Decentralized Review System for Transparent and Accountable Governance

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1 OVERVIEW

Governance [14] refers to the systems, processes, and institutions through which a society makes and enforces its collective decisions. Good governance [20] is important for the proper functioning of a society and the well-being of its citizens. It ensures that power is exercised transparently, accountability is enforced, and the rule of law is upheld. Governance also plays a key role in addressing social and economic issues, such as poverty, inequality, and environmental degradation. Effective governance is essential for attracting investment, promoting economic growth, and improving the quality of life for all members of society.

This is the reason governance influences sustainability [15], for people are also important resources entailed by the environment. The United Nations defines [26] *Sustainability* as “meeting the needs of the present without compromising the ability of future generations to meet their own needs.” Since a nation’s governance clearly affects its current populations (children, youth, aged), development (economy, education, employment, innovation), environment, etc., which further carries forward to the nation's future, governance thus clearly impacts sustainability at large.

There are technologies that can be employed in governance processes and their delivery for improved adherence to the rule of law, transparency, accountability, participation, and responsiveness in the decision-making process [21]. Such technology-enabled governance is called *Digital governance* [23], [22]. A very earlier version of technology-based governance was called *E-governance* [23], which only made use of websites to present information to citizens and other stakeholders.

With full *Digital transformation of governance* [16], the services can be delivered with the highest quality with multi-channel two-way delivery-cum-interaction with citizens, and government-to-government information flows and the subsequent decision-making as well. This lets recipients make informed decisions about choices and give their feedback [22], which contributes to improving the governance and its quality of delivery. However, the majority of existing digital governance platforms are centralized i.e. owned and/or maintained by the government itself.

Though the digital transformation of governance is essential, unavoidable, and promising, there are certain concerns with automation and autonomy. Most, if not all, of the digital transformation technologies are connected via the internet, and most are centralized i.e. owned by a single entity. Such centralized solutions suffer from a single point of compromise and failure due to both *cybersecurity-risks* and *bad-governance*, which account for a loss of 6% [24], [25], [2] of the total worldwide GDP amounting to a whopping total of US$ 7 Trillion. For these reasons, there is a need for a trust and accountability technology layer in the Digital governance systems that are immune to both single-point-of-failure cybersecurity issues and tampering from government authorities.

Several reports published by major international and national, intergovernmental and non-governmental, financial, universities [37] and think tank agencies such as United Nations (UN) [40], [35], World Bank (WB) [38], International Monetary Fund (IMF) [34], Africa Development Bank (ADB) [43], Transparency International [39], World Economic Forum (WEF) [41, 42, 36], etc. opine that ICT technologies can control corruption by making it hard to be committed. Often, the most important module in these ICT technologies in Digital governance is one that ensures transparency and accountability [44], [45].

The emergent *Blockchain* technology is being seen as the candidate technology for implementing the trust and accountability module across a range of applications and domains [31], [30], [32], [33]. Blockchain, being decentralized and distributed, is both immune to *single-point-of-failure* cyber-attacks [29] and is robust against cyber-attacks common with traditional centralized systems. Furthermore, because of the hashing-based chaining of blocks in the blockchain, tampering attempts are curtailed altogether.

Different countries have different governance organizations. The stakeholders in a government include citizens, executives and bureaucrats, taxing agencies, international organizations, political parties, the judicial system, and derived and related offices for the smooth functioning of administration and delivery of governance to citizens. From the perspective of corruption, stakeholders can be placed under two categories: governance deliverers and beneficiaries. Corruption [46] essentially involves the abuse of governing power to deprive the beneficiaries of their rightful resources allocated to them, including the services to be delivered to them. Annually 5% of global GDP is lost due to corruption [25], [50]. There are several interventions to curb corruption. One popular intervention [47], [51] is through “Community monitoring of governments in power,” which also includes “reviewing and complaints by citizens.”

The Digital governance systems do have modules that are specifically meant for accepting reviews (including complaints, appreciations, and suggestions) from beneficiaries, both collectively from communities and individually from citizens. However, most, if not all, of those implementations follow a centralized approach, which makes them susceptible to problems that nullify the very purpose of collecting feedback and complaints.

In this paper, we present a *blockchain-based review system* for the digital transformation of governance to improve the quality and efficacy of governance by engaging citizens and considering citizens’ satisfaction. Such a review system is key to realizing *impactful and sustainable governance*. It is worth noting that this decentralized-review system, which we report on in this paper, directly contributes towards the *Sustainable Development Goal* (SDG) *16* (SDG#16) of “Peace, Justice and Strong institutions.” [27].

A review system is an essential component of good governance because it helps to ensure that the government is accountable and responsive to the needs and concerns of citizens. By review system, we mean a process or tool that allows people to provide feedback on products, services, or other types of content. This feedback is usually in the form of a rating or review, where individuals share their experiences and opinions about a particular item or experience. It allows for ongoing evaluation and feedback on the performance of government agencies and programs and helps to identify areas of strength and areas for improvement.

A review system can also serve as a mechanism for holding government officials accountable for their actions and decisions by establishing clear criteria for evaluating performance and imposing consequences for non-compliance. This can build trust and confidence in citizens about the government and encourage more effective and efficient decision-making. Additionally, a review system can help to identify and address any issues or problems that may arise in the governance process and provide a forum for addressing the concerns and grievances of citizens. Overall, a robust review system can ensure that governance is responsive, transparent, accountable, and aligned with citizens' needs and priorities.

1.1 PURPOSE

In digitally transformed governance, there will be both humans and autonomous technology on the provider side of governance that process-enable-deliver services to the receivers. The decisions in processing a request might involve humans and/or autonomous digital agents. Once such governance is in place, the reviews from people, who benefit from the governance services, will improve the quality of services. Currently, there are governance systems in the shape of a web portal that includes a public review system, but all these implementations are based on centralized technologies. Such centralized systems let administrators tamper with the feedback and let them post dubious review comments.

An example of this is a *complaints channel*, but again, such a *complaint system* still is controlled by a central authority. What if this central authority itself is compromised or corrupt? In such cases, the complaints may never produce the intended effect. In this paper, we present a complete end-to-end *decentralized review system* based on blockchain technology to overcome the shortcomings of the existing centralized review systems, where a single entity controls all the reviews creating distrust in the review system. Such a blockchain-based system can at least preserve and hopefully improve the quality of governance and ensure that governance is responsive, transparent, and accountable.

1.2 SCOPE

In this document, we present how we systematically engineer blockchain technology together with encryption resulting in an accountable-transparent-trusted review system that is independent of owners/providers of the businesses that deliver such services/goods. To implement this *Decentralized Review System*, the Solana Blockchain and IPFS are utilized. Essentially, we typecast a review as a transaction, which is stored on this high-performance Solana blockchain platform. Since at times, reviews might be very large, IPFS protocol is used for storing such reviews, and on Solana, we store the references to those bulky parts of the reviews. Furthermore, our implementation also makes the reviewer accountable through a specific authentication. As the reviews are hosted on blockchain, the governance providers cannot tamper with or censor the reviews. The developed solution accommodates simple text, image, audio, and/or video-based reviews. This overall solution can be integrated into any kind of governance workflow involving interactions between citizens and government offices/officers.

As of current implementation, we are based on Solana, which is a *Public-Open blockchain platform* [53] together with the IPFS distributed decentralized filesystem. This version of our solution is only Proof of concept purposes. Our grandeur view is that eventually every nation, to benefit from the blockchain-based digital transformation, would have a dedicated distributed decentralized blockchain fabric for accountability and transparency purposes.

Such fabric could be managed by a neutral international or ombudsman-like regional agency following guidelines of non-governmental and/or international governmental organizations such as Transparency International, United Nations, World Economic Forum, World Bank, etc. In 2019, IMF and WB have launched their blockchain [48] towards their "Learning Coin" educational tokens. There are similar efforts [49] underway at the United Nations as well on their *SDGs for 2030* agenda.

1.3 STRUCTURE

This document is organized as follows:

- Chapter 2 – Motivation
- Chapter 3 – Decentralized Technologies
- Chapter 4 – System Architecture and Design
- Chapter 5 – Implementation
- Chapter 6 – Conclusion
- Chapter 7 – References

1.4 AUDIENCE

A review system should ideally be reliable, the reviews posted should not be expected to be altered, and the reviews' integrity should be guaranteed. However, the trust element is absent in centralized implementations. Decentralization increases confidence in the review process and contributes to introducing openness in governance.

As this paper summarizes the implementation of review systems with decentralized distributed blockchain technology, we consider the following as the target audience: Policy makers, international governmental agencies in United Nations, non-governmental international agencies such as Transparency International, international financial institutions such as World Bank, governance-related technology designers, researchers working in digital transformation, technologists involved in implementing accountability frameworks and the general public who evaluate the services offered by the government as stakeholders in a review system in the governance domain.

1.5 USE

The audience can use this document to learn how we introduce decentralization into review systems by utilizing technologies like blockchain and IPFS. We give a systematic motivation for blockchain based digital transformation. It will clarify how reviews in a decentralized review system are impervious to manipulation and why it is open, responsible, and reliable.

2 MOTIVATION

The success of any government relies on the ability to build trust among its citizens. Reviews are crucial in creating a sense of being heard among citizens. Reviews can help the government understand the needs of its citizens and improve its services accordingly. However, simply having a review system is not enough if citizens do not trust the system's integrity. Therefore, the objective is to build a review system that everyone can trust and cannot be tampered with, even by its maintainers. A decentralized system whose properties match these requirements will be perfect for our needs.

2.1 CHALLENGES AND LIMITATIONS OF TRADITIONAL REVIEW SYSTEMS

For a very long time, centralized review systems (CRS) have been the norm in most sectors and areas [1], both in private and government sectors. Reviews have a long-lasting effect on businesses affecting their sales, customer loyalty, reputation, etc. There are confirmed instances of several agencies brushing, censoring, tampering, and inflating reviews to derive business benefits across a range of industries. [2] presents insight into inflated reviews in the hotel industry; a similar incident of the review company Yelp is reported in [3]. Many such incidents have been reported about AirBnB [4], [5], Amazon [6], Alibaba [7], [8], etc. owners have been abusing the review system in a myriad of ways.

Because of the centralized nature of CRS, as detailed above, the reviews have become less trustworthy, transparent, and accountable. The motivation to tamper can have a similar negative impact if CRS continues to be used in governmental agencies. Traditional review systems can be subject to political influence, undermining their effectiveness and impartiality. Political influence can take many forms, such as pressurizing to downplay or ignore negative findings. Besides these shortfalls, centralized review systems are vulnerable to security flaws, wherein hostile actors might falsify reviews or steal confidential data, endangering the safety and security of users.

2.2 ENHANCING TRUST AND VERIFIABILITY IN REVIEW SYSTEMS

The shortcomings of a centralized review system come from its single point of failure and/or compromise nature. Reviews are stored under a single entity, making verifying their authenticity difficult in case of distrust. To overcome this problem, a decentralized solution can be adopted. Storing multiple copies of reviews across the network eliminates the single point of failure. Since the reviews are maintained by a disjoint authority, the motivations for tampering are ruled out.

Going forward, once Web3 becomes a reality, there would be a new standard of CSS, which would mandate NOT hosting of reviews by the buyer/provider-controlled websites. Such websites would strictly be pulling the reviews hosted on a decentralized review system (DRS). The solution we have developed is a DRS to realize this grander future.

We characterize a review as a transaction and store that review as a transaction on the blockchain. Every review is assigned a unique identifier and timestamp, which can be used to verify its authenticity. The translation details can also be made to include geo-tags.

A decentralized review system also provides other benefits. For example, it can be designed to be transparent, where all reviews are publicly visible, allowing citizens to view each other's feedback and a generic assessment of the governance office they are going to visit. Additionally, it can be designed to be anonymous, where citizens can provide feedback without revealing their identities, enabling them to provide honest and unbiased feedback.

However, storing large amounts of data on the blockchain can be impractical and expensive. This is where IPFS comes in. IPFS is a decentralized storage protocol that stores multiple copies of any data in the network worldwide. This means that reviews that are bulky can be split into lean and heavy parts and that heavy portion is stored on this IPFS network, eliminating the single point of failure. Using IPFS to store reviews and the blockchain to establish trust and verifiability can provide a comprehensive solution to the issues faced by centralized review systems.

3 DECENTRALIZED TECHNOLOGIES

We used Solana *Blockchain* and *IPFS* to implement the Decentralized Review System. IPFS protocol stores the multimedia part of the review, while the translation recorded on the Solana holds a reference to that portion on the IPFS. The workings of Solana and IPFS are discussed below in detail.

3.1 BLOCKCHAIN-*SOLANA*

Blockchain [17] is an emerging technology with many applications and use cases. It is a distributed and immutable ledger that is shared among all the nodes in the Blockchain network. The earliest work on Blockchain goes back to the 1980s by David Chaum [18]. Unlike a traditional database that supports *Create, Read, Update, and Delete record operations*, Blockchain only allows Create and Read record operations. To compensate for the Update and Delete operations, Blockchain supports consensus-based transactions, which can introduce corrections onto the previously committed transactions through new transactions with reference to the transactions being overwritten or deleted.

All transactions, after authorization, get stored by grouping into blocks and forming a chain of those blocks. Each time the network gets a new group of data, which is a collection of transactions, it creates a new block and adds it to the existing chain. A blockchain's power lies in the protocol used in deciding the next block and the non-feasibility of changing any block in the chain. Most Blockchain platforms in operation today have the functionality to implement business logic which gives the facility to perform transactions necessary for the applications automatically by writing a piece of code and deploying it once. This piece of code is called *Smart Contract* [9]. In essence, these smart contracts are the piece of code that runs simultaneously on the blockchain network to implement business logic. Blockchain technology together with Smart contracts leads to a class of applications often referred to as Decentralized Applications or *Dapps* in short.

Solana [10] is one of the widespread public high-performance blockchain platforms. It is well known for having a high transaction rate compared to other blockchain platforms. As for current hardware capabilities, Solana can accomplish 710,000 transactions per second. Solana handles business logic in the form of On-Chain programs. Developers deploy these On-Chain Programs for a particular application. An app interacts with the Solana Blockchain by sending one or more instructions. *Sealevel*, Solana's parallel runtime, can process transactions in parallel because Solana transactions describe all the states a transaction will read or write while executing. The runtime not only allows for non-overlapping transactions to run concurrently but also for transactions that are only reading the same state to execute concurrently as well.

Solana's consensus mechanism is based on a combination of Proof of History (PoH) and Proof of Stake (PoS) algorithms. PoH is a unique technology developed by Solana that enables the network to maintain a decentralized and trustless record of time. It ensures that uniform timestamps are maintained on transactions all over the network, making it easier to order transactions among validators in the exact temporal order of occurrence. This makes Solana's consensus mechanism faster and more efficient than other blockchain networks. In addition, the PoS algorithm used by Solana benefits from the correct timestamping of transactions provided by PoH. It eliminates the need for communication between nodes on the correctness of time consensus, which further speeds up the validation process and reduces energy consumption, making it more eco-friendly.

In a traditional Proof of Work (PoW) blockchain like Bitcoin, miners compete to solve complex mathematical problems, which requires a lot of computational power and energy consumption. However, in Solana's PoH algorithm, the focus is on timestamping transactions, which requires significantly less computational power and energy consumption than PoW. Furthermore, since PoH enables validators to reach consensus on the order of transactions without the need for frequent communication, the network is less prone to network congestion, which can further reduce energy consumption.

Overall, Solana's consensus mechanism is designed to be fast, secure, and energy-efficient [52], making it one of the most promising blockchain platforms for building decentralized applications.

3.1.1 PROGRAM DERIVED ADDRESSES

In Solana Network, data stored is maintained with accounts [11]. Typically, accounts need two sets of keys, a *private key* and a *public key*, to sign the transactions. Maintaining these keys is a cumbersome task and poses a security risk in case of a private key leak.

Solana provides an easy way to solve these problems in the form of *Program Derived Addresses* (PDAs) [12]. PDAs are designed to be controlled by a specific On-Chain Program. With PDAs, programs can programmatically sign for some addresses without needing a private key. With PDAs, we can ensure that no external user can generate a valid signature for the same account.

PDAs are generated from a combination of seeds and a program id. The seeds and program id are run through a sha256 hash function to find a valid PDA. We will find a number or bump in the range of 255 to 0 to use with the seeds and program id to generate a valid PDA, which is not a possible address of a typical account. With the same set of seeds and the bump, we can generate the same PDA, thus giving us access to desired account data.

3.2 INTER PLANETARY FILE SYSTEM (IPFS)

One of the requirements for storing our reviews is that they should be stored in a decentralized way so that manipulating them will be difficult. IPFS provides one such environment. The InterPlanetary File System (IPFS) [13] is a peer-to-peer (p2p) storage network. It is a distributed system for storing and accessing files with peers worldwide. Instead of the traditional way where the storage location identifies the data, IPFS identifies the data by its content, known as content addressing. Content addressing has two main benefits; firstly, we can fetch the data from any peer who stored it in the network as it uses content addressing; and secondly, if anyone manipulates the content of the file, then its identification changes, and it will be identified as a different file, which provides us with a necessary functionality, verifiability.

IPFS uses Merkle Directed Acyclic Graphs (DAGs) [19], where each node has a unique identifier, the hash of the node's contents. To build a Merkle DAG, IPFS splits the content into multiple blocks and stores them in the form of Merkel DAGs, meaning different parts of the file can come from various sources and be authenticated quickly. IPFS uses the SHA-256 hashing algorithm to generate the file's content addresses or CIDs.

Since IPFS uses CIDs instead of HTTP links, some browsers may not support IPFS natively. Gateways can facilitate the access of IPFS files with HTTP links.

4 SYSTEM ARCHITECTURE AND DESIGN

This chapter discusses the architecture and design of the system. First, we will discuss a high-level overview of the components of our system. Then, we will discuss the design of the blockchain-based decentralized application.

4.1 SYSTEM OVERVIEW: A CLASS DIAGRAM

The system's main functionalities are that a user: (i) should be able to add a review for an organization, and (ii) view other users' past reviews about the organization. Here, by organization we mean a *governance node* could be the *main office* or a *branch office*, where citizens visit to get access to government services.

Besides the above two main functionalities, there are other (trivial) functionalities like: enrolling an organization onto our decentralized review system, adding a new user, handling user authentication during login and other needs. The figures in this section will give the basic structure and flow of the system in providing those functionalities.

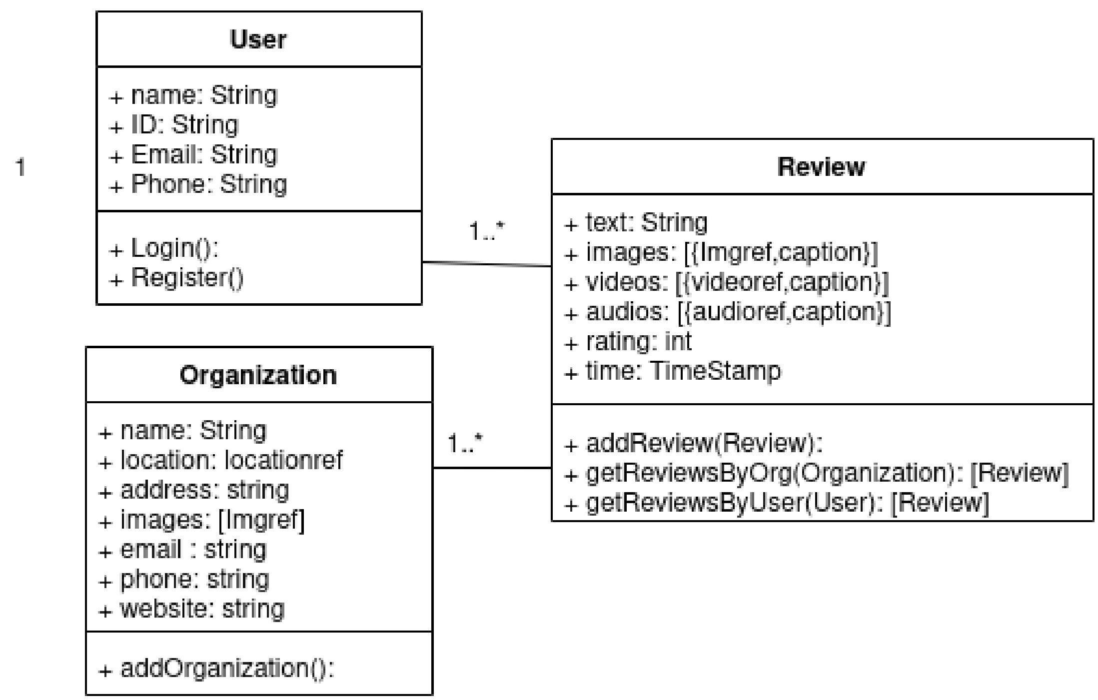

Figure 4-1: Class diagram.

The class diagram in Figure 4-1 shows the main elements in the system, their attributes, and the high-level methods implemented in the system. It includes User, Organization, and Review. The constraints on these elements are that a user can write multiple reviews, each organization can have multiple reviews, and each review is associated with a user and a single organization. As of now we implemented on a single blockchain platform, however, if, for whatever may be the concerns, the organization has a mandate to go in for a separate blockchain, then this can also be done. With organization naming space masking, in our current implementation, we can have multiple reviews from users about various services/products from different organizations.

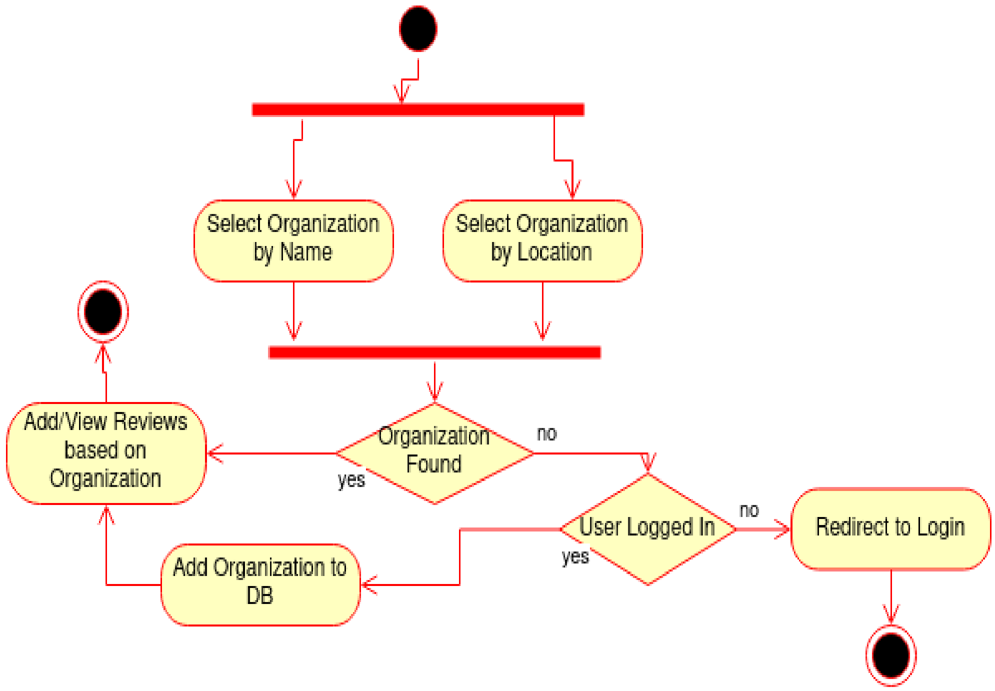

Figure 4-2: Searching and selecting an organization.

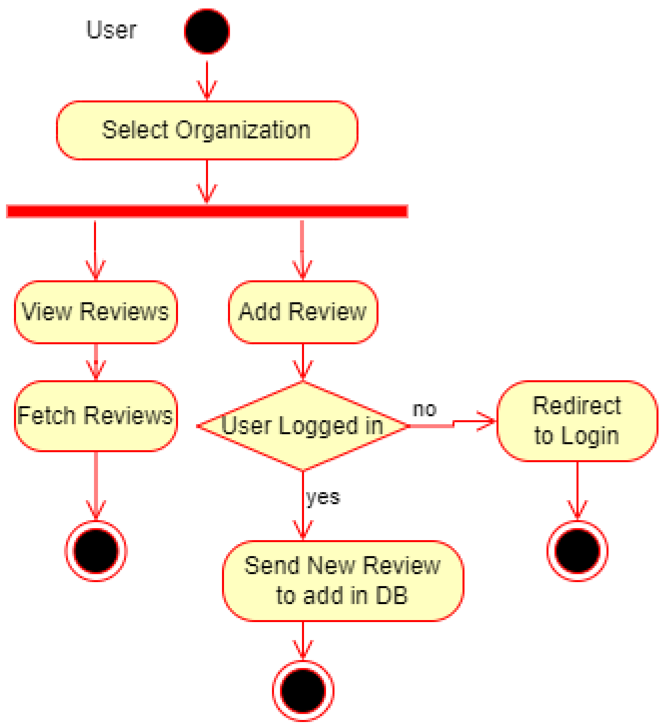

Figure 4-3: Fetching and adding reviews.

The above two figures show a more detailed view of the application's working. Figure 4-2 is the activity diagram which includes the work of searching and selecting an organization, and Figure 4-3 shows the activity diagram for adding and reading reviews. A user trying to search and view the reviews of an existing organization in the database can do so without the need for authentication. If the user wants to add a review or an organization, then the user must be authenticated to perform those actions. As shown in Figure 4-3, the user posting a review shall first select the organization and then go ahead with specific review details.

4.2 Decentralized Design

While the client-side experience of our decentralized review system may appear similar to traditional, centralized review systems, the underlying architecture marks a significant departure from the status quo. The critical difference is in the storage and retrieval of review data, which is securely stored on the blockchain rather than in a centralized database. Despite this significant divergence, the overall design of our decentralized review system remains intuitive and user-friendly, ensuring a seamless transition for users from traditional review systems to the decentralized paradigm.

This means any organization can enable this type of review system and import the reviews (with no filtering) on their portal with a simple plugin written as a Java-applet integrated into the base CSS of the portal. The same can be achieved with HTML5 as well. However, it shall be noted here that the organization cannot filter away and/or morph any of the results because the reviews are imported into this standalone plugin within the webpage. This could be a dedicated extension for this specific review purpose. The idea here is that the applet or feed widget is the one that fetches the reviews from the blockchain. To improve confidence, we can incorporate dynamic certificate-based continuous validation integrated into the banner of this applet.

We can use the Account Model and Solana's programming model to store the review data. Our design includes four types of accounts: *User Account*, *Review Account*, *Organization Account*, and *User Review Account*. A single On-Chain Program, which exists as a stateless account on Solana, is used to create, read, and write to the accounts based on a set of instructions. The detailed implementation and the efficiency of this account structure are discussed in the next section.

4.3 Review Multimedia Storage

While our decentralized review system stores review data securely on the blockchain, the challenge of storing multimedia attachments presents a significant hurdle. Due to the limited capacity of the blockchain, which constrains the data-size of reviews, storing large multimedia files is both impractical and expensive. Furthermore, retrieving such files is also problematic, requiring multiple reads to fetch a single file.

To overcome these limitations, we have implemented a solution that leverages a decentralized storage network, IPFS, which is also a blockchain-enabled technology. Designed specifically for decentralized file storage, IPFS allows us to store multimedia files outside of the blockchain while still ensuring their integrity and trustworthiness. By storing file data in IPFS and storing only references or addresses in the blockchain, we can maintain the security and immutability of our review system without incurring the high costs and technical challenges of storing multimedia on the blockchain.

5 Implementation

This chapter provides a detailed account of our system's basic implementation. While the current iteration of our system offers robust functionality, we recognize that additional features may be required to meet specific organizational needs. Our implementation is designed to be easily extensible, allowing for the seamless integration of additional functionality.

Central to our implementation is the storage and retrieval of reviews, as well as their linking to the appropriate organization. We have developed a comprehensive approach to review storage and retrieval, leveraging blockchain technology to ensure the security and immutability of our system. By focusing on these core components, we have created a solid foundation upon which additional features and functionality can be added as required.

5.1 Storing and Reading Data on Solana

5.1.1 Adding Data

Chapter 4 highlighted how Solana's On-Chain Program is utilized to create accounts and store data within them. This program consists of three core methods: creating an organization, creating a user, and creating a review. One of the key benefits of utilizing the On-Chain Program is that once it is deployed on the chain, it cannot be modified. This ensures that the system remains secure and transparent and eliminates any possibility of unauthorized modifications, such as adding methods to update or delete reviews. By leveraging the immutability of the On-Chain Program, we have created a robust and trustworthy review system that can be relied upon to maintain the integrity and transparency of the review process.

5.1.2 Reading Data

Solana's unique architecture allows anyone to read data from accounts on the chain simply by providing the account address, this is in the context of blockchain configured as public-open type. However, storing the address of every review can quickly become inefficient and result in significant overhead. To overcome this challenge, we have implemented a solution that leverages Solana's Program Derived Addresses (PDAs).

For each review, *the user* - who is posting the review, and the *organization* - about which the review is being posted, our system generates a PDA that can be reproduced by the on-chain program using a set of seeds unique to that entity. This approach ensures that we can efficiently store and retrieve data without incurring unnecessary overhead or compromising the system's security. By utilizing PDAs, we have created a scalable and efficient review system that can be trusted to maintain the integrity and immutability of all review data.

5.1.3 Accounts

In Section 4.2, we provided a brief overview of the account structure used in our implementation. In this section, we will delve into the details of the implementation.

The account structure we are using is illustrated in Figure 5-1. It consists of four types of accounts: User Account, Organization Account, Review Account, and User Review Account.

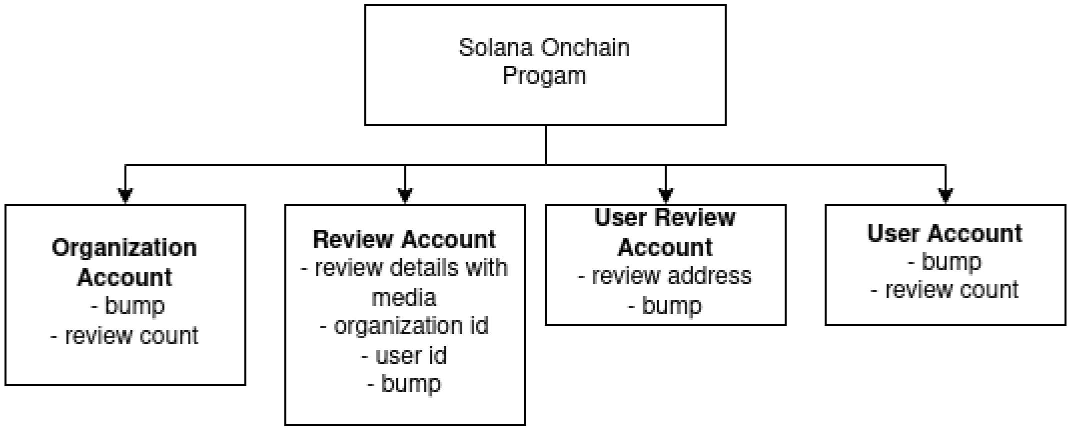

Figure 5-1: Solana account types reproduced from [11].

5.1.3.1 User Account

The user account within our review system is designed to store all relevant details pertaining to the user. In addition to basic user information, we also store a count of the total number of reviews submitted by that user. This information is particularly useful when fetching all reviews submitted by a particular user. We want to have genuine reviews and for this purpose we allocate a unique user-id per user. Thus we will have a separate review posting account associate with every user registered without system. Each user can either configure to show his ID as anonymous for the account or *per-posted-review* basis. On every review-post submission, if the account is configured for showing the user-id along with the review, the system would ask if the user would like to have the user-id invisible/anonymous. This provides a finer control at the granularity of per post basis.

To efficiently store and retrieve this data, our On-Chain Program utilizes a unique identifier provided by our system as a seed to derive a Program Derived Address (PDA) for each user. This approach ensures that we can easily and efficiently access all user data when needed without incurring unnecessary overhead or compromising the system's security.

5.1.3.2 Organization Account

Within our decentralized review system, organization accounts are designed to store all relevant details related to a specific organization. In addition to basic organizational information, we also store a count of the total number of reviews associated with that organization. This information is particularly useful when fetching all reviews of a particular organization.

To efficiently store and retrieve this data, our On Chain Program utilizes a unique identifier provided by our system as a seed to derive a Program Derived Address (PDA) for each organization. This approach ensures that we can easily and efficiently access all organizational data when needed without incurring unnecessary overhead or compromising the system's security.

5.1.3.3 REVIEW ACCOUNT

Within our decentralized review system, the Review account stores all relevant information related to a specific review. This includes all review details, as well as the IPFS addresses of any associated multimedia. This review might include text and multimedia such as audio, video and/or images.

To efficiently manage the storage and retrieval of review data, our On Chain Program utilizes a combination of organization PDAs and review counts as seeds to derive a Program Derived Address (PDA) for each review. When we want to fetch all reviews associated with a specific organization, we simply use the organization's PDA and iterate from 0 to review count-1, using each value to fetch the corresponding review. This approach allows us to easily and efficiently access all reviews of a particular organization.

However, fetching user reviews presents a unique challenge, as review PDAs can only be derived from organization IDs. To address this challenge, we created a separate account specifically for user reviews. We will discuss this in more detail next.

5.1.3.4 USER REVIEW ACCOUNT

A user review account serves as a bridge between the user account and the corresponding review account. It stores the PDA of the corresponding review account. The On Chain Program utilizes the unique identifier of the user who wrote the review and the review count of the user as seeds to derive the user review Program Derived Address (PDA). When we want to access all the reviews of a user account, we use its PDA to iterate from *0* to (*review_count* - 1), obtaining the user review PDA at each iteration. Subsequently, we read the corresponding user review account to obtain the PDA of the associated review account. From the review account, we can retrieve all the review details. By this means, we can easily access all the reviews of a user.

The review count of the user is incremented every time a new review is added by him/her, ensuring that the new review is included in the set of user reviews.

5.2 ADDING AND STORING REVIEWS

When a user requests to add a review, we first upload the multimedia to IPFS, which returns the content identifiers (CIDs). Next, the Onchain Program is invoked. The Onchain program utilizes the user's and organization's identifiers, along with the review data and corresponding CIDs of the multimedia attachments stored on IPFS, to store the review as a transaction on the blockchain.

Figure 5-2 is the activity diagram depicting how the review account is added to the Blockchain.

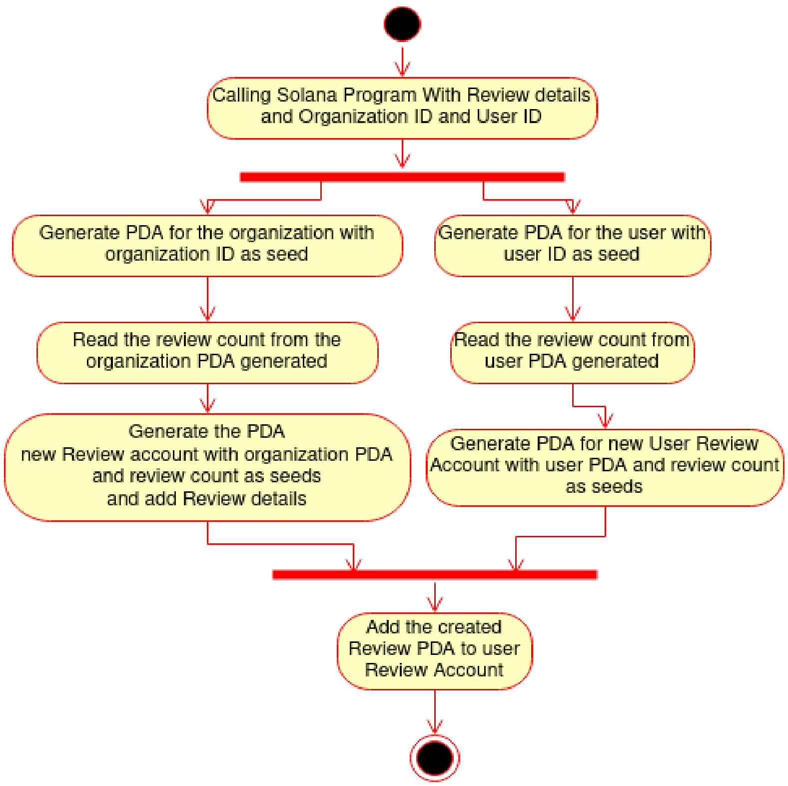

Figure 5-2: Adding review to blockchain.

5.3 Fetching Reviews

To fetch reviews for a specific organization or user, we first derive the corresponding PDA using their unique identifier. Next, we read the review count stored in their account. We then derive review PDAs using the organization/user PDA and review count as seeds and retrieve all the reviews by reading the corresponding review accounts.

All review data stored on the blockchain includes IPFS CIDs. The front-end uses these CIDs to load the multimedia from IPFS for display.

6 Conclusion and Further Scope

We have presented our work on developing a review-system that can significantly improve how a government works, but it must be trustworthy for citizens to accept it. Our research has shown that a decentralized review system can provide many benefits over traditional centralized systems, for that blockchain technology ensures that reviews are immutable and tamper-proof. This provides a higher degree of trust for both consumers and organizations.

However, while the core of the system must be designed carefully to ensure it cannot be modified at a later stage, there are many ways we can improve the system by adding customized features. For example, user authentication and verification can be added using government-issued identity cards to prevent fake reviews. Additionally, restricting the number of reviews posted per user for an organization in a given period can help prevent spam. Machine learning algorithms can be used as part of smart contracts to identify and flag fake reviews, if any, thereby improving the authenticity of the reviews on the platform.

There is a delicate balance between providing anonymity and preventing fake reviews. As such, we must prioritize our objectives and design our system without compromising its core values. Ultimately, the success of a decentralized review system will depend on its ability to provide a high degree of trust, transparency, and accountability, and we are excited to see how this technology can continue to evolve in the future. Our current implementation is of Public-open style, but it can be configured to any of the other three blockchain configurations.

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