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Research article

# Enhanced PBFT Blockchain based on a Combination of Ripple and PBFT (R-PBFT) to Cryptospatial Coordinate

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**ABSTRACT**

In this research, we introduce the combination of two Blockchain methods. Ripple Protocol Consensus Algorithm (RPCA) and Practical Byzantine Fault Tolerance (PBFT) are applied to cryptospatial coordinates to support cultural heritage tourism. The PBFT process is still used until the preparation process to ensure a maximum error of 33%. After this process, data will be entered into the RPCA node and calculated using the equation to minimize errors with a maximum limit of 20%. After this process, the data would be sent to the commit process to store data to all connected nodes in the Blockchain network, we call this combination of two methods as R-PBFT. Combining the two methods can enhance data processing's security and speed because it still uses the PBFT work combined with the speed of RPCA. Besides, this method uses a fault tolerance value from the RPCA of 20% to enhance data processing's security and speed.



## 1. Introduction

Nowadays, the blockchain leap outperforms fame other technology because this technology guarantees data validity and originality [1]. The procedure of Blockhain implements framework security so you can not change transaction data because all transactions occur anonymously [2]. Therefore Blockchain technology can be widely used, such as Finance, Health, Tourism, Supply Chain Management (SCM), and the Internet of Things (IoT) [3]. A Blockchain network consists of three types: the Public blockchain, where this network can read, use, and participate in a consensus process. The second is the Consortium blockchain, where consortium blockchain controlled by nodes has been chosen, and the last is the Private blockchain, where permission to read, write, and use a center on an organization [4].

Blockchain technology has many challenges in its application, such as how to design a suitable consensus protocol. Because Blockchain consensus consists of all nodes that maintain each other's data in the ledger in a distributed network. Sometimes some nodes become down or dangerous in the Blockchain network, affecting the consensus process. Therefore, a suitable consensus protocol can tolerate and minimize the disadvantages affecting the consensus outcome [3]. In a distributed network, there is no perfect consensus protocol. The determination of the consensus protocol needs to consider the system's consistency, availability, and fault tolerance [5]. Some of the main consensus protocols in

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8 (2) July 2022 133-141

the Blockchain network consist of Proof of Work (PoW), Proof of Stake (Pos), Delegate Proof of Stake (DPoS), Practical Byzantine Fault Tolerance (PBFT), Ripple Protocol Consensus Algorithm (RPCA) and several consensus mechanisms. which has been proposed for Blockchain [6].

Nowadays, the PBFT and RPCA algorithms are widely used by consortiums of Blockchain service providers. Miguel Castro of MIT proposed the PBFT algorithm in 1996 [7]. PBFT is a solution to ensure consistency of distributed systems with Byzantine-based failure nodes. This algorithm consists of consistency protocol, view-change protocol, and checkpoint protocol. Usually, the  node is used to determine the maximum error limit of the replica node of the system. This algorithm works without tokens, so it has high efficiency and low power consumption [8]. However, this algorithm has several problems, such as the exclusion of nodes that function as primary nodes, consistent and high communication interaction between each connected node, and operating efficiency [9]. RPCA algorithm can be used for Blockchain consensus. RPCA is influenced by the idea of the Byzantine quorum system [10], where a set of quorums collaborate to reach a specific agreement. Quorum is a list of trusted nodes called a Unique Node List (UNL). UNL works as a server that validates and maintains the XRP Ledger and gives votes to transactions made. In the validation process, the server can collaborate with UNL to validate transaction data [11].

There are five UNL selected via a static configuration operated to validate the consensus process by RPCA. This cause leads to centralization [12]. In addition, RPCA is applied every few seconds by all nodes to ensure transaction validity [13]. This research introduces the combination of Ripple and PBFT (R-PBFT) to enhance cryptospatial coordinat. R-PBFT can be combined with Geospatial Retrieval so it can be used in various sectors that require data containing geospatial earth, which requires special skills to handle geospatial data [14]. This technology is called Crypto Spatial Coordinates (CSC), which records data entry in a given time, location-related validation, and explicitly maps objects in time sequences [15]. CSC is a geospatial retrieval-based Blockchain technology where this technology requires a smart Contract to validate data. Smart contracts are computerized transaction protocols for executing contract terms. In the Blockchain context, smart contracts are scripts on the Blockchain of procedures stored in the system [15].

Much research has been done. Biswas et al [16] introduce a secure framework that integrates Blockchain technology with smart devices providing a secure communication platform in Smart City, Sun et al [17] propose to build an IoT-based smart city using Blockchain with a trusted distributed database. Furthermore, Wang et al [8]. discuss the credit-based enhanced PBFT Blockchain. Because PBFT cannot effectively select reliable nodes, the resources used are also quite significant. Therefore they introduced a credit mechanism-based PBFT (CDBFT). Feng et al [18] purpose a new model of modified PBFT algorithm into Scalable Dynamic Multi-Agent Practical Byzantine Fault-Tolerant (SDMA-PBFT) where SDMA-PBFT establishes several autonomous systems in each node and multicasting messages can be performed efficiently. Besides that Utomo et al [19] Develop an attendance application using fingerprints from the smartphone based on the PNPOLY algorithm for office attendance. This research limits the present application's use area if the user is in a polygon area that has been determined using the PNPOLY algorithm.

Furthermore Ye et al [20] Suggested a new algorithm, drawing a vertical line through the bottom point and scoring points by substitution method and then marking the variables. This algorithm does not require particular circumstances or perform a multiplier operation, so efficiency and stability improvements occur significantly. Then Siahaan et al [21] Discusses the Rabin Karp algorithm to detect the similarity of two strings. In this algorithm, the plagiarism level is determined based on the same hash value on checking the two documents. The main work of this paper is develop a blockchain-based cryptospatial coordinate mapping where the smart contract is used to detect the position where the surveyor is mapping the location. It must be in the coordinates of a predetermined location using the Point Inclusion in Polygon Test (PNPOLY) method [22]. While control the data consistency in the blockchain process using the Rabin Karp algorithm method [21] to limit the predetermined error tolerance in the process cryptospatial coordinate to support cultural heritage tourism has been done.

This paper is arranged as follows: Section II briefly presents the material and methods of PNPOLY, Rabin Karp Algorithm, PBFT, and RPCA. Then, Section III propose the R-PBFT method.


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8 (2) July 2022 133-141

Section IV shows the evaluations. Finally, Section V provides conclusions and directions for future work.

## 2. Materials and Methods

### 2.1. Point Inclusion in Polygon Test (PNPLOY)

PNPOLY is a method to determine the position of a point in a polygon region or vice versa [22]. PNPOLY is an improvement of the ray casting algorithm. The PNPOLY method runs a semi-infinite-ray from the test point and counts how many corners are crossed. When passing through this angle, the ray will move between the inside and outside positions. This displacement is called the Jordan Curve Theorem algorithm. This algorithm will continue to be carried out until the number of angles in the polygon area is limited [23]. The result is true if the test value is inside the polygon or false if it is outside the polygon [22]. The explanation of PNPOLY shows in Fig.1.

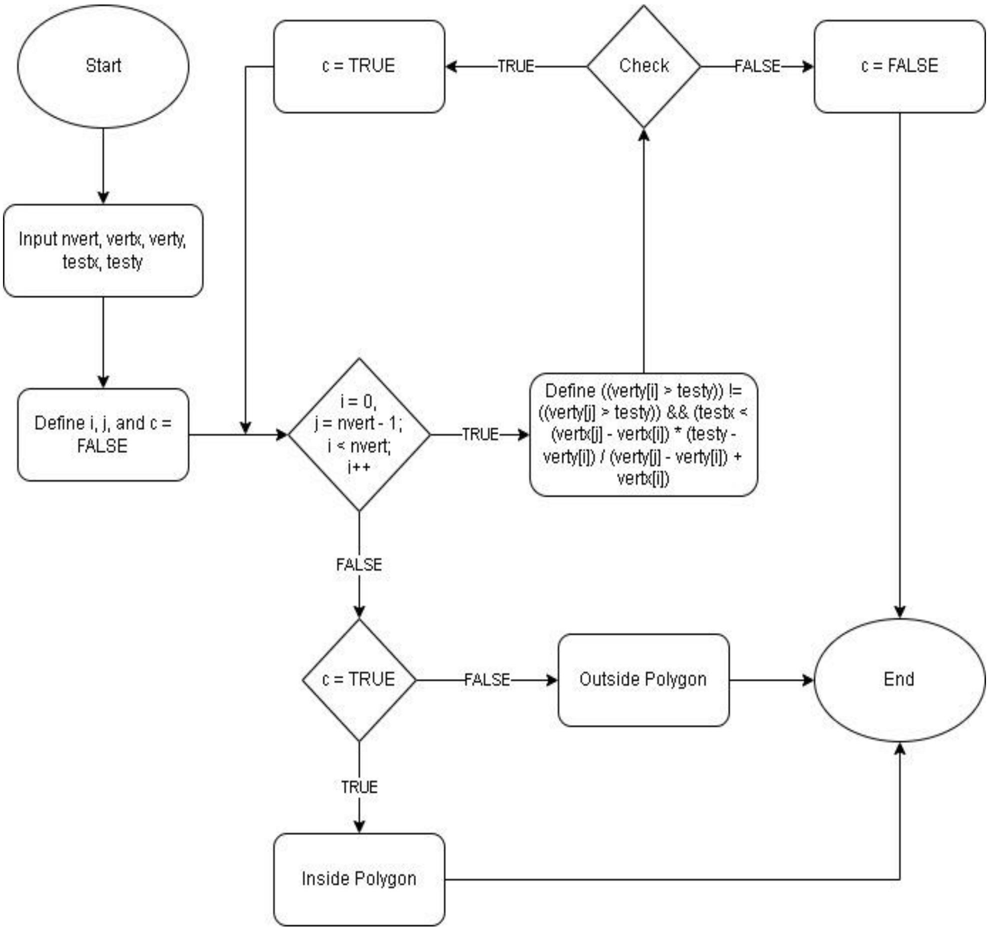

Fig. 1. The PNPOLY steps in this research

The equation of PNPOLY method as the follow:

$$n\sum\nolimits_{y=0}^{m} y(x_n - x_m) - m\sum\nolimits_{y=0}^{n} x(y_n - y_m) > nm(x_n y_m + x_m y_n). \quad (1)$$

Where $n$ is the point that intersects the polygon, $x$ and is point from the edge of the polygon, afterward and $y$ is a test point.

### 2.2. Rabin Karp Algorithm

The Rabin Karp algorithm is used for string matching and has advantages in the simple string matching process. This algorithm uses hashing to find a collection of string patterns in a text [24]. This research the Rabin Karp Algorithm use to guarantee of the data consistency in the blockchain process. There are steps ways to use this algorithm: first, K-gram to extract letters from the number of $k$ characters of a word which is read continuously from the source text to the end of the document. Second, Rolling Hash is function to convert a string to a unique value as a string marker. The equation of rolling hash as the follow:


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8 (2) July 2022 133-141

$$h(s)=(s[i]*b(n-1)+s[i+1]*b(n-2)+...+s[i+n-1]) \bmod q. \quad (2)$$

Where $s$ is search string length, $i$ is array value, $b$ is prima base number, $n$ is number of string lengths searched and q is a modul. And the last is String Matching where this step to compare hash value of text input with hash value of document [25].

### 2.3. Discrete Wavelet Feature Extraction

In this research, the Blockchain method used is PBFT. The advantages of this method are that it has high practicality and low algorithm complexity [3]. PBFT is a standard solution used to verify the byzantine failure of each node with distributed system consistency [8]. The equation of PBFT as the follow:

$$3f+1 \quad (3)$$

Where $f$ number of nodes is used. PBFT is an absolute finality consensus protocol by strong consistency [26]. This consensus method works by recording and producing blocks trusted by all connected nodes in the Blockchain network. There are two types of nodes. The first is primary, and the second is a replica. The PBFT process shows in Fig. 2.

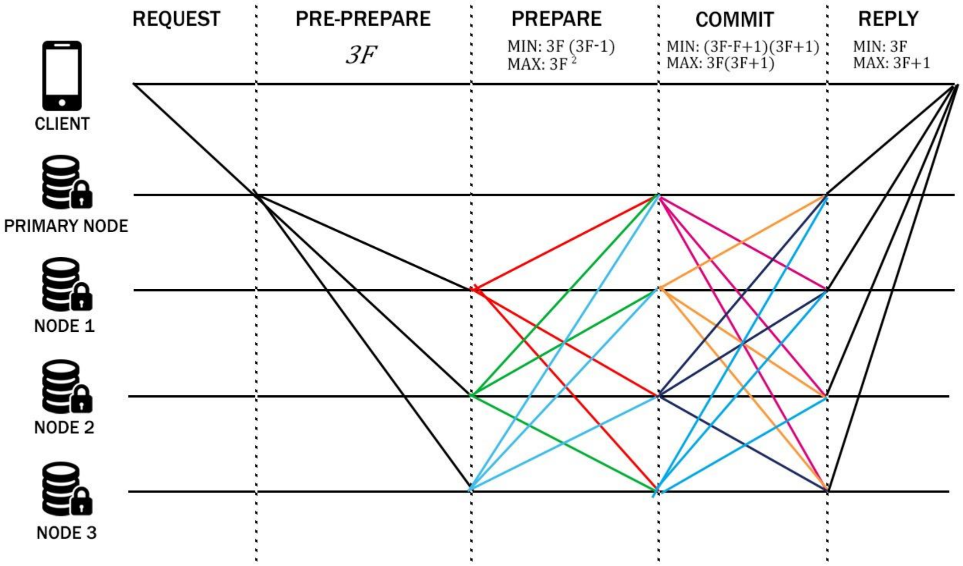


Fig. 2. The PNPOLY steps in this research

In PBFT there are four stage. First, pre-preapare stage, where main node check readiness of all nodes connected in the Blockchain network. If true the result is $3f$ . Second, prepare stage, this process send data Blockchain in the form of the name, address, description, coordinates, and photos of cultural heritage data to all nodes for smart contracts. If the minimum reply is $3f(3f-1)$ and maximum reply is $3f^2$ than next process can be done.

Third, commit stage, this process can be run if node receive message to minimum is $(3f-f+1)(3f+1)$ and maximum is $3f(3f+1)$ . This process used for add a new chain in the ledger after validate smart contract process using PNPOLY method. The last is reply, this process sent reply to user's if the previous process receive message to minimum is $3f-1$ and maximum is $3f+1$ where $f$ is number of nodes is used.

### 2.4. Ripple Protocol Consensus Algorithm (RPCA)

Ripple does not use PoW or PoS mechanisms to validate transactions because Ripple uses a consensus protocol to its specifications. This algorithm runs on a blockchain that is allowed, unlike Bitcoin and Ethereum [3]. The RPCA algorithm is applied every few seconds by all UNLs to ensure transaction validity. The consensus process in Ripple is validated by UNL owned in this network [27]. The equation of RPCAas the follow:

$$f \le \frac{(n-1)}{5} \quad (4)$$

Where $f$ is ripple is UNL. And the equation of probability of truth from $p*$ as the follow:

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8 (2) July 2022 133-141

$$p^{*} = \sum_{i=0}^{\left(\frac{n-1}{5}\right)} \binom{n}{i} p_c^i (1-p_c)^{n-1} \tag{5}$$

The RPCA process shows in Fig. 3.

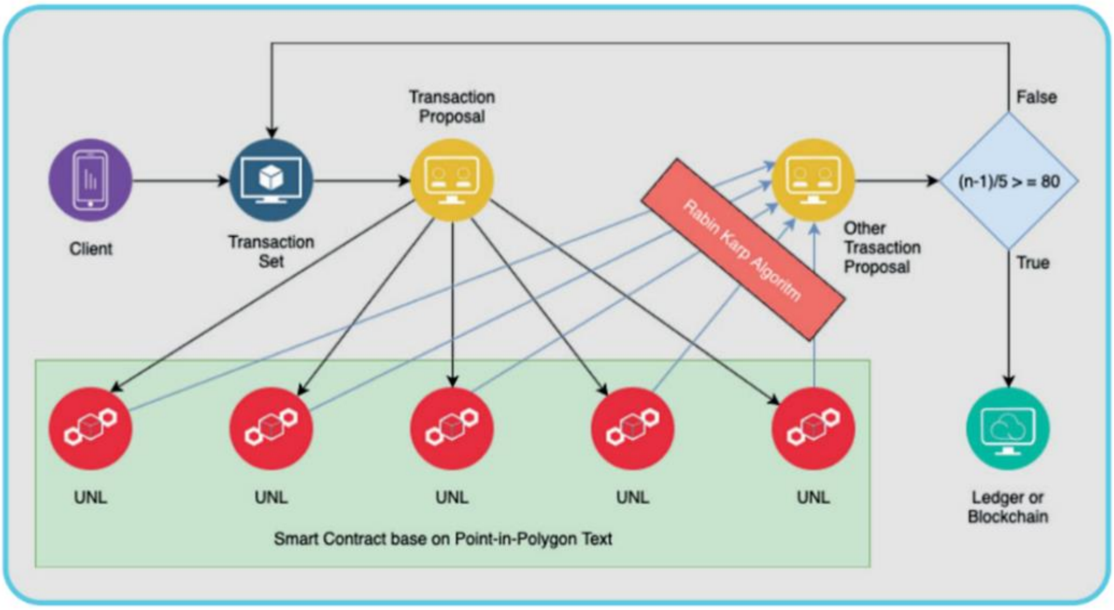


Fig. 3. Design Architectural The RPCA process in this research

Fig.3 show The RPCA process, where each server processes valid transactions and converts them into transaction sets. Then the server sends one transaction set to all UNLs for consensus processing. after that, If the node generates true, the transaction is sent to the transaction proposal process. Otherwise, the transaction set will be discarded or entered into the candidate ledger. Furthermore, If the previous process gets a maximum error of <= 20%, the transaction is recorded in the ledger or vice versa.

## 3. Results and Discussion

### 3.1. Propose The R-PBFT Method

In R-PBFT, there are six stages in the R-PBFT process have been developed: Request, Pre-prepare, Prepare, RPCA, Commit, and Reply. The first process is Request; this process starts with the client sending input data in the form of location, address, phone number, description, coordinates, and location photos. This data is sent to the primary node. The following process is Pre-prepare. The primary node carries out this process by sending input data originating from the request process to all nodes connected in the PBFT network (Node 1, Node 2, and Node 3) with the equation $3f$ .

Next is the Prepare process. In this process, the nodes connected in the PBFT Blockchain network will send a multicast to all connected nodes, and all connected nodes will check the string match of the data sent by other nodes with the Rabin Karp algorithm. In this process, the minimum error tolerance is shown in equation $3f(3f-1)$ , and the maximum error tolerance is shown in equation $3f^2$ . Furthermore, the RPCA process sends a multicast to 1 connected node and checks the string match of the data transmitted by the previous process using the Rabin Karp algorithm and is calculated to find out the number of RPCA with equation shown in equation , and the minimum limit in the equation $3f+1$ as the follow:

$$(3f+1)-\left(\frac{3f+1}{5}\right) \tag{6}$$

Where $f$ is the number of nodes used in the developed Blockchain, next is the commit process to check whether new blocks can be added to the Blockchain that has been developed with the equation as the follow:


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8 (2) July 2022 133-141

$$fr = \left(\frac{3f+1}{5}\right) / (3f+1) * 100 \quad (7)$$

Where is the maximum tolerance value, and is the number of nodes used in the developed Blockchain, if $fr < 20\%$ , then a new block would be added to the Blockchain or vice versa, and the primary node will send a reply message to the client. The R-PBFT architectural design that has been developed is shown in Fig. 4.

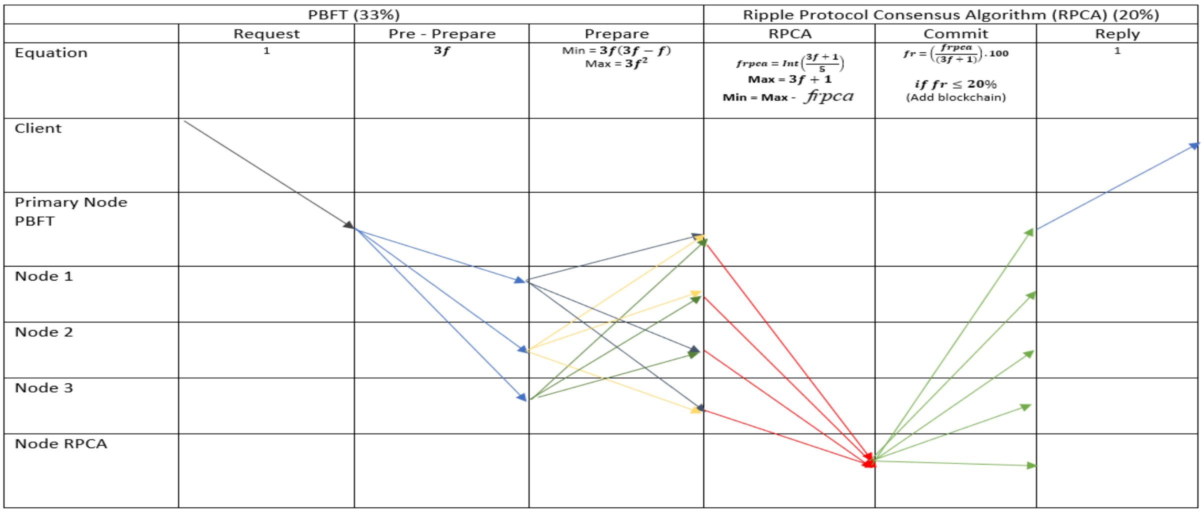

Fig. 4. Design Architectural The RPCA process in this research

### 3.2. Evaluations

In this research, two evaluations were carried out on the three methods of Blockchain (PBFT, RPCA, and R-PBFT). The first evaluation is to get the average time encryption to add data to the blockchain network, and the second test is carried out to get the average smart contract verification time that is written into the ledger of each method used. All tests were carried out 100 times to get the average time required. The result of two evaluations shows in Fig. 5 and Fig. 6.

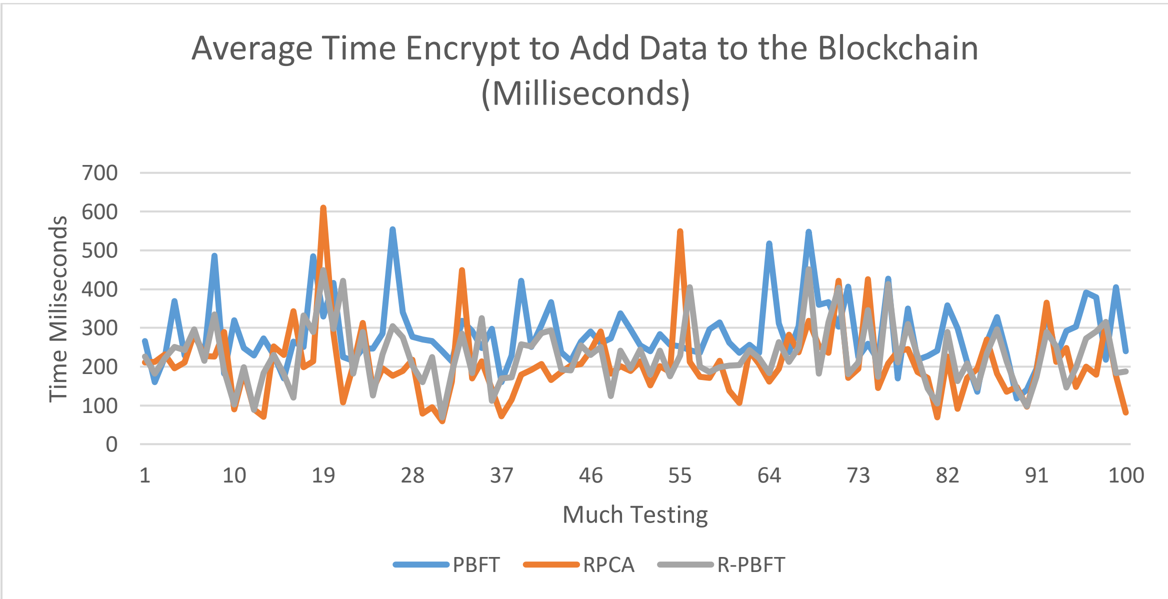


Fig. 5. Average time encrypt to add data to the Blockchain


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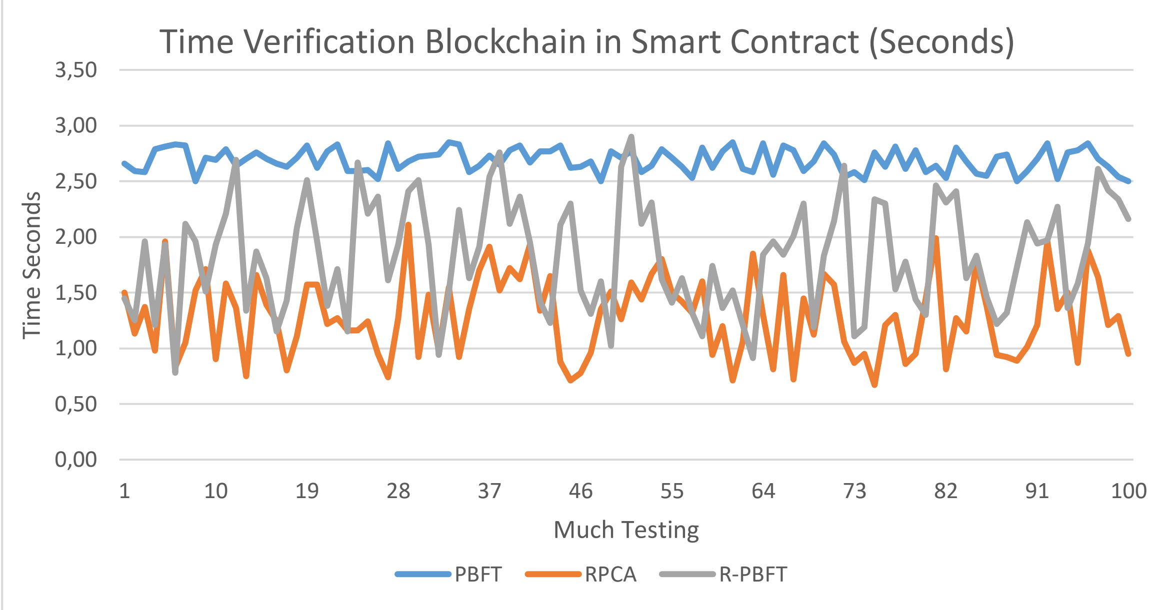


Fig. 6. Time Verification Blockchain in smart contract

Table 1. The result of average time evaluations were carried out 100 times.

| | Testing | PBFT | RPCA | R-PBFT |
|---|---|---|---|---|
| 1. | Comparison of latency to add a new chain | 0.28s | 0.20s | 0.22s |
| 2. | Verification Blockchain in Smart Contract | 2.26s | 1.29s | 1.83s |

In Fig. 5 shows Average time encrypt to add data to the Blockchain. The results of the evaluation of the RPCA method, which is the fastest amount, have an average time of 0.20s. Where the RPCA method is 26% faster than the PBFT method, which has an average time value of 0.28s, and 9.4% of the R-PBFT method, which has an average time value of 0.22s because PBFT emphasizes data consistency at each node, and the R-PBFT method also implements data consistency on each node owned before entering the Ripple process. In comparison, the R-PBFT method can create a new chain 18.74% faster than the PBFT method because the R-PBFT method uses one separate node to carry out the Smart Contract process, and only the primary node returns messages to the users.

In Fig. 6 shows the time verification Blockchain in smart contract. The results of the evaluation show that the time required to verification Blockchain in smart contract with the RPCA method is 52% faster than PBFT. Because the PBFT method sends a reply message to the user using the resources of all connected nodes in the consensus process, and the RPCA method is 31.97% faster than the R-PBFT method, this is because the R-PBFT method is still going through several processes PBFT but has been improved.

## 4. Conclusion

This research uses one mobile device and four computers with specifications: processor core I5, 8 Gb ram, and 256 SSD storage for PBFT. While RPCA uses nine and R-PBFT uses five computers with the same specification, respectively. Mobile apps using react native to develop applications and Blockchain develop using node.js. Three methods have been compared in this research (PBFT, RPCA, and R-PBFT).

The result of the average evaluation time encrypted to add data to the Blockchain obtained RPCA is faster than PBFT and R-PBFT, approximately 26% and 9.4%, respectively. At the same time, R-PBFT is faster than PBFT, approximately 18.74%. Because the R-PBFT method uses one separate node to carry out the smart contract process, only the primary node returns messages to the users, see Fig. 4.

The second test is the time verification Blockchain in the smart contract. The result results of the evaluation show that the time required to verify Blockchain in a smart contract with the RPCA method is 52% faster than PBFT and 31.97% faster than R-PBFT, respectively. Because the PBFT method sends a reply message to the user using the resources of all connected nodes in the consensus process, and the

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8 (2) July 2022 133-141

R-PBFT method is still going through several processes PBFT but has been improved, it is faster than PBFT, approximately 41.86%, see Fig. 4.

For future directions, R-PBFT can be enhanced with the combination credit mechanism-based to add the node rpca to select nodes that are ready to execute smart contracts in the Blockchain network. Furthermore, the Implementation of this application is not only limited to cryptospatial coordinates in the tourism sector but also can be implemented for other areas, such as education, religion, health, and many more.

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