [2]. Energy administration, in particular, is a broad field that incorporates many techniques for managing energy in networks. First, transmission energy can be controlled rooted on a policy to strike an equilibrium among the coverage, throughput, etc. and available energy, and there are data link layer protocols such as IEEE 802.11e that have energy optimizations rooted in network contention [3]. Secondly, networks can operate hardware-rooted EA to achieve energy efficient processing and memory by using techniques, in particular dynamically scaling voltage and frequency, gating of power, gating of clock, duty cycling, etc., rooted on processor and memory load [4]. Moreover, it includes battery management in devices using voltage scaling, device sleeping, and energy balancing to sustain the symmetry of network energy generation and consumption for the sake of maximizing network lifetime [5]. Other tasks in energy administration include energy cognizant functioning such as energy conscious routing considering energy levels of terminals in the network in the routing process [6], energy cognizant resource allocation that allocates resources such as computational resources, memory in an energy efficient manner [7], network virtualization allowing resource sharing, optimal resource allocation, energy cognizant virtual network functions that can contribute to saving energy [8], and energy cognizant load balancing that distributes workload among the nodes to have a balanced utilization while at the same time minimizing energy expenditure [9]. Furthermore, it also includes energy harvesting to convert energy sources, such as renewable energy resources, into electricity for the sake of increasing network lifetime [10]. Additionally, it also includes energy trading (buying and selling of electricity) in networks such as smart grids, where a decentralized energy market can be created for peer-to-peer energy trading without intermediaries [11]. Finally, energy balancing involves balancing energy generation and consumption in the network to improve its lifetime and is important in energy-constrained networks such as WSNs, where compressive sensing and data aggregation can be operated to achieve an energy balance [12].

A given EA approach can belong to one of the layers: the physical layer (duty cycling, voltage control, transmission power control, etc.), the data link layer (energy efficient media access control layer protocols, multiplexing, contention aware transmission, etc.), the network layer (energy cognizant routing, energy cognizant load balancing, energy cognizant resource allocation), and the transport layer (congestion and error control) [13]. Energy management can occur in one of the three architectures: centralized, distributed, or hierarchical. In a centralized approach, there is a centralized energy manager responsible for EA, in contrast to a distributed approach, where energy managers are implemented in end nodes [14]. In a distributed approach, each node has the freedom to decide on energy related tasks such as when to switch off and activate, which is a scalable solution compared to the centralized approach [15]. On the other hand, in hierarchical EA, it involves the features of both centralized and distributed EA, where there is a hierarchy of energy managers with inheritance [16].

A blockchain essentially involves a chain of blocks associated in a uniform or non-uniform way, built upon the framework of the immutable ledger network [17]. Explicitly, transactions/blocks are bonded in unity via a designated block/transaction, archiving the hash of more than one originating transactions/blocks and locking them in place [18]. On top of that, they engage in a collective approval process, among others, proof-rooted collective approval or vote-rooted collective approval, for ratifying the blocks among those of the same level ahead of a transaction/block is inserted into the immutable ledger network [19]. In addition, they apply cryptographic hashing techniques to uphold the genuineness, and digital authentication to uphold transaction accountability [20]. Also, they are able to infuse reliable cryptographic mechanisms, among others, information disclosure prevention proofs and quantum-proof cryptography for warding off quantum assaults [21], bolstering the traits of secrecy maintenance in blockchain. Conversely, actual blockchain, in its very essence, which eschews cryptographic mechanisms, among others, public-private key pair encryption, for upholding secrecy maintenance, is not fully secrecy-maintained as a result of blockchain entries/transactions are with disguised anonymity, denoting that entries/transactions are confirmed by a pseudonymous ciphered address as a replacement for authentic addresses of gadgets [22]. Furthermore, the intensity of secrecy assurance is changeable in accordance with the immutable ledger category: confidential, collaborative, and transparent. Transparent blockchain is the standard distributed ledger, whereas confidential and collaborative blockchains hold a defined intensity of singular leadership, offering heightened secrecy and dominance over access control of information compared to transparent blockchain [23].

Confirming our exploration, energy administration in blockchain-rooted networking is 7-folded in terms of the blockchain-rooted approach. First, blockchain can be operated to store and exchange data in a trustworthy manner, preserving data integrity for achieving a secure EA task. As evidence, it can be operated to securely store and exchange data required for nodal battery management, such as voltages, currents, etc. [24]. Secondly, it can contribute to EA by operating energy-efficient consensus approaches, in particular proof-of-authority, proof-of-stake, green proof-of-work, etc., in blockchain networks to save energy compared to the energy hungry proof-of-work consensus [25]. Thirdly, blockchain can act as an energy manager by implementing EA tasks such as nodal battery management [26], smart power management systems in the SealedGrid architecture [27], etc. in blockchain. Next, blockchain has been extensively operated to secure peer-to-peer energy trading in energy networks, ensuring trust and privacy in trading while at the same time providing an opportunity for handling trading disputes [28]. Similarly, it is operated in energy balancing in networks such as smart grids, vehicular energy networks, etc. to provide decentralized and secure energy flexibility by storing collected data in blockchain and aiding to balance energy supply and demand by cooperatively delivering energy for the demands [29]. Furthermore, blockchain can facilitate robust authentication and access control to get rid of Sybil attacks for the sake of providing anonymous authentication for securing an EA task using a conventional approach such as energy harvesting, energy cognizant network virtualization, etc. [30]. Moreover, blockchain has been operated for secure offloading, resisting security vulnerabilities in offloading and EA tasks for the sake of jointly performing an EA task such as energy harvesting in a secure manner [31]. Finally, Smart Contracts (SCs) have been extensively utilized to automate energy administration tasks such as battery management [26], energy cognizant resource allocation [32], handling trading disputes in energy trading [28], etc.

We'll then evaluate our review against other comparative studies. The review paper [33] presents existing work on blockchain for the internet of energy only and does not investigate on the broad scope of EA in blockchain-rooted networking. Similarly, the review paper [34] also focuses on blockchain-rooted solutions for renewable EA in grids. Likewise, the review papers [35], [36], [37], [38], etc. review on blockchain-rooted energy trading only. Furthermore, the survey paper [39] focuses only on blockchain-rooted solutions for peer-to-peer micro-grids. Moreover, the survey paper [40] focuses on blockchain and artificial intelligence solutions for the administration of energy clouds. None of these surveys focus on EA in the broad scope of blockchain-rooted networking. Therefore, we are the leading inspectors reviewing in this broad scope on diverse blockchain-rooted solutions for EA in networking incorporating diverse EA techniques where blockchain has diverse roles (7, rooted in this review) in the EA process. Thus, this review redresses a deficiency in the current state of knowledge and will be very useful for future researchers, as we analyze the blockchain-rooted EA frameworks for the sake of identifying barriers and possibilities and proposing guidance to overcome them.

Figure 1 conveys the index of subjects of this overview.

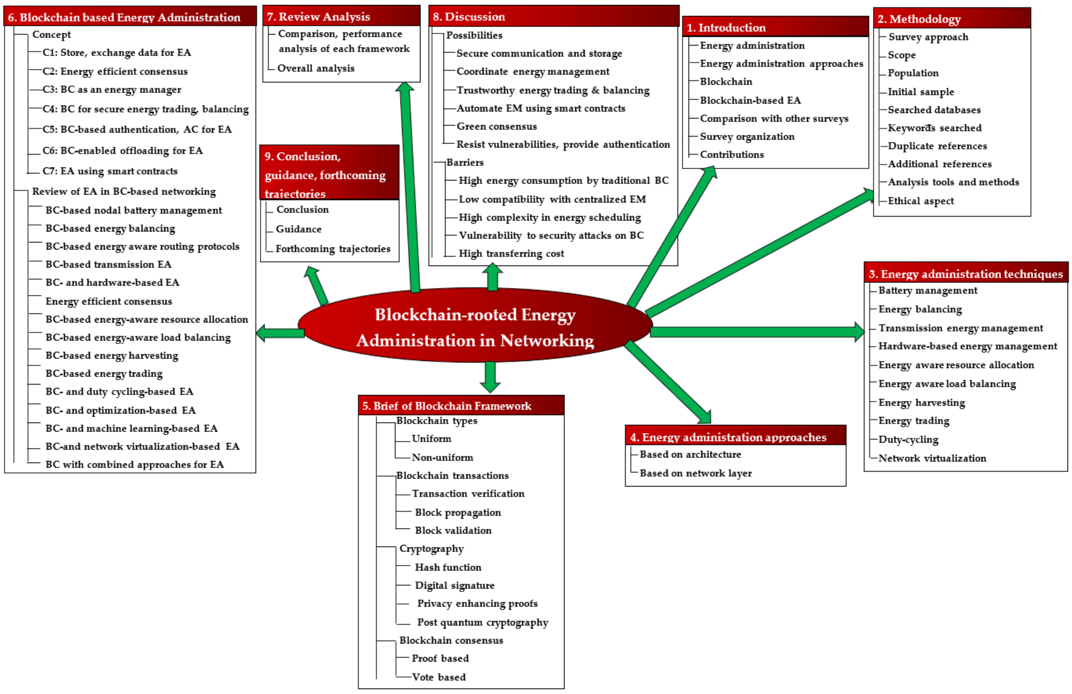


Figure 1 Index of subjects of overview of blockchain-rooted energy administration in networking.

1.1 Contributions to Prevalent Literature

- We divided and briefly clarified a briefing of different energy administration techniques (Section 3);
- Different classifications of energy administration methods in data transfer networks are briefly clarified (Section 4);
- A briefing on the blockchain network is unveiled (Section 5);
- Study on prevalent blockchain-rooted energy administration frameworks in data transfer networks (Section 6);
- Explore exhaustively on the studied blockchain-rooted energy administration frameworks (Section 7);
- The possibilities and barriers of blockchain-rooted energy administration are presented (Section 8);
- Proposing guidance and forthcoming trajectories for operating blockchain rooted energy administration are unveiled (Section 9).

2. Methodology

This review studies the extant investigations on blockchain-rooted energy administration present as electronic documents over the course of history, harnessing a detailed and prolonged process [41]. On top of that, it assesses a multitude of angles of energy administration in networking and the immutable ledger framework. For that reason, all novel scholarly articles and web documents documented on energy administration, blockchain-rooted energy administration, and blockchain represent the sample space in the frame of this work. However, the sample space references are impenetrable to study in this piece of work. For that reason, harnessing the right query phrases and qualification criteria, we harvested 83 references from novel scholarly articles and web documents.

We hunted Google Scholar intellectual content searching tool, ScienceDirect scientific data repository, ACM E-library, Wiley E-library, MDPI web content finder, and IEEE Xplore electronic technical storage. The top picked query phrases were "Network energy administration" OR "Blockchain-rooted network energy administration" OR "Blockchain-rooted nodal battery management" OR "Blockchain-rooted energy balancing" OR "Blockchain-rooted energy cognizant routing" "Blockchain-rooted transmission EA" OR "blockchain and hardware rooted EA" OR "blockchain energy efficient consensus" OR "Blockchain-rooted energy cognizant resource allocation" OR "Blockchain-rooted energy cognizant load balancing" OR "Blockchain-rooted energy harvesting" OR "Blockchain-rooted energy trading" OR "Blockchain-rooted duty cycling" OR "Blockchain and optimization rooted EA" OR "Blockchain and machine learning rooted EA" OR "blockchain and network virtualization rooted EA" OR "Blockchain".

Several determinants for appraising the articles established the qualification criteria. First, the cited document demands English expression, and secondly, it has to be extraordinarily germane to the query phrase. Next, for the sake of strengthening the trustworthiness of conducted review, periodical documents were elevated in importance than symposium papers and draft research papers. Still, we didn't give preference to investigating studies within a given document publisher inside the qualification criteria; conversely, we esteemed all document publishers similarly. The last qualification criterion expresses that a given cited document requires publication across the years of 1975 and 2023.

The first-stage sample was lessened to 80 document citations; afterwards, it was revealed that 3 document citations were redundancies. On top of that, we recited elucidations and explanations with respect to the multiple areas of interest tendered in this review using 13 cited documents. To make a comparison of this review with past reviews, we ultimately appended 8 review articles to the array of publications, securing the absolute total of document citations to 101.

To gauge prevalent energy administration in blockchain networking, taking into account several determinants, among others blockchain characteristics, energy administration characteristics, network qualities, and proficiency, we harnessed the tabulated data presentation for review content analysis. On top of that, we constructed graphical representations harnessing the MS spreadsheet application to neutrally appraise review data bonded to energy administration-rooted and blockchain-rooted determinants.

Ethics have no bearing inasmuch as this review corresponds with data transfer networks. Tables and Figures are presented center, as shown below and cited in the manuscript.

3. A Brief of Different types of energy administration Techniques

3.1. Battery Management

Battery EA techniques are typically operated in wireless networks with devices having limited battery power. Nodal EA and energy balancing are two techniques used for battery EA.

3.1.1. Nodal battery management

In nodal EA techniques, in particular, dynamic voltage scaling to dynamically allocate voltage to the microprocessor can be operated. As evidence, in distributed micro-sensor networks, the scaling of voltage dynamically upon the sensor instrument has been realized using a DC-DC stabilizer and a power-cognizant stabilizer [42]. Other techniques include dynamic power management techniques, in particular the sleeping of devices under low or no load conditions to save power. Research has shown that the approach of devices sleeping during idle times, such as in the absence of packets to process, can substantially save node energy compared to keeping the network devices active all the time [43].

3.2. Energy balancing

Energy balancing techniques attempt to maintain a balance among the network energy generation and energy consumption by predicting or measuring the generation and consumption dynamically and balancing the consumption to match with the generation to maximize network lifetime. These techniques are driven by data regarding energy consumption and generation, such as energy sources, channel conditions, residual battery level, etc. [44]. In [12], compressive sensing rooted data aggregation is utilized to balance the energy of instruments in a sensor network, which further reduces energy consumption by balancing the load to transmit data through cluster heads to sink nodes. This concept of data aggregation by forming clusters hierarchically is graphically conveyed in Figure 2.

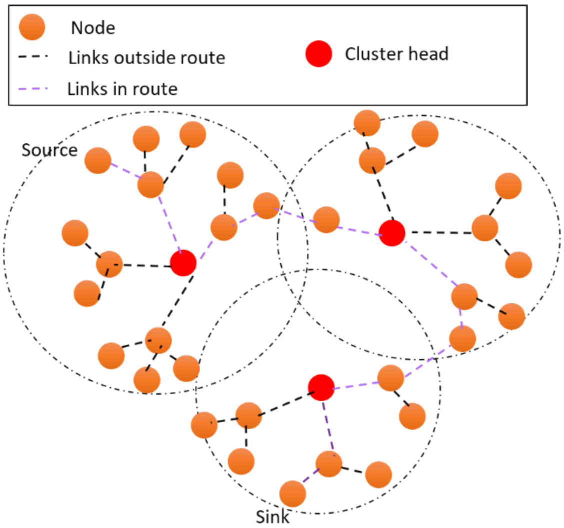


Figure 2 Energy balancing by compressive sensing rooted data aggregation by hierarchical cluster formation.

Moreover, in [45], for the sake of equalizing the energy depletion of the network, low energy depleting nodes are planned using a specified ratio of desired operations among functioning and nearby instruments.

3.3 Transmission Energy Management

Transmission power management involves adjusting transmission power rooted on routing protocols, transmission policies, or data link layer protocols.

3.3.1 Routing protocols

Energy cognizant routing -- Energy cognizant routing approaches contemplate on the instrument energy levels in the network and select routes that cause the minimum amount of energy depletion to improve the network lifetime [46]. An energy-cognizant routing method for biomedical low-power sensor networks uses an objective function that considers the expected transmission count and residual energy on each sensor device to find out the best paths to route packets [6]. Moreover, in [47], an energy cognizant routing approach is operated in data center networks using a heuristic algorithm to select a few network paths as extensively as possible to conserve energy of network devices.

Cluster rooted routing -- In cluster-rooted routing, the network is fragmented into clusters, where there is a cluster head that gathers and combines data from cluster participants and forwards it to the base station. Clustering reduces long distance transmissions by using energy cognizant clustering techniques that cluster the network and select the cluster head to reduce energy consumption. MOFPL is a multi-mission energy cognizant routing method that considers the impact of energy, communication latency, data transmission rate, displacement, and cluster size per area in the mission of fractionalized particle lion optimization for the sake of finding out the best cluster head and deciding the routing path [1]. Moreover, I-AREOR is an energy balancing opportunistic routing protocol rooted in clustering, considering residual energy, relative distance, regional density, and energy parameters rooted in a dynamic threshold [48].

3.3.2. Transmission policy

Transmission policy dictates the principles concerning data transmission by network devices. Transmission power can be controlled dynamically to reach a balance among the available power and the required throughput or packet delivery ratio. It can also be controlled by considering factors such as signal strength, distance to the receiver, etc. Some use a probability distribution to estimate network parameters for the sake of optimizing transmission power. In [49], flexible transmission power control is carried out in WSNs by each network instrument building a system for its nearby instruments to maintain a relationship with transmission power and link quality such that pair-wise transmission power control can be operated for each individual link. Moreover, transmissions can include efficient error handling techniques, in particular forward error correction, to reduce retransmissions and save energy. An innovative error recognition and rectification code known as the low complexity parity check code has been offered to rectify successive and non-successive bit errors that occur in data transmissions in wireless networks with low complexity without requiring reiterations in an energy efficient manner, preventing retransmission and also saving energy due to the low decoding complexity [50].

3.3.3 Data link layer protocols

MAC layer protocols such as IEEE 802.11e and IEEE 802.15.4e have energy optimization approaches rooted in network contention. Moreover, data-link frame aggregation can be operated to save energy by reducing communication overhead. As evidence, EEFA is a IEEE 802.11n network frame aggregation technique for energy-efficient scheduling that changes the frame size dynamically considering frame error rates for the sake of reducing energy consumption and channel contention [3]. Other techniques include collision avoidance (Eg: CSMA-CD) and multiplexing methodologies (Eg:time division multiple access) to reduce retransmission and save energy. Fatma et al. [51] present an energy optimized multiple-channel media access control methodology for underwater acoustic networks to achieve collision free communication by operating a control channel having a single slot allocated using grid-rooted slot assignment and multiple data channels allocated using quorum-rooted channel allocation, where simultaneous handshaking takes place, further saving energy.

3.4 Hardware rooted EA

In contrast to nodal battery management, hardware-rooted EA takes a device's component level approach to saving energy rather than the whole device itself. Energy efficient processing and memory resources are the key components of this approach.

3.4.1 Processor

The power management schemes for the processor deal with reducing the number of performed calculations, scaling voltage and frequency dynamically to control the operating voltage and clock frequency rooted on processor load, switching to idle states during no load conditions, power gating to shutdown unused cores, energy cognizant processor scheduling, and so on. Energy consumption can be reduced by employing efficient algorithms that consume a low amount of processor power [52]. Dynamic Voltage and Frequency Scaling (DVFS) has been offered and tested for micro-controller power control in wireless sensor nodes, and the efficiency of power control can be increased by selecting an appropriate DVFS technique rooted in micro-controller type [4]. Recently, a decentralized, three-fold Lyapunov optimization has been operated to curtail energy utilization in multi-core micro data centers by optimizing workload scheduling, per processor power gating, and per processor DVFS [53].

3.4.2. TCAM

Ternary Content Addressable Memory (TCAM) is a power-eating memory operated in routers in networks to store flow rules. Energy consumption in TCAM can be reduced by effective voltage scaling, partial TCAM activation, clock gating, etc. In [54], DVFS is operated for routing paths using TCAM in software-defined networks for the sake of creating a green data path where the controlling is done by the SDN controller and DVFS for TCAM is implemented in the switches. Moreover, GreenTCAM is a packet classification technique to reduce TCAM energy consumption where packet flow rules are classified into TCAM blocks such that each incoming packet needs to activate a minimum subset of these blocks for packet matching [55].

3.5. Energy cognizant resource apportionment

Energy cognizant resource apportion involves the allocation of resources such as computational resources, memory, etc. in cloud computing environments while being aware on the energy consumption. As an evidence, in [7], hybrid meta-heuristics: group teaching and rat farm optimization techniques are jointly operated for energy cognizant resource apportion optimization in a cloud computing environment where there is a feature extraction process and feature reduction using principal component analysis before optimization. Resources can be allocated dynamically by using predictive analytics to forecast energy consumption and work load demands and proactively allocate resources such that resource allocation is proportional to real-time demand. Fuzzy-rooted inference is used to develop knowledge regarding energy consumption, and it is operated in a cuckoo search algorithm to allocate resources in an energy optimizing form in a vehicular cloud computing situation [13].

3.6. Energy cognizant Load balancing

In energy cognizant load balancing, the workload is distributed among nodes to maintain balanced utilization while minimizing energy simultaneously. These methodologies attempt to equalize performance and energy efficiency [56]. Energy cognizant and QoS cognizant load balancing for renewable energy driven heterogeneous networks has been feasible by optimizing global network level weighted load utility for the sake of deriving online and offline algorithms to solve it [57]. Moreover, the workloads can be routed to servers run by renewable energy, known as green data centers, when possible to balance load and reduce energy consumption at the same time. In [58], optimization is utilized to distribute requests in data center networks considering energy consumption and cost, having a policy considering time zones, energy prices, and green energy.

3.7. Energy harvesting

Energy harvesting involves directly using available energy from the surrounding environment (renewable and ambient sources) to convert energy from a particular domain into electricity. This can be operated in network systems to amplify the network's surviving time and reduce the requirement for battery replacements. In [10], a solution to the limited energy available in WSNs is provided by solar energy harvesting for battery charging of the sensor instruments, which has resulted in high network surviving time and elevated throughput. In a wireless sensor network, the time division multiple access technique has been operated to divide the time into an energy harvesting period and a data transmission period for every sensor instrument, and these sensor instruments are scheduled to optimize energy efficiency by having a constraint such that an instrument can transmit if and only if its harvested energy is higher than energy consumption [59].

3.8. Energy trading

Purchasing and disposing of energy as electricity or other forms of energy in a market-driven environment is involved in energy trading. This concept is useful, especially in smart grids for decentralized energy trading, which is graphically conveyed in Figure 3.

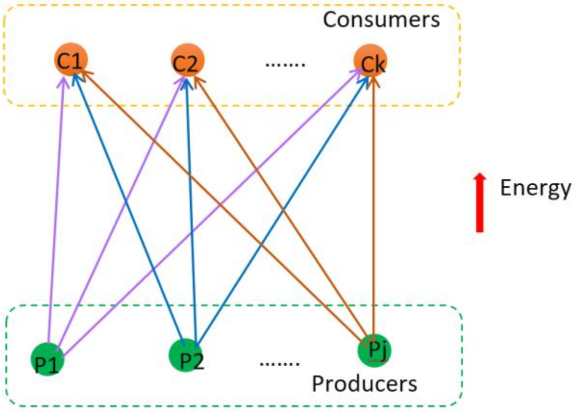


Figure 3 Peer to peer energy trading concept.

In [11], a decentralized market clearing technique for peer instrument-to-peer instrument energy trading among energy producers and consumers in a smart grid while considering agent secrecy, energy losses, and utility fees has been studied. Blockchains allow peer instrument-to-peer instrument energy trading that facilitates peers selling and buying energy without intermediaries. Moreover, customers can be incentivized to adjust their energy consumption during peak demand periods. Thus, some have used game theory to model interaction in the energy trading process among peers within a smart-grid that has been proven to reduce carbon emissions and energy costs [60].

3.9. Duty-cycling

Duty cycling is a technique to manage the power consumption of devices by periodically turning devices on and off. Conventional duty cycling involves implementing a fixed duty cycle for sleeping and waking devices. Thus, research has shown that the network coordinated duty cycling technique is more robust and efficient than fixed or random duty cycling at the expense of extra control overhead [61]. However, the modern approach to duty cycling is to optimize it rooted in operation styles and residual energy presence to dynamically manage energy responding to varying network conditions. To match with duty cycling, devices can be intelligently scheduled such that essential tasks are performed during the active period and vice versa. An energy efficient approach to adaptively controlling the duty cycle in a QoS cognizant form in WSNs has been feasible by adaptively changing the duty cycle rooted in the magnitude of the queue and precedence category of a packet, resulting in less waiting time of packets in queues [2].

3.10. Network virtualization

Network virtualization condenses and dissociates the network reserves from the underlying physical infrastructure. Due to the resource sharing capability, network isolation and segmentation allowing optimal resource allocation, support for network function virtualization to implement energy-aware network functions can contribute to better network EA. Network function virtualization has been realized in an energy optimizing form in an optical network supported by 5G mobile networks, where network functions are virtualized and mixed integer linear programming optimization is used to curtail aggregate power utilization by optimizing virtual machine location and utilization, showing that virtualization can result in a vast amount of energy savings [8]. Virtual network embedding involves the mapping of virtual demands to physical resources. In [62], a multi-objective network traffic bottleneck and energy cognizant virtual network embedding have been realized by mapping links using software-defined networking, where energy control is realized by setting inactive nodes to sleep mode.

Table 1 conveys an overview of prevalent literature on EA techniques.

Table 1 An overview of prevalent literature on energy administration techniques.

EA technique	**Prevalent literature**	**Manner**	**Performance**
Nodal battery management	DVS [42]	Dynamic voltage scaling using power aware regulators	Save device energy
	Reducing energy [43]	Sleeping and rate adaption	Halve energy consumption with small latency increment
Energy balancing	EB-data aggregation [13]	Compressive sensing-driven data aggregation	Improved network lifetime, low energy consumption, variance
	Steerable arguments [45]	Scheduled using a given ratio of desired functions	Improves network coverage quality, low energy consumption
Energy	EAR-BM [6]	Objective function -- expected TX	Network lifetime (21%), Peak energy

aware routing		count, residual energy	consumption (12%)
	EAR-DC [47]	Heuristic algorithm to select few network paths	Save network device power consumption
Cluster-rooted routing	MOFPL [1]	Multi-mission fractionalized particle lion optimization	High normalized network energy
	I-AREOR [48]	Consider residual energy, distance, density, energy parameters	High efficiency in maximizing network lifetime
Transmission policy	ATPC [49]	Pair-wise adaptive transmission power, link quality control	Fine tuning capability with more energy saving
	Efficient energy [50]	Low complexity parity check code	Energy efficient and 3 dB code gain
Data link layer protocols	EEFA [3]	IEEE 802.11n network frame aggregation technique	Reduce energy consumption and channel contention
	Collision avoidance [51]	Multi-channel media access control protocol	Energy saving control and data channel allocation
Processor EA	DVFS [4]	DVFS for micro-controller	57% increment of normalized power
	Online EA [53]	Lyapunov optimization to processor power gating, DVFS	4.5 times energy efficiency improvement
TCAM EA	Green data path [54]	DVFS for TCAM	Power consumption doesn't increase under high frequency
	GreenTCAM [55]	Packet flow rules are classified into TCAM blocks	93.6% power reduction, 5.6% TCAM overhead
Energy aware resource allocation	EARA [7]	Meta-heuristics: group teaching and rat farm optimization	High cost saving and energy efficiency
	Fuzzy-EARA [13]	Fuzzy inference, cuckoo search-rooted RA	Better make span, execution time, delay
Energy aware load balancing	Energy, QoS-aware LB [57]	Optimize global network level weighted load utility	Better load balancing and call blocking probability
	Cost and Energy-aware LB [58]	Optimize (distribute requests) considering energy con., cost	35% decrement in brown energy consumption
Energy harvesting	Solar energy harvesting [10]	Harvest solar energy to charge batteries of sensors	High network lifetime and throughput
	EE resource allocation [59]	TDMA-rooted energy harvesting and transmission	High energy efficiency in resource allocation
Energy trading	P2P-ET [11]	ET considering privacy, power losses, and utilization fees	Convergent, scalable solution
	Game theoretic ET [60]	Game theory to model interactions in energy trading process	Low carbon emissions and energy costs
Duty cycling	Sleep algorithms [61]	Network coordinated duty cycling	Achieve high duty cycle reduction having extra overhead
	Adaptive duty cycling [2]	Queue size and packet priority class rooted adaptive DC	Less queue packet waiting time, improved energy efficiency
Network virtualization	Energy-aware NFV [8]	Optimizing virtual machine location and utilization	Large energy savings
	Energy, congestion-aware VNE [62]	Congestion, energy cognizant VNE by sleeping and SDN	Improved runtime, energy consumption saving, low congestion

4. Different classification of Energy administration Approaches

4.1. Rooted in Energy administration architecture

4.1.1. Centralized

In centralized EA, a centralized authority is responsible for monitoring the network and making EA decisions. This approach is easy to manage; however, it can cause high latency and make it vulnerable to the central nexus of failure [63]. As evidence, in [14], a centralized EA and monitoring application is operated to minimize energy consumption and the footprint of 5G cross-haul infrastructure with the aid of software-defined networking.

4.1.2. Distributed

Distributed EA involves a distributed approach where energy managers are implemented at end nodes or close to end nodes (the network edge), without having a centralized authority. As evidence, in 5G ultra dense networks, a distributed approach for EA in the network has been implemented by allowing each cell to decide when to activate or deactivate itself, taking network traffic and signalling among the cells into consideration [15].

4.1.3. Hierarchical

In hierarchical architecture, a hierarchy of energy managers can exist, extending from local energy managers up to centralized managers, where energy managers in the lower levels can inherit from the upper levels. As evidence, a hierarchical power regulation approach in a two-tier multifarious mobile network operates a macrocell base station to decide the user power, considering the uplink power budget, and then femtocell users use their transmission power with interference allowance to suppress cross-tier interference [16].

4.2. Rooted in Network layer

Communication network EA approaches can be classified rooted on the OSI communication layer to which the EA technique belongs [64]. Thus, there are basically 4 layers in which the EA technique can operate: the physical, data link, network, and transport layers.

4.2.1. Physical layer

These include device level (duty cycling, voltage control, nodal battery management, transmission power control, etc. for switches, routers, etc.), energy harvesting, and device hardware component level (processors, memory) EA approaches.

4.2.2. Data link layer

In energy administration in the data link tier, energy efficient Media Access Control (MAC) protocols such as collision avoidance, contention aware transmissions, multiplexing, etc. are used to reduce energy consumption.

4.2.3. Network layer

Network layer EA approaches include energy efficient routing protocols, energy cognizant load balancing, etc.

4.2.4. Transport layer

Transport layer EA includes congestion control and error control techniques in transport layer protocols such as Transmission Control Protocol (TCP) [65].

4.2.5. Cross-layer techniques

In these techniques, multiple layers of the OSI layer may be incorporated to achieve the EA task. Examples are energy balancing, energy trading, energy cognizant resource allocation, network virtualization, etc.

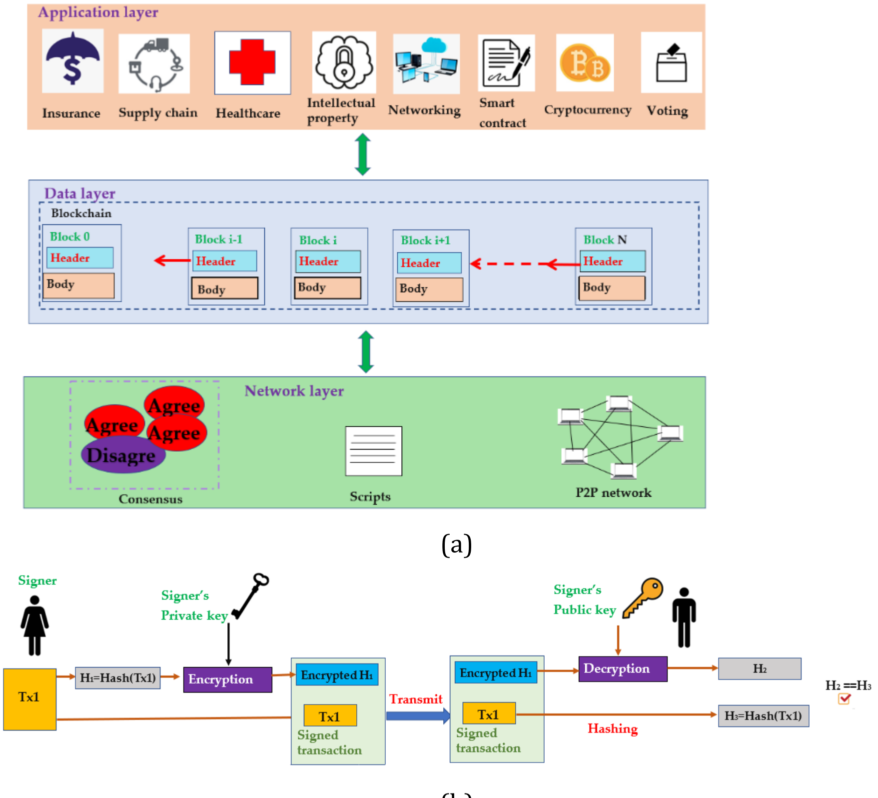
Table 2 conveys an overview of prevalent literature on EA approaches.

Table 2 An overview of prevalent literature on EA approaches.

Energy management approach	**Prevalent literature**	**Manner**	**Performance**
Centralized	Energy management [14]	Minimize energy consumption of infrastructure using SDN	Cost efficient resource utilization, energy saving
Distributed	Energy saving management [15]	Cell activation, deactivation, signaling	30% reduction in energy consumption
Hierarchical	Hierarchical power control [16]	Macrocell-femtocell transmission power control with interference allowance	Cross-tier channel gains with same outage
Physical layer	Sleep algorithms [61], Adaptive duty cycling [2], DVFS [4], Online EA [53], Green data-path [54], GreenTCAM [55], ATPC [49], DVS [42], Reducing energy [43], Solar energy harvesting [10], EE resource allocation [59]	Refer Table 1	Refer Table 1
Data link layer	EEFA [3], Collision avoidance [51]	Refer Table 1	Refer Table 1
Network layer	EAR-BM [6], EAR-DC [47], MOFPL [1], I-AREOR [48], Energy, QoS-aware LB [57], Cost and Energy-aware LB [58]	Refer Table 1	Refer Table 1
Cross layer	EB-data aggregation [12], steerable arguments [45], P2P-ET [11], Game theoretic ET [60], EARA [7], Fuzzy-EARA [13], Energy-aware NFV [8], Energy, congestion-aware VNE [62]	Refer Table 1	Refer Table 1

5.1. A Brief of Blockchain Framework

A chain of associated blocks or entries/transactions composes the immutable ledger, commonly called the blockchain. The blockchain framework consists of applications running on blockchain implemented on a data layer that uses consensus, peer to peer networking concepts of the network layer, as conveyed in Figure 4a.



(a)

(b)

Figure 4 Blockchain framework and transaction verification process. (a) Blockchain framework. (b) Digital signature transaction verification.

5.2. Designs

Every distinct block on a uniform blockchain, which composes of a data unit and header unit, is bridged to its prior block (omitting the root block), making use of the prior block's hash, and the entries/transactions in a data unit are mapped into a Merkle tree formation [18].

A non-uniform blockchain is composed of an accumulation of associated entries/transactions, where one entry/transaction could potentially endorse several different entries/transactions that were created ahead of time. These entries/transactions are absent in data units and header units, so Merkle trees are lacking [19].

5.3. Transactions/Entries

A node can kick-start a blockchain transaction/entry, which is, in the mean time, relayed to all those of the same level inside the network and locked, making use of the sender's unshared encryption key. A consensus protocol will kick-start once each node makes use of the public digital key to ratify the transaction/entry [66]. Computational nodes habitually take part in consensus/collective approval by inserting the transaction/entry enclosed by a block, which is, in the mean time, relayed to the immutable ledger network and shared by each node in the immutable ledger network, ensuing block ratification.

5.4. Cryptography

To uphold the genuineness of entries/transactions in the blockchain, a hashing technique is made use of to deliver a permanent size hash with scarcer crossings [20].

Making use of digital authentication, public-private key pair encryption that carries a secure key pairing is made use to ratify entries/transactions. To bolster the solitude of entries, it's possible as well be made use to encipher blockchain entries/transactions [67]. The transaction verification using digital authentication is conveyed in Figure 4b.

Information disclosure prevention proofs are made use to ratify entries'/transactions' accuracy, shrouding in secrecy the personal data of entries/transactions, bolstering solitude and inhibiting the relaying of delicate records [68].

Quantum-proof cryptography makes use of efficacious cryptographic protocols that are shielded from assaults from quantum data processors, among others improved Ed25519, Kyber, and the rest [21].

5.5. Consensus/Collective approval

Blockchain consensus makes use of widespread approval to establish and ratify inceptive blocks, upholding the genuineness of the immutable ledger network.

In vote-rooted collective approval, insights are delivered and retrieved in the midst of those of the same level as they partner in tandem to ratify blocks. In great demand, vote-rooted collective approval protocols make use of byzantine fault-resilience collective approval, inside which a coordinator inserts entries/transactions enclosed by a block, relays it, and nodes re-relay it to ratify the block retrieved using the parent is alike [22]. After each node got alike multiples of an inceptive block using above the 66% mark of the network's nodes, the block could be inserted into the immutable ledger.

Proof-rooted collective approval requires nodes to deliver compelling ratification due to the fact that they could be requited to insert an inceptive block into the immutable ledger. The most favored proof-rooted collective approval protocol is labeled proof-of-work, imposing a node to work diligently by fixing a tricky predicament to uphold its accountability [66].

6. Blockchain-rooted Energy administration in Networking

6.1 Conception

Hinging on this literary analysis, the blockchain-rooted energy administration conception can be subdivided into the next 7 subdivisions.

- C1 -- Blockchains to store and exchange data in achieving an energy administration task;
- C2 -- Operating energy efficient consensus approaches;
- C3 -- Operating blockchain as an energy manager;
- C4 -- Operating blockchain for secure energy trading and balancing;
- C5 -- Blockchain-rooted authentication and access control for energy administration using a traditional approach.
- C6 -- Blockchain enabled secure offloading for energy administration.
- C7 -- Operating an energy administration task using SCs;

Figure 5 graphically conveys the conception of blockchain-rooted energy administration in networking.

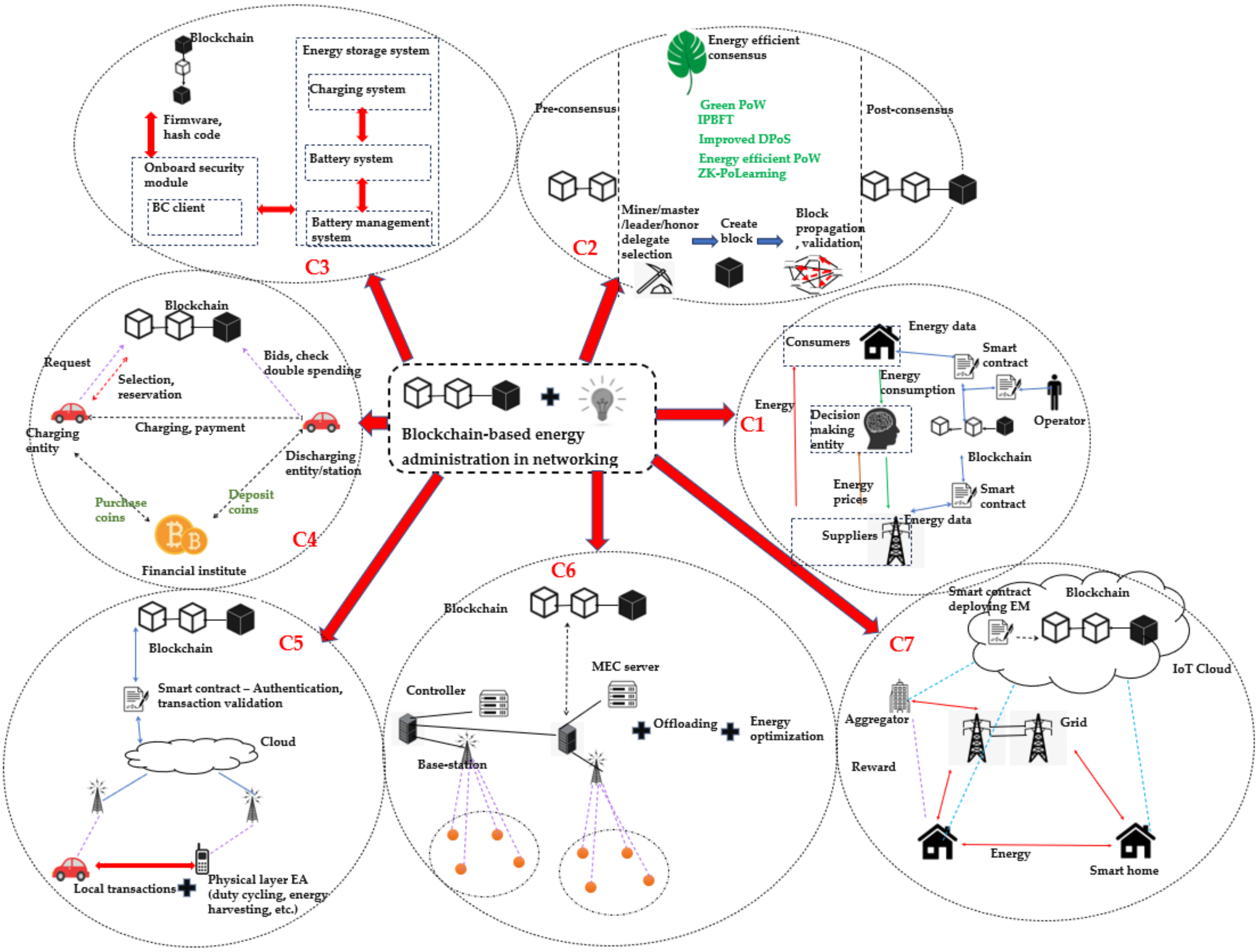


Figure 5 Conception of blockchain-rooted energy administration in networking.

6.2. Existing studies for blockchain-rooted EA in Networking

6.2.1. Blockchain-rooted Nodal battery management

Hyperledger-fabric blockchain has been offered as a secure communication framework in Internet of Things (IoT) wireless battery management systems to exchange, store, and synchronize data such as voltage, current, etc. for nodal battery control [24]. For efficient battery management by charging or swapping batteries in a network of electric vehicles, two blockchain-rooted implementations: Ethereum blockchain with SCs and the IOTA non-uniform blockchain have been effective for secure battery management [26]. Moreover, blockchain has been effective in managing critical tasks in a battery management system such as checking firmware, generation of patches, etc. for the sake of preventing firmware security vulnerabilities in an IoT network [69].

6.2.2. Blockchain-rooted Energy balancing

A blockchain-rooted energy flexibility market allows trading energy for prosumers in a peer instrument-to-peer instrument approach where energy flexibility is defined in the context of load modulation regarding energy outlines that allow achieving local energy balance of the demand side and live monitoring

[70]. Similarly, the Ethereum blockchain is operated to deliver secured and dispersed energy flexibility to adapt energy demand profiles to stakeholders where energy prosumption data collected from IoT instruments is deposited in the blockchain, and self-executing contracts define the energy flexibility level and balance the energy demand with production in smart energy grids [29]. To realize a regional energy balance in the vehicular energy network, BSIS is a permissioned blockchain with a proof of reputation consensus rooted secure incentive approach for cooperatively delivering energy in electric vehicles and energy nodes having different electricity loads for the sake of maximizing electric vehicles' utilities [71].

6.2.3. Blockchain-rooted Energy cognizant Routing protocols

A highly energy effective, trusted routing methodology for WSNs known as MF-WWO-WO uses MayflyWater wave optimization for cluster head selection, whale optimization to find a trusted path in an energy efficient manner rooted in multiple constraints, and trusted paths are supplied to the blockchain for subsequent secure routing [72]. Likewise, ATEAR is a thermal/energy cognizant routing methodology (algorithm) for wireless body area networks implemented using blockchain networks to ensure the compatibility of biometric figures with other healthcare people in which the routing takes place, taking into effect the heat level and prevailing energy of instruments [73]. For underwater WSNs, an energy effective routing methodology by avoiding void holes and additional energy consumption has been effective where a proof of authority consensus-rooted private blockchain is operated to avoid malicious node attacks in the WSN [74].

6.2.4. Blockchain-rooted Transmission EA

In Mobile Edge Computing (MEC) networks, an optimization task for energy consumption balancing for multi-device and multi-tasking is integrated with blockchain for security, where the cloud servers using more transmission energy are removed to manage the energy [75]. Researchers have suggested a green version of the high energy depletion and high delay Practical Byzantine Fault Tolerance (PBFT) as iPBFT, which has proven to have low communication overhead, high throughput, and consensus delay that can reduce the transmission power of blockchain networks, proposing it for green networks [76]. AIBS-IoTHS is a blockchain along with an artificial intelligence-rooted secure system in IoT healthcare networks in which meta-heuristic-rooted sunflower optimization for clustering and transmission energy control with energy efficiency have been realized, where blockchain is utilized for secure inter-cluster and intra-cluster communication [77].

6.2.5. Blockchain- and Hardware rooted EA

In [27], blockchain is utilized in a smart power management system in the SealedGrid architecture to monitor power usage in realtime and save energy by operating field programmable array-rooted hardware with dynamic voltage scaling features. Moreover, in another study, DVFS is applied to thwart nodal overwhelming, curtail energy utilization, and amplify the time of operating in the framework of a blockchain-rooted IoT network, which optimizes task allocation among network users in a disaster management scenario with the aid of SCs [78].

A co-processor specifically designed for blockchain mining in IoT network applications equipped with in-built hash computation, pipelining, and compression known as BLAKE-256/2s has shown high energy efficiency when implemented in FPGA compared to CPU and GPU processors. Thus, the BLAKE-256/2s processor is well suited to be operated to secure energy efficiency in blockchain-rooted IoT networks [79].

6.2.6. Energy efficient consensus

To analyze big data within industrial IoT networks operating artificial intelligence, a secure framework operating blockchain for secure data and resource exchange proposed a modified energy efficient delegated proof of stake consensus approach to store blocks [25]. Proof-of-work (PoW) is well known to be highly energy depleting. In [80], an energy effective approach to proof-of-work consensus to be operated in IoT networks is proposed by offloading blockchain mining to the edge network while miners are selected rooted on the specifications of the devices, such as processing power, memory, bandwidth, etc. Similarly, Green-PoW is a green version of the original PoW consensus of blockchain, where the computational endeavors of the second-best of a consensus episode are given the opportunity to mine the next block, effectively reducing 50% of energy consumption compared to the original PoW [81].

6.2.7. Blockchain-rooted Energy cognizant Resource apportionment

In blockchain-rooted cybertwin-rooted 6G networks that interchange digital reserves with cloud providers operating SCs, a resource apportionment system that builds profiles and does task assignment rooted on resource availability and delay tolerance among edge cloud service providers in an energy efficient manner has been studied in [32]. In blockchain-rooted MEC for industrial IoT networks, an optimization task is formulated with a weighted system cost consisting of energy consumption and computational cost, where the computational tasks are offloaded to the edge network to improve the efficiency of blockchain consensus, which is solved using Deep Reinforcement Learning (DRL), resulting in a computationally and energy efficient resource allocation system [82]. Similarly, in another MEC integrated IoT network rooted in blockchain, a new optimization technique known as collective reinforcement learning is operated to apportion reserves intelligently, dodging unnecessary exhaustion of resources by jointly optimizing the decision to offload, transmission power, and block intervals to minimize energy consumption, where blockchain is operated to conserve the genuineness of data [83].

6.2.8. Blockchain-rooted Energy cognizant Load balancing

In a blockchain-rooted medical care system operated in smart cities, blockchain is used to securely store the health data of each patient, with an effective methodology for nonce calculation consisting of a load balancing methodology to scatter the nonce computation between the mining instruments and a prioritization scheme for sensitive data [84].

6.2.9. Blockchain-rooted Energy harvesting

B-DEAH is a blockchain-rooted confidential, reliable, latency and energy harvest cognizant medical care surveillance system for Wireless Body Area Network (WBAN) IoT having sophisticated mechanisms for patient key registration, cluster chief decision rooted on prevailing energy and transmission power, cluster-rooted routing, data transmission, and packet classification [85]. For IoT healthcare networks, blockchain-rooted authentication has been assisted for energy harvesting and quality of service aware health task coordination by considering users, resource availability and cost, and quality of service requirements [30]. A joined task offloading and energy harvesting platform for IoT networks is assisted by Unmanned Aerial Vehicles (UAVs), where blockchain is utilized to resist security vulnerabilities in the offloading and energy harvesting processes, while the optimization problem is modeled as a Stackelberg game to represent the interactive engagements between IoT devices and UAVs and finally solved using DRL [31].

6.2.10. Blockchain-rooted Energy trading

A decentralized peer instrument-to-peer instrument residential energy trading market has been implemented in a permissioned blockchain that has two methodologies to determine the two-sided energy choices in the regional energy market: the first approach matches extra power availability and requirements, while the other is rooted in the displacement between available energy and requirements [86]. A recharging point-to-auto and auto-to-auto energy trading system for electric vehicles has been feasible by operating blockchain to preserve the privacy of the energy trading system in conjunction with an anonymous authentication technique and payment system to get rid of the Sybil attack with the help of blockchain technology [87]. For energy trading in the internet of electric vehicles, a consortium blockchain-rooted solution with numerous strategies is operated: First, blockchain ensures the trust of trading; secondly, SCs are used to handle trading disputes; hash lists in road side units are used to prevent data duplication; digital signatures are used to ensure data integrity; and finally, inter-planetary file system is operated for data storage [28]. For smart homes in a micro-grid, the Ethereum blockchain can be operated to store transactions regarding energy, where a miner can process them to know about the energy, and SCs can be operated to trade renewable energy automatically [88].

6.2.11. Blockchain- and Duty-cycling rooted EA

In WBANs, a framework known as the EiA-H2B model operates a hybrid hierarchical blockchain for sensor validation for election driven virtual categorization, a duty cycling MAC scheduling protocol to control energy and slot allocation to predict sensor states, relay selection and routing, and predicting emergency data [89]. IoTLogBlock is an IoT transaction recording, contract signing, and transaction verifying (authenticating) framework using blockchain and SCs that further uses radio and CPU duty cycling to achieve energy efficiency [90].

6.2.12. Blockchain- and Optimization-rooted EA

For a renewable AC/DC microgrid separated into multiple agents, a secure blockchain-rooted framework with a novel consensus approach among multiple agents has been offered for EA by solving an augmented Lagrangian function using whale optimization [91]. For smart home users to optimally manage usage of energy, a distributed algorithm driven by optimization that minimizes the cost subjected to schedule of loads, energy supply, etc. is implemented in SCs that are operated on blockchain for transactive EA [92]. Energy cost optimization and minimization of time for transferring jobs are performed in geo-distributed cloud data centers in conjunction with a secure work scheduling approach rooted in blockchain, considering time and space variables attached to electricity tariffs [93].

6.2.13. Blockchain- and Machine learning-rooted EA

In a healthcare IoT network, a permissioned blockchain is used to provide real-time security for healthcare transactions, while to achieve energy efficiency, multiple approaches are operated: computing tasks are offloaded to MEC, harvesting energy, and DRL is operated to optimize considering both energy constraints and security [94]. In a resource constrained IoT environment, a blockchain-driven framework consisting of a meaningful energy saving zero knowledge proof-of-learning consensus for educating a deep learning model with the aid of a Stackelberg game rooted incentive mechanism has been studied in [95]. Q-SDRM is a demand-response home EA system that operates the Ethereum blockchain in conjunction with an off-chain inter-planetary file system for secure transactions and DRL to reduce energy costs and energy consumption by making optimal price decisions [96].

6.2.14. Blockchain- and Network virtualization-rooted EA

In a software-defined network that controls and manages IoT devices, blockchain has been integrated to provide security and privacy against cyber threats while preventing the sole point of breakdown in SDN, while network function virtualization has been operated to save energy and balance load in conjunction with cluster head selection to amplify the energy effectiveness further [97]. In a sustainable city, cryptography and authentication enabling blockchain are operated to secure communication, while network virtualization is used for efficient data storage using virtual machines, providing an energy efficient system where machine learning is operated to provide parking space to drivers having location and timing [98].

6.2.15. Blockchain with Combined/Other approaches for EA

An stochastic architecture using scent-free transformation to tackle functional ambiguities of transportation in smart cities taking into account power generated by wind turbines where blockchain is operated to secure data transfer for the sake of achieving energy efficiency and management using vehicle-to-subway and vehicle-to-grid bilateral power flow approaches has been studied in [99].

7. Review Exploration

7.1. Exploration of separate works

Table 3 conveys the exhaustive exploration of blockchain-rooted EA frameworks in words of energy administration technique, BC concept and parameters, energy administration approach, network types, and published time.

Table 3 Exploration of blockchain-rooted energy administration frameworks.

EA technique	Proposal	Blockchain conception	Blockchain design	Blockchain consensus	Blockchain group	EA approach	Network design	Network group	Performance
Nodal battery management	WBM [24]	C1	Uniform	PBFT	Permissioned	Decentralized, physical layer	Generic	IoT	Feasible solution, acceptable latency
	Double [26]	C1	Uniform, non-uniform	PoW	Permissioned	Semi-decentralized, physical layer	Decentralized	IoT-EV	Acceptable transaction confirmation times
	OSM [69]	C3	Uniform	PBFT	Permissioned	Decentralized, cross layer	Decentralized	IoT-EV	Enhance firmware security
Energy balancing	EFM [70]	C4	Uniform	Generic	Public	Decentralized, cross layer	Decentralized	Micro-grid	Local energy balancing in demand side
	Smart-grid [29]	C4	Uniform	PoS	Public	Decentralized, cross layer	Generic	Smart-grid	Can match energy demand with production
	BSIS [71]	C4	Uniform	PoReputation	Permissioned	Decentralized, cross layer	Generic	VEN	Allocate RE to loads maximizing utilities
Energy aware routing	MF-WWO-WO [72]	C1	Uniform	Generic	Generic	Hierarchical, network layer	Decentralized	WSN	High throughput, lifetime, efficiency
	ATEAR [73]	C1	Uniform	BFT	Permissioned	Decentralized, network layer	Generic	WBAN	High throughput, network lifetime, bal. temper.
	Underwater [74]	C2	Uniform	PoAuthority	Private	Decentralized, network layer	Decentralized	WSN	Low transaction and execution costs
Transmission EA	Multi-tasking [75]	C1	Uniform	Generic	Generic	Hierarchical, physical layer	Hierarchical	MEC	Energy balance increment by 66%
	iPBFT [76]	C2	Uniform	iPBFT	Public	Decentralized, physical layer	Generic	Generic	Average delay--370ms, high throughput
	AIBS-IoTHS [77]	C1	Uniform	Generic	Generic	Hierarchical, physical layer	Hierarchical	IoT-healthcare	High privacy with energy efficiency
Hardware-rooted	SeGr [27]	C1	Uniform	PoW	Public	Decentralized, physical layer	Hierarchical	Sealed Grid	Production of 0.075 Ethereum/day
	Disaster [78]	C7	Uniform	Generic	Generic	Decentralized, physical layer	Generic	IoE	17% low errors, 30% better task migration
	BLAKE-256 [79]	C1	Uniform	Generic	Generic	Decentralized, physical layer	Generic	IoT	Better area efficiency, throughput than FPGA
Energy efficient consensus	DPoS [25]	C2	Uniform	DPoS	Generic	Decentralized, cross-layer	Generic	IIoT	Low energy consumption with high security
	Efficient-PoW [80]	C2	Uniform	PoW	Public	Decentralized, cross-layer	Decentralized	IoT-EC	21% better energy consumption
	Green-PoW [81]	C2	Uniform	PoW	Public	Decentralized, cross-layer	Generic	Generic	50% energy consumption reduction
Energy-aware resource allocation	Cyber-twin [32]	C7	Uniform	Generic	Generic	Decentralized, cross layer	Generic	6G-cybertwin	Low computation time, high energy efficiency
	Off-DRL [82]	C6	Uniform	PBFT	Generic	Decentralized, cross	Decentralized	IIoT-MEC	Low computational overhead,

						layer			energy consumption, cost
	Off-CRL [83]	C5	Uniform	Generic	Generic	Decentralized, cross layer	Decentralized	IoT-MEC	Low consumption overhead, service latency
Energy-aware load balancing	EALB [84]	C4	Uniform	PoW	Consortium	Decentralized, network layer	Generic	Healthcare-SC	Efficient patient prioritization-rooted mining
Energy harvesting	B-DEAH [85]	C1	Uniform	PoW	Public	Hierarchical, physical layer	Generic	WBAN-IoT	87% success rate, reliability, 41 kbps throughput
	QoS-EH [30]	C5	Uniform	Generic	Generic	Decentralized, physical layer	Generic	IoT-healthcare	Better energy consumption, resource cost, throughput
	UAV-EH [31]	C6	Uniform	Generic	Generic	Decentralized, physical layer	Generic	UAV-IoT	Low computational cost, high UAV utility
Energy trading	P2P-ET [86]	C4	Uniform	PBFT	Permissioned	Decentralized, cross layer	Decentralized	P2P-EA	Energy procurement cost, grid interaction lower
	EV-ET [87]	C4	Uniform	PoW	Public+ Private	Decentralized, cross layer	Generic	SG-EV	Privacy preserving with low overhead
	IoEV-ET [28]	C4	Uniform	PoW	Consortium	Partially decentralized, cross layer	Generic	IoEV	Acceptable gas consumption, High data integrity
	MG-ET [88]	C4	Uniform	PoW	Private	Decentralized, cross layer	Decentralized	Micro-grid	Automatic, unforgeable energy trading
Duty cycling	EiA-H2B [89]	C5	Hierarchical	PoAuthority	Consortium	Hierarchical, data link layer	Hierarchical	WBAN-IoT	Low energy consumption, high success rate
	IoTLogBlock [90]	C5	Uniform	PBFT	Permissioned	Decentralized, physical layer	Generic	IoT	Better memory, energy, computation usage
Optimization-rooted	AC/DC-MG [91]	C2	Uniform	Generic	Generic	Decentralized, cross layer	Decentralized	Micro-grid	Energy efficient consensus
	EM-SH [92]	C7	Uniform	PBFT	Public	Decentralized, cross layer	Generic	IoT-SH	25% reduction in overall cost
	Geo-DC [93]	C4	Uniform	PoW	Generic	Decentralized, cross layer	Generic	Data center	46% reduced time for workload migration
Machine-learning rooted	DRL [94]	C1	Uniform	PBFT	Permissioned	Decentralized, cross layer	Generic	IoT-healthcare	Balance security and energy efficiency
	DL-IoT [95]	C2	Uniform	ZK-PoLearning	Generic	Decentralized, cross layer	Generic	IoT	Low storage, computation, communication cost
	Q-SDRM [96]	C1	Uniform	PoW	Public	Decentralized, cross layer	Generic	Smart-grid	Low energy consumption, cost
Network virtualization	Vir-SDN [97]	C1	Uniform	PoW	Public	Decentralized, cross layer	Centralized	SDN-IoT-SC	High throughput, low gas consumption
	Parking-SC [98]	C5	Uniform	Generic	Generic	Decentralized, cross layer	Generic	IoT-SC	Offer parking space with energy efficiency
Combined approaches	Stochastic-SC [99]	C1	Uniform	Generic	Generic	Decentralized, cross layer	Generic	Smart city	Secure and good energy efficiency

7.2 Overall Exploration

Figure 6 conveys the graphical dispersion of BC-rooted energy administration in terms of BC conception and factors, energy administration approach, network category, and time.

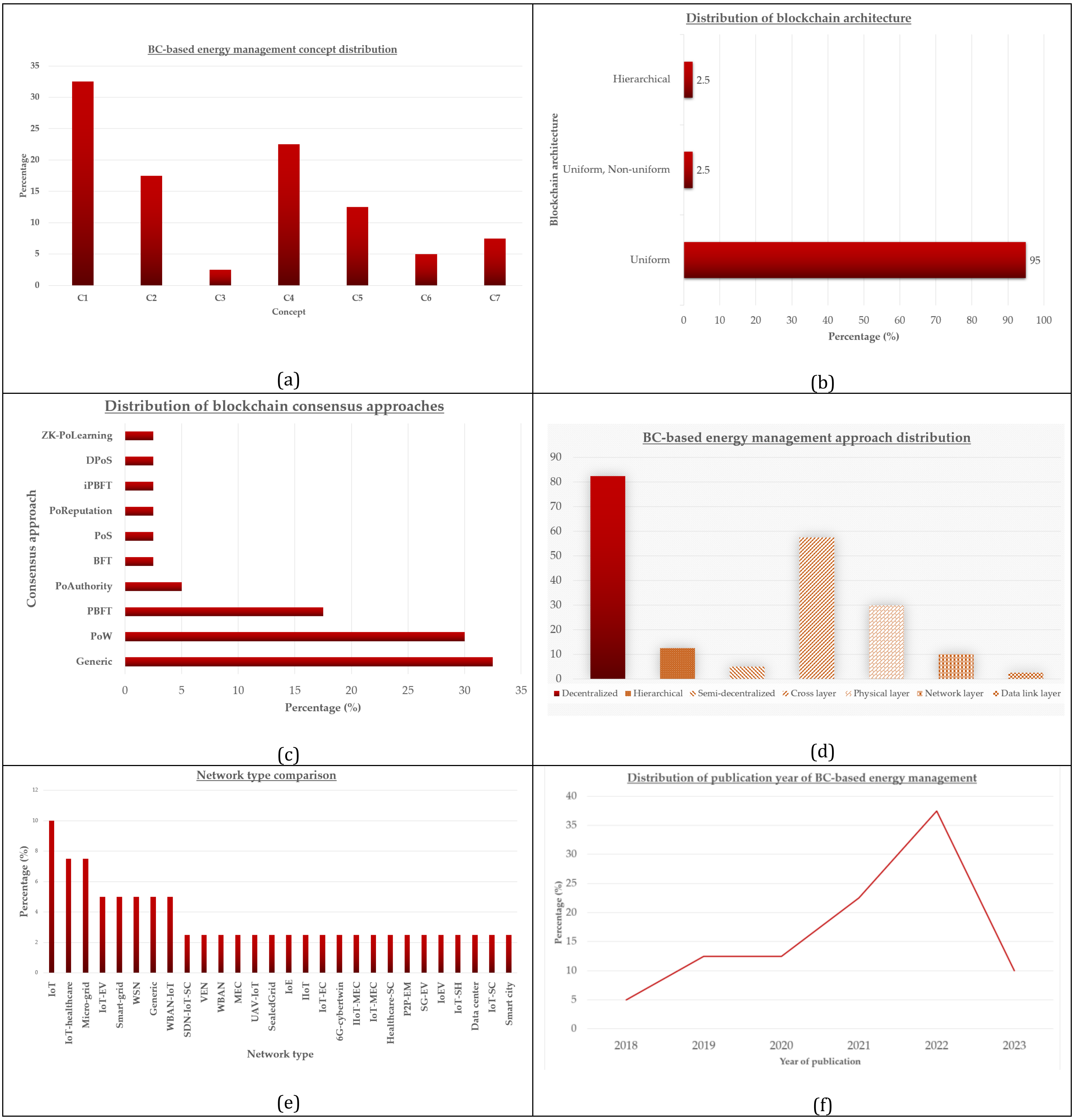


Figure 6 Overall exhaustive exploration (a)BC-rooted EA conception (b) BC category (c) BC collective approval (d) BC-rooted energy administration approach (e) Network category (f) Publicized time

Observing Figure 6a, C1 (Blockchain to store and exchange data for an EA task) is the highest sovereign BC-rooted energy administration concept, having the highest percentage of 32.5%, after C4 (22.5%), C2 (17.5%), C5 (12.5%), C7 (7.5%), C6 (5%), and C3 (2.5%). Next, in BC-rooted energy administration, 95% of frameworks operate a uniform blockchain, while 2.5% operate a combination of uniform and non-uniform, while the remaining 2.5% operate a hierarchical blockchain, observing Figure 6b. Moreover, observing Figure 6c, most frameworks (32.5%) have been structured to operate generic collective approval, after PoW (30%), PBFT (17.5%), PoAuthority (5%), and such. When exploring about the EA approach, as conveyed in Figure 6d, 82.5% of the frameworks are decentralized, 12.5% are hierarchical, and 2.5% are semi-decentralized. When examining on the layers of operation, 57.5% are cross-layers, 30% are physical layers, 10% are network layers, and 2.5% are data-link layers. Furthermore, observing Figure 6e, BC-rooted energy administration has been mostly applied for general IoT (10%), after IoT-healthcare (7.5%), Micro-grid (7.5%), IoT-Electric vehicles (5%), Smart-grid (5%), WSN (5%), Generic (5%), WBAN-IoT (5%), and such. Finally, when inspecting the variation of literature evolving related to BC-rooted EA, it is conclusive that the concept has been initiated approximately by 2018 and has been growing ever since until 2022 and reduced afterwards.

8. Discussion

8.1. Possibilities

8.1.1. Rendering safe telecommunication and storage for EA

In blockchain-rooted nodal battery management, blockchain can be operated as a means for secure storage and transmission of current and voltage data. Moreover, in energy cognizant routing, blockchain can act as a medium for storing trusted routing paths with enhanced interoperability and avoiding malicious terminals, while other techniques, in particular optimization, can be operated to find routes in an energy efficient manner. In transmission EA using optimization, blockchain can facilitate secure inter and intra cluster communication. Moreover, they can facilitate key registration and cluster head selection considering energy constraints and transmission power in cluster rooted energy cognizant routing approaches.

8.1.2. Coordinate EA

Blockchains can coordinate EA activities by using appropriate consensus approaches. As evidence, proof of reputation consensus can be operated to provide secure incentives for the sake of cooperatively delivering energy in an energy balancing system. Moreover, blockchain can be operated to monitor power usage in real-time in EA systems to make energy control decisions. In sensor networks, blockchains can be operated for sensor authentication, clustering using consensus, and controlling energy by approaches in particular duty cycling. Furthermore, blockchains can implement secure work scheduling approaches, considering time and space, to provide energy optimizations.

8.1.3. Loyal energy trading and balancing

Blockchain-rooted energy trading markets facilitate energy trading using a peer instrument-to-peer instrument approach. In these systems, blockchains can adapt the energy demand profiles of users using energy consumption data collected and stored in blockchains. Note that blockchain can implement the whole energy trading process, consisting of blockchain transactions that can match power supplies with demands. However, as Sybil attacks can be prevalent in energy trading platforms, blockchain-rooted energy trading should be equipped with secondary measures such as anonymous authentication, privacy preserving countermeasures, etc. In energy trading, trust can be ensured using blockchains, as digital signatures can be operated to protect data integrity and hash lists to prevent data duplication.

8.1.4. Automate EA using SCs

In smart energy grids, SCs can be operated to define the energy flexibility level and balance energy demand with supply. Moreover, SCs can be operated to exchange digital assets with cloud operators for the sake of creating user profiles and allocating resources considering energy and other quality of service parameters. In energy trading platforms, SCs can be operated to solve trading conflicts and trade renewable energy automatically by storing transactions regarding energy in the blockchain. Furthermore, SCs can enable automatic contract signing, transaction recording, and verification for the sake of controlling energy. Additionally, optimization techniques for EA tasks in networking can be operated on SCs to provide optimizations automatically upon varying network conditions such as energy loads, energy supply, etc.

8.1.5. Green consensus

Instead of using high energy depleting consensus such as proof-of-work, PBFT, etc., there are green consensus approaches that have been operated to curtail the energy utilization in blockchain networks that are very effective in EA scenarios. As evidence, iPBFT is a low energy depleting, high throughput, low delay version of the conventional PBFT consensus that has been offered for green networks. Moreover, there have been proposals for green consensus approaches, in particular delegated proof-of-stake, zero knowledge proof-of-learning, and green proof-of-work. Furthermore, even if high energy depleting proof-of-work is operated, such mining operations can be offloaded to an edge server to conserve energy in the core network. Furthermore, mining tasks such as nonce computation tasks can be distributed among mining terminals to balance the load.

8.1.6. Resist security risks and provide authentication

Blockchain can be operated to check for firmware security risks in EA tasks by checking firmware, generating patches, checking risks, etc. Moreover, they can be operated for user authentication for the sake of doing EA tasks such as energy harvesting, considering multiple factors such as user availability, cost, and QoS requirements. Furthermore, in network offloading tasks for energy conservation, blockchains can be operated as a barrier for security risks in offloading. Additionally, they can be operated to provide security and privacy against cyber threats and to prevent the central nexus of failure in centralized EA architectures.

8.2. Barriers

8.2.1. Elevated energy exhaustion by traditional blockchain

Traditional blockchain uses high energy depleting consensus methods, in particular proof-of-work, that deplete the energy of the terminals during block mining, propagation, and validation. The highest energy consumption can be found in public blockchains, while it is low in private and consortium blockchains. Energy consumption intensifies drastically with network magnitude, thus, challenging the whole objective of achieving energy efficiency in EA. However, there are energy efficient consensus approaches and scalable blockchains, such as non-uniform blockchains, that can be operated to lower the high energy consumption.

8.2.2. Low synchronization with centralized EA

Energy management using a centralized authority involves making centralized decisions for energy allocation, distribution, etc. However, blockchain-rooted EA is typically decentralized and does not involve a trusted third party, where EA tasks are distributed across the network participants (public blockchain). In blockchain, trust is ensured using the immutable ledger and distributed consensus. Thus, traditional systems using centralized EA can be reluctant to transfer from a centralized approach to a decentralized approach using blockchain, as there can be regulatory and legal implications at higher network administration level.

8.2.3. High intricateness in energy scheduling

In blockchain-rooted EA, energy-related transactions need to be deposited in the blockchain. These transactions need to be validated and inserted into the blockchain. Therefore, rather than using conventional techniques for EA such as game theory alone for energy trading, battery management techniques, optimization, machine learning, network virtualization, etc., the incorporation of blockchain in conjunction with these techniques intensifies the intricateness of the energy scheduling as energy transactions are required to be processed through the blockchain, despite some machine learning techniques being light-weight once trained [100].

8.2.4. Openness to security attacks on blockchain

Even though blockchains can amplify the security, seclusion, and steadfastness of EA tasks in networking, they are self-vulnerable to security attacks. They are vulnerable to eclipse attacks, 51% vulnerability, cryptojacking, selfish mining, code vulnerabilities in SCs, etc. [101]. Thus, it cannot be guaranteed that by operating blockchain for EA, it improves security by 100% in view of the well-known vulnerabilities that exist in blockchain. However, they provide a significant amount of security, privacy, trustworthiness, immutability, transparency, etc. for the EA tasks, as evident from the reviewed literature.

8.2.5. High disbursement in transferring to blockchain integrated EA

To directly use blockchain for EA or use blockchain to ensure the security and trustworthiness of EA using other approaches, the incorporation of blockchain will definitely add extra infrastructure and human resources. Blockchains need a significant amount of communication, computation, and memory resources in a network for their operation. As a blockchain network is implemented as a peer-to-peer network, each terminal of the network needs to be equipped with additional resources to integrate blockchain to perform the EA tasks. Thus, there is a cost to the gains supplied by the blockchain, such as security, trustworthiness, and automation.

9. Conclusion, Guidance, and Forthcoming trajectories

In this study, we studied various categories of energy administration techniques, in particular battery management, energy balancing, transmission EA, etc., and classed energy administration approaches rooted in network architecture and layers. Thereafter a gentle preface to the blockchain framework, we studied energy administration in blockchain-rooted networking in terms of different EA techniques. Hanging on this literary analysis, we recognized that blockchain-rooted energy administration in networking conception can belong to one among the 7 sub-divisions: blockchain for storing and exchanging data securely, energy efficient consensus, blockchain as an energy manager, secure energy trading and balancing using blockchain, blockchain rooted authentication and access control for EA, blockchain-rooted offloading for EA, and EA using SCs. Furthermore, we exhaustively explored the studied literature in terms of above spotted 7 subdivisions of conception, blockchain linked factors, network linked factors, and EA linked factors. Finally, we presented possibilities and barriers to applying blockchain for EA in networking.

This overview enriches the prevalent literature by rendering helpful knowledge associated with blockchain-rooted energy administration in networking. This can lead paths for the researchers to understand the current movements and disparities in blockchain-rooted energy administration to invest in ahead research work.

Hanging on the barriers spotted, next guidance can be bestowed to vanquish them.

- To improve energy efficiency, BLAKE-256/2s processors can be operated, as they have been specifically designed for blockchain mining purposes. Instead of operating high energy depleting proof-of-work that involves intense nonce computation tasks, low energy demanding consensus approaches, in particular proof-of-stake can be operated. Moreover, graph-rooted blockchains having parallel information processing power and non-linear interconnections among transactions can be operated to further improve energy efficiency.
- To overcome the challenge of transferring from centralized to distributed EA, human resources can be educated and trained to operate blockchain technology for EA. Higher network administrators can be convinced about the security features of blockchain for them to understand the requirement of integrating blockchain for existing EA systems so that they can remove the legal implications.

- There is some extent of increment in the whole complexity of EA in view of the inclusion of blockchain, which cannot be prevented. However, it can be minimized by optimizing SCs to work with low complexity, selecting a consensus approach that comes into a consistent state with less number of communications and operations, and operating a low complexity EA approach.
- To mitigate the known security vulnerabilities of blockchain, numerous strategies can be offered. An intrusion detection system can be incorporated in conjunction with the blockchain-rooted EA to monitor the network and detect network anomalies in real-time. Moreover, for the sake of preventing attacks such as selfish mining, incentive mechanisms can be designed to reward honest terminals, and a selection of consensus approaches, in particular delegated proof-of-stake, which is less susceptible to selfish mining, can be operated.
- To tolerate the inevitable infrastructure and human costs in migration to blockchain-rooted EA from traditional EA, the transition can be planned gradually without a sudden shift so that costs are distributed over time. To reduce human costs, organizations can train their own human resources instead of hiring blockchain experts from outside. Moreover, a private or consortium blockchain may be selected to improve both privacy and reduce extra costs.

Due to the application of blockchain for the administration of energy in networking, in addition to gains in security features among others data genuineness, trust, seclusion, etc., blockchains can coordinate and automate EA. Ahead research activities in this realm may consist of techniques for joint optimization of EA in the blockchain and communication network together. Other ahead works could be studies on the operation of quantum cryptography to improve the confidentiality of energy related data in blockchains that are resistant to quantum computing attacks.

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