# Frontrunning on Automated Decentralized Exchange in Proof Of Stake Environment

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**Abstract**

This paper will contain the analysis of frontrunning potential on Quipuswap - a decentralized exchange with automated marketmaking in the context of the Proof Of Stake family consensus algo over Tezos protocol, and a proposal to boost the frontrunning resistance of the protocol via the implementation of commit reveal scheme.

# Contents

# 1 Introduction

## 1.1 Frontrunning

The best way of getting a comlete idea of economic processes lies in the understanding of infomation asymmetry [1] as it provides the agents on the market with different facts at separate points in time. The agents tend to manipulate the information regarding business transactions to their benefit. Such a phenomenon is called frontrunning [2].

## 1.2 Frontrunning in blockchain

Blockchain is a decentralized network of nodes with constant data exchange regarding the modifications in their state or mempool. As the transaction order is not assigned until the finalization state any decentralized exchange based on Blockchain will be prone to frontrunning.

## 1.3 Doublespending

For the major part the issues related to doublespending [3] are similar to the ones related to frontrunning. Only doublespending affects a certain user's balance in several competing transactions when frontrunning resembles the competition to affect the state that belongs to a specific decentralised exchange.

# 2 Frontrunning in automated Dex

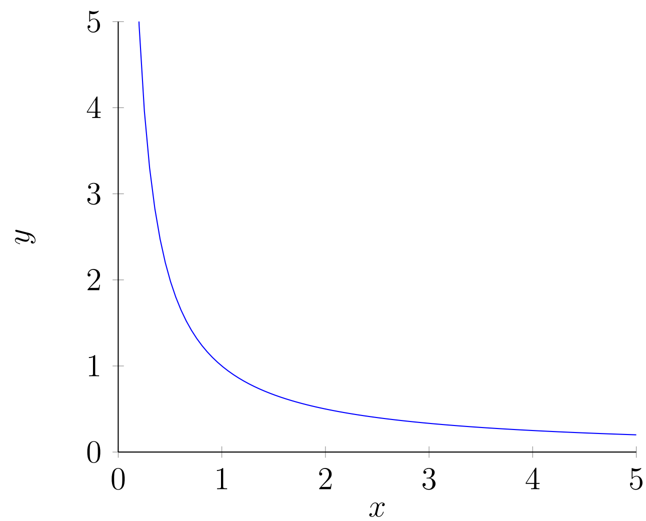
## 2.1 Quipuswap

In automated DEX (Decentralized Exchange) there are universal formulas to estimate the transaction price: those which stem from past trnsactions and those which affect the liquidity pool.

For example, Quipuswap [4] [5] is a uniswap-like [6] automated decentralized exchange with a fixed fee that equeals the following:

$$x \cdot y = k$$

where constant $k = 1$




Thus a transaction affecting product $x \cdot y$ [7] may be inserted before the user's transaction changing the transaction fee.

## 2.2 Quipuswap Fee

In Quipuswap transaction fee is incorporated and all possible revenue calculations shall taking the transaction fee into account.

$$feeRate = 333$$

meaning that $fee$ can be calculated according to the formula:

$$fee = \frac{1}{feeRate} = 0.003003003 \approx 0.3\%$$

# 3 Consensus algo families

## 3.1 Proof of Work

In Proof of Work [8] protocol every miner aims at finding a Proof of Work proof in order to modify the blockchain. The winner of the evolutionary pow lotery will be revealed only post factum and the possibility to create every particular block depends on the hashpower in every second of the process and will not be know until the very end.

There are several research papers [9] [10] [11] that analyse fruntrunning in PoW setting in detail.

## 3.2 Slot based Proof of Stake

In slot based Proof of Stake [12] [13] we have a set of slots

$$Sl = \{sl_0, sl_1...\}$$

as well as a set of blocks that reffer to one another

$$B = \{b_0, b_1...\}$$

## 3.3 Randomness in Tezos

For every cycle in Tezos a new randomness [15] is formed which assignes the baking priority providing us with the infromation regarding the bakers beforehand. $sl_i$.

$$sl_i = (baker_k, baker_l...)$$

In the beginning of every cycle the order of bakers and their priority is public.

# 4 Trade transaction in Quipuswap

To illustrate a possible attack this paper will only consider smart contract functions: $TokenToTez$ and $TezToToken$.

Attacks related to functions *investLiquidity* and *DivestLiquidity* are identical to $TokenToTez$ and $TezToToken$ thus such opportunities for frontrunning are not different from the ones listed and described below.

## 4.1 TezToToken

$s$ state of the current liquidity pool

$tezosAmount$ the number of Tez sent by a user

$tokenAmount$ minumum of tokens the user is willing to get back

$$TezToToken(s, tezosAmount, tokenAmount) :$$
$$S \times TezosAmount \times TokenAmount \to S \times TokenAmount$$

The result $S \times TokenAmount$ returns the new state and the number of tokens received by the user.

$$TezToToken(s, tezosAmount, tokenAmount) =$$
$$= \begin{cases} (news, tokensOut) & tokensOut \geq tokenAmount \\ (s, 0) & tokensOut < tokenAmount \end{cases}$$

Where $news$ and $tokensOut$ calculated as:

$$news.tezPool = s.tezPool + tezosAmount$$

$$news.tokenPool = \frac{s.invariant}{news.tezPool - \frac{tezosAmount}{feeRate}}$$

$$news.invariant = news.tezPool \cdot news.tokenPool$$

$$tokensOut = s.tokenPool - news.tokenPool$$

Overall the function by changing the token pool in accordance to the formula $x \cdot y = k$ and $k = 1$ provided that $tokensOut \geq tokenAmount$ meaning that the customer will be able to get the required number of tokens. Otherwise the exchange will not happen and the state liquidity pool will not change.

## 4.2 TokenToTez

$s$ state of the current liquidity pool

$tokenAmount$ the number of Tez sent by a user

$tezosAmount$ minumum of tokens the user is willing to get back

$$TokenToTez(s, tokenAmount, tezosAmount) :$$
$$S \times TokenAmount \times TezosAmount \rightarrow S \times TezosAmount$$

The result $S \times TezosAmount$ returns the new statea and the number of tokens received by the user.

$$TokenToTez(s, tokenAmount, tezosAmount) =$$
$$= \begin{cases} (news, tezOut) & tezOut \geq tezosAmount \\ (s, 0) & tezOut < tezosAmount \end{cases}$$

Where $news$ and $tezOut$ is calculated as:

$$news.tokenPool = s.tokenPool + tokenAmount$$

$$news.tezPool = \frac{s.invariant}{news.tokenPool - \frac{tokenAmount}{feeRate}}$$

$$news.invariant = news.tezPool \cdot news.tokenPool$$

$$tezOut = s.tezPool - news.tezPool$$

The function is identical to $TezToToken$.

# 5 Main attack method

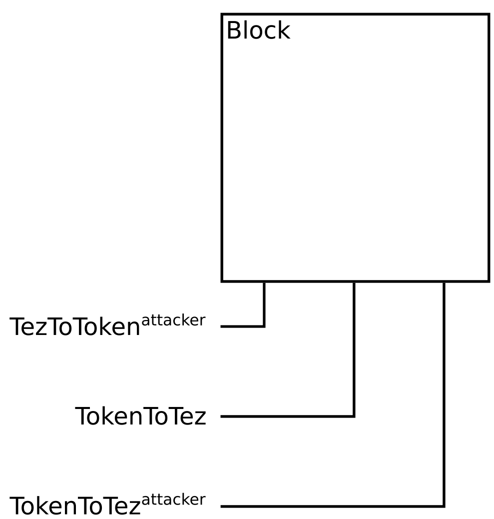
The user initiats a transaction in the system: $(TezToToken, tezosAmount, tokenAmount)$. The validators apply this transaction to the present state $s$.

If $TezToToken(s, tezosAmount, tokenAmount)$ is valid, it returns $(news, tokensOut)$ while $tokensOut \neq tokenAmount$. Such a transaction is prone to baker's attack attempts.

## 5.1 3 transactions in 1 block

If $baker_{attacker}$ forms a block $b_{attacker}$ in the slot $sl_{attacker}$ in such a case of an optimal attack the order of three transactions [16] will form the following set $b_{attacker}$.

$$(TezToToken^{attacker}, TezToToken, TokenToTez^{attacker}) \subset b_{attacker}$$




## 5.2 The order of transactions

1. $(s^1, tokensOut^{attacker}) = TezToToken^{attacker}(s, tezosAmount^{attacker}, \infty)$
2. $(s^2, tokensOut^{user}) = TezToToken(s^1, tezosAmount^{user}, tokenAmount^{user})$
3. $(s^3, tezOut^{attacker}) = TokenToTez^{attacker}(s^2, tokensOut^{attacker}, \infty)$

$\infty$ states that this transaction can be processed at any price. In practice $baker_{attacker}$ will assign a bigger price different from $\infty$ as there's no possibility to apply $\infty$ in Tesoz.

$tezosAmount^{attacker}$ is a prerequisite for $s^1$ transition into $tokensOut^{user} = tokenAmount^{user}$.

Condition for successful attack:

$$tezOut^{attacker} > tezosAmount^{attacker}$$

Profit for attacker will be:

$$profit = tezOut^{attacker} - tezosAmount^{attacker}$$

# 6 Limiting

To prevent frontrunning regarding the transaction, it's required to fullfill the following condition:

$$tokensOut = tokenAmount$$

Where $tokensOut$ is calculated in regards to $s$ the state of protocol as of the time of the transaction processing.

In this situation only one of such transactions will be incorporated into one block, as after the transaction has been accepted $s$ will be changed and it will no longer be possible to reach this condition $tokensOut = tokenAmount$.

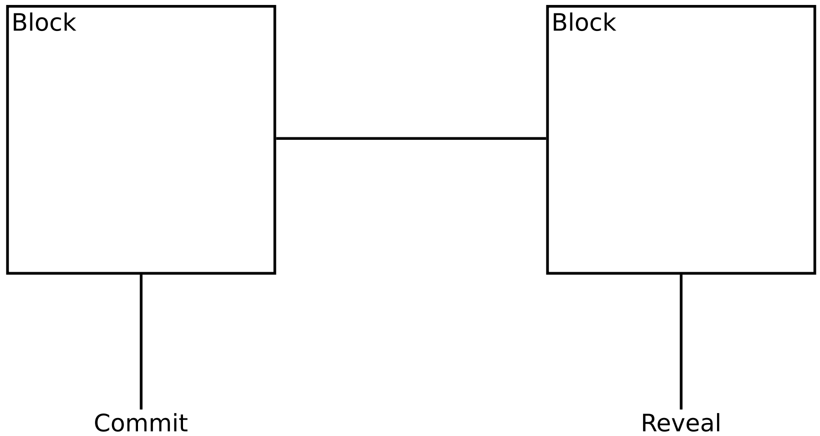
# 7 Commit-reveal

Possible protection solution is to ammend the protocol to make two-piece transaction. It will consist of the following two parts:

1. Commit - revealing $hash(TezToToken, tezosAmount, tokenAmount, salt)$
2. Reveal - revealing $TezToToken, tezosAmount, tokenAmount, salt$ that can be announced at any moment

The state of $s$ is transferred as of the time of publishing Reveal.

Commit and Reveal cannot be announced in one block thus preventing any possible manipulations by one $baker$.




## 7.1 Security deposit

Under Commit stage it will be possible to submit security deposits that may account for the priorities for future transactions. Meaning that Reveal transaction may be icorporated into the block in the following order:

$$deposit(tx_i) > deposit(tx_{i+1}) > ...$$

The outcomes of implementing the Commit Reaveal method alongside the security deposits will be quite interesting. It will endanger the security deposits of any baker that recoursed to frontrunning by creating several simultaneous transactions in TezToToken attacker and TokenToTex. Thus boosting the frontrunning resistance of the system.

## 7.2 Should the commit-reveal method be implemented?

As its implementation will drastically complicate the protocol, in fact transforming it into a new one, it is recommended to introduce this method in the following version of the protocol.

# 8 Arbitration prividge

Time in blockchain is discreet and is revealed in the for of block slots.

$$Sl = \{sl_0, sl_1 ...\}$$

While on the centralised exchange the bidding is a continious process within time.

When $baker_{attacker}$ with priority over $sl_{attacker}$ it gets the arbitration previlidge among the centralised exchanges.

To create conditions for such a situation, no frontrunning is required. It is sufficient to take advantage of the block creating ability and initiate $TezToToken^{attacker}$ or $TokenToTez^{attacker}$ and process the reverce transaction on the centralised exchange.

## 8.1 Commit-reveal

The Commit-reveal metod will impede the development of such a scenario. Only if the baker $baker_{attacker}$ controls 2 slots at a time - $\{sl_i, sl_{i+1}\}$. In this case both Commit and Reveal transactions can be initiated.

# 9 Conclusion

Decentralized exchanges, with or without automatic marketmaking, are prone to frontrunning. We see this in practice in ethereum conditions, we will see the same when QS is deployed in production.

This paper describes 2 attacks - a direct attack on a specific transaction in section 6 and an attack in which the baker has an advantage in arbitration in section 9.

In the event of an attack on a specific transaction, it is proposed to limit the execution of the transaction through a situation in which $tokensOut = tokenAmount$ for the current state. This will mean that there is no way to front-end this particular transaction, but will also reduce the likelihood of successful execution of this transaction.

For future versions of QS, the Commit-Reveal protocol is proposed with the prioritization of transactions using a pledge system. It should be viewed solely as a proposal for future versions due to its excessive complexity and radical change in the essence of the protocol.

# 10 Acknowledgments

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