Blockchain Technologies in E-commerce: Social Shopping and Loyalty Program Applications

Yi Han Lim[1], Halimin Hashim[1], Nigel Poo[2], Danny Chiang Choon Poo[3], and Hoang D. Nguyen[1(✉)]

[1] University of Glasgow, Singapore, Singapore
{2355358L, 2355332B}@student.gla.ac.uk,
Harry.Nguyen@glasgow.ac.uk
[2] Trolle, Singapore, Singapore
npoo3l@gmail.com
[3] National University of Singapore, Singapore, Singapore
dpoo@comp.nus.edu.sg

Abstract. With the rapid advancement of cryptography and distributed computing systems, blockchain technologies are highly anticipated to transform many industries with better transparency, high security, and low transaction costs. However, the scalability and performance of blockchains are limiting their utility and suitability in online services, especially e-commerce. This paper provides a survey of blockchain technologies to highlight their benefits and challenges in online shopping. We, therefore, propose two blockchain-based e-commerce applications with detailed design guidelines: social shopping and loyalty program. The study contributes to the cumulative theoretical development of social computing and blockchains. It also provides a number of implications for academic bodies, platform operators, and developers of blockchain technologies.

Keywords: Blockchain · E-commerce · Social shopping · Loyalty program · Transformation

1 Introduction

With the steady growth of communication and security technologies, blockchains have emerged as digital innovations that would transform many industries and businesses [1]. A blockchain is a shared, secured ledger, which is distributed across a network of devices. These devices verify transactions in encrypted blocks among network participants, which are not just limited to cryptocurrency but any product of value.

In e-commerce, the adoption of blockchain technologies is highly anticipated; nevertheless, the applicability of blockchains remains as limited due to the inherent scalability and performance issues in major blockchains such as Bitcoin and Ethereum. In average, the power consumption for a Bitcoin transaction is 3 to 4 times higher than the power consumption for 100,000 VISA transactions [2]. Therefore, this study investigates blockchain technologies and applications to identify their benefits and

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challenges in e-commerce. Moreover, we propose two blockchain-based applications with detailed design and implementation of social shopping and loyalty program.

Based on the survey of blockchains, the study contributes to the cumulative development of e-commerce and blockchains. It has also drawn out several insights and implications for academic bodies and developers in social computing.

The structure of the paper is as follows. Firstly, we review the existing blockchain technologies and applications in e-commerce in Sect. 2. Secondly, we present our proposed solutions with the design guidelines for social shopping and loyalty program. Lastly, Sect. 4 concludes our paper with findings and contributions in the final section.

2 Blockchain Technologies in E-commerce

Blockchain technology is a digital ledger that stores blocks of immutable transaction that occurs in the system. Each transaction produces a hash which is generated using the public key, the private key, the previous hash, the timestamp and transaction details as shown in Fig. 1. The public key is essentially an address which allows participants to identify each other, and the private key is used for authentication. The previous hash is stored to link the blocks together. Before this transaction will be stored into a block, it is broadcasted to the other nodes for consensus on the distributed peer-to-peer network. These nodes will verify that the transaction has not been altered, and once it has been approved by the majority of nodes only then it will be appended to a block.

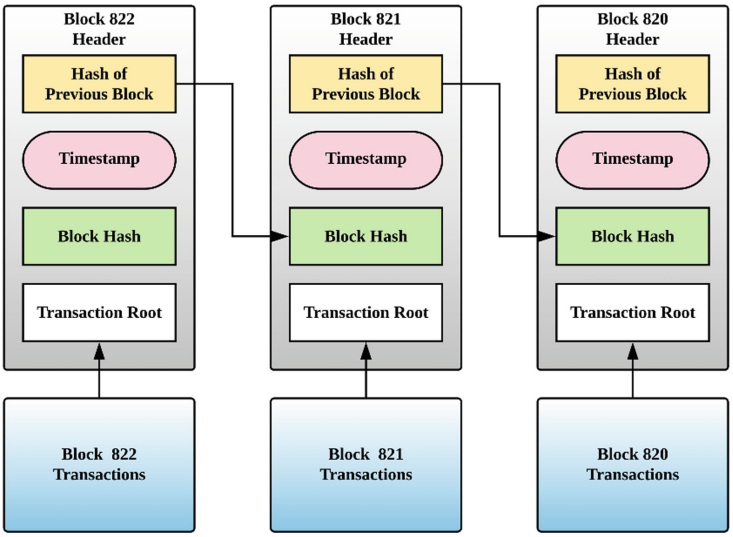

Fig. 1. Blockchain data structure

With the hype of cryptocurrency, there is a growing list of blockchain technologies, which were created with different purposes for various use cases. In this paper, we review a number of major blockchain solutions as shown in Table 1.

Table 1. A survey of existing blockchain technologies

Technology	Transactions per second	Block time in seconds	Security	Consensus	Flexibility
Bitcoin	7	~600	Medium	Proof of Work (PoW)	Low
Ethereum	15–25	~14–15	Medium	Proof of Work (PoW)	High
Qtum	>17	120–180	Medium	Proof of Work (PoW)	High
Hyperledger Fabric	3500[a] 120–300[b]	0.3–0.5	High	Proof of Agreement (PoA)	High
EOS	250[c]	0.5	Medium	Delegated Proof of Stake (dPoS)	High
Aeternity	30	<15	Medium	Hybrid Consensus: Proof of Work (PoW) and Proof of Stake (PoS)	High
BigchainDB	80	–	Varied	Proof of Stake (PoS)	High

[a]Published by Androulaki et al. [3].
[b]Benchmarked by Nasir et al. [4].
[c]Reported by Xu et al. [5].

Bitcoin. Bitcoin is a cryptocurrency that is peer-to-peer with no trusted single authority [6]. It is built on blockchain for the purpose of exchange and only executes rules that are related to trading. Bitcoin, however, is vulnerable to threats such as theft and hacking attacks despite heavily encrypted. As the first mover, the design of Bitcoin has inspired many other blockchain technologies.

Ethereum. Ethereum is an open source, public blockchain app platform which was proposed by Vitalik Buterin in 2013 [7]. It supports the modified version of Proof of Work consensus and allows programming of various types of smart contracts within the system. Ethereum is operating as cryptocurrency as a public distributed ledger for transactions. Nevertheless, the scalability of Ethereum is limited to 25 transactions per second; and it is prone to security breaches due to Solidity Language, causing storage to be compromised.

Qtum. Qtum is a hybrid platform that enables smart contract technology on the existing blockchain. It allows execution of smart contracts on mobile or Internet-of-Things (IoT) devices. Qtum is designed as a toolkit for robust and modular scripting on mainstream blockchains. New to the market, hence it is still in the testing phase and vulnerable to hacks especially at the exchange level [7].

Hyperledger Fabric. Hyperledger Fabric is an open-source, permissioned distributed ledger platform hosted by The Linux Foundation [3]. It is an extensible blockchain system featuring modular consensus protocols, which allows organizations to create and maintain a private channel with other specified members. This permissioned blockchain technologies permits the participants to authenticate themselves in transactions but also to prove authorization to perform a variety of system operations. The scalability and flexibility of Hyperledger Fabric are promising; nevertheless, its end-to-end throughput remains controversial as several benchmarks were concluded with mixed results [4].

EOS. EOS.IO is released in 2018 as open-source software to overcome the scalability issues of mainstream blockchains such as Bitcoin and Ethereum [8]. The software utilizes Delegated Proof of Stake (dPoS) consensus algorithm, in which transactions are validated by a set of master nodes known as ranked delegates. The development and maintenance of EOS such as ownership structure offer free usage for users, allowing validators to use resources according to their stakes, hence, no there is no transaction fee. However, it is still vulnerable to threats like numerical overflow, especially when arithmetic operations are executed, resulting in unchecked contracts, which eventually leads to loss of assets.

Aeternity. Aeternity was established by Yanislav Malahov in 2016 as a scalable blockchain platform [9]. It enables high bandwidth transactions, smart contracts with built-in oracles. The state channel and oracle system ensure a high degree of flexibility. The state channel allows functions to be initiated and fulfilled off-chain and prevents congestion of smart contract functions executing together. Furthermore, if a smart contract is disputed, the signed off-chain transaction can use used as a record for examination. The oracle allows real word data to be used in terms of smart contract functions. It connects to the internet and monitors the outcome in the contract, so that when results are stored, the contract will be executed. Withdrawals of token take a lot of time which makes users' asset high likely to be prone to get compromised due to the risky exchanges.

BigchainDB. BigchainDB is an open-source software that combines both blockchain properties and database properties for production-ready use cases [10]. It can be built on top of a variety of existing distributed databases. The security of each node and the entire network are extrinsic. It depends on the network built on how the rule of security for each node is. The higher standard of security of the network of nodes, the better it is able to withstand attacks. BigchainDB allows developers to deploy a blockchain proof-of-concept easily as compared to other blockchain technologies.

2.1 Benefits in E-commerce with Blockchains

The use of blockchain technologies in online shopping has been evolved beyond decentralized digital payments towards blockchain-based online and offline services [11]. The following highlights the benefits of blockchains in the context of e-commerce.

High Security. Blockchains provide transactions to be immutable due to the implementation of the technology. In the event that a block is altered, the block would be rejected by most of the nodes and the information would not persist in the ledger. This is because the block is hashed using the hash of the previous block which would link the blocks together and creating a chain. If a block is altered the data would also affect the hash for the subsequent block which in turn causes the nodes in the network to reject it. This ensures that the information has not been tampered with which would ensure e-commerce ecosystems for customers, suppliers, sellers, and shipping companies to highly protected.

In addition, the use of smart contracts eliminates an external third-party entity when doing a transaction exchange, without compromising the security in the midst of the transaction process. Smart contracts are designed to automate tasks based on the preset rules, omitting any forms of interference by any signatories.

Lower Transaction Cost. Retailers are often required to pay commission fees to use e-commerce platform. This is inevitable if they want exposure to a large audience that an e-commerce platform provides. These fees do not yet include the cost of using payment gateways such as PayPal and credit card which would further decrease their profit margin. Retailers will have little choice but to increase the price of these products to gain profit from selling on the platform. These increase in price would also cost customers to pay more for the product. With the introduction of blockchain technologies into these, it would remove the need for the intermediaries, and these payments can be made directly between the retailer and customer reducing the cost of the product and increasing profit.

Traceability. Tracing an order item back to its root origin proves to be an arduous task when products are traded using a centralized traditional E-commerce platform. Therefore, with blockchains, it allows an audit trail whenever an action is done during the transaction. This help to verify the authentication of the transaction, preventing frauds. This is especially useful for order tracking as blockchain allows immutable tracking. This means that customers are able to locate where their products, whether their products are genuine and what is contained etc. This helps to maintain the integrity and authenticity of products.

Trustless. In traditional forms of e-commerce platforms, information used by retailers is owned by the platform. These platforms offer guarantees and reviews of seller whereas, for payment gateways, they offered to keep safe of the transaction amount till its verified. This undeniably gives absolute controls to these platforms and gateways over their customers. Furthermore, trusting these platforms and gateways to store huge amount of confidential data posed a risk in terms of privacy issues, which is why these companies are the choice of targets for fraud and hacking attempts.

Therefore, blockchain can be employed to create a system where trust is no longer required. The cryptography in blockchain can completely eliminate the external intermediary. This allows the customers to run the complex consensus protocol unanimously, hence allow them to agree securely the type of data to be added into the ledger while ensuring data integrity. By doing so, it builds a base of trust which also removes the third party and thereby, reducing the transactional cost.

2.2 Challenges of Blockchain Adoption in E-commerce

Blockchain technologies come with their own challenges. Factors ranging from policy discordances to technical limitations hinder the adoption of blockchain in e-commerce. There are a number of the existing obstacles discussed as the following.

Scalability. The limited block size of blockchain technologies has resulted in the loss of scalability as compared to modern payment processors such as Visa or Mastercard. According to data shown, the Visa payment processor is able to do around 48,000 transactions per second whereas, for blockchain protocols such as Bitcoin, it is only able to reach 7 transactions per second with a fixated block size of 1 MB [2]. In order to be on par with these modern payment processors, one solution is to increase the limit of the block size. However, by doing so, it affects the number of power consumption due to the huge amount of data resources.

Furthermore, increasing the limit of block size creates a strain on the security as the probability of blocks being orphaned increases which inevitably affects the bandwidth cost and validation cost. The higher the limit of the block size, the larger the transaction load and with a decrease in transaction fee, security decreases.

Privacy. Public blockchains simulate the current World Wide Web, enabling public access of data to all participants [12]. They ascertain that the recorded data are readily available and reduce transactional costs. However, public access blockchains may imperil data privacy. Blockchain technologies depend on the write-only data process which makes them unable to remove any information [13]. Moreover, their core depends on a distributed data storage system where the same data is stored in the entire node network. Therefore, any forms of changes require an agreement made by the entire node network, making any removal of data difficult. Data control to public blockchains has raised an issue, especially when sensitive or confidentiality of data is involved as there is no way to rectify damages once these data are uploaded.

Compatibility. Despite blockchains providing transparency and immutable of data information, the efficiency of entering information might be an issue. For example, in existing solutions such as supply chain management systems, legacy systems are usually used to store information. Therefore, this results in incompatibility in data and system sensors which makes data access arduous. By integrating blockchain into supply chains, it may cause an overload of data for the system to handle. Furthermore, this may affect the quality of data stored into the ledger, causing inaccurate data assumptions in the following chains.

Acceptance. In order for e-commerce to incorporate blockchain, it will require a lot of investments in using these new technologies. This is an undeniable step in order for it

to be viable so as to provide traceability long the entire blockchain network. Furthermore, the issue to strike a balance between confidentiality and transparency of data in order to re-engineer business processes to use this distributed ledger to store and share data information requires in-depth discussions. It would be possible to access companies' business secrets and activities if all the information is stored in the ledger, resulting in loss of confidentiality. Therefore, this may lead to a reluctance for e-commerce companies to embrace blockchain wholeheartedly due to the culture of acceptance, organization, and standardization of its uses.

2.3 Existing Blockchain Solutions in E-commerce

With the rising bloom of online transactions, many e-commerce platforms have adopted a decentralized distributed ledger technology to reach out to their consumers to ensure efficiency with minimal cost. These are some of the existing solutions in e-commerce that imbued with blockchain as the following.

Legitimate Product Review System. Genuine reviews found online are usually based on assumptions. Positive reviews might be generated by sellers in order to increase their turnovers and negative reviews written by competitors to diminish fellow competitors. Also, there is no form of incentive for customers to leave reviews even if there were sales based on their reviews. The use of blockchain technologies can help to resolve the reliability of the verification of reviews. Furthermore, through referral systems, customers can be rewarded if their post leads to sales due to the ability of blockchain enabling to track all transactions. For example, Zapit, an US-based company utilized this to ensure compensations to both the reviewers and moderators, encouraging validity to ensure a win-win situation.

Supply Chain Management System. International shipping has proven to be a challenging problem faced by Shipping freights companies worldwide. In order to ship refrigerated goods from one country to another, a series of paperwork such as stamps and approvals are required in order for the process to be completed which result in high cost [14]. The use of blockchain technologies helps to eliminate inefficiency and digitize paper records. For example, Maersk, the world's largest shipping company, in collaboration with IBM, uses Blockchain technologies called TradeLens to provide an audit trail, allowing businesses to exchange information securely, connecting the vast global network of shippers, carriers, ports, and customs, so that all participants are able to access information in a unified view.

Employee Benefits System. An internal e-commerce platform has been successfully implemented for the Hainan Airlines (HNA) group to enrich employees benefit options [15]. It enables employees to have more options to claim their benefits and empowers suppliers with an additional channel to sell their products. The study revealed that blockchain of value in several ways: (1) cryptocurrency issuance, (2) sensitive information protection, and (3) no institutional intermediary. The implementation of such a win-win arrangement extended across three phases.

With the help of blockchain technologies, a number of existing solutions have been explored in e-commerce; nevertheless, there are vast fragmentations and differences in scales and sizes of blockchain applications. Furthermore, the full utilization of blockchain properties in e-commerce is yet to be investigated.

3 Proposed Blockchain Applications

Based on the survey of blockchain technologies in e-commerce, this study takes an important step to propose two applications for social shopping and loyalty program. These e-commerce applications are designed with the utilization of blockchain properties such as traceability and trustless in order to enhance customer engagement. They allow platform operators to embrace blockchain with minimal changes in technological infrastructure; thereby potentially leading to better compatibility and higher acceptance.

3.1 Social Shopping

The first proposed solution provides businesses and consumers a reinvented implementation of a social shopping functionality using blockchain technology as shown in Fig. 2. The prices of a product or service lower when the number of people who commit to buying increases [16]. This empowers the customers with a negotiating factor with the supplier to enjoy better savings as compared to purchasing product from brick and mortar establishment which most of time uses a fixed pricing model [17]. With the use of blockchains, social shopping leverages on the linked data structure and traceability of the technology to offer multi-tier dynamic pricings for groups.

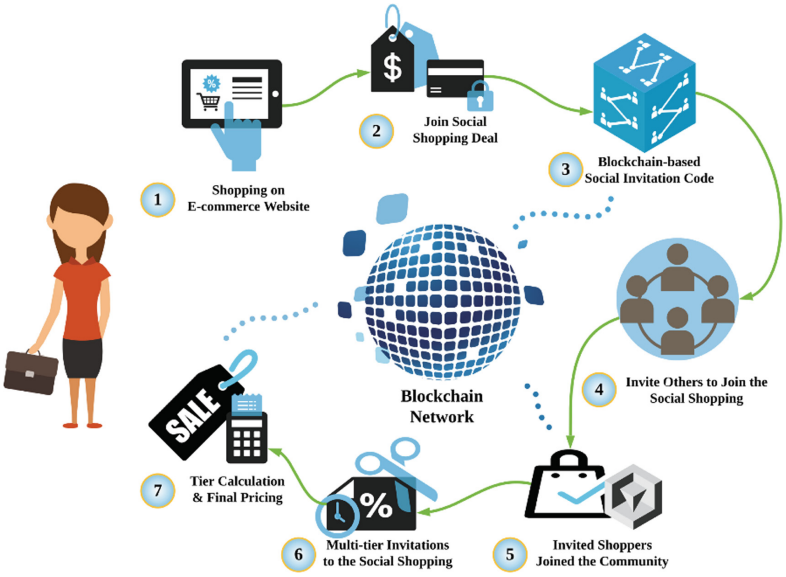

Fig. 2. Blockchain-based social shopping

1. **Shopping on an e-commerce website.** The key benefit of social shopping for customers is that they would have the potential to get a discount of the product being purchased as the price of a product is often the most important factor to customers. It would draw more traffic to shopping on the e-commerce website and increase the sales of the products using the customers' social connections.
2. **Joining social shopping.** The model of social shopping is associated with time-limited deals as shown in Fig. 3(A). Shoppers would browse the e-commerce platform and discover the products on multi-tier promotions. The preview of dynamic pricings as shown in Fig. 3(B) would be a differentiating factor for customers to buy a product.

Fig. 3. Social shopping - Prototype

3. **Blockchain-based invite code.** Each customer that join the social shopping would be added as a transaction on the blockchain with related information such as the promotion-based product, payment and shipping particulars. A social invitation code will be assigned as the address to the customer's block as shown in Fig. 3(C). The blockchain network can be public, private, or consortium; in which network participants are decentralized peers to prevent double claiming or duplicated invitations with the use of a consensus algorithm.
4. **Inviting others to join the social shopping.** This invitation code serves as an important pointer to keep track of the multi-tier referring structure based on the linked data structure of blockchain technology. Sharing it over emails, private messages, or social networking sites would allow customers to unlock a better pricing tier for the time-limited shopping deal.

5. **Invited shoppers invite more social friends.** The invited buyers would also be incentivized to invite more social friends for further discounts on their purchase. A new transaction will be added when a new buyer joins the social shopping with an invitation code. This block will contain the linkages between the inviter and the invitee, as well as, the parental referrers and the invitee if any.
6. **Gaining from multi-tier dynamic pricings.** With the use of blockchain technology, the hierarchical relationships between referrers and invited buyers can be captured on the chain with minimal computational complexity.
7. **Tier calculation and final pricings.** The system will enumerate customers' tier and compute final pricings on the chain when the time-limited shopping deal is expired. An example is illustrated in Fig. 4.

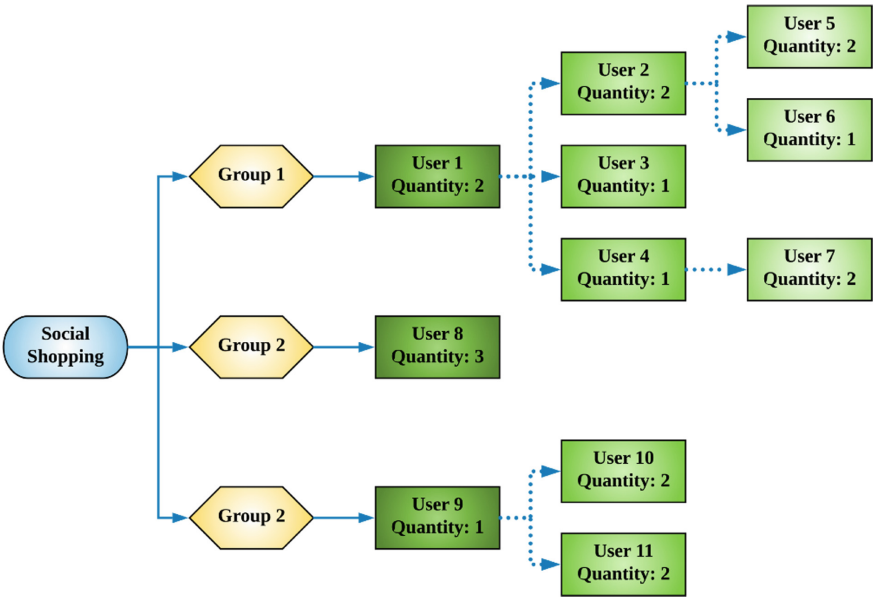

Fig. 4. An example of multi-tier social shopping

Participants are given discounts based on the number of items participants buy using their invitation code, there are different tiers to state how much of a discount they get as shown in Table 2.

Table 2. Multi-tier dynamic pricings

Tier	Discount
Tier 1	Quantity of 1 to 4: • Discount of 5% of each item
Tier 2	Quantity of 5 to 10: • Discount of 10% of each item
Tier 3	Quantity of 11 and more: • Discount of 20% of each item

In the example, User 1 would receive the tier 3 discount as Users 2, 3, and 4 join the social shopping using User 1's Invitation Code and also because User 5, 6 and 7 were invited by users who were invited by users who were invited by User 1, the user would also gain benefits from the invited users. The system is set up to allow users to back out of the group buy within the time limit of the group buy so even if a user backs out of the group buy, transaction records of the group buy are still available. The users who were invited by and who invited the user are not affected other than the reducing of quantity from the user backing out. From the diagram, if we use User 2 as an example of the user who backed out. User 1 would have a reduction in the quantity from 11 to 9 which will change him from Tier 3 to Tier 2. Similarly, for users under user 2 being user 5 and 6 would remain at their respective tiers.

Once finalized, the system will process the payment and begin the order fulfillment procedures like shipping the products.

3.2 Loyalty Program

The second proposed solution is to use purchasing tracking based on a loyalty program, integrating it with blockchain technologies as shown in Fig. 5. The solution will track customers' behavior when they are doing their shopping and stores each of their behavior activities into data which will be hashed and store into a database using blockchain [18]. The purchase tracking loyalty program will utilize a tier-based point system where there will be a different level of a point system in order to unlock different kinds of rewards. The more point accumulated by the customer, the better the rewards achievements unlocked. The points will be stored inside a single wallet where they will be converted and redeem in the form of promo codes or coupons. These promo codes will be enabled to use across major e-commerce loyalty programs.

Purchase tracking with blockchain resolves the problem of fragmentation of loyalty points across various loyalty programs. It allows the use of a single wallet where rewards will be tokenized and stored as a single type of token which can be utilized for other E-commerce loyalty programs. This prevents restrictions of redeeming rewards within the system. The use of blockchain enables it to convert reward points to a token for vast usage.

1. **Shopping on any e-commerce website.** Purchase tracking with loyalty program helps to retain existing customers and used to attract new customers, ensuring a better shopping experience. The advantage of blockchain is to integrate any e-commerce website into a loyalty network for a unified shopping experience.
2. **Making purchase transactions or taking rewardable activities.** The shopping behavior of customers will be tracked as demonstrated in Fig. 6(A) in order to tailor what kind of discount and gifts to ensure retention, attracting customers' attention. For example, when a customer buys a product, the transaction actions will be tracked where it will be stored as data. Each of these actions will have different loyalty points where some of them will have a max cap per day to ensure that consumer will not abuse the system.
3. **Session aggregation and blockchain forging.** During a shopping session, customer activities will be tracked and aggregated into an optimized data block for

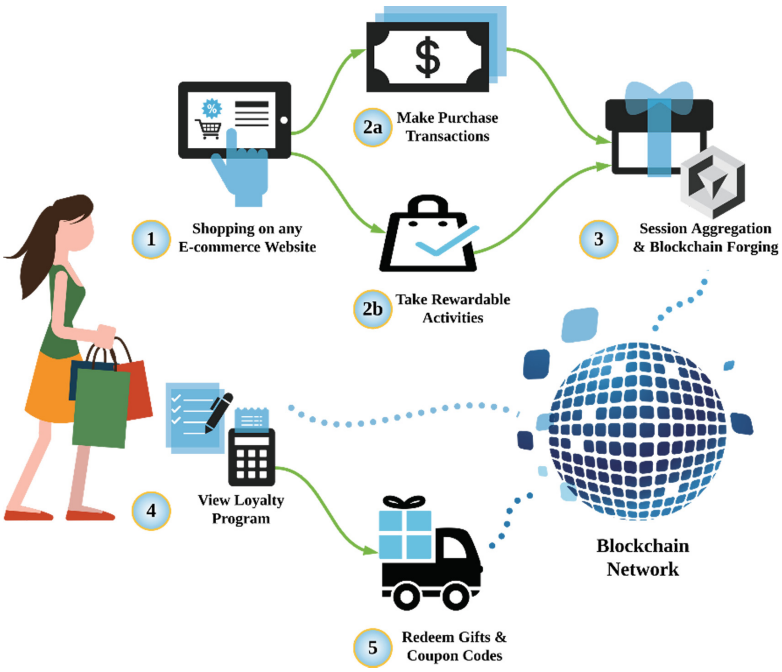

Fig. 5. Blockchain-based loyalty program

forging. These data will be hashed and stored into the blockchain network. Transaction data will be converted as loyalty points using a point converter in the E-commerce platform. Each of the points will be referenced to the previous block to ensure that there will not be double spending or duplicate points redeemed. These points will be tallied against the Reward Point Tier System where the customer will be required to meet the minimum target of the points for the different tier in order to unlock exclusive features catered to the customers.

4. **Viewing loyalty program.** The loyalty program module lists down all the reward history the customers had done during and after his shopping experience as illustrated in Fig. 6(B). This will enable purchase tracking of customers behavior on what they had shopped which can be used for future analysis of behaviors. The page also records the balance points as well as which tier the customer belongs to. Each of the transaction id and name are generated by the public and private key using blockchain so that there will not be any form of double spendings or duplicates.
5. **Redeeming gifts and coupon codes.** The redeem module allows customers to redeem their points where it will be generated into promo code based on the amount converter. These promo codes will be able to use for their next purchase of items. The redemption activity allows users to collect their promo codes whenever they are awarded, or they unlock any discount features. The points will also be utilized across other e-commerce platforms. Blockchain allows each transaction to be recorded and access by multiple parties immediately.

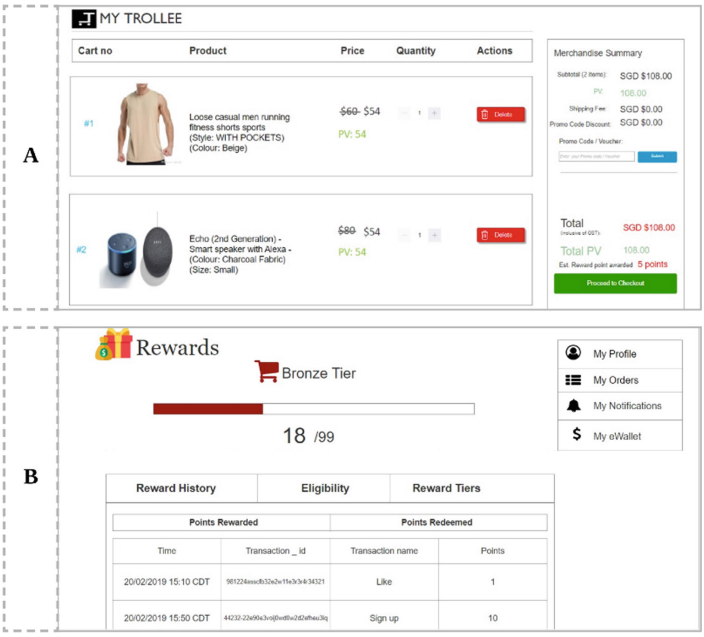

Fig. 6. Loyalty program - Prototype

The proposed blockchain-based applications in e-commerce have been developed in client-side programs, which support both mobile and web interfaces. Connected to a blockchain network via JavaScript Object Notation (JSON) serialization and deserialization, the implementation of these applications is highly compatible with major e-commerce platforms. It fully utilizes blockchain properties to reshape customer experience with better security and minimal investment in technological infrastructure. The study, therefore, demonstrates the utility and suitability of blockchain applications in e-commerce.

4 Conclusion

Our study has several implications for theoretical literature and practice of e-commerce and blockchains. First, the study provides a survey of existing blockchain technologies and application in e-commerce. Second, we highlight key blockchain properties with their benefits and challenges in online shopping sites. Third, the paper discusses several existing e-commerce applications with blockchains and proposes new applications with the full utilization of blockchain properties. These blockchain applications bridge the gaps between technological concepts and prototyping to support researchers, developers, and platform operators for rapid adoption, better compatibility, and higher acceptance. Last but not least, we designed and implemented a platform which is capable of transforming the current generation of e-commerce towards a more social and decentralized direction.

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