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Smart Contract and IPFS Decentralized Storage for Halal Certification Process

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***Abstract*—The halal industry today has achieved rapid development. Halal product is mandatory for Muslims and a big business for Indonesia. For others, it affirms the product's quality assurance and becomes a trending lifestyle. The product owner must submit an application and undergo several processes to obtain a halal certificate. However, there are challenges in the certification process and documentation. The proposed system automates the flow between certification processes through digital signing and stores the certificate and fatwa file. The study investigates the utilization of blockchain to manage the process and the integration of decentralized storage (IPFS) to store the digital version of the fatwa and certificate. A smart contract is designed and deployed on the Ethereum blockchain, and the transaction time and cost are analyzed. A smart contract enforces that certain actions are executed once the required conditions are fulfilled. The proposed system would cost 24.6 USD and require 227 seconds on average for the system setup. Each submission requires 9.86 USD and takes 92 seconds on average. Verification is free, and the average result can be obtained in one second. The appointed officer sets each entity to interact with the contract, and the digital documents (fatwa and certificate) are available online using IPFS. Progress of the certification is transparent to the public, increasing the public's trust. The study demonstrates a smart contract's capability to manage a product's certification process.**

***Keywords*— Halal product; certification process; smart contract; IPFS.**

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I. Introduction

Most communities or religions have a certain set of rules as a guideline for life. Jewish law describes foods permitted to be used as ingredients and to eat, also known as "kosher" [1]. Islamic law has similar dietary laws, which regulate how food is distinctively originated, processed, and prepared, so consuming is permissible. This law is widely known as "halal". As a confirmation that food has been originated and processed according to the law, a halal certification may be conducted by government authorities [2], Islamic councils [3], or non-government organizations [4]. By Law No. 33 (2014), the halal certification is conducted by the government agency of the Ministry of Religious Affairs [5]. Nevertheless, the certificate is published based on the MUI's recommendation.

Halal-certified product is a big business. As a Muslim-majority country, Indonesia dominates the global halal product markets. Indonesian Central Bank (Bank Indonesia) reported that the domestic halal market in 2020 was worth US$184 billion In Indonesia, with a huge potential export to the US$1.9 trillion global market [6]. Today, the halal industry has achieved rapid development. Halal products for Muslims are mandatory needs. For others, it affirms the product's quality assurance and becomes a trending lifestyle [7]. During 2021, HPAA published 16,297 halal certificates [8], while Fig. 1 describes halal certificates published by MUI from 2012 to 2019 [9].

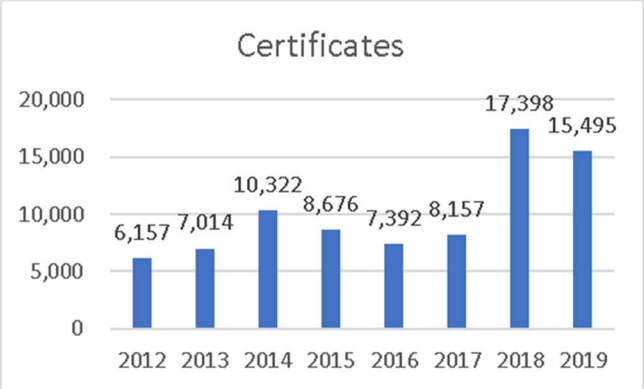

Fig. 1 Halal Certificate in 2012-2019

The current halal certification process has some challenges in the process flow and documentation, which become the focus of the research, as follows.

- The certification process flow needs to be more transparent to the public. Many product owners claim their products to be 'ongoing the certification process', but they have yet to apply to reality.
- The application and verification website is centralized and susceptible to attacks such as Denial-of-Service (DDoS) and phishing [10]. The current certificate provides a QR code that links to the website for certificate verification, but the website needs to provide detailed information.
- The certificate and fatwa documents are subject to forgery [11][12]. Today technology in digital manipulation software could easily change, for example, the certificate's expiration date or the product name.

The proposed system automates the flow between certification processes through digital signing and stores the certificate and fatwa file. The system utilizes smart contracts deployed on the blockchain and IPFS to trace the application process and audit publicly. Authorized signers are linked to a respective account, registered by authorized institutions, and enforced in an immutable contract. Later, transaction time and cost for each process are gathered and analyzed to measure the contract's performance.

Compared to previous research, the proposed research focuses on blockchain utilization through a smart contract in the halal certification process. It also uses an IPFS decentralized storage to archive the halal certificate, which the public can observe for visual verification. The proposed smart contract enforces integrity and transparency for each step in the certification process. This way, the blockchain, and IPFS provide a trustworthy system.

The rest of the paper is presented as follows. Section two describes the material and methods used in the proposed work and the previous research. Section three describes and discusses the findings. Section four draws the conclusion and possible future works.

II. Materials and Methods

This section describes the materials and method of the proposed work.

A. Related Works

Blockchain has been dubbed a disruptive technology in Industry Revolution 4.0 [13]. Blockchain has been implemented in numerous industries where traceability and data immutability are critical, such as in academics and education [14]–[16], management of hazardous material such as medical waste [17], drug traceability [18], and supply chain traceability [19]. There has been some research on blockchain and smart contract implementation in the halal industry. Chandra et al. [20] propose using blockchain in the halal supply chain to evaluate product ownership traceability. A similar concept was demonstrated by Hew et al. [21] and Tan et al. [22] with blockchain integration into Malaysia's food traceability system. Our previous work complemented the current research by focusing on a smart contract to record the hash of the fatwa and certificate, which also provides an online verification feature [23]. Since 2019, research in the Halal industry using blockchain technology is still at its infancy stage [24] but has increased over time, as shown by Yanti et al. [25] and Tasnim et al. [26]. The related works are summarized in Table I.

TABLE I
RELATED BLOCKCHAIN-BASED WORKS ON THE HALAL TOPIC

Authors	Year	Focuses
Chandra et al. [27]	2019	Examined halal product ownership tracking using Hyperledger Fabric
Hew et al. [21]	2020	Discussed the participation of all stakeholders and provided insights into the blockchain-based traceability system
Abidin et al.[28]	2020	The proposed conceptual framework for halal food product verification using blockchain
Tan et al. [22]	2020	Proposed conceptual framework to improve halal supply chain traceability
Novianti et al. [29]	2020	Proposed the design system that uses blockchain technology for tracing halal food status using a distributed system
Agung et al. [23]	2021	Proposed blockchain-based halal certificate recording and verification
Surjandari et al. [30]	2021	The Use of Hyperledger Fabric to design a blockchain network for the halal licensing process in the industry
Zulihuma et al. [31]	2022	Proposed the use of a smart contract to increase supply chain integrity in the halal food industry
Sumarliah et al. [32]	2022	research on the fashion industry's interest in systems that use blockchain technology to track halal fashion products
Proposed research	2022	Proposed blockchain-based smart contract to support halal certification process and decentralized storage for a digital certificate and fatwa files

B. Blockchain and Smart Contract

Someone introduced a blockchain called Satoshi Nakamoto in 2008, in which he proposed a platform for a digital cash system that could run without central authority[33]. A conventional digital cash system always relies on the central authority to clear the transaction and resolve disputes between parties. In most cases, the central authority becomes extremely powerful, and they could conduct misbehavior with little or nothing others can do. Examples include censorship, unilateral policy, sharing personal data, and data manipulation. Central authority also creates a single point of failure susceptible to a denial-of-service attack.

A blockchain can be treated as a database maintained by a community by computers connected to its network via the internet called nodes. Transactions are verified, and disputes are resolved in a consensus manner. In general, nodes can be categorized as such.

- Light/regular node, a computer connected to the blockchain network, can interact with the network, such

as initiating and validating transactions. In the proof-of-work consensus mechanism blockchain, validator nodes are called miners, while in the proof-of-stake consensus network mechanism blockchain, validator nodes are called stakers.

- A full node is a computer connected to the blockchain network replicating the blockchain files in its local storage.
- Masternode, a special node, acts as a verificatory and aims to manage, govern, and regulate the blockchain ecosystem. Masternode is eminent in proof-of-service consensus mechanism [34].

When a transaction is initiated, it is signed with the user's private key and then broadcasted to connected nodes in the network. Each node then validates the transactions, adds the new transaction to its memory pool, and broadcasts it to its peers. In a proof-of-work blockchain, a miner node picks the new transactions and solves the computational puzzle to compete with other miners to add its block candidate. After a block candidate from the winner miner is added, it is broadcasted to the network, and other full nodes update their blockchain.

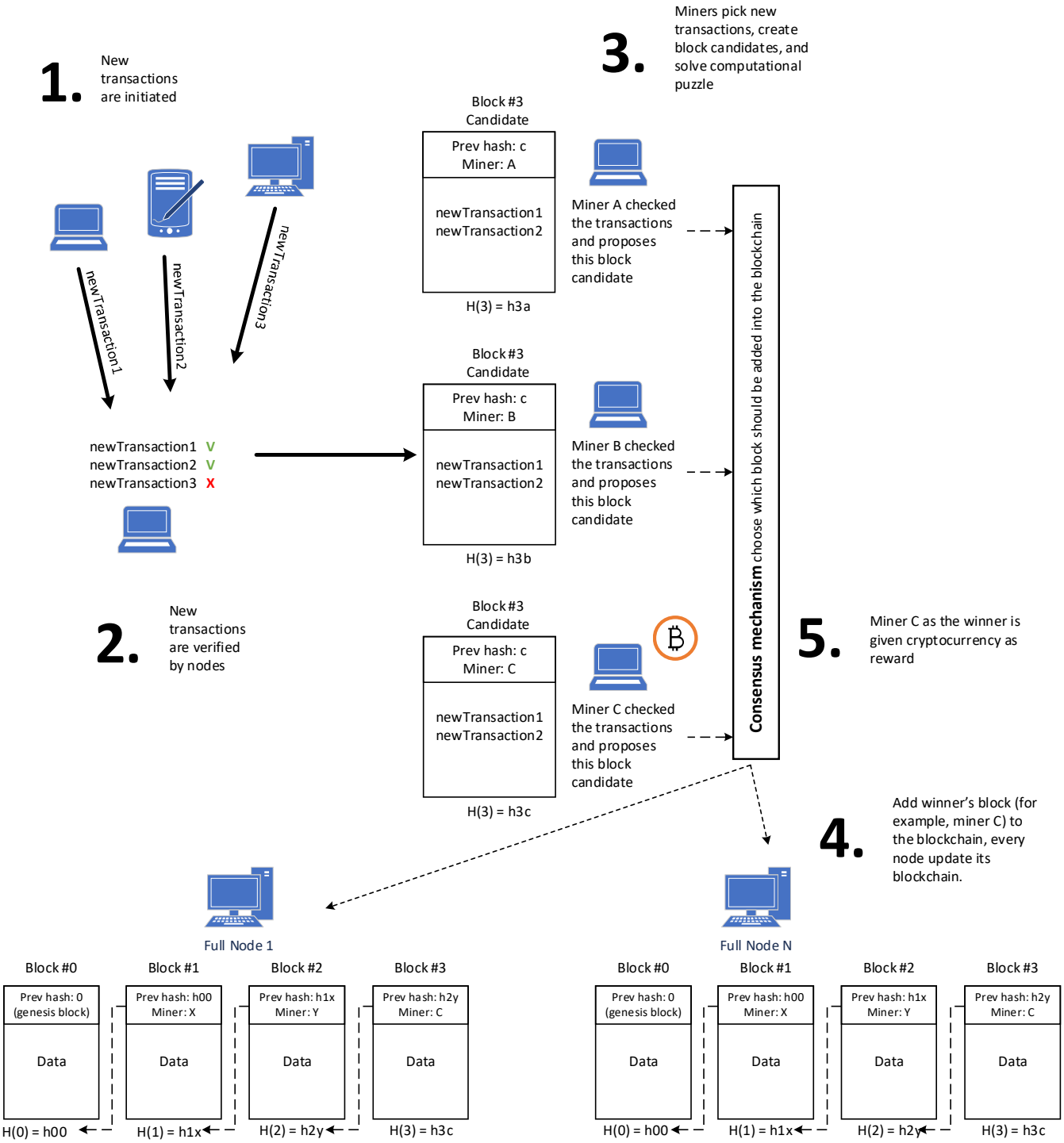

Fig. 2 How Blockchain Works

However, the mechanism will create a time gap between the initiated transaction and the mined data. Full nodes and miners play an important role in the blockchain ecosystem but invest heavily in hardware and computational devices. The operations of these nodes are also expensive [35]. Most blockchain ecosystems offer miners rewards to attract people to contribute as a node, and people using the blockchain must also pay a transaction fee. The process is visualized in Fig. 2.

Some blockchain can act like a touring machine and offer the capability to host and execute programs known as smart contract. The smart contract concept was proposed long before the blockchain as a small program executing predefined actions once the conditions are met [36]. However, the previous client-server architecture had limitations where the system owner (or the infrastructure owner) often had unlimited access to the system. Deploying smart contracts on the blockchain eliminates the problem since the system works in peer-to-peer mode, and any update to the contract requires consensus from the peers. Changing the data is also practically impossible since every node replicates the blockchain, and any modified attempt will be easily identified. The first blockchain, bitcoin, offers such limited capabilities, but until the Ethereum blockchain offers much more flexible and richer features, the era of Decentralized Applications (DApps) emerges [37].

C. *Inter-Planetary File System*

A file stored locally or in a server is susceptible to data corruption and loss. Unlike client-server online storage services, Inter-Planetary File System (IPFS) enables the user to store a file in a peer-to-peer mode across computers on the internet. To ensure the file will be available anytime, the document owner can pin the file on a local IPFS node or use the available remote pinning service [38].

D. *Halal Certification Business Process*

To acquire a halal certificate, the product owner applies through a website [39] managed by Halal Product Assurance Agency (HPAA) (Badan Penyelenggara Jaminan Produk Halal or BPJPH). According to the manual [40], there are seven subprocesses from the submission to the certification. The submitted application is then verified, and a registered Halal Audit Agency (HAA) (Lembaga Pemeriksa Halal or LPH) is assigned to conduct a series of tests to assess the product. The MUI then reviews the result, which declares whether the product is halal. If the product is declared halal, MUI will publish a decree, which will later be used as a consideration by HPAA to publish a halal certificate. The process normally requires a maximum of 97 days and can be extended to 117 days for domestic product, while foreign product requires up to 117 days and are extendible to 147 days [41]. The process is conducted sequentially, and the document generated in the previous subprocess is used in the subsequent process. However, the process in the application sequence is not observable to the public. The public could access MUI's and HPPA's websites for manual verification. However, the search result on the certificate is limited to product type, business owner, certificate number, certificate expiration date, and product name. The site can also not display or link to the certificate file.

E. *Proposed Work*

The proposed system utilized the Ethereum blockchain network as a platform for the smart contract and the IPFS network to store a digital file of the fatwa and certificate. All actors are connected to the system through the smart contract and act as a light node, while the Ethereum network provides full nodes. The proposed system architecture is visualized in Fig. 4.

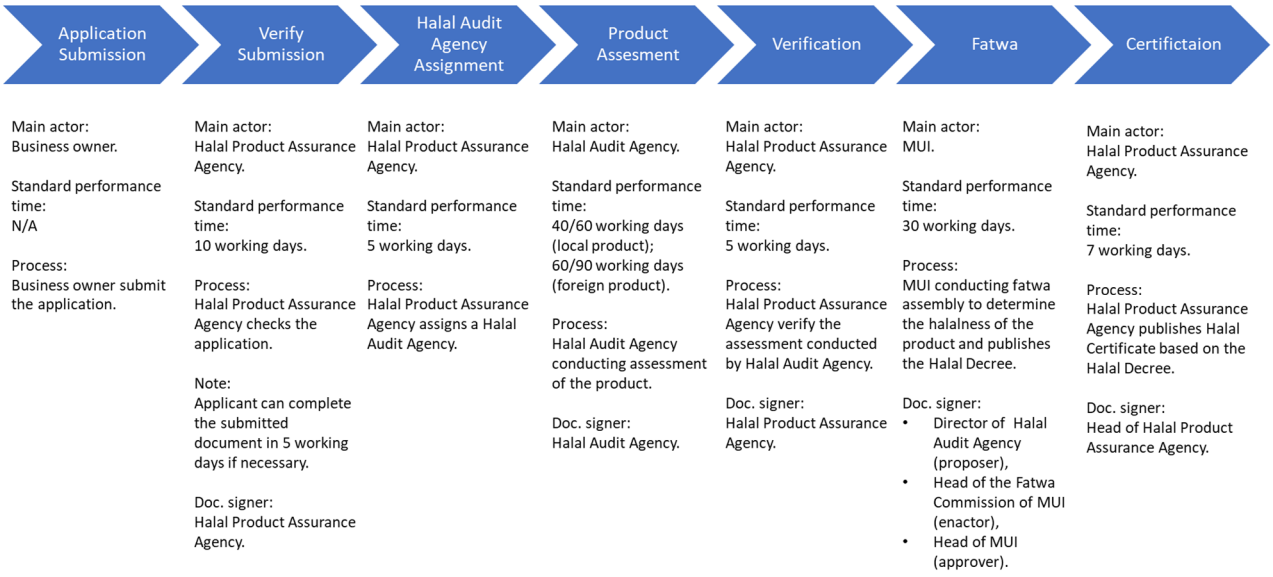

Fig. 3 Certification Business Process

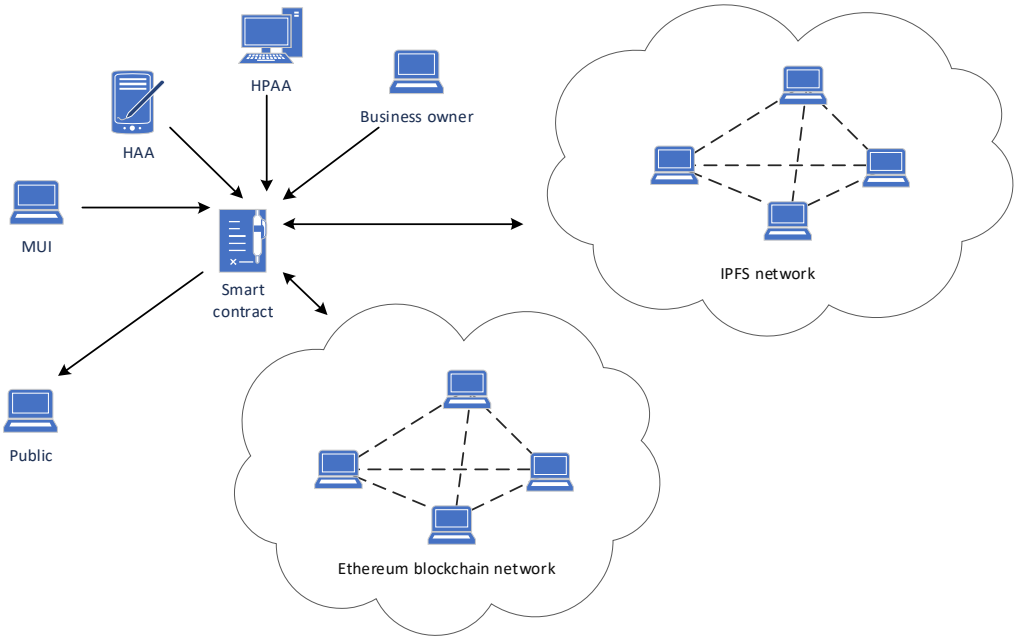

Fig. 4 Proposed Architecture

A smart contract is designed based on Fig. 3. The proposed research focuses on designing a smart contract to record the documents at each step and initiate the next process automatically after an authorized signer has signed the document in each subprocess. To achieve this, all actors directly involved with the contract should have an Ethereum address, and the transaction fee should be charged according to the network rates. The checking process, however, is free. The document files will not be saved directly into the blockchain to maintain lower costs. Instead, the digital copy of the document will be hashed, and the hash value will be saved, so instead of megabytes, only 64 characters of the hash will be saved for each document. The contract also provides two fields to store IPFS links to the digital copy of the fatwa and certificate. This feature is necessary since maintaining the digital file's exact form is quite difficult nowadays. The digital copy could go through digital transformation, such as compression, which is automatically applied by today's applications. Saving only the hash value in the contract will mark these files as fake because the transformation changes the hash value, as demonstrated by our previous research [23].

Fig. 5 describes the smart contract logic. It is designed so that once the submission document is declared complete, the process cannot be reverted until the final decision is declared. The submission will be reverted if it is incomplete and the business owner fails to complete it within the given period. Each process in Fig. 3 is mapped into a procedure in which the content can be modified only by an authorized entity. The submission status on every step is observable to the public for transparency.

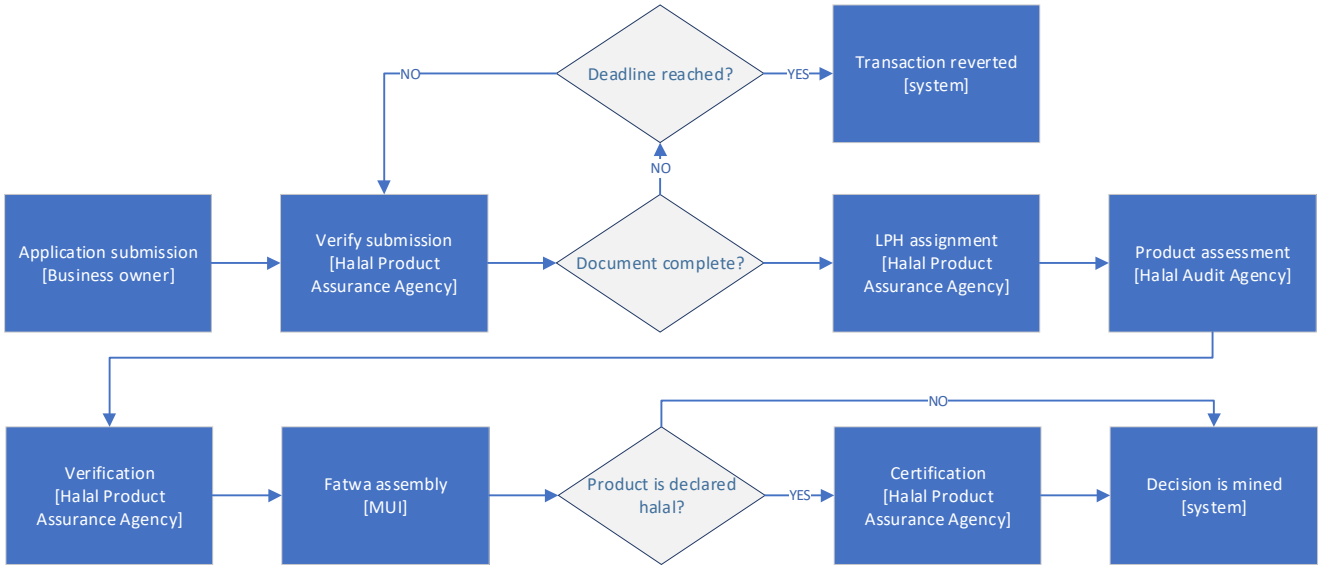

Fig. 5 Smart Contract Logic

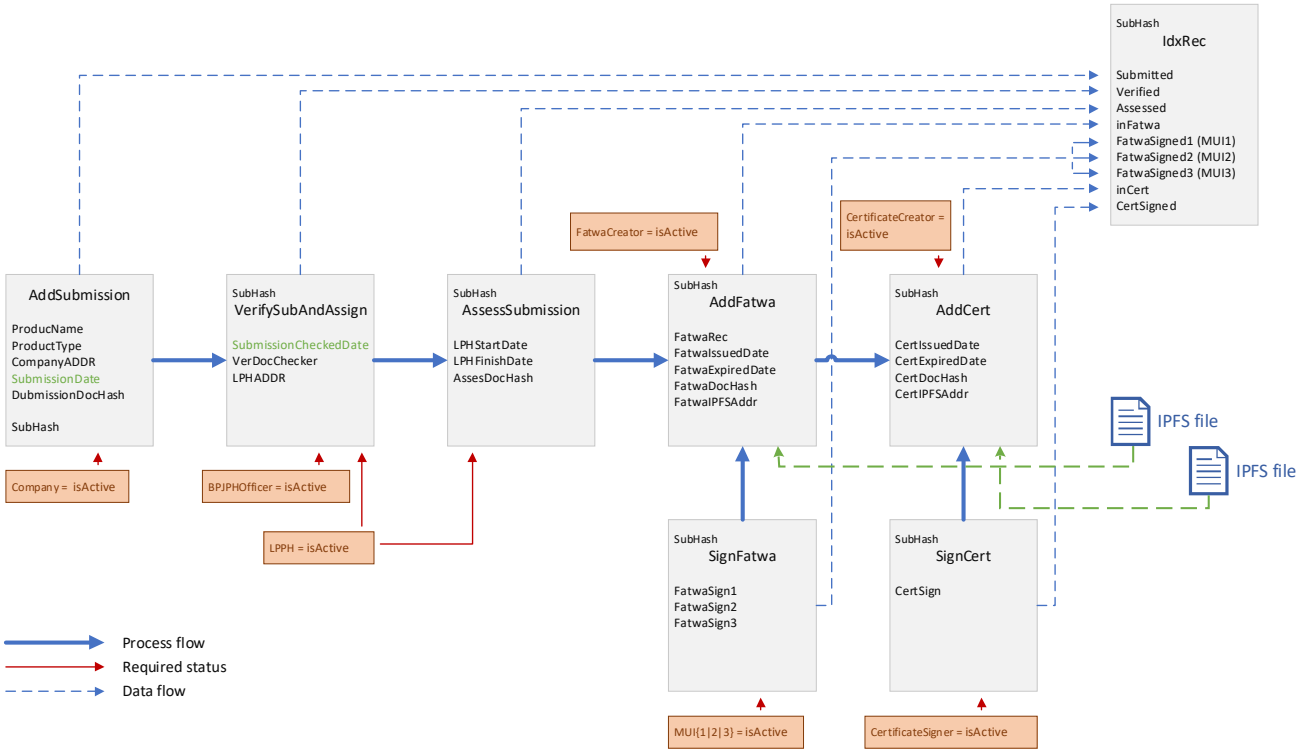

Fig. 6 Contract Logic

The smart contract consists of seven main functions, as described in Fig. 5. The status of the authorized entity for each function is set by the contract owner (in this case, the Halal Product Assurance Agency officer). The functions update the status in the IdxRec, which is accessible to the public. The smart contract automatically proceeds to the next function once the requirements are fulfilled. Below is the detailed process carried out by each function, as described in Fig. 6.

- AddSubmission. The function collects information about the product submitted by the product owner. The function also records the hash of the digital documents submitted to ensure the finality of the documents. The company should be listed as active by the government as a requirement.
- VerifySubAndAssign. After the submission, the HPAA officer will assign an HAA to assess the product further. However, should the officer find irregularities or incomplete documents, the officer can ask the product owner to complete the documents. Suppose the contract is still open for a specified period. In that case, the contract will automatically be closed (transaction reverted), and the product will be declared failed to complete the product submission. As a requirement, the function can only be executed by an appointed HPAA officer, and the HAA should be active.
- AssessSubmission. The assigned HAA conducted the product assessment and uploaded the results. The contract also stores the assessment documents hash to ensure the document's finality.
- AddFatwa. MUI conducts fatwa assembly to determine the status of the product based on the assessment result. The fatwa document is created and stored if it is declared as halal. Three MUI regional officers then sign the fatwa. The function also stores the fatwa document hash and IPFS address of the fatwa file.
- AddCertificate. After all the respective officer signs the fatwa, the certificate is created. The head of the HPAA is required to sign the certificate before it is declared final. The function also records the IPFS address of the certificate file.

III. Result and Discussions

The smart contract was deployed on the Ethereum blockchain and was executed to simulate the business process on May 17, 2022. The exchange rate of 1 ETH was approximately USD 2,988.40. The transaction time and cost were recorded and summarized in Table II. Fig. 7 shows a sample of the submission record and the submission status (IdxRec) derived from the smart contract. The result can be connected further with a web or mobile-based application to provide a better user experience.

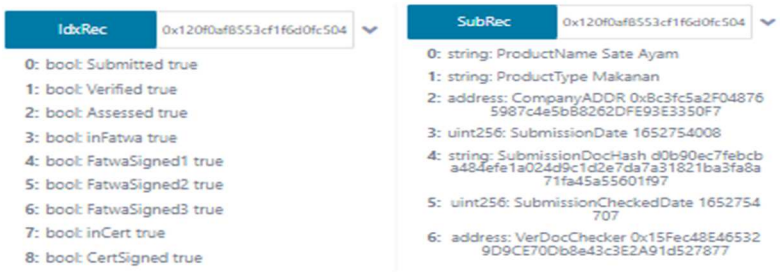

Fig. 7 Submission Record (left) and IdxRec (right)

TABLE III
TRANSACTION SUMMARY

No	Event	Action	Average Time (s)	Average Fee (ETH)	Average Fee (USD)
1	Contract deployment	One time action	5	0.007433533	22.21
2	Assign HAA	Repeat for every new HAA or to deauthorize HAA	15	0.000060175	0.18
3	Assign HPAA officer	Repeat for every new officer or deauthorize the officer	20	0.000065695	0.20
4	Assign fatwa creator	Repeat for every new officer or deauthorize the officer	20	0.000060688	0.18
5	Assign fatwa signer	Repeat for every new officer or deauthorize the officer	32	0.000093989	0.28
6	Assign certificate creator	Repeat for every new officer or deauthorize the officer	40	0.000060958	0.18
7	Assign certificate signer	Repeat for every new officer or deauthorize the officer	15	0.000060998	0.18
8	Create new submission	Repeat for every new submission	3	0.000633333	1.89
9	Verify submission	One for each submission	9	0.000348535	1.04
10	Product assessment	One for each submission	10	0.000363038	1.08
11	Create fatwa	One for each submission (if declared halal)	13	0.000464393	1.39
12	Sign fatwa	Three signers for each fatwa	9	0.000261986	0.78
13	Create certificate	One for each submission (if passed)	15	0.000471648	1.41
14	Sign certificate	One for each certificate	15	0.000236943	0.71
15	Verification	One for each certificate	1	0	0
16	Access to IPFS	One for each certificate	1	0	0

Table II shows that transaction time and cost are varied depending on the current network load. It is very hard to predict a transaction's exact time and cost. However, the data can be used as a reference to estimate daily transactions. Referencing the business process (Fig. 3) and the business process logic (Fig. 5), the process can be divided into three main activities.

- Contract initialization and preparation. This process includes deploying the smart contract and assigning the authority officers — the cost changes depending on the number of assigned persons responsible for the process. For a minimum, the process would cost 24.6 USD and need 227 seconds to execute successfully. The HPAA initiates the process, and the cost is deductible to its account. The time and cost needed to perform the activity are detailed in Equation 1 and Equation 2.

$$Time\ (s) = 5 + (Au_{HAA} \times 15) + (Au_{HPAA} \times 20) + (Au_{FC} \times 20) + (Au_{FS} \times 32) + (Au_{CC} \times 40) + 15 \quad (1)$$

$$Cost\ (USD) = 22.21 + (Au_{HAA} \times 0.18) + (Au_{HPAA} \times 0.20) + (Au_{FC} \times 0.18) + (Au_{FS} \times 0.28) + (Au_{CC} \times 0.18) + 0.18 \quad (2)$$

  Au_{HAA} indicates the number of HAA authorized to assess the certification; Au_{HPAA} indicates the number of HPAA officers; Au_{FC} indicates the MUI officer authorized to create the fatwa; Au_{CC} indicates the MUI regional officers authorized to sign the fatwa (three persons for each regional); Au_{CC} indicates HPAA officer authorized to create a certificate and finally the Au_{CSig} indicates the head of the HPAA.
- Processing submission. This process starts when the business owner creates a new submission and finishes when the certification results are published, or the owner fails to complete the submission. The process sequence handled by the smart contract requires 92 seconds and costs 9.86 USD per submission. Transaction initiators pay the cost; product owner (1.89 USD), HPAA (3.16 USD), HAA (1.08 USD), and MUI (3.73 USD).
- Verification. The public initiated the process to verify the fatwa and certificate document. The first verification method compares the hash value submitted by the user with the recorded hash value. The second is to manually compare the document provided by the user to the digital file saved in the IPFS. The average verification process time is one second, and it is free.

Blockchain and smart contracts can manage the process flow in the halal certification submission as a technology. Although the current client-server architecture system can be adjusted to characterize the proposed system, blockchain has several strategic values. First, it does not have a single point of failure. Data is replicated by nodes worldwide, so as long as the blockchain network exists, the data and contract will be accessible to everyone connected. Second, the contract is immutable, meaning every submission will be treated equally regarding administration and documentation. The immutability of the contract and the IPFS also help to eliminate the fake certificate and fatwa. Third, the submission progress is transparent and traceable. The features should build a strong foundation of trust for the people, especially Muslims and others who rely on the halal status of a product. Since nodes maintain the blockchain, companies, and governments also spend no maintenance or upgrade costs. The proposed research demonstrates that a smart contract

deployed on the blockchain can operate according to Indonesia's certification business process.

Although the transaction fee must be paid by the transaction initiator, in practice, it can be 'reimbursed' by sending Ether to the initiator. For example, the flexibility will benefit the government when subsidizing small and medium enterprises' products for halal certification. The smart contract, however, also has several limitations. First, the network determines the transaction fee, which fluctuates depending on the traffic. Second, the transaction time depends on the network condition, although the initiator can speed up the process by paying more.

The IPFS provides each file's link (content identifier or CID). After a file is uploaded, IPFS nodes will select and store a copy of the file in its node. So, while the CID is permanent, the file is not guaranteed to be permanently stored. To permanently stored the file, a file must be 'pinned', and the pinning service is not free. HPAA could install a node and pin the files locally as a solution. Other entities such as MUI, HAA, and the company could collaborate in pinning the files.

IV. Conclusion

The increasing trend in halal products requires a robust certification process management system. The current system provides a centralized application to submit and privately track the application process. However, many things could be improved with the current system. Consumers are more critical and demand transparent traceability in the certification process and easy access to the certification result. In the proposed system, a smart contract is combined with IPFS service to manage the submission of the halal certification and provide decentralized storage to store fatwa and certificate files.

However, pinning is required to store the certificate files in the IPFS permanently. A smart contract deployed on the blockchain inherits traceability, transparency, and immutability and provides a link to IPFS to store fatwa and halal certification permanently. Blockchain and IPFS network work in a decentralized fashion to eliminate the single point of failure, and peers replicate the data to ensure data availability when needed. As demonstrated by the research, the proposed system could resemble a solution to the current problem. The system acts as a trusted platform and runs on a public, decentralized system.

In the proposed system, assigning a person is conducted by a representative in the responsible body (for example, assigning fatwa signers conducted by an MUI officer). For better security, assigning a person can be set to a consortium approach, which requires any changes to be approved by a predefined portion or specified persons of the forum. The approach will require the contract to be updated and approved by the user.

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