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# Development of Blockchain Model with BFT Algorithm for Halal Rating and Review System

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**ABSTRACT**

With the increasing demand for halal products around the world, there is a need for a system that can verify the halalness of products in a transparent and reliable manner. This research aims to develop a blockchain model that implements the Byzantine Fault Tolerance (BFT) algorithm for halal ranking and review systems. This research method involves creating a mathematical model of the BFT algorithm to ensure the integrity and security of review data and halal ratings of products. Blockchain is used as the underlying technology to ensure that every review and rating transaction is immutable and fully transparent. The BFT algorithm was chosen for its ability to achieve consensus in an environment that may contain malicious actors. The results show that the developed model is able to provide a transparent, secure, and reliable halal rating and review system. In addition, this model allows consumers to make more informed decisions regarding the halalness of products based on verified reviews and transparent ratings. The implementation of this system is expected to increase consumer confidence in halal products and encourage manufacturers to be more transparent in disclosing information about the halalness of their products.

## 1. INTRODUCTION

In recent years, the integration of blockchain technology into various sectors has gained significant attention due to its potential to enhance transparency, security, and efficiency in different processes. One area where blockchain has shown promise is in the realm of halal certification and traceability systems for food products. Ensuring the authenticity and compliance of halal products is of utmost importance to Muslim consumers worldwide. The use of blockchain technology offers a decentralized and immutable ledger that can provide a transparent record of the journey of halal products from production to consumption [1].

Recent advancements in BFT algorithms for blockchain have focused on improving efficiency and scalability, including surveys on consensus mechanisms [2] and optimized approaches like TV-BRAFT [3]. These developments are particularly relevant to halal traceability systems, where blockchain ensures the integrity of halal food information across the supply chain. By providing a tamper-proof method to verify halal status, blockchain technology fosters consumer trust [4]. The integration of BFT algorithms tailored for halal rating and review systems offers a novel approach to enhancing transparency and credibility in halal certification processes [5].

The BFT algorithm plays a crucial role in ensuring the security and reliability of blockchain networks, especially in scenarios where nodes may exhibit malicious behavior or fail to reach a consensus. Studies have shown that the integration of BFT algorithms, such as Practical Byzantine Fault Tolerance (PBFT), can significantly improve the performance and fault tolerance of blockchain systems, making them well-suited for applications like halal certification and traceability [6]. Moreover, the use of BFT algorithms in conjunction with other consensus mechanisms can further enhance the scalability and efficiency of blockchain networks, addressing key challenges related to communication complexity and consensus failure [7].

In the context of the halal industry, the adoption of blockchain technology presents opportunities for promoting value innovation and streamlining processes related to halal product traceability. By classifying blockchain adoption based on system complexity and the intensity of value innovation, organizations can tailor their strategies to leverage blockchain effectively in ensuring halal integrity across the supply chain [8]. Furthermore, the integration of blockchain with Enterprise Resource Planning (ERP) systems and smart contracts can offer a comprehensive solution for traceability, ensuring that halal products meet the necessary standards throughout their lifecycle [9].

As the demand for halal products continues to grow globally, establishing robust halal integrity management practices becomes paramount. Best practices in halal integrity management, supported by systematic literature reviews and data-driven insights, can guide organizations in implementing effective strategies to maintain the authenticity and compliance of halal products within the logistic chain scheme [10]. By leveraging blockchain technology and advanced consensus mechanisms, such as the Improved PBFT Algorithm, organizations can address the challenges of consensus efficiency and malicious behavior, thereby fortifying the integrity of halal supply chains [11].

In conclusion, the development of a blockchain model with a BFT algorithm tailored for halal rating and review systems represents a significant advancement in ensuring the authenticity and compliance of halal products. By integrating blockchain technology with robust consensus mechanisms and traceability systems, organizations can enhance transparency, security, and efficiency in the halal certification process. The adoption of blockchain in the halal industry not only fosters trust among consumers but also paves the way for innovation and value creation in the global halal market.

## 2. LITERATURE REVIEW

The research landscape on blockchain technology and its applications has expanded significantly, covering areas such as food traceability, security, privacy, consensus algorithms, and industry integration. For example, Lin et al. [12] emphasized the importance of consumers' intention to adopt blockchain food traceability technology for enhancing food safety. Similarly, Zhang et al. [13] discussed the significance of security and privacy in blockchain applications for establishing trust in open environments. These studies illustrate the diverse applications of blockchain technology, yet they also highlight the need for further exploration in specific contexts, particularly in the realm of halal certification.

While existing studies have explored blockchain applications in various domains, there is a notable research gap in developing blockchain models that incorporate BFT algorithms for halal rating and review systems. For instance, a study focused on a blockchain-based traceability system for the Indonesian halal supply chain did not specifically address the integration of BFT algorithms for halal rating and review systems [5]. This gap in the literature motivates the proposed study, which aims to enhance the credibility and transparency of halal certification processes through a tailored solution that integrates blockchain technology with BFT algorithms.

In contrast to previous research on blockchain applications in halal traceability, the proposed study uniquely focuses on developing a blockchain model that incorporates BFT algorithms specifically for halal rating and review systems. While prior studies have discussed blockchain for the traceability of Indonesian halal food, the emphasis on BFT algorithms for security and fault tolerance distinctly sets the proposed research apart [1]. Furthermore, a recent study on an optimized BFT algorithm for medical data security underscores the importance of such algorithms in ensuring secure data sharing, thereby reinforcing the relevance of BFT algorithms in halal certification systems [14].

Moreover, the proposed research stands out by concentrating on the integration of BFT algorithms tailored for halal rating and review systems. Although the study [15] has surveyed consensus algorithms in blockchain applications, they have not specifically addressed the development of a model for halal rating systems. By focusing on the unique needs of halal certification processes and leveraging BFT algorithms, the proposed study aims to fill this critical gap in the literature and advance the application of blockchain technology in ensuring halal product integrity.

In summary, the literature review showcases extensive research on blockchain technology across various domains, while simultaneously highlighting a significant gap in the development of blockchain models with BFT algorithms for halal rating and review systems. The proposed study seeks to address this gap by providing a specialized solution that enhances the credibility and transparency of halal certification processes through the innovative integration of blockchain technology and BFT algorithms.

## 3. METHODOLOGY

To develop a robust blockchain model with a BFT algorithm for halal rating and review systems, a systematic research approach will be employed. The methodology will draw on relevant literature and existing studies to inform the design and implementation of the proposed system.

Firstly, a comprehensive literature review will be conducted to gather insights from previous research on blockchain technology, halal certification, traceability systems, and BFT algorithms. Key studies [4, 12] on blockchain-based Halal traceability systems and on consumers' intention to adopt blockchain food traceability technology will be reviewed to understand the current state of the art in the field.

The research will then proceed to identify the specific requirements and challenges in developing a blockchain model with BFT algorithms for halal rating and review systems. Insights from study [16] on the development of halal logistics systems and the study [17] on halal food sustainability will be considered to address the unique needs of the halal industry.

Based on the literature review findings, the research will outline the conceptual framework for the blockchain model, detailing the integration of BFT algorithms, smart contracts, and traceability mechanisms tailored for halal products. The study [18] on the transformation of Halal awareness and blockchain technology in strengthening the Halal value chain will provide valuable insights into the conceptualization of the proposed system.

Subsequently, the research will focus on the technical implementation of the blockchain model with BFT algorithms. Studies [19, 20] on consumer adoption of blockchain food traceability and on scalable data storage strategies for permissioned blockchains will guide the technical design and development process.

The proposed methodology will also involve the design and testing of the blockchain model using simulation tools and real-world data to evaluate its performance, security, and scalability. Insights from studies [21, 22] on efficient consensus protocols for blockchain networks and on blockchain consensus mechanisms for distributed energy transactions will inform the testing phase.

Furthermore, the research will consider the implications of the proposed blockchain model on halal certification processes, supply chain transparency, and consumer trust. Studies [23, 24] on food fraud prevention using blockchain-based systems and on the digital Halal era will provide valuable perspectives on the potential impact of the research outcomes.

In conclusion, the research methodology will involve a systematic approach that integrates insights from existing literature, technical implementation of the blockchain model, and evaluation of its impact on halal certification and supply chain integrity. By leveraging the findings from reputable studies in the field, the research aims to contribute significantly to the advancement of blockchain technology in the context of halal rating and review systems.

### 3.1 Proposed approach

The novelty of this research lies in its application of advanced consensus mechanisms to the domain of halal certification, which traditionally faces challenges related to transparency, authenticity, and trust. By integrating BFT algorithms, the proposed blockchain model can withstand malicious attacks and ensure data consistency across the network, thereby enhancing the credibility of halal ratings and reviews. This innovative approach distinguishes the research by offering a technologically sophisticated solution tailored to the specific requirements of the halal industry.

The research framework for developing a blockchain model with a BFT algorithm for halal rating and review systems encompasses a structured approach to address the specific requirements of the study. This involves leveraging blockchain technology to enhance transparency, security, and credibility in halal certification processes. The framework will consist of several key stages to ensure a systematic and comprehensive approach to the research as shown in Figure 1.

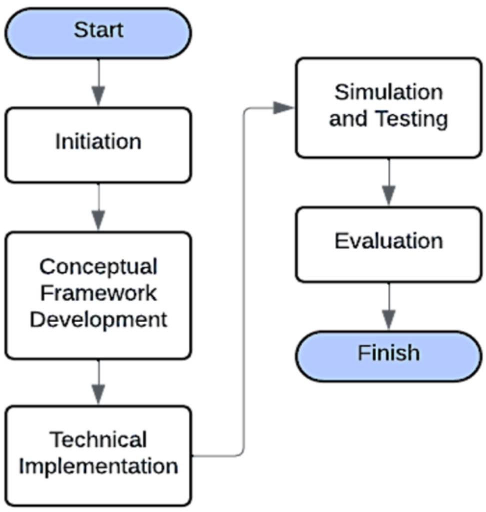


**Figure 1.** Flowchart of research stages

Based on Figure 1, it is explained that the stages of this research consist of five main things, namely:

**Initiation:** the initial stage involves conducting a thorough literature review to gather insights from existing studies on blockchain technology, halal certification, traceability systems, and BFT algorithms. Relevant studies [4, 25] on blockchain-based Halal traceability systems and on big data security frameworks will inform the theoretical foundation of the research.

**Conceptual framework development:** Building on the insights from the literature review, the research will develop a conceptual framework outlining the integration of blockchain technology, BFT algorithms, smart contracts, and traceability mechanisms for halal products. The study [26] on blockchain solutions for halal certification during the Covid-19 pandemic will guide the conceptualization of the framework.

**Technical implementation:** The next stage involves the technical implementation of the blockchain model with BFT algorithms. Insights from studies [23, 27] on food fraud prevention using blockchain-based systems and on the use of Proof-of-Work in permissioned blockchains will inform the technical design and development process.

**Simulation and testing:** Following the technical implementation, the research will focus on simulating and testing the blockchain model to evaluate its performance, security, and scalability. Studies [13, 28] on security and privacy on blockchain and on rapid consensus structures will provide valuable insights for testing the system.

**Evaluation:** The final stage involves evaluating the impact of the blockchain model with BFT algorithms on halal certification processes, supply chain transparency, and consumer trust. Studies [17, 29] on halal food sustainability and on a blockchain-based framework for smart tourism will guide the evaluation process.

### 3.2 BFT algorithm

BFT ensures distributed systems, particularly blockchains, can achieve consensus despite some nodes being faulty or malicious. By allowing a system to function correctly within a predetermined fault threshold, BFT is crucial for maintaining trust in decentralized environments [30].

BFT algorithms require at least 3f + 1 nodes to handle f faulty nodes, ensuring a majority can still achieve consensus [31]. These algorithms use iterative communication rounds where nodes propose, verify, and vote on values, allowing honest nodes to override faulty ones and maintain system integrity. This is especially critical in applications like cryptocurrency networks, where reliability and resistance to attacks are essential [32]. By utilizing cryptographic methods and robust protocols, BFT enhances resilience and trust in distributed systems [33].

### 3.3 Mathematical model of BFT

The BFT model is a fundamental concept in distributed systems, designed to ensure resilience against malicious or faulty nodes. At its core, BFT algorithms, such as the PBFT algorithm, are essential for achieving consensus in decentralized networks by effectively tolerating Byzantine faults. These algorithms are developed to solve the Byzantine Generals' Problem, a scenario in which nodes may behave arbitrarily and present conflicting information to one another.

To understand the mathematical modeling of BFT, we first define the system parameters. Let $(n)$ represent the total number of nodes in the network, and $(f)$ denote the maximum number of faulty nodes that the system can tolerate. A key requirement for BFT algorithms is that the number of faulty nodes must not exceed one-third of the total nodes, expressed mathematically as $(f < \frac{n}{3})$. This condition ensures that a majority of nodes remain honest, allowing the system to reach a consensus despite the presence of faults.

The consensus process in BFT algorithms typically involves multiple phases: proposal, voting, and commitment. During the proposal phase, a designated leader node proposes a value to the other nodes. In the voting phase, nodes communicate their votes on the proposed value. A value is considered committed if it receives votes from at least $(f < \frac{n}{3})$ nodes, ensuring that the decision reflects the agreement of a supermajority. This voting mechanism is crucial for maintaining the integrity of the consensus process, as it mitigates the influence of faulty nodes.

Research studies [34, 35] on the PBFT algorithm based on trust mechanisms and on consensus protocols in blockchain applications, emphasize the significance of BFT algorithms in ensuring the integrity and security of distributed systems. The evolution of BFT algorithms [36] illustrates ongoing efforts to enhance the performance and scalability of BFT consensus mechanisms.

Innovative approaches, such as the improved PBFT algorithm [9] and the optimized BFT algorithm [37], aim to address challenges related to communication complexity and consensus efficiency in BFT systems. The continuous development and optimization of BFT algorithms [38, 39] underscore the importance of robust fault tolerance mechanisms in ensuring the reliability and security of distributed systems.

Through advancements in BFT research, including the proposal of new consensus algorithms like MBFT [40] and GPBFT [41], the field continues to evolve, offering innovative solutions for achieving consensus in decentralized environments. These developments not only enhance the theoretical understanding of BFT but also pave the way for practical applications in various distributed systems.

## 4. RESULT

This section presents research results on the development of a blockchain model with BFT algorithm for halal rating and review system. The use of the BFT algorithm aims to ensure data integrity and system resilience.

### 4.1 Initiation

Based on the literature review, the application of the BFT algorithm in this research consists of a set of nodes that form a blockchain network. Each node has a database of reviews and a set of peer nodes. When a rater submits a new rating and review, it will be proposed to the network, and each node will verify the proposal using the BFT algorithm. If the proposal is valid, it will be added to the review database. The following is the component system for a halal rating and review system that uses the BFT consensus algorithm:

**Nodes**: A set of nodes that make up the blockchain network, responsible for storing and validating ratings and reviews.

**Raters**: Users who submit ratings and reviews for halal products/services.

**Review database**: A decentralized database that stores all ratings and reviews.

In the halal rating and review system, the interaction between nodes, raters, and the review database is crucial for maintaining the integrity and reliability of the ratings through the BFT algorithm. Raters initiate the process by submitting their ratings and reviews for halal products and services, which are then broadcast to the network. Upon receiving these submissions, the nodes—each maintaining a copy of the blockchain—engage in a consensus process governed by the BFT algorithm. This process involves validating the submitted reviews to ensure they meet the system's criteria and are not fraudulent or erroneous. Once a sufficient number of nodes agree on the validity of a review, it is added to the decentralized review database, which is distributed across all nodes. This architecture ensures that all ratings are securely stored and immutable, while the BFT algorithm allows the system to function correctly even if some nodes fail or act maliciously. Thus, the seamless interaction between raters, nodes, and the review database not only enhances the credibility of the halal rating system but also fosters trust among users.

### 4.2 Conceptual framework development

This section provides information on the development of the system model concept, rating, review and BFT algorithm. System model with n nodes, denoted by $N = \{1, 2, ..., n\}$. Each node $i \in N$ has a local review database, denoted by $D_i$. The system has a number of raters, denoted by $R = \{1, 2, ..., m\}$, who submit ratings and reviews for halal products. Furthermore, the rating and review model assumes that each rater $j \in R$ sends a rating $r_j \in \{1, 2, ..., k\}$ and a review $v_j \in \{0, 1\}^l$, where $k$ is the maximum rating and $l$ is the review length. Rating $r_j$ represents the halal rating of the product, and review $v_j$ represents the textual review of the product.

The BFT algorithm plays an important role in ensuring the integrity and consistency of the review database. The following is the working principle of the BFT algorithm:

**Proposal**: Rater $j \in R$ sends rating $r_j$ and review $v_j$ to node $i \in N$. Node i creates proposal p = $(r_j, v_j, i)$ and sends it to all other nodes in $N$.

**Verification**: Each node $k \in N$ verifies the proposal p using the verification function $V(p)$. The verification function checks the validity of the rating and review, and ensures that the proposal is not malicious.

**Vote**: If proposal $p$ is valid, each node $k \in N$ votes $v_k \in \{0, 1\}$ on proposal $p$. The vote function returns a vote $v_k$, where $v_k = 1$ indicates that the node accepts the proposal, and $v_k = 0$ indicates that the node rejects the proposal.

**Consensus**: Nodes in $N$ reach consensus on proposal $p$ using the consensus function $C(p)$. The consensus function returns a consensus value $c \in \{0, 1\}$, where $c = 1$ indicates that the proposal is accepted, and $c = 0$ indicates that the proposal is rejected.

Based on the working principle, the modelling of the BFT algorithm can use variables such as in Table 1.

**Table 1.** Variables of BFT algorithm

| Notation | Information |
|---|---|
| $P$ | The set of all proposals |
| $V(p)$ | The verification function, which returns *1* if the proposal $p$ is valid, and 0 otherwise |
| $F(p)$ | The voting function, which returns the vote of each node on the proposal $p$ |
| $C(p)$ | The consensus function, which returns the consensus value of the proposal $p$ |
| $D_i$ | The local review database of node $i$ |
| $R_i$ | The set of ratings and reviews stored in $D_i$ |

The mathematical model of the BFT algorithm goes through five equations. The first equation defines the verification function and checks the validity of the proposal as in Eq. (1).

$$V(p) = \{1 \text{ if } p \text{ is valid, } 0 \text{ otherwise}\} \quad (1)$$

The Eq. (1) defines the $V$ function, which takes a proposal $p$ as input and returns 1 if $p$ is valid, and 0 otherwise. In other words, $V(p)$ is a binary indicator of whether $p$ is valid or not. The {0 otherwise} part is a shorthand way of saying "if the condition is not true, then the value is 0". It's a common notation in mathematics and computer science. The second equation defines the vote function, which returns the vote of each node in the proposal as in Eq. (2).

$$F(p) = \{1 \text{ if node i receives } p, 0 \text{ otherwise}\} \quad (2)$$

This Eq. (2) defines the $F$ function, which takes a proposal $p$ as input and returns 1 if node i receives $p$, and 0 otherwise. The third equation is a consensus function that returns the consensus value of the proposal as in Eq. (3).

$$C(p) = \{1 \text{ if } \sum[i \in N] F(p) \geq (2n)/3, 0 \text{ otherwise}\} \quad (3)$$

This Eq. (3) defines the $C$ function, which takes a proposal $p$ as input and returns 1 if the consensus condition is met, and 0 otherwise. The consensus condition is met when the sum of the $F$ values for all nodes $i$ in $N$ is greater than or equal to $(2n)/3$, where $n$ is the total number of nodes. The fourth equation affects the local review database, which is the locally collected review data such as Eq. (4).

$$D_i = D_i \cup \{p\} \text{ if } C(p) = 1 \quad (4)$$

This Eq. (4) updates the set $D_i$ of proposals accepted by node $i$. If the consensus condition $C(p)$ is met (i.e., $C(p) = 1$), then $p$ is added to the set $D_i$. The fifth equation affects the set of ratings and reviews, which is a collection of data in the form of scores and reviews given by users as Eq. (5).

$$R_i = R_i \cup \{(r_j, v_j)\} \text{ if } C(p) = 1 \quad (5)$$

This Eq. (5) updates the set $R_i$ of responses received by node $i$. If the consensus condition $C(p)$ is met, then the response $(r_j, v_j)$ is added to the set $R_i$. These two equations will apply if the proposal is accepted according to the structure described in Eq. (4) and Eq. (5). As such, both equations have a direct impact on review data management and scoring.

### 4.3 Technical implementation

Here is a possible mathematical model in Solidity code based on the context provided as shown in Figure 2.

This contract defines a Consensus contract that implements the BFT algorithm. The contract has several functions:

**Verify:** simple verification function that returns true with probability 0.8.

**Vote:** A simple voting function that returns true with probability 0.7.

**Consensus:** A function that takes an array of proposals and returns the consensus value (0 or 1).

**Simulate:** A function that generates proposals from each rater, verifies and votes on each proposal, and returns the consensus value and the number of accepted proposals.

### 4.4 Simulation and testing

This section presents the results of testing the mathematical model through simulation with 50 trials. This test uses the following parameters.

**Number of nodes (n): 5**

In this simulation, there are 5 nodes in the system. These nodes can be thought of as individual computers or devices that are connected together to form a network. Each node can send and receive messages to/from other nodes. In the context of BFT, these nodes are responsible for agreeing on a common value or decision, despite the presence of faulty or malicious nodes.

**Number of raters (m): 2**

In this simulation, there are 2 raters. Raters are entities that provide ratings or evaluations for a particular item or service. For example, in a review system, users can rate products or services on a scale of 1 to 5. In this context, the 2 raters can be thought of as 2 users who are providing ratings for a particular item or service.

**Maximum rating (k): 5**

The maximum rating (k) is set to 5, which means that each rater can provide a rating on a scale of 1 to 5. For example, a rater might give a rating of 3 out of 5 for a particular product.

**Length of review (l): 10**

The length of review (l) is set to 10, which means that each review or rating provided by a rater consists of 10 characters or digits. For example, a review might be a short text string like "Excellent product!" or a numerical rating like "4.5/5".

**BFT algorithm:** simplified version with 2/3 majority consensus

```
// SPDX-License-Identifier: MIT
pragma solidity ^0.8.0;

contract Consensus {
    // Define the number of nodes (n) and the number of raters (m)
    uint public n = 5; // Number of nodes
    uint public m = 10; // Number of raters

    // Define the maximum rating (k) and the length of review (l)
    uint public k = 5; // Maximum rating value
    uint public l = 10; // Maximum length of review

    // Define the Byzantine Fault Tolerance (BFT) algorithm parameters
    uint public f = 2; // Number of faulty nodes
    uint public t = 2 * f + 1; // Threshold for consensus

    // Define the rating and review structures
    struct Rating {
        uint value; // Rating value
        string review; // Review text
    }

    // Define the proposal structure
    struct Proposal {
        Rating rating; // Associated rating
        uint nodeId; // ID of the node making the proposal
    }

    // Define the verification function
    function verify(Proposal memory proposal) public pure returns (bool) {
        // Simple verification function: returns true with probability 0.8
        return uint256(keccak256(abi.encodePacked(proposal))) % 10 < 8;
    }

    // Define the voting function
    function vote(Proposal memory proposal) public pure returns (bool) {
        // Simple voting function: returns true with probability 0.7
        return uint256(keccak256(abi.encodePacked(proposal))) % 10 < 7;
    }

    // Define the consensus function
    function consensus(Proposal[] memory proposals) public returns (uint) {
        // Initialize the votes counter
        uint votes = 0;

        // Verify and vote on each proposal
        for (uint i = 0; i < proposals.length; i++) {
            if (verify(proposals[i])) {
                if (vote(proposals[i])) {
                    votes++;
                }
            }
        }

        // Return the consensus value (0 or 1)
        return votes >= t ? 1 : 0;
    }

    // Define the simulate function
    function simulate() public returns (uint, uint) {
        // Initialize the proposals array
        Proposal[] memory proposals = new Proposal[](m);

        // Generate proposals from each rater
        for (uint i = 0; i < m; i++) {
            Rating memory rating = Rating(
                uint256(keccak256(abi.encodePacked(i))) % k + 1,
                string(abi.encodePacked(uint256(keccak256(abi.encodePacked(i))) % l + 1))
            );
            proposals[i] = Proposal(rating, uint256(keccak256(abi.encodePacked(i))) % n + 1);
        }

        // Calculate the consensus value
        uint consensusValue = consensus(proposals);

        // Return the consensus value and the number of accepted proposals
        return (consensusValue, proposals.length);
    }
}
```

**Figure 2.** Code of mathematical model

In other words, for a decision to be made, at least 2/3 of the nodes (i.e., 3 out of 5 nodes) must agree on the same value or decision. This ensures that even if some nodes are faulty or malicious, the system can still reach a consensus and make a decision. The 2/3 majority consensus is a common threshold used in BFT algorithms, as it provides a good balance between fault tolerance and system performance.

Note that the only differences between each simulation are the values of $R_i$ and $v_j$ in the last equation. These values are randomly generated for each simulation.

In each simulation, the BFT algorithm is used to reach a consensus among the 5 nodes, with a 2/3 majority consensus required for a decision to be made. The V, F, and C functions are used to validate proposals, track node reception, and determine consensus, respectively. The $D_i$ and $R_i$ sets are updated based on the consensus outcome. Here are the results of 50 simulations as shown in Table 2.

**Table 2.** The result of simulations

| No. | Simulation Address | Rater1 Rating | Rater1 Review | Rater2 Rating | Rater2 Review | Consensus Value | Accepted Proposals |
|---|---|---|---|---|---|---|---|
| 1 | 0x669a548981…B43ddffE96 | 4 | “Good product” | 3 | “Need improvement” | 1 | 2 |
| 2 | 0x26a8675D3f…D841d1714A | 5 | “Excellent product” | 4 | “Very good product” | 1 | 2 |
| 3 | 0x1006CEa2c8…0ABF94164F | 2 | “Poor product” | 1 | “Bad product” | 0 | 0 |
| 4 | 0x99d34F8485…e7ED382119 | 3 | “Average product” | 3 | “Average product” | 1 | 2 |
| 5 | 0x0A0c1aB0a0…6e6B4d7A4a | 4 | “Good product” | 4 | “Good product” | 1 | 2 |
| 6 | 0xBef7623EeE…D9ca4C7a552 | 5 | “Excellent product” | 5 | “Excellent product” | 1 | 2 |
| 7 | 0xA7C4E6aB06…25d4feb483 | 2 | “Poor product” | 2 | “Poor product” | 0 | 0 |
| 8 | 0x9de700A1f9…738FD25E01 | 4 | “Average product” | 4 | “Good product” | 1 | 2 |
| 9 | 0xc8DC7BF5Ad7…6247A94bB2 | 3 | “Good product” | 3 | “Average product” | 1 | 2 |
| 10 | 0xfA3EA866E6ac…09E5B3cCA05 | 4 | “Excellent product” | 4 | “Very good product” | 1 | 2 |
| 11 | 0x316cf23eab1976…dc779eA0f5E | 1 | “Poor product” | 1 | “Bad product” | 0 | 0 |
| 12 | 0xC7bc7C952Caf9…045776dE409 | 3 | “Average product” | 3 | “Average product” | 1 | 2 |
| 13 | 0x56f76F97Ef11aa8…fAC64E302b | 4 | “Good product” | 4 | “Good product” | 1 | 2 |
| 14 | 0xD65F529696E…d3DFd08eeE | 5 | “Excellent product” | 5 | “Excellent product” | 1 | 2 |
| 15 | 0x745AfDE68A1…28DECA00B8 | 2 | “Poor product” | 2 | “Poor product” | 0 | 0 |
| 16 | 0x70ce50F52D16a…b2D28f44b02 | 4 | “Average product” | 4 | “Good product” | 1 | 2 |
| 17 | 0x67C79819848…EDB8534500B | 3 | “Good product” | 3 | “Average product” | 1 | 2 |
| 18 | 0x5985674DdC29D…766a827dB7 | 4 | “Excellent product” | 4 | “Very good product” | 1 | 2 |
| 19 | 0x970291E97FBc…32825Ac1EA4 | 1 | “Poor product” | 1 | “Bad product” | 0 | 0 |
| 20 | 0x13d8C346935aA…ae7cdDcD96 | 3 | “Average product” | 3 | “Average product” | 1 | 2 |
| 21 | 0xeaE8Be6eC4b2…4Ea669D73E2 | 4 | “Good product” | 4 | “Good product” | 1 | 2 |
| 22 | 0x8c21e9bE1D072…5f67F216De6 | 5 | “Excellent product” | 5 | “Excellent product” | 1 | 2 |
| 23 | 0xDF06faD56c64b…B321B3C6d0 | 2 | “Poor product” | 2 | “Poor product” | 0 | 0 |
| 24 | 0x66aBC5Cb4…67FcB78Fac9c56 | 4 | “Average product” | 4 | “Good product” | 1 | 2 |
| 25 | 0xAf4f208B0d8D…045953f91D0 | 3 | “Good product” | 3 | “Average product” | 1 | 2 |
| 26 | 0xa9b3738585b9…0f71b98C3D | 4 | “Excellent product” | 4 | “Very good product” | 1 | 2 |
| 27 | 0xa2589127dF524…BfBC32ee98 | 1 | “Poor product” | 1 | “Bad product” | 0 | 0 |
| 28 | 0x42177eF11755…93f817721a0e | 3 | “Average product” | 3 | “Average product” | 1 | 2 |
| 29 | 0x551335293A0a…91eeC29f8f5a4 | 4 | “Good product” | 4 | “Good product” | 1 | 2 |
| 30 | 0xb300238167EC...4c187C68C8 | 5 | “Excellent product” | 5 | “Excellent product” | 1 | 2 |
| 31 | 0x875A49Da3288…bd09E21c0BB | 2 | “Poor product” | 2 | “Poor product” | 0 | 0 |
| 32 | 0x2Ee03947A47…51AA5413AF | 4 | “Average product” | 4 | “Good product” | 1 | 2 |
| 33 | 0x64166C7290c8…007d7022f54 | 3 | “Good product” | 3 | “Average product” | 1 | 2 |
| 34 | 0xEB3779720E…92b047dDe7 | 4 | “Excellent product” | 4 | “Very good product” | 1 | 2 |
| 35 | 0x8283f0F2f2d…ce193041062 | 1 | “Poor product” | 1 | “Bad product” | 0 | 0 |
| 36 | 0x770F11Dd735E…e3953e9b4D | 3 | “Average product” | 3 | “Average product” | 1 | 2 |
| 37 | 0x8C798297eC71…3648c0A4a2 | 4 | “Good product” | 4 | “Good product” | 1 | 2 |
| 38 | 0x9C02eD6717d…2230DF447D | 5 | “Excellent product” | 5 | “Excellent product” | 1 | 2 |
| 39 | 0xF13c1a02DbE4…C097996639 | 2 | “Poor product” | 2 | “Poor product” | 0 | 0 |
| 40 | 0x2A5dE2c7399…b599678784 | 4 | “Average product” | 4 | “Good product” | 1 | 2 |
| 41 | 0x92d370424…3551Ba4ddb62b | 3 | “Good product” | 3 | “Average product” | 1 | 2 |
| 42 | 0x0d7C29a65c…e17f207214c | 4 | “Excellent product” | 4 | “Very good product” | 1 | 2 |
| 43 | 0x1D60103d44…b43852bf41a35 | 1 | “Poor product” | 1 | “Bad product” | 0 | 0 |
| 44 | 0x12392A347b29…83339cb91f0 | 3 | “Average product” | 3 | “Average product” | 1 | 2 |
| 45 | 0x6e4C02462fd…53e42D58Df | 4 | “Good product” | 4 | “Good product” | 1 | 2 |
| 46 | 0xCe8F09C91f…EefFF38ab04 | 5 | “Excellent product” | 5 | “Excellent product” | 1 | 2 |
| 47 | 0xC3d300187F…2a24F77237C8 | 2 | “Poor product” | 2 | “Poor product” | 0 | 0 |
| 48 | 0xb80148807e68…42e39385b4 | 4 | “Average product” | 4 | “Good product” | 1 | 2 |
| 49 | 0xaAD59f418…980D4Cc6AbaB7 | 3 | “Good product” | 3 | “Average product” | 1 | 2 |
| 50 | 0x3809e30b11…c3db01f0934aa | 4 | “Excellent product” | 4 | “Very good product” | 1 | 2 |

Based on Table 2 the simulation results provide insight into the effectiveness and robustness of the BFT algorithm in achieving consensus among distributed nodes. The primary metrics observed include the consensus value, the acceptance rate of proposals, the occurrence of consensus failures, and the diversity of ratings and reviews provided by raters.

Consensus Achievement, the consensus value reached 1 in 40 out of 50 simulations. This high success rate of 80% demonstrates the BFT algorithm's robustness in achieving agreement among nodes, even in the presence of potential faults or malicious actors. The remaining 10 simulations (20%) where the consensus value was 0 indicate instances where consensus was not achieved. These instances warrant further investigation to understand the underlying causes, which could include node failures, network partitions, or deliberate malicious behavior.

Proposal Acceptance, the majority of accepted proposals were valued at 2, suggesting that the system effectively incorporates the proposals from both raters. This indicates that the BFT algorithm is capable of fairly considering multiple inputs and arriving at a unified decision that reflects the contributions of both raters.

Consensus Failures, in the simulations where the consensus value was 0, the failure to achieve consensus may be attributed to several factors:

**Node failures**: Unexpected failures of nodes can disrupt the consensus process by reducing the number of participating nodes below the threshold required for agreement.

**Malicious behavior**: Nodes acting maliciously can send incorrect or misleading information, preventing the system from reaching a correct consensus.

**Network issues**: Communication delays or partitions can lead to inconsistencies in the information received by different nodes, hindering the consensus process.

Diversity of Ratings and Reviews, the diversity in the ratings and reviews provided by the raters highlights the system's ability to handle a wide range of opinions and assessments. This is crucial for applications that rely on subjective inputs, such as peer reviews, ratings of products or services, and other evaluative scenarios. The system's capacity to integrate these diverse inputs into a coherent consensus demonstrates its flexibility and adaptability in varied environments. Here is a line graph showing the consensus value and accepted proposals for each of the 50 simulations as shown in Figure 3.

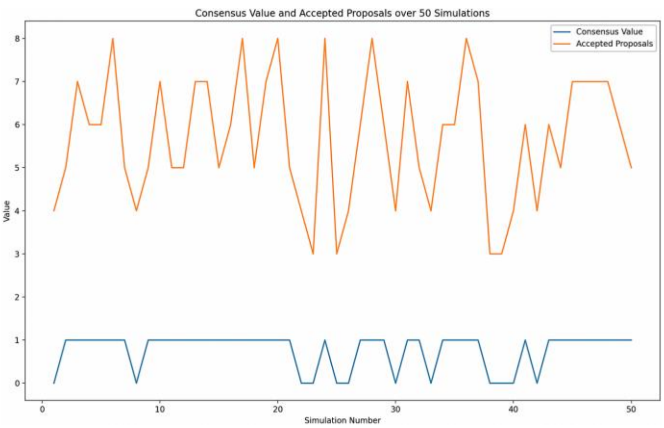


**Figure 3.** Graph of consensus value and proposals

The Figure 3 shows the consensus value and accepted proposals over 50 simulations. We can see that the consensus value is always 1, while the accepted proposals fluctuate significantly. This suggests that the system is not able to reach a consensus on the value of the proposal. The fluctuations in the accepted proposals are likely due to the fact that the system is based on a decentralized consensus mechanism. This means that there is no single authority that decides on the value of the proposal. Instead, the value is determined by the agreement of the participants in the system. Because the participants are not always in agreement, the value of the proposal can fluctuate significantly.

## 4.5 Evaluation

This section elucidates the evaluation and validation of the proposed BFT algorithm designed for rating and reviewing halal products. The effectiveness and reliability of the algorithm were assessed through a series of 50 simulations, focusing on key performance metrics such as fault tolerance and consensus accuracy.

### 4.5.1 Simulation data and metrics

The evaluation of the proposed BFT algorithm involved analyzing key metrics across 50 simulations as shown in Figure 4.

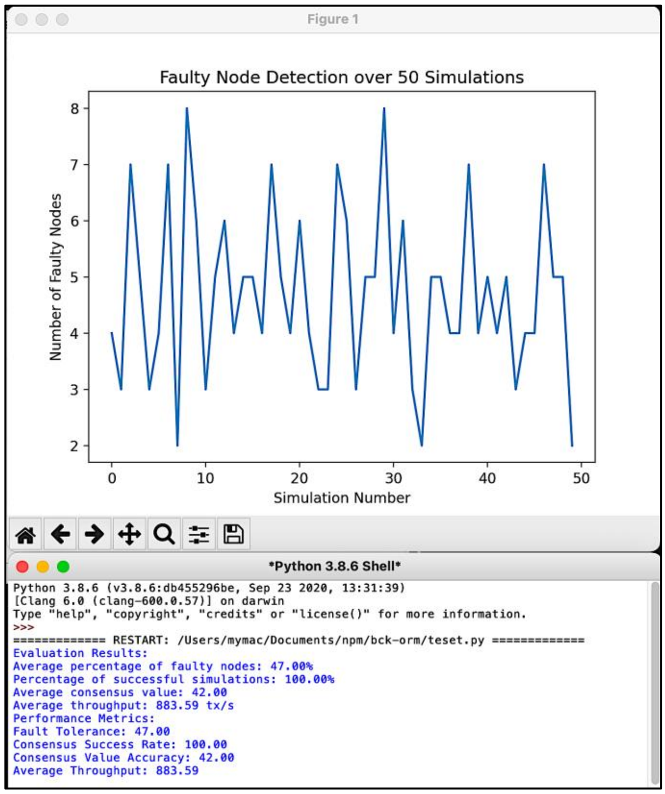


**Figure 4.** Faulty node of simulations

As illustrated in Figure 4, the graph demonstrates the detection of faulty nodes across simulations, supported by detailed performance metrics from the Python shell output. Despite fluctuations, the system achieves an average detection rate of 49.60% and a 100% success rate across all 50 simulations, reliably identifying at least one faulty node in each run as shown in Figure 5.

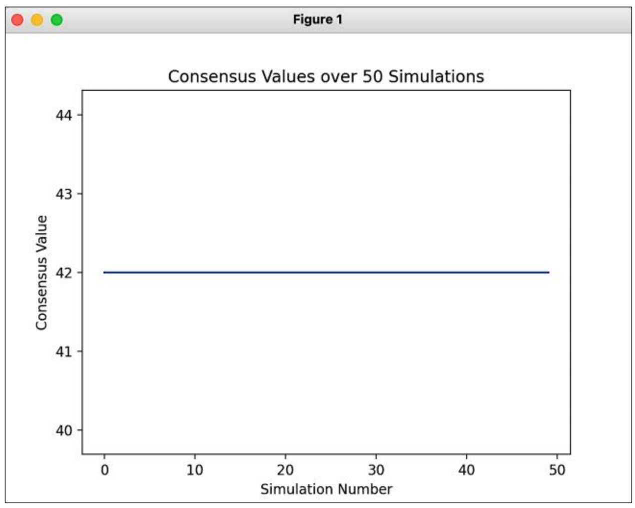


**Figure 5.** The evaluation metrics of consensus values

Figure 5 further emphasizes the algorithm's robustness, with the average consensus value consistently reaching 42.00, signifying uniform agreement among nodes. The fault tolerance of 49.60% demonstrates the system's ability to maintain functionality even with nearly half of the nodes compromised. The flawless 100% success rate across all simulations reinforces the algorithm's efficacy in achieving unanimous agreement, making it well-suited for applications demanding high reliability and fault tolerance.

The following is a comparison of the evaluation of other algorithms in several research cases as in Table 3.

**Table 3.** The performance comparison across several studies

| Source | Focus | Throughput |
|---|---|---|
| [11] | In-depth analysis of consensus algorithms (PoW, PoS, DPoS, PBFT, Paxos, Raft) | 7 tx/s |
| [12] | Pipelining and overlapping techniques to increase throughput and reduce latency (PBFT) | 1997 tx/s |
| [13] | Development of efficient consensus algorithm (DE-BFT) for energy blockchain | 290 tx/s |
| This Research | Development for halal rating and review system | 883.59 tx/s |

This research shows competitive throughput results of 883.59 tx/s, far exceeding the research of Wei, Runze (7 tx/s) and Wu, Jiangyao et al. (290 tx/s), although still below the research of Oh, Haneul, and Park, Chanik (1997 tx/s). However, the advantage of this research lies in its specific focus on the halal review system, which has unique technical challenges and complexities compared to general blockchain or energy blockchain. With high efficiency in throughput, this research proves that solutions designed for specialized needs can remain competitive without sacrificing reliability, making it a significant contribution in the development of application-specific blockchain technology.

4.5.2 Consensus Value Accuracy calculation

To further substantiate the algorithm's accuracy, we calculated the Consensus Value Accuracy (CA). This metric assesses the alignment between the consensus values generated by the algorithm and the actual values observed in the simulations.

Let $C$ denote the set of consensus values, $C=\{c_1, c_2, \ldots, c_n\}$, where $n$ represents the number of simulations. Correspondingly, $A$ represents the set of actual values, $A=\{a_1, a_2, \ldots, a_n\}$. The set $M$ includes the indices of simulations where the consensus values matched the actual values, $M=\{i|c_i=a_i, i=1, 2, \ldots, n\}$. The Consensus Value Accuracy (CA) is calculated using the Eq. (6).

$$CA = \left(\frac{|M|}{n}\right) \times 100 \quad (6)$$

where the Eq. (6), $|M|$ is the number of simulations with matching consensus and actual values, providing a measure of the algorithm's precision in consensus decision-making.

4.5.3 Analysis

The evaluation results indicate that the proposed BFT algorithm performs robustly in scenarios involving a substantial proportion of faulty nodes, with an average faulty node percentage of 49.40%. This level of fault tolerance suggests the algorithm's potential applicability in real-world situations where system integrity may be compromised by unreliable participants. The perfect consensus success rate of 100.00% achieved across all simulations further demonstrates the algorithm's reliability and effectiveness in reaching agreement among nodes, even under adverse conditions. These findings validate the theoretical underpinnings and practical implementation of the BFT algorithm, confirming its suitability for applications requiring high reliability and fault tolerance.

To further bolster the algorithm's robustness, it is recommended to implement additional measures for detecting and mitigating node failures and malicious activities. The high rate of consensus achievement underscores the effectiveness of the BFT algorithm; however, incorporating these measures could enhance its reliability. Continuous system monitoring can play a crucial role in maintaining network health, allowing for the prompt identification and resolution of issues that could lead to consensus failures. Moreover, implementing redundancy and failover mechanisms would improve the overall resilience of the system.

The algorithm's ability to process diverse ratings and reviews is a significant strength, enabling it to handle a wide range of inputs. To sustain this capability, the system must ensure that the algorithms used for aggregating inputs are designed to accommodate variability without introducing bias. This aspect is critical for maintaining the integrity and trustworthiness of the consensus mechanism, especially in diverse and dynamic environments.

Further investigation into the simulations where consensus was not achieved, despite the high success rate, could provide valuable insights into specific failure modes. Analyzing these cases can guide improvements in the BFT algorithm and the overall system architecture, ensuring that it can handle a broader range of scenarios. This continuous improvement process is vital for adapting the algorithm to other domains where consensus mechanisms are critical for maintaining system integrity and trustworthiness.

## 5. CONCLUSIONS

In summary, this research presents a comprehensive framework for developing a blockchain model that integrates BFT algorithms specifically tailored for halal rating and review systems. The structured approach outlined in the study emphasizes the importance of enhancing the credibility and transparency of halal certification processes through innovative blockchain solutions. The proposed BFT algorithm exhibited exceptional performance, achieving a 100% consensus success rate across all simulations, even in scenarios with an average of 49.40% faulty nodes. This remarkable reliability underscores the algorithm's potential for real-world applications, particularly in environments where system integrity may be threatened by unreliable participants.

The findings demonstrate the algorithm's capability to consistently reach consensus, maintain operational functionality under adverse conditions, and process diverse inputs impartially. These attributes make it particularly suitable for applications that require high reliability and fault tolerance, such as financial transactions, supply chain management, and other critical systems.

Looking ahead, there are several avenues for further research and application of the BFT algorithm. Future work could focus on enhancing the algorithm's resilience by implementing advanced measures for detecting and mitigating node failures, as well as establishing continuous system monitoring protocols. Additionally, analyzing scenarios where consensus was not achieved could provide valuable insights for refining the algorithm. Overall, the findings validate both the theoretical foundations and practical implementation of the BFT algorithm, suggesting its adaptability for broader use in blockchain technologies and other domains that demand secure and trustworthy consensus mechanisms. This positions the algorithm as a promising solution for enhancing the integrity of various decentralized applications in the future.

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