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Framework for smart contract blockchain in halal traceability, integrity, and transparency

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ABSTRACT

Currently, the halal status of a product may only be determined by the halal certificate or halal label displayed on the product packaging. Simply put, several halal-related issues, like cross-contamination, logistical issues, halal counterfeiting, global halal acceptance, and so forth, keep coming up. To address the numerous issues raised above, it is believed that a framework that can support worldwide halal provisions is necessary. The objective of this research is to create a blockchain smart contract framework for halal transparency, integrity, and traceability. Blockchain technology along with smart contracts can solve classic tracing problems including data leakage, manipulation, and invisible data. Organizational consistency across the halal production process and the availability of raw materials that adhere to sharia laws are two more basic challenges with halal certification that blockchain and smart contracts can resolve. The usual traceability problems, such as data explosion, material cross-contamination between halal and haram, and revelation of private information, can all be resolved by smart contracts that make use of on-chain, off-chain, and electronic product code information services (EPCIS).

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1. INTRODUCTION

Halal is now regarded as an element of religious observance and a Muslim living standard. However, various halal-related concerns continue to arise, such as cross-contamination [1], logistical issues, halal counterfeiting, and so on [2]. Currently, the halal status of a product may only be determined by the halal certificate or halal label displayed on the product packaging.

The process of certification involves auditing, calibrating, assessing, testing, inspecting, and examining a standard to determine whether it has been satisfied (ISO-IEC 17067). The absence of globally acknowledged halal standards has hampered efforts to assure the integrity of Halal products [3]. As a result, the search for a consistent world-class halal standard to rigidify halal product certification has become critical [4].

Upstream to downstream halal traceability is a crucial step in meeting halal criteria. Halal traceability must ensure that the raw ingredients, supporting materials, and equipment utilized in manufacturing, processing, and distributing products are sharia-compliant. Regretfully, especially in Indonesia, only those conducting halal audits are qualified to declare an ingredient halal. Transparency of all these elements will boost public confidence in a product's halal status [5].

Due to its complexity, the halal supply chain is vulnerable to fraud and cross-contamination, two things that could jeopardize the integrity of halal products [1], [6]. The non-acceptance of halal certification bodies by one another and the absence of standardization in halal standards both add to the problems with inaccuracy and authenticity in the sector [2], [7]. These issues show that halal certification procedures need to be standardized to improve the traceability, transparency, and integrity of the halal supply chain.

With the recent introduction of blockchain technology, these modern difficulties confronting the halal compliance may be addressed and remedied [8]. End users can swiftly accomplish transparency, traceability, and integration of the halal supply chain as well as quality assurance by integrating blockchain technology into a halal compliance system [9]. Blockchain provides traceability features required in halal chains by allowing customers to verify item integrity, improve trust levels, and improve process efficiency [1] via smart contracts [10]. A mix of blockchain technology and smart contracts that aid in traceability, transparency, and integrity is required to assure confidence, reputation, and originality of halal supply chain items. This is possible in the blockchain-oriented software engineering (BOSE) domain [11]. BOSE is a concept that employs software engineering principles to create a more methodical, controlled, and quantifiable approach to blockchain-based software development.

This research provides a conceptual framework for halal traceability, integrity, and transparency based on blockchain and smart contracts in a software engineering framework by improving the halal supply and meat chains. This research uses blockchain-based smart contracts, global halal standards, and electronic product code information services (EPCIS) to resolve data explosion tampering and avoid disclosing sensitive information while ensuring traceability, integrity, and transparency [12]. It is envisaged that this will increase Muslim customer faith in the halal status of the product as well as acceptance by various halal certification bodies.

2. METHOD

Using cutting-edge methodologies in the software development process for blockchain is a problematic yet promising research project. Many issues must be considered while establishing a halal blockchain that can meet halal needs from upstream to downstream and is easy to trace, transparent, and integrated system of a product's halal status. The research methods utilized in this study are briefly described in Figure 1.

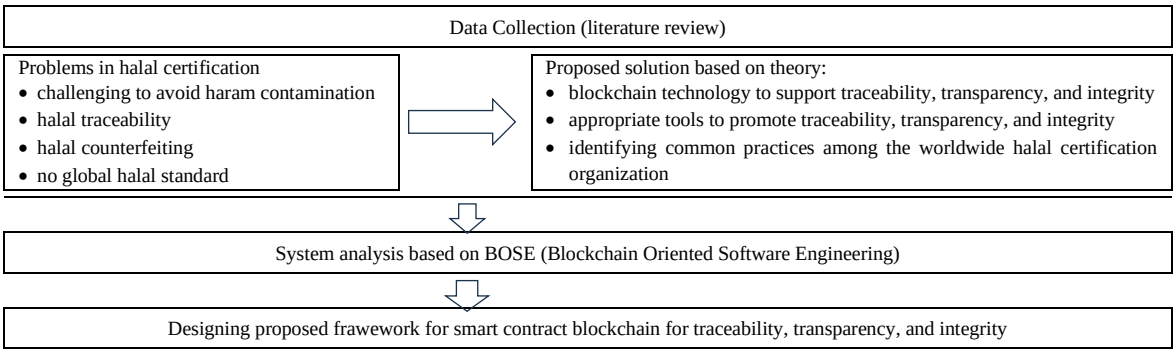

Figure 1. Research method

3. RESULTS AND DISCUSSION

3.1. Common global standards recognized by the Halal certifying body

To satisfy the wide range of customer demands and guarantee the traceability, integrity, and transparency of halal products on the international market, it is imperative to implement halal requirements and standards. The term halal requirements refer to several different elements pertaining to the preparation, manufacturing, and certification of items. These specifications are necessary to guarantee that the goods abide by the dietary regulations of Islam.

The general requirements for halal are further enhanced by the fact that various countries' halal certification bodies have their own standards and protocols for awarding certification. A comparative analysis method was be utilized to map the similarities between halal standards. This entails reviewing the literature on international halal standards and determining which halal standards are cited by Halal Certification Bodies

(HCB) in various nations. The basis for a proposed global halal standard can be formed by using this comparative analysis to find the shared clauses and commonalities among the various halal standards.

Halal certification from an approved halal institution is essential to certify whether these halal standards have been met. At least two halal standards must adopt the proposed common global standard. Simply said, HAS MUI 23000 (the Indonesian Council of Ulema's halal assurance system) will be applied if any provisions fall under the halal provisions of HAS MUI and are not found in any other halal standards. A proposed global standard is derived based on these provisions, as shown in Table 1.

Table 1. Global halal standard (modified from [4])

Aspect	Halal Standard	Source
	Material	
Origin of material	Products cannot be made from hazardous, poisonous, haram, or intoxicating substances	Global
Halal materials	Plants, animals (such as aquatic animals) that are halal, animals that have been slaughtered in accordance with Islamic law.	Global
Haram materials	The haram status of pig, *khamr* (intoxicant), blood, carrion, and non-compliantly with Islamic law slaughtered animal products, among other elements	Global
Alcohol	The *khamr* sector, which produces alcoholic beverages, should not produce alcohol.	Global
GMO material	Genetically modified organism (GMO) genes must not derive from *haram* materials	Global
Packaging material	No haram or dangerous material may be used to make packaging.	Global
Material document	Except for non-critical components, all materials must be accompanied by a certification proving their halal status.	Global
Material change procedure	Halal Certified Bodies (HCB) must approve the change of material to guarantee the new material is halal before using it.	HAS
Incoming material inspection procedure	A thorough examination of the material, including a review of the material's name, producer, and country of origin, is required to verify that it complies with HCB's approved materials.	HAS
	Product	
Product name	The product name should not persuade consumers to purchase haram goods.	Global
Sensory profile	The product's sensory profile should not result in haram items.	HAS
Packaging design/label	Label the product with the halal logo (optional).	Global
Brand of retail product	When it comes to retail products, registration is required for all items under the same brand that are advertised as halal.	HAS
Traceability	A facility free of *najis* (impure) must provide the traceability of certified items to guarantee they are manufactured from recognized sources. Materials that have been repackaged or relabeled as well as material code are included in traceability.	HAS
Handling of non-halal product	If non-halal products are supplied to customers who need halal products, they must be pulled from the market.	HAS
Legal aspect	Products have to abide by the law.	Global
Product testing	Testing halal ingredients for a certain product, like ethanol and pork	Global
	Facility	
Scope of facility	Equipment used for production, storing, moving, and serving	Global
Production facility	It has to be uncontaminated by *najis*.	Global
	Fulfill the standards for sanitation and hygiene.	Global
	The *haram* product and the halal facilities can be used interchangeably as long as the *haram* product is free of pork and cleaning is done before halal manufacture.	HAS
Production	Products are made utilizing *najis*-free halal ingredients and machinery.	Global
Storage and transportation	The halal facility may be used with haram products but must ensure no contamination of materials/ products by *najis* materials.	HAS
Display and serving	Facilities are free of *najis* contamination and solely focused on halal products.	Global
Converting non-halal facilities into halal facilities	Before producing halal, thoroughly clean the facilities that were contaminated by pork. It can no longer be used to make haram products after washing.	Global

Notes: HAS: Halal assurance systems

If a product satisfies the following requirements, it can be categorized as halal according to Table 1 provisions: i) it does not include any ingredients that are forbidden by sharia, ii) during production, shipping, and storage, halal and non-halal ingredients are never in contact, iii) halal materials must be used in the construction of all buildings, storage spaces, and packaging. Unless otherwise specified by a ban, which includes, among other things, alcohol, blood, pigs, and slaughter—all of which violate sharia law—all food is considered halal [13]–[16].

When applying for halal certification, the authorized halal certification organization must verify the information. The products, manufacturing facilities, additive materials, raw materials, halal assurance system, and all halal documentation listed in Table 2 will all be verified by this organization. This is to avoid the possibility of cross-contamination between halal and haram products, which can happen anywhere in the halal supply chain. An item's halal status must be confirmed by considering its whole supply chain, from the

procurement of raw materials to the point of distribution, and making sure that every stage conforms with Islamic halal requirements [17].

Table 2. Halal item verification (modified from [2])

No	Process	Verified Items
1	Suppliers	Halal raw materials
		Halal additive materials
		Halal packaging materials
2	Manufacturers	Separated machines and equipment for halal and haram products
3	Warehouses	Strict segregation between halal and haram products
		Adequate contamination control with haram products
4	Transportation	*Samak* (tanning) process is carried out after using trucks to transport non-halal meat.
		The separation between halal and haram meat
5	Wholesalers	The proper separation between halal and haram products
		Adequate contamination control with non-halal products
6	Slaughterhouse	*Samak* (tanning) process is carried out after slaughtering non-halal meat.
		The separation between halal and haram meat
		Do certain rituals before slaughtering.
7	Distributors	The proper separation between halal and non-halal products
		Adequate contamination control with non-halal products
8	Retailers	The proper separation between halal and haram products
		Adequate contamination control with non-halal products
9	LPH (Halal Supervisory Agency)	Halal raw materials
		Halal additive materials
		Halal packaging materials
		Halal list of product names
		Product processing documents
		Halal assurance system (HAS) document
		List of employees and their competence to HAS
10	BPJPH (Halal Certification Body)	List of recognized halal certification bodies (HCB)
		Country of origin of the product
		List of *madhhabs* (schools of law) followed related to halal practices or halal standards used.
		Halal certificate validity period
		Halal certification body that recognizes the product

3.2. Blockchain's necessity in the halal certification process

Cross-contamination in halal products is a result of inadequate raw material control. Sharia compliance and the provenance of a product can be confirmed using blockchain-based halal smart contracts [18]. Real-time recording and viewing of information are possible with blockchain technology. Transparency, traceability, and information sharing are made easier throughout the halal supply chain by blockchain. The provision of halal products and the incorporation of halal into all stages of the process, from procurement, transportation, and storage, to customer service and delivery, make up the halal supply chain [2].

Data explosion, trust transfer, and disclosure of sensitive information are a few of the crucial elements of system traceability on the blockchain that need to be looked at [12]. Data on the blockchain will explode, total system costs will rise, and query and data management performance will decline as data traceability improves. Collaborative data management for both on-chain and off-chain data handling is necessary to address the aforementioned problems [12]. Off-chain storage, typically on on-premises servers or the cloud, retains the majority of interaction process evidence and some traceability data off the blockchain. Operational support is the main purpose of on-chain data (e.g., to increase information dependability, provide information discovery, and so on). The issue of data explosion and privacy disclosure can be mitigated by putting this model into practice.

Unlike traditional software development, blockchain-based smart contracts are permanent, trustless, insert-only, and decentralized [19]. Therefore, one of the software engineering techniques available for BOSE [11], must be modified to obtain the unique qualities of the blockchain from traditional software engineering procedures. BOSE reduces paperwork and immutable records by combining software engineering and blockchain.

A smart contract integrates properties, functions, events, and modifiers without requiring middlemen [20]. Events signify the occurrence of specified statements, attributes represent storage variables, functions represent task execution, and modifiers represent actor authority. When it comes to halal issues, predetermined smart contract terms (such as the start of a product recall, the need for internal and external communication, information about halal permission, and so forth) cause automatic actions to be triggered. The time it takes to address halal issues is shortened by automated actions, which reduces reputational risk [8].

Blockchain technology guarantees that all participants can view all information stored in the blockchain and that all players as described in the smart contract can interact fairly, securely, and transparently [6]. For scalability, these contracts can be connected to Electronic Product Code Information Services (EPCIS) [21]. EPCIS could share event visibility pertaining to both digital and physical objects. Traceability and scalability in EPCIS require addressing four key events: *ObjectEvent, AggregationEvent, QuantityEvent*, and *TransactionEvent* [21]. Nonetheless, issues with data manipulation and information retrieval in EPCIS-based systems still require attention.

Distributed blockchain-based traceability solutions have the potential to mitigate traditional data tampering vulnerabilities. However, blockchain will face a number of difficulties with traceability, including data explosion, trust transfer, and other issues [12] Cross-contamination is a serious problem that compromises the integrity of the halal, as was previously mentioned [1], [22]. Consequently, a traceability system is an essential tool in the halal processing industry [23].

3.4. Proposed framework for smart contract blockchain in traceability, integrity, and transparency

The absence of an international halal standard for information exchanged among halal certification bodies is one major gap [24]. This leads to gaps in information and incompatibilities in terms of technology for data integration and sharing between companies [2]. To address this issue, a halal smart contract that incorporates a standard procedure acknowledged by several halal certifying bodies may be the answer.

Concerns about traceability, integrity, and transparency in halal-certified products are also brought up by the certification process [2]. Consequently, it is still imperative to have a system in place that can stop these problems. Integrity problems can be solved across the board, by implementing EPCIS. Through the tracking and tracing of halal products with unique identifiers, the EPCIS offer several benefits in terms of halal traceability. These benefits include improved communication and selective data export by facilitating information sharing among disparate partners across the supply chain network without compromising privacy and security [8], [18]. Yet, there are worries regarding the security and privacy of the data kept in the EPCIS system, since illegal access to the data in this technology could jeopardize the halal tracking system's integrity and jeopardize consumers' faith in the legitimacy and halal status of the offerings [6].

Off-chain and on-chain techniques can be used to get around EPCIS's shortcomings. In order to ensure the integrity of data, on-chain solutions are advantageous for keeping transparent and unchangeable records of that information [8]. By enabling stakeholders to monitor halal products throughout their whole lifecycle, on-chain solutions are especially helpful in improving traceability. This increases consumer trust in the halal supply chain and promotes transparency [18]. Off-chain solutions offer extra layers of validation and verification, which enhance on-chain technologies. Physical inspections, certifications, and audits by regulatory bodies and halal certification bodies, for instance, are essential off-chain processes that support the overall integrity of the halal supply chain [25].

3.4.1. Architecture of the system

The proposed smart contract blockchain and EPCIS-based architecture include the halal certification server and the traceability client. The halal certification server is built on the EPCIS architecture to collect and handle information about a product's key traceability. The halal traceability client, on the other hand, intends to search for halal product information regarding raw ingredients, methods, and anything else connected to a product's halal status. Figure 2 briefly explains the proposed architecture of the system design.

The halal certification server is made up of numerous modules, which are as follows:

- Module for capturing traceability information: This module obtains crucial traceability information related to the manufacturing process, storage, and circulation of products in the halal supply chain. It can be accomplished manually or by entering detailed occurrence data from the product cycle in the company's halal supply chain.
- Event information database: This database's principal function is to save and update information connected to the traceability information capture module.
- Module for information extraction: This module is made to take necessary data out of the database for traceability information. and prepare it for upload to the blockchain.
- Blockchain module: This module's primary function is data interaction, allowing users to become whole or lightweight blockchain nodes. The distinction is whether to participate in blockchain maintenance or not.
- Module to verify authority: It is the module's role to check corporate identification to ascertain whether any requester submitting a request for event information in the halal supply chain exists.

The halal traceability client is made up of two components, which are as follows:

- Blockchain module: This module handles the customer-system connection by requesting and confirming information on the blockchain. To cut down on maintenance expenses, these nodes are lightweight.
- Information cache database: the cache database stores and tracks information about the halal status of a product depending on user requests.

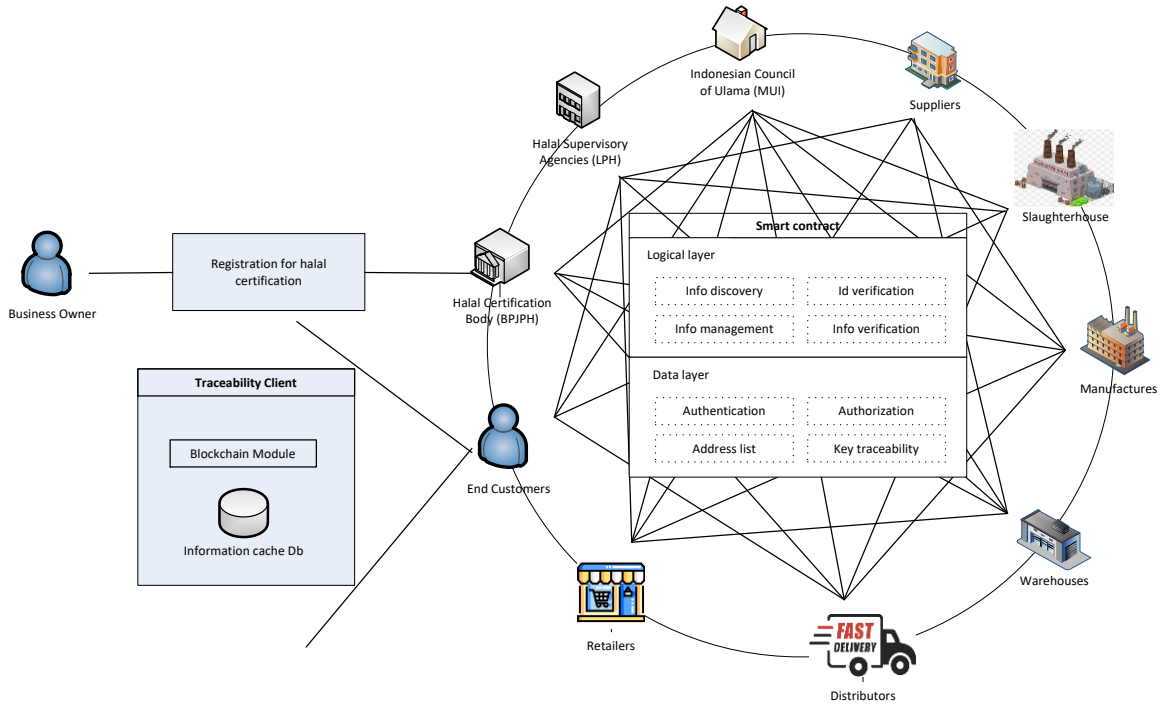

Figure 2. The proposed halal traceability system architecture

3.4.2. Design of the system

The system architecture intends to increase the performance of the blockchain system using off-chain and on-chain regulatory mechanisms. On-chain solutions are effective for maintaining transparent and unchangeable records, whereas off-chain solutions gradually increase the integrity and authenticity of halal products in the supply chain.

Most data interactions will occur outside of the blockchain. On-chain is used to help processes such as increasing information credibility and providing information discovery services. Thus, the problem of secret information exposure and data explosion can be resolved.

- Confidential information protection: visibility is one of the significant characteristics of a blockchain that offers equal access to all members. Much sensitive information should only be available to some members.
- Reducing blockchain data explosion: data recorded on the blockchain will continue to expand and amass, eventually resulting in a data explosion. It should be anticipated through data filtering, in which less fascinating data will be stored off the blockchain on local or cloud servers.

The following is an explanation of the model's unique mechanism:

- Off-chain: EPCIS is used to manage data off-chain. To define all operations throughout the halal chain, several types of events are used: i) product events, ii) trans events, iii) aggregate events, iv) ending events, v) transform events, and vi) transport events. Table 3 describes the role of each type of event.
- On-chain: To handle on-chain product data in the halal chain, the system makes use of smart contracts. Traditional key traceability information maintenance and administration necessitate attaching traceability information to detailed transactions in the blockchain system.

The smart contract structure is divided into logical and data layers to meet these requirements. The logical layer is in charge of i) allowing enterprise nodes to identify node addresses for halal chain items, ii) determining whether a node is included in the halal chain node list, and iii) the smart contract showing

public information to the consumer node, and iv) the smart contract must be capable of determining whether or not the requested event information has been processed.

Table 3. Type of event

Event name	Event type	Function of event
ProductionEvent	Bson	Maintain and manage event information in the production process
ProductEvent	Bson	Maintain and manage information in product processing
AggregateEvent	Bson	Maintain and manage the cumulative information created by the package in transportation.
EndingEvent	Bson	Maintain and manage end information of the product
TransEvent	Bson	Maintain and manage the transaction event information
TransformEvent	Bson	Recording pertinent event information in product processing

The smart contract's data layer contains the following information: i) proof of product authenticity in the halal chain; ii) proof of corporate identity in the halal chain of a specific product (company public key and appropriate address for the public key); iii) list of address index (IP address/URL of data location); and iv) primary traceability information. Traceability information will be found by: i) finding the smart contract that corresponds to the necessary data and ii) looking for traceability information within the contract data layer.

3.4.3. System data flow

Figure 3 shows the proposed data flow system.

a. Distribute data to the blockchain

The following describes the entire process of loading data into the blockchain:

- The certification applicant supplies a unique identification for each product (e.g., an RFID-assisted EPC code) and the accompanying event to be used as a traceability key. This traceability database is subsequently saved in a traceability information database in the cloud or a local server.
- The certification applicant extracts critical traceability information using the information extraction module and automatically generates transactions to smart contract A using the blockchain module. Transactions will be posted to the blockchain once the peer-to-peer (P2P) network has authorized them. This extraction includes information on product distribution to distributors and retailers.

b. Data interaction off-chain

The following is an example of off-chain data interaction:

- If a distributor or retailer wishes to know the status of a product, they may request by providing an identity code and the smart contract address. The smart contract will determine if it has access or not. If the smart contract is confirmed, it will display the server's address and handle the request.
- The smart contract will consider who asks for access (distribution or store). Once validated, the interaction authority management module will provide information based on the privileges granted to it.

c. Consumer inquiries

When consumers or the general public want to know if a product is halal, the fundamental approach is as follows:

- The consumer enters a product ID code or scans the QR code. BPJPH (Halal Certification Body) or LPH (Halal Supervisory Agency) must provide the identifying code in their inquiry.
- The smart contract will process the traceability on the on-chain and display the result if no identity is entered. On the other hand, if an identity is included, the smart contract will check the location of the product server and verify whether the identity has access rights to the server. All information will be displayed off-chain if done by BPJPH. On the other hand, the information shown is only limited to the authority granted by BPJPH if LPH carries it out.

d. Halal verification

When an LPH is tasked with determining the halal status of a product, the following procedures will be followed:

- Ensure daily halal assurance system (HAS) compliance.
- Laboratory testing must be performed to guarantee that no prohibited compounds are used.
- If meat is used as a raw material or as an additive, it must be assured that all growing, slaughtering, packaging, and distribution processes adhere to Islamic law.
- Ensure that halal and haram products are distributed separately. Assume the same transportation mode is employed for halal and haram transit. In that situation, it must be ensured that after the haram transportation track, it is tanned (Samak) or *istihalah* first.
- Ensure that there is a separate warehouse for storing halal and haram products.

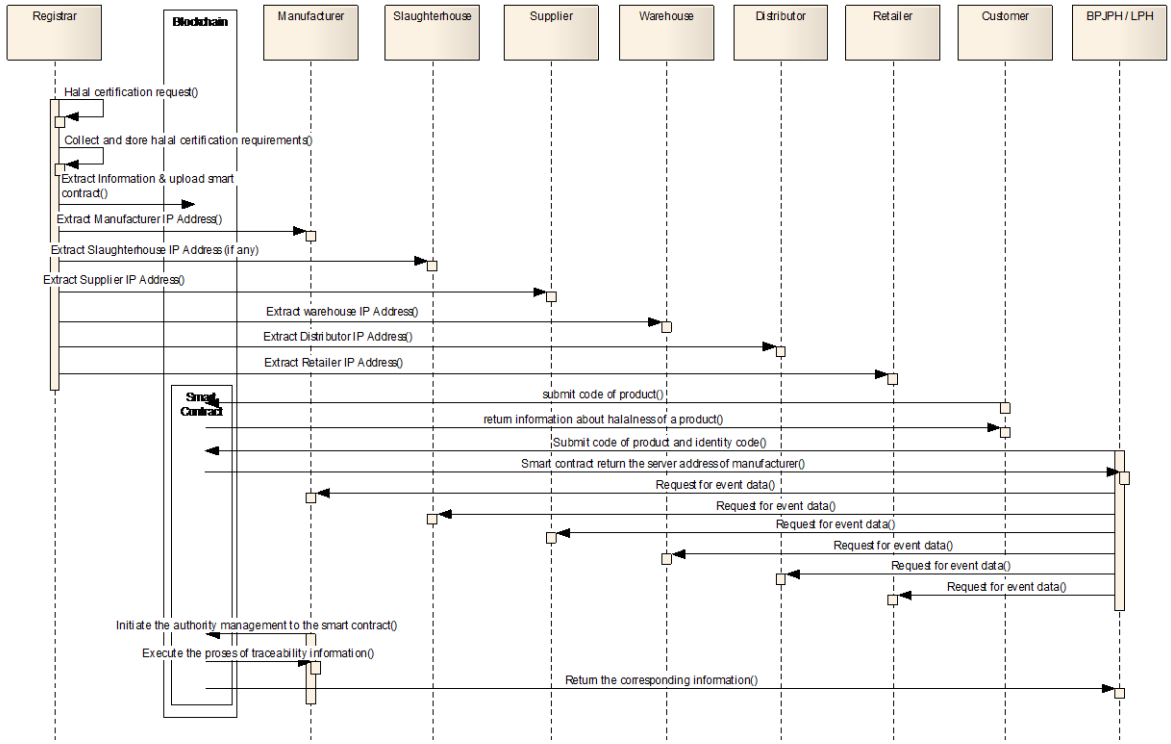

Figure 3. Data uploading process to the blockchain and how to trace the halal status of the product

3.5. Comparison between proposed framework with alternative framework

To be effective, the suggested framework needs to be contrasted with alternative frameworks. The benefits and drawbacks of one framework can be compared to others to determine where future improvements should be made. See Table 4 for more thorough explanation.

Table 4. Comparison the suggested framework with alternative frameworks

	Suggested framework	Blockchain based traceability system [26]	Blockchain technology in halal food product verification [2]
Using technology	Blockchain, smart contract, off-chain, on-chain	Blockchain, smart contract, off-chain, on-chain	Blockchain and smart contract
Halal standard adoption	Common procedures in global halal standard and halal assurance system (HAS)	MUI's standard	*Jabatan Kemajuan Islam Malaysia* (JAKIM's) standard
Development methodology adoption	Blockchain oriented software engineering (BOSE)	-	-
Further tools supported	EPCIS	Internet of things (IoT)	-
Coverage	Consumers, suppliers, slaughterhouses, manufacturers, warehouses, distributors, retailers, halal certification bodies	Slaughterhouse, abattoir, halal body, distributor, retailer, consumer	Consumers, suppliers, manufacturers, transporters, warehouses, wholesalers, distributors, retailers

4. CONCLUSION

Numerous concerns pertaining to halal, such as cross-contamination, logistical challenges, counterfeiting of halal, acceptability of halal globally, and so on, continue to arise. It is thought that a framework supporting global halal provisions is required to handle the many concerns mentioned above. The halal production process and the sourcing of raw materials that comply with sharia law can both be solved by blockchain technology and smart contracts.

In order to overcome several obstacles in the halal certification process, such as standardization, acceptability and recognition, transparency, and integrity, halal certifying authorities should adopt common procedures. To achieve optimal outcomes concerning halal traceability, transparency, and integrity, a blend

of smart contracts, off-chain, on-chain, and EPCIS can be employed. Transparency and halal compliance are two areas where EPCIS is helpful. Halal traceability and integrity are improved with the use of smart contracts. In the meantime, sensitive data is revealed to unapproved parties and less data is stored on the blockchain thanks to off-chain and on-chain technologies

More study is required to put the recommended framework into practice in one of the suitable programming languages. As a result, assistance and collaboration from all relevant stakeholders are required for halal certification. The goal is to boost acceptance at different global halal certifying bodies.

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