

A Review on Deploying Blockchain Technology for Network Mobility Management

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Abstract: In wireless mobile networks, Mobility Management (MM) is a critical aspect that involves different tasks such as handover management, location management, offloading, resource allocation, and others. Blockchain platform comprising of an array of linked blocks innately supports the incorruptibility, sustaining the authenticity, and sustain pseudonymous privacy. Traditional MM is centralized, in contrast to blockchain-grounded MM that is partially or fully decentralized in its approach. As the inaugural researchers to review on blockchain-grounded MM, we are proud to cluster the blockchain-grounded MM concept under 7 clusters and closely study each framework with respect to different aspects such as blockchain specific parameters, MM specific parameters, network parameters, and more. We gathered a sample of 92 source references by curating the articles for eligibility criteria examined from electronic archives utilizing a comprehensive and enduring way. Grounded on this inspection, blockchain-grounded MM reinforces the overall security, trust, and privacy of location management and resource allocation, blockchain-grounded secure handover, facilitating registration and authentication, automatic MM utilizing smart contracts, reducing vulnerabilities, repairing low quality data, coordination, fair scheduling, in offloading, and blockchain-grounded resource allocation. Close studying proves that out of blockchain grounded MM frameworks, 37.5% utilize blockchain grounded secure handover, 92.5% utilize simple blockchain architecture, 32.5% utilize PoW consensus, 100% distributed MM, 97.5% host grounded MM, 95% packet reordering tolerant MM, 52.5% QoS aware MM, and 12.5% proposed for 5G networks. Finally, we present the openings and obstructions of the concept of blockchain-grounded MM and then catering surmounting advices.

Keywords: Mobility administration, Blockchain, Mobile networks, Blockchain grounded mobility management.

1. Introduction

Mobility management (MM) is an important aspect in mobile networks such as vehicular adhoc networks, mobile adhoc networks, cellular mobile communication networks, Wi-Fi networks, etc. [1].

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MM mainly involves in 4 aspects: handover management, location management, offloading, and resource allocation. Efficient handover management involves in maintaining the wireless connection when a device migrates from a given access link to another where in soft handover, a continuous connection is maintained while in hard handover, the old link is disconnected before the new one is set up [2]. Moreover, the handover approach can be reactive in response to an activity such as degradation of signal to noise ratio, or be proactive otherwise using predictive analytics [3]. Similarly, location management that involves the serving network to know about the mobile devices' location is also can be proactive and reactive, where in reactive approach, the device sends its location upon demanding instances while in proactive approach, the device sends its location periodically [4]. Specifically, location management

necessarily involves registering of devices location either proactively or reactively and involves paging (searching) of the device location in reactive location management [5]. Offloading involves in transferring tasks, computations, or data traffic to other networks or capable remote resources to reduce the workload of mobile nodes to improve their performance [6]. Namely, high intense traffic such as video and large file downloads can be offloaded to a Wi-Fi network to lower unnecessary delays of cellular subscribers [7]. Moreover, MM deals with allocation of radio resources such as power, spectrum, bandwidth considering user mobility patterns, signal strength, etc. to fulfill reducing interference using techniques including optimization, machine learning, beamforming and MIMO, and so on [8].

In cluster-grounded and centralized MM, there are cluster heads or a centralized authority such as a base station, eNodeB, etc. responsible for MM tasks such as handover, power control, bandwidth allocation, etc. [9]. Distributed MM is basically host-grounded while non-distributed approach is primarily network grounded. Conventional mobile networks utilize network-grounded MM, while researchers have recently proposed and evaluated distributed MM with the aid of new platforms suchlike blockchain [10]. MM also involves quality of service grounded flow prioritization and allocating network resources for different services appropriately to satisfy minimum service requirements [11]. However, some networks can focus on maintaining continuous connectivity rather than adhering to different quality of service requirements in MM and it can depend on the type of mobile network considered [12].

A blockchain inherently comprises of an array of blocks linked in a simple or mesh approach in accordance with the design of the transparent ledger platform [13]. Particularly, transactions/blocks are intertwined through a specified block/transaction safeguarding the hash result of multiple parental transactions/blocks securing their immutability [14]. Specifically, they utilize a consensus procedure suchlike proof-grounded consensus or vote-grounded consensus for checking the validity of the blocks within associates prior a transaction/block is included in the transparent ledger platform [15]. Furthermore, they utilize cryptographically secure hashing to sustain the incorruptibility and electronic signature for

sustaining transaction authenticity [16]. Furthermore, they are suited for the integration of strong cryptographic methods suchlike proofs of secret knowledge and quantum-resistant cryptography for strengthening defenses opposed to quantum challenges [17] strengthening the attributes of confidentiality in blockchain. But, unmodified blockchain in native form that refrain from cryptographic methods suchlike asymmetric encryption technology for sustaining the confidentiality, is not entirely confidential in light of blockchain operations/transactions are having camouflaged profile signifying that operations/transactions are located by a secure fake address replacing legitimate addresses of devices [18]. Additionally, the magnitude of confidentiality preservation is subjected to modification depending on the transparent ledger category: restricted-access, partnership-grounded, and open-access. Open access blockchain is the conventional decentralized blockchain whereas restricted-access and partnership-grounded blockchains possess a specific magnitude of command supremacy supplying added concealment and data access supervision than open-access [19].

In accordance with the findings of this survey, blockchain grounded MM can be 7-folded. First of all, blockchain technology itself can be utilized for secure handover by providing handover authentication and energy efficient handover. In this approach, unnecessary repeated re-authentication can be prevented and can cater access control having fine granularity with private and anonymous handover [20-21]. Furthermore, frameworks such as BEPHAP facilitates anonymous handover authentication with the aid of cryptographic methods [22]. Secondly, blockchains can facilitate privacy preserving location management with the aid of additional encryption techniques and by providing certificates. In these instances, blockchain can be utilized for secure location data management and consensus [23]. Thirdly, blockchain can be utilized for node registration and authentication to access location information in a privacy preserving manner such as done in FogAuthChain [24]. Next, blockchain and smart contracts (SCs) have been utilized to implement a secure paging service [25].

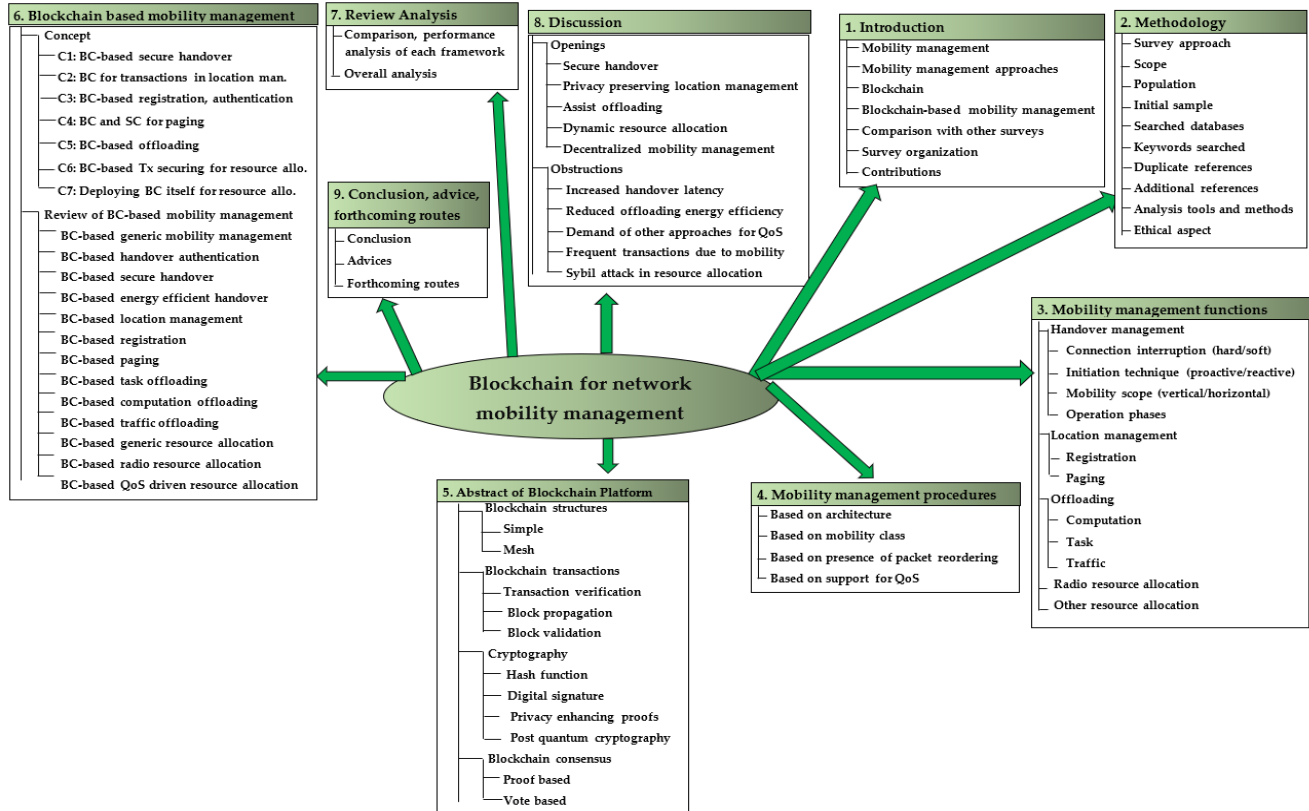


Fig. 1: Organization of blockchain-grounded mobility management review.

Blockchain can be utilized in numerous ways such as preventing the effect of malicious nodes making an impact on offloading decisions, prevent data losses, enable fair scheduling, repair low quality data, etc. [26], [27]. Next, blockchain has been utilized for securing communication and storage while resources are allocated using a conventional technique. Namely, in [28], blockchain is utilized for privacy, where offloading of activities and assignment of radio resource are jointly optimized among applications to minimize costs and delay. Finally, we reviewed work where blockchain itself has been utilized for resource allocation without using a traditional technique such as optimization or artificial intelligence. Namely, blockRAS is a blockchain-grounded resource allocation system that manages demand and supply of resources among 6G users and resource providers that has been capable of providing high reliable communication [29].

At this juncture of drafting, to our current understanding, we are the inaugural examiners on blockchain-grounded network MM in all MM tasks of

handover, location management, offloading, and resource allocation. Thus, this review bridges an existing knowledge deficit in the existing body of knowledge on blockchain grounded MM. The review organization is demonstrated in Fig. 1.

1.1 Contributions to Living Literature

- We tagged and briefly elaborate an abstract of mobility management functions (Section 3).
- Mobility management procedures in networking systems are briefly elaborated (Section 4).
- An abstract of the blockchain platform is exhibited (Section 5).
- Inspect on living blockchain-grounded mobility management frameworks in data networks (Section 6).
- Closely study the inspected blockchain-grounded mobility management frameworks (Section 7).

- Openings and obstructions of blockchain grounded network mobility management is conversated (Section 8).
- Advices and forthcoming routes for utilizing blockchain grounded mobility management is exhibited (Section 9).

2. Methodology

This inspection looks into the present studies on blockchain-grounded MM distributed among scholars across time exploiting a comprehensive and enduring way [30]. Specifically, it delves into multiple perspectives of network MM and blockchain scheme. So, all novel research findings and online resources disclosed electronically on network MM, blockchain-grounded network MM, and blockchain form the entire resource set in current context. However, entire resource set references are immune to evaluation in a given survey. So, exploiting befitting search queries and eligibility criteria, we aggregated 97 references from novel research findings and online resources.

We examined Google Scholar research tool, ScienceDirect research repository, IEEE Xplore electronic engineering database, ACM electronic archive, Wiley electronic archive, and MDPI document retrieval service. The search queries of primary choice were "Network MM" OR "Blockchain-grounded MM" OR "Blockchain-grounded handover" OR "Blockchain-grounded location management" OR "Blockchain-grounded offloading" "Blockchain-grounded resource allocation" OR "Blockchain".

Numerous variables for curating the articles formulated the eligibility criteria. As the first eligibility criterion, the report needs to be drafted in English and next, it mandates remarkable applicability to the search query. Next, to achieve boost the authenticity of conducted inspection, research journals were assigned top priority when weighted against conference papers and pre-peer review articles. Nevertheless, we weren't partial to scholarly publications within a designated publishing company in the eligibility criteria; alternatively, we deemed all publishing companies uniformly. The last eligibility criterion utters that a designated report needs to be published in the period of years of 1990 and 2023.

The original sample was diminished to 92 source references consequent uncovering of 5 source references were repetitions. Specifically, we mentioned specifications and explanations dealing with the different titles provided in this inspection using 15 reports. To analogize this inspection with historical inspections, we afterwards reviewed numerous inspection articles, yet they were excluded from the specimen of documents, as we discovered zero inspecting on blockchain for network MM, carrying the overall count of source references to 107.

To inspect contemporary blockchain-grounded solutions for network MM using numerous variables, suchlike blockchain characteristics, MM characteristics, network attributes, and functionality, we exploited the table-grounded information format for inspection contextual exploration. Specifically, we produced visual data exploiting the MS spreadsheet program to unbiasedly assess inspection data coupled with MM-grounded and blockchain-grounded variables. Ethics are inapplicable seeing that this inspection is related to MM.

3. An Abstract of MM Functions

3.1 Handover Management

Handover management deals with enabling network nodes to maintain the wireless communication while moving from one access link to another changing their points of attachment to fulfill providing uninterrupted access to information. The concept of handover in mobile networks is representationally demonstrated in Fig. 2. As demonstrated in Fig. 2, when the mobile gadget travels in the specified path handover will take place as A, C, B, C, D, E in order. In [1], a handover management scheme for two-layer cellular networks that is aware of the velocity of the mobile nodes by modeling using stochastic geometry, skips handover to some base stations within the user movement path to fulfill maintaining higher connection times and reduce handover failure rates. Another work uses Markov chain formulation to estimate the probability of neighbor eNodeB transition of mobile nodes and available resources to fulfill selecting optimal eNodeB and connect to mobile nodes virtually using OpenFlow tables in a software-defined 5G ultra-dense networks [31].

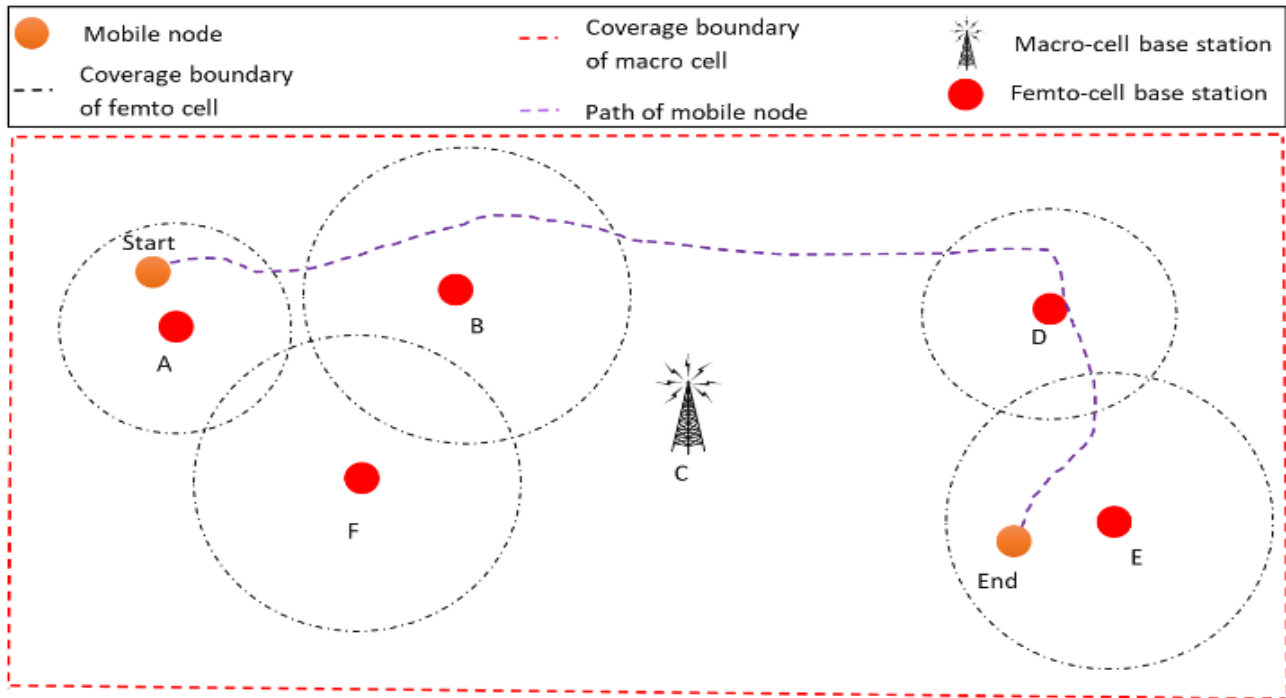


Fig. 2: Concept of handover in mobility management.

3.1.1 Handover approach grounded on connection interruption

Hard handover (HH) - In HH, the connectivity association to the old cell is terminated before connectivity association to the new cell is established. A HH approach grounded on received signal strength in an LTE network has achieved a tradeoff among quantity of HHs and outbound link signal to interference factor for a bandwidth capacity of 1.25 MHz [32]. As hard over generally consumes a higher handover delay, a fast hard handover strategy for WiMAX IEEE 802.16e standard has been presented using a quality of service passport handover approach having a fast connection CID assignment tactic to handover facilities with those of in-progress facilities in target base station [33].

Soft Handover (SH) - SH enables seamless handover where the mobile gadget sustains connectivity association with the old and new cells in the handover procedure before losing the connection with the old cell. A soft handover approach for control/user plane split network in high-speed railway networks using dual links by using two antennas to reduce the handover outage probability and bi-casting to decrease communication interruption has been

studied in [2]. A segmented SH scheme for voice over internet protocol traffic using carrier aggregation in 4G LTE mobile networks where remaining traffic is transmitted between eNodeBs has yielded low handover outage probabilities [34].

3.1.2. Handover approach grounded on initiation technique

Reactive Handover (RH) - In RH, handover is initiated in response to a certain event such as degradation of signal to noise ratio. A reactive handover optimization approach for Ipv6 mobile networks by optimizing node movement detection and addressing configuration schemes requiring only a few signaling messages has resulted in a low handover latency [35]. In an effort to reduce handover latency in fast proxy Ipv6 networks, a fast handover triggering scheme using link layer information to predict two cases in the mobile nodes and establish bidirectional channel for handover has been feasible [36].

Proactive Handover (PH) - In PH, predictive analytics and optimization are utilized to predict a possible connection loss and initiate a handover proactively before the connection is lost [37]. ABRAHAM is a machine learning powered PH tactic that utilizes predictive analytics on the network to preserve quality

of service in handover in a software-defined network handover management framework [3]. Moreover, federated learning has been utilized to learn a model for proactive handover in a manner reducing the overall communication cost for training while adhering to limited storage capacities of users adapting to the dynamic mobility pattern in millimeter wave vehicular networks [38].

3.1.3 Handover mobility scope

Global mobility/Vertical Handover (VeH) - VeH occurs when the mobile gadget travels across multifaceted access networks resembling a global mobility scenario. In this case, the IP address changes as the network interface changes. In an effort to provide immediate and dwell vertical handover in optical wireless networks, fuzzy logic grounded decision-making handling uncertainty has been utilized to combine advantages of both techniques to achieve low packet transfer delays [39]. A decision independent solution utilizing multihoming capability and extension of dynamic access configuration of the stream control transmission protocol have been applied in overlay architecture of UMTS/WLAN to decrease latency and increase throughput in vertical handover [40].

Local mobility/Horizontal Handover (HoH) - HoH takes place when the mobile equipment roams within the homogeneous access network resembling a local mobility scenario. In this case, the IP address is a constant, as the network interfacing module does not change. For software-defined wireless networking architecture having dense wireless local area networks, an algorithm for user prioritization, classifying stations into two priority levels has been effective in guaranteeing quality of service to users by enhancing horizontal handover [41]. A utility function considering signal to noise proportion network burden is formulated for HoH decision in automobile-to-automobile communication reducing ping-pong ramification and enriching throughput by picking network having lower burden [42].

3.1.4. Handover Operation phases

A handover is involved with three phases in operation: initiation, preparation, and transfer connection [43].

- **Initiation phase** - In the initiation phase, a handover is initiated either by an event or proactively, and identifies a cell or an entity to handover considering factors such as signal strength, bandwidth, network load, etc.
- **Preparation phase** - In this phase, first the target cell is evaluated and resources are allocated in it. Next, session data is transferred from the originating to the objective network element. Finally, handover judgment is made to proceed with the handover.
- **Transfer connection phase** - This is the step that real transition of the connection takes place. The data path is changed from the source to the target network and handover confirmation is received.

3.2 Location Management (LM)

LM alludes to the capability of the assisting network to recognize the location of a mobile node's interface spot within the access link to fulfill delivering the data packets. There are two approaches for location management as reactive and proactive.

Reactive location management - In reactive location management, mobile devices send the location to the network upon a demanding situation such as making a phone call or initiate a data session. This approach has a low signaling overhead, however, can cause a higher latency. In reference [44], a responsive location service inquiring current location of mobile nodes of mobile adhoc network has been utilized for location grounded routing outperforming dynamic source routing. Another reactive location grounded service has been tested for collecting separate space-time facts regarding tasks and mobility [4].

Proactive location management - In proactive location management, mobile devices periodically update the network on its location even when the device is not moving or utilized for data transfer. The devices maintain a tracking area or location area list and send an update to the network when it moves into a fresh tracking area. In [45], authors present an energy saving approach for prolonging the battery life of mobile gadgets in proactive location management involving GPS and GSM cell ID positioning. Another research implements a proactive location service by

pushing location information to close friends to fulfill reducing lower lookup delay and reduce signaling cost where close friends are identified using relationships between the users [46].

3.2.1 Registration

Location registration involves in location tracking and updating the location of a mobile gadget in the access link to the network either proactively or reactively. A location tracking algorithm called alternative location algorithm which has been observed to be affected by user mobility patterns, call traffic, and registration areas portable residence time variance has been utilized to diminish location refreshing expenditure inside a PCS network [47]. Moreover, code division multiple access personal communication networks utilize two location algorithms to utilize previous and current registration areas with a registration function to infer personal station current location from the incoming call [48].

3.2.2. Paging

Paging refers to searching and finding out the location of a mobile device by a network within its coverage. Thus, paging messages can be broadcasted to multiple base-stations in a mobile network to search for a target device. Paging allows communication with a selected set of mobile devices using group paging improving efficiency and signaling overhead. First level paging involves searching for the device in the

last known cell and second level paging searches in the neighboring cells if the device is not found in the original cell. For high mobility user equipment, a location management scheme with hierarchical and combined paging and location monitoring where both radio access network and core network are engaged to minimize signaling overhead [49]. An improved lightweight paging approach in LTE, preventing multiple copy paging messages sent to base stations to track mobile equipment, reduces communication initiation delay by MM entity selecting paging regions considering passaged time from the final location refreshing operation [50].

3.3 Offloading

Offloading in mobile communication networks alludes to the procedure of transferring tasks, computation, data traffic from the mobile gadget to another gadget to improve the quality of service and performance of mobile gadgets.

3.3.1 Computation Offloading

Computation offloading involves in transferring resource hungry computations from mobile devices to powerful and capable remote servers or cloud infrastructure to fulfill preserving the limited computational resources available in the mobile devices. The concept of computation offloading is representationally demonstrated in Fig. 3.

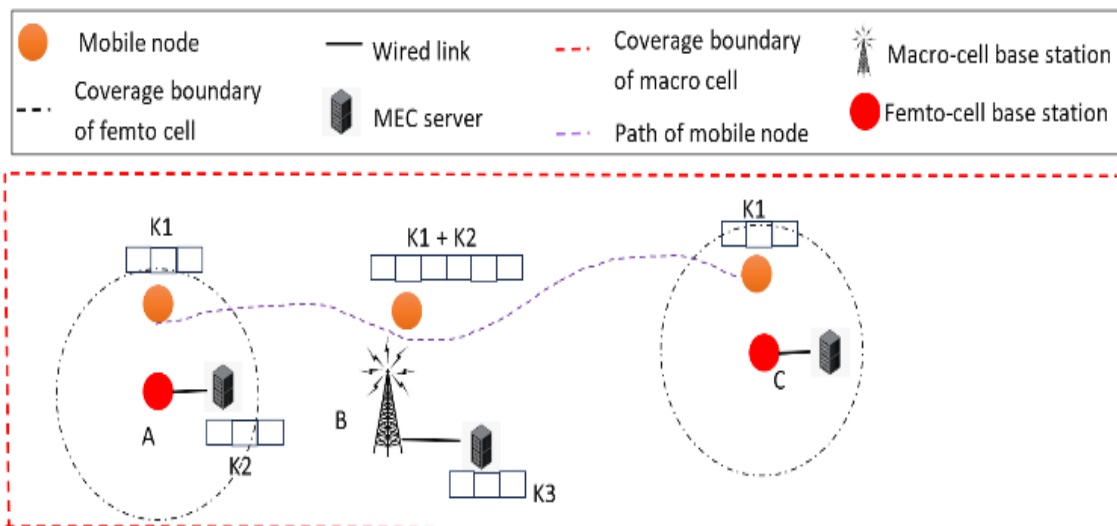


Fig. 3: Concept of computation offloading in mobility management.

As demonstrated by Fig. 3, when the mobile node is in coverage of femto-cell A, K2 amount of computations can be offloaded to Mobile Edge Computing (MEC) server associated with femto-cell A and K3 amount of computations offloaded to MEC server associated with macro-cell B while only K1 computations are performed by the mobile gadget locally. However, when the mobile gadget is in coverage of only macro-cell base station B mobile gadget will have to bear K1+K2 computations locally, as only K3 computations can be offloaded to MEC entity associated with macro-cell base-station B. This can contribute to energy efficiency and conserve resources in the devices [51]. A two-layer game theoretic greedy scheme is proposed in [6] for computation offloading from the mobile network to edge server associated with mobile base station in ultra dense internet of things networks. In hybrid fiber-wireless networks, cloud-edge collaborative computation offloading using two approaches: approximation- and game-theoretic-grounded has shown better computation offloading performance and scalability compared to other mobile-edge computation offloading approaches [52].

3.3.2 Task Offloading

Task offloading involves in offloading tasks or responsibilities within different equipment in the mobile network or between mobile devices and edge devices that help to balance the workload of mobile devices by transferring tasks when overloaded to another device or mobile edge. Moreover, this improves fault tolerance as tasks can be transferred from a fault device to a healthy one. A task offloading framework inside a mobile edge-cloud network requiring a virtual network duty with a delay tolerance has been implemented by maximizing admitted requests and minimizing operational cost by creating or sharing virtual network function instances [53]. Moreover, a three-layer network composed of mobile gadgets, edge, and cloud, an optimization operation of task offloading is developed by considering task offloading decision and computation infrastructure reservation to diminish average task period under constraint of energy of end devices [54].

3.3.3 Traffic Offloading

Traffic offloading involves in diverting traffic from heavily loaded cellular networks to alternative networks. Traffic offloading can be mainly realized in 3 ways: using small cells, using Wi-Fi networks, and using opportunistic communication.

Using Small Cells (SCs) - SCs are operated by low power proximal range base station that are not typically operated under supervision of cellular network operators utilized in areas with high user density. These can be utilized to offload traffic to transmit at higher data rates from macro cells. In [55], a dual connectivity enabled traffic offloading in multifaceted mobile networks has been feasible with the ambition of diminishing on-grid energy expenditure of small and macro cells, where small cells are powered using energy harvesting. Moreover, in narrowband internet of things networks, a multi-user multi-access point joint traffic offloading using small cells and power minimization optimization task is formulated with constraints of high throughput and secrecy [56].

Using Wi-Fi networks - Wi-Fi networks provide effective way of traffic offloading specially in environments with high user density. These networks are effective in traffic intensive data such as video and large file downloads. In unmanned aerial vehicular network driven by software-defined networking and coupled with Wi-Fi, the controller optimizes the queuing delay of cellular subscribers by selecting base station, cellular subscriber association with Wi-Fi access point and traffic offloading [7]. Moreover, in vehicular networks, control channel offloading from dedicated short-range communication to Wi-Fi has resulted in improved control channel throughput under dense vehicular traffic scenarios [57].

Using opportunistic communications - In opportunistic communication grounded offloading, alternative communication technologies such as using device to device communication, using unlicensed spectrum, etc. [58]. In Device-to-Device (D2D) communication, gadgets directly communicate among themselves in proximity using technologies such as Bluetooth or peer to peer Wi-Fi to offload traffic from the mobile network.

Table. 1: An abstract of living literature on network mobility management functions.

MM function	MM approach	Living literature	Approach	Performance
Handover management	Generic	Velocity-aware handover [1]	Stochastic geometry, skip base-station handover	High connection time, low handover failures
		Probability-grounded handover [31]	Markov chain-grounded optimal eNodeB selection	Low handover delays and failures
	Hard handover	Signal strength-grounded handover [32]	An algorithm grounded on received signal strength	Trade off among handover with uplink SNR
		Realtime handover [33]	QoS passport handover with CID assignment	Fast hard handover
	Soft handover	Dual-link handover [2]	Bi-casting with two antennas	Low outage probability, communi. Interruption
		Fractional soft handover [34]	Carrier aggregation	Low handover outage probability
	Reactive handover	Reactive handover optimization [35]	Optimize node movement detection, address conf.	Low handover latency, signalling overhead
		Handover triggering [36]	Predict two cases to establish bidirectional channel	Low handover delay
	Proactive handover	ABRAHAM [3]	Predictive analytics to preserve handover QoS	High throughput improvement
		Federated-learning-grounded [38]	Federated learning to train a model for handover	Lower communication cost and overhead
	Vertical handover	Vertical handover decision making [39]	Fuzzy logic to model uncertainty	Low packet transfer delays
		SCTP [40]	Multihoming, configuration of SCTP	Low latency and increased throughput
	Horizontal handover	Prioritization-grounded handover [41]	Algorithm for user prioritization	Better quality of experience, throughput, delay
		Utility-grounded handover [42]	Utility function considering SNR of network load	Reduced ping pong effect, improved throughput
Location management	Reactive	Reactive location service [44]	Inquire current location of mobile nodes	Better than GLS and DSR
		Geo-referenced data collection [4]	Collect individual space-time data	Location service adheres to privacy policies
	Proactive	Cell ID positioning [45]	GPS and GSM cell ID positioning	High energy efficiency
		Proactive location service [46]	Pushing location to close friends	Lower lookup delay, signalling cost
	Registration	Location update [47]	Alternative location algorithm	Low location update cost
		Implicit registration [48]	Two location registration area algorithm	Better signaling cost wrt. single location
	Paging	Paging [49]	hierarchical and combine paging with location tracking	Low signaling overhead
		Lightweight paging [50]	Select areas, prevent multiple copy for paging	Low communication initiation delay
Offloading	Computation offloading	Mobile edge computation offloading [6]	Game theoretic greedy scheme	Superior offloading within multiple edge servers
		Collaborative comput. offloading [52]	Approximation- and game-theoretic-grounded	Better scalability, offloading performance than edge
	Task offloading	Network function requirement [53]	Creating, sharing virtual network functions	Reduced operational cost and delay
		ADMM [54]	Minimize task duration under energy constraint	24% task duration reduction
	Traffic offloading - small cells	Green oriented TO [55]	Minimizing on-grid power consumption	Low power consumption of small, macro cells
		Secure traffic offloading [56]	TO using small cells, minimize power consumption	Low offloading cost, power consumption
Traffic offloading -	Delay-oriented TO [7]	Select base station, WiFi AP,	Low queuing delay	

	Wi-Fi		traffic offloading	
		Wi-Fi assisted TO [57]	Control channel offloading from DSRC to Wi-Fi	Improved control channel throughput
	Traffic offloading -- Opportunistic communication	D2D-TO [59]	Maximize TO subj. long-term data rates	Better offloading performance and throughput
		Opportunistic LTE and Wi-Fi [60]	TO and resource sharing using opportunistic Wi-Fi	TO, resource sharing have equivalent performance
Resource allocation	Radio	Power and bandwidth alloc. [8]	Power, bandwidth proximal strategy optimization	Meet latency constraints, minimize interference
		MIMO resource allocation [62]	Machine learning, beamforming, optimization	Low execution time, similar sumrate to CV2X
		Spectrum sharing [63]	Multi-agent reinforcement learning to share spect.	Improved sumcapacity, payload delivery rate
	Other	Computing resource allocation [64]	Stackelberg game-grounded trading and matching	FNs, DSOs and DCOs achieve optimum utility

A D2D communication in a cellular-Wi-Fi integrated network is utilized first in cellular band to aggregate cellular data and then offloaded to Wi-Fi network which is modeled as an optimization problem considering aggregating nodes and connected users to aggregating nodes to fulfill maximizing offloaded traffic subjected to constraints of long-term data rates [59]. Moreover, unlicensed shared spectrum can be utilized to offload traffic reducing traffic in licenses spectrum. In [60], a strategic tactic is used for collaborative utilization of resources or traffic offloading using Wi-Fi access points in a cellular mobile network to fulfill sharing the non-licensed spectrum of access points.

3.4 Radio Resource Allocation (RRA)

RRA in MM alludes to efficient allocation and utilization of radio frequency resources. Dynamic spectrum and bandwidth allocation by adjusting the width of frequency bands, etc. considering user mobility patterns and location, signal strength, interference, etc. is a major task in radio resource allocation [61]. Moreover, another aspect of this is radio resource power control to reduce interference and manage energy of the mobile nodes. RRA achieving energy conservation attempts to extend the lifespan of the network. Thus, a combined power and bandwidth reservation for a vehicular network using proximal strategy optimization method to learn an optimal policy using strategy gradient to fulfill selecting the frequency sub-band and power has been feasible for a vehicular network [8]. Specifically, beamforming and Multiple Input Multiple Output

(MIMO) can be utilized to allocate radio resource efficiently to focus transmit power and data streams towards specific users. A radio resource allocation system for massive MIMO system utilizes machine learning for radio resource allocation and utilizes beamforming for each radio frequency chain accompanied by an optimization problem for maximizing throughput constrained by total transmit power and number of radio chains [62]. Furthermore, this includes interference mitigation avoiding resource allocation strategies to reduce interferences in densely populated cells and dynamic spectrum sharing that dynamically shares the available spectrum among multiple users. In [63], vehicle-to-infrastructure spectrum in a vehicular network is shared for vehicle-to-vehicle links using multi-agent reinforcement learning where vehicular connections serving as agents gain insight to raise spectrum sharing and power reservation by experience.

3.5 Other resource allocation

Except radio resource allocation, there are other resources such as computational resource allocation, IP address allocation, authentication and security credential allocation, allocation of billing records and agreements, etc. In a three-tier network consisting of fog node, data service operators, and data service subscribers, computation resources are allocated by using a Stackelberg game-grounded trading approach to sell computing resources from operators to subscribers and accompanied by a many-to-many matching scheme to pair data service subscribers and fog nodes [64].

Table. 1 demonstrates an abstract of living literature on network mobility management functions.

4. An Abstract of Different MM Procedures

4.1 Grounded on MM Architecture

4.1.1 Distributed MM

In distributed MM, there exist no centralized node for MM and each node is responsible for its MM by exchanging information with other mobile nodes. For performing strategic tasks such as target tracking efficiently, distributed MM is achieved using distributed optimization considering node mobility, connection loss potential, and sensing coverage loss [65].

4.1.2. Centralized MM

In centralized MM, a centralized authority (a base station or eNodeB) is responsible for managing handover, location, power control, spectrum allocation, etc. [66]. Performance analysis comparing distributed MM with centralized MM proves that distributed approach yields in low latency and has high scalability [9].

4.1.3. Cluster-grounded MM

In cluster-grounded MM, the network is subdivided into small groups (clusters) every cluster having a cluster head and cluster members. In contrast to centralized approach, cluster head is responsible for managing the mobility within the cluster where tasks such as spectrum sensing, radio resource allocation, etc. take place locally within the clusters. Namely, a target tracking system for a mobile sensor network utilizes location grounded in clustering to achieve cluster time-planning and node time-planning within cluster to fulfill reducing energy consumption in tracking [67].

4.2 Grounded on the mobility class

4.2.1. Host grounded

In host grounded MM, the primary responsibility for managing the mobility lies with the host (end devices) and lacks a centralized MM entity unlike in conventional networks. Blockchain-grounded MM is

often host-grounded. Thus, the gadgets are duty-bound for handover and location coordination as the gadget moves through the network by using approaches including distributed consensus and information exchange. Host identity protocol is an example of host grounded in MM. A distributed host-grounded in mobility coordination framework distributes mobility anchors in level of access network for the mobile nodes to be served by close mobility anchors keeps previous IP addresses attached to previous anchors for maintaining continuous communication [68].

4.2.2. Network grounded

Network grounded mobility coordination is the conventional approach utilized in mobile telecom networks suchlike GSM, LTE, and 5G where there is an MM entity responsible for mobility coordination. Proxy Mobile IPv6 (PMIPv6) being a network grounded in mobility coordination protocol has shown superior performance in terms of MM compared to its distributed version MIPv6 [69].

4.3. Grounded on presence of packet reordering

4.3.1. Packet Reordering (PR) sensitive

Packets can be reordered during handover and can degrade the performance of packet order sensitive applications [70]. Thus, packet reordering sensitive MM makes sure that packet order is retained even under handovers and network changes. However, it has been shown that packet reordering increases the delay and jitter [71]. Smart buffering and packet marking can be utilized to reorder packets that may go out of order during handover using FPMIPv6 to mark end of delivery for new and old paths [72].

4.3.2. Packer reordering tolerant

There are applications such video streaming and file downloads that are tolerant of packet reordering. For such applications, the MM can be packet reordering tolerant where the handover optimization can consider optimizing other factors such as handover latency rather than ensuring correct packet order [73].

Table. 2: An abstract of living literature on network mobility management procedures.

MM Procedure	Living literature	Approach	Performance
Distributed	Distributed target tracking [65]	Distributed optimization - mobility, loss potential, etc.	Good quality of target tracking, high energy consumption
Centralized	Distributed/centralized [9]	Centralized controller, dynamic mobility anchoring	Centralized approach is less scalable, has high latency
Cluster-grounded	Cluster-grounded target tracking [67]	Location grounded clustering and scheduling	Reduced energy consumption
Host-grounded	Host-grounded MM [68]	Deploys mobility anchors to maintain communication	Better handover latency and throughput
Network-grounded	All IP-MM [69]	Proxy Mobile IPv6 (PMIPv6)	PMIPv6 has better performance than MIPv6
PR sensitive	IPv6 handover [72]	Smart buffering and packet marking for reordering	Fast handover, effectively handles pkt reordering
PR tolerant	Loss-free handover [73]	Consider handover latency optimization	Improved probability for loss-free handover
QoS aware	QoS-aware handover [74]	Selects base station adhering to video QoS	Improved quality of experience
Best effort	Best-effort VoIP handovers [12]	Study mobility actions and events in handover	Link acquisition latency contribute for call failure

4.4. Grounded on support for Quality of Service (QoS)

4.4.1. QoS aware

QoS aware MM makes sure that QoS parameters are maintained (providing different levels of service to different types of traffic) when the mobile devices move through the network. This involves flow prioritization and dynamically adjusting network resources such as bandwidth allocation to satisfy QoS requirements such as packet loss, latency, throughput, etc. For instance, in [74], for QoS perceptive video transmission in multifaceted macro and small cell LTE networks, handover selecting the appropriate base station adhering to video QoS parameters has been studied.

4.4.2. Best effort

Best effort MM focuses on providing continuous connectivity by MM rather than adhering to different QoS requirements of traffic [75]. A best effort voice over IP handover between wireless local area network and CDMA evolution data optimized networks has shown that EVDO link acquiring latency contribute towards call failures [12]. Table. 2 demonstrates an abstract of living literature on network mobility management procedures.

5. An abstract of Blockchain Platform

An array of linked blocks or operations/transactions constitutes the transparent ledger labelled as blockchain.

5.1 Structures

Every specific block inside a simple blockchain, which constitutes a content sector and header sector is linked to its predecessor block (barring the initial block) utilizing the predecessor block's hash result, and the operations/transactions inside a content sector are segmented into a Merkle tree composition [14]. Mesh blockchain constitutes a mesh of linked operations/transactions where one operation/transaction may prove the integrity of many additional previous operations/transactions. These operations don't have content sectors and header sectors, thus Merkle trees do not exist [15].

5.2 Transactions

A consumer can launch a blockchain transaction/operation, which is following that conveyed to all associates inside the network and concealed utilizing the sender's exclusive access key. A consensus procedure will launch once each consumer utilizes the digital signature's revealed key to check the validity of the transaction/operation.

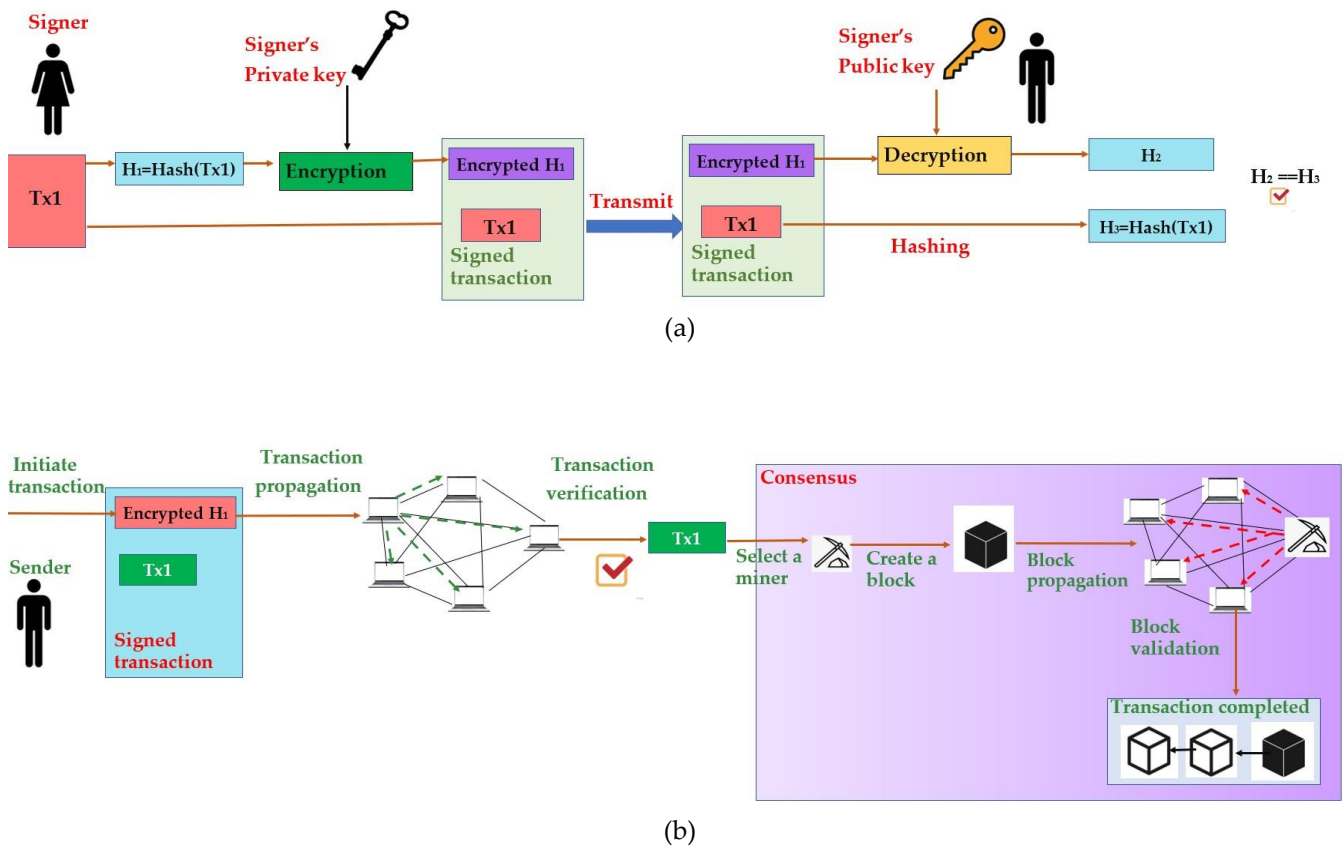


Fig. 4: Transaction process. (a) Transaction validation using digital signature. (b) Common transaction procedure.

Transaction verifiers regularly participate in consensus by including the transaction/operation inside a block, which is followed by a conveying around the transparent ledger network and engaged by each consumer in the transparent ledger network subsequent block attestation [76]. Validation of transactions using digital signature and the common procedure of a transaction are demonstrated in Fig. 4.

5.3 Cryptography

To sustain the incorruptibility of operations/transactions in blockchain, secure hashing is utilized to offer steady size hash results with scant same outputs [13]. Utilizing an electronic signature, asymmetric encryption technology exhibiting cryptographic keys is utilized to check the validity operations/transactions. With a view to strengthen the confidentiality of digital content, it might also be

utilized to make secret blockchain operations/transactions [76]. Proofs of secret knowledge are utilized to check the validity of operations'/transactions' accuracy privately holding the sensitive data of operations/transactions, strengthening confidentiality and impeding the conveying of individualized evidence [16]. Quantum-resistant cryptography utilizes productive cryptographic methodologies that are defend against challenges from quantum computational tools, suchlike SIKE, execution time optimized Ed25519, and whatnot [17].

5.4 Consensus

Blockchain consensus utilizes widespread agreement to form and attest untrodden blocks, sustaining the incorruptibility of the transparent ledger platform.

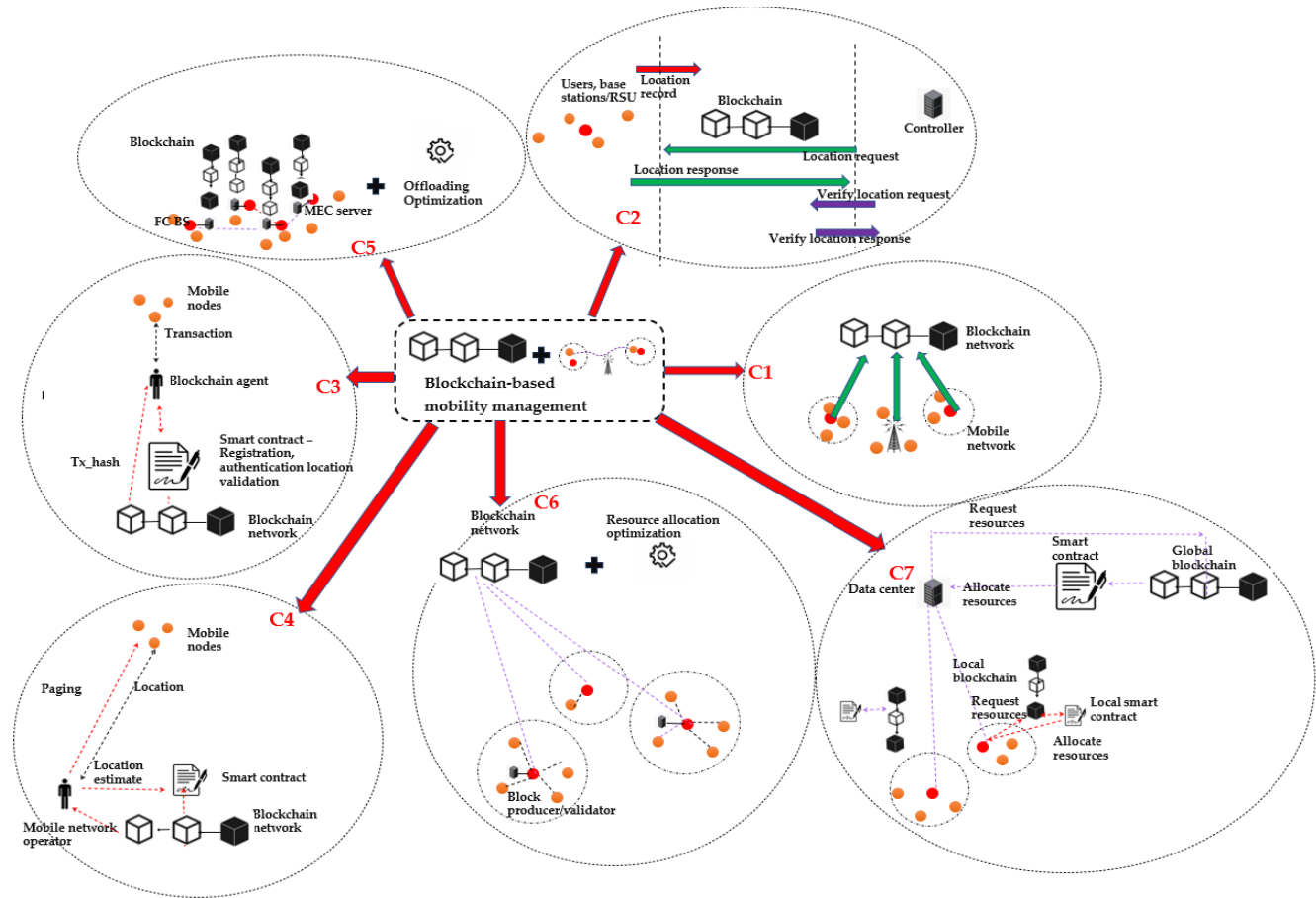


Fig. 5: Principle of blockchain-grounded network mobility management.

In vote-grounded consensus, relevant data are conveyed and acquired inside group of the associates as they contribute jointly to check the validity of blocks. The widely acclaimed vote-grounded consensus methodology utilizes byzantine fault-resilience consensus, within which a controller includes operations/transactions inside a block, conveys it, and consumers reconvey it to attest the block acquired through the parent is twin [18]. Given that each consumer got twin duplicates of an untrodden block through beyond a two-third portion of the network's consumers, the block is destined to be included to the transparent ledger.

Proof-grounded consensus requires consumers to offer compelling evidence as a result of why they are destined to be recognized for including an untrodden block to the transparent ledger. The most well-liked proof-grounded consensus methodology is known as proof-of-work enforcing a consumer to complete tasks by addressing an arduous puzzle with a view to

sustain its validity [76]. There exist alternative proof-grounded green consensus methods that take into account nodes stake, authority, reputation, etc. as proof.

6. Blockchain-grounded MM

6.1 Principle

Stemming from this survey, blockchain-grounded MM principle can be clustered into the pursuant 7 clusters.

- C1 - Blockchain grounded secure handover - This involves handover authentication, secure handover, and energy efficient handover using blockchain technology itself;
- C2 - Utilizing blockchain to preserve privacy and trust for communication and storage in location management;
- C3 - Utilizing blockchain for registration and authentication of network nodes;
- C4 - Utilizing blockchain and SCs for paging;

- C5 - Utilizing blockchain to reduce the vulnerabilities, protect data privacy, repair low quality data, prevent data loss, coordination, enable fair scheduling, etc. in offloading;
- C6 - Utilizing blockchain for securing transactions to fulfill allocating resources using a conventional technique;
- C7 - Utilizing blockchain itself for secure resource allocation.

The principle of blockchain-grounded mobility management is representationally demonstrated in Fig. 5.

6.2 Review on Blockchain grounded MM

6.2.1. Blockchain grounded generic MM

A decentralized group mobility coordination system grounded on blockchain has been utilized to decrease handover latency and expenditure associated with signaling during authentication in group communication scenarios in vehicular adhoc networks [10].

6.2.2. Blockchain grounded Handover

Blockchain-grounded Handover authentication

Handover authentication involves in a device authenticate itself with new access point during handover which is essential for effective connection transition in wireless networks. Blockchain has been presented for vehicle to infrastructure communication's handover authentication in vehicular adhoc networks where the vehicles perform low weight computations during handover [21]. Software defined networking and blockchain technologies have been integrated for authentication handover to fulfill preventing repeated handover and unwanted re-authentication in fifth generation mobile networks while satisfying the low delay requirements of those networks [20]. HO-Auth is a framework utilized in IoT networks to detect malicious users utilizing deep learning with the aid of channel state information where user profiles are built using blockchain for secure authentication handover [77]. A fine-grained access control system by using private and anonymous handover authentication utilizing a consortium blockchain and attribute grounded

signature with multi-attribute authority scheme has been effective [78].

Blockchain-grounded Secure handover

In non-orthogonal multiple access technique, a two-tier encryption technique utilizing a blockchain has been investigated for secure data handover in wireless networks [79]. Zero knowledge proof protocol has been utilized accompanied by blockchain for secure handover for an IoT device from one gateway to another securely and anonymously with mutual authentication [80]. A scheme for deriving secure keys using blockchain for secure handover in fifth generation mobile networks with full forward key separation has provided security benefits over 4G [81].

Blockchain-grounded Energy efficient handover

In fog network architecture, a distributed MM framework utilizing three different types of blockchains (proof of work in fog server level, region-wise blockchain to control mobility anchors and access routers, user-wise blockchain comprising of mobile nodes) to fulfill solving hierarchical security problems and capable of providing energy-efficient handover has been studied in [82]. Mesh blockchain with proof of space consensus approach is utilized preserving energy for context-aware authentication and handover with the aid of Markov decision process within networks sliced using generative adversarial networks while balancing load by the software-defined controllers known as SliceBlock [83]. BEPHAP is a computationally efficient and anonymous handover authentication framework in inter-domain by utilizing blockchain and cryptography designed for internet of vehicles that is resistant to security attacks [22].

6.2.3 Blockchain grounded Location management

Blockchain-grounded Privacy conservation location management

In vehicular networks, a blockchain grounded in trust safeguarding scheme provides the opportunity for the automobiles to use certificates to get location-grounded services without revealing private information [84]. Moreover, order preserving encryption accompanied by blockchain's Merkle tree are utilized to provide multiple-level privacy

conservation for sharing location in a medical information system known as BMPLS [85]. Alternatively, trust value is computed for creating a trusted cloaking area for a set of cooperative vehicles with the aid of network edge to fulfill preserving the location privacy of the request vehicle requesting the location grounded services where blockchain is utilized for secure data management [86]. In an effort to ensure user privacy and trustworthiness of location, a decentralized approach known as proof-of-location has been presented to provide trustworthy geographical locations of network users to provide location-grounded services to them [23].

Blockchain-grounded Registration

Distributed ledger is utilized for recording the location (space and time information) of mobile nodes of a network in a secured manner and access control is implemented to securely access the location information in a privacy preserving manner [87]. FogAuthChain uses Ethereum blockchain for registration and authentication of Fog devices mutually (device-to-device) grounded on location in a decentralized, computationally efficient, and secure style [24]. CrowdBLPS is a mobile crowd sensing system that utilizes blockchain to prevent repudiation and tampering while preregistration and selection of data preserving privacy of location is presented in [88]. In preregistration phase of the CrowdBLPS, SCs are utilized to select data and location privacy is ensured using optimization techniques and cloaked area generation.

Blockchain-grounded Paging

Hyperledger fabric has been utilized to secure the client's location data while providing location paging and answering service by integrating with a 3-way handshake procedure to establish secure communication among users has been known as BILPAS [89]. A Geofence has been feasible by utilizing SCs in blockchain to by collecting location information of devices using paging to fulfill providing location grounded services while a location encoding system also utilized to transform polygons into grid cells [25].

6.2.4. Blockchain grounded offloading

Blockchain grounded in Task offloading

Mobile edge computing grounded in blockchain network has been presented for the mobile users to offload the data processing and blockchain mining activities where the offloading task and mining profit are emulated as an optimization task and provided solution using Deep Reinforcement Learning (DRL) minimizing offloading utility where the offloading decisions are made grounded on blockchain transaction states [90]. In an IoT network, a task offloading and energy harvesting approach for resource constrained IoT devices has been presented by utilizing unmanned aerial vehicles where these tasks are formulated as an optimization problem and solved using DRL where blockchain is utilized to reduce the vulnerability issues of offloading tasks [91]. Consortium blockchain has been utilized to protect privacy of data, assess and mend inferior quality data using a consensus algorithm accompanied by a reinforcement learning approach for activity organization for an activity offloading platform from resource bound gadgets to edge computing in internet of energy [92].

Blockchain grounded in Computation offloading

BCO is a blockchain grounded in computation offloading framework for 5G telecom networks to offload computation from user equipment to edge gadgets where the ambition of the blockchain is to prevent data loss and a genetic algorithm is utilized for achieving the offloading task [26]. Alternatively, blockchain has been utilized to prevent illegal computation offloading to an edge-cloud network from a mobile vehicular network to optimize offloading minimizing delay, energy usage, and flow expenditures while resolving the offloading task using a DRL technique [27]. Likewise, in [93], blockchain is utilized as a computation offloading coordinating framework by announcing offloading requests and then coordinating offloading between user equipment and edge nodes in ultra dense networks accompanied by a user matching algorithm to consider execution time and energy usage. Moreover, two computation offloading problems: device to device computation offloading and blockchain mining offloading in a 5G mobile network which are formulated as a stock market and Stackelberg game respectively, which are solved using pricing schemes has been studied in [94].

Blockchain grounded in Traffic offloading

A mesh blockchain has been effective as a scalable solution in offloading data in mobile communication networks while optimizing time cost using a game theoretic method to fulfill reducing cellular network congestion [95]. For fifth-generation mobile communication networks, blockchain has been utilized to make sure that scheduling of data offloading resources to Wi-Fi is fair where users can create Wi-Fi zones to use own data plans which also makes use of software-defined networking paradigm to get better inter-provider communication [96]. For space-air-ground fused networks, blockchain and federated reinforcement learning are utilized in combination to offload traffic from ground network in a secure manner without affecting offloading decisions from the malicious nodes. In the precedingly mentioned scheme, traffic offloading process is modeled as a Markov decision procedure and node security is evaluated using enhanced Practical Byzantine Fault Tolerance (PBFT) consensus approach in blockchain [97].

6.2.5. Blockchain grounded in Resource reservation

Blockchain grounded in Generic resource reservation

A dynamic resource allocation scheme by fusing blockchain and DRL in unmanned aerial vehicles enabled fifth-generation radio access networks where blockchain serves the security aspect of virtual transactions and DRL is utilized to solve the resource reservation activity in mobile user equipment modeled as a hierarchical Stackelberg game [98]. Block-RAS is an asset allocation system built using secure and trustworthy public Ethereum blockchain to coordinate the requirement and supply of assets among the 6G users and asset providers to fulfill providing low delay, high reliable, optimum bandwidth communication among them [29]. Likewise, blockchain is proposed for achieving dynamic resource sharing in 6G with improved security and automation while it is integrated with artificial intelligence for decision making regarding the resource allocation [99]. Moreover in [100], a framework known as Block6Tel is proposed utilizing blockchain-grounded auctioning for secure spectrum and other resource allocation among service providers in 6G mobile networks that has shown superior

performance in terms of resource utilization and overhead. In internet of vehicles, a blockchain network is formed by edge computing nodes with an auction approach to store automobile's driving data in blockchain and then allocate resources grounded on heuristic algorithms considering resource demand of the miners [101].

Blockchain grounded in Radio Resource reservation

For connected autonomous vehicles, a radio and computing resource allocation where a nonfungible token-grounded blockchain is utilized to reserve resources for a specific road segment in given time has effectively reduces the number of uncompleted tasks [102]. Similarly, in a blockchain grounded in multi-access edge computing system, joint optimization is performed to optimize computational and radio resource allocation minimizing energy consumption and delay to provide the best trade off in performance between multi-access edge computing system and blockchain [103]. In a device free sensing mobile network that utilize blockchain for securing the privacy, joint optimization of task offloading to mobile edge, computation asset reservation, and radio resource reservation among applications with the objective of minimizing user cost has achieved good achievement in relation to energy utility and delay [28]. Moreover, in 6G private networks, to fulfill allocating spectrum for coexisting shared spectrum access in a trustworthy manner, blockchains have been utilized to log data and network interactions while two new functions have been introduced to manage coexisting spectrum access [104].

Blockchain grounded in QoS-driven resource reservation

In a blockchain-grounded femtocell network, the engaging activities between macrocell base-station and femtocell user is modeled as a Stackelberg game to allocate the pricing and power optimally satisfying quality of service parameters (transmission rate of macrocell, delay of femtocell) [105].

7. Review Study

7.1 Studying of unique entities

Table. 3: Studying of Blockchain grounded mobility management frameworks.

MM Function	Reference	BC principle	Blockchain structure	Blockchain consensus	Blockchain class	MM approach	Network structure	Network class	Performance	Dis. year
Generic	Group MM [10]	C1	Simple	Generic	Generic	Distributed, host-grounded, PR-tolerant, best effort	Decentralized	VANET	Decreased handover latency, cost	2019
Handover authentication	HA-VANET [21]	C1	Simple	Generic	Generic	Distributed, host-grounded, PR-tolerant, best effort	Distributed	VANET	Secure and efficient handover	2022
	HA-5G [20]	C1	Simple	DPoS	Public	Distributed, host-grounded, PR-tolerant, best effort	Centralized	SDN-5G	Privacy protecting, low handover delay	2019
	HO-Auth [77]	C1	Simple	Custom	Private	Distributed, host-grounded, PR-tolerant, best effort	Decentralized	IoT	0.91 detection accuracy, corrupt data protection	2021
	MA-ABS [78]	C1	Simple	PBFT	Consortium	Distributed, host-grounded, PR-tolerant, best effort	Generic	Wireless	Privacy preserving and efficient handover	2021
Secure handover	NOMA [79]	C1	Simple	Generic	Generic	Distributed, host-grounded, PR-tolerant, best effort	Generic	Wireless	Spoofing attack, hijacking resistant	2018
	ZKP [80]	C1	Simple	Generic	Generic	Distributed, host-grounded, PR-tolerant, best effort	Decentralized	IoT	Better time complexity, cost, energy cons.	2021
	BC-MM [81]	C1	Simple	Generic	Generic	Distributed, host-grounded, PR-tolerant, best effort	Generic	5G	Improves handover performance than 4G	2020
Energy-efficient handover	DMM [82]	C1	Simple	PoW	Private	Distributed, host-grounded, PR-tolerant, best effort	Hierarchical	Fog	Low energy consumption	2018
	SliceBlock [83]	C1	Mesh	PoS	Generic	Distributed, host-grounded, QoS-aware, PR-tolerant	Centralized	SDN-6G	Preserve energy during handover	2022
	BEPHAP [22]	C1	Simple	Generic	Generic	Distributed, network-grounded, PR-sensitive, best effort	Generic	IoV	Efficient, resistive against security attacks	2023
Privacy preserving location management	Loc-VANET [84]	C2	Simple	PoPr	Permissioned	Distributed, host-grounded, PR-tolerant, best effort	Decentralized	VANET	Resilient to trust model attacks	2020
	BMPLS [85]	C2	Simple	PoW	Generic	Distributed, host-grounded, PR-tolerant, best effort	Generic	Medical	Feasible privacy-preserving location sharing	2018
	Cloaking [86]	C2	Simple	PoW	Consortium	Distributed, host-	Generic	Vehicular	Suppress dishonest	2020

						grounded, best effort	PR-tolerant, host-grounded, best effort			coorporative vehicles	
	PoLo [23]	C2	Simple	PoLo	Public	Distributed, grounded, best effort	host-PR-tolerant, best effort	Generic	Generic	Privacy preserving, location trustworthy	2018
Registration	Inviolable [87]	C3	Simple	PoW,DPoS	Pub., Pri.	Distributed, grounded, best effort	host-PR-tolerant, best effort	Generic	Generic	Low communication overhead, Ethereum feasible	2021
	FogAuthChain [24]	C3	Simple	PoW	Public	Distributed, grounded, best effort	host-PR-tolerant, best effort	Hierarchical	Fog	Computationally efficient and secure authentication	2020
	CrowdBLPS [88]	C3	Simple	PoW	Public	Distributed, grounded, QoS-aware	host-PR-tolerant, best effort	Centralized	IoT	Provide non-repudiation, non-tampering	2019
Paging	BILPAS [89]	C4	Simple	PBFT	Permissioned	Distributed, grounded, best effort	host-PR-tolerant, best effort	Generic	Indoor	High privacy communication tunnel	2021
	Geofence [25]	C4	Simple	PoW	Public	Distributed, grounded, best effort	host-PR-tolerant, best effort	Generic	Generic	Cost increases linearly with grid cells	2018
Task offloading	RL [90]	C5	Simple	PoW	Public	Distributed, grounded, QoS-aware	host-PR-tolerant, best effort	Decentralized	MEC	Enhance user privacy, low energy consumption	2020
	DRL [91]	C5	Simple	Generic	Generic	Distributed, grounded, QoS-aware	host-PR-tolerant, best effort	Generic	IoT	Low computation cost, maximize utility	2022
	IoE [92]	C5	Simple	Custom	Consortium	Distributed, grounded, QoS-aware	host-PR-tolerant, best effort	Generic	IoE	Evaluate, repair data quality	2021
Computation offloading	BCO [26]	C5	Simple	PoW	Generic	Distributed, grounded, QoS-aware	host-PR-tolerant, best effort	Generic	5G	Low average resource utilization	2021
	DRL [27]	C5	Simple	RBFT	Generic	Distributed, grounded, QoS-aware	host-PR-tolerant, best effort	Hierarchical	SDV	Low long-term delays, energy consu.	2020
	D2D [93]	C5	Simple	Generic	Generic	Distributed, grounded, QoS-aware	host-PR-tolerant, best effort	Distributed	UDN	Low energy consuming matching algorithm	2019
	Pricing [94]	C5	Simple	PoW	Public	Distributed, grounded, QoS-aware	host-PR-tolerant, best effort	Generic	5G	Improved utility of demanders and suppliers	2022
Traffic offloading	DAG [95]	C5	Mesh	ABFT	Generic	Distributed, grounded, best effort	host-PR-sensitive, best effort	Generic	Internet	Scalable, low computational cost,	2020

						QoS-aware			time	
	Wi-Fi [96]	C5	Simple	PoW	Public	Distributed, host-grounded, PR-tolerant, QoS-aware	Generic	5G	Efficient communi., unbiased decision making	2020
	FRL [97]	C5	Simple	EPBFT	Generic	Distributed, host-grounded, PR-tolerant, QoS-aware	Generic	SAGIN	Better security and latency wrt. others	2022
Generic resource allocation	B-ERA [98]	C6	Simple	Generic	Generic	Distributed, host-grounded, PR-tolerant, QoS-aware	Generic	5G	Better utility service, QoS satisfaction	2023
	6G-public [29]	C7	Simple	PoW	Public	Distributed, host-grounded, PR-tolerant, QoS-aware	Generic	6G	Scalable, better BW utilization, delay, packet loss	2020
	DRS [99]	C7	Hierarchical	PoW/PoS	Generic	Distributed, host-grounded, PR-tolerant, QoS-aware	Generic	6G	Optimize user profit ratios	2021
	Block6Tel [100]	C7	Simple	Generic	Generic	Distributed, host-grounded, PR-tolerant, QoS-aware	Generic	6G	Better resource utilization and overhead	2021
	Auction [101]	C6	Simple	PoW	Public	Distributed, host-grounded, PR-tolerant, QoS-aware	Generic	IoV	Good social welfare, resource utilization	2022
Radio resource allocation	CAV [102]	C7	Simple	PoW	Public	Distributed, host-grounded, PR-tolerant, QoS-aware	Generic	CAV	Reduces uncompleted tasks by 69\%	2023
	MEC [103]	C6	Simple	DPoS	Generic	Distributed, host-grounded, PR-tolerant, QoS-aware	Decentralized	MEC	Optimal trade-off among energy, DTF	2020
	Edge-cloud [28]	C6	Simple	Generic	Generic	Distributed, host-grounded, PR-tolerant, QoS-aware	Decentralized	MEC	Good energy consumption, delay performance	2023
	6G-DLT [104]	C6	Simple	Generic	Generic	Distributed, host-grounded, PR-tolerant, best effort	Generic	6G	No performance analysis presented	2022
QoS-driven RA	Femtocell [105]	C6	Simple	Generic	Generic	Distributed, host-grounded, PR-tolerant, QoS-aware	Hierarchical	Femtocell	Solution converge, Enhances QoS, guaranteed relay	2019

Table. 3 demonstrates the studying of blockchain-grounded mobility management frameworks with respect to mobility management function and technique, blockchain related concept and parameters, network related parameters.

7.2 Overall Study

Fig. 6 graphically demonstrates the scattering of blockchain-grounded mobility management frameworks inspected in this piece of review. As demonstrated by Fig. 6 (a), the utmost overarching BC-grounded MM concept is C1 (37.5%), coming after C5 (25%), C6 (15%), C2 (10%), C7 (10%), C3 (7.5%), C4 (5%). Next, 92.5% of BC-grounded MM frameworks use simple BC architecture while only 5% use the mesh architecture, and 2.5% use the hierarchical architecture, as demonstrated by Fig. 6 (b). When studying about the blockchain consensus procedure in BC-grounded MM frameworks, it is assured, as demonstrated by Fig. 6 (c) that equivalent high percentage (32.5%) of frameworks either use PoW consensus procedure or have been tailored for generic consensus without specifying a specific consensus procedure, coming after custom consensus (5%), DPoS (5%), PBFT (5%), and more. Furthermore, BC-grounded MM frameworks have been 100% distributed, 97.5% host-grounded, 2.5% network grounded, 95% packet reordering tolerant, 5% packet reordering sensitive, 52.5% QoS aware, and 47.5% best effort, as demonstrated by Fig. 6 (d) Moreover, it is demonstrated by Fig. 6 (e) that highest percentage

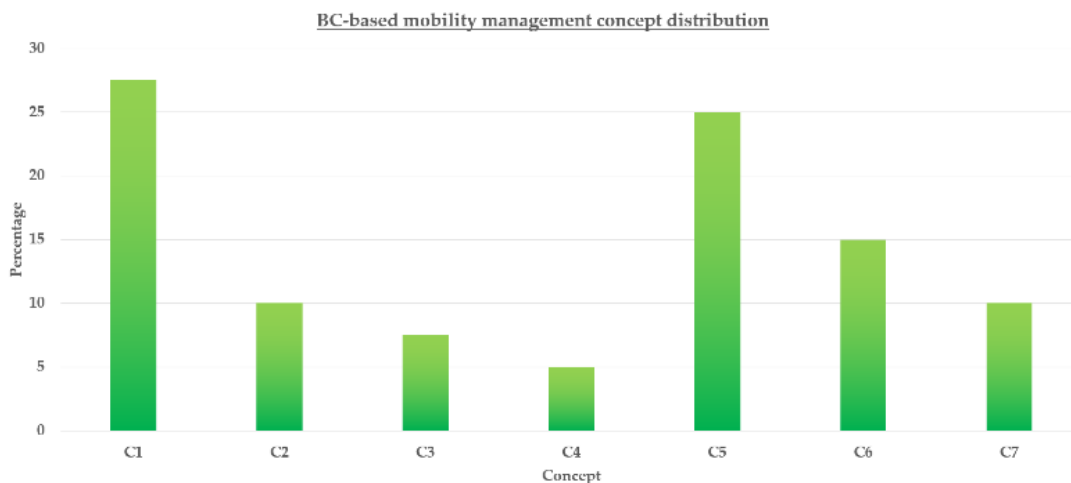
(12.5%) of BC-grounded MM frameworks have been proposed for 5G networks, coming after by 6G (10%), IoT (10%), MEC (7.5%), generic (7.5%), VANET (7.5%), and more. Finally, it is demonstrated by Fig. 6 (f) that BC-grounded MM frameworks' volume per year has amplified since year 2018 until year 2020 and then an undoubtedly decreasing trend of research interest is observed afterwards.

8. Discussion

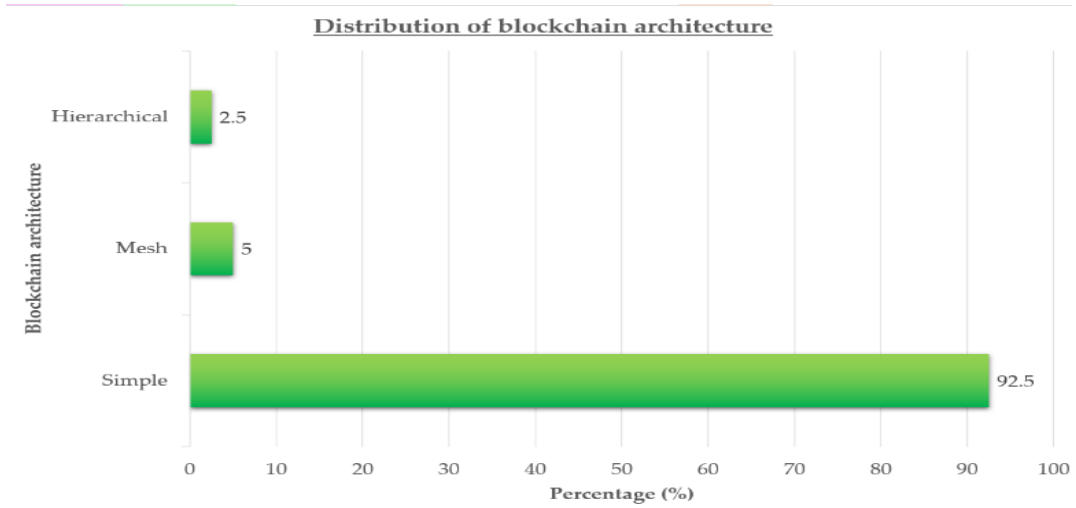
8.1 Openings

8.1.1. Secure handover

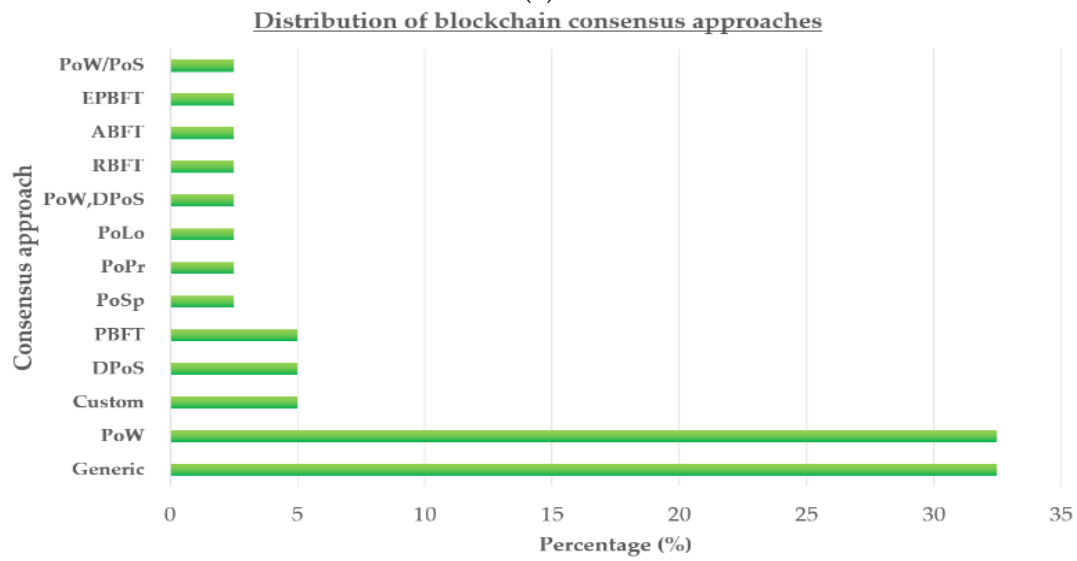
In mobile communication networks, blockchains aid in handover authentication and securing it. Handover is a step where attackers can gain control of network connection by mimicking as legitimate mobile devices so that robust authentication and handover security countermeasures must be utilized to prevent such attacks. Blockchains facilitate seamless handover authentication preventing re-authentication and repeated handover. Moreover, blockchains can keep a record of malicious user profiles to prevent authentication of malicious users during handover. Furthermore, blockchain-grounded handover authentication can be integrated with a traditional access control strategies and zero knowledge proofs to improve its anonymity and privacy features. Additionally, multi-layered encryption and key generation techniques can be utilized in blockchain to raise the security of handover.



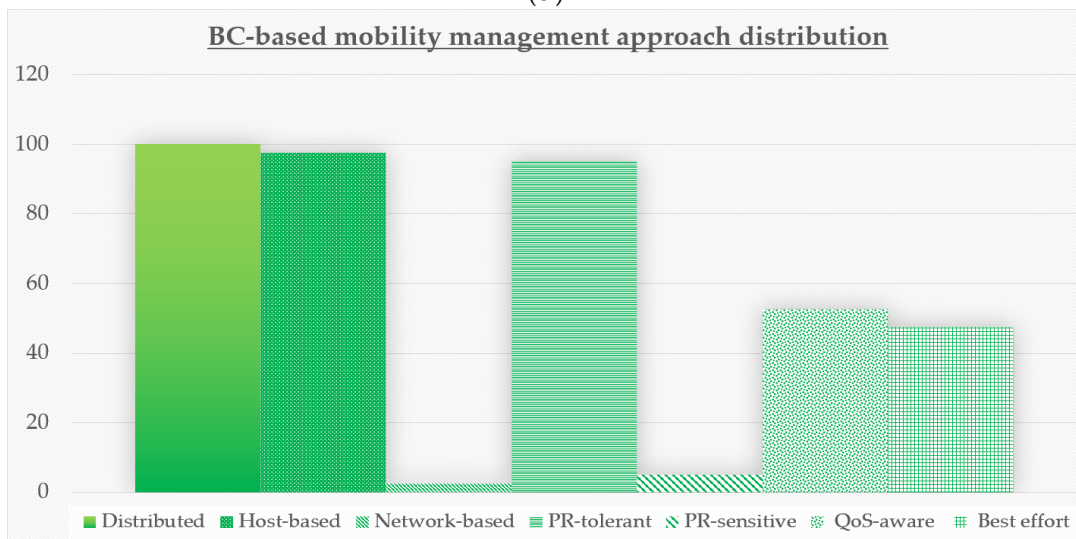
(a)



(b)



(c)



(d)

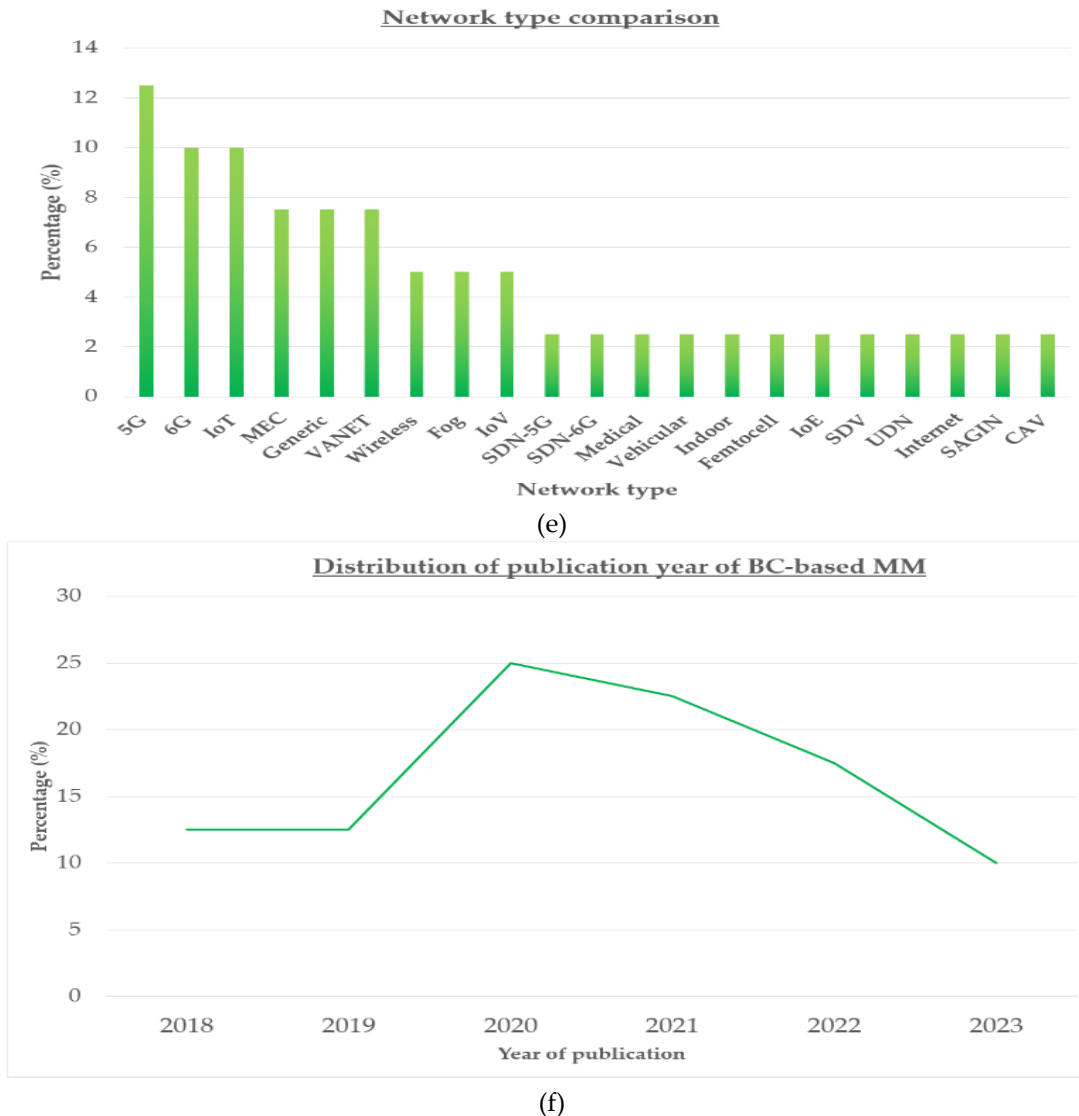


Fig. 6: Overall study (a) BC-grounded mobility management principle (b) Architecture of blockchain (c) Blockchain consensus (d) BC-grounded MM approach (e) Class of network (f) Disclosed year

8.1.2. Privacy safeguarding location management

In location management, the network has the visibility of each individual user’s location in the access link that is realized using paging and registration tasks. However, knowing the location of a device can compromise the privacy of a user. Blockchains can facilitate location management without revealing the private information. Specifically, it can utilize a trust grounded scheme using different techniques including certificates, multi-layered encryption, trusted cloaking areas, and location-grounded consensus to disseminate location information grounded on the derived trust values preventing privacy exposure. Moreover, blockchains

can securely store the location information and utilize access control strategies to access the location information such that only approved entities can entry to the location data. Furthermore, storing location information in blockchain prevent repudiation and tampering such that users cannot deny storing of information while attackers cannot mutate the location data.

8.1.3. Assist task, computation, and traffic offloading

Even though task, computation, and traffic offloading tasks are primarily realized using optimization and artificial intelligence techniques, blockchain can facilitate these processes in numerous

ways [106]. First, blockchain transaction states can be assisted in reaching offloading decisions. Secondly, they can reduce the vulnerability of offloading tasks and illegal offloading by securely storing transactions in the blockchain in a privacy safeguarding style and use consensus to evaluate the quality of data. Moreover, blockchain can prevent data loss during offloading tasks by securely storing data. Furthermore, they can act as a coordinator for offloading tasks to announce offloading requests facilitating communication among user equipment and edge nodes. Additionally, they can also make sure that offloading tasks are scheduled fairly while blockchain consensus can be utilized to evaluate the security of offloading tasks.

8.1.4. Dynamic resource allocation

Blockchains can facilitate in dynamic resource allocation considering the changes in the network status and behavior to dynamically reserve resources to match varying network requirements. They can be utilized to manage the demand and supply of resources with improved security. Moreover, blockchain can be utilized for auctioning for resource allocation where data is stored in the blockchain and resources are allocated grounded on demands and supplies of the service providers. Furthermore, token grounded blockchain can be utilized for allocating resources. Additionally, blockchains can be utilized for securing the privacy in frameworks where resource allocation is realized using optimization techniques. During resource allocation, blockchains can be utilized to log data and interactions of the network to provide trustworthy resource allocation.

8.1.5. Decentralized MM

Blockchains allow decentralized mobility coordination where there is no centralized authority governing the management of mobility. Therefore, they do not require trusted third parties to monitor the MM tasks such as handover, location management, offloading, and resource allocation. Blockchains use consensus approaches in reaching agreements for transactions related to MM eliminating the requirement of centralized authority. Moreover, SCs can facilitate automatic utilization of MM tasks upon reaching certain conditions. For example, when a user equipment's signal to noise ration degrades below a

given threshold, proactive handover can be executed using SCs. Moreover, location-grounded services can be provided considering user's location and resources can be allocated dynamically considering network conditions automatically without involvement of a trusted third party.

8.2. Obstructions

8.2.1. Increased handover latency

Even though blockchains can improve the security of handover and provide handover authentication, it can at the same time introduce an additional latency during handover process. Blockchains consume a considerable amount of time for transaction creation, propagation, and validation in the consensus process. In modern mobile communication networks such as 6G, very low latency is desirable during the handover process. Thus, it is tough to achieve such low latency requirements specially when the network capacity is large such that the additional latency introduced by the blockchain network is significant.

8.2.2. Lessened energy efficiency of offloading

The main purpose of offloading such as in computation offloading is to transfer the workload (task/computation/traffic) from mobile network to a secondary platform to raise the energy conservation of the mobile network. However, when blockchain is integrated in the offloading process for performing different assignments such as using blockchain transaction states for offloading decisions, reduce security vulnerabilities in offloading, protect data privacy, prevent data loss, prevent illegal computations, coordinate offloading, enable fair offloading, etc., additional energy is consumed by the blockchain in achieving these assignments. Thus, blockchains cause the effective energy efficiency of the offloading assignment to reduce unless energy-efficient approaches are utilized.

8.2.3. Demand of secondary approaches to maintain QoS

Even though blockchain has been utilized for QoS driven resource allocation such as in [107], where a blockchain femtocell network attempts to maximize

transmission rate of macrocells and minimize delay of femtocells, QoS achievement is realized using optimization and by modeling interactions as a Stackelberg game. Blockchains indeed degrade the QoS of MM by introducing additional latencies and causing additional energy expenditures. In an effort to compensate for such losses, QoS for a particular MM assignment such as handover, resource allocation, etc. need to utilize secondary mechanisms such as artificial intelligence or optimization techniques.

8.2.4. Frequent transactions by virtue of mobility

In a mobile communication network, appliances are typically in continuous motion. Therefore, the location of the appliances changes frequently and appliances can engage in frequent handover between multiple cells leading to high number of handover decisions, location registration and paging, offloading decisions, and resource allocation decisions in MM per unit time. Thus, when these MM assignments are realized with the aid of blockchains, the quantity of transactions that are needed to be operated per unit time is high which is challenging by virtue of demanding of high computation and memory resources.

8.2.5. Fragility to sybil attacks in resource reservation

In blockchain grounded in auctioning for resource reservation such as spectrum in mobile networks, sybil attack is possible where malicious users create fake identities to fulfill deceiving the auctioning process preventing fair resource allocation. In these attacks, multiple fake appliances are often created to get auctioning advantage in large proportions. Even though robust authentication, reputation grounded activity monitoring can reduce these types of attacks in blockchain networks, it is tough to completely irradiate the whole threat.

9. Conclusion, Advices, and Forthcoming routes

In this inspection, we first inspected diverse MM assignments such as handover, location management, offloading, and resource allocation and then exhibited an abstract of diverse MM approaches grounded on architecture, mobility class, packet reordering, and support for QoS. In the time following, providing an abstract on blockchain platform, we inspected the

blockchain-grounded MM in living literature. Stemming from this survey, we perceived the blockchain-grounded MM principle in 7 clusters: secure handover, secure storage for MM, registration and authentication of network appliances, SCs-grounded paging, blockchain to reduce vulnerabilities in offloading, transaction securing for resource reservation, pure blockchain grounded in resource reservation. Next, we closely studied the inspected literature with respect to different MM approaches, techniques, blockchain associated principle, blockchain specific parameters, etc. and finally conversated openings and obstructions of blockchain-grounded MM. This review paper reinforces the living knowledge domain regarding blockchain-grounded MM by inspection of existing frameworks and closely studying them using different criteria to pinpoint the progression, voids, openings, and obstructions in blockchain-grounded MM. Thus, this review paper will fulfill the opportunity for academicians to quickly obtain information regarding blockchain-grounded MM. Stemming from the studied obstructions, pursuant advices can be formulated for blockchain-grounded MM.

- In an effort to reduce handover latency, low latency consensus approaches including delegated proof-of-stake can be utilized. Moreover, prioritization mechanisms can be utilized to ensure that high priority handovers are completed with a lower latency than others. Furthermore, handover bundling technique can be utilized to reduce the handover overhead where multiple handovers are bundled into one and utilize batch processing using SCs.
- Even though effective energy efficiency reduction of the blockchain-grounded offloading cannot be prevented, it can be minimized to a certain extent. First, incentivization can be designed such that energy efficient behavior is rewarded and excessive energy utilization behavior is penalized. Furthermore, offloading approaches may consider the energy factor in arriving at offloading decision to make offloading energy efficient.
- Instead of relying on secondary approaches for QoS maintenance in blockchain-grounded MM, the manner in which blockchain is utilized, can

be adjusted to prevent QoS from degradation. First proposal is to shard the blockchain into multiple subsets such that each shard can work independently. The second proposal is to utilize side-chains or off-chain processing for mobility related data while only critical data is stored in the blockchain.

- Mobility can enlarge the rate of transaction processing in blockchain-grounded MM. It can be tackled using several means. First, mesh blockchain can be incorporated to process mobility related transactions parallelly successfully presenting a way to handle enlarged number of transactions by virtue of mobility. Alternatively, considering a batch of transactions and processing them as a batch can also improve the efficiency of transaction processing.
- Sybil attack prevalent in blockchain-grounded resource allocation can be reduced by implementing robust authentication using blockchain itself. Furthermore, the activity of appliances in the network can be monitored to gain insight into the behavior to assign a reputation score for each appliance, effectively pinpointing malicious appliances which create fake identities.

In conventional approaches for MM, blockchains are not utilized. By integrating blockchain in the technique of MM, researchers have been able to enlarge the effective faithfulness, privacy, incorruptibility, etc. of MM. Future research may deal with providing multi-chain solutions for MM such that different blockchain-grounded MM frameworks become interoperable. Besides, prospective research may inspect how quantum computing-grounded cryptographic techniques that can be utilized to further improve the confidentiality of mobility related information to counter-attack quantum computing threats.

Conflict of Interest

Author declared "No conflict of interest".

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