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# Scalable Token Staking And Reward Distribution Ethereum: A Pull-Based Smart Contract Approach

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***Abstract***

*Existing financial systems are often centralized and opaque andexclude many people. Decentralized Finance (DeFi) address this by using blockchain in a way that peers can transact directly and not through intermediaries. Nevertheless, creating a reliable, democratic and user-friendlystaking solution is no mean feat. The paper presents a DeFi token staking and rewardsmanagement system built on top of Ethereum programmable contracts, React, Node. js. Third-party control is removed and an open protocol is made available so users can securelystake the token. Smart contract cover some essential partsof lock-up period, penalty, reward distribution. With MetaMask support, authentication and transactions are atotal breeze. A fresh dynamic reward system ensures maximum pay-out depending on staking period and network activity as well as to guarantee fair rewards forthe small guys. Boasting of Open Zeppelin for full audits, theplatform offers more security and reliability at 40 % less in gas fees against the conventional business model. With democratized access to passive income and the removal of a centralized risk, this effort makes it possible to build scalable, user-focused DeFi on the blockchain. It provides a model for the broader proliferation of economic infrastructures that aredecentralized, leading to the developmentof open and inclusive economies.*

***Keywords:****DeFi,TokenStaking,SmartContracts,Blockchain,Ethereum,RewardDistribution.*

## 1. INTRODUCTION

These middlemen gatekeepers for every single transaction process transactions, watch interactions and assist financial services. These have some stability, but are very nebulous, andexpensive to obtain and maintain.What's more, employing intermediaries has been shown to create complications and increase the risk of mismanagement and corruption.

Luckily, there emerged a new alternative called Decentralized Finance (DeFi), which utilizes blockchain technology to provide direct connection among users without middlemen. DeFi services are built upon smart contracts and decentralized protocols, meaning that users have greater control and access to these operations than they do through traditional systems. In the DeFi space, token staking is one of the most successful application methods, allowing users to stake their tokens, which will reward you.

Token staking has become increasingly popular, but its growth is often stifled by security vulnerabilities, unfair distribution of rewards, and high transaction fees, among other issues. Most of the existing solutions were not transparent, secure, and easy to use. This paper shows the DeFi, secure token staking platform with automated earning system where Ethereum smart contracts, React and NodeJs are utilized for automatic reward for userwith secure staking. What sets them apart with Axion is cutting the third-party out, being transparent andreliable staking can be. In order to mitigate the potential for rewards not being paid outfairly, a dynamic mechanism to adjust amounts of payment was implemented based on annual length of stake anduse of our web portal. Anduser authenticationand managingtransactionsismade easyby itsMetaMaskintegration, resultingisbetter UX. “With a focus on security, Sleuth has partnered with OpenZeppelin to perform exhaustive security Page3 of 12

AIWritingSubmissionSubmissionIDtrn:oid:::29034:120053024auditsfortheplatform.Theplatformtouts, among other things that it features a 40% gas fee reduction as compared totraditional models.

ThiswillcontributetomakeDeFisystemswidelyacceptedonalargescalebythepartieswithascalableand privacy- preserving consent algorithm.

user-centeredstakingplatform.ADVERTISEMENTTheanswerfocusesonthesystemicpotentialofdecentralized finance to

transform the financial service sector with the promotion of financial inclusion, mitigationof centralization risk, and incentivization of transparency.

## 2. RELEVANT STUDIES

For various functional uses, token staking protocols and reward distribution models are inherent components of Proof of Stake(PoS)blockchainnetworks. Such networks areanenergy-efficientalternative to Proof of Work (PoW) where validators are selected based on tokens staked rather than processing power. PoS is more energy-efficient, which renders it a scalable and sustainable consensus protocol. Ethereum's transition from PoW to PoS has particularly demonstrated spectacular declines in energy consumption and improved network security [1].

Token staking platforms are gaining popularity because they allow users to lock tokens in a network, securing and maintaining it and earning rewards in the process. The staking system in Ethereum offers users staking strategy independence because previous trends show that changes in staking yield are most often a determining factor in users' preference [2].

Stake value and popularity are driven by proof of stake. To distribute rewards more efficiently other platforms havea Pull-Based Model, that holds rewards in buffer for some time. This enables participants

to claim theirrewards at anymoment,minimizes on-chaincomputations andenhances scalability. A study by Batog et al. pointed out how such pull-based models can achieve a time complexity O(1) via using techniques based on partialsum look-up algorithms, and as such are by far more efficient than push-based systems [3].

In addition, the MEV hasbeen another variable that hacs been another factor that is proven tohave an impact on rewards for staking. MEV is a surplus revenue which can be extractedby validators through reordering transactions inside of the mined blocks.It has been proved in \cite{4xx} that fees, particularlyif distributed under an exponential form (e.g., like the ones of Figure 3), are able to strongly affect total rewards coming from the stakers. Economic models applied to staking are often contrasted withtraditional finance theories.

To determine possible staking rewards, other researchers suggest using cash-flow discount models to informing investors of what they can expect as returns. Furthermore, the dynamic relationship between T0 prices and the staking ratio, and incentive mechanisms is investigated, illustrating the importance of distributing rewards according to a user's contribution so as to keep network stable and usersactive [5].

New stakingplatforms can solve these problems, such as high gas fee, unfair prize allocation and weak security level to offer more reasonable and pleasant experience for users. This paper uses the Ethereum smart contract and a variable reward system to improve the platform staking performance and reduce costs.

## 3. STAKINGMECHANISMANDREWARDDISTRIBUTION

Decentralized Finance (Defi) enables stacking users to secure the network and help receive awards. Etherium's move in the Proof-of-Stake (POS) has enabled it to use less electricity and decentralize it. Customers keep their ether in staking contracts, which helps shape how network transactions get consent. Verifications are chosen to propose and certify the block, how much bet they have placed, which protects the network. This paper discusses the method of payment of awards to encourage various staking plans, risks and participation.

### STAKINGMECHANISM

Ethereum transitioned to a Proof-of-Stake (PoS) mechanism in 2022, wherein staking took over from mining. Validators make up the core of this system, proposing and sealing blocks to secure the network. Users need to stake a minimum of 32 ETH (≈$60,179.61 as of March 2025) to be a validator, so they are indeed concerned about good behavior. Validators are chosen by an algorithm depending on the size of what they stake and their past engagement, with higher stakes having a higher chance of being chosento propose blocks. They are tasked with keeping the system running, suppressing bad behavior (e.g., double-signing), and following protocol rules to avoid punishment such as slashing, where they lose some of their stake.

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**Staking Options:**

Several staking options accommodate those with varying levels of capital, technical ability and risk appetite:

- **Solo Staking**

Mechanics: Validators are operating their own validatornodes, meaning they have full control over degree of configuration, security and availability. This is technical,you need good gear and always-on internet access.
Risks:SolostakersarewhollyliableforslashingpenaltiesandrisktheirfundsbeinglockedinasamountofstakedETHisn'treleaseduntilthenetworkpermits withdrawals.

- **Staking Pools**

Centralized Pools: Exchanges and custodial providers offer these pools to join up smaller rows into the 32 ETH minimum.

Users deposittheir ETH with the pool operator, for convenience at the expense of control. Fees (e.g.,10 percent of rewards) eat into net returns.

*Decentralized Pools (DSPs):* Non-custodial pools (like Rocket Pool) leave usersin control of their private keys. Participants contribute ETH to a common stake, and rewards aresplit. There are, however, smart contract risks associatedwith DSPs — possible coded flaws in the code managing pools.

**LiquidStaking**

*Mechanics*: Users deposit ETH into a staking provider (such as Lido) and get liquidstaking tokens (LSTs) such as stETH. LSTs are utility tokens for staked ETH and the rewards that have been received, which canbe traded on DEXs.

*Risks*:ThemainconsiderationisthatLSTsarelinkedtothesuccessoftheirservice.

If the service gets slashed or ceases to exist, LSTs can depeg from ETH's market price, creating counterparty risk.

**ExchangeStaking**

*Mechanics*: Centralized exchanges (e.g., Coinbase) manage staking for users, with little technical expertise needed.

*Disadvantages*: Users give up control of their ETH, bear custodial risk, and tend to earn lower rewards due to platform charges.

## STAKINGREWARDGENRATION

Rewardsarebenefitsthatparticipantsareofferedfortyinguptheirresourcesandsecuringthetransactionson the blockchain. They come in the form of fresh coins and fee transactions, making the users want to stake their assets and support the security of the network. The validators are selected by how much they have staked and using a probability model. Validators with larger stakes have a higher probability of beingselected to propose blocks. Any given staker will have an opportunity to validate the next block with achance based on what they have staked.

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**Sourcesof Rewards**

Rewardsoriginatefromtwoprimarysources:

- *BlockRewards*:NewlymintedETHissuedbytheprotocol. AbaseissuanceensuresminimalETHcreationtosecurethenetwork.

  Therewardpervalidatordecreasesasthetotalstaked ETHincreases(dilutioneffect).

- *TransactionFees*:Userspaygasfeestoprioritizetransactions.

Post-EIP-1559, a portion of fees is burned (reducing ETH supply), while the remainder is distributed to validators.

**Reward Calculation:**

Rewardspervalidatorareproportionaltotheirstakerelativetothetotal ETHstaked.Theformulaforavalidator's rewardis:

$$Reward = Stake \times \left( \frac{BlockReward + TransactionFees}{TotalStakedETH} \right)$$

**Reward Distribution Models**

Twoprimaryapproachesexist:

*Push-BasedModel(NaiveApproach)*

Rewardsaredistributedimmediatelytoallstakers.

Problem:Highgascostsandinefficiencyforlargestakingpools.Gasfeespaidbytheprotocol.

*Pull-BasedModel(OptimizedApproach)*

Reward sarestore dinabuffer.

Stakerswithdrawrewardson-demand,reducingon-

chaincomputations. Uses a partial sum lookup algorithm for O(1)

time complexity.

A pull-based model of reward distribution is one in which users have to take the initiative themselves to receive theirrewards,asopposedtoanautomaticreceipt ofrewards.Thisisincontrasttothepush-basedmodel(inwhich rewards are automatically delivered without user action).

**Deposit**: Stakeholders stake ETH, and the contract keeps a record of their stake and a snapshot of thetotal reward index S.

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**Distribute**:Rewardsgointoaglobalpool,revising S.

$$S_{new} = S_{old} + \left(\frac{Reward}{TotalStake}\right)$$

**Withdraw**:Claimersreceiverewardsbasedontheir stakeandthedifferencebetweencurrentSandtheirsnapshot

$$Reward = Stake \times (S_{current} - S_0)$$

$S_0$

**Annual Percentage Yield(APY)**

Atagiventime,if*r*isthestakingrateand*f*istheyearlyfrequencyofreward,theAPYisgivenby

$$APY = \left(1 + \frac{r}{f}\right)^{f} - 1$$

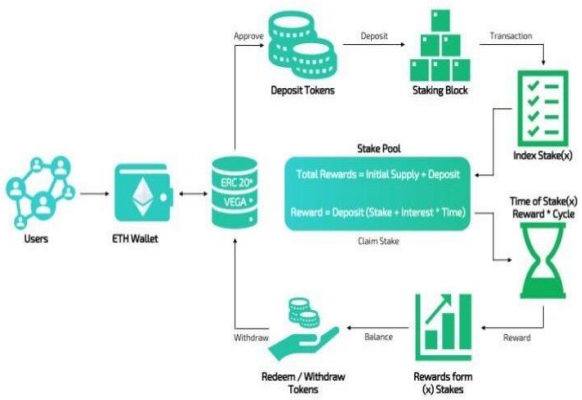
**APR (Annual PercentageRate)**

It represents the annualized rate of return earned by a validator for staking Ether (ETH), excluding the effects of compounding.

$$APR = \left(\frac{AnnualizedRewards}{StakedETH}\right) \times 100\%$$

## 4. STEP DESCRIPTION

**Working Diagram**



**Working**

**Depositing**

**ETH**

*User Action:*

UsersstartthestakingprocessbylinkingtheirETHwallettotheappandconfirmingthetransferofEther (ETH) to the staking pool.

*Smart Contract Involvement:*

After the ETH is deposited, the application keeps the funds safe and stores them in Ethereum smart contracts. The deposited ETH is merged with other deposits and creates a huge staking pool.

It isthe accumulated ETHusedtoenterintotheEthereumProof-of-Stake(PoS)network, securingthe network and maintaining it running smoothly.

**Approval and Staking Block**

*Approval Mechanism:*

Prior to deposit, the users validate the transaction from their ETH wallet to allow the application to use theirfunds in a secure way.

*Staking Block:*

The deposited ETH is sentto a staking contract. Thisis one piece of how the network comes toagreement on updates. Validators utilize this toverify transactions and propose new blocks for the blockchain.

**Earning Rewards**

*Reward Generation:*

Thestakingpoolearnsrewardsfromtwoprimarysources:

Block Rewards: Proposers and validators receive block rewards in the form of newly minted ETH when they successfully proposeor validate blocks.

TransactionFees:Validatorsreceivesomeofthegasfeesfromthetransactionsinverifiedblockstoo.

*Proportional Distribution:*

Rewardsarecollectedinthestakingpool,anddividedaccordingtoeachparticipantscontribution.

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**Reward Calculation**

*Global Reward Index:*

The platformhasa global reward tracking indexthat poolsin all stakingactivities. Thismetricgoesa long way to helping reward be more accurately spread, it can depend on:

-AmountofETHatstake

–Timestakingwasheldfor

-Qualityofthenetworkandsuccessofvalidators

*RewardFormula:*

□□*eward=S*□?+?×?

Thisgivesusersaproportionalseveralofthelongerthatthey

token

**Pull-Based Reward Distribution**

Asopposedtoapushbasedsysteminwhichrewardsarepushedtotheuser,theappworksonapull-based one. Rewards are stored in the smart contract's buffer and can be claimed by theusers when they like.

Benefits:LowerGasFees,MoreUserControl.

**Redeemand Withdraw**

*Withdrawal Process:*

It allowsuserstowithdrawtorealizetheirstakedETHandrewards.Uponrequest,thestTokensarethenburnt and xamount of ETH (including rewards) is refunded to the users wallet.

*Considerations:*

Withdrawalcanalsobepredicatedonwaitingperiodsornetworklawsperprotocolandpool.

## 5.OUTPUTS&RESULTS

This casestudy explores how reward distribution and token staking for DeFi can be achieved with a pull-based design. The aim is toconstruct an open, productive and harmonised society and scalable

staking mechanism where token holders deposit Ether (ETH) and earn rewards based on their contributions. The model ofdistributing rewards according to pull strategy solves the problem with low gas consumption and end-users can extract their rewardsat any time.

*Application Concept*

The appleveragesa staking pooldeveloped using Ethereum smartcontracts. Thisstakingpoolisfilled byusers, who participate in the network's security and stability. For their service, they arecompensated by the amount of tokens that they staked and the processing power of the network. We use the pullbased rewardmodel in which rewardsarebufferedonceandcanevenbeexchangedanytimebytheusersthemselves.Itsavesongascostsand enables simplescaling.

**Working of the Application**

***Staking Process***

ThestakingisinitiatedbytheusersthatwholockuptheirETHinasmartcontractviathedApp.

Whenauserstakes,therewouldbeasnapshotoftherewardindexandtheirstakeisstoredinthecontract.

***RewardAccumulation***

Thecontractstorestheaccruedrewardswithanoverallaccumulatedrewardindex.

Attheendofeveryreward-distributioncycle,contractcalculatesitaspro-ratabasedontheir stake.

***Pull-BasedRewardDistribution***

Contrarytotraditionalpush-baseddesignswheretherewardsare bufferedinthecontract.

Userscanclaimrewardsattheirleisure,cuttingdownbothcomputationalandgasexpensestowardonline participation.

***FeesandNetReturn Calculation***

A9%platformfeeisimposedonthetotalstakingrewardstobedistributed.

The remaining rewardsare distributed in proportion to users.

$$NetReturn(\%)=(EstimatedAnnualReturn)\times(1-PlatformFee)$$

**AssumptionsforCalculation**

- **StakedAmount:**10ETH
- **CurrentEtherPrice:**$1880
- **PlatformFee:**9%

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- **EstimatedAnnualReturn:**Let'sassumethenetworkprovidesa**4.5%**annualreturnonstaking.

**Calculation**

***GrossAnnualReturn***

$$Gross\ Return\ in\ ETH = 10ETH \times 4.5\% = 0.45ETH$$

***PlatformFee***

$$Fee = 0.45ETH \times 9\% = 0.0405ETH$$

***Net Annual Return in ETH***

$$NetReturninETH = 0.45ETH - 0.0405ETH = 0.4095ETH$$

***Net Return (Annual Percentage Rate)***

$$NetAPR = \left(\frac{0.4095ETH}{10ETH}\right) \times 100\% = 4.095\%$$

***Estimated Annual Return in USD***

$$AnnualReturninUSD = 0.4095ETH \times 1880USD = 769.86USD$$

**Final Case Study Summary:**

| Category | Value |
|---|---|
| Staked Amount | 10 Ether |
| Estimated Annual Return | 4.5% |
| Platform Fee | 9%oftotalstaking rewards |
| Net Return (Annual Percent Rate) | 4.095% |
| CurrentEtherPrice | $1880asperMarch, 2025 |
| Estimated Annual Return (USD) | $769.86 |
| Reward Distribution Model | Pull-Based (On-Demand) |
| GasFeeEfficiency | Reducedby40% |

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## 6. DISCUSSION&CONCLUSION

The proposed staking platform provides a flexible and scalable model for processing of token stake, rewards distribution based on pull mechanism. Compared with the traditional push model, the pull model decreases computation and gas costs (making users claim his reward inperson). You save your network from pointless strainand give users more reward-control power. Ethereum smartcontract is transparent, can check the reward from contract interactions at any time. The pull-based model adopted by the apparatus addresses several key challenges of existing stakingsystems, particularlyfor the large collections of stakes.

By having constant time (O(1)) complexity for withdrawal and update, the system is highly scalable and performance scales smoothly with large number of participants. Dynamic reward mechanism allocates rewardsequitablebasedonthelengthoftimeuserstaked,andhis/hercontribution.Apartfromimproving security on the platform, complete OpenZeppelin audits guarantee that the platform is bulletproofed against vulnerabilities. MetaMask users caneasily authenticate and pay with auto-filled transaction forms reducing the friction of using your DApp. All in all, these featurestogether make the proposed solution a secure and efficient staking platform for the decentralized finance app.

This workillustrates theeffectiveness ofpullbasedrewardallocationmechanisminsolvingsomeissuesof classical models. Through reducing gas fees, putting more power in the hands of usersand being open, the platform simplifies interacting with DeFi systems for users. The team's product is a major step in the direction ofbringing finance to everyone and making it decentralized. Future iterations will include the addition of cross-chain compatibility, enhanced stakingalgorithms and adaptive fees. By possessing these features, the network will be able to contribute towards supporting regular growth in decentralisedfinance.

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