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A COMPARATIVE ANALYSIS OF CONSENSUS PROTOCOLS FOR DEALING POWER THEFT ISSUE IN PAKISTAN

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ABSTRACT

Power is considered as a bone for life, lifeline of a country's economy; a key instrument for the socio-economic evolution of any country. Pakistan faces the issue of power theft that worsen the economy of utilities. The purpose of research is to modernize the Pakistan's power sector with the usage of Blockchain. Research is based on a comparative analysis of proof of stake (POS) and proof of authority (POA) consensus protocols for the power theft issue for small, medium or large scales of consumers; results showing automated and pre-selected processing time of transactions running on different nodes of POS and POA along. By Comparative analysis of POS and POA; it is shown that performance of Blockchain remains unaffected by the consensus protocol. To further strengthen the findings the statistical analysis data is carried out to establish uniqueness of sampled data. The result establishes that Blockchain performs equally well for different architectures of proposed architecture. The consensus protocol helps in achieving suitable governing style with no affect Blockchain performance.

KEYWORDS: Power Theft · Blockchain · Consensus · Proof of Stake · Proof of Authority

1. INTRODUCTION.

Power theft becomes a worldwide matter of concern because of significant economic wealth. Nowadays, Pakistan is in severe energy crisis because of governmental failure, poor administration, instability of manual power system and corrupted energy sector; resulting power outage causes problems not only for residents but also causes the industries shutdown [1]. During some past decades, a positive uplift noticed in Pakistan's economy and hence demand of energy is also increases but sadly to meet the demand of power no beneficial steps have been taken which causes reduction in production and hence declining the economy. Currently, the power demand overshoots supply causes "load shedding"; a common happening being confronted by the whole country. The shortage is because of lack of planning, poor management, low investment on new technologies, lack of infrastructure, political instability of gov-ernment and due to some technical and more of non-technical losses. The non-technical losses are line loss and power theft, from

which power theft plays an important role in shortfall and higher energy rates [2]. The power losses cause loss of revenue, poor quality of services and hence declining economy. Adding to it, there are many political, governmental and financial factors that halt the development progress in the energy sector.

By keeping in view the growing digitalism, political and socio-economic norms, crudely designed rules, poor administration of utilities and lack of infrastructure, there is need of emergence in Pakistan's conventional energy sector. The main aim of this research is to provide a tamper proof solution for secure power sector. Blockchain coupled with IOT devices like smart meters supports to achieve this functionality. The Blockchain as protocol enables peers to transmit assets without any trusted third party. Network automatically record and validate transactions publicly. All transactions are stored on small verified blocks; local on different devices related to different participants (nodes) of the Blockchain. Each block is represented with specialized hash code (numbers, letters and special characters). These hashes link each block of network by referencing the hash of preceding block. The constant process of validation is done by some specialized members of Blockchain (validators or miners), huge computation is needed to solve complex mathematics. This validation process ensures that every member of the Blockchain is an addition to the chain of encrypted blocks without revision of preceding blocks. But the exact approach applied according to the consensus mechanism of the Blockchain [3]. Blockchain being a decentralized, P2P network doesn't allow unauthoritative middleman to interfere with transactions, this fabricates a system that is prevailing from single source attacks, but there is still a radical problem. How settlements forge? How about things getting done? Think as a leader of a normal centralized corporation. Decision makers or leaders take decisions, but this is not the phenomenon of a Blockchain network as Blockchain has no "leader". What is the need of decentralized energy system for deciding? You need a consensus regarding what happened formerly and the occurrence of future happening over the huge number of par- ticipants that have mutual reliance for surety of safeguarded energy. This is the perfect pinpoint of the actual suitability of Blockchain.

Compared to traditional distributed computing with a clear client-server model, a Blockchain network allows every participant to be both a client (to issue transactions) and a server (to validate and finalize transactions). The underlying ledger data structure—the Blockchain—is the consensus target that comprises chronologically ordered and hash-chained blocks. Each block holds a bundle of valid transactions, and transactions across the Blockchain should be consistent with each other (i.e. no double-/over-spending nor appropriation).

Consensus mechanisms [4] [6] are an essential part of the network because they ensure the secrecy and integrity of data. They help in preventing double-spend attacks and other tampering attacks. The algorithm's main objective is to reach consensus in a distributed network devoid of any third party and with members who don't have reliance on each other. The validity of the transaction is done by these consensus mechanisms. They also make sure that the transactions being made follow the defined protocol rules. These are basically the steps are to be followed under the rules to produce the desired results. The consensus protocols are the basic rules of the Blockchain are to be followed in order to validate a transaction. So Bitcoin and Ethereum are basically the protocols [7]. There are three main key features to determine the efficiency of the protocols; safety, real-time value and fault-tolerance. The protocol is secure if all the nodes generate identical valid results. By real-time value we mean that a value is produced of all the non-faulty nodes participate. A protocol is fault tolerant if it recovers from failure of participating nodes [5]. As people have trust issues; Blockchain is introduced in the energy sector to ensure transparency. With the advent of Blockchain based system in energy sector integrity is achieved, resulting in a decrease of power theft. In Blockchain information control is not the responsibility of a single person; open information for all members of the Blockchain which ensures the transparency which is never before Blockchain [8]. Fundamentally, the Blockchain have a distinct set of inherent qualities that add significance to conventional and emergent Blockchain applications of energy sector. Because of these specifications, Blockchain ranked as a crucial technology beside with AI, Big data and IoT by digital economy outlook 2017 [9]. Despite

rapid changing in energy trading, the extent of the Blockchain based applications in power sector is rarely researched. The existing research in power sector focuses only on the technicalities of particular Blockchain solutions. In this paper, we comparatively analyze the proof of stake (POS) and proof of authority (POA) consensus protocols for the power theft issue for small, medium or large scales of consumers. The primary contributions of this paper can be summarized as follows:

- We further explored effects of consensus mechanism on tamper proof Blockchain based energy consumption [20] record keeping system using Ethereum smart contracts.
- We suggested POS and POA consensus protocols for small, medium or large scales of consumers.
- The analysis of performance using POS and POA consensus of by simulating automated and pre-selected processing time of transactions running on different nodes.

The remaining paper is structured as follows. Section 2 summarizes the related work. Section 3 presents our proposed work. Section 4 concludes the paper.

2. RELATED WORK:

Power theft is a worldwide matter of concern. The white collar criminality is committed everywhere regardless of economic strength of countries. Power theft in Pakistan is especially seen in Karachi and Lahore. Several researches and methods have been generated to counter power theft. In general there is wide research on criminalities and corruption, still limited publications investigated corrupted energy sector. Faisal Jamil explores the key determinants that confer in power theft by some questionnaires from residence of the twin cities (RWP & ISB) [11]. Smith investigates stimulus of power theft, its effects, and proposes some corrective measures. According to his research poor governance is a strong determinant of power theft, and the countries with low liability, political vulnerabilities, low administrative efficacy, bribe and high corruption rate are at a higher level of power theft. As a remedial measure he suggests application of practical solutions like as tamper proof meters corresponding with some management practices, for instance, appraisals, tracking, and even whole reestablishment of the power sectorial ownership, rules and regulations [11]. Clarke and Xu investigate elements of contribut- ing corrupted power utilities and firms using enterprise corrupted data remunerate to power services in twenty one developing economies from Eastern Europe and Central Asia [12]. Overall, literature centered mostly on key determinants of power theft spotted that poor administration is the major cause of cor- rupted power sector and ratio of each determinant contributing in theft. Many theft detection research available; however there are no such publications on remedial measures. This article is a further extension to research carried by [20].

By keeping in view the security features of Blockchain, researchers are now finding interest in energy market using Blockchain; a decentralized database working on multiple computers simultaneously. All transactions are saved in small blocks after verification. A hash link is present in every block; this link is a reference to previous block. Miners are responsible for the constant process of verification; complex mathematical problems are solved by huge computational power. A Blockchain can be called a chain of blocks, where each block holds several events and transactions in it. Transactions are transmitted to every node after it has been validated. Few Blockchain categories have been defined using different perceptions. Blockchain has gradually gained popularity in the research field. The earliest particular Blockchain based publications published in 2012 and examined Bitcoin technical problems [13], in 2015 the first Blockchain application developed for the real sector [14]. Study shows that generally most of the energy market is mainly associated with peer-to-peer energy trading and smart contracts using Blockchain properties. However, literature shows that there are few publications by nonacademic institutes and some management consultants in Blockchain within energy market. Technical aspects regarding Blockchain applications in energy market are only addressed by some [15]. There is a study on which collected data is stored in

Consumers	Blockchain	Consensus	Mechanism	Governance	Validation
Small Scale	Public \ Decentralized	Proof of Stake: Permission less	Weightage of tokens	Consensus is publicly managed	Anyone participating in Blockchain network
Medium Scale	Consortium \ Hybrid	Proof of Au-thority: Permissioned	Reputation and identity	Multiple participants in consensus process	Authorized nodes
Large Scale	Private \ Distributed	Proof of Author-Reputation : Permissioned	Reputation and identity	Managed by single Owner	Authorized nodes

Table 1. Classification of Blockchain

Blockchain via Wireless Sensor Network (WSN) which observes the power distribution grid. The directed acyclic graph is generated using the information stored in Blockchain and clustering algorithm is applied to it to detect fraud [16]. Regardless of the rapid changing Power outlook, the extent of the applications of the Blockchain in the power sector is rarely researched somehow. The living Pub- lications in Blockchain centered on technicalities of specific Blockchain based systems. There are many authors who've adopted unique methods to prevent power theft. Some of them include surveys, machine learning algorithms, feature genetic algorithms, anomaly spotting framework. Every method has its own weaknesses and strengths, but none is focused on providing a validated and tamper proof transactions.

3. Proposed Consensus Protocols for Dealing Power Theft.

In this section; offering suitable consensus mechanisms for dealing power theft issue for different sizes of consumers. Firstly, if Blockchain implementation in energy sector on behalf of a certain community where no certain authoritative for check and balance then proof of stake is the best option. As participation is based on some kind of stakes by participants; chances of tempering are exterminated because eventually it is participant's stake which suffers the most. Participants are also rewarded to maintain the network while in a proof of work-based system miners only endeavor to raise their interests without actually improving the network as none of their coins are at stake. Secondly, if government support is available for making a secure power sector that is devoid of corruption and vulnerabilities, then Proof of authority is the best choice. Table 1 shows the brief information of consumers' categorization, respective Blockchain governance, and suitable consensus mechanism.

3.1. Small Scale Consumers.

Such Blockchain is implemented by a person for the small town. These people are willing to eradicate power theft from their society or town. Public Blockchain is incentive based, which encourages miners to mine block and secures the network. Their validation takes time in public Blockchain and the transparency of data is low. To confront such issues POS can be used as a consensus protocol in public Blockchain. Low computational power is needed and it also improves speed. Details of PS are given in Algorithm 1 For participating in a consensus process participant must invest a stake it may be cited as some kind of network tokens or e-coins. Proof of Stake assembling the premise that participant who owe bulk of coins in a Blockchain network gave engrossments for maintaining the network and the worthiness of coins. A randomization process is used in proof of stake based system for determining the producer. Staking tokens is the eligibility criteria for becoming a validator (i.e. block producer). For the process of

Algorithm 1 Proof of Stake:Working

Let Nodes N_i Stake S_j ethers where $i, j \in I$

while $S \neq Nill$ **do**

  if N_i has highest ethers **then**

    SELECT N_i as validator V_j

  end if

  {For preventing large staked node from dominating Blockchain network}

  {**Part 1: Randomize Validator Selection Process**}

  if N_i has highest ethers and Lowest hash value **then**

    SELECT N_i as validator V_j

  end if

  {**Part 2: Coinage Validator Selection Process**}

  if N_i has highest ethers $\times$ no. of days the ethers have been held as stake **then**

    SELECT N_i as validator V_j SET coinage of $N_i = 0$

    {Now for becoming validator Ni must wait certain period of time}

  end if

end while

V_j checks the transactions in the block

if transactions found valid **then**

  V_j signs the block

  Block is now appended to the chain

  V_j get reward associated to the transaction.

end if

if V_j validates the same block at same time **then**

  Then rewarded the validator of longest chained block

end if

if V_j wants to stop being validator **then**

  his ethers along with earned rewards will be released after a certain period of time;

  meanwhile network verifies no fraudulent blocks are added by V_j

  if network detects fraudulent transactions THEN Vi lose a part of his staked ether **then**

    Process repeats for next validator selection.

  end if

end if

validator decision considering number of factors; mainly depend on the Blockchain design, but commonly, the probability of becoming a validator is relative to the bulkiness of person's stake. Another considerable factor is the persistence of coins staked. Validators are given incentive for their services. The validator's incentive again depends on the Blockchain design. Normally, they either give incentive to all, or some of, the settlement tariff of created block transactions, or sometimes they receive a definite number of coins induced by inflation. From security perspective, proof of stake leverages pledge for attacks alleviation. In contrast to a proof of work miner whose chances to proffer a block is relative to its brute force hashing power, the chances to claim a block of a proof of stake minar is relative to the worth of his stake. From an economic perspective, proof of stake results in a miner's return on cost independent to the system (wastage of hashing power and electricity) [17].

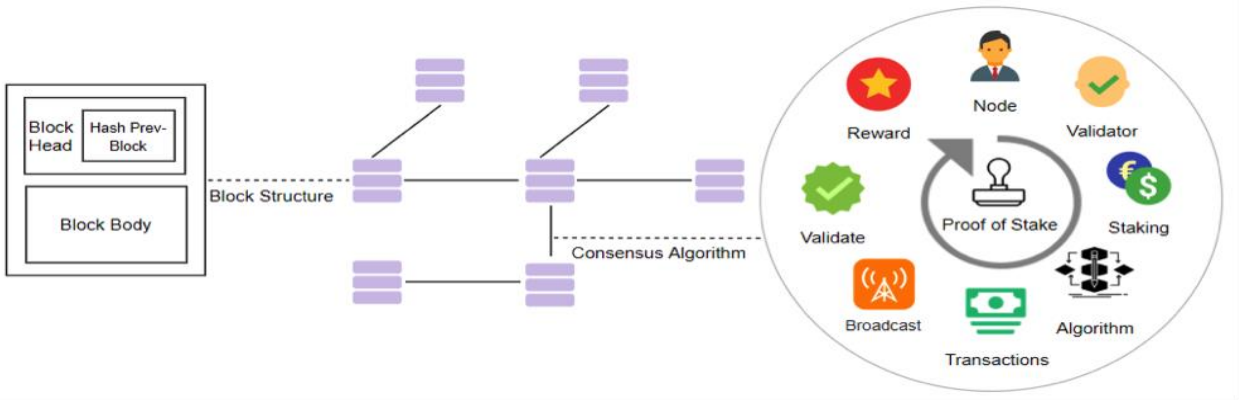
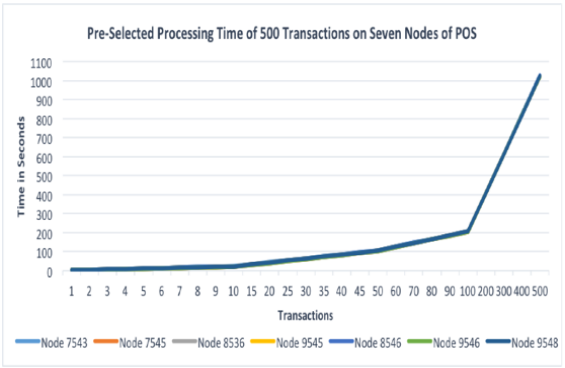
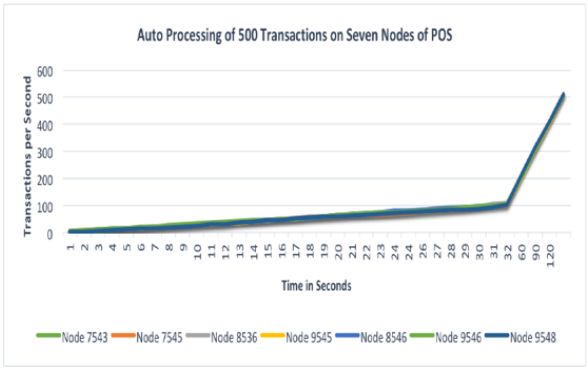


Figure 1. Consensus for Small Scale Consumer (Public Blockchain)



A)



B)

C)

Figure 2. A) Pre-selected Processing Time of 500 Transactions on Seven Nodes of POS B) Auto processing of 500 Transactions on Seven Nodes of POS C)Comparison of Pre-Selected and Auto Mining Transactions per Second of POS

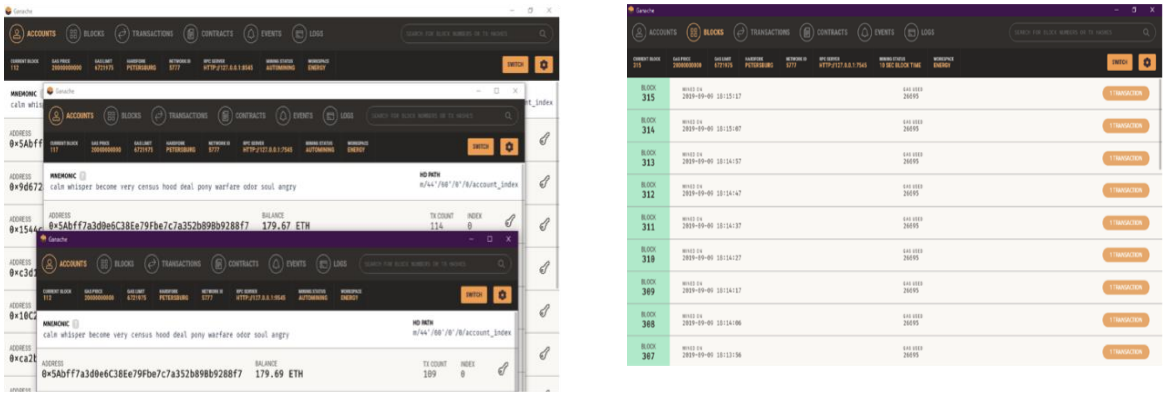


Figure 3. A) Mining on Three Nodes B) Processing Time along with Block's Information

Following steps followed by small scale consumers participating in public Blockchain by using proof of stake as a consensus mechanism. Entire data will be open to everyone. Anyone can read transactions, send and join the network. There is no identity privacy.

1. People willing to join public Blockchain network.
2. Participating nodes apply for the post of validator.
3. For becoming validator participants must stake some coins.
4. Selection algorithm elects participant as a validator by considering his amount of stake. 5. Now block creation is the responsibility of the validator.
6. Transactions are being held by validity.
7. Broadcast to Blockchain network.
8. Validator validates the broadcasted transaction.
9. Validator receives a pre-fixed reward for validation.
10. Other miners (Participating nodes) will stake their balance to be chosen as the next validator.

Our Simulate Energy Blockchain's using Ganache; a virtual private Blockchain with 10 accounts each account having 100 ethers. Each account has a unique address and a private key. All the transactions being made, the contracts created, call to a contract and value transferred can be easily seen in the transactions tab. A unique transaction hash is generated for every transaction; with the help of it the transaction can be validated and viewed on Etherscan. As Ganache is working on POS and POA based mechanism. Ethers used as stakes for every transaction, along with different authoritative nodes. It offers auto mining or pre-selected mining. Auto mining chooses random time intervals for validating every transaction; most of the times more than 100 transactions in 30secs while pre-selected mining restricts you to set validation time between the intervals of 2-10 sec per transaction, which makes the processing slow. Figure 2(A) shows the pre-selected processing time of different intervals of 500 transactions, placing on seven different nodes of POS Energy Blockchain Figure 3(A). It has the ability of processing of 15 transactions in 30sec. Figure 3 (B) shows the auto processing time of different intervals of 500 transactions, placing on seven different nodes of POS Energy Blockchain. It has the ability of processing of almost 100 transactions in 30sec. Transactions processed on nodes randomly. A comparison Figure 2(C) of pre-selected or auto mined transactions processing shows the high throughput of auto-mined transactions; makes the system scalable. Processing time can be viewed from log file or with block's information Figure 3(B).

3.2. Medium Scale Consumer. The medium scale consumers can be the consumers of few cities or even one city. Consortium Blockchain is used for this size of consumers. In consortium Blockchain, the electricity usage information can be shared among the nodes. Only specified and trusted users can store

data. The copy of data is shared only to the authorized users. Every node in this can produce new blocks

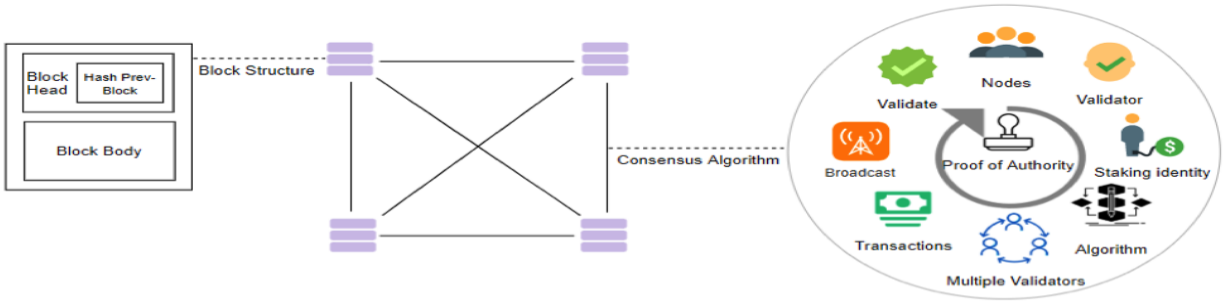


Figure 4. Consensus for Medium Scale Consumer (Consortium Blockchain)

and add them to the Blockchain. The block headers are the same as that of traditional Blockchain. The body of the block is candidate's data that is private and a signature of the node. Proof of Authority (Algorithm 2) can be used with this Blockchain architecture as theft is to be detected the security concerns are really important. Proof of authority is a special case of proof of stake in which a participant stakes his identity rather than fiscal tokens or coins. To entitle as a proof of authority leader and connect with the consensus team, a participant must need to undergo a significant procedure to act as authoritative. It normally requires a verified unique identity, manifesting the potential of contributing continuously to the consensus, and revealing publicly all testimonials. Thus, the consensus team should be substantial, and publicly inspected so that participants can invest on the consensus team for reliable transactions and prolong the Blockchain network. If an authoritative be bad or appear as incompetent, he will be refuted by participants and peer authenticators. In order to reach a consensus, a ratio is defined. If a certain amount of nodes validate, the block is considered validated. Following steps followed by medium scale consumers participating in consortium Blockchain by using proof of authority as a consensus mechanism.

Algorithm 2 Working of Proof of Authority:Working

Let Nodes N_i Stake S_j ethers where $i, j \in I$

Nodes goes through the formal identity verification process through proof of authority network Dapps

To becoming eligible for staking identity, participating nodes have to pass eligibility criterion (i.e., no criminal record, good moral values, committed to their work etc.)

Select N_i as authoritative A_i

Each selected authority creates an account ac_i

Account addresses of all the authorities are added into the validator list $V[ai]$

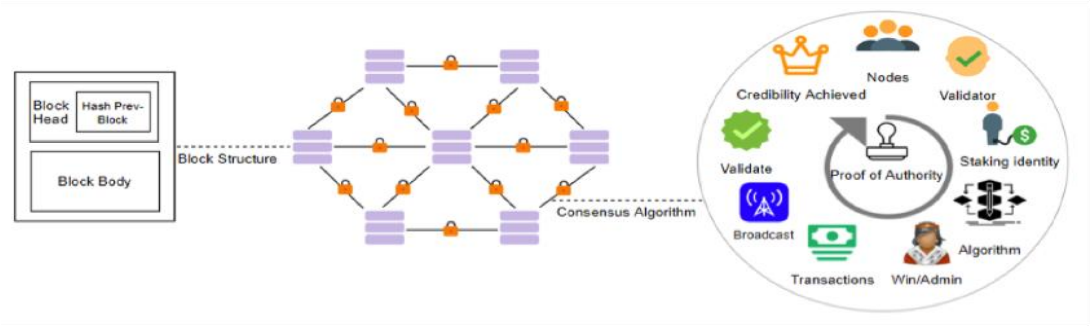
Authorities manages Blockchain network according to the agreed specifications

Allocate incentive to retain the position they have gained

Data will be private and public. The communication between all the nodes will takes place without the violation of privacy rights.

1. A node creates a block with its signature.
2. Participating nodes applying for validator post by staking their identity. Selection algorithm selects validator randomly. In Consortium Blockchain multiple validators are selected.
3. The block is validated by selected trusted nodes by viewing the signature on the block.

4. If a threshold of acceptance set by the network is achieved a block is validated, otherwise not.
5. The block is then added to Blockchain network.



6. Figure 5. Consensus for Large Scale Consumer (Private Blockchain)

3.3.3. Large Scale Consumers. For large number of consumers, Private Blockchain is more efficient. In this private Blockchain every person participating is authorized and the consumers who control the Blockchain are specified and trusted. In our case, the users who control the Blockchain will be the manager or analyst in the energy sector or any other power related organization. The information of all the participants is kept private. The consumers who have been granted permission by the organization will participate in the Blockchain. Private Blockchain allows faster transactions of huge volumes of data. It will be more suitable to be implemented in a country or any wide area. For increasing more security and validation, control POA are used (Algorithm 2) . The organization's manager will be the validating nodes in this consensus mechanism. Their identity will be known in advance with which they will be allowed to validate transactions. In a country, the manager or analyst of the grid of any city will be a trusted validator and validate transactions. Every block contains the public key of the user; it is the identity of the user. Electricity usage information, smart meter reading and extra surplus energy these parameters are stored in the Blockchain and are kept private. Steps followed by large-scale consumers participating in private Blockchain by using proof of authority as a consensus mechanism: A node creates a block with its signature.

1. Participating nodes applying for validator post by staking their identity.
2. Selection algorithm selects validator randomly. Or other nodes select validator by keeping in view
   their prestigious identity.
3. The block is validated by selected trusted node by viewing the signature on the block.
4. The block is now part of the Blockchain network.

Figure 6(A) shows the pre-selected processing time of different intervals of 500 transactions, placing on seven different nodes of POA Energy Blockchain. It has the ability of processing of 15 transactions in 30sec.Figure 6(B) shows the auto processing time of different intervals of 500 transactions, placing on seven different nodes of POA Energy Blockchain. It has the ability of processing of almost 100 transactions in 30sec. Transactions send in nodes randomly. Comparison Figure 6(C) shows the high throughput of auto mined transactions; makes the system scalable.

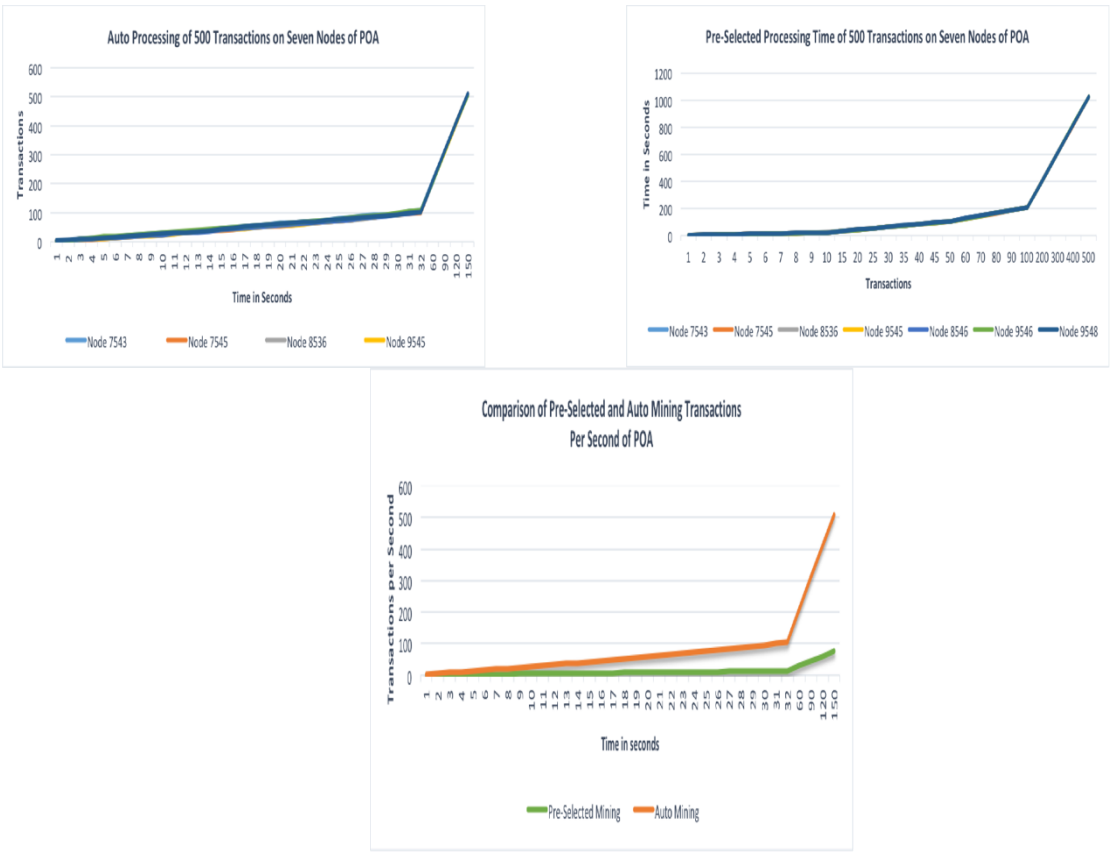
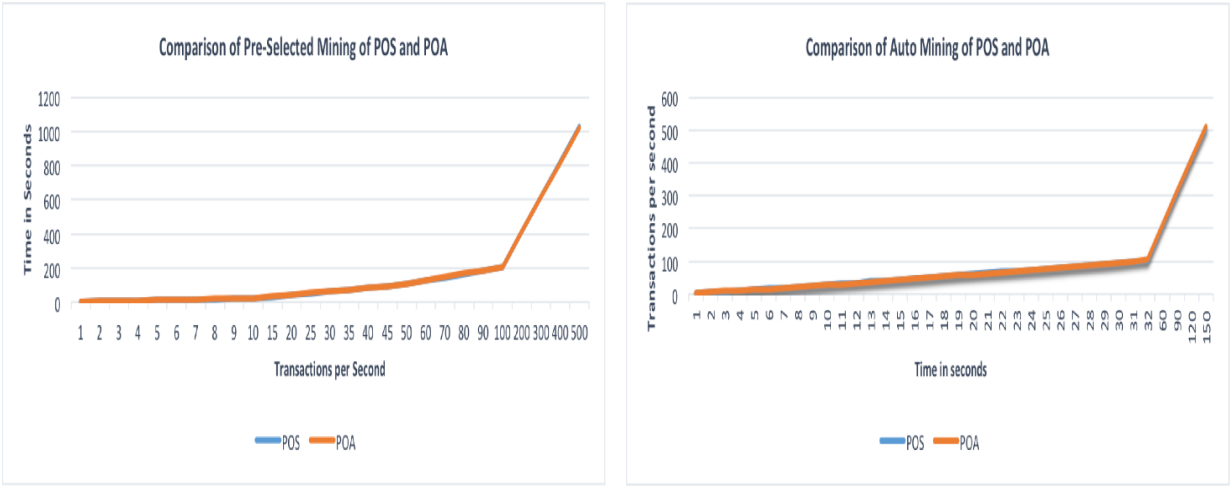


Figure 6. A) Pre-selected Processing Time of 500 Transactions on Seven Nodes of POA B) Auto processing of 500 Transactions on Seven Nodes of POA C) Comparison of Pre-Selected and Auto Mining Transactions per Second of POA



A) B)

Figure10. A)Comparisonof Pre-Selected Miningof Transactionsof POS and POA

B) Comparison of Auto Mining of Transactions of POS and POA

Analysis of variance (ANOVA) on POA pre-select mean transection time vs POS pre-select mean transection time has shown the p-value of <2e-16. Similarly, the p-values for POA auto-mine and PS – auto-mine are < 2e-16.. Establishing that data are unique yet the there is no such difference in throughput of POA and POS, the only difference in governance [18-19] as illustrated in figure 7. By Comparative analysis of POS and POA; we find that there is no such difference in performance of both, as POA is a derived form of POS; the only difference is in their governance type. By analyzing comparison graphs of pre-selected and auto mining transactions of POS and POA the validity of statement is achieved.

4. Conclusion.

In this paper, we suggested a Blockchain based solution for power theft issue in Pakistan using Ethereum smart contracts with the combination of Ganache setup; that will guarantee the tamper proof power sector. Our main focus is on consensus protocols on which energy Blockchain system is established. Paper suggested POS and POA consensus protocols for small, medium or large scales of consumers by keeping in view their needs. We performed a comparative analysis of both POS and POA consensus protocols and found that there is no such difference in their performance, the only difference is in their governance type. The study simulated pre-selected or auto mining of transactions; we also performed a performance analysis of both pre-selected or auto mining on both POS and POA consensus protocols. Auto mining is always found best in both protocols, with more than mining of 110 transactions in 30 seconds. Such high throughput of auto mined processing makes the system scalable. The technologies of our system will be updated time to time with respect to the advancement in the technologies. Future work is in-depth analysis of other scalability factors. Further research should appraise other government or private sectors to make them secure and trustworthy. This will ultimately decree the revenue boosting for the utilities and powerful economy.

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