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A Comprehensive Study of Hyperledger Sawtooth Blockchain Architechture to Combat Covid19

Shital Dongre[1], Shantanu Sontakke[2], Pradunya Maladhari[3], Sagar Sikchi[4], Talib Hussain[5], Aadarsh Kandewar[6]
[1]*Guide,* [2, 3, 4, 5]*BTech Students, Department of IT Engineering and MCA, Vishwakarma Institute of Technology, Pune, Maharashtra, India*

Abstract: ***It may take many weeks if not days for developers and technologists to create technology based on Permissioned Blockchain to help the society to fight the Covid19. But we have provided them with a comprehensive study of Hyperledger Sawtooth so that that can help them in quickly deploying their blockchain applications that are designed to be highly scalable and usable at the enterprise-level. We also worked closely with an NGO to look at the problems faced during the Covid19 crisis. To address such pressing needs during the pandemic, we propose an effective usage of blockchain and discuss how it can be used to help frontline workers, track patients and combat Covid19. Moreover, we have provided them with the pseudo-code of the Sawtooth Supply-chain transaction processor for everyone to quickly grasp the important aspects of it and focus on developing solutions.***

Keywords: Blockchain, Covid19, coronavirus, technology, tracking, supply chain, transparency, trust

I. INTRODUCTION

The world has come across one of the worst pandemics it has ever seen caused by the SARS-CoV-2(severe acute respiratory syndrome 2), with countries grappling with precarious situations and the economies coming to a standstill. The Covid-19 disease caused by the virus has spread across the globe, with millions being affected and thousands of people dead. There has risen an urgent need for people to fight this virus and contain it. Industry leaders and governments have been forced to find an urgent solution to this problem. One of the most promising technologies that can help to contain this virus is the blockchain technology.

Blockchain has been considered as revolutionary by many and its power as a disruptive technology cannot be neglected. It has undoubtedly been considered as the next biggest technology and has often been compared to the internet in terms of its capability to revolutionize the world. It is defined as a record of cryptographically hashed blocks that are linked with each other where each subsequent block contains the cryptographic hash of the previous block. It consists of a peer-to-peer network following strict protocols allowing inter-node communication where an open and distributed ledger records transactions in a verifiable and immutable way. It was the brainchild of a person (or a group of people) called Satoshi Nakamoto in 2008 in the form of cryptocurrency called Bitcoin which is a permissionless blockchain that allows anyone to join the network and perform transactions with high anonymity [1]. Bitcoin was the first digital currency to solve the pressing problem of double spending.

But for real world applications such as in the businesses, enterprises, organisations, etc. there is a greater need to implement permissioned blockchain models that allow only verified nodes to participate in conducting of specified activities. Permissioned blockchain allows transparency as well as security at the same time. The invention of blockchain was aimed at providing a completely decentralized way to conduct business, thus eliminating potential middlemen. But many blockchain mechanisms developed by various companies are in fact not decentralized although they claim it to be some kind of permissioned blockchain. So, the need for decentralized blockchains is eminent. Blockchains can also help strengthen democratic institutions such as the executive and the judiciary, while maintaining a high degree of transparency. A key problem that arises is the unwanted influence of powers and forces on the work being conducted, resulting in biased outcomes or unfair results. Blockchain is that technology which is capable of solving the issues of trust, a major challenge that has risen during the pandemic. People have failed to trust each other in such a scenario and also there has been mistrusts between the governments creating panic worldwide. While it may not be clear how the situation can return to a normal state, but it can certainly be ensured that it doesn't turn abnormal. And using decentralized technologies such as Blockchain may solve a lot of problems during this alarming crisis.

Blockchain can easily win the competition for being the best technology to ensure social distancing. During social distancing, it has been advised by WHO (World Health Organisation) and many scientists to maintain a safe distance from each other to avoid spreading of the virus. Till now, only this seems to be the solution for containing the virus and cutting off the hotspot regions from the rest of the areas. Constantly maintaining a safe distance and running essential services, businesses at the same time has become a tedious and almost impossible.

Blockchain offers decentralization which is perfect when people want to carry out certain businesses, tasks, exchange of services because there is no single centralized entity controlling everything. Here there is great deal of transparency and security which allows entities to trust the technology and services offered by blockchain, instead of directly trusting each other even if it means for them to operate at a distance or follow social distancing. Permissioned blockchains like Hyperledger Sawtooth that can solve business level problems seem to be the best to solve immediate needs.

II. LITERATURE REVIEW

Seyednima Khezr, Md Moniruzzaman et al. (2019) have provided a comprehensive review of emerging blockchain-based healthcare technologies and related applications. Also discussed blockchain based healthcare applications which consists of four layers i.e. healthcare raw data, blockchain, healthcare application, and stakeholders. They have given a detailed comparison of a data management, supply chain management and internet of medical things for healthcare in blockchain. Also gives information about Health IoT infrastructure and data security [2].

Asad Ali Siyal, Aisha Zahid et al. (2019) have discussed different applications of blockchain in healthcare sector such as Electronic Health Records, clinical research, medical fraud detection, neuroscience research and pharmaceutical industry. Also discussed some challenges such as standardization and social challenges in health sector as well discussed some opportunities and future perspective of this technology in healthcare sector [3].

Sudip Bhattacharya1, Amarjeet Singh et al. (2019) discussed uses of blockchain in health and different sectors related to it such as at hospital level system, resource management in health system, patient level applications and diseases surveillance at community level. Also gives some information about real time surveillance for Non-Communicable Diseases (NCDs) within the global health security agenda [4]. Marko Hölbl , Marko Kompara et al. (2018) have provided a theoretical basis for need of blockchain technology in healthcare sector. It has comprehensive discussion of distributed ledger technology in blockchain. It has discussed establishment of blockchain and current research trends for blockchain in healthcare as well as elements used in healthcare publications. It gives comparative review on published papers based on blockchain used in different sectors [5].

Gregor Blossey, Jannick Eisenhardt et al. (2019) some basic conceptual and applications of blockchain technology are discussed by them. They have pointed some key features of blockchain which can enhance integration and coordination among the member of supply chain. It will provide theoretical basis to intelligent quality management of supply chain and provides foundation to develop theories about information related to it [6]. Ajay Funde, Pranjal Nahar (2019) have explained concept of Product Ownership Management System (POMS) of products for anti-counterfeits that can be used in post supply chain by using QR code. They have also proposed system architecture which is blockchain based POMS in the post supply chain. This also gives survey of different techniques used by researchers for implementation of blockchain in various sector [7].

Andreas Kamilaris, Agusti Fonts et al. have examined impact of block chain technology on agriculture and food supply chain and discusses overall implications, challenges and potentials related to this sector. It also provides theoretical basis of food safety, security, quality and integrity which will also useful for further progress using blockchain. It also discussed challenges and open issues related to blockchain in agriculture sector and food chain management [8].

Mehrdokht Pournader, Yangyan Shi et al. (2020) have studied 4T application i.e. Technology, Trust, Trade and Transparency in supply chain, logistics and transport management. Also discussed applications of blockchain in commercialisation and industrial sector [9].

III.BLOCKCHAIN AND HYPERLEDGER SAWTOOTH FEATURES

Any good blockchain must have the following features for it to be truly called a blockchain-

1) *Decentralized:* Blockchain has a high degree of decentralization which guarantees that the power is not concentrated into the hands of a single entity.
2) *Immutability:* This feature means that once transactions are made by a person or a node, they get added to a block which are strongly hashed and connected to each other. This means that the information added in these blocks cannot be changed as it would require each subsequent block for the attacker to be changed which is computationally difficult.
3) *Transparency:* Any system that is not transparent is hard to trust. Thus, blockchain enhances trust via achieving a good level of transparency as well as providing security at the same time.
4) *Security:* The distributed ledgers must have immutability. They should also use strong encryption such that the they data is secure. It should also provide facilities for authentication of peers using the concept of digital signature that uses public and private keys to ‘digitally’ sign the transactions such that it is verifiable.

5) *Consensus:* A blockchain has consensus algorithms that achieve consensus across the distributed ledgers which is extremely important to maintain consistency across the network. It also solves the problem of preventing malicious nodes from attacking the system for example there is a Byzantine Generals problem that it tries to solve.
6) *Trust:* This technology tries to build trust among individuals or organizations that wish to conduct businesses with each other but do not necessarily trust each other. It tries to avoid middlemen so that there are no obstacles or unwanted parties compromising the trust and security.

Hyperledger Sawtooth has all the properties that a blockchain has. It has several interesting features which are given as follows-

a) According to the white paper provided by Hyperledger, this blockchain technology provides a framework to build enterprise-grade distributed ledgers [10]. It's an open source project developed by Intel under the umbrella of the Linux Foundation. It is designed with a prime focus on security, scalability and modularity and extensibility.
b) It consists of a peer to peer network in which the messages containing information about the blocks, transactions, peers, etc. are passed between the nodes via TCP in a structured form using Protocol Buffers made by Google. Its nodes can control who are able to connect to the network, submit transactions and who can send messages and thus participate in consensus process.
c) It has a distributed log that has an ordered list of all the transactions that are nothing but the actual blockchain i.e. a cryptographically linked structure of blocks. The correct ordering of the distributed log is required for the nodes to reach a consensus. The consensus algorithms are then required to achieve this. Thus, there is a strict order in which the transactions should occur. But it is also possible to modify the data structure to allow partial ordering such that the data structure is like a directed acyclic graph. This would make the blockchain to be partitioned but would reduce storage requirements and improve scalability.
d) It consists of smart contract that are a sort of state machines that take a specific input, process it and produce an output. This part consists of the core of the business logic via which specific functions are implemented. Sawtooth builds on these smart contracts and looks it as a transaction processor. When the transactions pass through the distributed log, they are directed towards the respective transaction processor. Hyperledger Sawtooth supports both the types-stateless (UTXO) as well as stateful models that are like that of Ethereum.
e) Sawtooth developers can develop the smart contracts or transaction processors in 7 different languages- Python, JavaScript, Rust, C++, Go, Ethereum Virtual Machine and Java, thus offering a variety of languages to write your code to get any desired business implemented.
f) An integration or plugin with Hyperledger Burrow has been provided which allows Sawtooth to run Solidity contracts, the language used for developing Ethereum Smart contracts. It has been named as Sawtooth Seth and thus can run Ethereum Smart Contracts freely without the need of Ether cryptocurrency or gas.
g) Smallbank Transaction Family is provided to Sawtooth that is able to handle performance analysis for benchmarking and performance testing. It can also be integrated with Grafana that can be used for Hyperledger Sawtooth Performance Testing. It is completely free and open source, providing analytics and interactive interfaces and graphs for visualization.
h) The resulting state of the transactions are stored in distributed format in Radix Merkel Tree. The flexibility has been provided for the developer to define the method of serialization and each transaction processor has been provided with its own namespace.
i) Sawtooth provides different consensus protocols to choose from based on their differences in latency, throughput, finality, etc. This includes algorithms such as Dev_mode, Proof of Work-style PoET (Proof of Elapsed Time), PoET-Simulator and RAFT consensus algorithm.
j) The Sawtooth Settings Family that is responsible for storing on-chain configuration settings like the type of consensus mechanism used and the enabled transaction processors in the network, has two authorization options- either a single authorized key that can make changes or multiple authorized keys that can make changes. When there are multiple keys, a required percentage of votes need to be signed in order to make the change.
k) Hyperledger Sawtooth can be quickly deployed on AWS (Amazon Web Services) cloud platform which supports its full functionality. Also, the language in which the client application is developed can be different from the language you might use to implement the transaction processors.
l) Multiple transaction processors allow parallel execution of transaction which increases the number of transactions that can be committed per second.

IV. HYPERLEDGER SAWTOOTH ARCHITECTURE

The Sawtooth Architecture mainly consists of the following components-

1) *Client:* The client is the one that sends requests to the server. In Sawtooth they can do this in an asynchronous way which allows multiple requests to be sent and waiting time is reduced. The signing of transactions also happens here.
2) *REST API:* The requests from the client is sent via the REST API using common JSON/ HTTP standards. It is used for submission of transactions and reading of blocks. The REST API mostly treats the validator as a black box for submitting transactions and fetching results. It is also well documented using the OpenAPI specification. It is readable both machine and human readable. The REST API also supports some of the common HTTP codes. The client is connected to the validator node using this. It uses JSON to send the metadata back and forth.
3) *Transaction Processors:* The transaction processors are responsible for handling the core business logic. They also have the authority to either allow or decline transactions from being added to the state. They validate the transactions after the client sends it. It then applies the necessary changes and adds them into the next block. A validator can contain one or more transaction processors. These multiple transaction processors also achieve parallelism and thus offer good performance. These also have the transaction family which defines the set of possible transactions. The transaction handler class in transaction processors are the ones that contain the business logic.
4) *Consensus Engine:* It is that component of Sawtooth that defines the consensus algorithm to be used in the network. It is important to select the correct one.
5) *Validator:* As its name suggests, the validator checks the validity of the blocks being added. It checks for on-chain transaction permissions and verifies who is allowed to issue blocks and batches. A single block has multiple batches and a single batch has multiple transactions.

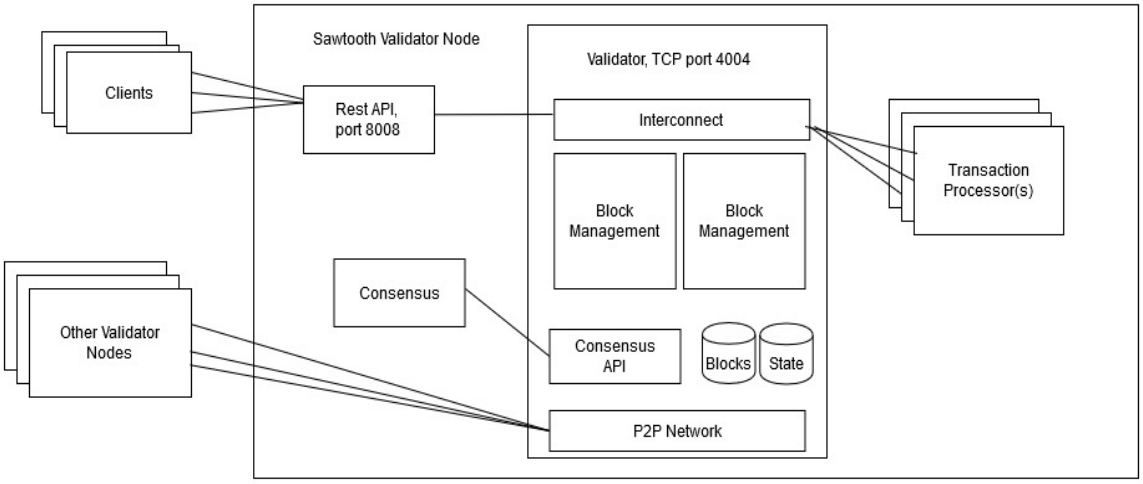

Fig. 1 Hyperledger Sawtooth Architecture diagram

V. HYPERLEDGER SAWTOOTH DATA STRUCTURE

The Hyperledger Sawtooth core data structure is as follows-

1) *Transactions:* These are the entities that make modifications to state after getting created and applied. These are submitted to the validator by the client. The validator validates the transaction and applies it after which a change is caused to state. These contain header, header signature and payload.
2) *Batch:* The transactions are wrapped inside of a batch. This is always followed and either all transactions within a batch are committed to state together or none at all. Batches are known as change of the atomic unit. Batches consists of header, header signature and transactions. It should be noted that first serialization occurs to put transaction into a batch.
3) *Transaction Header:* This transaction header contains public key, family version, family name, nonce, etc.

A person is able to define his own addressing schema using protobufs.

VI. SAWTOOTH SECURITY

There are several defense-in-depth tests to prevent cheating by a rouge node.

1) *Z test* - Tests that block claiming validator is not winning too frequently.
2) *C test* - It checks that a new node must wait C blocks after admission before its blocks will accepted. This is to prevent others from trying to game identities and some obscure corner scenario.
3) *K test* - It makes sure that the node can publish at most K blocks before its peer require it to recertify itself.

There are many security aspects of Sawtooth which are as follows-

a) Permission is required for every transaction as well as validation in Sawtooth (through transaction key and validation key respectively). Extensible settings regarding the permissions are stored in the blockchain (initially in block 0). For example: sawtooth. validator. transaction_families

b) Unlike public blockchain that are permissionless, Hyperledger sawtooth can be permissioned blockchain or permissionless according to us. You can have transaction key for Sawtooth client apps or validation key for Sawtooth network nodes. Public key can be used to restrict what keys are allowed to submit by the client. Permissioning can be on-chain or off-chain configuration as well. On-chain configuration applies to entire network where the changes made propagate automatically to all nodes and this type of configuration is generally preferred. As compared to it the off-chain configuration is per node.

c) Transaction key permissioning controls what clients can submit whereas validation key permissioning controls what nodes are allowed to make changes to the Sawtooth network. This is enforced with network roles.

d) Each and every IDs, policies, roles are tracked using Sawtooth Identity Transaction.File. The file validator.toml tracks these off-chain. Two types of keys, public key and private key are present for every client. Public key is the one that's visible to all whereas private key is only known to that particular client. Id plays the role of public key of a transactor or a validator. The client signs transactions which is submitted to the validator node using their private key. Key management is the responsibility of the client application and is not mentioned by Sawtooth software. The key must be secured from use by others. Transactions have a nonce to make them unique. The public key is sent along with the signature. The public may optionally be used to identify the client or another option is to use authentication.

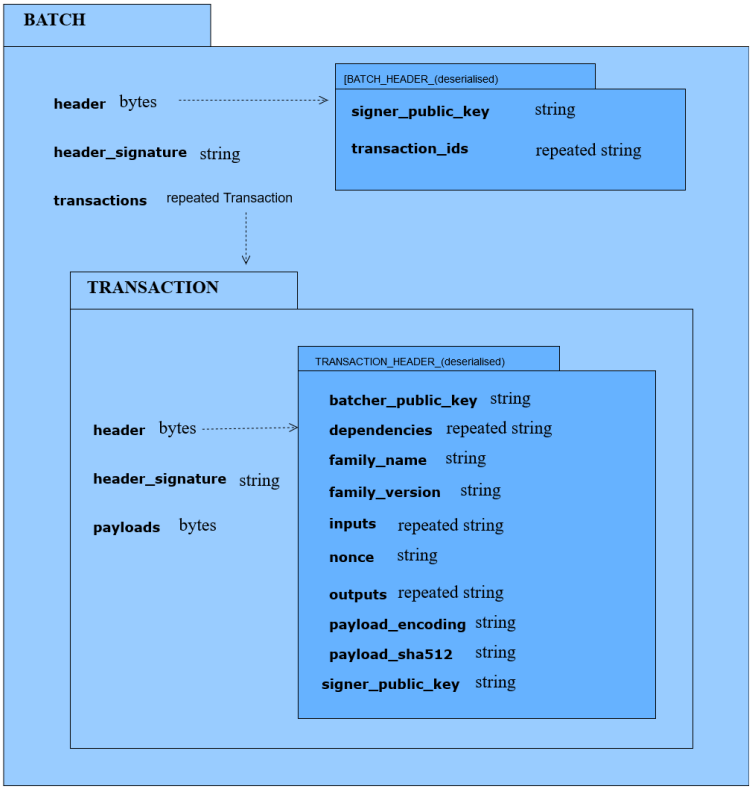

Fig. 2 Hyperledger Sawtooth Data Structure

VII. THE COVID-19 CRISIS

It looked as if it came too soon and no one was prepared for it. The unexpected pandemic took everyone by surpise reducing us humans to a mere witness of the hapless situation. It has put an immense pressure on the healthcare sector and has paralysed the livelihoods of many. The situation of India was no different. The entire country had been put to a lockdown and the state borders and been shut. Maharashtra was the worst hit state, constantly reporting new cases of coronavirus patients everyday. To help address the situation, our research team worked closely with a Pune-based NGO which was the brainchild of highly passionate engineers, entrepreneurs, start-up founders and a variety of very motivated individuals.

This NGO was helping hospitals all over Maharashtra to procure essential equipments such as PPE (Personal Protective Equipments) kits, N95 Masks, Sanitizers, Gloves, etc. There were more than 70 hospitals across the state along with whom they were constantly in touch and taking note of their demands and taking note of the graveness of the situation at the ground-level. We had a chat with a few doctors, managers, etc. which explained the shortage of protective equipments they were facing. The NGO helped them by getting these essential equipments from where the stock was available, transporting these to the hospitals and thus donating them. They were also raising money for them in order to make these things freely available to them. But they faced many challenges. One of the major challenges that they faced was in the supply chain part. As all the districts of Maharashtra were under lockdown, they faced problems doing cross-border deliveries and for procuring the goods as well.

One of the problems that they also faced was that of the trust and integrity problems. It was hard to get the exact demand of essential equipments required from the hospitals staff and the purchase managers. Some of the doctors and managers requested for a higher demand of PPE kits and masks that they required, clarifying afterwards that they may need it in future which was clearly not the solution to solve the Covid19 problem as there was limited stock available. The red zones or the so called hotspot regions were under a greater threat and required a more urgent attention. So stocking of these live saving gears by the hospitals would create an even greater problem. So, the NGO was trying to tap into the real needs and address them first which seemed to be a good strategy.

Another problem that they faced was that of trust. The suppliers and delivery persons had faced trust problems on many fronts. It was hard for people to trust each other as they constantly feared of coming in contact with this deadly virus. They were finding it difficult to get donors also for raising the money as the donors were unable to trust them that they are actually using the money for doing the right work. The challenges that they constantly could truly be solved using the blockchain technology, especially Hyperledger Sawtooth, given its diverse features and scalability. So, we'll analysed the Sawtooth supply chain application and how it could cater to the demanding needs.

VIII. SAWTOOTH SUPPLY CHAIN EXAMPLE

A. *Sawtooth Supply Chain*

Sawtooth consists of a high level of supply chain example which can be studied to start developing applications quickly according to their needs by cloning the git repository[16]. We givena basic example of what the terms here are-

1) *Agent*- This is the person who registers the asset
2) *Asset*- An asset can be anything that is a physical object and has a value to it that needs to be exchanged via supply chain
3) *Records*- The assets are st6ored as records that have a specific format as defined by the protocol buffers
4) *Record Type*- The asset can be defined to be of a certain type like medicine and ventilators. These two different types of records will thus have a separate client page as they have different properties.
5) *Properties*- These are the ones that define the records, like temperature, quantity, etc.
6) *Property Pages*- These are the pages that have reporters list in them and help to list pages
7) *Reporter*- An agent can choose to authorise reporters i.e. specifically chosen agents by the owner of the asset when creating the asset
8) *Proposal*- A proposal is made by the owner when creating the asset. He can choose certain agents to be authorized as reporters who are then become the only peers to be granted rights to update those values.

B. *Proposed Model for during Covid-19*

The problems that the above blockchain solution can solve are-

1) Permissions to do cross-border deliveries of essential goods like PPE kits, N95 masks, sanitizers, medicines, etc.
2) Certifying/ Quality checking of new supplies can be done. Blockchain can ensure that only verified individuals have the right to certify and that the information is authentic. Digital signatures are used by Sawtooth for verification.

3) Hospitals can instantly put their demands which can be verified using digital signatures. Transparency of their demands and a single blockchain where everyone can see that can be used to keep a track of real demands.

4) Using of Uncertified or bad quality protective equipments have resulted in the death of many during this crisis. Blockchain can be modified to allow only certified and good quality products to be transferred, thus saving lives.

5) Two way verification here, ensures that the asset has indeed been transferred and that too to the right person in need.

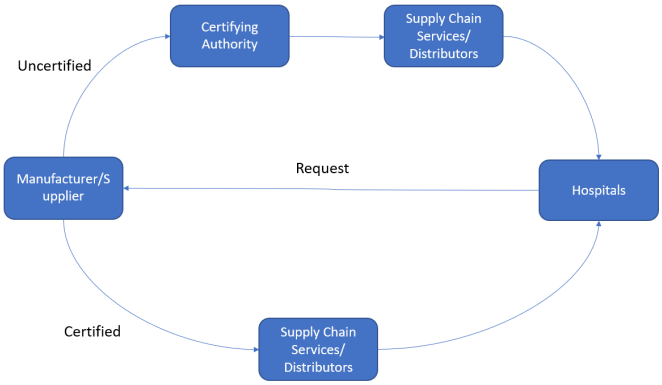

Fig. 3 A simple supply chain model diagram

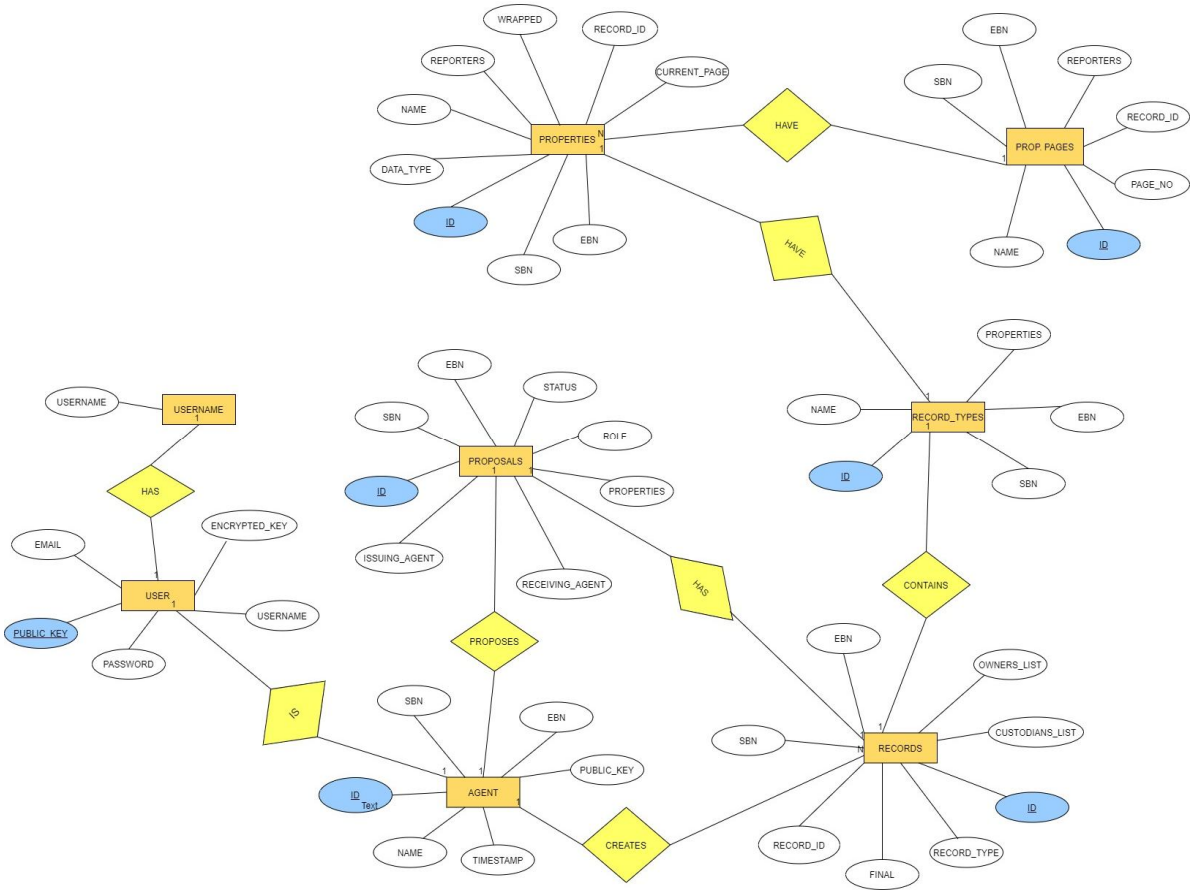

Fig. 4 Entity Relationship diagram

IX. PSEUDO-CODE OF SAWTOOTH SUPPLY CHAIN

The transaction handler is the most important aspect of Sawtooth as it has the Business Logic or the Blockchain's logic that you want to implement. We have provided the pseudo code of the supply chain transaction handler so that it is easy for people to understand so that they can modify it quickly during the Covid-19 pandemic to meet their needs accordingly [17].

X. CONSENSUS IN HYPERLEDGER SAWTOOTH

There are different consensus algorithms in Hyperledger Sawtooth. These are very important to choose from based on the type of blockchain application you are trying to make on to tackle Covid19. Somewhere performance may be much important such an in a hospital where every second counts. Some may require scalability such as a large supply chain network operating within a state such as Maharashtra where supplying of essential goods needs to be done. So, consensus can be looked as the right spice you want for your dish. Too much of a certain spice may lead to slow eating of food (here it implies that as the nodes increase it may happen that your performance drops while using a certain consensus algorithm). So, the consensus algorithm needs to be chosen wisely. Sawtooth uses a pluggable consensus for both lottery and voting algorithms [11]. They are given as follows-

1) *PoET:* IT is a Nakamoto consensus algorithm called PoET(Proof of Elapsed Time). It uses a lottery for leader election supported a guaranteed wait time which is provided through a Trusted Execution Environment (TEE). For the aim of achieving distributed consensus efficiently, an honest lottery function has several characteristics that are defined in [12] as:

a) *Fairness:* The function has to distribute leader election across the widest possible population of participants.

b) *Investment:* The worth of controlling the leader election process should be proportional to the value gained from it.

c) *Verification:* It should simple for all of the participants for verifying that the leader was legitimately selected.

The current implementation of Hyperledger Sawtooth builds on a Trusted Execution Environment provided by Software Guard Extensions (SGX) by Intel. This ensures the security and randomness of the leader election process which does not require high and costly power to run as the consensus for many blockchain need. Every PoET validator requests a random time to attend from a trusted function before claiming leadership. The validator which has the shortest wait time for a specific transaction block becomes the elected leader. It also meets the standards for an honest lottery algorithm. It randomly distributes leadership election across the whole population of validators. Here the probability of election is directly proportional to the resources contributed, where resources are general-purpose processors with a TEE. It has increased robustness and supports good scalability. This blockchain algorithms offer a good deal of difficulty for the hackers. It is also an excellent consensus mechanism for permissioned networks where you want only verified participants to join the network. It provides Byzantine Fault Tolerance also but a drawback of this algorithm is that the finality of the blocks can be delayed due to the formation of forks which needs to be resolved.

2) *PBFT:* Practical Byzantine Fault Tolerance are guarantees that even when some nodes are faulty or are behaving maliciously, as long as a minimum percentage of nodes are connected and are working properly and behaving honestly, the network is safe and live [13]. Here all nodes must be connected to each other. Blocks that are committed by the nodes are final, unlike consensus algorithms such as Proof of Elapsed Time (PoET) which is lottery based. It is leader-based meaning that a primary node is responsible for producing candidate blocks i.e. secondary nodes which vote on the blocks produced by the primary. The leader then changes in a round-robin circular order. The nodes pass many messages among themselves to maintain a healthy leader node in the network. Not anyone can join the network and it does not support open enrolment. But nodes can be added and removed by an administrator. One major requirement for this algorithm is that it must have at least 4 nodes, otherwise it won't work. This algorithm is based on the Practical Byzantine Fault Tolerance by Miguel Castro and Barbara Liskov. It guarantees that at a given time, no more than one third of the nodes can be unreachable behave dishonestly at any given time. All PBFT consensus messages are serialized as Protocol Buffers or protobufs. Sawtooth has solved the 'silent leader' problem that a traditional PBFT has using idle timeout that triggers a view change. Each node starts its idle timer after a block is committed, the primary node must publish the next block and broadcast a pre-prepare message for the block before the timer expires or else the secondary node initiates a view change. This seal proves that the network agreed to commit the block and that the block was committed validly. PBFT is considered the best for usage by Sawtooth if you have a small network of nodes that are say less than 20 as it gives better performance along with healthy and secure network [14]. If the network increases and gets bigger than20 nodes, then it should with its consensus mechanism to PoET.

3) *Raft:* This is a leader-based consensus algorithm in which the algorithm defines an election process where leader is established and then recognized by all the followers (Docs). So, only one node can publish the block i.e. the leader node. Here no forking happens in the network as only one node publishes the block. This results in increased performance. In Raft a majority of nodes must agree on all the progress that is made. It does not support open membership to ensure safety. The population of nodes is fixed unless changed by an administrator. Raft networks must be small here (typically somewhere between 1 and 10) and the leader waits for a majority of nodes to agree on a new entry before it can be committed. The number of messages to be exchanged increases exponentially as the size of the network increases. So large networks are not supported by Raft as it is not advised. It is not a Byzantine fault tolerant algorithm as it was made to be crash fault tolerant—it can continue to make progress

as long as a majority of its nodes are available. However, Raft only guarantees safety and availability under non-Byzantine conditions, which makes it ill-suited for networks that require Byzantine fault tolerance.

XI. MORE WAYS TO COMBAT COVID-19

The timely delivery of hospitals is crucial and can be tracked via blockchain. Blockchain can be used to show transparency to donors where donors can see where and how their money was actually used. This builds trust among them and helps raise donations for NGOs fighting with the frontline workers which is extremely crucial. It can be used to ensure that ethical practices are being followed no matter how worse the situation is. It's the only way to restore peace, harmony and trust among individuals whose positions have been threatened by the Covid19 crisis. Blockchains can be used for issuance of a country's official currency as a digital currency to avoid transferring of coronavirus from one person to another via cash. Governments can use a decentralized architecture here allowing individuals to invest their money to make a 'cloud bank' where they can act as a treasurer secretary, but have no authority to touch or manhandle the digital currency. The governments can then pay a certain fee to these individuals based on the amount of digital currency issued/stored and the number of people who are using this digital currency on their 'cloud bank' node. Here there will be no problem of security attacks as all the nodes will be running on the same transaction processors, thus preventing any malicious activities by the nodes. It will also help in maintaining digital distancing of citizens as they will not be required to touch any physical things unlike cash notes. It can help revive the economy while keeping the flow of cash in the economy. Again, the use of blockchain here is a must as you want to ensure transparency and that no one person is indulging in any kind of malpractice.

There have been cases reported in many countries in which the Covid-19 patients who got cured and tested negative, got tested positive for the second time. This can be an alarming indication as Geolocation of people who tested positive first and now tested negative. This might be an alarming sign as we know very little about this virus. A solution to this can be to put all the testing resulting on blockchain and monitoring the geolocation of such people and the area near them. A single source of information that is credible and authentic can be provided by blockchain.

XII. CONCLUSIONS

Thus, blockchain can help create faster supply chains for hospitals and it can solve many problems during the crisis. It is one of those rare technologies that is decentralized which can benefit for maintaining Social distancing during the Covid-19 pandemic and it also has the transparency and security features embedded in its core that increases trust among the individuals of the society. A single source of tamper-proof information is also necessary during the pandemic and permissioned blockchains like Hyperledger Sawtooth that are scalable might be the best solution that the market has to offer.

XIII. ACKNOWLEDGMENT

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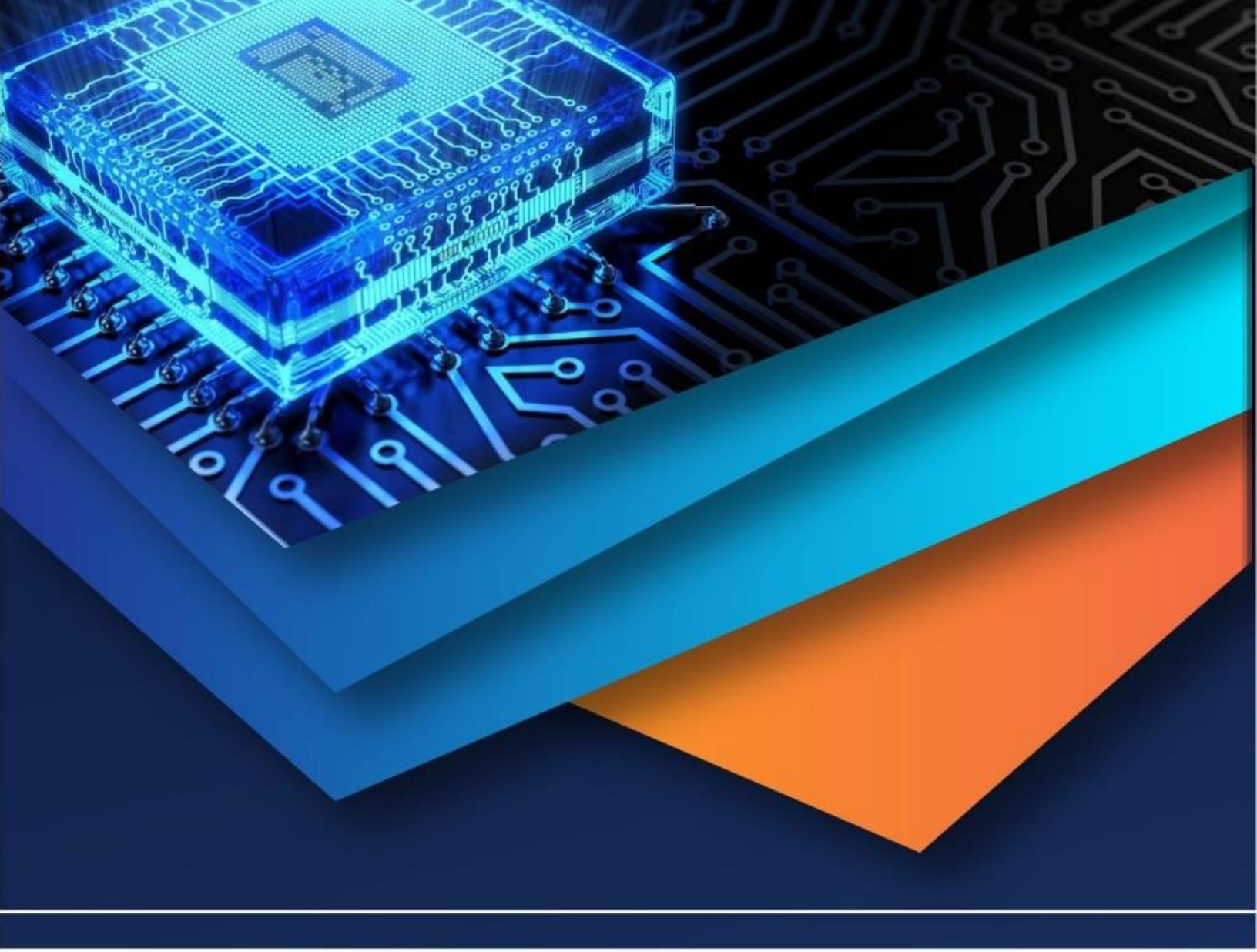

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