International Journal of Computing and Digital Systems
ISSN (2210-142X)
Int. J. Com. Dig. Sys. #, No.# (Mon-20..)

Blockchain Based Student Grievances Redressal System, Performance Analysis and Proposing Artificial Intelligence-Based Model

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Received ## Mon.20##, Revised ## Mon. 20##, Accepted ## Mon. 20##, Published ## Mon. 20##

Abstract: Ensuring the integrity of data is essential to protect sensitive information from unauthorized alterations. Employing appropriate tools and methodologies is crucial in preventing data manipulation. This is especially vital for maintaining the integrity of various types of information, such as financial transactions, online assets, patient health records, insurance details, data from IoT sensors, supply chain information, and logistics data. Data integrity plays a pivotal role in maintaining the accuracy of student grievance information, as higher authorities may be tempted to manipulate it for institutional interests. Within the realm of higher education, it is imperative for universities to establish a secure environment where students feel comfortable expressing their grievances. Traditional methods for registering complaints were not secure, lacks in maintaining privacy and transparency and thus contributing to heightened frustration and fear. This article suggests a viable solution to this issue by implementing a student complaints system based on blockchain technology. The proposed approach involves simulating the use of the Hyperledger Fabric framework, leveraging blockchain to ensure its resistance to tampering. This study also reveals an approach of computing overall system throughput and latency by making use of Hyperledger Caliper. The simulated result indicates minimal latency and high throughput even after injecting the transactions at different TPS (Transaction per second) rates. At last, an artificial intelligence-based model is proposed for smooth functioning of such systems.

Keywords: Blockchain, Hyperledger Fabric, Hyperledger Caliper, Fabric Performance, Artificial Intelligence

1. Introduction

Blockchain is an innovative technology that enables the creation of immutable ledgers through a decentralized peer-to-peer network. The concept of immutability ensures that once a transaction is made there should be no way to tamper it by any means. This immutable ledger of transactions is distributed among peers over the network where every peer holds the full ledger. Thus, failure of a single node has no effect on the performance of the whole system [1], [2]. Blockchain technology maintains a chain of blocks where each block is connected with the previous block by a unique hash cryptography key. Each block is having a fixed structure and SHA256 algorithm is utilized to generate a cryptography hash. This algorithm receives values of various fields of a block as input like block number, previous block hash, timestamp, nonce, merkle root and transactions to issues a unique SHA256 hash to that block [3], [4]. A typical blockchain structure is illustrated in Figure 1. Data immutability and auditability are inherent features of the blockchain technology which makes it suitable for maintaining student grievance data [5]. Grievances are quite common in institutions no matter it is an academic or non-academic. Sufferers find it very challenging to approach higher authorities of management and most of times the complaints remain unattended. This is a sensitive area where maintaining data integrity is vital as higher authorities may manipulate it due to institutional interests. Therefore, keeping such data on a central machine that too without tamper proof technology must be avoided. Presently, institutions keep such data on a central server which is prone to data manipulation and removal.

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Due to the advancements in blockchain technology, several blockchain frameworks have been introduced for the industry such as Hyperledger fabric, Ethereum and R3 Corda. The Hyperledger itself has several flavors like Hyperledger iroha, Hyperledger sawtooth and Hyperledger fabric [6]. The Hyperledger fabric is the most efficient of all these frameworks, and this study is leveraging it to create such systems.

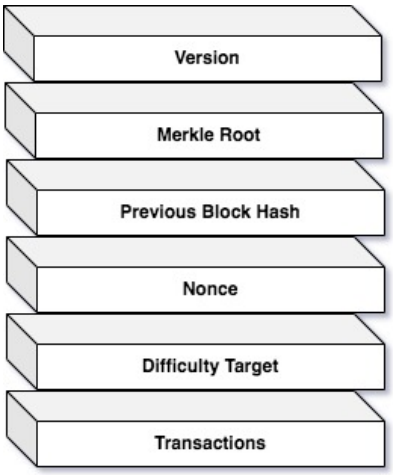

Figure 1. Block Structure

This research work contributes by recommending and putting into practice a highly sophisticated student grievance system using cutting-edge blockchain technology and tools like Hyperledger fabric and Hyperledger Caliper. Caliper is a tool for measuring system performance, especially latency and throughput, and Hyperledger Fabric is a blockchain platform. Both are utilized over the Dockers platform for setup and initialization. The proposed system will ensure that once a grievance is submitted, there should be no way to remove or manipulate it.

The proposed system leverages the immutable and decentralized nature of blockchain technology to create a transparent and secure platform for students to submit their grievances. By using smart contracts, the system can automate the process of reviewing and resolving grievances, reducing the time and resources required for resolution. In addition to providing a more efficient and effective grievance system, the proposed solution also empowers students by giving them greater control over the process. Students can track the status of their grievances in real-time, and the system ensures that their identity and privacy are protected throughout the process. Overall, this article argues that a blockchain-based student grievance system has the potential to revolutionize the way universities handle student grievances. By providing a secure, transparent, and student-centric platform, the system can help to create a more positive and supportive campus environment for all students. The rest of the paper is organized as follows. Section 2 presents a related work and section 3 is proposing an enhanced model to mitigate grievance related issues. Section 4 demonstrates the working environment and Section 5 suggests an approach to evaluate the system performance. At last, we proposed an advanced AI (artificial intelligence) based model, draw our conclusion and present issues which needs to be addressed in future.

2. LITERATURE REVIEW

The traditional paper-based grievance redressal systems are no more required due to several issues like poor transparency, document mishandling and prone to easy manipulation [7]-[9]. A fair and transparent online grievance redressal is extremely necessary at schools and universities to avoid extortion, harassment, corruption, and negligence. It has been observed that students hesitate and fear to make a complaint due to lack of a transparent system. Transparent and tamper proof grievance system is needed to eliminate any chance of ignorance and misuse of power by the higher authorities.

Several online solutions have been proposed in the past to overcome the issue but none of the solutions is tamper proof as higher authorities may remove or modify complaints even in the online databases [10],[11]. The authors in [12] proposed one such solution for educational organizations but did not deploy a decentralized and tamper proof mechanism. Another study proposed a blockchain based solutions for addressing people grievances, but this solution was not proposed for student grievances. In fact, this solution was proposed for social welfare where people can register complaints anonymously against poor public services like damaged roads [9]. One another study proposed a blockchain based grievance management system but lacked in several aspects like absence of state-of-the-art blockchain framework like Hyperledger fabric and evaluation of system performance to deliver high throughput and low latency [13]. In nutshell, introducing blockchain in educational institutions is a need of the hour [14].

Most of the online grievance management systems are based on a centralized server and hence removal or tampering is much easier. In contrast, a decentralized grievance redressal system can restrict such attempts due to the availability of all complaints on every single peer on the network.

A very few blockchain based grievance redressal systems are available and that too are not utilizing the modern blockchain frameworks and tools. There are several blockchain open source blockchain frameworks like Hyperledger Fabric, Aries, Besu, Indy, Iroha and Sawtooth. Each of these frameworks has a unique feature. Hyperledger Fabric helps developing solutions with a modular architecture and enhance performance while preserving privacy [15]. Hyperledger Aries is effective for the solutions that focused on transmitting and storing verifiable digital credentials. Hyperledger Besu is an Ethereum client and can also run on test networks. Hyperledger Indy is used to provide digital identities for interoperability whereas Iroha is used for IoT (Internet of Things) applications. Hyperledger Sawtooth is primarily used for designing applications based on smart contracts. Hyperledger Fabric is hosted by the Linux foundation, and it permits permissioned blockchain network where participating members are known and authenticated [16]. It delivers better performance because it is permissioned blockchain and thus there is no need to solve Byzantine Fault Tolerance (BFT). Blockchain systems may also utilize artificial intelligence for smart solutions, but such solutions must be designed carefully [17]-[20].

The related literature indicates that there is a need of transparent and tamper proof student grievance redressal system over the distributed peer-to-peer network to eliminate any chance of ignorance and misuse of power by the higher authorities. Table 1 shows that conventional grievance systems were implemented using centralized solutions and were deficient in terms of privacy, immutability, and auditability. It is thus evident from table 1 that a prominent solution is required which is suitable is all aspects.

TABLE I. Related studies addressing grievances issues

Year	Technology	1	2	3	4	5	6	Ref.
2018	Android Based	✓	x	x	x	x	x	[21]
2020	PHP	✓	x	x	x	x	✓	[22]
2020	Android Based	✓	x	x	x	x	✓	[23]
2020	Ethereum	✓	x	✓	✓	✓	✓	[24]
2021	Node.JS, MongoDB	✓	x	x	x	x	x	[25]
2022	Django and AI	✓	x	x	x	x	✓	[26]

Note: Security(1), Privacy(2), Decentralized(3), Immutable(4), Auditable(5), Transparent(6)

3. PROPOSED APPROACH

In this section, the proposed approach for designing, implementing, and testing system architecture for registering and resolving student grievances is introduced. Various algorithms and tools have also been discussed in this context.

The proposed approach is to design a system architecture for the grievance redressal system and deploying them using state-of-the-art blockchain framework and tools. Hyperledger Fabric and caliper are preferred for the implementation of the proposed system. The proposed model consists of four main entities namely student, authorities, certificate authority and the blockchain network maintaining the ledger of complaints. This is also illustrated in the Figure 2.

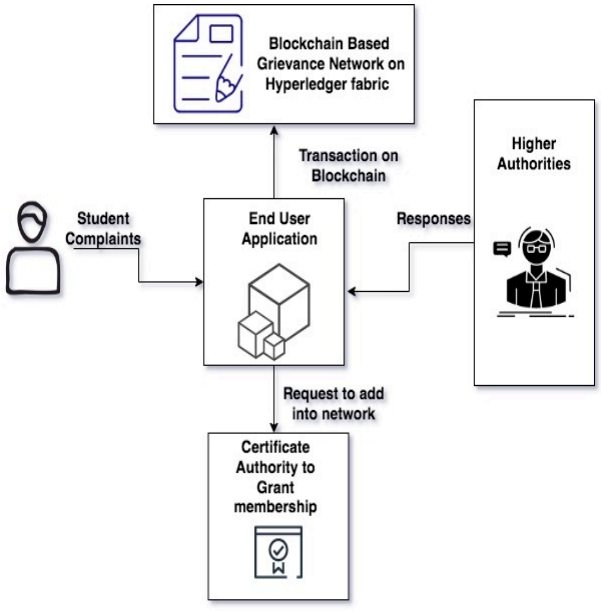

Figure 2. Proposed model

The student will initiate the transaction by raising an issue by using the client application. The raised issue will then be stored into the blockchain network. The higher authorities will get the intimation through the client applications and their acknowledgements and actions will then store back into the blockchain ledger. This client application acts as an end user application and submit transactions in a JSON (JavaScript Object Notation) format. It is mandatory for both the students and higher authorities to get an authentication certificate from the certificate authority. This certificate is issued by the certificate authority which is one of the key components of a Hyperledger fabric.

The certificate authority does not participate in majority of the fabric activities. It is required only when a new user is added or whenever there is a need to revoke a certificate. The system restricts the users to follow the certain steps while participating in the network. The algorithm followed by the proposed system for students and higher authorities are described below respectively.

Algorithm 1: Student Side

1. One time request for the authentication certificate
2. Waiting for approval
3. Opening client application
4. Initiating transaction
5. Waiting for higher authority responses
6. Getting intimation when acknowledgment is received
7. Raising objections/feedback
8. Following step 3 to raise a new complaint

Algorithm 2: Authorities Side

1. One time request for the authentication certificate
2. Waiting for approval
3. Opening client application
4. Reading complaints/issues
5. Writing acknowledgements/suggestions
6. Getting intimations when any objections is raised
7. Following step 5 again
8. Following step 3 to read and write a new acknowledgment

All raised issues and acknowledgments will stay forever on this immutable ledger for auditability and past reference.

4. WORKING ENVIRONMENT

This section is disclosing the system configuration for the proposed model. The proposed model is using the state-of-the-art tools and technologies. The overall setup involves a server, Linux operating system, Dockers, Hyperledger Fabric framework and Caliper. The server configuration is disclosed in the Figure 3, snapshot of actual machine.

TABLE II. Working environment

Software	Version	Purpose
cURL	7.71.1	To make http requests
Docker	20.10.12	Packaging application into container
Node.js	16.10.0	Hyperledger fabric SDK for Node.js
NPM	7.24.0	Node package manger
Ubuntu	20.04	Underlying operating system
Hyperledger Fabric	2.3.1	Blockchain Framework
Fabric Ca	1.4.9	Client Certificate Authority
Fabric Peer	2.3.1	Peer denotes a client
Peer Orderer	2.3.1	Orderer organization
Chaincode	2.3.1	Actual ledger

Hyperledger Fabric and Caliper are two different entities. Caliper is a tool that works on top of the Hyperledger to evaluate the system performance.

This research work setup the working environment keeping the proposed model in mind. The software configuration and working environment is disclosed in the Table 2.

Node.js is used to generate a chaincode to initialize and manage states of an immutable ledger through transactions submitted by the frontend application. Node.js acts as a communication medium between Client and Fabric. Without certificate authority, peers and orderers cannot join an organization. A peer orderer dispatches a block to peers and finally peers receive these transactions through a common channel and updates their ledger.

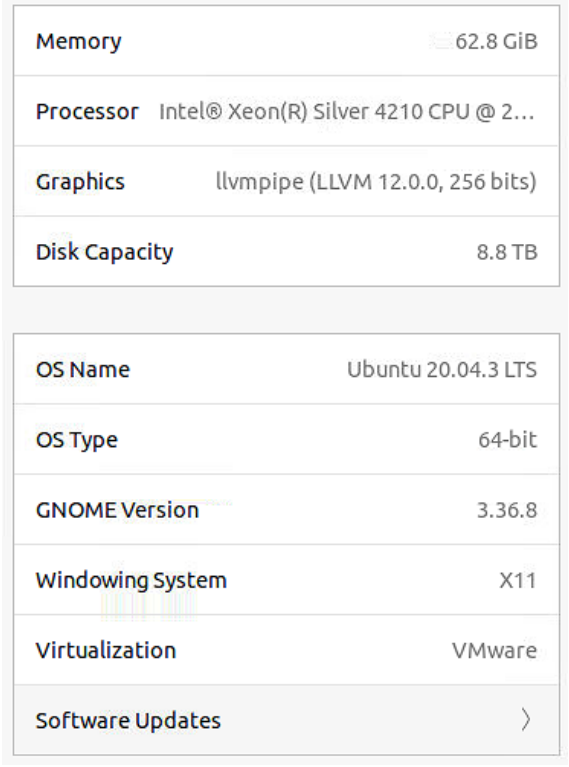

Figure 3. Snapshot of system configuration

5. EVALUATION APPROACH

The proposed model needs evaluation to find out the performance of the system. Throughput and latency are the key evaluation parameters when the system is relying on issuing and committing transactions. Thus, this work is evaluating system performance based on these two parameters. Such kind of evaluation need tools that are capable to inject bulk transactions on the network that too at different transaction rates. Hyperledger Caliper is one such tool that can be configured to put heavy transaction load on the network and in parallel can also compute throughput and latency.

In nutshell, it is a blockchain benchmarking tool that enables users to evaluate the effectiveness of a blockchain implementation using a number of predefined use cases. This evaluation approach is also depicted in the Figure 4. In this figure the system under test is Hyperledger fabric 2.3.

The caliper benchmark configurations specify which network to use and at what rate transactions should be infused.

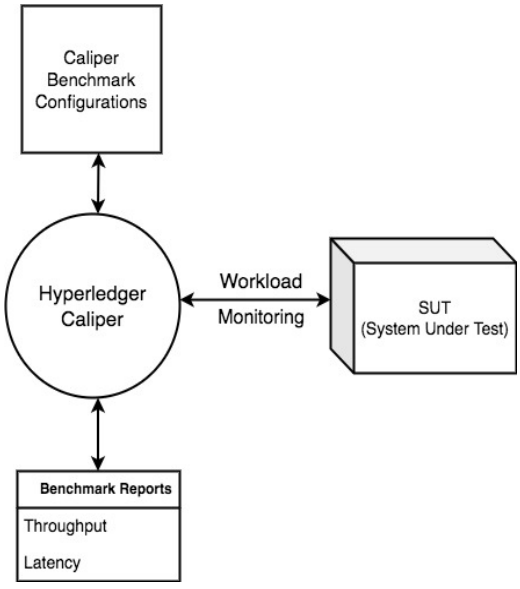

Figure 4. Evaluation approach using caliper

6. MODEL IMPLEMENTATION AND SIMULATED ENVIRONMENT

The proposed model was simulated using two organizations, two peers each organization, one common channel and an orderer organization. The complete scenario is depicted in the Figure 5. In this environment two different organizations having two peer each were created. These organizations can be assumed as academic institutions and peers as endorsers.

A single orderer was established to deliver the blocks to all organizations connected with a single common channel. An orderer is a fabric component that is responsible to make blocks and their broadcasting to peers.

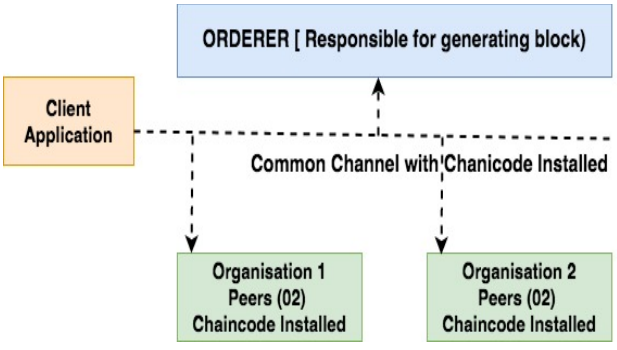

Figure 5. Simulated environment

A client application was developed in Node.js to initiate the transactions.

Node.js is a server-side JavaScript framework to handle request and response in both synchronous as well as in asynchronous mode. The chaincode also commonly known as smart contract was set up on channel as well as peers of organizations. Every peer will maintain an up-to-date copy of the ledger which is essential for a distributed environment.

Programmability is a key feature of blockchain networks and popularly known as smart contract capability. In Hyperledger fabric, this feature is known as chain-code. In general, chain-code deploys the business logic to attain the business purposes. Business logic contains data manipulation. The Data or inputs continuously comes from the outer world or from the current state kept in the ledger. Certain access control and constraints may be applied upon the data. The result is either returned to the chain-code requestor or stored in the ledger. This can be done by coding appropriate functions in a chain-code.

This chain-code holds code for storing and retrieving grievances written in Node.js programming language. A package file was first created from the chain-code source which was later installed on the channel and organizations. This package file is actually a linux zipped file made with the following peer life cycle command.

```
peer lifecycle chaincode package basic.tar.gz \
--path../asset-transfer-basic/chaincode-javascript \
--lang node \
 --label basic_1.0
```

Another important concept in fabric is deploying a channel. A channel provides a mechanism to group organizations having similar interests in a consortium based on business purposes. A channel may have one organization, all organizations, and may be some of them. The packaged chain-code (smart contract) is then installed on both the organizations one by one. It is also accomplished through the peer lifecycle command as illustrated below.

```
setGlobals 1/setGlobals 2
peer lifecycle chaincode install basic.tar.gz
```

In general, different channel may be deployed for a different application. The fabric was initially setup with two organizations and two peers only as illustrated in the Figure 6 and then setup with two organizations with four peers.

As far as the client application is concerned, the transaction could be read/write through node.js application. In this study, GUI enabled frontend was not designed. Only REST (Representational State Transfer) API (Application Programming Interface) was created to interact with the blockchain ledger.

7. RESULT ANALYSIS

The performance of the proposed model was tested in the Hyperledger Caliper which is a blockchain benchmark tool used to measure the performance [27]-[29]. It can be configured to generated heavy workload for the Fabric. Latency and throughput were used as a metrics to measure the performance.

The reason for implementing the proposed model on Hyperledger Fabric is its wider acceptance in the industry. In addition, it is presently being used in 400 proofs of concept and production applications. The experiment was conducted by creating two organizations having two peer each. This study first evaluated how the blockchain network will behave when transactions are infused at 100 TPS (transactions per second) and 200 TPS. The objective is to observe can the system accommodate the same TPS. The results are depicted in the Figure 6.

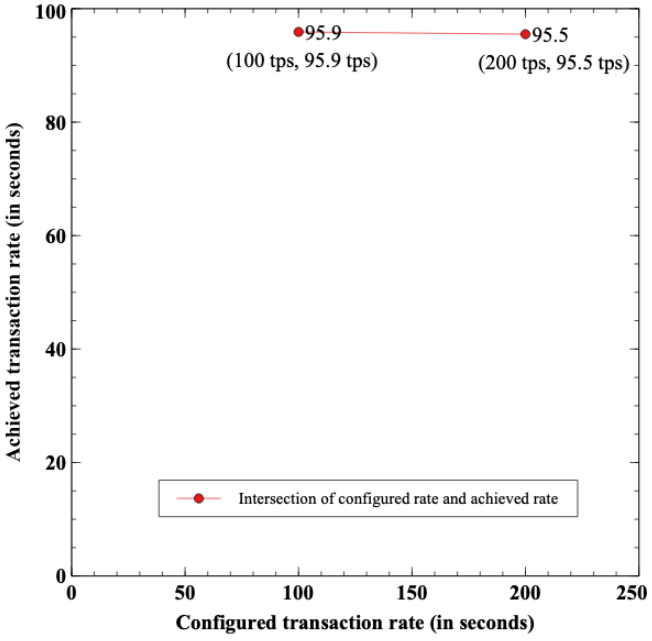

Figure 6. Configured rate and actual achieved rate

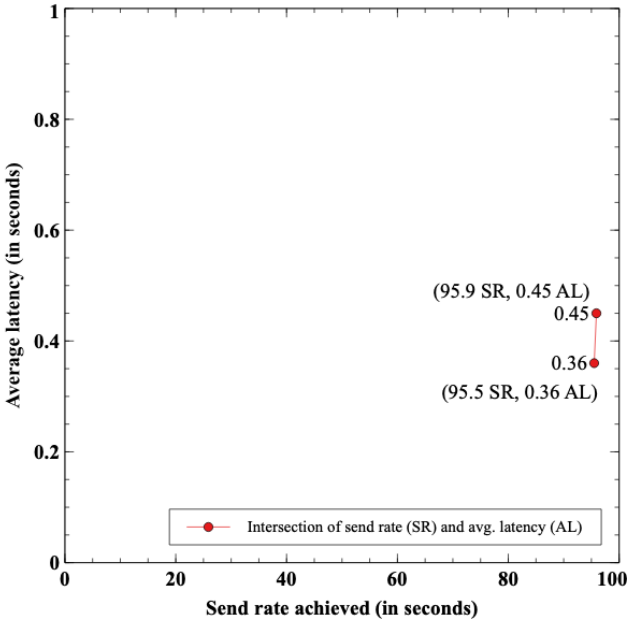

Figure 7. Transaction latency

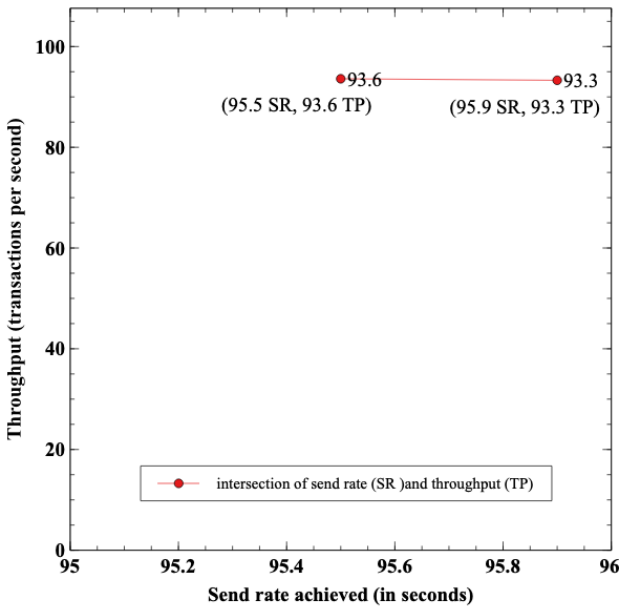

Figure 8. Transaction throughput

Figure 6 illustrates that during infusing transactions at 100 TPS and 200 TPS the achieved transaction rate was 95.9 and 95.5 TPS. It indicates that the blockchain scenario developed in this study could only accommodate transactions in the range between 95 to 96 TPS.

On further evaluation it is found that corresponding to achieved transaction rates the average latency was 0.45 seconds and 0.36 seconds. This is also depicted in the Figure 7. These latency values are very minimal and suitable for industrial applications.

This study also computed the overall throughput. Figure 8 illustrates that when transactions were infused at 95.5 and 95.9 TPS the achieved throughput was 93.6 and 93.3 TPS.

The caliper tool computes throughput of successfully committed transactions only. In both the cases, higher transaction rates have no inverse impact on latency as well as throughput. This study computes the results by assigning workload from caliper tool.

8. ARTIFICIAL INTELLIGENCE-BASED MODEL FOR GRIEVANCES SYSTEM

Registering complaints by students in a highly privacy protected environment and resolving issues timely by higher authorities makes the overall system efficient and effective. Sometimes it is also vital to observe the sentiments behind the complaint as well as finding patterns of way of resolving complaints by higher authorities through observing historical data of a particular higher authority. Artificial intelligence can play a vital role in resolving these two issues. The literature reviewed earlier in this article concludes that there is presently no artificial intelligence-based student grievance system that can observe sentiments and prioritize the cases.

By employing AI tools to analyze the sentiments expressed in student complaints, administrators can gain a deeper understanding of the emotional context conveyed in the grievances. Making use of this knowledge can assist in resolving challenges related to empathy and improving satisfaction. This can aid in prioritizing cases and suggesting suitable solutions. On the other hand, by observing patterns of resolving complaints by a particular higher authority, decisions regarding retaining or replacing higher authorities can be made. In this regard, this study is also proposing an artificial intelligence-based students grievance model converged with blockchain technology for better results. The proposed model is depicted in the Figure 9.

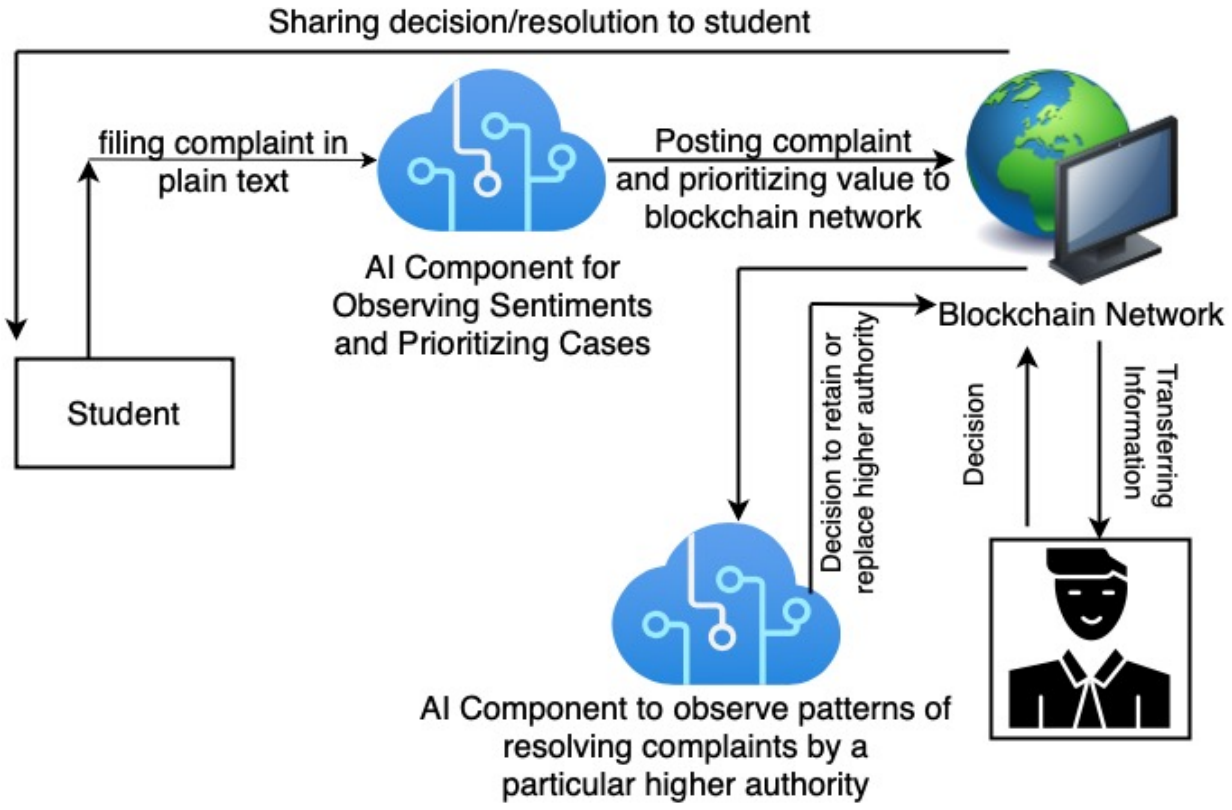

Figure 9. Proposed AI based model

The transaction flow of the proposed AI based model initiates when the user submits a transaction on the system. Initially transactions are in a plain text wherein user explains the grievance in detail. This transaction is then passed to the first AI component which is trained to analyze keywords within the plain text to observe the sentiments. Thereafter, based on the observations and intensity of sentiments a numeric value (1 to 5, where 1 refers to lowest priority and 5 refers to highest priority) is assigned to prioritize the cases. Then plain text along with a priority value is submitted to the blockchain network which then stores the complaints in an encrypted manner on a immutable blockchain ledger. In parallel, the same transaction is forwarded to the concerned higher authority.

Once higher authorities resolve the complaint, decision in the form of transaction is then submitted back to the blockchain ledger and blockchain network will automatically sends the acknowledgement to the complainant. The automatic acknowledgments work due to the smart contracts written on the blockchain network. Smart contracts are specialized code that executes automatically when certain programmed rules are met. The second AI component is trained to observe the history of any complaint resolver to find the patterns of resolving cases. This component also considers the complainant feedback to decide whether a particular complainant should still be retained or replaced with some other authority.

9. CONCLUSION AND FUTURE SCOPE

This study highlights the need for a viable solution that will allow students to share their issues and complaints without difficulty. One such promising solution is blockchain, which is safe, decentralized, unchangeable, auditable, and scalable. The Hyperledger fabric blockchain framework is employed in this study due to its effectiveness.

The experimental study was carried out by generating two organizations having two peers each. These organizations may be assumed as educational

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institutions and peers as students. These peers will act as a endorsers and initiate a transaction to register the complaints.

Two measures, latency and throughput, were used to test the proposed model. A total of 1000 transactions were injected into the Hyperledger network at different rates (in TPS) respectively in order to measure throughput and latency. This study demonstrates that the throughput is unaffected by the transaction rate. Moreover, adjustments in the transaction rates had no effect on latency either.

The capacity of a blockchain-based grievance system to provide privacy and immutability is one of its benefits. Future research could benefit from this study's explicit demonstration of how to create such systems. This study's only drawback is that it doesn't assess throughput and latency as organizations and peers multiply. This is referred to as scalability, and in future investigations, its impact must be calculated. In order to assess the effect of scalability on latency and throughput, this study suggests that the network be tested with many peers and more organizations.

In contrast to this blockchain based promising solution, the past studies were merely focusing on providing online solutions to register grievances. The outcome of this study suggests that immutable and privacy enabled ledger to support grievances are possible and needs to be deployed in educational institutions to avoid extortion, harassment, corruption and negligence.

This study has also proposed an AI based model for student grievances which can prioritize cases by observing the intensity of sentiments. This is merely a proposed model and has not been implemented but this will open doors for researchers to work in this direction as it is the need of the hour. This model also suggests that case histories of solved grievances must be evaluated timely along with student's feedback to that only deserving authorities can be retained and others can be replaced.

Another research area which is still to be explored is testing the Hyperledger network when transactions are coming from a remote location. It is crucial since, in a real situation as students might file complaints from anywhere. Scalability testing is also crucial as in a real scenario there can be huge number of peers (students) and multiple organizations. Such a complex network may impact overall performance. Moreover, such a real scenario would be more complicated and challenging as it requires real nodes and cloud services.

ACKNOWLEDGMENT

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