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Dinari: A blockchain lab for supporting blockchain learning, research, and innovation in Tanzania

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Abstract

Blockchains have caught the attention of governments, businesses, and researchers due to their potential to revolutionize the way data is stored and consumed. Despite the current interest in blockchains globally, there has been unsatisfactory progress of this promising technology in developing countries, including Tanzania. One factor hindering the advancement of blockchain in the country is the lack of knowledge of the technology itself. Challenged by the situation, this study implemented a blockchain lab to provide a platform for users to explore and practice various concepts of blockchain. This online lab, called Dinari, was implemented using Ethereum blockchain and was hosted on a cloud server. Experiments were conducted to verify the performance of the developed lab. Results from the experiment show that the platform gives an average transaction processing time of 15.17 seconds. The processing times were within an acceptable range of performance when compared with other online platforms, such as Mainnet and Kovan that provide average processing times of between 8.8 seconds and 18.3 seconds. The study can be scaled up in future to deploy more use cases, including health, in addition to the existing payment use case.

Keywords

Blockchain Lab

Digital currency

Dinari Platform

1. Introduction

Blockchain has attracted global attention of businesses, governments, and researchers for its promising applications in a wide range of fields [1]. In business, the interest in blockchain applications is evidenced by the total wealth accumulated in blockchain based crypto assets, which was worth around 1.185 Trillion USD as of March 2023 [2]. In research, blockchain has significantly impacted the scholarly community. For instance, the number of papers indexed by Web of Science database has increased from two papers in 2013 to two thousands and seven hundreds (2,700) in 2020 [1]. The number of citations has also grown rapidly in the period, from only eight in 2014 to about thirty two thousands (32,000) in 2020 [1]. Significant blockchain research can be seen in several sectors, including health [3-5] energy [6,7] supply chain and logistics [8-10] agriculture [11, 12], and forestry management [13].

Despite the advances of blockchain technology globally, there has been little progress in adopting the technology in developing countries, including Tanzania [14]. Saif et al. [14] group factors for low adoption of blockchain technology in these countries. as technological challenges [15], governance challenges [16, 17], organizational challenges [18-20] and knowledge challenges [21]. Lack of knowledge on a new technology can limit successful adoption of the technology [21]. For the case of blockchains, it is the major challenge for hindering blockchain implementation in developing countries [21]. The lack of knowledge includes total lack of familiarity about a technology, partial or insufficient knowledge about the technology, or lack of skilled and knowledgeable professionals to implement the technology [21]. The objective of this study was to develop and test the performance of a blockchain lab that can be used for learning and practicing the concepts of blockchain technology in Tanzania.

Blockchain can be defined as a public ledger that sequentially records transactions among users operating within a decentralized peer-to-peer network [22]. The term blockchain came to the mainstream after being used in a white paper titled "Bitcoin: A Peer to Peer Electronic Cash System" [23]. The first application to be deployed on a blockchain was Bitcoin, a digital currency that has found wider acceptance and popularity. The success of Bitcoin has accelerated the deployment of blockchain in sectors beyond digital currency [22]. There are three types of blockchains categorized based on the permissions available for users to join a blockchain network. The categories are public blockchains, private blockchains, and consortium blockchains [22]. Public blockchains, also called permissionless blockchains, are the ones that any user can join and participate in the network [24]. Private blockchains, also called permissioned blockchains, are owned by a person or organization that governs the network, giving permission to users who are allowed to access data and participate in the maintenance of the platform [24]. Consortium blockchains, also called federated blockchains, are owned by multiple organizations sharing the responsibilities of maintaining the blockchain [24].

Several blockchain laboratories have been set up on the Internet for users to learn and practice the concepts of blockchains. Most of these labs have been setup by universities to provide access to their students or by commercial entities to support e-learning courses. Some of these labs include Blockchain Lab (BC-Lab) set up at the Massachusetts Institute of Technology (MIT) for students to work on real-world projects that use blockchain technology and digital currency research (https://mitsloan.mit.edu/action-learning/blockchain-lab#tour-welcome). The Blockchain Technology Laboratory (BTL) based at the University of Edinburgh which is focused on distributed ledger technologies (https://www.ed.ac.uk/informatics/blockchain). The Arizona State University's Blockchain Research Lab (https://blockchain.asu.edu/). NC State University Blockchain Simulation Lab (https://www.ise.ncsu.edu/blockchain-simulation/) and Delft University of Technology Blockchain Lab (https://www.blockchain-lab.org/). Most of the labs that were visited have been set up by universities or commercial entities. Consequently, access is provided to either students and staff of the respective universities or to subscribed users for the case of commercial platforms.

2. Methods and Materials

The implementation of this study was broken down into two main activities. The first activity was to develop a blockchain system and host it on a cloud-based server. The second activity was to test the performance of the developed system by collecting and analyzing usage data. The methodology used for the development of the blockchain system was Rapid Application Development (RAD) where activities of requirements collection, system design and development were performed within short iterations. The tools used in this activity include Docker container, Docker compose, Geth Ethereum implementation, Nginx web server and PhP web development. In the second activity, experimentation method was used to verify the performance of the developed platform. During the experiments, users were exchanging transactions while measurements were collected and analyzed. The collected measurements were the time to process a transaction from sender to receiver (T). The following tools were used in this activity: MetaMask Ethereum wallet, Etherscan.io and Eth-net-stats.

The blockchain lab was implemented using Geth, an open source Ethereum implementation. The blockchain nodes were implemented using container technology. The containers were created using Docker platform on Ubuntu 20 Server operating system. The server was a cloud-based virtual private server (VPS) provided by Digital Ocean server hosting solution. The VPS specifications were CPU 4 vCPUs, 8GB RAM, 50GB SDD and network transfer limit of 5TB per month. The developed blockchain platform had six (6) nodes connected via a local area network. Of the six (6) nodes, the first two were boot and interface nodes, and the remaining four nodes were miner nodes. The boot node or bootstrap node is a lightweight node that was used to facilitate interconnection between nodes. The node was configured to listen port 30303; nodes joining this blockchain network were synchronized with each other via the bootnode. An interface node was set up to allow external interaction with the blockchain. In this study, external integration was needed for wallet and performance measurement integration. The interface node was configured to expose JSON-RPC API over HTTP endpoint on port 8545. Miner nodes were responsible for mining, verifying transactions, and creating new blocks.

A measurement platform was set up to collect data for evaluating the performance of the developed platform. Two tools were used, *Eth-Net-Stats* which was used to measure transaction processing time and number of transactions per block, and *Eth-Lite-Explorer* which gave detailed transactions information such as amount transferred. The measurement tools were deployed on the same subnetwork as the blockchain nodes. Eth-Lite-Explorer was set to collect data from the interface node via port 8545. Eth-Net-Stats was set to collect data by listening to all nodes via port 3000. Figure 1 shows the architecture of the blockchain lab.

3. Implementation

The deployment of the docker containers was done using the Docker Compose tool. Four files were created for deploying the blockchain network: *genesis.json*, *Dockerfile*, *.env*, *docker-compose.yml*. The contents of the files are described in the subsequent sections.

The genesis file provided blockchain with the necessary information for creating the first block, genesis block. The following *genesis.json* file was created:

```
{
    "config": {
        "chainId": 1983,
        "homesteadBlock": 0,
        "eip150Block": 0,
        "eip155Block": 0,
        "eip158Block": 0,
        "byzantiumBlock": 0,
        "constantinopleBlock": 0,
        "petersburgBlock": 0,
        "ethash": {}
    },
    "difficulty": "1",
    "gasLimit": "12000000",
    "alloc": {}
}
```

Where:

config.chainId — this is the blockchain identifier

config.ethash — this specifies proof-of-work (PoW) as a consensus mechanism

The docker file was used for spawning a docker image from which containers running blockchain nodes were created.

This file was saved as *Dockerfile* with no extension:

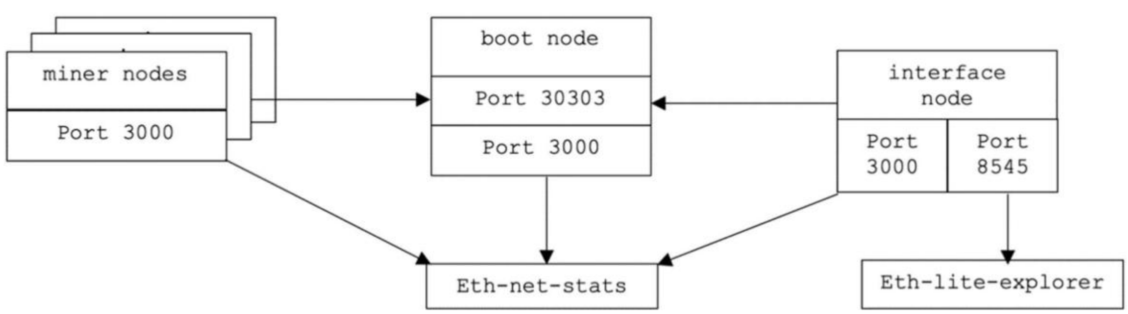

Figure 1: Blockchain Lab Architecture.

```
FROM ethereum/client-go
ARG ACCOUNT_PASSWORD
COPY genesis.json /tmp
RUN geth init /tmp/genesis.json \
  && rm -f ~/.ethereum/geth/nodekey \
  && echo ${ACCOUNT_PASSWORD} > /tmp/password \
  && geth account new --password /tmp/password \
  && rm -f /tmp/password
ENTRYPOINT ["geth"]
```

Where:

FROM instruct the file to use official Geth image from Docker Hub

ARG is an argument for account password which is set in .env file

COPY copies the *genesis.json* file into /tmp folder

RUN initiate the genesis block

ENTRYPOINT specifies default command when the container is executed

The *.env* file was used to store environmental variables used by *Dockerfile* and *docker-compose* files. The file content is shown below:

```
# The ID of Ethereum Network
NETWORK_ID=1983
# The password to create and access the primary account
ACCOUNT_PASSWORD=mypass23
# The netstat password
ETHNET_PASSWORD=mypass123
# The Subnet IP address
SUBNET_IP=10.10.10.0/28
#Node key for the boot node
NODE_KEY=59233b25bfa4c214a8713
e07a395a5d11478de10f36c6c80ba5369
541f73bc44
#eNode Id to be used by connected nodes
ENODE_ID=
enode://c636515b084e5dcfb39c0e00e3d
0dd5b5c4ba7c04d9a4adc3aad4eea6ab2
5561f0fa09fce119e2aebdcfa34d02a3c8f
551b814e31df6940fa937f16e0624fc40
```

The docker-compose.yml file was used to deploy the blockchain network based on the parameters defined in the *genesis*, *Dockerfile* and *.env* files. The content of the docker-compose file is described in APPENDIX. The four files were saved under */home/dinari/* directory in the hosting server. The command "*docker-compose up -d*" was run in the directory to run the docker-compose file. The docker-compose.yml file created nine (9) nodes as follows: one (1) webserver, two (2) monitoring dashboards, one (1) bootnode, one (1) interface node, and four (4) miner nodes. The webserver hosted a landing page on which users could access the blockchain infrastructure. The landing page is accessible through URL *https://dinari.co.tz*. Figure 2 shows the snapshot of the landing page.

The landing page consisted of web links to various pages, such as wallets, block explorers and statistics dashboard. Figure 3 shows a snapshot of the statistics dashboard.

Experiments were conducted by users exchanging transactions with each other using MetaMask blockchain wallet. The wallet was installed as a mobile app on users' smartphones and integrated to the Dinari platform using details below:

Network Name: *Dinari*
RPC URL: *https://dinari.co.tz/interface/*
Chain Id: *1214*
Symbol: *DNR*

Figure 4 shows snapshots of steps performed to send transactions using the Metamask app.

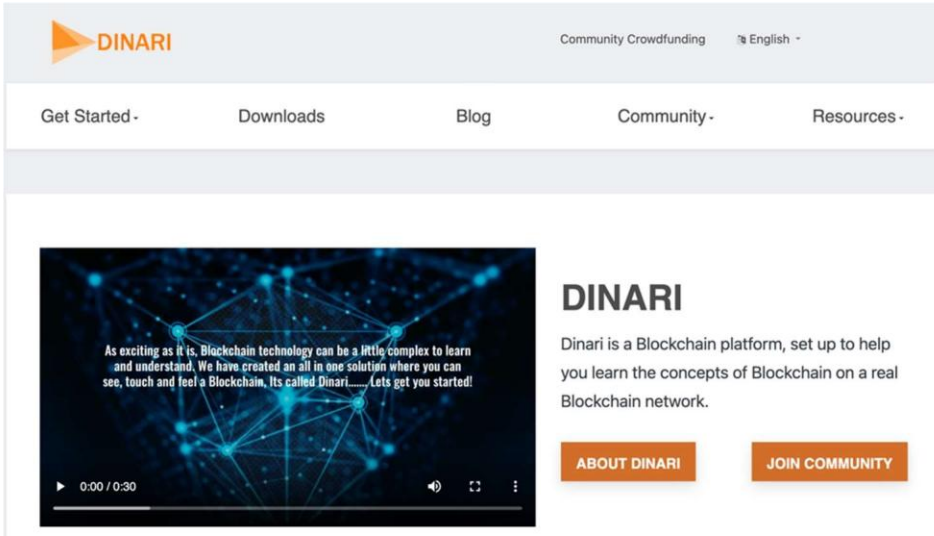

Figure 2: Snapshot of Dinari Landing Page.

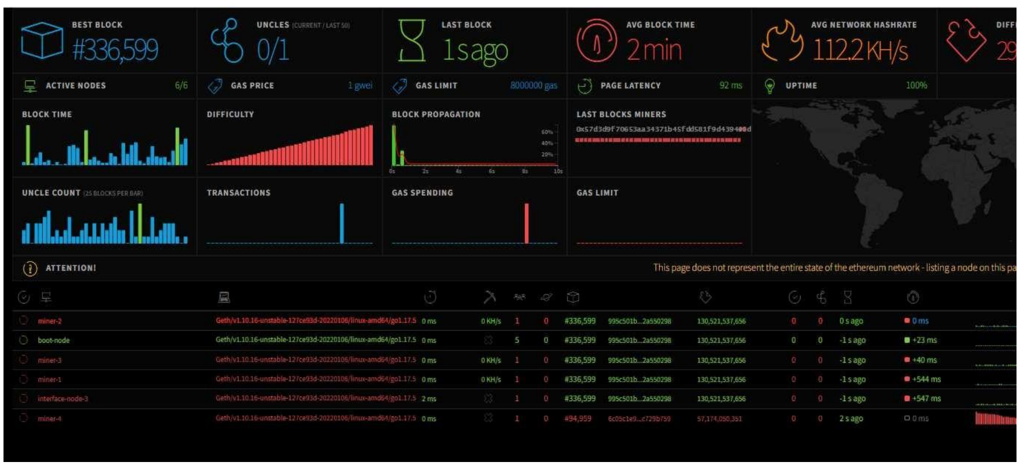

Figure 3: Snapshot of the Eth-Net-Stats Dashboard.

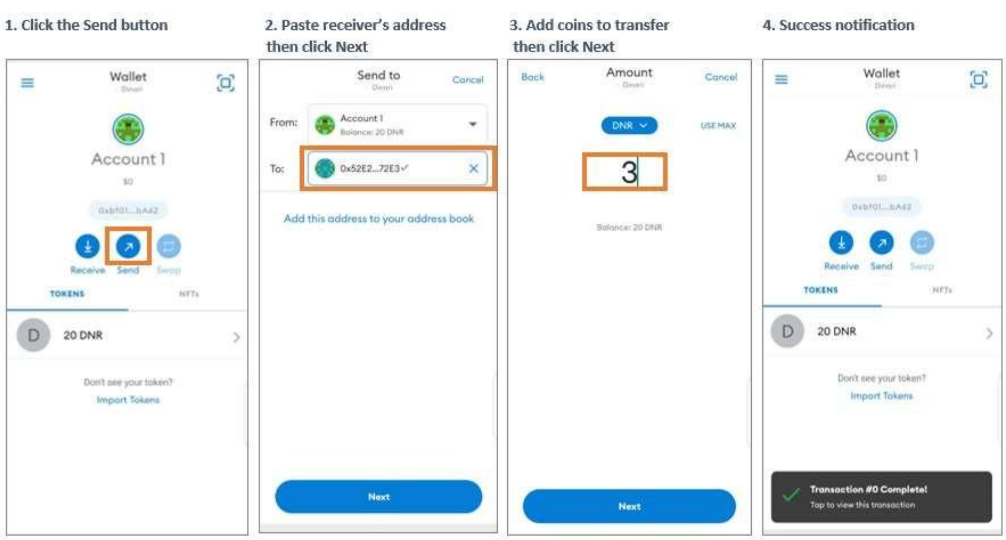

Figure 4: Snapshot of MetaMask App.

5. Results and Discussion

Transaction processing time measurements were recorded for the transactions that were exchanged over the blockchain network. Table 1 shows a summary of the recorded measurements.

From Table 1, the recorded transactions times had a minimum value of 1 second, maximum value of 55.34 seconds, and an average value of 15.17 seconds. The obtained results were compared with transaction times from other public Ethereum networks such as Mainnet, Ropsten, and Kovan. Table 2 shows the transaction times recorded from the other networks using Etherscan tool (etherscan.io).

From Table 2, it is seen that the transaction times recorded from the other public networks does not differ much from the times recorded from the Dinari platform. For example, Mainnet had an average transaction time of 11.1 seconds, Ropsten 8.8 seconds and Kovan 18.3 seconds; these results are within the same range with the average processing time of 15.2 secs recorded from Dinari.

Table 1: Sample Transaction Times.

Source Address	Destination Address	Amount (DNR)	Time (sec)
0x57D3D9f70	0x57D3D9f70	3	4.66
	0x18b1b0C33	4	3.34
	0xD2C2Da579	5	5.02
	0x1C4e874E7	3	2.00
	0xD0b8B4E2F	4	19.64
	0x9EB5801d7	5	1.00
	0x4B8945239	3	34.40
	0x1D5c4e6de	4	26.78
	0x44127fA35	5	4.14
	0x18b1b0C33	3	55.34
	0x899e80D59	4	10.52

Table 2: Transactions Times Comparison with Other Ethereum Networks.

Transaction times (sec)			
Dinari	**mainnet**	**Ropsten**	**Kovan**
4.7	6	16	20
3.3	2	2	17
5.0	6	14	19
2.0	3	1	17
19.6	33	3	19
1.0	1	13	17
34.4	9	9	19
26.8	9	14	17
4.1	37	7	19
55.3	4	16	16
10.5	12	2	21

Results from the comparison of the performance between Dinari against other public blockchains suggest that the developed platform is functioning within an acceptable range of performance and can, therefore, be used for learning and practice with an acceptable performance.

6. Limitation of the Study

The developed solution currently provides support for a single use case which is digital payments. Support for other potential use cases, such as health or governance, opens an area of further research.

7. Conclusion

This study aimed at developing an online and open access blockchain lab that can be used for learning and practicing the concepts of blockchains. The study also aimed at testing the performance of the lab for feasibility of public access and usage. To achieve its objective, a blockchain platform called Dinari was developed and published online for public access and usage. Experiments were done to collect data for verifying the performance of the developed platform. The measurements show that the developed platform was within an acceptable range of performance when compared with other public blockchain platforms. With its functionalities and performance, the lab has a potential to help users learn and practice concepts of blockchain. This advantage may stimulate the development of blockchain ecosystem in Tanzania.

CONTRIBUTIONS OF CO-AUTHORS

Anthony Kigombola	ORCID: 0000-0003-1838-5861	Wrote the skeleton of the paper and conducted experiments.
Mercy Mbise	ORCID: 0000-0002-7606-7231	Reviewed the paper, wrote introduction and methodology sections.
Prosper Mafole		Reviewed and formatted the paper.

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APPENDIX

docker-compose.yml file

```
version: '3.7'

services:
  webserver:
    hostname: webserver
    image: nginx:latest
    ports:
      - "80:80"
      - "443:443"
    volumes:
      - backup:/usr/share/nginx/html
    networks:
      priv-eth-net:

  netstats:
    hostname: netstats
    environment:
      - WS_SECRET=${ETHNET_PASSWORD}
    image: kamael/eth-netstats
    ports:
      - "3000:3000"
    networks:
      priv-eth-net:

  eth-explorer:
    hostname: eth-explorer
    environment:
      - APP_NODE_URL=http://server-ip:8545
    image: alethio/ethereum-lite-explorer
    ports:
      - "8090:80"
    networks:
      priv-eth-net:

  bootnode:
    hostname: bootnode
```

```
    env_file:
      - .env
    image: geth-client
    build:
      context: .
      args:
        - ACCOUNT_PASSWORD=${ACCOUNT_PASSWORD}
    command:
      --nodekeyhex=${NODE_KEY}
      --nodiscover
      --ipcdisable
      --networkid=${NETWORK_ID}
      --ethstats boot-node:${ETHNET_PASSWORD}@netstats:3000
    networks:
      priv-eth-net:

  interfacenode:
    hostname: interfacenode
    env_file:
      - .env
    image: geth-client
    depends_on:
      - bootnode
    command:
      --bootnodes=${ENODE_ID} @bootnode:30303
      --allow-insecure-unlock
      --http
      --http.addr="0.0.0.0"
      --http.port=8545
      --http.api="eth,web3,net,admin,personal,miner,txpool,rpc"
      --http.corsdomain="*"
      --networkid=${NETWORK_ID}
      --ethstats interface-node:${ETHNET_PASSWORD}@netstats:3000
    ports:
      - "8545:8545"
    networks:
      priv-eth-net:

  miner1:
    hostname: miner-1
```

```
    env_file:
      - .env
    image: geth-client
    depends_on:
      - bootnode
    command:
      --bootnodes=${ENODE_ID} @bootnode:30303
      --mine
      --miner.threads=1
      --networkid=${NETWORK_ID}
      --ethstats miner-1:${ETHNET_PASSWORD}@netstats:3000
    networks:
      priv-eth-net:

  miner2:
    hostname: miner-2
    env_file:
      - .env
    image: geth-client
    depends_on:
      - bootnode
    command:
      --bootnodes=${ENODE_ID} @bootnode:30303
      --mine
      --miner.threads=1
      --networkid=${NETWORK_ID}
      --ethstats miner-2:${ETHNET_PASSWORD}@netstats:3000
    networks:
      priv-eth-net:

  miner3:
    hostname: miner-3
    env_file:
      - .env
    image: geth-client
    depends_on:
      - bootnode
    command:
      --bootnodes=${ENODE_ID} @bootnode:30303
      --mine
```

```
      --miner.threads=1
      --networkid=${NETWORK_ID}
      --ethstats miner-3:${ETHNET_PASSWORD}@netstats:3000
    networks:
      priv-eth-net:

  miner4:
    hostname: miner-4
    env_file:
      - .env
    image: geth-client
    depends_on:
      - bootnode
    command:
      --bootnodes=${ENODE_ID} @bootnode:30303
      --mine
      --miner.threads=1
      --networkid=${NETWORK_ID}
      --ethstats miner-4:${ETHNET_PASSWORD}@netstats:3000
    networks:
      priv-eth-net:

networks:
  priv-eth-net:
    driver: bridge
    ipam:
      config:
      - subnet: ${SUBNET_IP}

volumes:
  backup:
```