

ABC: Asynchronous Blockchain without Consensus

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Abstract. There is a preconception that a blockchain needs consensus. But consensus is a powerful distributed property with a remarkably high price tag. So one may wonder whether consensus is at all needed.

We introduce a new blockchain architecture called ABC that functions despite not establishing consensus, and comes with an array of advantages: ABC is permissionless, deterministic, and resilient to complete asynchrony. ABC features finality and does not rely on costly proof-of-work.

Without establishing consensus, ABC cannot support certain applications, in particular smart contracts that are open for interaction with unknown agents. However, our system is an advantageous solution for many important use cases, such as cryptocurrencies like Bitcoin.

1 Introduction

Nakamoto’s Bitcoin protocol has taught the world how to achieve trust without a designated trusted party. The Bitcoin architecture provides an interesting deviation from classic distributed systems approaches, for instance by using proof-of-work to allow anonymous participants to join and leave the system at any point, without permission.

However, Bitcoin’s proof-of-work solution comes at a serious cost. The security of the system is directly related to the amount of investments in designated proof-of-work hardware, and to spending energy to run said hardware constantly, forever. The system’s participants need to be rewarded for running this hardware and paying for energy in an incentive-compatible way, which introduces game-theoretic vulnerabilities.

In the decade since the original Bitcoin publication, researchers have tried to address the wastefulness of proof-of-work. One of the most prominent research directions is replacing Bitcoin’s proof-of-work with a proof-of-stake approach. In proof-of-stake designs, the participants who hold a digital resource (such as a cryptocurrency) vouch for new transactions. Alas, proof-of-stake comes with its own problems.

Prominently, existing proof-of-stake designs critically rely on randomness. To achieve consensus, the participants of such systems repeatedly choose a leader among themselves based on the amounts of cryptocurrency they hold. Despite being random, this choice needs to be taken collectively and in a verifiable way,

which complicates the problem, as it essentially asks for a random-but-not-really-random solution. Another potential vulnerability is posed by the necessary requirements related to the communication between the participants regarding message loss and timing guarantees.

Our Contribution We introduce an asynchronous blockchain design that features an array of advantages by not relying on establishing consensus in the first place. In other words, we present an Asynchronous Blockchain without Consensus (ABC).

ABC is permissionless in the same way as existing proof-of-stake systems. Participants of ABC holding an exchangeable resource (such as a cryptocurrency) take part in approving new transactions.

We assume the functionality provided by asymmetric encryption and hashing. Apart from these cryptographic necessities, ABC is completely deterministic.

ABC is asynchronous, and as such fully resilient to all network-related threats, such as delaying messages from some party, or network eclipse attacks. By disabling communication, an adversary can stop the system from creating and approving new transactions, but cannot invalidate previously approved transactions or approve otherwise impermissible ones.

Unlike proof-of-work, the security of the system does not depend on the amount of devoted resources such as energy, computational power, memory, etc. Similarly to proof-of-stake, ABC requires that more than two thirds of the system's digital resource is held by participants that obey the protocol.

On the negative side, not being able to establish consensus prevents some applications from being feasible. For example, smart contracts open for interaction with previously unknown agents are not feasible.

On the other hand, many important applications, such as cryptocurrencies, do not require consensus [3], and ABC offers an advantageous solution for those scenarios.

2 Intuition

An adversary issuing conflicting transactions is a primary threat to blockchain systems. Traditionally, it has been assumed that blockchains need to feature consensus to choose *exactly* one of the transactions issued by a misbehaving party. ABC deviates from technical definition of consensus in that in such situations, we require that *at most* one transaction is chosen.

For simplicity, we describe ABC in the terminology of a cryptocurrency. A more formal description follows in Section 4. As usual in cryptocurrencies, the main operation is a transaction, which transfers cryptomoney from one or more inputs to one or more outputs. Every transaction refers to at least one previous transaction, such that all transactions form a directed acyclic graph (DAG).

A transaction t is confirmed by the system if enough later transactions (directly or indirectly) refer to t . If a transaction receives enough support, no other transaction conflicting with t can become confirmed. In particular, if the owner

attempts to issue a transaction t' which is trying to spend (some of) the same input(s) as t , the system will reject t' . If an owner issues two conflicting transactions t and t' at roughly the same time, it is possible that (a) either t or t' gets confirmed (but not both), or (b) neither t nor t' are ever confirmed. Case (b) happens if some system agents see and try to confirm t , while others see and try to confirm t' . The system might stay in this state forever with the agents split between t and t' , with no clear majority. Crucially, such a situation can only arise if the owner of t and t' misbehaves. The results are in every sense equivalent to the misbehaving agent forgetting the private keys for the inputs, and do not constitute any threat to the system.

It is somewhat intuitive to verify that such a system does work correctly if the cryptocurrency amounts are statically assigned to some agents, and a set of agents controlling more than two-thirds of the cryptocurrency obeys the protocol. Surprisingly, in Section 5 we will show that correctness is still given even if the agents can freely exchange said cryptocurrency among each other! Thus, we establish a system philosophically close to proof-of-stake, but asynchronous and deterministic instead.

If implemented naively, the system requires that over two-thirds of the existing currency is exchanged after some transaction took place in order to confirm said transaction. In many scenarios, the associated delay might be prohibitively large. Thus, in Section 6.1 we identify the need for some stakeholders to delegate their role in confirming transactions to other agents, who issue special transactions solely to confirm other transactions. Indeed, in existing proof-of-stake systems an identical need is present, as it is unreasonable to require all stakeholders to constantly participate in the maintenance of the system themselves.

3 Model

We assume that our blockchain is used and maintained by its participants called agents. We assume that all agents are connected by a virtual network similar to Bitcoin's, where agents can broadcast their messages to all other agents. New agents can join this network to receive new and also prior messages. Agents can also leave the network. Unlike Bitcoin's network, messages are delivered asynchronously: A message broadcast will eventually arrive at every agent, however, there is no guarantee that the message arrives within any time bound.

Each agent holds private/public key pairs. Agents who follow the protocol are called honest. The set of agents who do not follow the protocol is controlled by the adversary. The adversary behaves in an arbitrary way.

4 Protocol

In this section we describe the various components of the protocol.

4.1 Genesis

The *genesis* is the data known upfront to every agent. The genesis specifies a set of initial public key-value pairs. The value represents the amount of cryptocurrency, or the stake, held by the agent in possession of the private key corresponding to the public key. Each genesis key-value pair is called an (initial) output.

The agent who knows the private key of a key-value pair controls that output. For simplicity of presentation, we assume that all initial values sum up to $3f + 1$, every output is uniquely identified by the associated key, and any output is controlled by a single agent.

4.2 Transactions

Definition 1 (transaction). *The genesis is a transaction with only outputs (key-value pairs). Every other transaction t contains:*

- *A non-empty set of references to (hashes of) previous transactions. The transactions will form a directed acyclic graph (DAG). The set of transactions reachable by references from t is called $\text{past}(t)$.*
- *The inputs, where each input is an output of a transaction in $\text{past}(t)$. Transaction t is said to spend these inputs. In the context of t , the inputs to transactions in $\text{past}(t)$ are called spent. The inputs of t cannot be spent in $\text{past}(t) \setminus \{t\}$. The transaction is signed by the private keys corresponding to the inputs. In other words, the agent creating the transaction controls the inputs of the transaction.*
- *The outputs, which are key-value pairs. The sum of values of the outputs is equal to the sum of values of the inputs. This sum is also referred to as the value of the transaction t .*

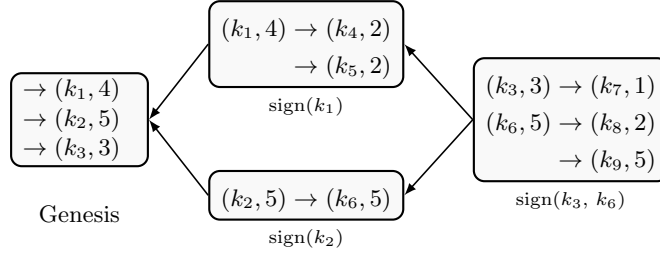


Fig. 1. Example transaction DAG.

We abuse notation and by $\text{past}(t)$ refer to a set of transactions or a DAG depending on context.

Since the communication network is asynchronous, each agent might be aware of only some portion (subgraph) of the transaction DAG. If an agent observes a transaction t , we assume the agent observed all transactions in $\text{past}(t)$ as well. If an agent receives a transaction t but some transactions in $\text{past}(t)$ are missing, the agent cannot be sure that t is in fact a transaction that does not reference invalid data. Hence, the agent ignores t until $\text{past}(t)$ is received in full. If some transactions in $\text{past}(t)$ are missing, the agent will ask other agents in the communication network for these missing transactions. Such a situation might be compared to receiving a block without knowing the parent block in the Bitcoin blockchain. Hence, whenever we refer to a subgraph of the transaction DAG, the genesis is the only sink of that subgraph. We can also define past for outputs and sets:

Definition 2 (past, future). *For any output o of a transaction t , we write $\text{past}(o) = \text{past}(t)$. For a set of transactions T , $\text{past}(T) = \bigcup_{t \in T} \text{past}(t)$. If $t \in \text{past}(u)$ then $u \in \text{future}(t)$.*

Note that when an output o is referred to as an input to a transaction t , $\text{past}(o)$ is still meant to refer to $\text{past}(u)$ rather than $\text{past}(t)$, where u is the transaction that output o .

Definition 3 (depends). *If a transaction v spends one or more outputs of transaction u , then v depends on u . Dependence is transitive and reflexive, i.e. every transaction depends on itself and if v depends on u and w depends on v , then w depends on u .*

Notice that the dependence relation is a subrelation of $u \in \text{past}(v)$, and could also be represented by a DAG. In Figure 1, the outputs of the genesis are spent in the other three transactions. However, when we mention a DAG, we always mean the DAG formed by references.

Definition 4 (conflicts). *If two transactions u and v spend the same output, they conflict. Moreover, for two conflicting transactions u, v , every transaction that depends on u conflicts with every transaction that depends on v .*

Transactions are confirmed based on other transactions that reference them. Intuitively, for a transaction t to become confirmed, some set of transactions C_t need to reference transaction t in $\text{past}(C_t)$. If these transactions C_t together account for more than two-thirds of the stake in the system, and there is no evidence of misbehavior of the creator of t in $\text{past}(C_t)$, then t becomes confirmed. The transactions C_t and $\text{past}(C_t)$ serve as the proof that t is confirmed.

Definition 5 (confirmed, illicit). *Some transactions are confirmed depending on the DAG. Genesis is by default confirmed. Given a DAG with some confirmed transaction u , all transactions conflicting with u are called illicit.*

A transaction t is confirmed if there exists a set C_t (always including t itself) of confirming transactions $C_t = \{t, t_1, \dots, t_k\} \subseteq \text{future}(t)$, such that:

- The transactions that t depends on are confirmed.
- t is the only transaction spending the inputs of t in $\text{past}(C_t)$.
- All transactions C_t are not illicit in $\text{past}(C_t)$. Only transactions illicit in $\text{past}(C_t)$ can conflict with any C_t .
- There is a set S_t of inputs o_i to transactions C_t such that $t \notin \text{past}(o_i)$ for all i and the sum of values of these inputs is at least $2f + 1$.

Note that it is still possible that adding a transaction to the DAG might confirm a chain of dependent transactions such that there are no intermediate states with transactions being confirmed one by one.

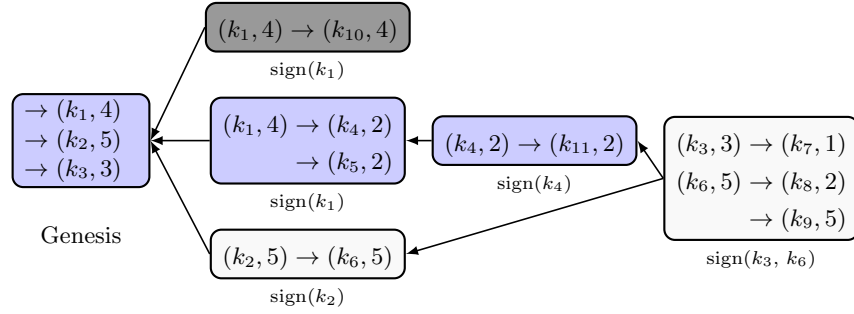


Fig. 2. Example transaction DAG. Blue transactions are confirmed, and the grayed out transaction is illicit.

4.3 The Protocol

Most importantly, we assume that honest agents never attempt to spend the same output more than once. In other words, honest agents do not create conflicting transactions. Another important requirement is that whenever an honest agent created a transaction t_1 , this transaction will be referenced by the next transaction t_2 the same honest agent creates, i.e., $t_1 \in \text{past}(t_2)$. As a consequence, it is impossible that for some other agents A and B , A observes t_1 but not t_2 , while B can see t_2 and not t_1 .

Algorithm 1: The protocol of issuing a new transaction t .

- 1 Transaction t references all previously observed transactions.
 - 2 Broadcast transaction t to the network.
 - 3 Destroy the private keys used to sign the transaction t .
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For the security of the system, whenever an honest agent has created a transaction, the agent permanently destroys the private keys corresponding to the

inputs, such that there is never another transaction spending the same inputs, even if the agent subsequently became adversarial.

Definition 6 (burned outputs). *An output o is called burned in G if an honest agent issued a transaction with o as an input, and destroyed the corresponding private key. Additionally, o is not illicit in G .*

Agents do not know if outputs are burned or not (except if an agent generated and later destroyed the corresponding key(s) of an output o itself).

4.4 The Adversary

The adversary behaves in an arbitrary way, and thus might create conflicting transactions that do not reference each other and send them to different sets of recipients.

Any messages sent by honest agents is immediately seen by the adversary. The delivery of each message from an honest agent to an honest agent can be delayed by the adversary for an arbitrary amount of time.

We assume that initially the adversary controls outputs with values summing up to x , with $x \leq f$. In other words, the adversary has a stake of x at the beginning. Since the total initial stake is $3f + 1$, the honest agents controls at least $2f + 1$ of the stake at the beginning.

Whenever the adversary has some $x < f$ of the stake, the adversary can instantly acquire control of an output $y \leq f - x$ controlled by an honest agent, or instantly force any honest agent to issue a transaction with outputs a, y , $y \leq f - x$, where the adversary controls y and some honest agent controls a . We say the adversary has $x + y$ amount of stake from that point on.

Whenever the adversary controls some x of the stake, the adversary can issue a transaction t of an amount $y \leq x$ to an honest agent. From the instant t is confirmed, we say the adversary controls $x - y$ of the stake.

5 Double-spending

This section is devoted to the problem of double-spending the same output twice, which is at the core of any cryptocurrency. We show that if our assumptions are met, it is impossible that any two conflicting transactions are confirmed.

Suppose the system produced some transaction DAG G by the process described in Section 4.

Corollary 7. *If a transaction t is confirmed, then all transactions that t depends on are confirmed in $\text{past}(C_t)$.*

Proof. Follows directly from Definition 5. □

We will show any DAG produced under our assumptions enjoys the following property:

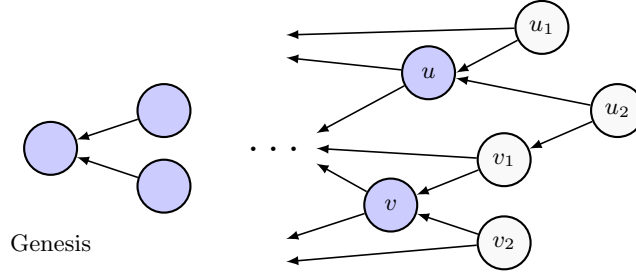


Fig. 3. Property 1: u and v are confirmed, v can be seen in $\text{past}(C_u)$.

Property 1. For every pair of confirmed transactions u and v , either $u \in \text{past}(C_v)$ or $v \in \text{past}(C_u)$.

If Property 1 holds, our core security guarantee follows:

Lemma 8. *Suppose Property 1 holds for G . Then, for no pair of conflicting transactions u, v both u and v are confirmed.*

Proof. Suppose for contradiction there is a pair of conflicting, confirmed transactions. By Definitions 3 and 4 and Corollary 7 we can find transactions u and v that spend the same output and both are confirmed.

By Property 1 without loss of generality, assume $u \in \text{past}(C_v)$. Then, Definition 5 is violated with respect to v , a contradiction. \square

Lemma 9. *Suppose Property 1 holds in G . Then, all inputs to transactions issued by honest agents are burned.*

Proof. Recall that according to the protocol, honest agents permanently destroy the private keys corresponding to their inputs. What remains to be shown is that honest inputs are not illicit if Property 1 holds.

According to our assumptions, outputs controlled by honest agents are outputs of honest transactions or confirmed adversarial transactions. Honest agents do not issue conflicting transactions, and by Lemma 8, no transactions conflicting with another confirmed transaction can be confirmed. Hence, inputs of honest agents do not conflict with confirmed transactions and are not illicit. \square

To show that Property 1 holds, we introduce an auxiliary property. Intuitively, Property 2 asserts that if at any point an agent does not see some transaction t that has already been confirmed by the system, then some unspent outputs of value $f + 1$ are already burned in the DAG this agent observes. To become convinced that some other transaction u is confirmed, the agent has to observe t first, unless $u \in \text{past}(t)$ already.

Property 2. Any subgraph of G not including some confirmed transaction t is such that some unspent outputs O summing up in value to at least $f + 1$ are burned.

Lemma 10. *Suppose Property 1 holds for G , then Property 2 holds for G .*

Proof. Let G be minimal such that Property 1 holds but Property 2 does not hold. Suppose for contradiction there is a confirmed transaction u in G such that there is a subgraph H of G not including u with burned unspent outputs summing to at most f .

By Definition 5, there are inputs S_u to transactions C_u summing in value to at least $2f + 1$, such that $u \notin \text{past}(S_u)$. Suppose the honest of those inputs $S_u^h \subseteq S_u$ sum in value to at least $f + 1$. Then either: 1. the outputs of value $f + 1$ that S_u^h depend on are burned in H , a contradiction, or 2. H does not include some confirmed adversarial transaction that S_u^h depend on and a contradiction follows from choice of G and Property 2. . We conclude the inputs $S_u^a \subseteq S_u$ issued by the adversary sum in value to at least $f + 1$.

By our assumptions, some of the adversarial outputs in S_u^a were acquired after some others in S_u^a were used as inputs in a confirmed transaction v . Hence, by Definition 5 $v \notin \text{past}(C_u)$. Let G' be the DAG right before the last confirming transaction $t \in C_u$ was issued. Since $v \notin \text{past}(C_u)$, v is confirmed in G' . By choice of G , Property 2 holds for G' . However, $\text{past}(C_u) \setminus \{t\}$ is a subgraph of G' not including v . Therefore there are burned unspent outputs R in $\text{past}(C_u) \setminus \{t\}$. After t is issued, we observe independent outputs in R and C_u summing up to at least $3f + 2$, a contradiction. \square

Lemma 11. *Suppose Properties 1 and 2 hold for G and that G' is obtained from G by adding a new transaction t . Then Property 1 holds for G' .*

Proof. Let u be a transaction confirmed in G' but not G , such that there is no other transaction $u' \in \text{past}(u)$ confirmed in G' but not G .

Consider some transaction v confirmed in G and suppose for contradiction that $v \notin \text{past}(C_u)$ and $u \notin \text{past}(C_v)$. Let $G_\cap = \text{past}(C_u) \cap \text{past}(C_v)$. Note that G_\cap does not include v and is a subDAG of G . By Property 2, in G_\cap there are burned outputs O which remain unspent in $\text{past}(C_u)$ that sum up to the value of $f + 1$.

First, consider if u can be conflicting with some output in O . By Definition 6 and choice of u , there would need to be some transaction spending the same inputs as u in $\text{past}(C_u)$, contradicting Definition 5. Hence, no transactions conflicting with outputs in O are confirmed in G' .

Then, u and C_u are not conflicting with outputs O . The transactions in C_u cannot be conflicting, and there are independent inputs of these transactions amounting to $2f + 1$ in value. Together with outputs O , we observe independent outputs summing up in value to $3f + 2$, a contradiction.

Recall Property 1 holds in G . So far we have established that if a transaction v is confirmed in G and a transaction u is confirmed in G' , then $v \in \text{past}(C_u)$ or $u \in \text{past}(C_v)$. It remains to consider a pair of transactions newly confirmed in G' .

Let w be a transaction confirmed in G' but not G . Then, $t \in C_u$ and $t \in C_w$, so both $u \in \text{past}(C_w)$ and $w \in \text{past}(C_u)$.

Hence, $u \in \text{past}(C_x)$ or $x \in \text{past}(C_u)$ for any transaction x confirmed in G' and Property 1 follows. \square

Lemma 12. *Properties 1 and 2 hold for G .*

Proof. Suppose for contradiction that G is the smallest transaction DAG such that one of the properties does not hold for G , and let G' be the DAG before the last transaction t was issued in G . By choice of G , Properties 1 and 2 hold for G' . By Lemmas 11 and 10, Properties 1 and 2 hold for G , a contradiction. \square

Theorem 13. *No two conflicting transactions are ever confirmed.*

Proof. Follows from Lemmas 12 and 8. \square

6 Improvements

6.1 Stake Pooling

As described so far, the system requires over two-thirds of the existing currency to be moved after some transaction t took place merely to confirm transaction t . In many applications, the associated overhead and delay might be prohibitively high.

In this section we describe a way for stakeholders to delegate their role in confirming transactions to other agents. Hence, the number of transactions needed for a confirmation might be reduced so that the needed time is negligible, while preserving a strongly decentralized nature of the system.

In ABC, to delegate an output o of a transaction t to another agent for the purpose of confirming other transactions, we introduce a second public/private key k^2 associated with an output o . Then, o can be spent normally by some transaction $t_1 \in \text{future}(t)$, where o carries no weight with respect to confirming transactions.

The private key k^2 is held by some other agent able to additionally sign his transaction $u \in \text{future}(t)$ with k^2 to increase the value of u by the value of o , while being unable to spend the output o . For the purpose of security, the key k^2 should be used once, and a replacement key should be indicated in u , so that the next issued transaction can be signed with said key, and so on.

The stake associated with o remains delegated to the agent controlling k^2 , until some output o_2 that depends on o specifies the second key associated with it, changing the agent whom the stake is delegated to. Analogously to how double-spending is impossible, the stake previously delegated in o is not usable for confirming transactions after o_2 is confirmed, as o_2 would be visible in $\text{past}(C_u)$ of some C_u confirmed by the stake of o as indicated by Property 1.

However, the values of inputs and outputs of a transaction are often different. To make the assignment of outputs to delegates unambiguous, we can require that every output specifies the second key k^2 . Alternatively, the protocol can be augmented with a default way of assigning portions of the outputs to the previous

delegates, so that if no key k^2 is specified for any output, the assignment of stake to delegates does not change.

For the purpose of analyzing security with respect to double-spending, delegating stake to the adversary by honest agents is equivalent to sending the stake to the adversary, with the difference that it can be reclaimed. Hence, the analysis of Section 5 applies to the new context under the assumption that the stake controlled *and* delegated to the adversary does not exceed f at any point.

6.2 Transaction Fees

To prevent spamming attacks and to incentivize maintaining the system by the stakeholders, transaction fees can be introduced.

In Section 6.1 we have introduced a second key associated with a transaction specifically for the purpose of confirming other transactions and collecting fees, without spending inputs. Transactions signed only with the second type of keys k^2 would only contribute to confirming other transactions and pay no fee, while only being valid if they contribute to confirming a certain number of new transactions (that require a fee), to prevent spamming.

Since in our setting we refrain from establishing consensus, we will also refrain from attempting to choose an agreed upon subset of stakeholders that should receive a fee from a particular transaction. Instead, we suggest that all stakeholders at any point are eligible to a portion of every transaction fee. For example, every transaction t with inputs O can be granted additional amount ϵ to be spent as an output collected from transactions being confirmed:

$$\epsilon = \frac{v(O)}{3f + 1} \sum_{u \in \text{past}(t) \setminus \text{past}(O)} \text{fee}(u) \quad (1)$$

where $v(O)$ is the value of the inputs, $(\text{past}(t) - \text{past}(O))$ are the newly referenced transactions, and $\text{fee}(u)$ is the transaction fee paid by u . The fee amount might depend on the size of the bit representation of u , or the number of inputs and outputs in u can be limited by the protocol.

6.3 Money Creation

If the fees are collected according to Equation (1), the fees paid by transaction issuers equal the fees collected by those confirming them, and the overall amount of stake remains the same overtime. However, the system might be set up so that the amount of cryptocurrency increases over time. For example, the collected fee ϵ might be multiplied by a constant $\alpha > 1$. Assuming every agent possesses less than one-third of the overall stake at any point, issuing normal transactions spending inputs would still incur a cost as long as $\alpha \leq 3$.

As an additional role in Bitcoin and related systems, proof-of-work serves to distribute newly created money in an unbiased way. ABC could employ proof-of-work for this purpose as well. For this purpose, transactions could be allowed to include proof-of-work and receive an extra amount of stake to spend as an output.

However, for these rewards to vary over time, we would need to introduce some mechanism for the protocol to interact with passing time in some way, which we leave as outside the scope of this paper.

6.4 Transaction Processing

Similarly to traditional blockchains, in ABC all verifiers process all transactions. However, in many settings, such as for example day-to-day credit card payments, rapid succession of dependent transactions does not occur, despite high volume of transactions processed by the system overall. Thus, processing of such transactions by stakeholders in the ABC system can be parallelized to a great extent.

Transaction fees prohibit sustained transaction spamming, but flooding the network with transactions temporarily is possible for an attacker willing to spend resources. However, during such an attack, legitimate transactions would not depend on the attackers transactions and similarly could be processed in parallel, greatly reducing the effect of the attack on the liveness of the system.

7 Related Work

Traditionally, distributed ledgers [6, 1] operate with a carefully selected committee of trusted machines. Such systems are called permissioned. The committee repeatedly decides which transactions to accept, using some form of consensus: The committee agrees on a transaction, votes on and commits that transaction, and only then moves forward to agree on a next transaction.

Bitcoin [8] radically departed from this model and became the first permissionless blockchain. In the Bitcoin system, there is no fixed committee; instead, everybody can participate. Bitcoin achieves this by using proof-of-work. Proof-of-work is a randomized process tying computational power and spent energy to the system's security, while also requiring synchronous communication. However, Bitcoin's form of consensus hardly satisfies the traditional consensus definition. Instead of terminating at any point, the extent to which the consensus is ensured raises over time, approaching but never reaching certainty. More precisely, in Bitcoin transactions are never finalized, and can be reverted with ever decreasing probability.

Similarly to Bitcoin, ABC allows permissionless participation and does not conform to the traditional definition of consensus. In contrast to Bitcoin, ABC does not rely on wasting energy solely to run the system securely, works under full asynchrony, does not rely on randomization, and prohibits reverting committed transactions.

To address the problems associated with proof-of-work, proof-of-stake has been suggested, first in a discussion on an online forum [9]. Proof-of-stake blockchains are managed by participants holding a divisible and transferable digital resource, as opposed to holding hardware and spending energy. Rigorous academic works proposing proof-of-stake systems include designs such as Ouroboros [5] or Algorand [2]. Proof-of-stake blockchains seek to solve consensus and thus rely on

synchronous time. The use of (pseudo-)randomization in proof-of-stake systems is not without complications, and often considered a security risk. In contrast to proof-of-stake systems, ABC allows for completely asynchronous communication. ABC is also simpler.

In the work closest related to ours, Gupta [4] proposes a permissioned transaction system that does not rely on consensus. In this design, a static set of validators is designated to confirm transactions in a manner similar to ours.

The authors of [3] show that the consensus number of a Bitcoin-like cryptocurrency is 1, or in other words, that consensus is not needed. The paper provides an analysis and discussion of which applications rely on consensus and to what extent, all of which is directly relevant to ABC.

The authors of [7] provide an asynchronous permissioned system by relying on advanced cryptographic techniques. The main differences from ABC are that the system is permissioned, much more involved, reliant on randomization, and offers consensus.

8 Conclusions

In this paper we presented ABC, an asynchronous blockchain without consensus. ABC provides the functionality of Bitcoin without consensus, without proof-of-work, without requiring synchronous time, without relying on randomness, fast and with finality. The design of ABC is arguably the simplest possible design for a whole set of blockchain applications.

On the other hand, ABC does not offer traditional consensus. There are applications which do need consensus, in particular when smart contracts need to interact with unknown users.

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