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In a world where sustainable and collaborative behavior is increasingly important due to climate change, environmental concerns, and social engagement, individual willpower may not be enough to sustain positive behavior for long-term sustainability. To encourage collaborative behavior, many blockchain-based applications are emerging that provide an incentive in the form of fungible tokens, non-fungible tokens (NFTs), or reputation points. Existing services address specific solutions such as waste disposal, peer-to-peer energy management, and sustainable mobility. However, the tokens issued by these services generally can be used only by the services themselves and are not interchangeable with other tokens. This paper proposes a platform that aggregates different blockchain-based services, and that exploits a conversion mechanism enabling the user to convert a given service token with other service tokens. The conversion is not based on a monetary value, rather, it relies on the amount of saved CO2 a service token represents. The platform provides a token (the "sCO2" token) anchored to a fixed amount of saved CO2, that may be converted for token of other services or used to get a discount on various municipal services such as waste tax, parking, public transport, etc. The proposed system aims to increase the engagement and awareness among citizens and end-users, provide an accountable and transparent way to track people's sustainable behavior, and issue certificates to organizations based on how much CO2 their services have helped save.

CCS Concepts: • **General and reference** → General conference proceedings; • **Computer systems organization** → *Distributed architectures*; • **Software and its engineering** → **Software design engineering**.

Additional Key Words and Phrases: blockchain, smart contracts, collaborative behavior, common good, social reputation

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1 INTRODUCTION

In 2015, the United Nations developed the Sustainable Development Goals (SDGs) framework [1] to promote prosperity and peace for the planet and its population. The SDGs are organized into 17 goals that emphasize ending poverty, achieving sustainable economic growth, improving health and education, and taking concrete action to mitigate climate change and protect the environment, among other goals. Governments and private companies are encouraged to register their initiatives and policies that contribute to accelerating one or more SDGs. In this scenario, new technologies play a key role in the process of accelerating the achievement of the SDGs. Among new technologies, blockchain is one of the most remarkable innovations of the twenty-first century. It enables the recording of transactions and data in a ledger, which is shared and distributed using a peer-to-peer network architecture. The most successful use of blockchain technology is the autonomous execution of programmable pieces of code that perform some actions and record variables

[1] https://www.un.org/sustainabledevelopment/

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and results on the distributed ledger – the so-called smart contracts (SC). The network can benefit from these programs because their code is publicly available so any peer in the network can inspect it, and the source code of smart contracts cannot be changed since the blockchain is immutable. Blockchain and smart contracts can help companies reduce the cost of data storage activities and develop sustainable activities and businesses using incentives through gamification techniques. In addition, blockchain can provide tamper-proof data that companies and governments are committed to achieving sustainable goals, as anyone on the network can autonomously verify the stored data.

Although blockchain is notoriously not the most environmentally friendly technology, it can still be convenient for a company to rely on blockchain rather than on a centralized database. In general, despite the relatively high energy consumption, blockchain technology can be a valid choice for a company that does not want to rely on third-party services and wants to grant transparency and tamper-proof properties, allowing users to participate in the service governance. Furthermore, the change in the consensus algorithm some blockchains are undergoing (i.e., from proof-of-work to proof-of-stake) can reduce energy consumption by about 98%.

In this paper, we focus on solutions that use blockchain to promote sustainable behaviors and actions that provide a reward in the form of token incentives or reputation scores. We reviewed the literature to identify relevant blockchain-based projects, services, and proposals in waste management, energy, and transportation that encourage sustainable behaviors for businesses and individuals. We propose an architecture to aggregate such services and projects at the municipal level, allowing users and organizations to demonstrate their commitment to the SDGs.

The benefit of such a platform is that it does not impose restrictions on service providers' business models. In this way, each service provider is free to implement its own business solution, in its smart contracts, and still be able to use the proposed platform as long as the service provider's business logic is based on token release. Hence, ideally, the platform will manage through a few smart contracts the service provider's token (which are managed by the smart contracts developed and deployed by the service provider). Specifically, the proposed platform allows the authentication of users in a privacy-preserving manner and the conversion of tokens obtained from services registered on the platform through a proprietary token. Once the user deposits on the platform the tokens he/she wants to convert (received as a reward for using other services), the platform releases an equivalent amount in the form of "sCO2" tokens (a token used to convert each service's token into saved CO2 equivalents). The platform tokens can be accumulated to obtain non-fungible token (NFT) badges, which certify that the user has achieved pre-defined goals (i.e., net carbon neutrality or a specific amount of CO2 saved). The sCO2 platform token can be converted into other tokens provided by registered services to use specific services. The company registering its services on the proposed platform must provide a detailed report indicating the amount of CO2 saved that one token represents. The service providers can rely on a third-party service that evaluates the amount of saved CO2. We are aware that the calculation of saved CO2 is not an easy task, and many approaches have been proposed in literature [3, 11, 23]. In our work, we assume that the calculation of saved CO2 is performed by domain experts. At the end of each month, the platform publishes reports on the total CO2 saved by the registered organizations, as well as a certificate confirming their commitment to the respective SDGs.

The contribution of the paper can be summarised as follows: a) we provide an extended overview of services and projects that rely on blockchain technology to engage users in collaborative and sustainable behavior; b) we provide a platform that municipalities can use to aggregate blockchain-based services; c) we propose a token conversion method based on CO2 saved instead of a monetary basis to reduce speculation and malicious behavior; d) we propose an incentive mechanism based on gamification to encourage sustainable behavior and engagement among users, organizations, and communities. The remainder of the paper is organized as follows: Section 2 presents the main blockchain-related services and projects in the waste, energy, and management sectors. Section 3 provides an overview of the proposed

approach. Section 4 provides a detailed explanation of the main components of the platform along with the usage workflow from the perspective of both users and service providers. In Section 5, the benefits and concerns of the proposed approach are discussed. Finally, conclusions and future work are reported in Section 6.

2 REVIEW OF EXISTING SERVICES AND PROJECTS

Several works presented how to use blockchain technology to reward users or organizations for good behavior. They are mainly presented in the context of waste management, energy management and trading, and sustainable transportation services. Approaches adopted to engage and incentivize users exploit: reputation score among network players (R); token distribution (T); reward/penalty (RP); deposits that will eventually be returned, based on user's behavior (D).

2.1 Waste management

Waste collection and segregation have become one of the main challenges to mitigate climate change and avoid environmental problems. In fact, traditional waste management systems do not provide a sufficient solution to preserve the environment. The main concerns are related to waste segregation, waste collection and disposal, and route optimization. In recent years, an increasing number of projects have proposed the use of blockchain technology to ensure transparency and promote user engagement. As can be noted in Table 1, most of the projects and proposals rely on the Ethereum blockchain (only two on Hyperledger Fabric and other blockchains). The main scopes of the waste management system proposed concern general waste collection, solid waste collection, and traceability/disposal of plastic and electronic waste.

2.2 Energy management

There are several projects reported in the literature related to energy management systems using blockchain technology. Table 2 lists selected solutions that provide a reward to network actors based on energy production/consumption. Many of the proposed systems are energy trading systems between producers and consumers or are designed to automatically manage energy distribution through the network. As can be seen, academia has not converged on a predominant solution in terms of the blockchain used. In fact, a wide variety of blockchain solutions have been explored, from the public (i.e. Ethereum) to permissioned (i.e. Hyperledger Fabric). As it can be seen from Table 2, the majority of projects preferred a reputation system rather than a token-based incentive to drive engagement and reward participants. This choice can be partially explained by the fact that energy trading is a process that requires quick decisions, so a mechanism for releasing/buying tokens may not be an effective solution.

2.3 Transport management

Table 3 shows the available projects and works that provide an incentive for sustainable mobility. The main projects are related to electric vehicle (EV) charging sharing during pickup, light electric vehicle (LEV) self-charging, reducing vehicle greenhouse gas emissions, and promoting the use of bicycles for short trips. Half of the proposed solutions are Ethereum-based, and most provide a token-based reward to users who perform sustainable actions.

2.4 Motivations behind the current work

In recent years, the number of services promoting sustainable behavior has increased. To promote good behavior, many of them use blockchain-based solutions that leverage token-based reward, reputation, and gamification mechanisms [2]. Among these incentives, a token-based solution is generally preferred because the user can convert tokens and

Table 1. Description of waste management projects and proposed approaches in terms of scope, reward mechanism, used blockchain, and code availability; reward mechanism is classified as reputation score (R), token distribution (T), reward-penalty approach (RP), deposit (D); ✓: code available, x: code not available

Ref.	Scope	Description	Reward mechanism	Used blockchain	Code available
[27]	Generic waste collection	SmartBins allow waste collectors to efficiently collect the garbage when the bins are full following the optimal path. If the waste is segregated, a reward is given to the stakeholder.	Token (no information about the mechanism that regulates token distribution) (T)	Ethereum	x
[15]	Electronic waste tracking system	The system allows the tracking and tracing of electronic products from the manufacturing stage to the disposal phase issuing a certificate for correct data destruction.	Reputation system between manufacturers, recycling plants, and smart-bins (R)	Ethereum	x
[22]	Solid waste segregation	A reward in terms of tokens is given to the user for proper waste disposal after smartbin's cross-check confirmation.	Token reward based on weight and type of segregated waste (T)	Polygon (Matic), Binance Smart Chain, Ropsten	x
[4]	Traceability and safe dismissal of smartphones	The system aims to trace smartphones from the manufacturing stage to selling, re-manufacturing, refurbishing, and finally recycling.	No reward/reputation is provided to customer/stakeholder.	Ethereum	✓
[24]	Electronic waste management	The system aims to trace electronic and electrical components from the selling phase, the dealing phase, and the possible second-hand market selling, and finally to the proper dismissal.	Buying the product, the customer pays tax, which will be redeemed after the proper good dismission (D).	Ethereum	x
[10]	Traceability and safe dismissal of electric and electronic devices	The proposed approach traces electronic and electrical components between the stakeholders and their proper collection for dismissal.	If a stakeholder does not reach the e-waste collection target, an amount is transferred from the owned account to the Government account. If a customer returns the e-waste, the stakeholder returns a percentage of the product's original cost to the customer (RP).	Ethereum	x
[6]	Electronic waste management	An android app is proposed in order to find the nearest bin and promote proper electronic waste dismissal.	A reward is issued in terms of reputation score based on the type and amount of given electronic waste (R).	Hyperledger Fabric	x
[9]	Solid waste management in small municipalities	A wallet application is developed to receive and transfer Green Coins gained from correct solid waste segregation.	A reward in terms of tokens (Green Coins) is given to volunteers based on the type and amount of solid waste segregated (T).	Ethereum	x

benefit from discounts on the platform. In addition, a token-based reward enforces engagement through gamification processes. Existing platforms, such as those reported in Table 1, 2, and 3, provide services related to a specific domain, such as transportation, energy management, waste, or agriculture (thus proposing a "vertical" solution that addresses a specific context). In this work, we propose instead a "horizontal" solution that could potentially include several aspects characterizing sustainable behavior. Therefore, we present a platform, based on the building blocks reported in [14],

Table 2. Description of energy management projects and proposed approaches in terms of incentive and code availability; reward mechanism is classified as reputation score (R), token distribution (T), reward-penalty approach (RP), deposit (D); ✓: code available, x: code not available

Ref.	Scope	Description	Reward mechanism	Used blockchain	Code available
[5]	Energy trading among producers and consumers	Using smart meters, the consumer and the producer can buy/sell electricity.	Installing a smart meter, the user gets a green certificate. Moreover, a reputation system is implemented between nodes (R).	– (framework only)	x
[30]	Charging pile among electric vehicular networks	Through smart meters, private charging pile and electric vehicles can trade electricity.	A reputation score is assigned from the electric vehicle and private charging pile to the local aggregator (R).	Ethereum	x
[29]	Peer-to-peer energy trading between producer and consumer	Blockchain-based system for P2P energy trading based on reputation.	A reputation score is assigned to the seller and buyer (R).	Custom blockchain (Goland)	x
[28]	Peer-to-peer energy trading between producer and consumer	Hybrid blockchain-based system (preserving producer's and consumer's privacy) for P2P energy trading based on reputation.	A reputation score is assigned to the seller and buyer (R)	–	x
[33]	Peer-to-peer energy trading between prosumer in local community	Blockchain-based system for peer-to-peer energy trading between prosumers.	A reputation score is assigned to the seller and buyer, taking into account a deposit and feedback ratings (R)	JUICE	x
[19]	Energy dispatching model in local community	Blockchain-based system in order to reduce the load energy pick in a consumer community based on a centralized aggregator.	A reward is given to the user every 24h in the form of a token that depends on the individual consumption and the individual contribution to consumption during production hours in order to balance the electric load (T).	Hyperledger Fabric	x

that could gather all the services at the municipal level. As mentioned above, our platform relies on an intermediary token, that is used to enable the conversion among different tokens. In this way, service providers are free to develop custom business logic without having to follow some strict guidelines for using the proposed platform (i.e., a specific token management system). The aim of this platform is to promote city services that encourage sustainable behaviors and participation among users through NFT-based certificates, with the ultimate goal of certifying the commitment of users and service providers to sustainable behaviors and SDGs.

To the best of our knowledge, only one other work has used blockchain technology to support a "horizontal" system that rewards different types of actions in the context of social goods [18]. In particular, Lopez et al. [18] proposed a blockchain-based solution aimed at promoting the adoption of sustainable behaviors at the University of Deusto. Participants are divided into three types: campaign organizers, campaign participants, and the organization's administrator. Community members can create campaigns that promote good actions that are rewarded. The Deusto Social Coin (DSC) is distributed as a reward and can be used to purchase goods. Our solution differs from the one described [18] in terms of target audience, architecture, and reward mechanism. First, our platform targets municipal

Table 3. Description of transport management projects and proposed approaches in terms of incentive and code availability; reward mechanism is classified as reputation score (R), token distribution (T), reward-penalty approach (RP), deposit (D); ✓: code available, x: code not available

Ref.	Scope	Description	Reward mechanism	Used blockchain	Code available
[32]	The system promotes the LEV charging with green energy.	LEV users are encouraged to charge LEVs in solar panel charging points.	A reward is given to the user in terms of tokens in proportion to the percentage of battery they charge in the solar stations (T).	Ethereum	x
[7]	The proposed system encourages users to self-charge LEV, reducing the greenhouse gas produced by the actors in charge to substitute low batteries.	LEV users are incentivized to self-charge, substitute batteries, and bring LEV to the charging point.	A reward is given to the user when the LEV battery is charged. Moreover, if the charging station is powered with renewable energy, an additional token (CO2 compensation) is released to the user (T).	Hyperledger Fabric	x
[21]	CO2 and NOx emission control	Encourage drivers to behave well in terms of speed and good practices in order to emit less CO2 and NOx.	A token-based reward is given to the user that consumes less CO2 or produces a reasonable amount of it. The token can also be sold to other drivers to avoid penalties (T).	Ethereum	x
[17]	Avoid electric pick load	The system encourages EV charge sharing during pick load.	A token-based incentive is given to sell energy during pick load (T).	- (framework only)	x
[31]	EV for sustainability.	The system promotes EV purchasing to reduce greenhouse emissions.	A token-based reward is given to the driver calculated from traveled km (T).	EOS	x
[26]	Bike driving for sustainability	Incentive people to use bikes rather than cars to move for short distances.	A token-based reward is given to the user. (T)	–	x
[13]	Bike driving for sustainability	The user gets a reward to use bikes to move around to reduce greenhouse emission,	Not specified.	Ethereum	x
[25]	Peer-to-Peer car sharing	The system promotes peer-to-peer car sharing to reduce pollution.	A Reputation score is calculated from data collected from a device inside the car along with the user's feedback (R)	Ethereum	x

citizens and blockchain-based services (community members do not propose rewarding sustainable behavior) to encourage citizens to use services that are committed to sustainable actions. Furthermore, the proposed platform aims to be used as a dashboard for all registered city services, allowing users to convert tokens obtained from a service provider to tokens provided by another service provider. In other words, our platform does not release a token-based reward but allows users to convert already owned tokens (gathered using the municipality's services) into a token linked to CO2 emission savings (the sCO2 token), and eventually into NFT-based certificates and discounts. The sCO2 token has no monetary value and cannot be spent outside the platform or used to purchase goods or services. Instead, it acts only as an intermediary token, to enable the conversion among different tokens. Differently from [18], it is not meant to be used to pay for services and goods. The conversion of the user's owned token into sCO2 is crucial since the platform does not own any service provider's tokens. Hence, the platform can guarantee the conversion from one

token to another only if some users deposited the designed token before. To the best of our knowledge, there are no other solutions that promote the services provider token conversion on a municipality level and release certificates and discounts if carbon neutrality is reached, or a significant amount of CO2 is saved.

3 PROPOSED APPROACH

In the previous Section, we emphasized that the number of ("vertical") blockchain-based services promoting good behavior (especially focused on achieving SDG goals) has increased in recent years. However, from a user's perspective, it may be difficult both to know all the services operating at the city level and to obtain the service's token to use the relevant platforms. Furthermore, a person who uses a service extensively and is rewarded with more tokens than he/she can consume on the service platform may want to convert them into other tokens that could be used for some other city services. An example can be represented by an EV driver who collects tokens as a reward for every kilometer driven. The user may want to convert excess tokens to access another service, such as cab sharing. To address these issues, we propose a city service that aggregates token-based services into a web platform, shown in Figure 1[2], where service providers and users can register and freely convert tokens from one service to another. The token conversion is regulated by an indicator of the amount of CO2 saved per token unit (i.e. the CO2 that the user has not emitted by using a service). The calculation of the amount of CO2 saved per token unit is performed by the service provider on the basis of domain experts' knowledge. A simple example of saving CO2 calculation (that should be used only to understand how the proposed system works) is the following. Let us imagine that an EV driver receives 1 token as a reward for driving 10 kilometers. In this case, the driver saves an average of 118 CO2 grams[3] per kilometer (compared to a diesel car). This value is calculated as the CO2 consumed by a diesel car driving one kilometer minus the CO2 consumed by an EV driving the same distance). Therefore, the sCO2 for such a token is 1180g.

In the proposed system, the service provider encourages environmentally friendly behavior by giving the user a certain number of tokens. Thus, the token represents the exact amount of CO2 that the user has saved by using the service. In addition, the platform is expected to have its own coin – with a fixed amount of CO2 – that can be collected or used to convert an equivalent amount of other service provider tokens into sCO2. A rebate and reputation mechanism is implemented to encourage user and provider registration. From the user's perspective, a pre-defined amount of platform coins can be converted into NFT-based badges that certify his/her good behavior, achievement of carbon neutrality, or a significant amount of CO2 saved. In addition, various discounts on municipal services (i.e. public transportation, waste tax, school services, etc.) are expected to be issued along with the certificate. The platform also generates a monthly and annual report showing the total amount of CO2 saved per service, ranks all registered services, and provides them with a certificate. Through this mechanism, organizations can publicly demonstrate their commitment to the SDGs, enhancing their credibility and reputation.

4 ARCHITECTURE

This Section provides a detailed explanation of the proposed platform, which consists of a web interface where network players can perform operations such as registration, authentication, token conversion, and reward redemption, and of a backend, composed of a set of smart contracts. The workflow is discussed in detail in the following.

[2]All icons in the Figures are gathered from https://www.freepik.com
[3]https://ourworldindata.org/grapher/carbon-footprint-travel-mode

4.1 Web App

As mentioned above, network participants can interact with the platform through a web application. The app supports wallet connection, user registration and authentication, peer-to-peer token conversion, and goal achievement to increase user engagement. A mobile app is expected to be developed to promote fast token conversion among peers.

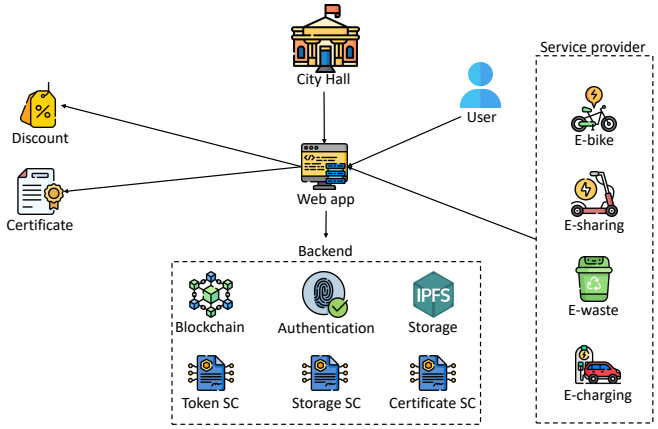

Fig. 1. General system architecture

4.2 Registration

Since the main goal of the platform is to promote good behavior by releasing discounts to citizens, the municipality may want to identify the citizen for security, accounting, and legal reasons. Therefore, the platform must provide registration and authentication components to address these issues. Nowadays, privacy is one of the main concerns as far as web authentication is concerned. Recently, the self-sovereign-identity (SSI) management has been proposed by the W3C[4] specification. The SSI aims to empower individual autonomy and ensure the sovereignty of its participants. The individual is responsible for storing her own verifiable credentials and delivering them when required by a service provider. Since SSI offers a higher level of privacy and security from a user perspective, we choose to integrate an SSI system into the platform in order to manage user registration.

The registration process is expected to leverage the most common SSI solutions, such as uPort [20], LifeID [1], or SelfKey [8]. During the registration phase, the entity (i.e., the user or service provider) must also provide an identifier (a public key) and cryptographic proof that the public key is solely controlled by the entity (i.e., cryptographically signing a message containing a short token).

The platform then requests authorization from the entity to gain data access for the registration process, as shown in Figure 2. The authorization workflow is controlled by one of the SSI solutions mentioned above. In fact, through the SSI application, the entity is able to interact with the blockchain and prove its identity in order to make the requested data accessible to the platform. In the case of a service provider registration, the entity has to provide, together with the public key, a detailed report containing the accounted CO2 per unit token saved by its service (used to calculate the equivalent amount in sCO2 tokens), according to the workflow shown in Figure 4. The provided report is stored in a

[4]https://github.com/w3c/webauthn

decentralized repository using the Inter-Planetary File System (IPFS[5]), and the document hash is permanently stored on the blockchain by the "Storage SC" smart contract. After this process, the service provider's token can be converted on the platform and its saved CO2 indicator is updated. Once registered, users/service providers can interact with the platform.

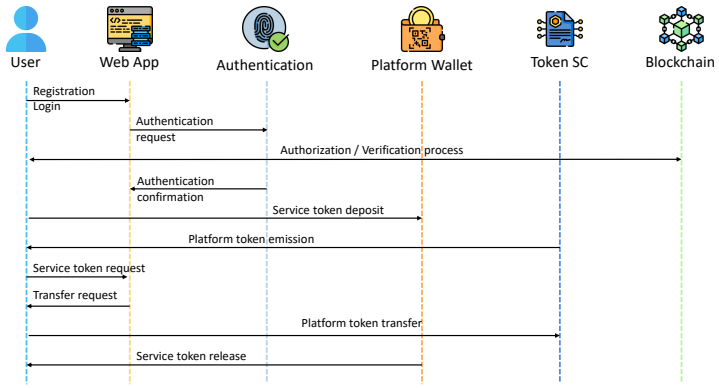

Fig. 2. Service provider registration/authentication and CO2 report upload workflow

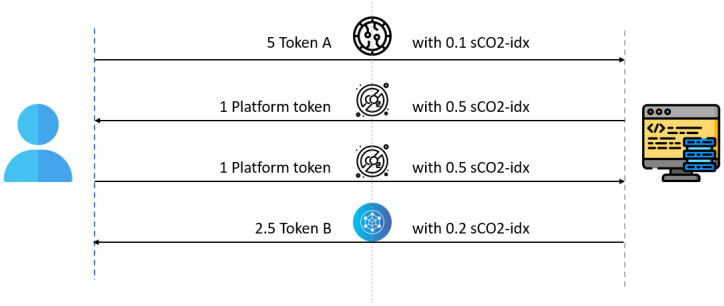

Fig. 3. Token conversion workflow

4.3 Token conversion

The token conversion component aims to list all registered services and the corresponding tokens and allows users to freely convert tokens. In fact, the main objective of the platform is to make available to citizens all the services that promote sustainable behavior through a reward based on tokens and to allow users who have a surplus of tokens (i.e., in case the user is particularly well-behaved or has very healthy habits) to convert them into other tokens that can be used to benefit from another service registered on the platform. The conversion is regulated by a saved CO2 indicator (the amount of saved CO2 that each unit token represents), which is certified by the service provider's report during the registration process.

[5]https://ipfs.tech/

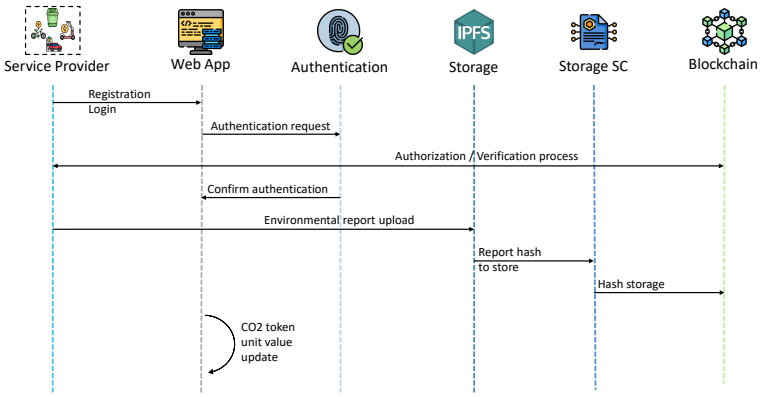

Fig. 4. Usage from a service provider perspective

As shown in Figure 2, users must deposit the token they wish to convert (i.e., into sCO2 tokens to obtain another service's token) into the platform's wallet. The platform then sends a transfer request to the "Token SC" smart contract, which provides the user with an equivalent amount of the sCO2 platform token. The user can then use the platform tokens to purchase the service token of their choice for the amount of sCO2 they can afford or are willing to spend.

In case the user wants to convert his/her own tokens (Token A) into another service token (e.g., Token B), as shown in Figure 3, he/she sends a conversion request to the platform, by specifying the amount to be converted. The platform then asks the user to confirm the transfer (i.e. the user signs a transaction) in order to make "Token SC" smart contract to return the corresponding amount of sCO2 (i.e., the platform token) to the user. Finally, the user can convert sCO2 tokens into the token of the preferred service (i.e., Token B).

4.4 Certificate and discount emitter

The certificate issuer component is responsible for minting a non-fungible token (NFT) to certify that an entity has reached a milestone. From the user's perspective, to encourage user engagement, an NFT is sent to the user's address when a certain goal is reached, such as monthly or annual carbon neutrality, or a set of pre-defined amounts of CO2 saved (e.g. 50–100–200 kg of CO2 saved). In order to demonstrate the user's commitment, the NFT is minted when the corresponding amount of CO2 in terms of sCO2 tokens is sent by the user to the platform. In other words, the user must accumulate a certain number of platform tokens to receive the NFT badge. Together with the badge, the platform also releases a discount for municipal services among those available (i.e. public transport, waste tax, school services, etc.) selected by the user. After the authentication phase, the user can request the release of an NFT based on the amount of CO2 saved. The platform then asks the user to prove the ownership of the amount of CO2 saved and the user must transfer the requested amount of sCO2 to the "Token SC" smart contract. After the "Token SC" smart contract receives the correct amount of token, the platform creates the certificate, stores it in a decentralized repository using the IPFS format, and invokes the "Certificate SC" smart contract to store the document hash on the blockchain, transferring the ownership to the user's registered account.

The platform also issues a certificate on a monthly and annual basis, containing information about the ranking position and the amount of CO2 that an organization's services have helped to save. The certificate is automatically

generated and stored in a decentralized repository. As a final step, the "Certificate SC" smart contract stores the certificate on the blockchain and transfers its ownership to the corresponding service provider address. The certificate can be used by the organization to increase its reputation among sustainable services and its commitment to SDGs indicated in the report provided during the registration phase.

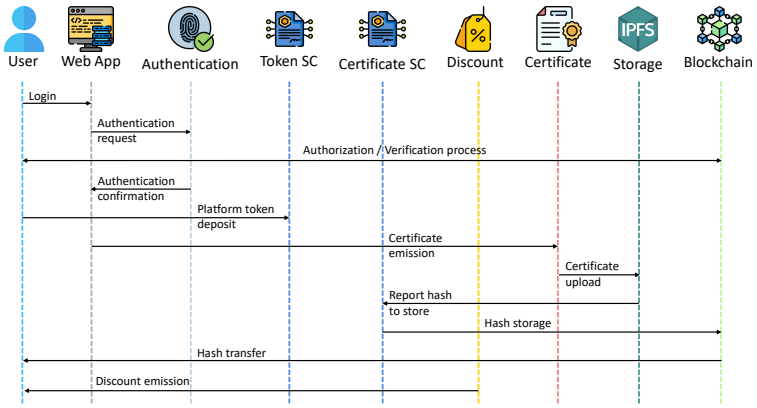

Fig. 5. User incentive

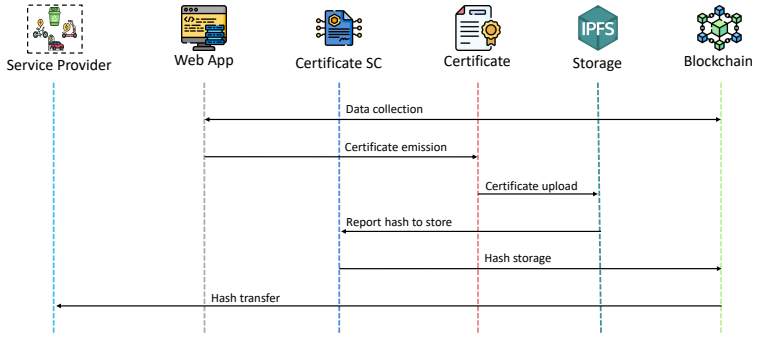

Fig. 6. Service provider certificate issuing

5 DISCUSSION

Municipalities can benefit from the proposed platform in terms of reliability, trustworthiness, and security since the platform uses blockchain technology to store data. Moreover, exploiting such a platform could show a city's commitment to promoting and acquiring services that enhance sustainable behaviors and actions through rewards. Despite the concerns about its energy consumption (that is expected to be reduced by future research innovations [12]), blockchain can bring benefits to both users and organizations. In fact, the user is rewarded with NFT certificates and can convert

tokens obtained from a service into a token that he/she could use in another city service. On the other hand, the organizations can prove their commitment to their SDG target through the tamper-proof certificates that the platform autonomously transfers them.

A potential drawback of the system could be related to the saved CO2 indicator. As mentioned above, there are different approaches proposed in the literature to calculate the CO2 saved, and having a non-standardized CO2 calculation framework could lead to inequalities. Indeed, depending on the saved CO2 calculation, there may be services that are more environmentally preserving than others, hence users subscribing to those services could have more purchasing power in terms of saved CO2. This problem could be mitigated by limiting the purchase of service tokens to a defined amount in a determined period of time or limiting the daily token conversion in terms of sCO2.

Concerning the adoption of the developed system, it must be highlighted that this paper only aims at describing the technical (i.e., IT-related) aspects, without focusing on the economic or anthropologic ones. Indeed, we are aware that the acceptance, adoption, and diffusion of the token system would require further analysis and investigation. The increasing number of sCO2 points may lead to inflation and decreasing acceptance. The community may need to be involved in the design and governance phase to avoid an increasing drop-out rate over time. A possible solution could be to simulate the behavior of the proposed platform from a governance, economic, sociologic, and adoption point of view with a well-known framework such as the one proposed by [16].

6 CONCLUSION

Since the development of the SDGs framework by the United Nations in 2015, an increasing number of companies and services are taking action and changing internal processes in order to meet such goals and gain a reputation for their commitment to more sustainable actions. Blockchain technology is proving to be one of the most suitable in terms of commitment. In fact, many service providers are shifting to the use of blockchain to unlock an incentive when a good action is performed, as often self-will is not enough to pursue sustainable behavior. This mechanism promotes both engagement through incentives and environmentally friendly and sustainable habits. Since many service providers use a token-based incentive rather than reputation or penalty methods, and since each service requires its own token to be used, we proposed a platform that aggregates all services offered in a city. This approach can promote awareness of city services that support good behavior, and allow the user to convert possible excess tokens (i.e., earned tokens that the user does not need) for other service tokens on a CO2 saved per unit token basis using the platform's proprietary token. The conversion of service provider tokens into platform tokens is proposed to avoid the exchange of tokens into FIAT money. This method avoids speculation and reduces malicious behavior (we designed our system to avoid an increase or decrease in the price of tokens). The users can collect the platform tokens and use them to redeem a series of NFT-based certificates testifying users' commitment to sustainable action. Along with the NFT badge, the user also gets a discount to be used for municipal services, proportional to the amount of saved CO2 goal reached. From an organization perspective, the platform issues on a monthly and yearly basis an NFT-based certificate reporting the amount of CO2 organizations' services helped to save and the ranking positioning. As our objective was to present some preliminary details on how our system could work, in future works we aim to analyze implementation-related issues, such as the performance and the economic-related aspects of the proposed solution. We will also evaluate whether to rely on permissioned or permissionless blockchains, we will define the requirements for the proposed system and we will evaluate the need to comply with token standards. Finally, we aim to evaluate the engagement that the platform can achieve among citizens using the proposed reward mechanism and to measure the service provider's involvement in providing the CO2 saving report.

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