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Deferral: on the Feasibility of High-volume Blockchain-based Referral Systems

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***Abstract*—Digital marketing has transformed referral marketing, revealing limitations in traditional centralized systems such as trust, transparency, and efficiency, however, the potential advantages of decentralized systems remain underexplored. This paper investigates the feasibility of a high-volume, decentralized referral system. The approach assesses smart contract prototypes for cost-effectiveness and performance in high-user engagement scenarios in different EVM-compatible blockchains and referral strategies, such as multilevel referrals. Findings confirm the technical viability as a blueprint for designing and implementing similar systems, highlighting challenges in real-world deployments, such as Sybil attacks, and the interplay between technical and economical design factors.**

***Index Terms*—Referral System, Blockchain, Decentralized, Digital Marketing**

I. Introduction

Digital marketing has fundamentally transformed referral programs and systems. Customers engaged in contemporary programs wield significantly more influence and potential, thanks to the reach and opportunities that digital platforms offer [6]. By nature, digital marketing involves practices and tasks facilitated by digital technologies and channels. As a result, processes like planning, designing, executing, and maintaining a referral program have become complex. Today's referral programs are typically large automated systems capable of handling several operations [6]. The digitization of these programs allows them to accommodate a substantially higher volume of users, creating a surge in referral completions and added participants. Such amplified scale imposes distinct demands on performance, costs, and security when ensuring the cost-effective processing of many referrals [11].

Traditionally, are built as centralized systems [11]. By their nature, centralized systems face limitations such as a lack of transparency, vulnerability to fraudulent activities like fake account creation, dependence on intermediaries leading to additional costs and potential points of failure, slow processing of referrals, and geographical restrictions [15]. This environment makes it challenging for users to trace their referrals and claim rewards, diluting trust in such systems.

This paper explores the potential of leveraging Blockchain (BC) technology to address these issues. Using decentralized, BC-based systems can enhance transparency and reduce dependence on intermediaries [16]. However, it is essential to underline that these systems bring challenges, especially compared to other use case scenarios. Notably, scalability becomes crucial in high-transaction environments like referral programs. The design of the referral program on a BC, including its features, rules, and reward structures, has to be carefully designed in a Smart Contract (SC). In addition, ensuring user identity in a decentralized setup (*e.g.*, preventing Sybil attacks) is complex, as conventional verification methods may not be directly applicable.

The scarce literature regarding BC-based referral programs [2], [9], [15] makes the analysis presented in this paper timely and relevant. The main contributions of this paper are as follows:

- A feasibility analysis for high-volume, multilevel volume referral systems, focusing on performance and cost implications and considering multilevel referral contract designs on Ethereum-compatible public BCs.
- Providing an implementation roadmap for BC-based referral programs, supported by multiple SC templates, which can serve as foundational blocks for future research.

This paper is organized as follows. Section II presents related work. While Section III describes Deferral's design with an overview of referral contracts, Section IV evaluates and discusses results. Observations are part of Section V.

II. Related Work

Referral rewards have been thoroughly researched since they can significantly influence the outcome and design of referral programs. The allocation of rewards and its effects are explored together with the motivation and attitude of customers towards referrals [5], [12], pricing decisions and strategy of a product or service [5], or the conversion rates and the total number of referrals [12], [10].

[4] lists a few examples of software packages for referrals like Ambassador [1], or ReferralCandy [14], and there exist more [13], [20]. However, their architecture and implementation are not open-source, as it is part of their business secret. Hence, it can be assumed that these referral systems are implemented based on centralized

architectures. Besides academic literature and work, a few projects are trying to provide ways for decentralized referral marketing. Selected examples are Attrace [2], Energiswap [8], and RefToken [15].

Attrace [2] presents a decentralized referral protocol for Web3, utilizing SCs and BC oracles to foster transparency and trust in promoting crypto projects. Although the platform aims for lower fees and swifter payments, it retains central components that are not open-source.

Energiswap [7], part of the Energi World ecosystem [9], offers a DEX on its Ethereum-compatible BC. This compatibility ensures that SCs designed for Ethereum function seamlessly on the Energi BC. However, detailed documentation about these SCs and their reward mechanisms remains limited.

RefToken [18], a platform for promoting DApps and *ICOs*, utilizes SCs on the Ethereum chain to oversee referrals. Data pertinent to referrals is stored on the BC to counter referral fraud. Despite its initial promise and available white paper [18], the platform is currently inactive.

III. Designs for Blockchain Referral Systems

The proposed design comprises two multilevel SC designs In a decentralized framework, the evaluation of referral procedures and reward distribution would typically be governed by a referral SC. The referrers (issuing recommendations) and referees (receiving recommendations) could initiate a transaction with the SC (*cf.* referral payment evaluator in Figure 1), citing information about another user who referred the participant, *i.e.*, the referrer. They differ in design aspects, especially from the technical implementation point of view. Contracts are coded in Solidity, a Javascript-like language compiled into the Ethereum Virtual Machine (EVM) [19]. The following referral designs were implemented and analyzed:

1) **Multilevel Rewards** use a payment quantity and a threshold value. Distribute rewards to the most recent referrer and multiple previous referrers, creating a referral chain with rewards distributed along.
2) **Multilevel Token Rewards** show a different use of arbitrary ERC20 tokens that serve as the cryptocurrency for referral payments and rewards instead of native assets.

*1) **Multilevel Rewards**:* The main functionality of the multilevel reward contract is distributing rewards to the most recent and multiple previous referrers (*cf.* Figure 1). To complete a referral process, a referee has to send a certain amount of payment transactions that, on the one hand, surpass the defined payment quantity threshold in terms of transactions sent and, on the other hand, exceed the payment value limit in terms of total accumulated value sent through the payments.

The contract introduces a referee reward percentage value, enabling two-sided referral rewards similar to the third version of the referral payment value contracts. Secondly, it includes a maximum reward level value stored on

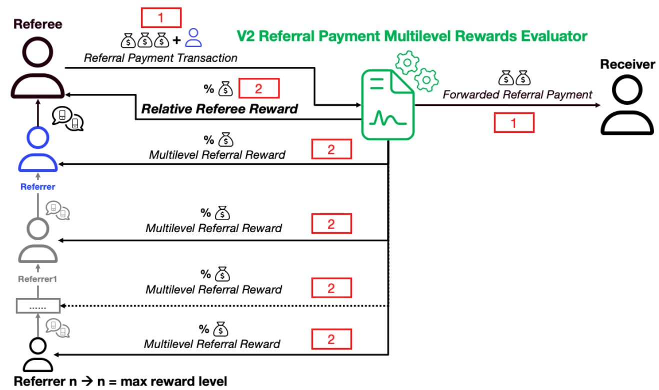

Fig. 1: Referral Multilevel Rewards Contract

the contract. This value determines the maximum length of the referral chain for reward distribution, *i.e.*, to how many previous referrers the rewards are distributed (*cf.* Figure 1). In an exemplary scenario, user (1) is referred by user (2), who is then referred by user (3), who is, in turn, referred by user (4), and so on. The maximum reward level value on the contract is set to three.

If user (1) completes the referral process, the referral rewards are distributed to the three nearest referrers of user (1) up along the referral chain. Assuming the total reward is 60 ETH and all these rewards are distributed to the referrers, *i.e.*, the referee reward percentage is set to 0%, user (2), user (3), and user (4), would each receive a reward of 20 ETH. If the maximum reward level is set to six, from user (2) to user (7), every referrer would receive 10 ETH. If, in the same example, the referral contract has defined a referee reward percentage value of greater than 0%, *e.g.*, 50%, 30 ETH would be sent to the referee who completed the process. The other 30 ETH would be distributed equally to the eligible referrers along the referral chain.

*2) **Multilevel Token**:* The primary distinction is that with this design, an arbitrary ERC20 token can now be utilized as a cryptocurrency for referral payments instead of native cryptocurrency assets. Consequently, the forwarded payment and referral rewards are sent, received, and distributed as an ERC20 token. The multilevel token reward contract permits and accepts only one predefined token, which must be stored on the contract. It cannot be updated after the initial creation of the referral contract. Changing the currency token for ongoing referral processes and referral payments would lead to inconsistencies in the process evaluations and reward distribution.

Introducing the possibility of using an ERC20 token opens doors to additional use cases. For instance, multiple companies, *i.e.*, their referral systems, could use the same ERC20 token as a reward. Users could earn the same rewards across multiple referral systems, creating a shared referral reward ecosystem. Such an ecosystem could open doors for further marketing activities. For example, rewards as ERC20 tokens integrated into the DeFi space, making the tokens tradable on a DEX (Decentralized Exchange).

IV. Experimental Evaluation

In evaluating the intricacies of multilevel referral programs, particularly our open-source designs involving straightforward multilevel referrals and the ERC 20-based multilevel tokens, it's essential to measure them on key dimensions:

- **Cost Analysis**: includes transaction execution and deployment costs from user and provider perspectives to identify the most economically viable solution.
- **Performance and Scalability**: analysis of the referral contracts' performance and scalability under high user volume and transaction influx.
- **Security**: discussion on the robustness of the different referral designs against Sybil attacks.

A. Cost Analysis

Evaluation scripts include several configurations and combine different measures and metrics. Data regarding gas prices for different EVM-based BCs were fetched. In EVM-based evaluation BCs, gas refers to the unit of measurement required to quantify the computational effort needed to execute transactions. The gas used for a transaction is the foundation that, in combination with the gas price, defines how expensive the execution of that particular transaction on a specific BC is.

TABLE I: Gas Reporter Output Showing *GasUsed* for the Deferral Contract Deployments

Deferral Contract Deployments	GasUsed
Multilevel Rewards	1249422
Multilevel Token Rewards	1411504

Table I present the gas used for the initial deployment of the different contracts regarding the evaluation runs done with 500 users. A similar picture shows that larger and more complex contracts implementing more functionality require more gas to be deployed. It can be observed how the average gas used per transaction is the lowest value for the referral payment transmitter design, as these contracts provide the simplest versions for referral systems. Thereon, the results are similar and close for all versions of the referral payment quantity and value evaluator contracts.

Furthermore, the evaluation results across all the solution smart contracts can be reviewed, focusing on the gas costs required on the different evaluation chains and the resulting fiat costs in USD for the calculated gas used metrics. The historical gas and fiat prices of the evaluation chains depicted in Figures 2 and 3 underscore how the evaluation results could vary if the underlying price values were recorded on a different day. The shown high volatility of gas and fiat prices is an important factor when evaluating the results.

Looking at the fiat prices over the same period, Figure 2 shows how the Ethereum fiat price also significantly fluctuates. However, for the Polygon layer-2 BC, which showed volatile gas prices, the price in USD is stable over time. All

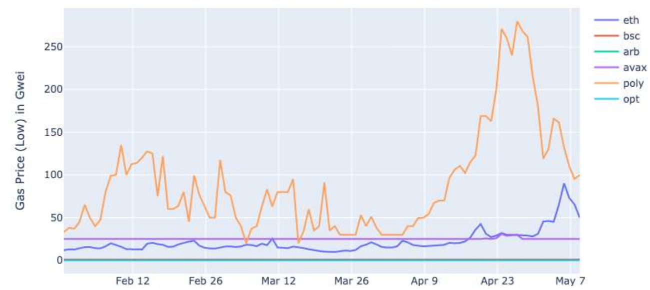

Fig. 2: Gas Prices [*Gwei*] over Time per Evaluation Chain

Fig. 3: Fiat Prices [*USD*] of Evaluation Chains over Time

the prices are shown in Figure 3 (right) refer to one default unit of the corresponding chain. For instance, the price of one MATIC on Polygon, one Ether on Ethereum, or one BNB on Binance.

Moreover, Figure 3 highlights how the Arbitrum and Optimism chains also use Ether as a native cryptocurrency. Consequently, the lines of the Ethereum, Arbitrum, and Optimism prices overlap in Figure 2 and cannot be distinguished. Eventually, the big price differences shown before concerning costs in USD between the different evaluation chains are emphasized again. All evaluation results related or calculated using either the gas price of a specific evaluation chain or its cryptocurrency fiat price demonstrate only a snapshot. This snapshot is based on the gas and fiat price values fetched and recorded during the execution of the evaluation scripts.

B. Performance and Scalability

In the case of hundreds of users participating and completing the referral process, the difference in gas used for the final transaction of a user to complete the process can grow significantly. This is even more acute for Multilevel Referral contracts, where a referral payment chain is created in response to a transaction. For instance, in the final transaction of user (1), the rewards must only be sent to one previous referrer. However, for user (10), ten previous referrers already receive rewards. As a result, the final transaction of user (10) requires more gas since the assets must be sent to ten other users. Due to this functionality, the costs and durations of the completed transactions for the participants increase with higher volumes of users.

Further, these transactions take longer to execute as the contract must perform more send operations.

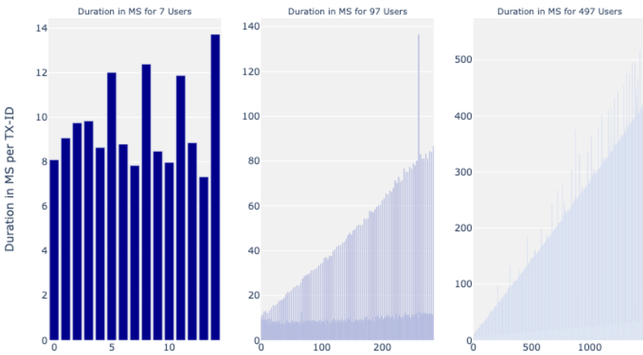

Fig. 4: *Duration [ms]* per Transaction Multilevel Rewards Contract. Simulation of 7, 97, and 497 Users

By taking a look at the gas used for the individual transactions within the three evaluation runs in Figure 4, it can be observed how every third transaction is increasing in cost the more users are involved. Thus, especially in the evaluation runs with 100 and 500 users, the distributions of the gas used per transaction are skewed extremely negatively. As a result, the gas used and the duration of the referral payment transactions are higher for users that participate later in the referral system. For instance, it takes longer and is more expensive for user (10) than for user (1) to complete the referral process on the Multilevel Rewards contract. In the case of hundreds of users participating and completing the referral process, the difference in gas used for the final transaction of a user to complete the process can grow to several million.

C. Sybil Attacks

One of the main concerns in referral systems is the Sybil attack, where an attacker can create multiple accounts and refer themselves to gain benefits [17]. Multilevel rewards contracts impose a stricter criterion on qualified users who can become referrers. This implies that every referrer has to be a registered and identified user who has done a payment transaction before *i.e.*, a customer. In decentralized systems, mechanisms for control and identity verification become more complex, yet are crucial for the system's feasibility.

The use of Decentralized Identity (DID) verification protocols [3] is an approach against Sybil attacks. These protocols could leverage attestations from various sources, like social media accounts and phone numbers, to establish and verify unique user identities on-chain. They essentially enable a form of pseudonymous reputation, which can be used to guard against Sybil attacks. However, it is important to consider that this increases complexity and could introduce privacy concerns. Balancing robust Sybil attack prevention and user privacy should be a key consideration in designing such systems.

V. Observations

Deferral illustrated the intricate considerations in the design and implementation of multilevel referral smart contracts, suggesting potential for cost and performance optimization through off-chain components. All smart contracts produced, deployment documentation written, and evaluation steps made are open-source [19], reinforcing the reproducibility and transparency of this work.

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