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Blockchain adoption in project management

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Abstract

Blockchain applications strive to develop an ecosystem that satisfy the needs of users in high-security requirements. The enterprises such as finance, insurance, the internet of things, and supply chain have seen more comprehensive blockchain research than the project management field. This research surveyed several blockchain applications to fill this gap and identified key traits applied to the project management field. This research concluded to build and test a prototype of a blockchain-based project management application. The model's operation implemented blockchain proof-of-work concept to specific areas of the project management field. The model deployed a smart contract on a permissionless blockchain testing environment, Electro-Optical System (EOS), to track project activities and manage project resources. The resulting model verified and recorded each project stakeholder transaction based on the smart contract across the blockchain nodes. This research demonstrated the feasibility of developing and highly secured decentralized project management tools that do not require a trusted third party.

Keywords: Blockchain, Traceability, Permissioned, Permissionless, Project Management

Introduction

A blockchain is a type of distributed ledger technology (DLT) that provides a foundation for creating decentralized, secure, and dependable activities (Pop et al., 2020). The advantages of this technology include transparency, openness, and traceability by joining several computer science disciplines such as cryptography, data structures, and consensus algorithms (Narayanan, 2016; Zhao et al., 2017). Blockchains seek to establish an ecosystem that is creditworthy among its participants in today's environment of sensitivity and a requirement of high security (Li, 2019). The basic infrastructure of blockchain is sufficient to provide enough creditworthy data-level storage and operations (Froese, 2010). Nick Scabo's introduction of smart contracts in 1994 ensured blockchain would acquire substantial benefit because it automatically executed transactions using script according to specified criteria (Christidis & Devetsikiotis, 2016; Cong & He, 2019; Li, 2019). Users of a blockchain cannot retroactively alter these records without altering subsequent blocks and their entire network (Li, 2019). It is the basis of this security that encourages the exploitation of potential blockchain-based applications.

Some non-financial areas of blockchain application are smart energy and grids, digital identity schemes, biometrics, healthcare, supply chain, among others (Pan et al., 2019; Perrons, 2020). In supply chain management, the integration of the broad application of IoT devices in the supply chain with the interface blockchains provides with the physical world ensure devices used to carry out supply chain functions such as inventory control, pricing, transportation, among others, can be exploited to improve its efficiency (Pournader et al., 2020).

The main characteristic that all existing blockchain technologies and future blockchain models attempt to leverage is transparency (Maesa & Mori, 2020; Nakamoto, 2008). Maesa and Mori (2020) also point out

that immutability, tamper resistance, and persistence of blockchain's data storage ability are crucial blockchain properties, which ensures auditability of all applications built on blockchains.

The maritime industry deals with a lot of documentation specific to cross-border trade and transportation. It had to deal with a language barrier's challenges for a long time, high volumes of paperwork that prove cumbersome for management, and slow documentation processing. These challenges provide a conducive environment to perpetrate fraud and loss of goods and poor services. An estimate between 15% and 50% of global container shipping transportation costs were due to the time spent on paperwork (Yang, 2019). Maersk and other large shipping firms have worked hard to digitize documents and transactions using blockchain technology. Blockchain technology also enables shipment and distribution time monitoring and a broader range of global logistics partners such as shippers, ocean freight forwarders, shipping carriers, terminal operators, and customs offices. Blockchain technology enhances transparency between all parties involved and improves scheduling activities carried out by the various partners within a supply chain (Yang, 2019).

Project Management Body of Knowledge (PMBOK) provides guidelines to assess the traceability, transparency, and security of blockchain in project management areas such as contract management, finance management, asset, inventory management, and purchase management. Traceability is the ability to track information after the information within a blockchain is verified (Hofstede, 2007).

Contract Management

A smart contract is an agreement that can self-execute parts of its functions (Swan, 2015). Conditional logic statements written into these contracts provide a means of tracing tasks completed, resources allocated, and payments made. The initial phase of most projects is usually the most expensive and high risk (Glass, 2005). Stakeholders try to alleviate the associated risk through adequate contract planning, and blockchain-enabled contracts, also called smart contracts, offer an option to achieve this (Hughes, 2017). Eliminating uncertainties associated with payment and resource allocation can mitigate the risk of project failures from unsatisfactory agreements and disputes. Additionally, smart contracts encourage a shift in reshaping trust behavior from humans to traceable systems.

Finance Management

Information and material flow are critical in managing projects successfully. For example, in the construction industry, streamlining the flow of materials and effective coordination and communication of activities in projects from planning to distribution for clients contribute are success factors (Nanayakkara et al., 2019). Currently, delivery notes, invoices, and purchases operate with centralized systems or manual paperwork. Blockchain eliminates the manual and centralized systems into a distributed digitized form (Sat, 2000; Jang 2007). With information and material flow entered in the blockchain ledger, decision-making becomes more accessible with validated and traceable logs (Guegan, 2017).

Asset and Inventory Management

The unique project-based nature of industries, such as construction and manufacturing, requires adequate quality control. An adequately maintained supply chain is needed to ensure such quality requirements (Rodrigo et al., 2019). A significant challenge faced by traditional supply chains has been buyers' inability to validate the actual value of purchases reliably. Blockchain overcomes the lack of transparency encountered in conventional supply chains and can track project owners' purchase order flows through

blockchain's open ledger system. All records of the item are available for stakeholders to access, enabling audits of prospective quality issues.

Budget & Schedule Management Framework

Figure 1 illustrates the framework for budget and schedule management. There are three main components to demonstrate the framework: Stakeholders, Smart contract, and Blockchain ledger.

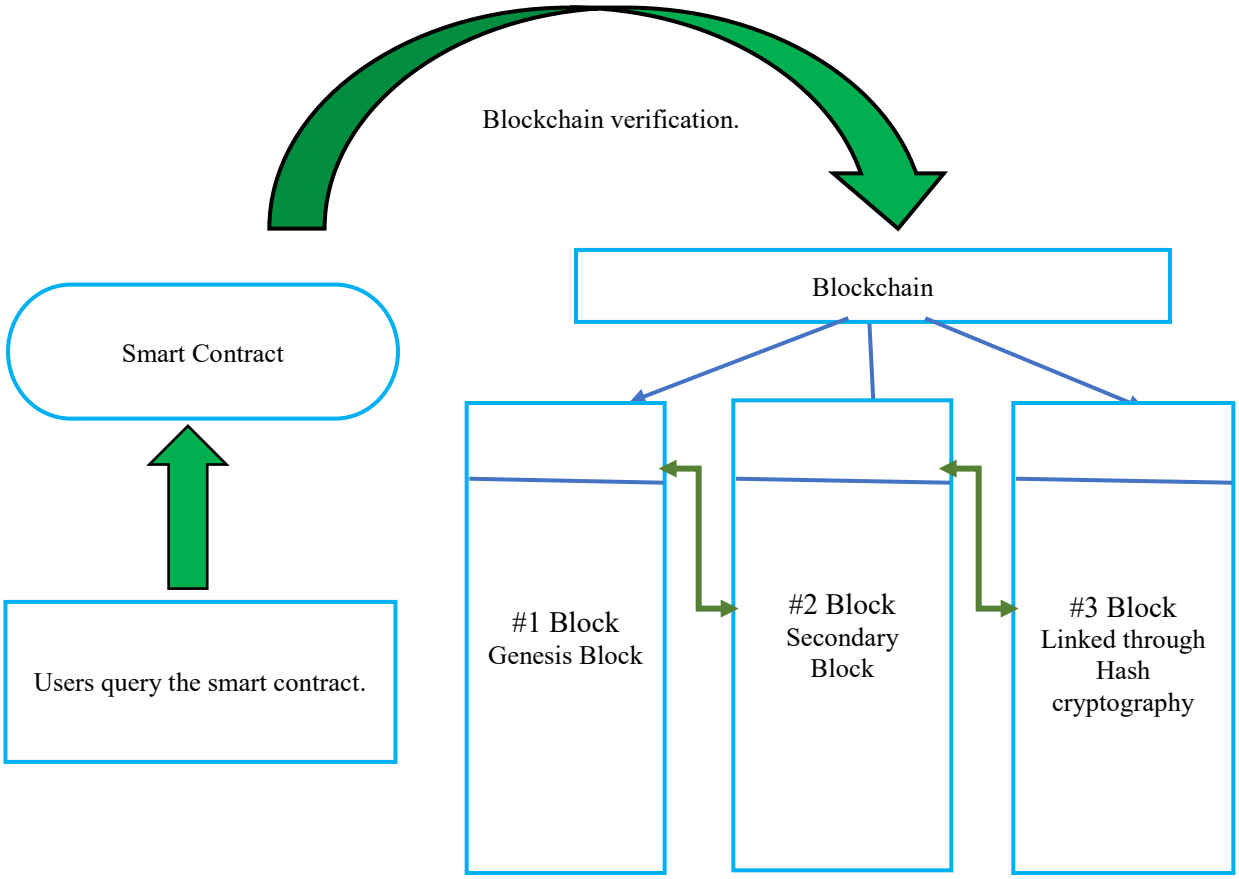

Figure 1. Blockchain-based project management concept.

Methodology

This research uses a public blockchain platform to build a project management framework. The activity and cost data in tables below served as input for the model. The figures in this section capture the prototype model interfaces deployed on the blockchain testnet platform.

Project Activity/Cost Tracking Platform on Blockchain

The project activity/cost tracking platform used the EOSIO blockchain platform. The reason for choosing EOSIO is that it is a public blockchain with a relatively lower transaction cost. EOS developers have

provided a testing environment, "Jugle3 Testnet," a testing environment for EOS and decentralized applications.

Table 1. Blockchain platform performance evaluation.

Features	Bitcoin	Ethereum	Hyperledger-fabric	EOSIO -Testnet
Network	Public	Public, Private, Hybrid	Private	Public
Mining	Permissionless	Permissionless, Permissioned	Permissioned	Permissioned
Transactions	Anonymous	Anonymous	Public, confidential	Public, Confidential
Consensus	PoW	PoW, PoS	Ordered	DPoS
Cryptocurrency	Bitcoin	Ethereum	None	EOS
Transaction integrity	Yes	Yes	Yes	Yes
Transaction throughput	7	8 to 9	>3500	16 to 18+
Latency	10 minutes	15-20 seconds	less than others	120 seconds
Energy consumption	High	High	Less than others	Less than others
Coding complexity	High	Low	High	Medium
Application	Financial only	General	General	General

Note: Adapted from Kim, T., Ochoa, J., Faika, T., Mantooth, A., Di, J., Li, Q., & Lee, Y. (2020). An overview of cyber-physical security of battery management systems and adoption of blockchain technology. *IEEE Journal of Emerging and Selected Topics in Power Electronics*.

Blockchain-based Model Architecture

The blockchain administrator or project manager would enter the project's project activity and budget breakdown structure to issue its smart contract. Figure 2 demonstrates the framework for management of a blockchain-based project management tool. Users would then interact with the blockchain platform to validate their authenticity. If the user is legitimate, the blockchain network marked them as such, and the user can proceed to confirm their task completion.

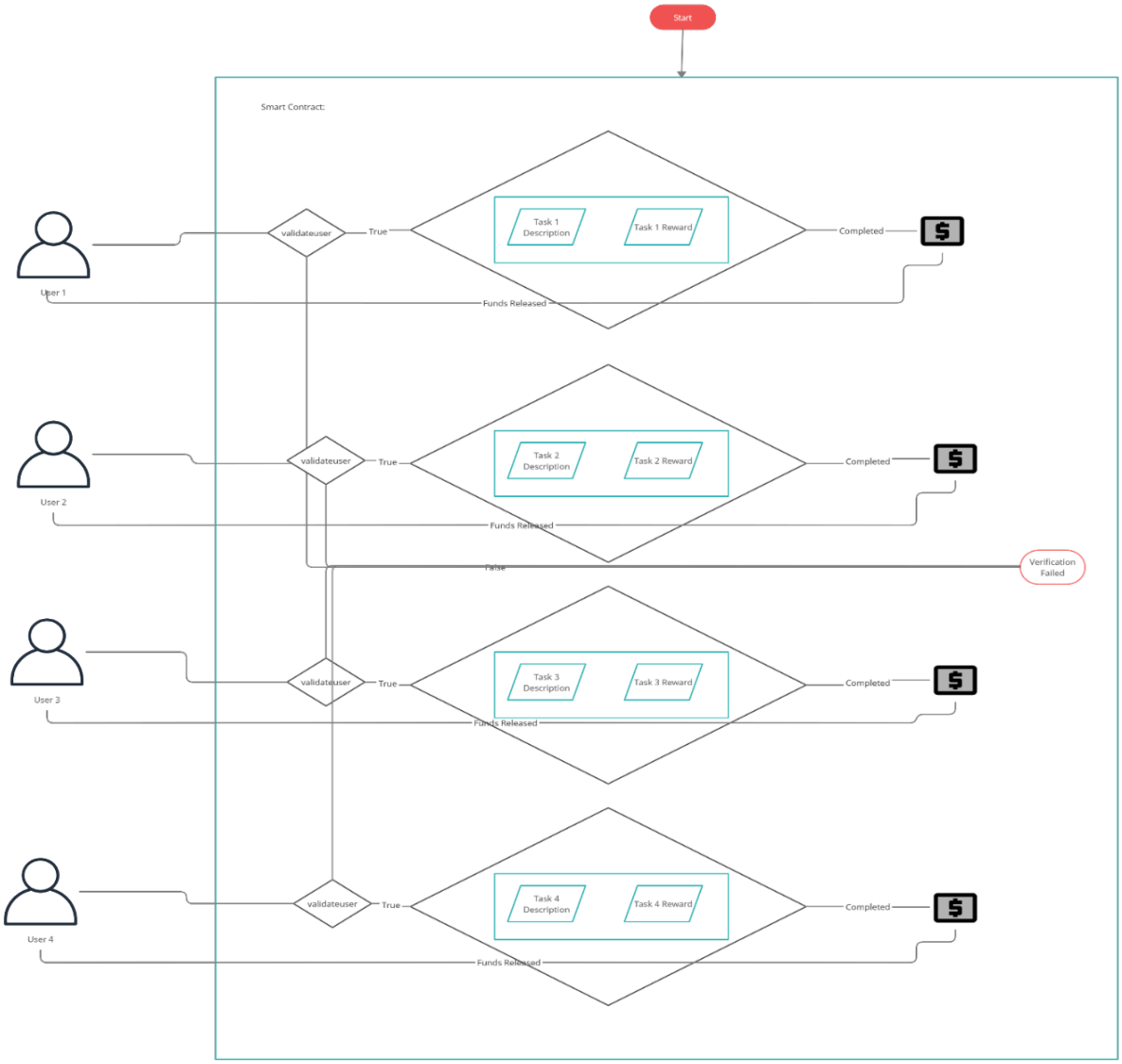

Figure 2. Illustration of blockchain-based project management architecture

Program Running Environment

The project scheduling platform requires a simple computer that supports the latest browser to run the EOS public blockchain program. The following minimum program running environment is needed: CPU # core i3, RAM # 2GB, and Windows/Ubuntu/MAC system. The test case was performed with the HP computer with CPU # core i5, RAM of 4GB, and Windows 10 operating system.

Model Test Case scenario

A college is holding a fund-raiser in the spring semester. They intend to hire a band to entertain participants. The project manager created a work breakdown structure and estimated the event's site preparation duration. Table 2 shows an example case of project activities, schedules, and classification based on the Work Breakdown Structure. The information in Table 2 provides the consensus for building the smart contract.

Table 2. Test case: Project activities and their duration.

Activity	Description	Predecessors	Duration (Days)
A	Site selection	None	4
B	Purchase concessions	A	3
C	Facility rentals	A	2
D	Stand Building	A	2
E	Installation of wiring and generator	C	4
F	Security	B	2
G	Installation of lighting	E	5
H	Audio system installation	E, F	2
I	Stage construction	D	4
J	Teardown	G, H, I	4

Setting-up Stakeholder Blockchain Accounts

The open-source blockchain resource, "*https://jungle3.bloks.io/*," was used to host the project management prototype smart contract. In a private/close source blockchain, the administrator creates stakeholder IDs on a permissioned-blockchain network. A unique blockchain-account user ID corresponds with each of the ten identified stakeholders of the project activities listed from A through J and secured using a pair of EOS-generated public keys.

Table 3 outlines project activities' categories carried out by corresponding stakeholders and their associated Blockchain ID. The whitelisted names under the Blockchain ID column are the smart contract users hosted on the https://jungle3.bloks.io blockchain platform. In this prototype, the smart contract owner bears the user ID "*scheduler112*."

Table 3. Project activity stakeholder ID.

Activity	Users/contractors	Blockchain ID
A	Paula Abdul Enterprise	paulaabdulcr
B	Sam George LLC	samgeorgellc
C	Rich Paul Ventures	ricepaulbros
D	Kilnock ventures	kilnockventu
E	Marvin Isaac Mathers	isaacmathers
F	Martial Matte	martialmatte
G	Jack Randall	jackrandall1
H	Stern Paul	paulstern111
I	Ramon John Choudarnt Ent.	johnchoudary
J	Lucinder Cahill LLC	lucialcahill

Signing-in to Jungle3 Testnet Platform

The blockchain testnet platform, https://jungle3.bloks.io , allows signing in through EOS cryptocurrency wallet. The digital wallets shown in Figure 5 serve to authenticate users and hold digital rewards issued by the smart contracts on the EOS blockchain.

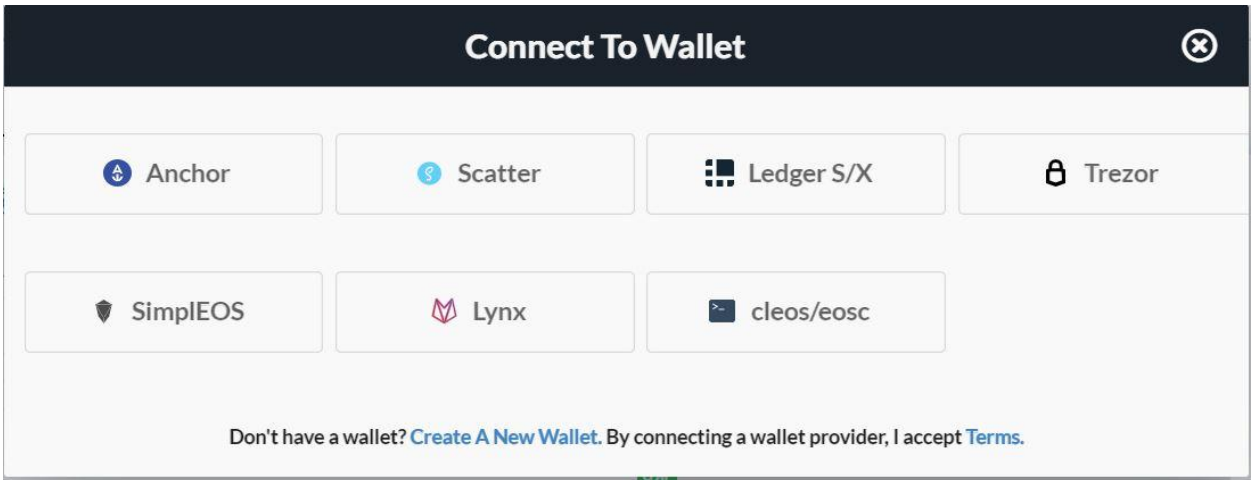

Figure 3. Digital wallets for sign-in.

"Anchor" was used in this exercise to sign in to the blockchain platform, as shown in Figure 4.

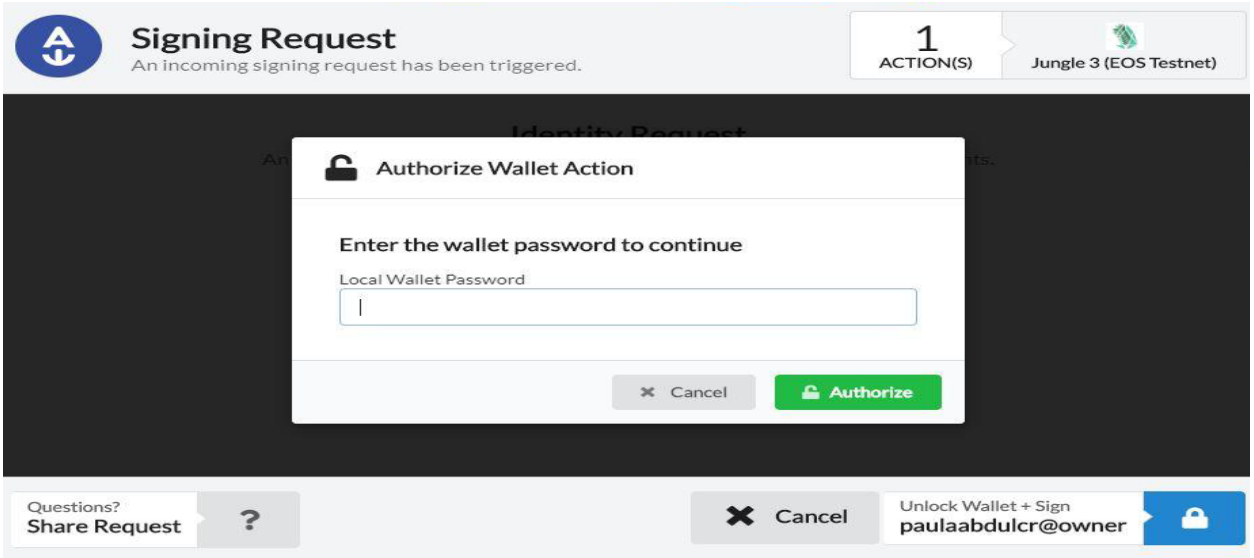

Figure 4. Anchor digital wallet sign-in.

Blockchain Smart Contract Pseudocode

The project management blockchain framework is facilitated by writing and publishing an interactive smart contract for authorized users. This research used the C++ programming language to write the smart contract. The pseudocode for the smart contract is as follows:

```
i.      This program allows authenticated users to receive a reward token
calculated based on the duration of work done. //The "smart contract" titled
"projectmanagement" is initialized.

ii.     The public contract flat hourly rate is 0.1 EOS/hr

iii.    Name users = "whiteListedUser," captures authenticated users who can
interact with the smart contract for their reward

iv.     Define activities [[eosio::action]] to initiate a project

v.      Calculate reward of user uint64_t total_payment =
number_of_hours_worked*hourlyrate;

vi.     Print("The user", nameofuser, "has earned reward",total_payment);

vii.    Convert payment to EOS currency = number_of_hours_worked *
asset(hourly rate*10000,

viii.   Transfer fund action (permission_level{ _self, "active"_n },
"eosio.token"_n, "transfer"_n, std::make_tuple(_self,blockchainacountname,
quantity, string

ix.     ("Reward claimed for completing task "))
             ).send();

x.      Repeat the remaining project activities and assign their respective
reward claim functionality.

xi.     Compile and publish output file on https://jungle3.bloks.io
```

Results

The blockchain records validated transactions across its ledger, and all users on the blockchain will have access to view details of the successful execution. No user can update the blockchain ledger beyond this. The activity is confirmed successful for the whitelisted user shown in Figure 5 below.

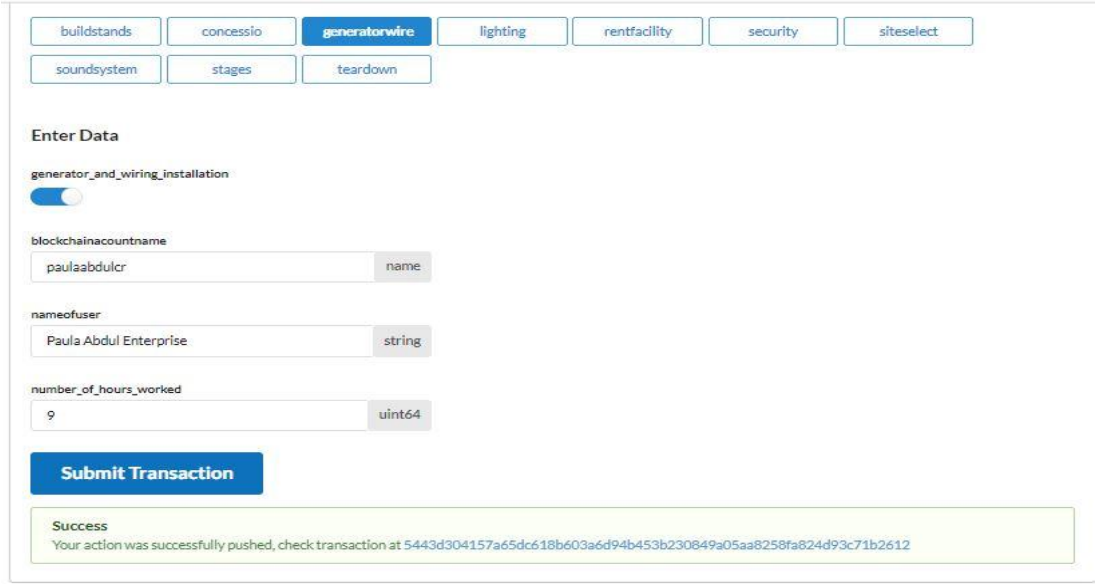

Figure 5. Validated transaction.

The open resource, jungle testnet, host the smart contract; another blockchain user, Harvey Carlson, with ID *fruitloop234*, can access the blockchain and view the smart contract Figure 6 below. However, since the contractor not included in the project's smart contract on the blockchain and is consequently a "blacklisted" user, the contractor's request to claim a project's reward fails, as shown in Figure 6. This information was recorded across the blockchain for all users to see.

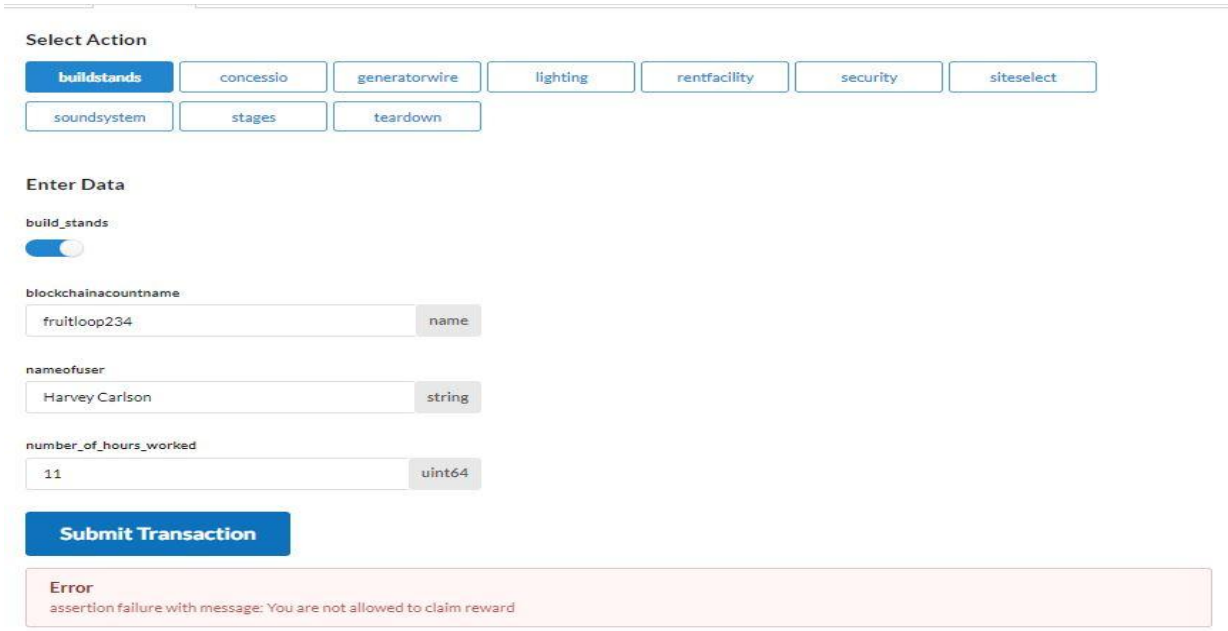

Figure 6. Unauthorized transaction confirmation.

The reward activity carried out on the blockchain in the form of 1 EOS, based on duration worked, is recorded, and issued to the stakeholder, as seen in Figure 7.

TX	Date	Action	Data	Search memo...
5443d304	Mar 31, 2021 02:53:31 AM	Send Token	scheduler112 → paulaabdulcr 1.8 EOS	Reward claimed for completing task
5443d304	Mar 31, 2021 02:53:31 AM	scheduler112 - generatorwire	**generator_and_wiring_installation:** true **blockchainacountname:** paulaabdulcr **nameofuser:** Paula Abdul Enterprise **number_of_hours_worked:** 9	
9e39448e	Mar 23, 2021 05:38:29 AM	Send Token	scheduler112 → paulaabdulcr 1 EOS	Reward claimed for completing task
9e39448e	Mar 23, 2021 05:38:29 AM	scheduler112 - siteselect	**site_selection:** true **blockchainacountname:** paulaabdulcr **nameofuser:** Paula Abdul Enterprise **number_of_hours_worked:** 5	

Figure 7. Transaction reward issuance.

Transactions carried out on the contract are securely saved on the blockchain, as shown in Figure 8. The transactions can be queried and viewed by all peers on the ledger. Information such as date, location, action, and reward serve as inputs to assess project performance from a decentralized environment securely.

TX	Date	Action	Data	Search memo...
9e39448e	Mar 23, 2021 05:38:29 AM	Send Token	scheduler112 → paulaabdulcr 1 EOS	Reward claimed for completing task
9e39448e	Mar 23, 2021 05:38:29 AM	scheduler112 - siteselect	**site_selection:** true **blockchainacountname:** paulaabdulcr **nameofuser:** Paula Abdul Enterprise **number_of_hours_worked:** 5	
46c19896	Mar 23, 2021 01:03:38 AM	Send Token	scheduler112 → paulaabdulcr 0.4 EOS	Reward claimed for completing task
46c19896	Mar 23, 2021 01:03:38 AM	scheduler112 - generatorwire	**generator_and_wiring_installation:** true **blockchainacountname:** paulaabdulcr **nameofuser:** Paul Abdulcr **number_of_hours_worked:** 2	
f44b6c25	Feb 13, 2021 10:50:47 AM	Set Code	The code was updated. SHA256: 0169f452bc2ef56e627f586887c91ac1e8ef5ac43e67872e853d752676b06f5a Download WASM	
fe27f176	Feb 13, 2021 10:27:07 AM	Send Token	scheduler112 → paulaabdulcr 1 EOS	Reward claimed for completing task

Figure 8. Transaction tracking on the blockchain.

The verification process times out for 120 seconds, after which the transaction is confirmed and becomes irreversible, as shown in Figure 9.

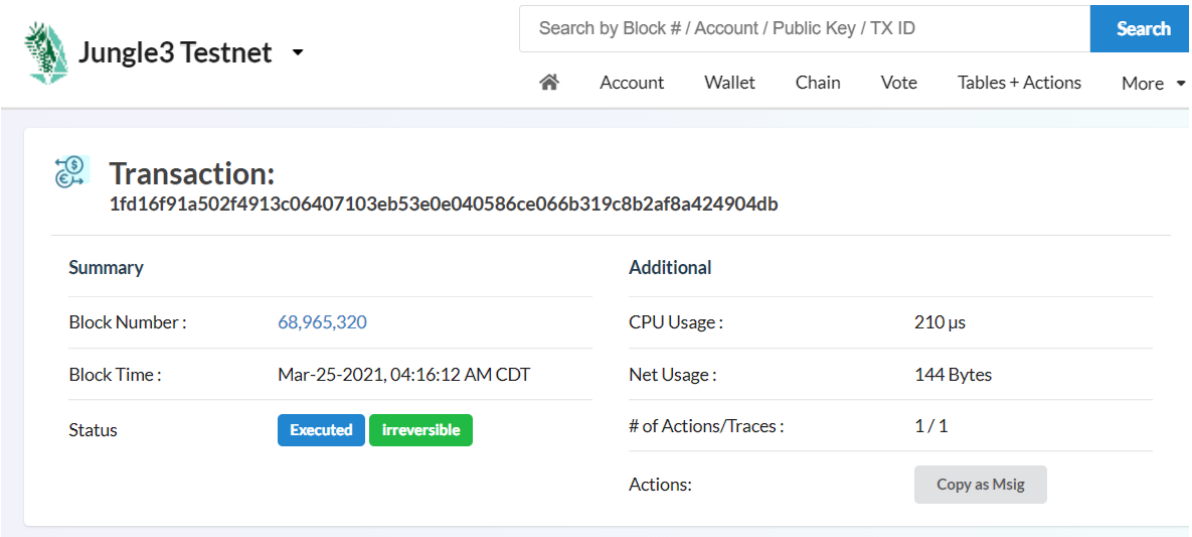

Figure 9. Completed transaction execution and irreversibility.

The immutability of blockchain provides an advantage to audit transactions across the platform.

Discussion

The blockchain-based project activity tracking and budget management platform deployed on the jungle testnet server showed the possibility of launching a decentralized project management tool. The tool showcased blockchain's ability to use its inherent hash validation cryptography feature to validate, record, and secure a ledger based on an interactive smart contract.

Transactions validated over the blockchain platform required users to authorize transactions by signing through their wallets. Each transaction confirmation counts down 120 seconds for peer confirmation. In this test case, the project details are relatively minor, and the countdown timer for verification is minimal. However, larger projects with a significantly higher number of transactions will increase the verification time. The verification wait time is an inherent issue with most blockchain platforms. Slower transactions and longer wait times can delay project schedules.

Several challenges were implementing the blockchain model. Firstly, identifying the right blockchain platform to execute the smart contract was critical to its success. Considering the python programming language is a relatively easy high-level program to use, the preliminary proposal considered using python to deploy the smart contract on a Hyperledger fabric to code the initial smart contract.

The Hyperledger open-source community is a broader one and offers a lot of development resources. Hyperledger Fabric is free but has an associated production cost based on the computing infrastructure required. The EOS blockchain platform was chosen as the alternative to offset the associated cost during production; the EOS blockchain is not compatible with python programming. As a result, the smart contract adopted the C++ language due to its EOS compatibility. This incompatibility requires developers to either take a refresher Bootcamp in C++ programming language to facilitate the smart contract's writing and deployment.

Secondly, a ubuntu virtual machine compiled the smart contract code before its deployment. This process was not as seamless as deploying in the cloud or on a Hyperledger fabric. Also, there is less modularity by the EOS platform in production. However, the EOS blockchain resources, including a testing environment,

zero (0) test cost, relatively lower production cost, and security, served as important factors to consider for this model implementation. This blockchain's security by signing transactions via authorized wallets and transparency to the blockchain public were relevant for this research. A private blockchain setting, such as IBM Hyperledger or cloud blockchain offered by Amazon Web Services (AWS), user security, and transparency, provides only permissioned users and peer-voting systems access to participate.

Overall, blockchain technology advances would facilitate a reduction in the transaction verification wait-time; such tools would become more efficient in delivering increased transparency and immutability. Integrating a data cumulation feature in the smart contract would allow for better activity tracking and an easier budgeting ledger. In the future, users can easily program the store data in a more interactive form for simplicity. Also, current advances in data analysis, machine learning, and artificial intelligence to this model would improve its transparency, performance, privacy, and modularity.

A framework built on the jungle3 testnet blockchain environment hosted a smart contract that authenticated and tracked a fixed payout amount, calculated based on the work duration carried out to achieve the research objective. The smart contract allowed the authenticated users to select the project activity they were responsible for by requesting a set of data such as blockchain ID, the contractor's real name, and work duration. Upon submitting this information, the blockchain computed, verified, and paid out the project activity budgeted amount in the form of a transaction. The novelty of this research is that a permissioned blockchain network, EOSIO with the EOS cryptocurrency, served as the budgeted payout currency for transactions. Each activity's transaction was recorded and remained immutable after validation on the blockchain network.

There are two main contributions of this study. This research's academic significance is to provide more context into the feasibility of applying blockchain technology in the project management field. For project management professionals and enterprise use, this research helps them understand how projects managed on blockchain-based platforms can provide assurance for data integrity, improve activity tracking at a reduced cost, and reduce process waste.

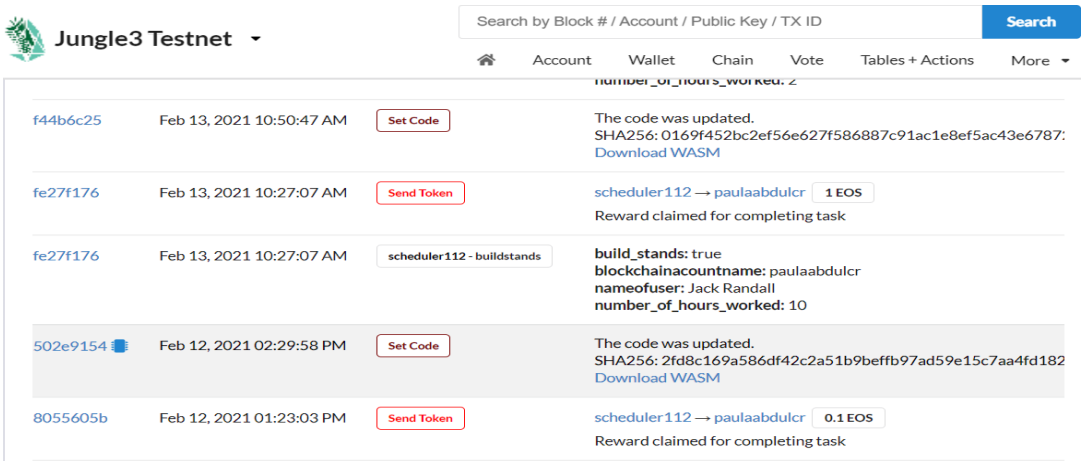

Figure 10. Blockchain-based project management platform.

Each transaction of action carried out did not require a third-party authorization system, potentially reducing project budgets' financial cost. It is clear the EOS.IO platform used in this research provided a free testing platform for the implementation of the smart contract with the integration of EOS cryptocurrency. However, more advanced, and older blockchain-based currencies such as Bitcoin and Ethereum have higher transaction costs. One promising aspect of the current blockchain sphere is that technological advancements

in IoT, cryptography, data structures, and consensus algorithms would facilitate the industrial adoption of blockchain technology and further research its application.

To improve this research and prototype developed, additional features to include would be a customizable blockchain platform that would allow the accumulation of recorded data. Additionally, there is a research gap using a private blockchain to implement this tool at little to no production cost requirement. Also, future studies can involve the application to real-life test cases including the impact of using permissionless versus permissioned-based project management tools.

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