A BLOCKCHAIN-BASED APPLICATION FOR FOOD WASTE REDUCTION

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ABSTRACT

Food waste is a major global concern and engenders profound ramifications of environmental and socio-economic dimensions, while on the other hand, food insecurity affects a significant part of the global population. The co-existence of food waste and food insecurity in urban environments is a paradox of modern cities. The research project presented in this paper introduces a solution using blockchain technology to address both of these issues, simultaneously. The project aims to develop a decentralized mobile application (dApp), which facilitates the reduction of food waste and provides safe and nutritious meals to food-insecure individuals. The tokenization capability provided by the blockchain technology, through the utilization of smart contracts, is used to incentivize food waste reduction and track surplus availability. Citizens use the project's token as currency to purchase food portions, while the participating food service establishments from the retail sector, receive the tokens in exchange for the saved surplus. In this paper the architectural design and all the components of the decentralized application are outlined and described and a holistic view of their interconnection into an IT architecture is provided. This description is followed by an initial discussion of the tokenization process of the proposed ecosystem and its main characteristics that are going to guide the development of the project's tokenomics, by taking into account token's supply, distribution, utility and market demand to estimate the token's value.

KEYWORDS

Blockchain, Smart Contracts, Tokens, Tokenization, System Architecture, Food Waste

1. INTRODUCTION

Food waste is an increasingly critical issue worldwide, impacting environment and society in a multi-dimensional way. It contributes to greenhouse gas emissions and depletes water and land resources (Munesue & Masui, 2019). If food waste was a country, it would be the third largest emitting country in the world, after China and USA (UNEP, 2021). Economically, it causes $936 billion per year in economic damages (FAO, 2014) and socially, it exacerbates inequalities, especially in metropolitan areas where it occurs along food insecurity. Food waste takes place in every link of the food supply chain (Parfitt et al., 2010) from primary producers and processing to retail stores and final consumers. Especially in hospitality and food service sector, according to studies, nearly one third of all food is wasted and almost half of the waste, can be avoided (Papargyropoulou et al., 2019). The level of the food supply chain that includes among others, the restaurants and eateries in the cities, i.e., the retail sector, plays significant role in arising food waste. Initiatives to mitigate the phenomenon include improved supply chain management, innovative packaging and storage solutions, redistribution of surplus food to those in need, and educational campaigns that aim to shift consumer attitudes and behaviors (Attiq et al., 2021; Strotmann et al., 2017; Wikström et al., 2019). The efforts of the project presented in this paper target those in need, that suffer from food insecurity, as the recipients of the food surplus generated by the retail sector, in order to try to effectively tackle the repercussions emerging from food waste, with the utilization of the blockchain technology and its derivatives, i.e., smart contracts and tokens.

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2. SYSTEM ARCHITECTURE

The core objective of the project presented in this paper, namely BLOCKFOODWASTE, is to develop a mobile application based on blockchain, for reducing food waste from the food service establishments of the retail sector, such as restaurants, eateries, bakeries etc. The users of the application are divided in two categories: a) the Food Service Establishments (FSEs) that offer their food surplus (supply) and the citizens that suffer from food insecurity or are willing to help the mitigation of food waste problem (demand). The IT architecture is critical in the development of any information system no matter of its size, development approach, structural type and domain of application and the same applies to this project's case. The technical components that are used to build the project's decentralized application (dApp) help to ensure that it is secure, scalable and interoperable with other dApps and systems. The research team decided to treat the development efforts of the discrete components separated, in order to rationalize software development processes and gain time. This decision separated the first two large building blocks of the architecture i.e., BFW blockchain from the Application system. The software development follows an agile approach, because agile methods are suited to develop systems whose requirements are not completely understood since the beginning, or tend to change, as it is this case. The choice for the public blockchain network that will be utilized in the Proof-of-Concept phase of this project is the Ethereum blockchain, but due to its high gas fees, it may not be the blockchain of the project's final product. Based on the above, an initial take of the high-level system architecture is depicted in **Figure 1**. For figure clarity purposes, interconnections between nodes in the blockchain component have not drafted, yet they are implied. All the nodes are connected to each other, and they continuously exchange the newest information on the blockchain with each other. This ensures all nodes are updated.

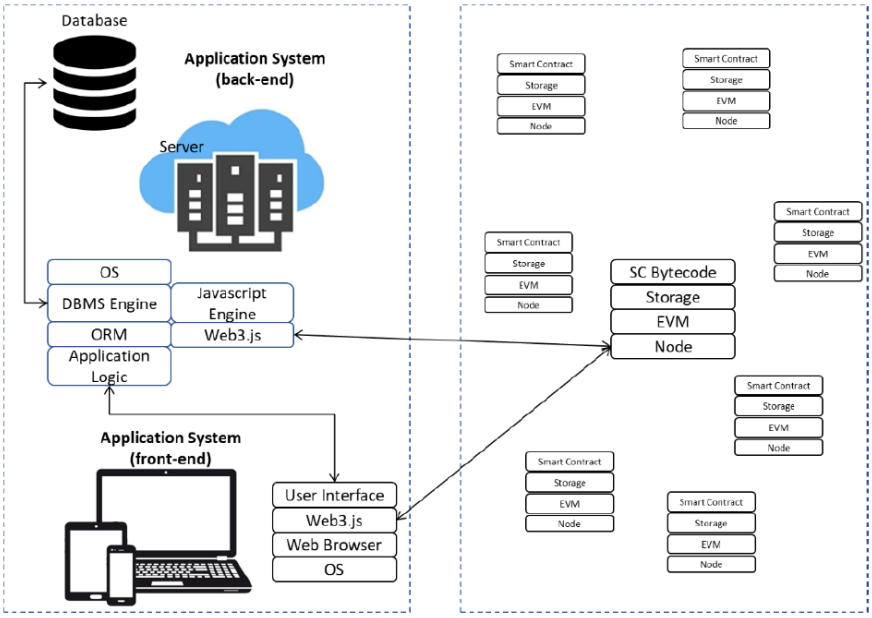

Figure 1. High Level IT Architecture of the BFW Distributed Application

The Application system is composed of a software system running on mobile devices and/or on servers, exchanging information with users and external devices. Its User Interface (UI) runs on a Web browser and in a mobile app interface. The server component stores data that cannot be stored in the blockchain and performs business computations. As shown in **Figure 1**, interaction between Ethereum nodes and the system application (mostly managing the creation and dispatches of transactions) will be carried out using Web3.js through HTTP, IPC, or WebSocket. Object-relational mapping (ORM) is a programming technique in which a metadata descriptor is used to connect object code to a relational database. Object code will be written in object-oriented programming (OOP) languages such as Java or C#. Finally, in the blockchain component, EVM (Ethereum Virtual Machine) is the runtime environment that executes Ethereum smart contracts. Ethereum contracts are written in Ethereum's proprietary Turing-complete scripting language, called Solidity, which will be used to develop the project's smart contracts and their embedded business logic.

Further drilling down in the dApp architecture, at this point, outlining the interaction of the two discrete blocks of **Figure 1** is in order. In **Figure 2**, a simplified version of the interaction between the two components is presented, along with available software tools for creating the smart contracts (VScode and Remix IDEs), cloud service providers such as Microsoft Azure and Amazon Web Services and finally Ethereum wallets, such as MetaMask and Exodus.

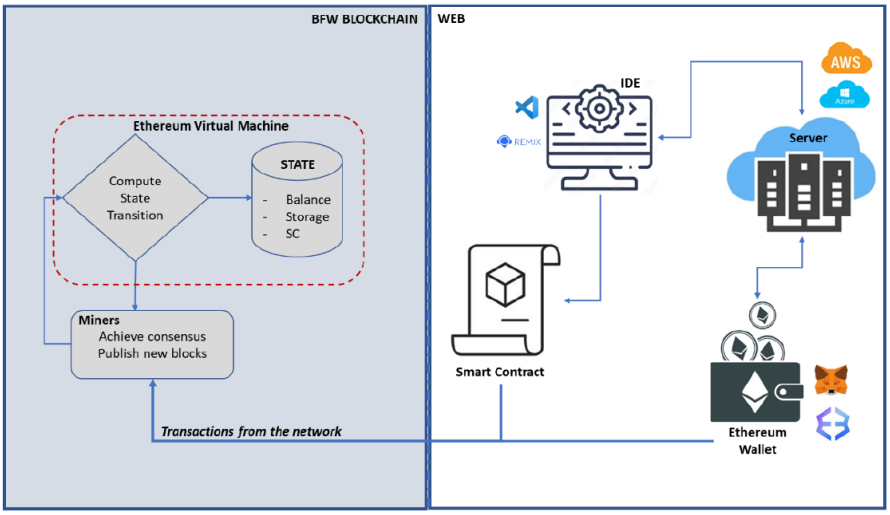

Figure 2. Component Interaction

Having determined the upper-level architecture of the project's dApp and in order to provide more details of the proposed approach, an outline of the iterative software development process is provided. The high-level expectations (requirements) for each discrete component, are the following:

Mobile App: The mobile app should have a user-friendly interface for citizens to browse and place an order for surplus food from participating FSEs. It should have integration with blockchain to securely record transactions and track food waste reduction and use GPS or other location-based services to show available surplus food nearby the interested citizens.

Web Platform: The web platform should provide an interface for food service establishments to manage their surplus food inventory and track food waste reduction. It should have integration with blockchain to securely record transactions and track food waste reduction. Additionally, it should have an analytics dashboard to monitor food waste reduction and track the performance of participating FSEs and a reporting system to generate reports, such as on food waste reduction goals.

Blockchain: The blockchain should be used to securely record transactions and track food waste reduction. It should provide transparency and immutability in recording the transactions and food waste reduction and allow for the creation of smart contracts to automate the process of surplus food distribution and food waste tracking.

Database: The database should store the information about participating food service establishments, surplus food inventory, citizen orders, and food waste reduction tracking. It should be scalable to accommodate the growing number of transactions and data as the food waste reduction platform grows and should be securely managed to protect sensitive information.

The information above, constitutes the generic requirements of the BFW project so it can efficiently reduce food waste while providing a free, secure and transparent solution for both citizens and FSEs. Additionally, the research will decide later in the project for the inclusion of an advertising system, as a result of a full-blown cost and sustainability analysis. The advertising system should be integrated into the mobile app and web platform to provide funding for the food waste reduction initiative and should display relevant and non-intrusive advertisements to customers, which can provide the necessary funding to support the free food waste reduction platform.

Finally, data architecture is also an important aspect in the development of a dApp because it defines how data is stored, organized, and managed within the dApp. A well-designed data architecture helps ensure data integrity, security, scalability, and accessibility, all of which are critical for the success of a dApp. Additionally, a clear and consistent data architecture makes it easier for developers to build and maintain the dApp, and for

users to interact with the dApp and its data. Ultimately, a strong data architecture is essential for the long-term viability and success of a dApp. In the case of this project, the proposed data architecture for the BFW dApp has the following dimensions:

Data Storage: The blockchain would be used to securely store data such as food types, food inventory levels, expiration dates, and any transactions related to food waste reduction. This data would be immutable and transparent, ensuring that all stakeholders can have trust in the information stored.

Data Access: The data stored on the blockchain and processed by the backend system would be accessible to all users and FSEs for free, in line with the goal of reducing food waste and making a positive impact on the environment. Access to the data would be controlled through secure authentication and authorization mechanisms to ensure that only authorized users can access the data.

Data Processing: A backend system would process the data stored on the blockchain and generate reports and insights for both citizens and FSEs.

Data Visualization: The mobile app and web platform would provide interactive visualizations of the data to help eating citizens and FSEs understand the impact of their actions on food waste reduction. These visualizations would include graphs, charts, and maps that provide insights into the sources and causes of food waste and highlight the successes of food waste reduction efforts.

Data API: A REST API would be provided to allow mobile app and web platform users to access the data stored on the blockchain and processed by the backend system. This API would enable users to see real-time information about food waste reduction efforts in their area and take action to support these efforts.

3. TOKENIZATION

The first step in the tokenization process is to identify the asset that will be represented by the digital token that is going to be created. In the context of the BFW project, tokenization is used to track and incentivize the reduction of food waste with the cooperation of participating citizens and FSEs. As such, the asset that is represented by the digital token is the surplus food available to the ecosystem everyday by the FSEs. The project's token, which is named BFW, will be created using a smart contract that outlines the terms and conditions of the token, such as its value, ownership, and transferability and will be added in a blockchain. As it was mentioned, for the proof-of-concept phase of the project, the smart contract will be added in Ethereum blockchain that supports token creation and management. So, the project's smart contract will be used to manage the allocation, transfer, and redemption of the BFW tokens. A detailed description of the smart contract building process in Ethereum follows:

− The smart contract will be deployed on the Ethereum blockchain, making it available to all participants in the above-mentioned network. The smart contract will define the rules and conditions for the allocation, transfer, and redemption of tokens.

− Tokens will be issued through the smart contract, and the contract will determine the number of tokens that will be issued and the conditions under which they can be issued to FSEs and citizens, based on their food waste reduction efforts.

− The contract will be monitored by all parties on the Ethereum blockchain, providing transparency and accountability for the tokenization process. For example, citizens and FSEs will be able to view the terms of the contract and the status of token transfers and trades on the blockchain ledger.

− The smart contract will manage the allocation of tokens to eating establishments and users based on predefined conditions.

− The smart contract will validate and execute token transfers and will ensure that tokens are transferred only in accordance with predefined conditions.

− The smart contract will define the conditions under which tokens can be redeemed and the rewards that will be provided.

− The contract could be updated as needed by the BFW consortium, allowing for flexibility and adaptation to changes in the food waste reduction efforts. Contract updates will be validated by the Ethereum network and recorded on the blockchain ledger.

− The code for the smart contract in Ethereum will be designed to be secure and transparent, and to enforce the terms of the agreement for reducing food waste. The contract will be publicly available on the Ethereum

blockchain for review and auditing. The code will be free for everyone to use, allowing for widespread adoption and participation in reducing food waste.

The novel ecosystem is built around the BFW token, so the token's smart contract will automatically issue the tokens to participating FSEs and citizens based on their food waste reduction efforts. Tokens will be used as a currency to purchase surplus food or other products from participating business entities. This incentivizes users to participate in food waste reduction and aligns their interests with the goals of the platform. For example, for every kilogram (or portion) of food saved from going to waste, the participating establishment would receive a certain number of BFWs. FSEs can redeem their tokens in exchange for free access or discounts on platform services (e.g. ads), access to analytics and resources and other incentives, or even donate the tokens back to food insecure citizens, directly or through other organizations. This aligns the interests of eating establishments with the goals of the platform, as they will have an interest in reducing food waste to earn more tokens. The same applies to citizens who place an order from their mobile App, to receive meals from participating FSEs.

The BFW tokens will be managed using a blockchain wallet, integrated into the mobile app to provide customers and restaurants with a secure and convenient way to manage their tokens and track food waste reduction. Traditionally, the equivalent of one token would depend on the value assigned to the token by market demand and supply. In that sense, the exact value of one (1) BFW token can only be determined through market dynamics, i.e., the use of the token within the food waste blockchain ecosystem, and the overall success of the food waste reduction efforts. In the beginning, a potential approach could be to set the initial value of one BFW token based on the cost of preventing a certain amount of food waste, for example, 1 BFW token could represent the cost of preventing 1 kilogram of food waste. This value could then fluctuate over time based on market demand and supply. Ultimately, the value of one BFW token would be determined by a combination of factors, including the success of the food waste reduction efforts, the adoption of the food waste blockchain application, and the demand for the token within the ecosystem. The project's initial take on the subject has produced three alternatives, which can also can be used in combination, as follows:

− Mass of food not wasted (kg): Assign a fixed value to each kilogram of food waste prevented, for example, 1 BFW token per kilogram of food waste prevented. This approach would directly reflect the environmental impact of the food waste reduction efforts and incentivize users to reduce as much food waste as possible.

− Food portions: Assign a fixed value to each portion of food waste prevented, for example, 1 BFW token per portion of food waste prevented. This approach would be more accessible for consumers and could be more easily translated into everyday actions.

− Food market value: Assign a fixed value to each dollar of food waste prevented, for example, 1 BFW token per dollar of food waste prevented. This approach would reflect the economic impact of the food waste reduction efforts and incentivize users to reduce food waste in a cost-effective manner.

The blockchain can enforce rules and conditions for token transfer, such as minimum food waste reduction goals, to ensure that the tokens are used effectively to incentivize food waste reduction. The tokenization process within the ecosystem has to be designed meticulously, as the main objective is to keep the platform sustainable, so it's important to carefully consider all revenue sources and how they align with the project's mission against food waste. In the future, project partners will consider all available options in terms of initiating alternative revenue streams, in order to remain sustainable such as: Advertising, Sponsored content, E-commerce, Data licensing etc. The initial token supply and exchange rate depends on several factors such as the purpose of the token, the target audience, market demand, and competition. The purpose of the token will dictate the total supply and the exchange rate. In the project's case, the token will be used as a medium of exchange and as such, its supply should be large enough to meet the demand. The market demand for the token will also play a role in determining the initial supply and exchange rate. The token's exchange rate should be in line with the market demand. Since, BFW will operate in a closed market, the need for the token exchange rate to be in line with similar tokens in the market is absent.

The next step in the project for the research team, is to decide the overall tokenomics of the system and then use financial modeling and market analysis tools to estimate the potential value of the BFW token. The tokenomics will be decided considering the following parameters:

− Token supply: The total number of tokens that will be created and set in circulation.

− Token distribution: The allocation of tokens to various stakeholders, including project partners (in essence the founders and early investors) and community members.

− Token utility: The function of the token within the food waste blockchain application, such as serving as a medium of exchange, reward, or governance mechanism.

− Token economics: The underlying economic model, such as inflationary or deflationary, and how it affects token supply and demand.

− Network effects: The potential for the value of the token to increase as more people use the food waste blockchain application.

− Market demand: The potential demand for the token from various groups, such as food waste reduction organizations, consumers and later investors. Competition as expressed by the presence of other food waste blockchain solutions and how they compare in terms of tokenomics will be evaluated but not considered as decisive factor at this stage of business model development.

4. CONCLUSION

Food waste is a challenge that calls for collaborations, in order to create a more equitable, efficient and sustainable food system. By understanding the multifaceted nature of food waste, technology can be utilized to significantly reduce waste, alleviate hunger and conserve resources. The high level of the BLOCKFOOWASTE project's technology landscape and baseline data, provided in this paper, aligns with the above-mentioned goals, by minimizing food waste, and contributing to the well-being of food insecure individuals in urban areas. The project's system and data architecture aspire to provide a secure, transparent, and scalable solution for reducing food waste from restaurants and other eating establishments. It can enable the members of the community to work together towards a common goal, leveraging the strengths of blockchain, to make a positive impact on the environment. By using tokenization, the project's application can incentivize participating FSEs and citizens to reduce food waste, track their progress, and reward them for their efforts. Blockchain technology offers an anonymous and automated manner to accomplish the food donations from the FSEs, using smart contracts. The use of smart contracts provides a secure way to manage the tokenization processes (token issuance, allocation, transfer, trading, and redemption), allowing for widespread adoption and participation in reducing food waste.

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