Towards Reliable Computation Offloading in Mobile Ad-Hoc Clouds Using Blockchain

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Abstract. Mobile Ad-hoc Cloud (MAC) refers to the computation offloading of a mobile device among the multiple co-located mobile devices. However, it is difficult to convince the randomly participating mobile devices to offer their resources for performing the computation offloading of other mobile devices. These devices can be convinced for resource sharing by limiting the compute shedding of a device nearly equal to the computation that same device has already performed for other mobile devices. However, this cannot be achieved without establishing the trust among the randomly co-located mobile devices.

Blockchain has been already proven for the trust-establishment between multiple independent stakeholders. However, to the best of our knowledge, no one has used blockchain for reliable computation offloading among the independently operating co-located mobile devices of MAC. In this position paper, we proposed the mapping of blockchain concepts for the realization of reliable computation offloading in MAC. We have also identified the future research directions that can be focused for improving the proposed integration of blockchain and MAC.

Keywords: Mobile Ad-hoc Cloud · Mobile Cloud Computing
Mobile edge computing · Multi-access Edge Computing · Blockchain

1 Introduction

Mobile Cloud Computing (MCC) refers to the computation offloading from mobile devices to the nearby fog computing layer or the cloud computing layer for reducing the resource consumption of mobile devices [19]. It not only helps in preserving the battery of mobile devices for longer time intervals but also ensures the quick execution of CPU intensive tasks by the dedicated resources of fog/cloud computing layer [5]. Multi-access Edge Computing (MEC), in contrary to MCC, shifts the computation from cloud towards edge devices [15]. Increasing capabilities of mobile devices are encouraging researchers and practitioners to exploit the resources of edge devices for performing the tasks that were

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previously confined to the dedicated resources of fog/cloud only. MEC not only reduces the response time but also minimizes the cost of operating the dedicated resources that are required for MCC.

Mobile Ad-hoc Cloud (MAC) [20] is formed by the collaborative computation offloading among the multiple co-located mobile devices and it supports some of the features of both MCC and MEC. Participants of MAC observe the MCC features when they offload their computation to the neighbouring mobile devices and these neighbouring mobile devices are supporting the MEC by performing the computation at the edge of the network. Mobile devices of MAC are voluntarily working in collaboration for supporting each other. However, there must be some motivation for encouraging the random mobile devices for joining the MAC.

In this position paper, we have proposed the initial offering of idle resources by the volunteer mobile devices, for supporting the computation offloading for other co-located mobile devices, and nearly the equal amount of resources will be offered to the same devices for sharing their computational load in future. This is achieved by metering the consumed resources of a mobile device for supporting the computation offloading for neighbouring peer devices and earning the nearly equal amount of resources so that the device can use the earned resources for offloading its computation in future. However, it is the reliability of the metering and awarding system that motivates the volunteer devices for joining the MAC and in this paper, we have presented the blockchain for the reliable computation offloading in MAC.

Blockchain is already there for tackling the trust management issue among the independently operating entities [4]. However, to the best of our knowledge, no one has used the blockchain for establishing trust among the voluntarily collaborating mobile devices of MAC. We have not only mapped the blockchain concepts for managing trust among the random mobile devices of MAC but also identified new research directions that can be focused for improving the proposed integration of blockchain and MAC.

Upcoming section two elaborates the importance of MAC and the challenge of trust establishment associated with it. Section three explains the features of blockchain that can be employed for tackling the trust establishment challenge of of MAC. Section four elaborates some of the related work and last section concludes this paper along with some future research directions.

2 Importance of Mobile Ad-hoc Cloud and Its Challenge of Trust Establishment

With the exponential growth in the capabilities of mobile devices in last decade, efforts have been made to exploit the under-utilized resources of powerful mobile devices. MAC is an effective way of collecting the resources of multiple independently operating co-located mobile devices and capitalize the collected resources for distributing the computational load of few of the neighbouring mobile devices. This section explains the importance of MAC by differentiating the horizontal resource sharing in MAC and the vertical resource sharing of fog/cloud. It also

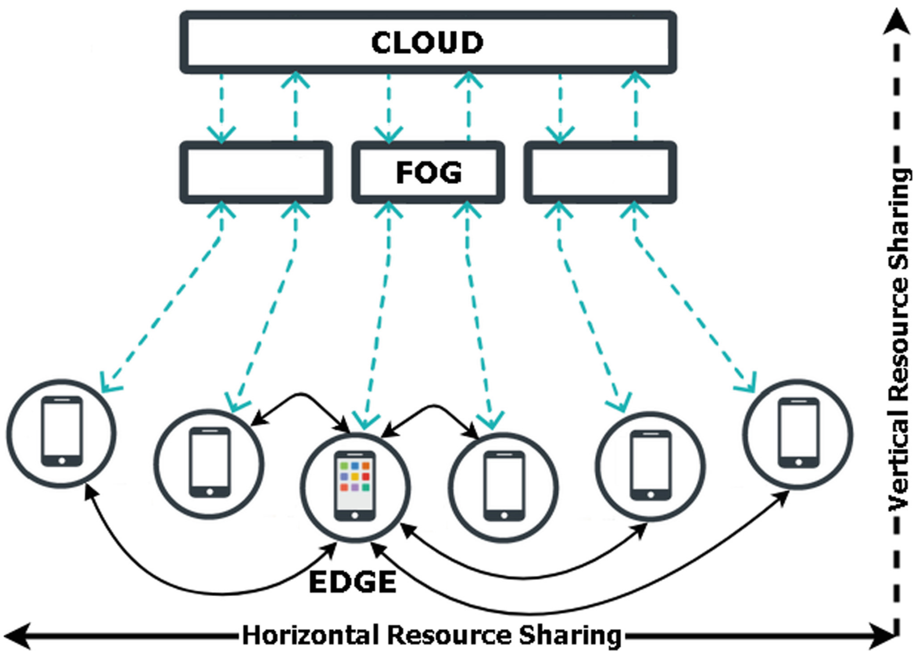

Fig. 1. Horizontal resource sharing in MAC vs vertical resource sharing

elaborates the need for trust establishment among the independently operating co-located mobile devices of MAC.

Figure 1 contains a mobile device running multiple applications and is interested in reducing its resource consumption along with the reduction in response time of CPU intensive tasks. Mentioned mobile device has two options available to offload computation by vertical resource sharing or horizontal resource sharing. Dotted lines in Fig. 1 are referring to the option of vertical resource sharing while solid lines are representing the horizontal resource sharing option. In case of vertical resource sharing, mobile device will first offload the computation to the nearby fog node. If the fog node has enough resources available for performing the required computation then it will not involve the cloud computing layer. However, if more computational resources are required then the computation will be further offloaded to the cloud computing layer.

In case of horizontal resource sharing, the mentioned mobile device will not involve the fog computing layer and will only consider the neighbouring mobile devices for offloading its computation. Hence, all the participating mobile devices formulate another computing layer at the edge of the network, known as the Mobile Ad-hoc Cloud (MAC) computing layer. Following is the comparison of horizontal resource sharing in MAC with the vertical resource sharing option.

Operational Cost of vertical resource sharing is greater than the cost of horizontal resource sharing because fog/cloud computing layers are based on dedicated resources while co-located mobile devices of MAC only offer their idle resources for horizontal resource sharing.

Scalability of horizontal resource sharing is more than the vertical resource sharing because the number of machines in cloud can rarely reach up to few hundred-thousands, number of fog nodes can reach up to few millions while billions of edge nodes are currently operating [1]. Moreover, in case of MAC, every new coming mobile device also serves as an addition to the overall MAC resources and it ensures the scalability of horizontal resource sharing.

Response Time will be less for horizontal resource sharing as compare to the vertical resource sharing because for vertical resource sharing, both fog and cloud nodes are not hosted closer to the mobile devices whereas for the horizontal resource sharing, neighbouring mobile devices are co-located to the device device interested in offloading and it results in the reduction of response time.

Trust establishment is not very crucial for the dedicated resources based vertical resource sharing in fog/cloud computing layers. However, it is required for the horizontal resource sharing because of the high churn rate of participating devices. Churn rate [9] can be defined as the rate of mobile devices leaving the MAC. High churn rate results in the higher number of stranger devices participating in the MAC. Blockchain ensures the reliable collaboration among the strange devices and its integration with MAC is discussed in next section.

3 Blockchain: An Enabler for Trust Establishment in Mobile Ad-hoc Cloud

Blockchain [18] has already been proven as the perfect solution for removing dependency on a central entity and distributing the authority among multiple independently distributed entities. Bitcoin is the first and most popular application of blockchain [12]. There are many important features in blockchain that makes it unique and effective in comparison to other application development techniques. In this section, we have elaborated the strengths of blockchain that can be used for tackling the trust establishment challenge of MAC.

3.1 Blockchain and Its Integration with MAC

Blockchain is a tamper proof distributed ledger and following are some of its important features that can be integrated within MAC to ensures the reliable computation offloading within independently operating mobile devices of MAC.

Transparency through shared ledger. Shared ledger is the main feature of blockchain and it is also important for supporting transparent coordination among multiple participating devices of MAC. Miners are the devices that ensure the propagation of updated ledger among all the participants of MAC. This shared ledger will contain the metering and awarding details against each participant which not only gain the trust of participants but also ensures the transparency. This will also incentivize the more devices to join the MAC equipped with proposed computation offloading scheme.

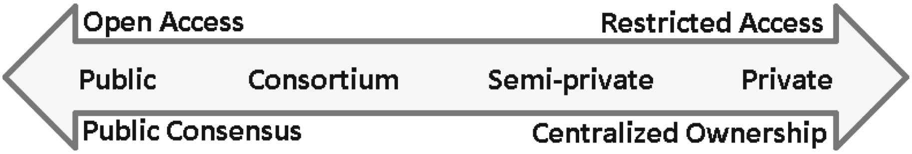

Fig. 2. Classification of blockchain networks based on the ownership and access

Public blockchain network. Miners are the devices that control the growth of blockchain using consensus [14]. Based on the assignment of mining rights, blockchain networks can be classified into four different categories [13], of public, private, consortium and semi-private (compared in Fig. 2). We are proposing the public blockchain for integration with MAC so that any mobile device can join or leave the network and it will help in establishing a transparent and open system.

Proof of Existence (PoE) ensures the data integrity without sacrificing its privacy [3]. This is achieved by passing the original data to a one-way hashing algorithm and using its output for representing the original data. Many blockchain projects [8,17] are already using it for various use cases especially for storing the sensitive information on blockchain.

Trust through consensus algorithm. It is really important to establish the trust among the mutually cooperating mobile devices of MAC. Miners of blockchain uses the consensus algorithm [23] for automatically establishing the consensus against any conflicting situation, without involving any central authority. Thus consensus algorithms help in making system more reliable and temper-proof. Proof of Work (PoW) [7] is the first consensus algorithm which has been used in the first application of blockchain known as bitcoin. However, it consumes a lot of energy and therefore, many other variants of consensus algorithms (like proof-of-stake [10], proof-of-reputation [6] etc. [16]) have been successfully adopted in the industry.

3.2 Three Generations of Blockchain for Each of the Three Phases of Data Value Chain

Data value chain helps in making decisions from the data and it is categorized into three broader phases of data discovery, data integration and data exploitation [11]. Different blockchain protocols and platforms are targeting each of these phases and existing blockchain tools can be categorized into three generations, targeting each of the phases of data value chain. However, most of the existing blockchain platforms belong to the first two generations and thus the blockchain community is mostly focused on the first two phases of the data value chain. Next is the description of three phases of data value chain along with the blockchain solutions targeting each of these phases. This discussion will help in understanding the proposed integration of blockchain and MAC with reference to the existing blockchain solutions (Fig. 3).

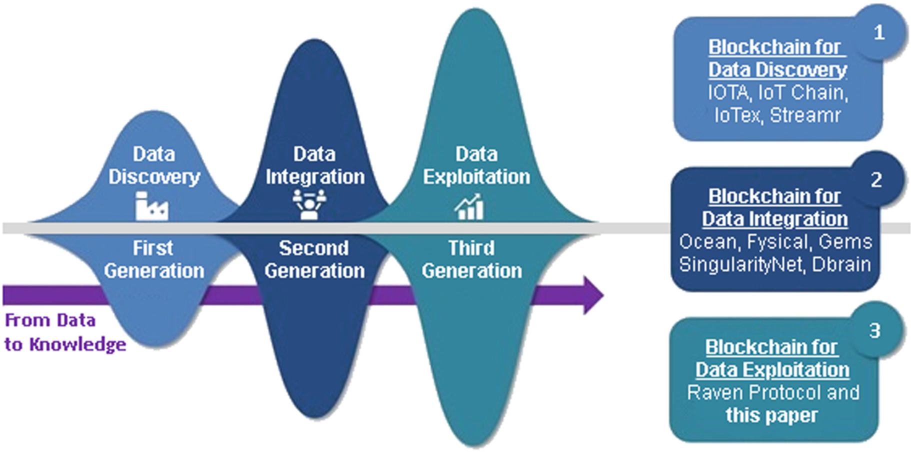

Fig. 3. Three generations of blockchain tools for three phases of data value chain

Data Discovery is the first phase of data value chain and is only concerned with the data. First generation of blockchain tools focuses on this phase by efficiently collecting the data from different devices or sources. IOTA[1], IoTChain[2], IoTex[3] and Streamr[4] are some of the blockchain projects that are targeting the first phase of data value chain.

Data integration is the second phase of data value chain and it covers the curation of data by integrating it from different data streams or sources. Second generation of blockchain solutions are targeting this phase of data value chain. Ocean Protocol[5], SingularityNet[6], Fysical[7], Gems[8] and Dbrain[9] are few of the blockchain solutions that provides that integration and supports this second phase of data value chain.

Data Exploitation is the third phase of data value chain and is focused on the analysis of data. Currently a protocol named as Raven[10] is targeting this third phase of data value chain. However, it is just in a proposal yet and no operational details are available. Moreover, Raven is only confined to the collaborative computation for deep learning. However, our proposed integration of blockchain and MAC can be used for any type of CPU intensive tasks including the computation for deep learning.

1 https://iota.org/.
2 https://iotchain.io/.
3 https://iotex.io/.
4 https://streamr.com/.
5 https://oceanprotocol.com/.
6 https://singularitynet.io/.
7 https://fysical.org/.
8 https://gems.org/.
9 https://dbrain.io/.
10 https://ravenprotocol.com/.

4 Related Work

Incentive based approaches are already in practice for motivating the mutually collaborating participants. Most of the existing incentive based solutions can be broadly categorized in to three groups viz. (1) reputation based [22], (2) reciprocity based [2] and credit based [24]. This paper also falls under the category of credit based incentive solutions as we are proposing to award the computation in return to the resource consumption that was previously done by the same mobile device for supporting the computation offloading of other MAC devices.

Ashkan et al. [21] proposed the computation sharing between the nodes of fog layer. However, it was done without distributing the authority through blockchain. There is a blockchain based Raven protocol(See Footnote 10) which is trying to accomplish the computation sharing for deep learning. However, it is just a proposal yet and no operational details are available. Moreover, it is only confined to the computation sharing for deep learning while our proposed integration of blockchain and MAC can be used for sharing computation for any type of tasks.

5 Conclusion and Future Work

This paper is focused on incentivizing the co-located mobile devices to share their resources for supporting the computation offloading for each other. Transparent metering and auditing is required for gaining the trust of the participating mobile devices and therefore, we have proposed the integration of blockchain and MAC for establishing the trust among the participating devices of MAC. Following are some of the research areas that can be focused for improving the proposed integration of blockchain and MAC.

Consensus algorithm. Proof of Work (PoW) is the consensus algorithm used in bitcoin, the most popular application of blockchain. However, the PoW consumes alot of energy and there are many alternative consensus algorithms available that offers different set of features along with less energy consumption. Therefore, extensive experiments must be conducted for finding the most appropriate consensus algorithm for MAC.

Miner selection. Miner is a machine that runs the consensus algorithm and controls the growth of blockchain. In order to establish a fully distributed global network of blockchain enabled MAC, few of the mobile devices should also serve as miners. A scheduling algorithm must be implemented for ensuring the optimal selection of miner based on the peer ranking algorithm.

Peer ranking algorithm. A peer ranking algorithm must be developed to rank the participating mobile devices based on their available resources. This algorithm will help in deciding how much computation load can be shifted to any particular device.

SLOs for awarding computation. Proper SLOs (Service Level Objectives) must be defined to ensure the transparent awarding of computation against the shared resources of a mobile device.

ACL instead of PoE. Our proposed integration of MAC and blockchain is based on a public blockchain network which works similar to the bitcoin network and allows anyone to join or leave the network at any time. Considering the open nature of public blockchain network, PoE is proposed for preserving the privacy of data of participating devices. However, ACL (Access Control List) [25] can also be applied for securing data within the members of the blockchain network. Hence, PoE can also be replaced with ACL to provide the fine-grained control of data stored in distributed ledger of blockchain.

Reliable data analytics. A validating system must be incorporated within the blockchain based MAC for confirming the accuracy of results submitted by the participating mobile devices. It will help in accomplishing the reliable data analytics through MAC.

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