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A Layered Architecture and Taxonomy for Blockchain-empowered Reputation-based Reward Systems

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***Abstract*— Blockchain based rating and review systems have changed the operational structure of the traditional market by introducing characteristics like immutability, security, anonymity etc. to liberate users from potential malicious acts of sellers such as altering and hiding ratings or reviews, collusion with users or service providers. The lack of standardization for developing decentralized applications does not depict flow of information and cataloguing of specific functions and roles for a particular set of tasks. The development of decentralized applications for e-commerce systems is in its immature age of progress and has lack of interoperable sharing of data and workflows for new innate systems. Thus, it is significant to catalogue blockchain-based rating and review systems by identifying key parameters to generate a taxonomy and develop a conceptual layered framework for identifying core components and their interaction. This manuscript presents a substantial analysis of existing blockchain-empowered reputation-based reward systems. It uses an iterative approach following observed to rational and rational to observed for taxonomy development. The analysis results identify 11 key parameters for categorizing systems and propose a 4 layered architecture to signify IPFS, P2P network, Blockchain and DApps. The proposed model identifies underlying subsystems, their services, and their interaction. The new taxonomy identifies natural roadmaps in system development process. This study is key because it allows developers to design new reputation-based reward framework in different dimensions by following an open workflow with a common understanding of underlying core entities.**

Keywords— Blockchain; e-commerce; machine learning; reputation system; reward system.

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I. INTRODUCTION

The 21st century has emerged as a service at the door due to the availability of the internet on every hand. It has opened a new door for business operations. Before the real world, it depended solely on mouth publicity and physical visits to sell and buy the products and services. Technological advancement and the introduction of affordable 4G and 5G telecom services have eased business operations and increased business reachability in remote areas.

Consumers' trust in services and goods is an important attribute for the growth of a business. So, trust and risk are two important features to consider in consumer interaction. Trust can be defined as the willingness of a party to depend on another with a sense of security even though the risk is present [1]. Risk can be defined as the importance of an outcome to a party in a non-zero failure situation [1]. The relationship between trust and risk can be expressed using Equation 1.

$$Trust_i \propto \frac{1}{Risk_i} \quad (1)$$

$$Trust_i \propto Reputation_i \quad (2)$$

Trust in a system can be established and measured by building a reputation for the parties, services, and goods, which can be expressed using equation 2. The reputation systems use attributes [2], contextual information [3], or facets [4] to mine useful information and recommendations. It allows the parties to make the decisions and can be called a trust decision [5]. The reputation systems used by E-commerce websites and platforms allow users to provide a rating and write a review for the products and services; for example, Amazon provides a choice for providing ratings 1-5 and writing a review. Thus, consumers' ratings and reviews help build trust in other users to transact with strangers.

The feedback mechanism adopted by eBay generates trust among the users, allowing them to transact with strangers [6]. The rating and review system allows getting contextual data that get meaning using reputation systems [7]. The meanings

of the words recommender, reputation, or rating and review systems are significantly different but sometimes used interchangeably. A recommender system helps a user to make a buying decision. Well-known e-commerce applications, e.g., Netflix, Amazon, YouTube, etc. use recommender systems to help their users in decision-making [8]to increase their revenue. A recommender system influences the user's decision by presenting the reputation of their products, services, and sellers. The reputation system calculates a reputation score using ratings and reviews provided by the end consumers. The biggest challenge for e-commerce applications is increasing consumer interactions to get ratings and reviews. E-commerce platforms and business entities reward end users, e.g., with coupons, discounts, or money to increase the number of user ratings and reviews.

The inherent centralized architecture of traditional rating and review systems presents a subtle threat of fabrication, modification, deletion, or selection of only higher ratings or reviews by intermediaries or business entities to the consumers to increase their profit. On the other end, users can collude to increase their rewards. In 2009, Nakamoto [9] presented a subtle solution to overcome the need for a Bitcoin intermediary built on Blockchain technology.

A. Background

Since 2009, Blockchain has been associated with digital currency exchange, but it has expanded to affect a wide range of industries and attract the interest of researchers and developers. Furthermore, smart contracts have advanced technology by enforcing norms between two interacting parties and allowing for converting paper contracts to digital contracts [23]. Blockchain systems follow a basic paradigm that includes transactions that are digitally signed by the sender, a block that includes transactions that are hashed, and block finalization by a consensus mechanism. Blockchain systems have seven basic building blocks summarized in Table 1.

TABLE I
BASIC BUILDING BLOCKS OF BLOCKCHAIN TECHNOLOGY

Key Component	Description
Governance	Governance defines access permission. e.g., private Blockchain, public Blockchain, etc.
Node	A Node is a computer or server that stores complete or partial data on the Blockchain and acts as a communication point.
Balance model	Blockchain is a stateful system that records state transition using either UTXO or the Account model.
Transaction	A transaction executes the Blockchain system from one state to another state. Patricia Merkle Tree [My1.14] or Binary Merkle Tree [My1.13] are used to store the transaction information in the block header.
Block	A series of transactions executed in the blockchain system and block header constitutes a block. The Block header contains a hash of the previous block, thus creating a chain of blocks.
Consensus	A blockchain system appends a validated and decentralized agreed block in a chain of blocks using a predefined set of rules called consensus.
Storage	Blockchain has certain data storage limitations and is inefficient for storing large data files.

B. Motivation and Contribution

Blockchain provides a decentralized solution for trust, transparency, immutability, and anonymity [10]. The introduction of smart contracts in Ethereum [11] has added new capabilities to make it applicable in different domains, e.g., the healthcare sector [12], cloud computing [13], Internet of Things (IoT) [14], [15], [16], rating systems [17], gaming [18], marketplace [19], certifications e.g., halal certificate [20], etc. other than cryptocurrencies [21]. Several researchers and decentralized application developers have proposed different blockchain-based solutions for reward systems using ratings and reviews provided by the end users. Still, blockchain-based reward systems do not have a standardized layered architecture. This motivates an in-depth study of research articles to present a taxonomy of blockchain-based reward systems and to propose a reference layered architecture. This study centers on blockchain-empowered reward systems and is not generalized to blockchain classifications and principles.

The contribution of this paper is two-fold. First, this research article proposes a layered architecture for blockchain-based reward systems. Second, this research article presents a taxonomy of blockchain-based reward systems using an iterative methodology. The set of dimensions is derived by reviewing the numerous research articles published earlier by the academician and the white papers and yellow papers presented by the decentralized application developers. This research article does not propose a new iterative methodology. It uses the methodology presented by Nickerson et al. [22]. The proposed layered architecture and taxonomy is the first work for blockchain-empowered reputation-based reward systems. The rest of the research article is organized as follows. The Material and Method section presents an in-depth survey of blockchain-based rating and review systems to familiarize readers with the discussions in the following parts. The Results and Discussion section introduces a novel four-layered architecture and taxonomy for blockchain-based reward systems.

II. MATERIAL AND METHOD

This section presents an in-depth survey of blockchain-based rating and review systems to identify the services, conventions, and dimensions for the proposed layered architecture and taxonomy for the blockchain-empowered reputation-based reward systems.

A. Blockchain Empowered Reputation-Based Reward Systems

1) GastroAdvisor [24]*:* The system aims to provide a rating/review system for the restaurant industry exclusively for dining out. It offers a new FORK token cryptocurrency to make payments using its platform. Registered users can write reviews of three types: classic, certified, and Blockchain-certified reviews. A registered user can write classic reviews for the restaurants, but one can write certified reviews after only availing themselves of the services from the restaurant. Blockchain-certified reviews are for the restaurants accepting payments in FORK tokens and saved within the Blockchain. It gives a fixed number of FORK coins as a reward to the users

and restaurant owners for participating in different activities. The reward in the system is in the form of money, and it is fixed for different services.

TABLE II
REWARDS FOR USERS AND OWNERS OF GASTROADVISOR [A]

Actor	Activity	Reward (in Fork Token)
User	Classic Review	0.5
	Certified Review	5
	Blockchain Certified Review	10
	Add Picture/Videos	2
	Add/Correct Venue Information	1
	Add Venue	2
	Add Picture of Food	1
	Add Video of Food	2
	Add Recipe	4
Owner	Claim Page and Manage Infos	150
	Activate Online Booking	300
	Counter Token Acceptance	500
	Every Silver Certified Review	5
	Every Blockchain Gold Certified Review	10

Note. [A] The data is adapted from GastroAdvisor [24]

2) BCRB Model [25]: BCRB model complements the conventional Emission Trading Scheme using the reputation system and Blockchain Technology. The significance of emission trading is that it reduces global emissions, as a 16% increase is predicted in energy-related CO2 emission, a major component of greenhouse gas emissions. In the BCRB model, the auditor evaluates a firm's past emission rates and emission reduction strategy and determines its reputation. The firm gets a reward in the form of visibility and priority in conjunction with the asking price. The reward in the system is in the form of preferred services, not monetary.

$$PriorityValue = \frac{AskingPrice}{Reputation-basedfactor} \quad (3)$$

TABLE III
THE VISIBILITY AND PRIORITY OF OFFERS B

Price	Reputation	
	Bad	Good
High	High Visibility, Very Low Priority	High Visibility, High Priority
Low	Low Visibility, Low Priority	Low Visibility, Very High Priority

Note. [B] The data are adapted from [25]

3) Rep on the block [26]: Rep on the block is a new blockchain to store single-dimensional reputation, 1 for the successful and correct file transaction and 0 for the unsatisfied transaction, but it does not publish the calculated reputation score on the Blockchain. The reputation score for a user is based on the average of multiple users' reputation scores and can be calculated using passed parameters by the client. The reward mechanism in the system imposes a penalty on the low-reputation users for acting as dishonest users identified by the single-dimensional reputation and incentivizing miners to find a block. The incentive and penalty amounts are monetary and depend on the system definitions.

4) Dentacoin: The Blockchain Solution for the Global Dental Industry [27]. Dantacoin is a blockchain-based dental treatment platform supporting standard reviews, trusted reviews, and market research surveys. Any user of the system can write standard reviews, while an actual patient can only write trusted reviews. The dentist's office triggers trusted reviews by using the patient's e-mail address. It allows the reviews to be stored on Blockchain. It integrates an intelligence tool named DantaVox that consists of 8-100 questions on healthcare topics for surveys. The reward amount is company-controlled and fixed in some respects. This intelligent system measures the user's effort in filling out the form and generates an incentive amount in Dantacoin. Trusted reviews attain higher rewards in dantacoin compared to standard reviews.

5) Friendz [28]: Friendz is a blockchain-based digital marketing community-engaged platform. It uses blockchain technology for the transfer of funds and service completion certification. Three actors: clients, users, and approvers, participate in the platform's campaign process. Clients buy a campaign based on budget, size, target users, creativity, concept, and social network. The system rewards the users for submitting the ratings on a scale of 1-5 and approvers for approving the contents. The reputation is expressed in terms of user profile quality that is based on the rating of the approvers and users. Any user can participate as an approver after completing enough campaigns and passing the approver test. The reward system is company-controlled and depends on the budget of the campaign and user profile quality.

6) Revain [29]: The system's objective is to make it easier for people to provide feedback on products and services. The platform, users, and businesses all communicate using RVN tokens. It integrates an automatic review filtering component and records all reviews on the Blockchain. A user can write a maximum of 5 reviews in a day and get a reward after approval from the company. Revain charges a fee from a company to use its services and calculates the amount for user rewards as given in equation 4 and the platform fee.

$$AmountforUserReward = (0.9 \times Revainfee) \quad (4)$$

$$Reward_{User_i} = \frac{AmountforUserReward}{\sum_{i=1}^{n} User_i} \quad (5)$$

Equation 5 shows that each rewarded user gets an equal share of the reward amount, but the platform restricts the reward amount to a maximum of 10 RVN.

7) Decentralized Rating Framework [30]: The decentralized Rating Framework is a blockchain-based recommendation strategy. It allows users to provide ratings and reviews for an item and publish it on Blockchain using smart contracts. It introduces the concept of user skill on a category of the item representing his expertise in that area. When a user continues to review items of the same category or property, it increases his expertise and can be modeled as a reputation. Thus, the system increases the reputation of the users for their skills. The reward system incentivizes users using tokens proportional to their reputation. This framework does not propose any new reputation and reward model but ensures that existing models do not collapse the framework.

8) Lina.Review [31]: The Lina platform is a hybrid blockchain-based social review platform that encompasses trust and reputation. It allows individuals or companies to create specific free review practices on the platform but

charges a maintenance fee. It allows merchants to decide the award amount in Lina tokens for the different offered services. It records the submitted reviews on the Lina Core private blockchain and awards users after approval from staff or helpers as shown in Fig. 1 adapted from [31].

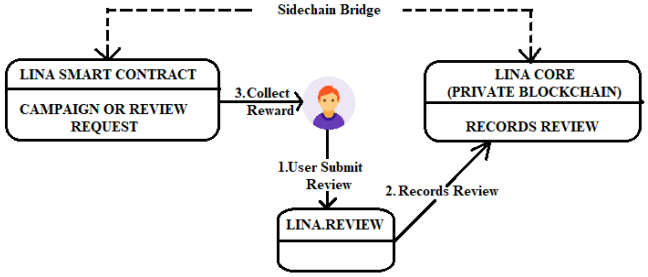

Fig. 1 Review and Reward Flow [31]

9) Blockchain-based Online Review System [32]: This system is built on Ethereum and Inter-Planetary File System. It allows users to submit reviews on the IPFS and hash of reviews on the Ethereum network, as shown in Fig. 2 adapted from [32]. The Ethereum address of the service provider must have enough balance to generate a token and map it to the reviewer. Ethereum smart contract verifies the hash of the review and users' Ethereum address using a token. After verification of the review, the system allocates monetary rewards to the reviewer and increases the review numbers. Although this system does not directly impose a reputation mechanism for the reviewers and service providers, it allows legitimate reviewers.

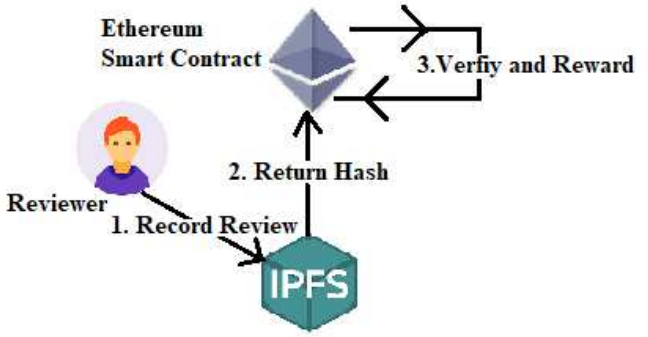

Fig. 2 Review Storage and Reward Mechanism [32]

Blockchain-based Decentralized Reputation System [33]. The BC-DRS system consists of two major components. First, IPFS stores product information, reviews, and ratings, and second, Blockchain stores the user's reputation score, as shown in Fig. 3 adapted from [33]. It allows mutual feedback and rating between buyers and sellers. Buyers submit their reviews and ratings for products, and sellers submit their ratings for the buyers. This system uses smart contracts to implement a reputation evaluation scheme and monetary incentive mechanism. It considers not only the weighted ratings given by the users but also transaction time, transaction amount, and previous reputation score of the user for calculating the current reputation score that resists unfair ratings and malicious modifications.

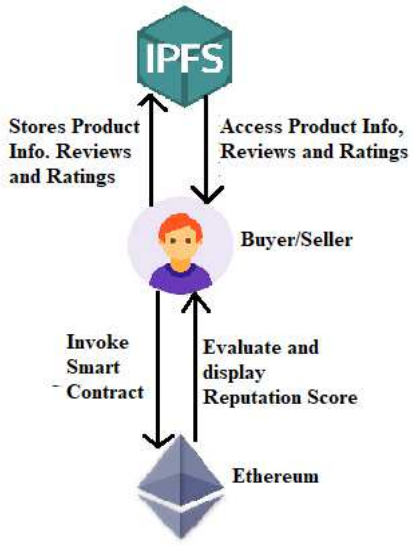

Fig. 3 System Architecture of BC-DRS [33]

III. Results and Discussion

A. Proposed Layered Architecture for Blockchain-Based Reward Systems

Blockchain-based reward systems have drawn significant consideration from developers and researchers, but no standard layered architecture remains. This section presents our generalized layered architecture for blockchain-based reward systems. The major goals of the proposed layered architecture are as follows:

- It splits the design into layers encapsulating similar tasks and describes the information flow between different layers.
- The objective of each layer is to provide services directionally, as the network layer provides communication services to both the storage layer and blockchain layer.
- It ensures the Blockchain and Storage layers' independence by offering services from the Network layer.

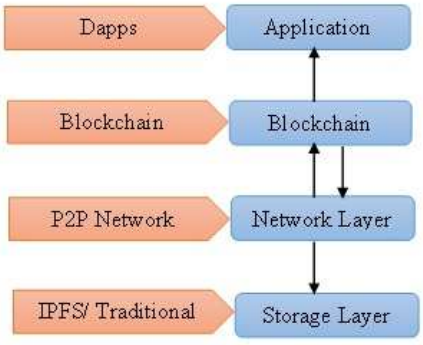

Fig. 4 Proposed Generalized Layered Architecture

As shown in Fig. 4, the proposed model consists of four layers with specific functionality to support the reward-based system development on Blockchain.

1) Storage Layer: The main functionality of the storage layer is related to data storage. It is an optional layer of services. Big-size files are costly to store on the blockchain network. So, users of the system can store data on IPFS that is immutable and can store the address of that data node on the blockchain network. A traditional database can be used by calculating hash at the record level or file level that can be further stored on the blockchain network.

2) Network Layer: The main functionality of the network layer is to provide p2p communication between nodes within the blockchain network or to the IPFS nodes. It provides node discovery, transaction propagation, block propagation, and agreement legality services to the Blockchain Layer.

3) Blockchain Layer: This layer services significant functions of Blockchain. It addresses the different types of blockchain networks, e.g., public Blockchain, private Blockchain, and the underlying consensus algorithms, e.g., proof-of-work, proof-of-stake, etc. Decentralized consensus is core to eliminate the necessity of central authority. It presents a single true state of the system by validating every transaction. It provides smart contract creation and deployment functionalities to implement a contract between executing nodes.

4) Application Layer: This front-end layer allows writing scripts, interfaces, and decentralized apps and hides the technical aspects of the blockchain layer. The main functionality of the application layer is related to the front-end development for interacting with smart contracts on an underlying blockchain network.

B. Taxonomy of Blockchain-Based Reward Systems

The multiplicity in designing a blockchain-based reward system can result in the replication of works. Researchers have proposed their solutions for architectural design [34], consensus methods [35], secure UAV networks [36], and blockchain technologies [37], but Blockchain-based reward systems remain unsolved. Our work is primarily focused on the literature on blockchain-based reward systems; thus, it is the first approach of subsequent advancements in this domain. This sub-section presents our taxonomy as given in Fig. 5.

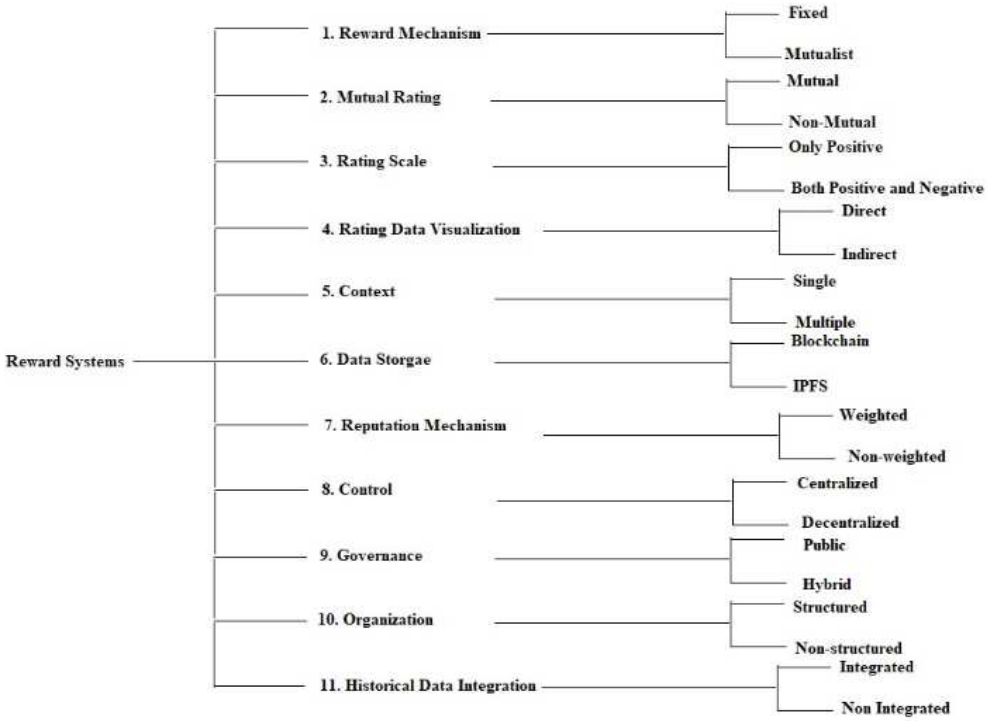

Fig. 5 Key Parameters

The primary goal is to determine key parameters and use an iterative approach following observed to rational and rational to observed [22]. The details of the key parameters are as follows.

1) Reward Mechanism (Fixed vs Mutualist): The reward mechanism differentiates between fixed and mutualist reward systems empowered by Blockchain. A fixed reward system specifies a constant reward for its services, while a mutualist reward system imposes a reward mechanism that depends on multiple parameters.

2) Mutual Rating (Mutual vs non-Mutual): For a reward system to prevent bad-mouthing, the mutual rating needs to be captured. Buyers can rate services or goods the seller provides, and a seller can rate a buyer on that. This mutual rating can lead to collusion between seller and buyer, resulting in a praise attack, thus paving a path for developing non-mutual rating systems.

3) Rating Scale (Only Positive, Both Positive and Negative): We have categorized the reward system as incorporating only a positive rating scale, positive and negative rating scales, or unary rating.

4) Rating Data Visualization(Direct vs Indirect): Rating a product or service can increase or decrease the trust of a new user in a strange seller. It can result in an increase or decrease in a company's sales. So, organizations include ratings provided by a user in reward calculation, which may

result in a greedy system where each participating entity shall make an effort to increase revenue and reward by giving higher ratings. A weighted rating mechanism normalizes the ratings provided by the different users at different points of time to minimize the effect of outlier data sets.

5) Context (Single vs Multiple): Information from distinct domains can add proportional meaning to data and transactions. For calculating rewards, not only are the ratings of an item important, but other information, such as transaction amount, successive transaction interleave time, etc. should also be considered. We have categorized reward systems as single context systems where only a single parameter such as rating or review is maintained or multiple contexts systems where the system also maintains other attributes such as user skills, transaction amount, etc.

6) Data Storage (Blockchain vs IPFS): A reward system can offer two data storage techniques. First, only on the Blockchain when the data size is small and costs less regarding transaction processing fees or rewards. Large data files can bloat blockchain nodes and incur high storage costs. Second, a hybrid solution can be used by introducing IPFS to save large files and Blockchain to save the address of the IPFS node in conjunction with the hash of the file.

7) Reputation Mechanism (weighted and non-weighted): The simplest approach for reputation computation is averaging all positive ratings. Both positive and negative rating scale systems improvise using the summation technique where each positive rating adds to the total score and a negative rating subtracts from the total score. A different approach applies to weighing ratings using other parameters such as transaction value, transactions interleaved time, etc.

8) Control (Centralized vs decentralized): Most of the blockchain-empowered reward frameworks are of a hybrid type where the rating module is decentralized, but the reward module is centralized. In such systems, users get rewards after approval from the company or seller. The other approach is fully decentralized, where a user gets a reward calculated by using parameters such as rating, transaction value, etc.

9) Governance (Public vs. Hybrid blockchain): Governance defines systems as private and public blockchain systems. The underlying architecture in a hybrid blockchain system is decentralized, but a group or organization manages it. In public blockchain systems, user nodes can randomly join and leave the network without any centralized management in the form of distributed governance.

10) Organization(Structured vs non-Structured): In a structured organization, new nodes follow a topology and have a set of neighbors defined by a location. In contrast, an unstructured organization allows a new node to join randomly and has a unified view of the system.

11) Historical Data Integration(Previous reputation vs non-previous reputation): Historical data integration controls the weight of the independent parameters and provides a rational view of the system. Reputation-based reward systems can be categorized based on whether or not the previous reputation is included. The inclusion of previous reputation scores may be advanced using users' reputations in the different categories and shows his/her specialization in a particular domain. Table IV shows the classification of reviewed blockchain-empowered reputation-based reward systems.

TABLE IV
TAXONOMY OF BLOCKCHAIN-EMPOWERED REPUTATION-BASED REWARD SYSTEMS

Reputation Systems	Reward Mechanism	Mutual Rating	Rating Scale	Rating Data Visualization	Context	Data Storage	Reputation Mechanism	Control	Governance	Organization	Historical Data Integration
Gastro Advisor	F	NMR	P	D	S	B	Nw	C	Pu	Ns	Nin
BCRB Model	M	NMR	P	I	Mu	B	Nw	D	H	S	Nin
Rep on the Block	F	NMR	P	D	S	B	W	D	Pu	Ns	In
Dentacoin	F	NMR	P	D	S	B	Nw	C	Pu	S	Nin
Friendz	M	NMR	P	D	S	B	Nw	C	Pu	Ns	In
Revain	F	NMR	P	D	S	B	Nw	C	Pu	Ns	Nin
Decentralized Rating Framework	M	NMR	P	I	S	B	Nw	D	Pu	Ns	In
Lina.Review	F	NMR	P	D	S	B	Nw	C	H	Ns	Nin
Blockchain-based Online Review System	F	NMR	P	D	Mu	I	Nw	D	Pu	Ns	Nin
BC-DRS System	M	MR	B	I	Mu	I	W	D	Pu	Ns	In

F=Fixed, M=Mutualist, MR=Mutual Rating, NMR=Non-mutual Rating, P=Positive Rating only, B=Both Positive and Negative Rating, D=Direct, I=Indirect, S=Single, Mu=Multiple, B=Blockchain, I=IPFS, W=Weighted, Nw=Non-weighted, C=Centralized, D=Decentralized, Pu=Public, H=Hybrid, S=Structured, Ns=Non-structured, In=Integrated, Nin=Non-integrated

IV. CONCLUSION

This manuscript presents an in-depth survey of Blockchain-empowered reputation-based reward systems and proposes a new reference layered architecture to concrete a methodology for developing decentralized applications. Our effort adds to the current works to set standards and taxonomies for blockchain-based research proliferation. Our proposed model and taxonomy for blockchain-based reward systems is likely the first work of succeeding progressions and presents supporting material for developers and researchers. The proposed model identifies their roles and services provided to other layers in four layers. In addition, this manuscript presents a definitive taxonomy for a detailed

categorization of blockchain-empowered reputation-based systems to explain systems' architecture and organization. The resulting study shows that the proposed layered architecture and taxonomy are essential instruments for analyzing and comparing the existing blockchain-based reward systems and for developing new reputation-based reward systems on the Blockchain.

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