We Know What They've Been Put Through: Revisiting High-scalability Blockchain Transactions

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Abstract

Scalability has been a bottleneck for major blockchains such as Bitcoin and Ethereum. Despite the significantly improved scalability claimed by several high-profile blockchain projects, there has been little effort to understand how their transactional throughput is being used. In this paper, we examine recent network traffic of three major high-scalability blockchains—EOS, Tezos and XRP—over a period of three months. Our analysis reveals that only a small fraction of the transactions are used for value transfer purposes. In particular, 95% of the transactions on EOS were triggered by the airdrop of a currently valueless token; on Tezos, 82% of throughput was used for maintaining consensus; and only 2% of transactions on the XRP ledger lead to value transfers. The paper explores the different designs of the three blockchains and sheds light on how they could shape user behavior.

1 Introduction

As the most widely-used cryptocurrency and the first application of a blockchain system, Bitcoin has been frequently criticized for its slow transactional throughput. Many blockchains have since been designed and developed in order to improve scalability, notably EOS [5], Tezos [18], and XRP [43].

Although many of these systems have been around for several years already, to the best of our knowledge, no in-depth evaluation of how their transactional throughput is actually used in practice has been performed. Analyzing how this transactional throughput is used is not only important to understand how these systems could be improved, but also to detect and understand suspicious activities which could negatively impact them.

Contributions. We contribute to the body of literature on blockchain in the following ways:

1. We perform the first large-scale detailed analysis of transaction histories of three of the most widely-used high-throughput blockchains: EOS, Tezos, and XRP.

2. We classify on-chain transactions and measure each category's respective share of the total throughput, in terms of the number of transactions and their financial volume.

3. We showcase various types of spammy activities that have inflated throughput statistics and caused network congestion.

Summary of Findings. Despite the advertised high throughput and the seemingly commensurate transaction volume, a large portion of on-chain traffic, including payment-related transactions, does not result in actual value transfer. The nature and purpose of non-payment activities varies significantly across blockchains.

Specifically, we observe that the current throughput is only 20 TPS (transactions per second) for EOS, 0.08 TPS for Tezos and 19 TPS for XRP. We show that 95% of the throughput on the EOS blockchain was used for the airdrop of a valueless token, 82% of transactions on the Tezos blockchain were used to maintain consensus, and that only 2% of transactions on the XRP ledger resulted in value transfer.

Paper organization. The remainder of this paper is organized as follows. In Section 2 we provide the necessary background on each of the blockchain platforms studied. In Section 3 we describe the data collected from the three blockchains and conduct high-level analyses. In Section 4 we present several investigative case studies that highlight how transactions are (mis)used in the three blockchains. In Section 5 we summarize related work and conclude in Section 6.

2 Background

In this section we briefly explain the fundamentals of permissionless blockchains and describe the structure of the three blockchain systems that we evaluate, highlighting their various design aspects.

2.1 Blockchain Basics

In its essence, a blockchain is an append-only, decentralized database that is replicated across a number of computer nodes. Most blockchain systems store data in the form of "transactions". A transaction typically contains information about its sender, its receiver, as well as the action taken, such as the transfer of an asset. Newly created transactions are broadcast across the network where they get validated by the participants. Valid transactions are grouped into data structures called *blocks*, which gets appended to the blockchain by referencing the most recent block. Blocks are immutable and state changes in the blockchain require new blocks to be produced.

Network latency and asynchrony inherent in the distributed nature of blockchains lead to a number of challenges. In particular, a blockchain must be able to reach consensus about the current state when the majority of participating nodes behave honestly. Thus, a consensus protocol prescribing a set of rules to resolve disagreement is applied for the validation process.

The Proof-of-Work (PoW) consensus, introduced by Bitcoin and currently also implemented by Ethereum, requires the participant to solve a computationally expensive puzzle to create a new block. Although PoW can maintain consistency well, it is by nature very time- and energy-consuming, which limits its throughput. Indeed, to preserve security while maintaining a sufficient degree of decentralization, scalability is often sacrificed [41].

Another issue related to blockchain systems is the need for all participants to replicate the data. Since blockchains are append-only, participants need to ensure that their storage capacity keeps pace with the ever-increasing size of blockchain data. It is therefore crucial for blockchains to be designed in such a way that the storage used increases only moderately with time.

2.2 Consensus Mechanisms

In response to the scalability issues related to PoW, many blockchains have developed other mechanisms to ensure consensus.

Delegated Proof-of-Stake (DPoS) in EOS. EOS uses the Delegated Proof-of-Stake (DPoS) protocol which was first introduced in Bitshares [4].

Users of the EOS blockchain, stake `EOS` tokens to their favored block producers (BPs) and can choose to remove their stake at any time. The 21 BPs with the highest stake are allowed to produce blocks whereas the rest are put on standby. Blocks are produced in rounds of 126 (6 $\times$ 21) blocks. The order of block production is scheduled prior to each round and must be agreed upon by at least 15 block producers [5].

Liquid Proof-of-Stake (LPoS) in Tezos. For its consensus mechanism, Tezos employs an extension of the DPoS protocol—Liquid Proof-of-Stake (LPoS) [34]. With Tezos' LPoS, the number of block producers—or "bakers" in Tezos' terminology—can dynamically increase or decrease [18]. Any nodes with a certain amount of staked assets exceeding a threshold, arbitrarily defined to be 10,000 `Tezos` (about 14K USD at the time of writing), are allowed to become a baker. A baked block must receive at least 32 endorsements to be included in the blockchain [34].

XRP Ledger Consensus Protocol (XRP LCP). The XRP ledger, a distributed payment network created by *Ripple Labs Inc.* in 2012, uses the XRP ledger consensus protocol [7]. Each user sets up its own unique node list of validators (UNL) that it will listen to during the consensus process. The validators determine which transactions are to be added to the ledger. Consensus is reached if at least 90% of the validators in each ones' UNL overlap. If this condition is not met, the consensus is not assured to converge and forks can arise [7].

2.3 Account and Transaction Types

In this section we describe the types of transactions that exist on the three blockchains.

2.3.1 EOS

EOS differentiates between system and regular accounts. The former are built-in accounts created when the blockchain was first instantiated, and are managed by currently active BPs. System accounts are further divided into privileged and unprivileged accounts. Privileged accounts, including `eosio`, `eosio.msig`, and `eosio.wrap`, can bypass authorization checks when executing a transaction [15, 19] (see Section 2.2).

EOS system contracts, defined in `eosio.contracts` [16], are held by system accounts. One of the most commonly used system contracts is `eosio.token`, which is designed for creating and transferring user-defined tokens [15]. Regular accounts can freely design and deploy smart contracts.

Each smart contract on the EOS blockchain has a set of actions. Actions included in non-system contracts are entirely user-defined, and users have a high degree

Category	EOS Action name	#	%	Tezos Operation kind	#	%	XRP Transaction type	#	%
P2P transaction	transfer	2,257,001,096	**91.6**	Transaction	599,366	16.2	Payment	69,868,703	**46.2**
							EscrowFinish	214	0.0
Account actions	bidname	243,942	0.0	Origination	2,073	0.1	TrustSet	2,825,199	1.9
	deposit	199,317	0.0	Reveal	28,626	0.8	AccountSet	119,455	0.1
	newaccount	114,710	0.0	Activate	960	0.0	SignerListSet	13,486	0.0
	updateauth	61,071	0.0				SetRegularKey	468	0.0
	linkauth	59,417	0.0						
Other actions	delegatebw	364,376	0.0	Endorsement	3,021,296	**81.7**	OfferCreate	76,193,386	**50.4**
	buyrambytes	163,052	0.0	Delegation	14,611	0.4	OfferCancel	2,303,023	1.5
	undelegatebw	156,454	0.0	Reveal nonce	28,626	0.8	EscrowCreate	473	0.0
	rentcpu	154,517	0.0	Ballot	155	0.0	EscrowCancel	35	0.0
	voteproducer	65,888	0.0	Proposals	90	0.0	PaymentChannelClaim	122	0.0
	buyram	599,951	0.0	Double baking evidence	4	0.0	PaymentChannelCreate	30	0.0
	Others	205,674,738	8.3				EnableAmendment	1	0.0
Total		2,464,858,529	100.0		3,695,807	100.0		151,324,595	100.0

Figure 1: Distribution of transaction types per blockchain.

of flexibility in terms of structuring and naming the actions. This makes the analysis of actions challenging, as it requires understanding their true functionality on a case-by-case basis. While many actions have a candid name that gives away their functionality (e.g. `payout` from contract `betdicegroup`), some are less expressive (e.g. `whaleextrust` from contract `clearsettres`).

In Figure 1, we show different types of existing actions. Since actions from non-system contracts have arbitrary designs, we only examine actions that belong to system accounts for the moment, as these are already known and easier to classify. We make one exception to this and include the actions of *token* contracts, as they have a standardized interface [21]. Overall, we can see that token transfers account alone for more than 91% of the transactions. The rest of the transactions are mostly user-defined and appear under "Others" in the table, while actions defined in system contracts only account for a very small percentage of the entire traffic volume.

2.3.2 Tezos

Tezos has two types of accounts: implicit and originated. Implicit accounts are similar to the type of accounts found in Ethereum, generated from a public-private key pair [40]. These accounts can produce—or "bake"—blocks and receive stakes, but cannot be used as smart contracts. Bakers' accounts must be implicit. Originated accounts are created and managed by implicit accounts without having their own private key [28]. They can function as smart contracts, and can delegate voting rights to bakers' implicit accounts [25].

"Transactions" on Tezos are termed "operations." Operations can be roughly classified into three types: consensus related, governance related and manager operations [1]. Consensus related operations, as the name indicates, ensure that all participating nodes agree on one specific version of data to be recorded on the blockchain. Governance related operations are used to propose and select a new set of rules for the blockchain. However, these events are very rare and only involve bakers, which is why these operations only represent a low percentage of the total number of transactions. Operations mainly consist of delegations and peer-to-peer payment transactions. As shown in Figure 1, `endorsement` operations account for a vast majority, 82%, of total operations. Endorsements are performed by bakers, and a block needs a minimum of 32 endorsements for it to be accepted [26].

2.3.3 XRP

XRP also uses an account-based system to keep track of asset holdings. Accounts are identified by addresses derived from a public and private key pair. There are a handful of "special addresses" that are not derived from a key pair. Those addresses either serve special purposes (e.g. acting as the `XRP` issuer) or exist purely for legacy reasons. Since a secret key is required to sign transactions, funds sent to any of these special addresses cannot be transferred out and are hence permanently lost [42].

XRP has a large number of predefined transaction types. We show part of them in Figure 1. The most common transaction types are `OfferCreate`, which is used to create a new order in the decentralized exchange provided by XRP, and `Payment`, which is used to transfer assets. There are also other type of operations such as `OfferCancel` used to cancel a created order or `TrustSet` which is used to establish a "trustline" [43] with another account.

2.4 Expected Use Cases

In this section, we describe the primary intended use cases of the three blockchains and provide a rationale for the way they are being used, to better understand the dynamics of actual transactions evaluated in Section 3.

EOS. EOS was designed with the goal of high throughput and has a particularity compared to many other blockchains: there are no direct transaction fees. Resources such as CPU, RAM and bandwidth are rented beforehand and there is no fixed or variable fee per transaction [5].

This makes it a very attractive platform for building decentralized applications with a potentially high number of micro-payments. Many games, especially those with a gambling nature, have been developed using EOS as a payment platform. EOS is also used for decentralized exchanges, where the absence of fees and the high throughput allow placing orders on-chain, unlike many decentralized exchanges on other platforms where only the settlement is performed on-chain [37].

Tezos. Tezos was one of the first blockchains to adopt on-chain governance. This means that participants can vote to dynamically amend the rules of the consensus. A major advantage of this approach is that the blockchain can keep running without the need of hard-forks, as often observed for other blockchains [11, 12]. Another characteristic of Tezos is the use of a strongly typed programming language with well-defined semantics [27] for its smart contracts, which makes proving these for correctness easier. These properties make Tezos a very attractive blockchain for financial applications, such as the tokenization of assets [6].

XRP. Similar to the EOS blockchain, the XRP ledger supports the issuance, circulation, and exchange of customized tokens. However, in contrast to EOS, the XRP ledger uses the IOU ("I owe you") mechanism for payments. Specifically, any account on the XRP ledger can issue an IOU with an arbitrary ticker — be it `USD` or `BTC`. Thus, if Alice pays Bob 10 `BTC` on the XRP ledger, she is effectively sending an IOU of 10 `BTC`, which literally means "I (Alice) owe you (Bob) 10 `BTC`". Whether the `BTC` represents the market value of bitcoin depends on Alice's ability to redeem her "debt" [47]. This feature contributes to the high throughput on the XRP ledger, as the speed to transfer a specific currency is no more constrained by its original blockchain-related limitations: For example, the transfer of `BTC` on the XRP ledger is not limited by the proof-of-work mechanism used in the actual bitcoin blockchain (typically-10 minutes to an hour to fully commit a block), and the transfer of `USD` is not limited to the speed of the automated clearing house (ACH) (around two days [22]).

3 Data Analysis

In this section, we first present our dataset and the approach we used to collect it. We then provide a high-level overview of the transactional throughput usage and further analyze the specific transaction patterns of the different blockchains.

3.1 Data Collection

We first discuss our data collection process. We show an overview of the characteristics of the data in Figure 2. We note that the numbers of transactions is not the same as in Figure 1 because here we count only a transaction once, while in the previous table we counted all the "actions" included in a single transaction.

EOS. EOS nodes provide an RPC-API for clients to interact with [17]. In particular, the API allows clients to retrieve the content of a single block, including its transactions, with the `get_block` endpoint [14]. EOS also has a list of block producers which usually provide a publicly accessible RPC endpoint. Out of 32 officially advertized endpoints, we shortlist 6 of them who have a generous rate limit with stable latency and throughput.

We collect our data in reverse chronological order, starting from the most recent block, number 98,324,735 at the time of collection.

In the end, we obtain 16,299,999 blocks containing 376,819,512 transactions, covering 3 months of data, from October 1 to December 31, 2019. On average, 1 day of transactions are stored across 165,000 blocks, corresponding to approximately 121GB of data when compressed with gzip.

Tezos. Tezos full nodes also provide an RPC endpoint. However, unlike EOS, Tezos does not provide a list of publicly-accessible endpoints that can be used to fetch data. Since the data is still of a manageable size, and to avoid relying an external service such as a block explorer, we run a full node and synchronize it to the latest state. We proceed in the same way as for EOS, starting from the latest block and going backwards.

We obtain 131,801 blocks containing 3,345,019 transactions covering 3 months of data, from September 29 to December 31, 2019. The total size of the blocks collected account for approximately 560MB of data when compressed with gzip.

XRP. XRP has both an RPC-API and a websocket API with similar features. Although there are no official public endpoints for XRP, a high-availability websocket endpoint is provided by the XRP community [39]. We use the `ledger` method of the Websocket API to retrieve the data in the same way we did with EOS and Tezos.

In addition, we use the API provided by the ledger explorer XRP Scan [33] to retrieve account information

	Sample period		Block index		Count	Count	Storage
	from	to	from	to	of blocks	of transactions	.gzip, GB
EOS	Sep. 30, 2019	Jan. 3, 2020	82,024,737	98,324,735	16,299,999	376,819,512	121
Tezos	Sep. 29, 2019	Dec. 31, 2019	628,951	760,751	131,801	3,345,019	0.56
XRP	Oct. 1, 2019	Dec. 31, 2019	50,400,001	52,431,069	2,031,069	151,324,595	76.4

Figure 2: Characterizing the datasets for each blockchain.

such as username and parent account.[1] Since large XRP users such as exchanges often have multiple accounts, this account information can be used to identify and cluster accounts.

In total, we collect more than 2,000,000 blocks covering 3 months of data, and containing a total of more than 150 million transactions. The total size of the compressed data is about 76 GB.

3.2 Transactions Overview

In this section, we present summary statistics and high-level illustrations of the transactions contained in the datasets of the three different blockchains.

In Figure 3, we decompose the number of transactions into different categories. XRP and Tezos have well-defined transaction types, and we use the most commonly found ones to classify the different transactions. EOS does not have transaction types per se with possible actions being defined by each contract. To be able to classify the transactions and understand where throughput is coming from, we manually label the top 100 contracts by grouping them into different categories and assign one of the categories to each transaction. Interestingly, there is a huge spike in the number of token transactions from the 1st November, 2019 onward. We find that this is due to a new coin called EIDOS [13] giving away tokens. We will describe this more extensively as a case study in Section 4. Before this peek, the number of transactions in EOS was vastly dominated by games, in particular betting games. Tezos has a high number of "endorsements", which are used as part of the consensus protocol, and only a small fraction of the throughput are actual transactions. It is worth noting that the number of "endorsements" should be mostly constant regardless on the number of transactions, and that if the number of transactions were to increase enough, the trend would reverse.

On the XRP ledger, both successful and unsuccessful transactions are recorded. A successfully executed transaction executes the command—such as `Payment`, `OfferCreate`, `OfferCancel`—specified by its initiator, while the only consequence of an unsuccessful transaction is the deduction of transaction fees from the transaction initiator. As shown in Figure 3 and Figure 7, roughly 10% of transactions are unsuccessful, with the most frequently registered errors being `PATH_DRY` for `Payment` (insufficient liquidity for specified payment path) and `tecUNFUNDED_OFFER` for `OfferCreate` (no funds for the currency promised to offer by the offer creator). Successful transactions mostly consist of `Payment` and `OfferCreate` which account for 46% and 50% of the total throughput, respectively (Figure 7).

The number of `OfferCreate` is mostly constant across time but the number of `Payment` has a very high variance, with some periods containing almost no payments and others having significant spikes. In Section 4.3, we reveal why most transactions during these high-volume periods are economically meaningless. In fact, only 1 in 19 successful `Payment` transactions involve the transfer of valuable tokens (Figure 7).

Except for the two spam periods, we observe that `OfferCreate` is the most common transaction type. Apart from deducting transaction fees, `OfferCreate` transactions do not have any other effect on the initiating account's balance unless the offer becomes fully or partially fulfilled before its expiration time. An offer can also be cancelled or superseded by a new offer. We discover that merely 0.2% of successfully created offers are fulfilled to some extent (Figure 7).

All in all, 2.3% of transnational throughput on the XRP ledger appears to carry economic value.

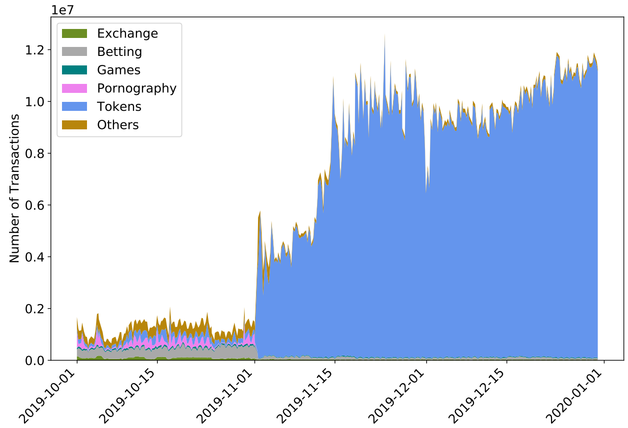
3.3 Top Accounts Transaction Patterns

To understand better what the major sources of traffic are, we analyze the top accounts on EOS, Tezos, and XRP, and find various transaction patterns.

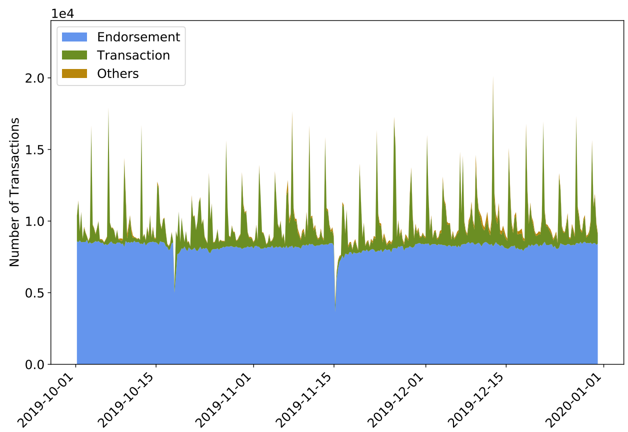
EOS. In Figure 4, we show EOS accounts with the highest number of received transactions. We can see that the `eosio.token` account, which is the account used to handle EOS token transfers, is by far the most used account and that almost all calls to this account use the `transfer` action.

This is not particularly surprising as this is the main method of performing value transfers on EOS. The next few contracts are more interesting, as they give a fairly accurate representation of the different ways in which

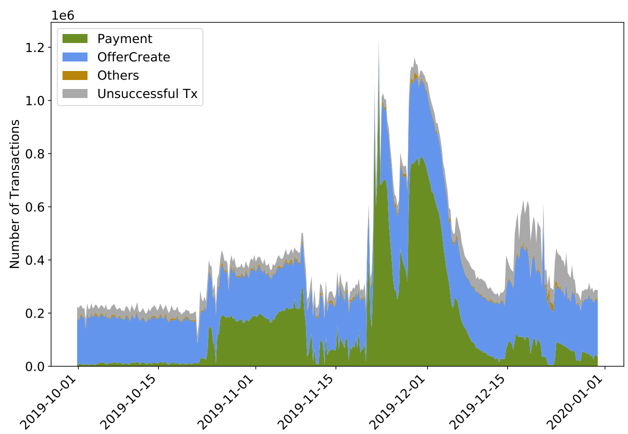
[1] A parent account sends initial funds to activate a new account.



(a) EOS throughput across time



(b) Tezos throughput across time



(c) XRP throughput across time

Figure 3: Throughput across time, y-axis represents transaction count per 6 hours.

Name	Description	Tx Count	Actions Name	%
eosio.token	EOS token	131,411,890	transfer	99.999%
			open	0.0001%
pornhashbaby	Porn website	24,552,456	record	99.86%
			login	0.138%
betdicetasks	Betting game	24,244,530	removetask	68%
			log	11.86%
			sendhouse	7.00%
			betrecord	3.92%
			betpayrecord	3.88%
whaleextrust	Decentralized exchange	9,047,627	verifytrade2	29.79%
			clearing	17.74%
			clearsettres	14.33%
			verifyad	13.89%
			cancelorder	2.23%
eossanguoone	Role playing game	8,696,646	reveal2	28.27%
			combat	15.93%
			deletemat	10.12%
			sellmat	5.968%
			makeitem	2.822%

Figure 4: EOS top applications as measured using the number of received transactions.

EOS is used. The second account from the top, is a porn website which uses EOS as a payment system. The third account from the top, is a betting website where all the bets are performed transparently using EOS. However, around 80% of the actions—`removetask` and `log`—are bookkeeping and the actual betting related actions such as `betrecord` represent a very low percentage of the total number of transactions. The fourth contract is a decentralized exchange and is used to exchange different assets available on EOS. The most used action, `verifytrade2`, is used to settle trades on-chain. Finally, the fifth account from the top is a role-playing game on EOS. Most actions represent an action in the game and EOS is used as a storage for the game.

Next, we look at the top accounts in terms of outgoing transactions. We show the top senders and the top accounts to which they send transactions in Figure 5. Three out of five of the top senders send a vast majority of their transactions to another of their account. These are somewhat akin to RPC calls in non-blockchain applications but are, in the case of EOS, performed on-chain. The majority of the other transactions are sent to transfer some assets—either EOS or some other type of token available on the EOS blockchain.

Tezos. Next, we analyze the transactions on Tezos. As Tezos neither has account names nor actions in the transactions metadata, analyzing the top receivers' accounts is less interesting as it is very difficult to perform any type of attribution. However, we find interesting patterns form observing the top sending accounts, which diverge substantially from what we previously saw in EOS. We show the top senders and some statistics about them in Figure 6. Most of the top senders in Tezos seem to follow

Sender	Sent count	Unique receivers	Receiver	# of transactions	% of transactions
betdicegroup	35,150,255	34	betdicetasks	24,244,530	68.90%
			betdicegroup	4,768,591	13.55%
			betdicebacca	1,812,993	5.15%
			betdicesicbo	1,770,341	5.03%
			betdiceadmin	1,224,500	3.48%
mykeypostman	11,778,190	7	eosio.token	138,639,137	94.04%
			mykeylogica1	8,689,661	5.89%
bluebetproxy	6,255,614	16	bluebetproxy	3,136,527	50.14%
			eosio.token	1,817,302	29.05%
			bluebettexas	522,041	8.35%
			bluebetjacks	182,511	2.92%
			bluebetbcrat	177,748	2.84%
bluebet2user	5,781,071	15	lynxtoken123	5,574,173	96.42%
			eosio.token	51,723	0.89%
bluebetbcrat	5,490,267	15	bluebetbcrat	4,346,721	79.17%
			eosio.token	1,016,165	18.51%

Figure 5: EOS account pairs with the highest number of sent transactions.

Sender	Sent count	Unique receivers	Avg. # of transactions per receiver	Stdev of transactions per receiver
tz1cNARmnRRrvZgspPr2rSTUWq5xtGTuKuHY	43,099	1508	28.58	8.25
tz1Mzpyj3Ebut8oJ38uvzm9eaZQtSTryC3Kx	38,417	38416	1.00	0.01
tz1YrmJw6Lje27gWqZ94gU9mNavEjkHu1xGc	25,631	553	46.35	20.44
tz1MoonPbyMJSqMVsVwExgVc5egnv18CgSDq	21,691	651	33.32	21.23
KT1DzGefKWdrwWn9HxcYtKR46todiC66bxsH	19,649	1280	15.35	2.52

Figure 6: Tezos accounts with the highest number of sent transactions.

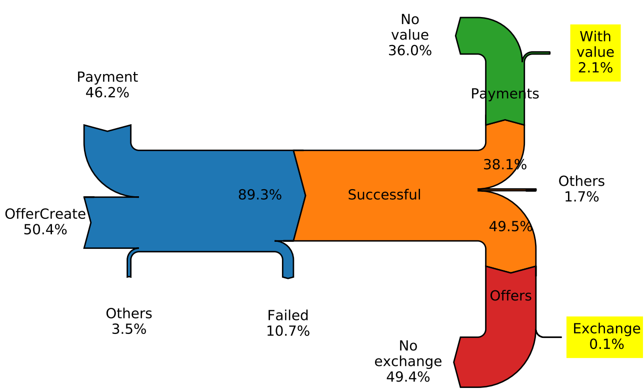


Figure 7: XRP throughput from October 1, 2019 to December 31, 2019. Highlighted transactions carry economic value.

a similar pattern: Sending a small number of transactions (between 15 and 45) to many different accounts. Another important thing to note is that 4 out of 5 of these accounts are not contracts but regular accounts, which mean that the transactions are most likely automated by an off-chain program.

XRP. From October 1, 2019 to December 31, 2019, a total of 90 thousand accounts collectively conducted 150 million transactions, i.e. an average of 1.7 thousand transactions per account.

The distribution of the number of transactions per account is highly skewed. Approximately one third (30 thousand) of accounts have transacted once during the entire observation period, whereas the 18 most active accounts are responsible for half of the total traffic. Figure 8 lists of the top 10 accounts by the number of conducted transactions. With the only exception of `rs9tBKt96q9gwrePKPqimUuF7vErgMaker`, all these accounts share suspiciously similar patterns:

1. more than 98% of their transactions are `OfferCreate`;
2. they are either descendants of an account from Huobi, a crypto exchange founded in China, or frequently transact with descendants from Huobi;
3. they have all transacted using `CNY`;
4. their payment transactions conspicuously use the same destination tag `104398`, a field that—similar to

a bank reference number—exchanges and gateways use to specify which client is the beneficiary of the payment [46].

The aforementioned similarities, in particular the third one, signal that those accounts are controlled by the same entity, presumably with a strong connection to Huobi. The frequent placement of offers might come from the massive client base of the entity.

3.4 Analysis Summary

Here, we highlight some some of the observations about the data described above.

- EOS transactions can be roughly divided by the category of contracts they belong to. Before the arrival of the EIDOS token, approximately 50% of these are transactions to betting games. The rest was split between token transfers and various forms of entertainment, such as games not involving betting as well as payments to pornography web sites. The launch of the EIDOS token increased the total number of transactions by more than 10 times, resulting in 95% of the transactions being used for token transfers.
- The vast majority (82%) of transactions on Tezos are used by the `endorsement` operation to maintain consensus. This is due to the fact that every block needs at least 32 endorsements to be confirmed [34] and the number of transactions on the network is still low. The rest of the throughput is mainly used by transactions to transfer assets between accounts.
- `OfferCreate` and `Payment` are the two most popular transaction types on the XRP ledger, accounting for 50% and 46% of total throughput respectively. One tenth of the transactions fail and only 2% of the transactions in the observed throughput involve actual value transfers.

4 Case Studies

In this section, we present several case studies of how the transaction throughput on the three blockchains is used in practice, for both legitimate and less legitimate purposes.

4.1 Inutile Transactions on EOS

Exchange Wash-trading in EOS. We investigate WhaleEx, who claims to be the largest decentralized exchange (DEX) on EOS in terms of daily active users [38]. As shown in Figure 4, the most frequently-used action of the WhaleEx contract is `verifytrade2`, with a total of 3,855,488 calls over the three months observational period, which corresponds to approximately one action every two seconds. A `verifytrade2` action is executed when a buy offer and a sell offer match each other and signals a settled trade.

Firstly, and most obviously, we notice that the buyer and the seller of a trade are often *the same*. This means that no asset is transferred at the end of the action. Furthermore, the transaction fees for both the buyer and the seller are 0, which means that such a transaction is achieving absolutely nothing else than *artificially* increasing the service statistics, i.e. wash-trading.

Further investigation reveals that accounts involved in the trades signalled by `verifytrade2` are highly concentrated: the top 5 accounts, either as a "seller" or a "buyer", are associated with over 70% of the trades. We compute the percentage of such transactions for the top 5 accounts and find that each of these accounts acts simultaneously as both seller and buyer in more than 85% of the transactions they are associated with. This means that the *vast majority* of transactions of the top 5 accounts represent wash-trading.

Next, we analyze the amount of funds that has been moved, i.e. the difference between the total amount of crypto-currency sent and received by the same account. For the most active account, we find that only one of the 32 currencies has a balance change of over 0.7%. The second most frequently used account has a similar transaction pattern, with 8 out of the 17 currencies that it traded showing no balance change, i.e. the account received and sent exactly the same amount of the currency. The rest of the top accounts all follow a very similar trend, with almost all the traded currencies having almost the same sent and received amounts.

Boomerang Transactions in EOS. As shown in Figure 3a, there was a very sharp increase of activity on EOS after November 1, 2019. After investigating, we find that these increase is due to the airdrop of a new coin called EIDOS [13].

The token distribution works as follows: Users send any amount of `EOS` to the EIDOS contract address, the EIDOS contract sends the `EOS` amount back to the sender and also sends 0.01% of the `EIDOS` tokens it holds. This creates a "boomerang" transaction for the `EOS` token and a transaction to send the `EIDOS` token. The tokens can then be traded for `USDT` (Tether) which can in turn be converted to other currencies. There are no transaction fees in EOS and users can execute transactions freely within the limits of their rented CPU capacity. Therefore, this scheme incentivizes users with idle CPU resources on EOS to send transactions to this address, creating a large increase in the numbers of transactions.

Soon after the launch of this coin, the price of CPU usage on EOS spiked by 10,000% and the network entered

Account	Type	Count	TotalCount	% of total throuput
r4AZpDKVoBxVcYUJCWMcqZzyWsHTteC4ZE	OfferCreate Others Payment	11,261,043 208,593 38	11,469,674	7.3%
rQ3fNyLjbvcDaPNS4EAJY8aT9zR3uGk17c	OfferCreate Others Payment	11,257,406 26,166 12	11,283,584	7.1%
rh3VLyj1GbQjX7eA15BwUagEhSrPHmLkSR	OfferCreate Others Payment	11,143,893 26,913 34	11,170,840	7.1%
r4dgY6Mzob3NVq8CFYdEiPnXKboRScsXRu	OfferCreate Others Payment	11,018,421 25,702 94	11,044,217	7.0%
rs9tBKt96q9gwrePKPqimUuF7vErgMaker	OfferCreate Others	2,688,775 131,477	2,820,252	1.8%
rBW8YPFaQ8WhHUy3WyKJG3mfnTGUkuw86q	OfferCreate Others	2,339,647 865	2,340,512	1.5%
rDzTZxa7NwD9vmNf5dvTbW4FQDNSRsfPv6	OfferCreate Others	2,339,372 937	2,340,309	1.5%
rnruxxLTbJUMNtFNBJ7X2xSiy1KE7ajUuH	OfferCreate Others	2,336,597 958	2,337,555	1.5%
rV2XRbZtsGwvpRptf3WaNyfgnuBpt64ca	OfferCreate Others Payment	2,336,505 874 32	2,337,411	1.5%
rwchA2b36zu2r6CJfEMzPLQ1cmciKFcw9t	OfferCreate Others Payment	2,335,682 825 15	2,336,522	1.5%

Figure 8: Most active accounts on the XRP ledger.

a congestion mode. In a normal mode, users can consume more CPU than they staked for, but when the network is in congestion mode they can only consume the amount staked. Although this is how the network is supposed to behave, it is problematic if it lasts for a non-negligible period of time. For example, EOS is used for games where many users make a small number of transactions without staking CPU. When the network enters congestion mode for a long period of time, these users cannot continue to play unless they actively stake EOS for CPU. This has caused some services [10] to threaten with their migration to another blockchain.

The coin seems to be operated by an entity called Enumivo but there is very scarce information about what service it will provide. Given the very hostile tone in communications [2], it is very unclear whether the person behind the airdrop is trying to orchestrate a DoS attack on the EOS network or if the token will be used to provide some service.

Summary. One of the major selling point of EOS is its absence of transaction fee. Although this clearly provides advantages for users, it can also result in spammy behaviors, as we saw in this section. In cases such as the WhaleEx wash-trading, this does not have any direct negative impact but with the EIDOS token, this backfired as the network had to enter congestion mode and users have to stake an amount much higher than what they would pay in transaction fees on Bitcoin [10].

[2] https://twitter.com/enumivo/status/1193353931797057536

4.2 Governance Transactions in Tezos

One of the main particularities of Tezos compared to other blockchains is its on-chain governance and self-amendment abilities. Given that only *bakers* are allowed to send such transactions and that they can only perform a limited number of actions within a certain time frame, governance-related transactions represent only a very small fraction of the total number of transactions: merely 245 within our observation period. However, given that this type of transaction is rather unique and has, to the best of our knowledge, not been analyzed before, we analyze how the different phases of the governance process are executed in practice.

Tezos Voting Periods. Tezos voting is divided into four periods, each lasting around 23 blocks [18]. During the first period, the proposal period, bakers are allowed to propose an amendment in the form of source code to be deployed as the new protocol for Tezos. At the end of this period, the proposal with the highest number of bakers' votes is selected for the next period: The exploration period. During the exploration period, the bakers either choose to approve, refuse or abstain on voting on the proposal. If the quorum and the minimum positive votes—both thresholds are dynamically adjusted based on past participation—is reached, the proposal enters the testing period. During the testing period, the proposal is deployed on a testing network, without affecting the main network. Finally, the last period is the promotion vote period, which works in the same way as the exploration period but if successful, the new protocol is deployed as the new main network.

Analyzing Tezos Voting. To investigate the entire voting process in Tezos, we collect extra data associated with the last amendment called Babylon 2.0 [8], which was proposed on August 2, 2019 and promoted to the main network on October 18, 2019. We show the evolution of the votes during the different voting phases in Figure 9.

During the proposal period, a first proposal, called Babylon was submitted at the beginning and slowly accumulated votes. During this phase, the authors of Babylon, Cryptium Labs[3] received feedback from involved parties and released an updated protocol, Babylon 2.0. Votes can be placed on multiple proposals which is why the number of previous votes on Babylon did not decrease. At the end of the vote, the participation was roughly 49%. It is worth noting that, although in practice any baker can propose an amendment to the network, from the creation of the Tezos blockchian up until the time of this writing, only Cryptium Labs, who is supported by the Tezos Foundation, has made proposals.

During the exploration phase, participants can vote "yay" to support the proposal, "nay" to reject it or "pass" to explicitly abstain from voting. We can see that there are absolutely no negative votes during this period and the only abstention is from the Tezos Foundation, whose policy is to always abstain to leave the decision to the community. This phase had a participation of more than 81%, which is vastly higher than for the previous round but could be mostly explained by the fact that explicit abstention counts as participation, while in the previous proposal phase, there is no way to explicitly abstain.

Finally, the promotion phase started after the testing phase during which the proposal was deployed on a test network. The trend was mostly similar to what was observed in the exploration period but the number of votes against the proposals increased from 0 to 15%, as some bakers encountered troubles during the testing period due to changes in the transaction format that led to breaking components [29].

Summary. There are currently four phases in the Tezos voting system. First, participants can submit proposals, then they decide whether to try the elected proposal on a testing network and finally whether to amend the main network using the proposal. However, at the time of writing, only a single participant has ever proposed amendments. Furthermore, in every exploration period seen, the proposal has always received more than 99% of approvals, except once when the participation during the proposal period was less than 1% and the proposal received more than 99% of rejections [35] during the exploration period.. Although the current voting scheme could be useful in the future, we believe that in the current state of the network, the proposal and exploration periods could be merged. This would allow a reduction in the time until amendments ship to the main network without compromising the functionality or security of the network.

[3] https://cryptium.ch/

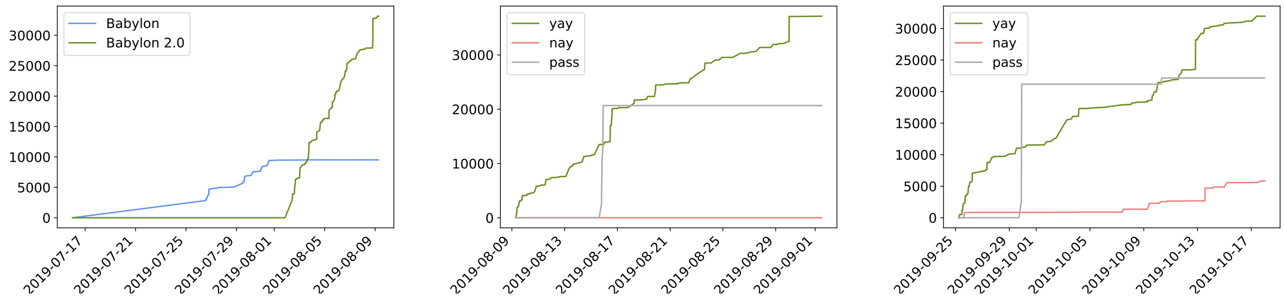
4.3 Zero-value Transactions in XRP

Payments with zero-value tokens. As described in Section 2.4, the XRP ledger offers autonomy in currency issuance. On the flip side, this means that it is easy to generate seemingly high-value, but in effect valueless and useless transactions. Currencies bearing the same ticker issued by different accounts can have drastically different valuation due to the varying level of trust in their issuers and the redeemability of their IOU tokens, which has in the past caused confusion among less informed users (Figure 10).

In fact, the only currency whose value is recognized outside of the XRP ledger is its native currency `XRP`, which is also the only currency that cannot be transferred in the form of IOUs. Non-native currencies can be exchanged with each other or to `XRP` via decentralized exchanges on the ledger. Therefore, a reliable way of evaluating a currency by a certain issuer is to look up its exchange rate against `XRP`. Normally, only IOU tokens issued by featured XRP ledger gateways are deemed valuable; in contrast, tokens issued by random accounts are most likely to be deemed worthless. During December 2019, the average exchange rate of `BTC` IOUs varied greatly, from 0 to 36,050 `XRP`, depending on their respective issuer (Figure 11a).

The ledger experienced two waves of abnormally high traffic in the form of `Payment` transactions in late 2019, the first between the end of October and the beginning of November, the second—at a higher level—between the end of November and the beginning of December (Figure 7). The reason behind the increased traffic is `rpJZ5WyotdphojwMLxCr2prhULvG3Voe3X`, an account activated on October 9, 2019 who itself managed to activate 5,020 new accounts within one week with a total of 1 million `XRP` (roughly US$ 250,000), only to have them perform meaningless transactions between each other, wasting money on transaction fees. The behavior triggered a heated debate in the XRP community where a member revealed that the traffic imposed such a burden to his validator that it had to be disconnected [48].

Ripple suspected it to be "an attempt to spam the



(a) Proposal period **(b)** Exploration period **(c)** Promotion period

Figure 9: Tezos Babylon on-chain amendment voting process.

Figure 10: A tweet questioning the transaction value on the XRP ledger.

ledger" with little impact on the network[4]. However, large exchanges such as Binance suffered from temporary `XRP` withdrawal failures, who cited the XRP network congestion as the cause [2]. It remains something of a mystery how such an expensive form of "spam" benefited its originators.

The payment transactions from the spam did not carry any value, since they involved transferring `BTC` IOU tokens not to be accepted outside of the spammer's network.

To quantify true value-transferring `Payment` transactions, we retrieve the exchange rate of all the issuer-specific tokens that were transferred between October 1, 2019 and December 31, 2019. Only 5.5% of all successful `Payment` transactions involve tokens with a positive `XRP` rate (Figure 7).

In Figure 12, we show the top senders and receivers of those transactions, as well as the most popular currencies being transferred. To cluster accounts, we rely on user names as the identifier, as one entity can have multiple addresses under a given user name (e.g. `Binance`, `Coinbase`). For accounts with no registered username, we use their parent's username, if available, plus the suffix "descendant" as their identifier.

As one might expect, `XRP` is by far the most used currency on the ledger in terms of payment volume: 43 billion `XRP` for three months, or 360 million `XRP` per day. The calculation aligns with the 24-hour `XRP` payment volume self-reported by Ripple.[5]

The top 10 senders cover 51% of this volume, while the top 10 receivers are the beneficiaries of 43% of the volume. Payments from Ripple alone account for 10% (4 billion) of the `XRP` volume, largely due to transactions

Issuer name	Issuer account	Rate
Bitstamp	`rvYAfWj5gh67oV6fW32ZzP3Aw4Eubs59B`	36,050
Gatehub Fifth	`rchGBxcD1A1C2tdxF6papQYZ8kjRKMYcL`	35,817
BTC 2 Ripple	`rMwjYedjc7qqtKYVLiAccJSmCwih4LnE2q`	409
not registered	`r3fFaoqaJN1wwN68fsMAt4QkRuXkEjB3W4`	1
not registered	`rpJZ5WyotdphojwMLxCr2prhULvG3Voe3X`	0

(a) Average rate (in `XRP`) of `BTC` IOUs issued by exemplary accounts during December 2019. Data retrieved through `https://data.ripple.com/v2/exchange_rates/BTC+{issuer_address}/XRP?date=2020-01-01T00:00:00Z&period=30day` [44].

Date	Seller account of `BTC` IOU	Rate
2019-12-14	`rHVsygEmrjSjafqFxn6dqJWHCdAPE74Zun`	30,500
2020-01-09	`rU6m5F9c1eWGKBdLMy1evRwk34HuVc18Wg`	1
2020-01-09	`rU6m5F9c1eWGKBdLMy1evRwk34HuVc18Wg`	0.1

(b) Rate (in `XRP`) of `BTC` IOUs issued by `rKRNtZzfrkTwE4ggqXbmfgoy57RBJYS7TS` at different time. In all the three exchange transactions, the account that buys the `BTC` IOU against `XRP` is `rMyronEjVcAdqUvhzx4MaBDwBPSPCrDHYm`. Data retrieved from `https://data.ripple.com/v2/exchanges/BTC+rKRNtZzfrkTwE4ggqXbmfgoy57RBJYS7TS/XRP` [45].

Figure 11: Rate (in `XRP`) `BTC` IOUs on the XRP ledger.

[4] `https://twitter.com/nbougalis/status/1198670099160322048`

[5] On February 10, 2020, Ripple reported 343 million of `XRP` payment volume `https://xrpcharts.ripple.com/`.

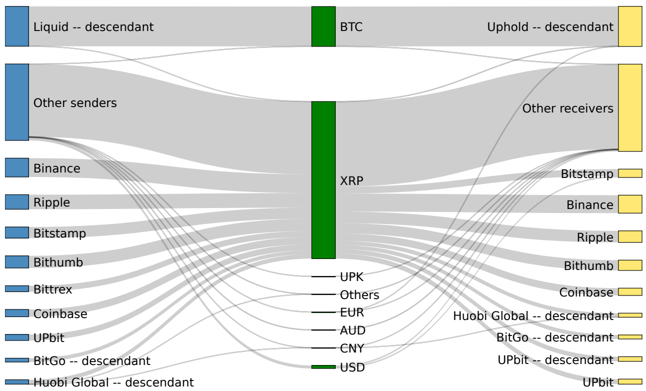


Figure 12: Value flow on the XRP ledger between October 1, 2019 and December 31, 2019. The bandwidth of each flow represents the magnitude of aggregate value transferred denominated in XRP. Only Payment-type transactions are recorded.

associated with the monthly release of one billion XRP from escrows. While the XRP release itself is captured through EscrowCreate-type transactions, 90% of the released funds (2.7/3 billion XRP) were unused and returned to escrows for future release [32] through Payment-type transactions. All other top accounts presented are held either by exchanges, or, in rare cases, by accounts that were opened by an exchange. Binance appears to be the most avid XRP user, sending 5.2 billion and receiving 5.0 billion XRP during the observation period.

The most popular IOU tokens for fiat currencies include USD, EUR and CNY (Figure 12). While the ledger witnessed inter-account movements of 2.3 billion USD, 2.8 billion EUR and 43 million CNY, only a small fraction of the corresponding tokens have value. Specifically, 171 million USD, 3 million EUR and 15 million CNY issued had positive exchange rates against XRP. The average on-ledger exchange rates of those three fiat currency tokens, irrespective of their issuers, were 4.9 XRP/EUR, 5.4 XRP/EUR and 0.7 XRP/CNY, largely in accordance with the off-ledger exchange rates.[6]

This leads to an aggregate trading volume of 843 million, 19 million and 10 million XRP for USD, EUR, and CNY, respectively, during the observation period.

The most conspicuous payment transactions were the transfer of 360,222 BTC IOU, issued by rKRNtZzfrkTwE4ggqXbmfgoy57RBJYS7TS, an account activated by Liquid (liquid.com), from the issuer itself to rMyronEjVcAdqUvhzx4MaBDwBPSPCrDHYm, an account activated by uphold (uphold.com). The BTC IOU token was exchanged at 30,500 XRP, resulting in a valuation of 11 billion XRP of those payments. We examine the legitimacy of the exchange rates in the next step.

Fulfilled offers with zero-value tokens. The issuer is not the only factor behind the value of an IOU token. Even IOU tokens for the same currency from the same issuer can at times exhibit vastly different rates. Figure 11b shows an example where the BTC IOU from the same issuer rKRNtZzfrkTwE4ggqXbmfgoy57RBJYS7TS was traded at 30,500 XRP in December 2019 but then declined to 0.1 XRP within a month.

The three exchange instances in Figure 11a were OfferCreate transactions where the initiator intended to sell BTC ICO for XRP. We discover that all three offers were filled by the same account rMyronEjVcAdqUvhzx4MaBDwBPSPCrDHYm, who received the aforementioned BTC IOU tokens directly from the issuer's account. Additional evidence on social media reveals that the IOU issuer's account is held by a man named Myrone Bagalay.[7] It becomes obvious that the offer taker's address, starting rMyronE, must belong to the same person.

By tracing the transaction history of the concerned accounts, we notice that the two offer creators' accounts received their initial BTC IOU tokens through payments from the offer taker. Furthermore, one offer creator's account, rU6m5F9c1eWGKBdLMy1evRwk34HuVc18Wg, was activated by the offer taker's account. Now we can safely assume that all the accounts involved are controlled by that Myrone Bagalay, who issued BTC IOU tokens and traded them at arbitrarily determined rates with himself.

What Myrone Bagalay did is completely legitimate within the confines of XRP. In fact, one of the key features of the ledger is the flexibility to establish a closed economy with a limited number of mutually-trusting users who can exchange self-defined assets that are not necessarily acknowledged outside of the economy. However, this makes it challenging to gauge the true value transfer on the XRP ledger, since an IOU token's exchange rate can be easily inflated or deflated.

Additionally, privately-issued IOU tokens that are never exchanged on the ledger, while seemingly worthless, might be valuable to their transactors after all, should they reach an agreement on those tokens' value off the ledger.

Summary. In summary, the throughput on the XRP ledger during our observation period appeared to be fraught with zero-value transactions. We learned that both transaction volume and token value on the XRP ledger are highly manipulable. One must thus fully understand the underlying measurement approach to correctly interpret the resultant statistics.

[6] https://finance.yahoo.com/.

[7] See https://youtu.be/gVoyCEPvO30 and https://www.twipu.com/MyroneBagalay/tweet/1161288087386894341.

5 Related Work

Existing literature on transactional patterns and graphs on blockchains has been largely focused on the Bitcoin network,

Ron et al. [31] were among the first to analyze transaction graphs Bitcoin. Using on-chain transaction data with more than 3 million different addresses, the authors found that Mt. Gox was at the time by far the most used exchange, covering over 80% of the exchange-related traffic.

Kondor et al. [20] focused on the wealth distribution in Bitcoin and provided an overview of the evolution of different metrics across time such as node in-degree, out-degree or yet the evolution of the Gini coefficient. They find that the Gini coefficient of the balance distribution has increased quite rapidly and show that the wealth distribution in Bitcoin is converging to a power law.

McGinn et al. [23] focus their work on visualising Bitcoin transaction pattern. At this point, in 2016, Bitcoin already had more than 300 million addresses, indicating exponential growth over time. The authors propose a visualisation which scales well enough to enable pattern searching. Roughly speaking, they present transactions, inputs and outputs as vertices while treating addresses as edges. The authors report that they were able to discover high frequency transactions patterns such as automated laundering operations or denial-of-service attacks.

Ranshous et al. [30] extended previous work by using a directed hypergraph to model Bitcoin transactions. They model the transaction as a bipartite hypergraph where edges are in and out amounts of transactions and the two types of vertices are transactions and addresses. Based on this hypergraph, they identify transaction patterns, such as "short thick band", a pattern where Bitcoins are received from an exchange, held for a while and sent back to an exchange. Finally, they used different features extracted from the hypergraph, such as the amount of bitcoin received but also how many times the address was in a pattern such as the one described before, to train a classifier capable of predicting if a particular address belongs to an exchange.

Di Francesco Maesa et al. [9] analysed Bitcoin user graphs to detect unusual behaviours. The authors find that discrepancies such as outliers in the in-degree distribution of nodes are often caused by artificial users' behaviour. They then introduce the notion of pseudo-spam transactions, which consist of transactions with a single input and multiple outputs where only one has a value higher than a Satoshi, the smallest amount that can be sent in a transaction. The find that approximately 0.5% of the total number of multi-input multi-output transactions followed such a pattern and that these were often chained.

Several other works also exist about the subject and very often try to leverage some machine learning techniques either to cluster or classify Bitcoin addresses. Monamo et al. [24] attempted to detect anomalies on Bitcoin and show that their approach is able to partly cluster some fraudulent activity on the network. Toyoda et al. [36] focus on classifying Ponzi schemes and related high yield investment programs by applying supervised learning using features related to transaction patterns, such as the number of transactions an address is involved in, or its ratio of pay-in to pay-out. Bartoletti et al. [3] also use a similar approach to detect Ponzi schemes and manage to obtain an F1-score of about 0.7 for predicting if an address is conducting such a scheme.

6 Conclusions

We investigate transaction patterns and value transfers on the three major high-throughput blockchains: EOS, Tezos, and XRP. Using direct connections with the respective blockchains, we fetch transaction data between October 1 and December 31, 2019. With EOS and XRP, the majority of the transactions exhibit characteristics resembling DoS attacks: 95% of the transactions on EOS were triggered by the airdrop of a yet valueless token; and only 2% of transactions on the XRP ledger lead to value transfers. For Tezos, since transactions per block are largely outnumbered by mandatory endorsements, most of the throughput, 82%, is occupied for maintaining consensus.

Furthermore, through several case studies, we present prominent cases of how transactional throughput was used on different blockchains. Specifically, we show two cases of spam on EOS, on-chain governance related transactions on Tezos as well as payments and exchange offers with zero-value tokens on XRP.

The bottom line is: the three blockchains studied in this paper demonstrate capacity to carry out high throughput; however, the massive potential of those blockchains has thus far not been fully realized for their intended purposes.

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